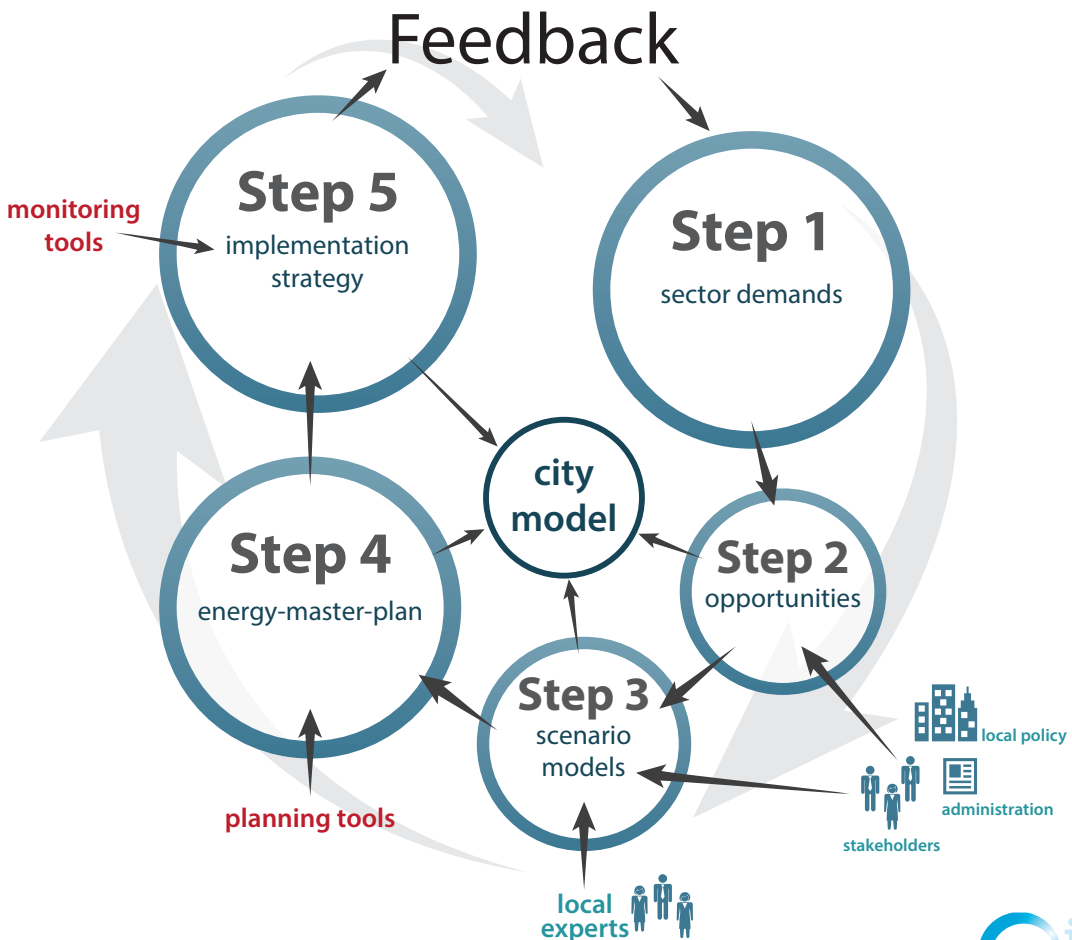


Case Studies and Guidelines for Energy Efficient Communities

A Guidebook on Successful Urban Energy Planning

IEA EBC ANNEX 51





Case Studies and Guidelines for Energy Efficient Communities

A Guidebook on Successful Urban Energy Planning

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Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster co-operation among the twenty-eight IEA participating countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD&D).

Energy in Buildings and Communities

The IEA co-ordinates research and development in a number of areas related to energy. The mission of one of those areas, the EBC - Energy in Buildings and Communities Programme, is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBSCS.)

The research and development strategies of the EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshop, held in April 2013. The R&D strategies represent a collective input of the Executive Committee members to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy conservation technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five focus areas of R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

The Executive Committee

Overall control of the program is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial. To date the following projects have been initiated by the Executive Committee on Energy in Buildings and Communities (completed projects are identified by (*)):

- Annex 1: Load Energy Determination of Buildings (*)
- Annex 2: Ekistics and Advanced Community Energy Systems (*)
- Annex 3: Energy Conservation in Residential Buildings (*)
- Annex 4: Glasgow Commercial Building Monitoring (*)
- Annex 5: Air Infiltration and Ventilation Centre
- Annex 6: Energy Systems and Design of Communities (*)
- Annex 7: Local Government Energy Planning (*)
- Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
- Annex 9: Minimum Ventilation Rates (*)
- Annex 10: Building HVAC System Simulation (*)
- Annex 11: Energy Auditing (*)

- Annex 12: Windows and Fenestration (*)
- Annex 13: Energy Management in Hospitals (*)
- Annex 14: Condensation and Energy (*)
- Annex 15: Energy Efficiency in Schools (*)
- Annex 16: BEMS 1- User Interfaces and System Integration (*)
- Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
- Annex 18: Demand Controlled Ventilation Systems (*)
- Annex 19: Low Slope Roof Systems (*)
- Annex 20: Air Flow Patterns within Buildings (*)
- Annex 21: Thermal Modelling (*)
- Annex 22: Energy Efficient Communities (*)
- Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
- Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
- Annex 25: Real time HVAC Simulation (*)
- Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
- Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
- Annex 28: Low Energy Cooling Systems (*)
- Annex 29: Daylight in Buildings (*)
- Annex 30: Bringing Simulation to Application (*)
- Annex 31: Energy-Related Environmental Impact of Buildings (*)
- Annex 32: Integral Building Envelope Performance Assessment (*)
- Annex 33: Advanced Local Energy Planning (*)
- Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
- Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
- Annex 36: Retrofitting of Educational Buildings (*)
- Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
- Annex 38: Solar Sustainable Housing (*)
- Annex 39: High Performance Insulation Systems (*)
- Annex 40: Building Commissioning to Improve Energy Performance (*)
- Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
- Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
- Annex 43: Testing and Validation of Building Energy Simulation Tools (*)
- Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
- Annex 45: Energy Efficient Electric Lighting for Buildings (*)
- Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
- Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
- Annex 48: Heat Pumping and Reversible Air Conditioning (*)
- Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
- Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
- Annex 51: Energy Efficient Communities (*)
- Annex 52: Towards Net Zero Energy Solar Buildings
- Annex 53: Total Energy Use in Buildings: Analysis & Evaluation Methods (*)
- Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings
- Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO)
- Annex 56: Cost Effective Energy & CO₂ Emissions Optimization in Building Renovation
- Annex 57: Evaluation of Embodied Energy & CO₂ Emissions for Building Construction
- Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements

- Annex 59: High Temperature Cooling & Low Temperature Heating in Buildings
- Annex 60: New Generation Computational Tools for Building & Community Energy Systems Based on the Modelica & Functional Mockup Unit Standards
- Annex 61: Development & Demonstration of Financial & Technical Concepts for Deep Energy Retrofits of Government / Public Buildings & Building Clusters
- Annex 62: Ventilative Cooling
- Annex 63: Implementation of Energy Strategies in Communities
- Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles
- Annex 65: Long-Term Performance of Super-Insulation in Building Components and Systems

Working Group - Energy Efficiency in Educational Buildings (*)

Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)

Working Group - Annex 36 Extension: The Energy Concept Adviser (*)

(*) – Completed

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Country	Research Group	Participants
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USA	US Army Corps of Engineers, Champaign, IL	<i>A. Zhivov</i>

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The different chapters of this Guidebook have been written by different authors and co-authors, as specified in the table of contents. The responsibility to structure the whole book and to edit the different contributions was with the Guidebook editing team, Prof. Jacques Kimman (NL), Armand Dütz (D) and Reinhard Jank (D).

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As it is experienced in many co-operative projects of this kind, when most of the work is done, the tedious work of cross-reading, error search, consistency checks etc. is left to a few persons who are engaged in bringing this product to a final shape that is withstanding the professional standards of the intended audience. In this specific case, with authors who predominantly are not native English

speakers, it is all the more important to have a supporter who was able to overcome language barriers, streamline everybody's contributions and achieve the textual clarity that is necessary to enable a widespread dissemination in the professional world. This supporter was Jessica Webster of Natural Resources Canada, Ottawa, who not only was engaged in the writing of one of the Guidebook's chapters (about energy modelling tools) but who also worked through the whole allegedly 'final' body of text to bring it into a form that was ready for print. All of us, co-operating in this Annex 51, but in particular I myself as Operating Agent of this Annex, are deeply indebted to Jessica for her enduring dedication and, in particular, for her excellent sense of language that allowed her to understand what was meant by sometimes clumsy phrasing and to transform it into an English text that is a joy to read. Thank you very much, Jessica!

Karlsruhe, October 2013
Reinhard Jank
Operating Agent, Annex 51

List of Abbreviations

ADEME	Agence de l'Environnement et de la Maitrise de l'Energie
BAFA	<i>Bundesamt für Wirtschaft und Ausfuhrkontrolle</i>
BAT	Best Available Technology
BAU	Business As Usual
CAD	Canadian Dollar
BC	British Columbia
BIPV	Building Integrated Photovoltaics
CCA	Capital Cost Allowances
CDM	Clean Development Mechanism
CFL	Compact Fluorescent Lamps
CHF	Swiss Franc
CoM	Covenant of Mayors
DC	Direct Current
DCC	Development Cost Charges
DCF	Danish Carbon Fund
D-ECA	District Energy Concept Adviser
DHW	Domestic Hot Water
DKK	Danish Krone
DPA	Development Permit Area
DSM	Demand Side Management
EBC	Energy Conservation in Buildings and Community Systems (IEA Implementing Agreement)
EDF	Electricité de France
eea	European Energy Award
EECBG	Energy Efficiency and Conservation Block Grant Program (United States)
EEEF	European Energy Efficiency Fund
EEG	<i>Erneuerbare Energien-Gesetz</i> (Renewable Energy Sources Act)
EiFER	European Institute for Energy Research (a joint initiative of EDF France and the Technical University of Karlsruhe)
EnEV	<i>Energieeinsparverordnung</i>
ERDF	European Regional Development Fund
ERS	Energy Rating System (Canada)
ESF	European Social Fund
ESCOs	Energy Service Companies
EU	European Union
EUR	European Euro
FCM	Federation of Canadian Municipalities
FIT	Feed-In Tariff
GHG	Greenhouse Gases
GIS	Geographical Information Systems
GMF	Green Municipal Fund
HfT	<i>Hochschule für Technik, Stuttgart</i> (University of Applied Sciences)
ICLEI	Local Governments for Sustainability (former: International Council for Local Environmental Initiatives)
IEA	International Energy Association
IEE	Intelligent Energy Europe
JI	Joint Implementation
JHF	Housing Finance Agency (Japan)
JPY	Japanese Yen
KfW	<i>Kreditanstalt für Wiederaufbau</i>
KWKG	<i>Kraft/Wärme-Kopplungs-Gesetz</i> (German Cogeneration Act)
LCA	Life Cycle Analysis
LED	Light Emitting Diode
LEP	Local Energy Planning

LIC	Local Improvement Charges
LiDAR	Light Detection and Ranging
LIP	Local Investment Program (Sweden)
METI	Ministry of Economy, Trade and Industry (Japan)
NB	New Brunswick
NEDO	New Energy and Industrial Technology Development Organization (Japan)
ORC	Organic Rankine Cycle
PCP	Partners for Climate Protection
PPP	Public Private Partnerships
PV	Photovoltaics
R&D	Research and Development
REITs	Real Estate Investment Trusts
ROI	Return On Investment
SEK	Swedish Krona
SFB	<i>Stromsparerfonds Basel</i> or Basel Electricity Savings Trust
SIA	<i>Schweizerischer Ingenieur- und Architektenverein</i> (Swiss Association for Engineers and Architects)
USD	United States Dollar

Energy Related Abbreviations

ΔE – difference in energy use (before and after the implementation of specific energy-related measures)

CHP – Combined Heat and Power

EPBD – Energy Performance of Buildings Directive

DC – direct current

DH - district heating

DHW – domestic hot water

h^{-1} – per hour

kWh – kilowatt hour

$kWh/(m^2 \cdot a)$ – kilowatt hour per square meter per year

kW_p – power production of PV modules at maximum (peak) solar irradiation

m^2 – square meter and m^3 – cubic meter

MWh – megawatt hour and MWh/a – megawatt hours per year

TWh – terawatt hour and TWh_{el} – terawatt hour of electric energy

Table of Contents

1	Introduction (Reinhard Jank, Jessica Webster).....	15
1.1	Climate science and policy background	15
1.2	Implications for communities	15
1.3	Systems approach	16
1.4	International co-operation and Annex 51 approach.....	18
1.5	Guidebook approach.....	19
1.6	A few words on terminology.....	21
2	Local Energy and Climate Change Policy (Armand Dütz; Thomas Bloch, Lisa Jank)	24
2.1	Local energy planning as a key factor in climate protection policy.....	24
2.2	Legal and policy frameworks	25
2.3	Financial frameworks.....	34
2.3.1	Funds	34
2.3.2	Grants	37
2.3.3	Feed-in tariffs	38
2.3.4	Subsidies	42
2.3.5	Tax schemes.....	43
2.3.6	Additional options.....	46
2.4	Voluntary agreements and networks.....	46
2.5	General conclusions on legal and financial frameworks	48
3	Local Energy Planning Methods: From Demand to Future-proof Solutions (Reinhard Jank; Ken Church, Jacques Kimman, Andreas Koch, Olivier Pol, Alessandro Dalla Rosa, Helmut Strasser, Jessica Webster).....	51
3.1	The transition process	51
3.1.1	Leadership models	52
3.2	The local energy planning transition process	55
3.3	Step 1 Create an energy and emissions inventory or balance	56
3.3.1	A few words on data	56
3.3.2	A few words on inventories.....	57
3.3.3	Data sources to profile energy demand.....	59
3.3.4	Other types of data sets to contextualize energy demand and supply	62
3.3.5	Data sources to profile conventional energy supply	63
3.3.6	Data sources to profile renewable energy supply	63
3.4	Step 2 Engage stakeholders, create a vision and set targets	66
3.4.1	Stakeholder analysis.....	66
3.4.2	The transition arena	68

3.4.3	The energy working group	68
3.4.4	Create a vision	69
3.4.5	Set targets	70
3.5	Step 3 Assess opportunities and develop scenarios	71
3.5.1	Assess opportunities	71
3.5.2	Supporting indicators	72
3.5.3	Scenarios	73
3.5.4	Backcasting and forecasting	74
3.5.5	Roadmaps	76
3.5.6	Charrette	78
3.6	Step 4 Create municipal energy master plans and neighbourhood energy plans	79
3.6.1	Municipal energy master plan	79
3.6.2	Neighbourhood energy plans	81
3.7	Step 5 Implementation, monitoring, evaluation and feedback	85
3.7.1	Process design instruments	86
3.7.2	Integrated management strategies	87
3.7.3	Process management co-ordinator	88
3.7.4	Responsibilities of municipal departments	88
3.7.5	Co-ordinating the energy working group	89
3.7.6	Monitoring	90
3.7.7	Evaluation and feedback	91
3.8	Technical improvement options, economic feasibility	93
3.8.1	Technology and policy approaches available to governments	93
3.8.2	Technologies available to the developer / contractor	97
3.8.3	Technologies available to the occupant	104
4	Community Energy and Emissions Inventory and Modelling Tools to Support Local Energy Planning (LEP) (Jessica Webster; Carsten Beier, Reinhard Jank, Andreas Koch, Yoshiyuki Shimoda)	106
4.1	Introduction	106
4.2	The scope of LEP and the need for inventories and models	106
4.3	Energy and GHG emissions inventories	108
4.3.1	Selected examples of inventories and balancing tools in practical application	108
4.4	Energy modelling approaches	111
4.5	Examples of models in development and practical application	115
4.6	User needs	123
4.7	Selecting a modelling approach	124
4.8	Communicating the modelling concept	126

4.9	Perspectives on future directions	127
5	The District Energy Concept Adviser (D-ECA): Software from IEA EBC Annex 51 to Support District Energy System Planning (Heike Erhorn-Kluttig)	130
5.1	The tool in brief	130
5.2	Background and aim	130
5.3	Tool sections.....	132
5.4	How to use the main sections	133
5.4.1	Performance rating	133
5.4.2	Case studies of energy efficient districts	135
5.4.3	Energy efficient strategies and technologies	137
5.4.4	Energy assessment of districts	138
5.5	User guide	146
5.6	Test calculations to assess the accuracy of the calculation tool.....	146
5.6.1	Evaluation results of the exemplary district Stuttgart-Burgholzhof	149
5.7	Download source.....	151
6	Energy Efficient Neighbourhood Case Studies (Heimo Zinko; Bahram Moshfegh)	153
6.1	Neighbourhood case studies	153
6.2	Successful neighbourhood developments	153
6.2.1	Energy efficiency is profitable.....	153
6.2.2	The decision making process.....	155
6.2.3	Planning urban development projects	159
6.2.4	Implementation.....	161
6.2.5	Barriers.....	163
6.3	Lowering energy demand efficiently	165
6.3.1	Single buildings or whole neighbourhoods?	165
6.3.2	Increased comfort paid for through energy efficiency	166
6.3.3	Monitoring and evaluation.....	170
6.4	Lessons learned from neighbourhood case studies	172
6.4.1	Why districts or neighbourhoods?.....	172
6.4.2	An integrated planning approach.....	172
6.4.3	Organization	173
6.4.4	Quality agreement and control	173
6.4.5	Policy instruments	173
6.4.6	Planning for lowest cost.....	174
6.4.7	Planning tools	174
6.4.8	Information and education	174
6.4.9	Involving residents	175

6.4.10	Energy efficiency	175
6.4.11	Technological achievements and solutions	175
6.4.12	Monitoring	176
APPENDIX to Chapter 6		177
7	Energy Efficient City Case Studies (Wendy Broers, Ursula Eicker, Olivier Pol, Helmut Strasser)	189
7.1	Introduction	189
7.2	Case studies.....	189
7.3	Vision and targets	193
7.3.1	Realistic vision and targets.....	193
7.3.2	Linking short-term actions with long-term targets.....	196
7.4	Process and organization	197
7.4.1	Continuous process	197
7.4.2	Integrated approach.....	201
7.5	Support and involvement	203
7.5.1	Creating support	203
7.5.2	Involving the right people at the right time	206
7.5.3	Involving the public	208
7.5.4	Involving the real estate industry	210
7.6	Knowledge and risk management.....	211
7.6.1	Sharing knowledge	211
7.7	Co-benefits	214
7.7.1	Economic benefits	215
7.7.2	Social benefits.....	216
7.7.3	Environmental benefits	216
APPENDIX to Chapter 7		217
8	Summary and Conclusions (Reinhard Jank; Armand Dütz, Jacques Kimman, Jessica Webster)	224
8.1	Key results and implications	225
8.1.1	Neighborhood energy planning.....	225
8.1.2	Municipal energy planning	226
8.1.3	Computer-based planning tools	227
8.1.4	Legislative frameworks	227
8.2	Municipal energy transition process	228
8.3	Eight guidelines for local energy planning success	232
8.4	Concluding remarks.....	237
8.5	Where should we go from here?.....	237

List of References	238

Attachments	243

Attachment A. Primary Energy and GHG Performance of Energy Systems (Reinhard Jank)	244
Attachment B. Green Building Rating Systems (Ken Church, Alessandro Dalla Rosa)	250
Attachment C. Low-Energy, Passive House and Net-Zero Energy Buildings (Ken Church)	252
Attachment D. Energy Generation from Renewable Sources (Alessandro Dalla Rosa)	255
Attachment E. Economics of Energy Retrofitting and Energy Performance Contracting (Ken Church)	258
Attachment F. Energy Benchmarking of Neighbourhoods (Reinhard Jank)	263
Attachment G. Energy Performance of Typical Cogeneration Systems (Reinhard Jank)	271
Attachment H. Municipal Energy and Emissions Inventories (Reinhard Jank)	278
Attachment I. Municipal Energy Improvement Potentials/ Efficiency Opportunities (Reinhard Jank)	282
Attachment J. Planning Methods in Neighborhood or District Energy Planning (Reinhard Jank, Andreas Koch)	288

1 Introduction

1.1 Climate science and policy background

Global economic crises and national debts command the attention of the public today. Energy security and global warming have largely disappeared from media headlines and are lower on decision makers' agendas. Energy and climate challenges have not however retreated. In 2007, prior to the economic crises, the *2 degree target* was acknowledged at the Climate Summit of Copenhagen, implying that the atmospheric concentration of carbon dioxide (CO₂) must be kept below 450 parts per million (ppm). In May 2013, atmospheric CO₂ concentrations reached 400 ppm, up from 280 ppm in pre-industrial times. Climate research tells us that with regard to the 2 degree target the total amount of CO₂ that can be emitted by 2050 is about 1.000 gigatons (Gt), or an average of 25 Gt every year from now until 2050. However in the year 2011, over 34 Gt of CO₂ were emitted. The Intergovernmental Panel on Climate Change (IPCC) projects that, to prevent more than 2 degrees of global warming, the zenith of CO₂ emissions must be reached by 2020, followed by reductions to 30% or less of the current global emission until 2050.¹ This corresponds roughly to policy targets in some industrialized countries to reduce greenhouse gases (GHG) emissions by 80% by 2050.

The current estimate of fossil energy resources (gas, oil, coal) in the soil corresponds to an emission potential of 15,000 Gt of CO₂.² There are therefore many more fossil fuel resources than we can afford to burn. Considering energy and GHG policy, the overarching message is that, long before we run out of fossil energy resources, we must find a solution to the energy and climate change challenge.

1.2 Implications for communities

Taking the threat of global warming and corresponding long-term GHG emissions targets seriously, the question becomes: which sectors can have the greatest impact and can do the most towards achieving these targets? Systems analysis tells us that, unfortunately, there are no easy answers. Urgent and effective action is necessary in all areas of energy use. The built environment accounts for more than 40% of energy use and CO₂ emissions globally. Leveraging renewable energy supply, the built environment is the most important sector to contribute to energy and climate policy targets.

Today, more than 50% of the world's population lives in urban areas, a figure that is increasing. Thus, adaptation and development of cities for tomorrow and a significant increase of the use of renewable energy should ideally be top priorities of the future transition processes required to reduce environmental impact and resource consumption. However, is the prospect of serious climate change impacts compelling enough to trigger necessary changes in awareness and behavior today?

Robust arguments must increasingly be made to articulate the co-benefits and achieve the broad acceptance necessary to prompt action at the local level. Examples include:

- increase energy supply security by reducing dependence on imports from politically unstable regions;
- reduce economic disruptions caused by rising energy prices;
- increase cost savings for energy users by improving energy-inefficient buildings or equipment;
- realize local economic advantages by capitalizing on local investments in energy conservation or renewables;
- improve and modernize local infrastructure;

¹ IPCC's 5th Assessment Report will be available in draft in autumn 2013 and the final report in April, 2014. www.ipcc.ch.

² Figures of this kind are subject of scientific debates, e.g. in the new IPCC interim report currently under development. This introduction discusses plausible widely-acknowledged figures rather than exact data based on the large body of scientific literature.

- promote sustainable urban development in general.

The co-benefits of working towards energy and GHG emissions targets are clear. Above all, quality of life will improve in modern neighbourhoods with functioning infrastructure. This has been a topic since the UN World Congress on Sustainability in Rio 1992. Since Rio, experience has shown that sustainable urban development is feasible, but is hardly ever achieved when measured by long-term fossil fuel and GHG emissions reduction targets.

Today it is generally acknowledged that these targets can, in principle, be achieved with existing technologies. There are communities that have been successful, but they are rare exceptions. Considering that it is primarily existing buildings that must be subject to the required transition, the prevailing attitude is that cities are too complex to successfully organize a coordinated effort to reduce energy use and resulting GHG emissions. This opinion is in direct opposition to the position taken by energy and environmental activists who advocate for concerted action on the basis of existing (theoretical) potential for change.

In recent years, there has been significant progress in energy conservation and renewable energy technology development. The construction of buildings with very low energy demand, including net-zero energy buildings, has been demonstrated in various weather regions. This has been enabled by significant improvements in window technology, insulation materials, ventilation, control devices, user interfaces and energy conversion technologies. These advances have been paralleled by development of planning instruments, including tools for building or energy system simulation and optimization previously restricted to academic use. Consequently, opportunities to achieve the energy and GHG emissions reductions targets look more promising today than they did in the 1990s. At that time, it was rightly supposed that there would be large efficiency potentials in cities. This was but naively postulated however, since many communities who became members of the International Climate Alliance expected that targets would be achieved with modest effort already within 15 or 20 years.

1.3 Systems approach

The radical transition necessary to replace most fossil energy sources from our energy systems needs to be more than a linear extrapolation of current incremental change processes. Beyond a certain share of renewable electricity generation, there must be a transition to a system that is capable of managing large fluctuations in supply and storing large amounts of energy in electrical, chemical and thermal forms. Consequently, the building stock of a city cannot be considered simply as a number of energy consumers who must dramatically reduce their energy use, while remaining demand is met with renewables. Buildings in the future rather will play an active role in the overall energy system, by not only using energy but generating and storing energy as well. To make this a reality, a transition to *the smart grid* is necessary. The beginnings of smart grid technologies can be seen today in the installation of smart meters, development of electrotechnical interoperability standards and pilot smart grid research and development (R&D) projects. *Smart building* approaches, under development for over two decades, are particularly justified in the context of a smart grid. The real challenge is to develop a *smart city*, based on a *smart energy network*. It is this transition to smart cities - in a very comprehensive sense – that is the key to success in the long-term.

A systemic approach to urban energy planning is required, one that considers all sub-systems and energy users and energy generation in a *holistic systems perspective*, rather than as individual components operating independently. This view is made more complex by the fact that many different decision makers and investors, many with divergent interests, are responsible for actions and investments on a level very much below a *whole system level*. As a result, a combined top-down and bottom-up strategy is required, where the big picture is defined by the municipality in consultation with stakeholders and implementation decisions are made on the level of neighbourhoods and individual infrastructure projects (see figure 1-1). This is necessarily a long and iterative process that

requires decades rather than years to complete. The key role in this process is played by the municipal administration.³

Additionally, due to very different geographic, political and socio-economic conditions in different countries, not at least substantial differences in energy prices, different policies are required to successfully achieve energy and GHG emissions targets. It is not always evident at the outset however which local policy is most promising. Trial and error in planning processes is inevitable; what is successful in one country may encounter barriers in another. For example, large hydro energy resources in Sweden or Austria allow for strategies that cannot be applied in Denmark or Germany. In contrast, some countries have similar challenges but take different policy approaches. For example, both Japan and Canada are focused on infrastructure renewal following disasters such as the earthquake and nuclear crisis in Fukushima, Japan in March 2011 and the railway disaster in Lac Mégantic, Quebec, Canada in July 2013. Despite these types of differences, there is a common ground on the community and neighbourhood scales that allows for comparison of different approaches. Establishing local energy policies and fostering the necessary energy transition processes requires that we learn from past successes and failures.

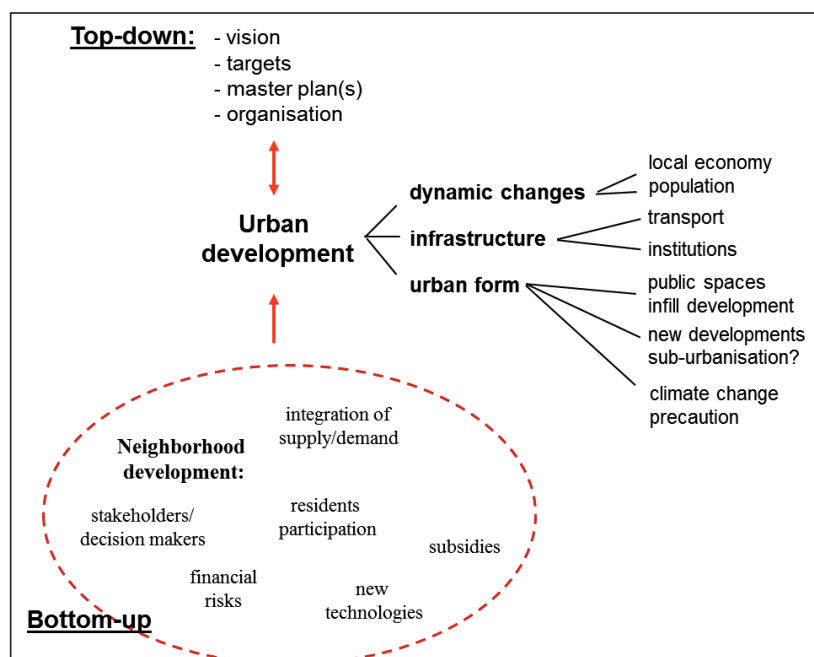


Figure 1-1: Municipal energy planning requires both bottom- up and top-down approaches to be successful.

Among the towns and cities of countries participating in Annex 51 that have undergone extensive energy transformations, large and ongoing institutional effort and significant investments are required. These are estimated to be over 10,000 euros (EUR) per person, totaling approximately 3 billion EUR for a medium-sized city of 300,000 inhabitants as was estimated for Karlsruhe, Germany as of 2011.⁴ Is such a big investment – needed in most if not all cities – conceivable?

³ Recently, a toolkit has been developed by the Department for Regional Policy of the EU Commission (published in spring 2013) to support communities establishing efforts for an integrated sustainable urban development. This tool consists of checklists to match local activities with general sustainability requirements (www.rfsc.eu).

⁴ „Machbarkeitsstudie Klimaneutrales Karlsruhe 2050“, Karlsruher Klimaschutz- und Energie-Agentur, Karlsruhe (2011).

Economic and demographic growth and change in cities is achieved through substantial ongoing investments in infrastructure and the building sector. These large investments influence the structure and spatial distribution of the built environment and have long-term energy implications. This ongoing process of change is an opportunity to guide development towards net-zero energy and carbon neutral. A wise local government can use the urban planning process as a lever to steer development in the right direction, provided that it knows that direction. This is why an overarching long-term strategic sustainability plan and a municipal energy master plan linked with detailed planning and implementation in neighbourhoods are needed by each community.

1.4 International co-operation and Annex 51 approach

During the last two decades, local and urban energy planning activities have been carried out in several countries; approaches and planning methods have differed from country to country and from consultant to consultant. Activities by international organizations such as the ICLEI Local Governments for Sustainability, the International Climate Alliance (in Europe) and The Climate Registry (in North America) have supported municipalities in establishing local GHG policies. Tools and databases useful for local energy and emissions planners have been developed. In addition, due to energy inventory requirements from international bodies such as IPCC, the EU Commission and the Covenant of Mayors (CoM) initiative, a convergence can be observed with respect to approaches and methods. As a result, local administrations and planners can leverage available databases, data sources and calculation methods for energy and GHG inventories.

Despite efforts and progress made to date, those engaged in local energy and emissions planning including policy makers, urban planners, elected officials and other stakeholders encounter many challenges in their day to day work. These include poor management structures, a lack of organization within sectors and incremental thinking. Disciplines such as urban planning, infrastructure, energy, transportation, facilities management, architecture, while multidisciplinary by nature, in practice are too often carried out in isolation. Also missing is a systematic transfer of knowledge and lessons learned to move technical innovations from research and development (R&D) to broad application in urban development. These gaps impede energy analysis and project implementation and, above all, a holistic view of the community as a system. These were among the reasons for creating the IEA-EBC Annex 51 *Energy Efficient Communities: Case Studies and Strategic Guidelines for Urban Decision Makers*.

Another motivation for Annex 51 was an urgent desire for knowledge exchange on current practices by several countries whose governments had recently established programs to support the energy transition in communities.

The initial perspective when designing Annex 51 was that technical barriers to successful municipal energy and climate policy included insufficient:

- strategic planning know-how;
- implementation process management capacity; and
- availability of tools and instruments for decision making, planning and monitoring.

This research Annex takes place within the framework of the International Energy Agency (IEA),⁵ a Paris-based international autonomous organization that works to ensure reliable, affordable and clean energy. *Implementing Agreements* are signed to organize international collaboration on energy technology R&D around themes such as *Energy Conservation in Buildings and Community Systems*

⁵ <http://www.iea.org>.

(EBC).⁶ Within the implementing agreements, individual collaborative projects on a select technical theme are called *Annexes*.

Countries participating in Annex 51 included: Austria, Canada, Denmark, Finland, France, Germany, Japan, The Netherlands, Sweden, Switzerland and the United States. The work plan consisted of developing and reviewing case studies on current conventional local or neighbourhood energy planning practices (Subtask A), innovative neighbourhood developments (Subtask B) and energy planning at the city-wide or municipal scale (Subtask C) carried out or still underway within participating countries. Information was collected from these case studies on methods, tools and implementation strategies employed in practice as well as lessons learned when projects encountered pitfalls or failed. Taking into account the aforementioned barriers, information from the case studies, supplemented with examples from other related national and international initiatives, was used to develop this *Guidebook on Successful Local Energy Planning* (Subtask D). The District Energy Concept Advisor (D-ECA), a software tool to support local energy planning in the early design phases, was also a product of Subtask D. Detailed case study evaluations done within Subtasks A, B and C (Figure 1-1) are summarized in individual Subtask reports. These can be downloaded from the Annex 51 website at <http://www.annex51.org>.

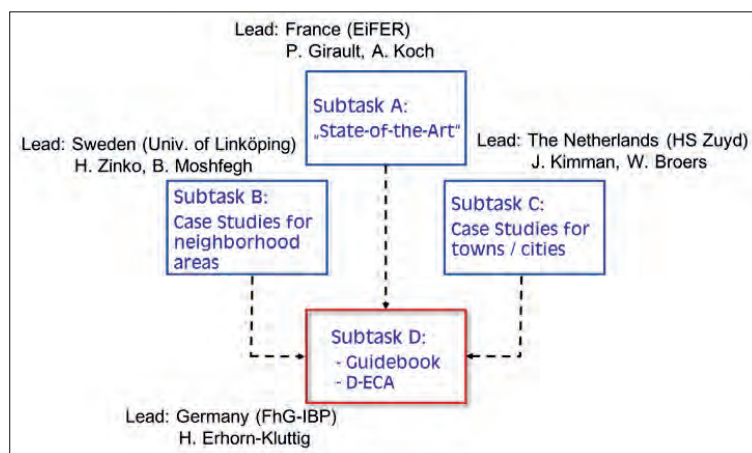


Figure 1-2: Work structure of Annex 51 and subtask leaders

1.5 Guidebook approach

This Guidebook describes current and innovative local energy planning (LEP) approaches on the city-wide or neighbourhood scales with the aim of contributing to a further streamlining of methods. The information presented is based on knowledge gained and lessons learned through case studies from Annex 51 participating countries and on international approaches more broadly.

While local or community energy planning is already addressed in a variety of existing literature (e.g. *Deutsches Institut für Urbanistik*, 2011 and CoM, 2010), this Guidebook distinguishes itself by being anchored in recent practical experience and in taking an integrated approach. This integrated approach involves viewing communities in a whole systems perspective, looking at the local energy transition process as on-going and iterative and drawing on expertise from urban planning, municipal management, architecture and engineering, and local stakeholders.

⁶ www.EBC.org.

This *Guidebook on Successful Local Energy Planning* is intended for urban planners and local decision makers; researchers, students and anyone engaged in or interested in local energy planning will also find it useful. It provides a broad overview of the international and national frameworks that create the context for energy planning at the local level. The local energy planning transition process is described in five steps. Qualitative and quantitative methods are reviewed for stakeholder engagement, energy and GHG emissions inventory development, scenario creation and relevant forecasting and backcasting techniques and the application of more advanced modelling and simulation tools. The District Energy Concept Advisor (DEC-A) is described, a tool developed as a part of Annex 51, designed to support district or neighbourhood scale district energy and retrofit pre-feasibility analysis early in the planning process, when data is otherwise scarce. Considerations for developing strategic municipal energy master plans and neighbourhood energy plans are outlined. Existing tools and technologies to assist with project implementation are reviewed at the neighbourhood and city-wide scales. Conventional and innovative neighbourhood energy planning and leading city-scale planning case studies are presented. Key results are summarized in eight guidelines for successful local energy planning.

To provide readers with a more detailed roadmap, the Guidebook and its eight Chapters are organized as follows:

Chapter 1 provides the background, rationale and general approach to Annex 51. The motivations provided by climate change are discussed as well as the need for international co-operation including through the International Energy Association. The approach to Annex 51 is described and participating countries are listed, followed by the present Guidebook structure overview.

Chapter 2 begins with international energy and climate change frameworks such as the Kyoto Protocol and Energy Performance in Buildings Directive (EPBD). Related national energy and climate change policies, legal and financial frameworks are presented through examples from Annex 51 participating countries. Voluntary agreements and networks such as the European Union Covenant of Mayors, ICLEI –Local Governments for Sustainability are also presented.

Chapter 3 discusses the transition process and leadership models. The five steps to take for a successful local energy planning transition process are outlined in detail. Step 1 develop an energy and emissions inventory; Step 2 engage stakeholders, create a vision and establish targets; Step 3 assess opportunities and create future scenarios; Step 4 develop municipal energy master plans and neighbourhood energy plans; and Step 5 implement policies and projects, monitor, evaluate and adjust the process. Policies and technologies available to municipalities, developers and the public are also reviewed in support of implementation. Additional technical details on calculation procedures can be found in the appendix.

Chapter 4 reviews computer-based energy and emissions inventory and modelling approaches, presenting key concepts and describing selected inventories and models and experiences gained in their practical application. The aim is to foster a general appreciation of the types of inventories and selected examples of models available and their benefits for the LEP process. Developments around open data, cloud computing and the general increase in the interconnectedness of systems and processes that will provide more computing power to respond to local energy planning needs.

Chapter 5 describes the District Energy Concept Adviser (D-ECA), a software tool developed by *Fraunhofer Institut für Bauphysik* to accompany evaluation of the Annex 51 case studies. The D-ECA supports calculation of energy balances on the neighbourhood scale for different building archetypes and their energy performance as well as energy supply options that may be applicable in a given neighbourhood. The tool allows for quick comparison of different energy conservation or energy supply alternatives that might be considered by developers or other local stakeholders, in terms of energy end-use, primary energy or CO₂ emissions of the planned neighbourhood.

Chapters 6 and 7 present the main results and lessons learned from the case studies in Subtask B and C (Figure 1-2). Evaluation of the case studies revealed that technical problems posed less of a challenge for energy planning than originally thought. The real problem was found to be a management problem, in particular social and organizational challenges encountered in initiating and leading the necessary transition processes on all levels of local decision making. Examples from Annex 51 case studies experiencing these challenges are provided throughout the Guidebook.

Chapter 8 is aimed at municipal decision makers and readers looking for an executive summary. It reviews the 5 steps in the local energy planning transition process at a high level. It summarizes the reviews aspects of the local energy planning transition process and presents main messages and conclusions.

The **Attachments** present detailed calculation procedures as a supplement to the step-by-step LEP process outlined in Chapter 3. They are intended for energy planners who find themselves tasked with having to develop reliable quantitative estimates to guide planning at the pre-feasibility stage. They are not intended to replace professional engineering expertise required to determine economic feasibility and energy systems design.

Since information on local energy planning is available from numerous sources, this Guidebook does not aim to be exhaustive. Rather, it reviews the facts and statements considered to be the most important and useful for the reader based on the case studies and knowledge of Annex 51 participants. References, including websites, were selected according to this same principle. Readers are encouraged to additionally consult the peer-reviewed literature, speak with experts and plug into networks supporting municipal energy and climate planning.

It is obvious to anyone considering energy use and supply in communities that the built environment has direct implications for transportation energy use. Owing to the scope of the IEA's Implementing Agreement on Buildings and Community Systems (IEA EBC), transportation is not addressed in this Guidebook. Industrial energy management, which can present opportunities for local energy systems, is also not included for the same reason.

1.6 A few words on terminology

Owing to the fact that 11 countries participated in Annex 51, representing 8 different languages, some important lessons learned relate to terminology. Every attempt has been made to use clear and consistent terminology in the Guidebook. Some key terms used and their variations are explained here for the reader's benefit.

In a previous IEA research initiative, *Annex 33 Advanced Local Energy Planning Energy Conservation in Buildings and Community Systems* the term *local energy planning* (LEP) refers to energy planning at the scale of both neighbourhoods and whole cities or towns. Over thirteen years later, it is clearer that there are fundamental differences in the planning objectives, methods and tools applied at these different scales. The Guidebook strictly distinguishes between the two, by referring to energy planning activities at the neighbourhood, district, quarter, area or building cluster scale as *neighbourhood energy planning* and to those at the city-wide or municipal scale as *municipal energy master planning*.⁷ LEP is preserved as a general term encompassing both and the *local energy planning transition* process as a whole

⁷ These terms are a departure from those originally selected: 'local planning' was to denote neighbourhood planning and 'urban energy planning' city-scale planning. However as terms neither urban nor local immediately brought to mind a picture of where the activities were taking place – in the whole community or in a district? What was the opposite of these terms? The opposite of urban is rural and local is either regional, national or international. Energy planning takes place in both urban and rural contexts. While local planning definitely isn't national planning, it also wasn't clear that it isn't city-wide. As a result, in almost every instance where urban or local was used additional words had to be added to ensure the description was specific for example, "local energy planning at the neighbourhood scale" or "city-wide planning managed by the municipal administration".

Following this logic, overarching city-wide strategic energy plans are called *municipal energy master plans*. A useful operational definition is provided by the newly-launched Ontario Municipal Energy Plan Program:⁸

"A municipal energy plan (MEP) takes a comprehensive approach to energy planning by considering the broader context of energy use, infrastructure, and land use planning. It includes all sectors in a community: residential, commercial, industrial, municipal and transportation. A MEP:

- *Assesses the community's energy use and greenhouse gas (GHG) emissions*
- *Identifies opportunities for conserving energy, improving energy efficiency and reducing GHG emissions*
- *Considers impact of future growth and options for local clean energy generation*
- *Supports local economic development"*

Many communities will already have municipal energy master plans by other names such as Roadmaps, Sustainable Energy Action Plans (SEAPs), Community Energy and Emissions Plans (CEEPs) or Local Action Plans (LAPs). These plans may contain more or less detail; some communities may create broad strategic plans and subsequent city-wide action and implementation plans whereas others may include strategic, action and implementation elements in the same document.

At the neighbourhood scale, *neighbourhood energy plans* are more detailed plans focused on technical feasibility, engineering design and cost assessment. While some neighbourhoods or districts may have these overarching strategic yet detailed energy plans, at least in Canada there are only a few examples of these to date. Neighbourhood scale energy and emissions strategies and actions may also appear in neighbourhood or local area land use plans. It is equally likely however that neighbourhood energy planning documents might not be called plans at all but rather be one or more detailed pre-feasibility or feasibility assessments or engineering design studies for retrofits of specific buildings or groups of buildings, or district or renewable energy technologies.

With respect to *energy and emissions inventories* and *balances* describing the current context (or *baseline* or *base case* or *reference case*), it appears that inventories characterize primarily the structure of demand, while balances undertake additional work to characterize and 'balance' both demand and supply. Inventories are more common in North American energy and emissions planning whereas balances are more common in Europe, possibly owing to better data availability.

Thinking upstream about the various site-to-source ratios and conversion factors used to calculate *well-to-wheel primary energy use* this term was retained where it appeared in the text. . Another less precise decision was made with regards to *emissions* which is used both on its own and together with *carbon dioxide equivalent emissions* and *greenhouse gas (GHG) emissions* interchangeably.

It is also important to impart clarity to the terms used to describe going from the present to the future. Scenario analysis can be accomplished using both qualitative techniques such as brainstorming and quantitative techniques such as computer-based simulation tools. The baseline or base case or reference scenario is also called Business-As-Usual (BAU). Any other scenario, having assumptions that can range from modest and incremental to paradigm-shifting, is strictly speaking an alternate scenario. Each alternate scenario however is usually given another unique locally-relevant name. For example, 'Standard Suburban', 'Neighbourhood Centers' and 'Downtown Infill' were the names given to the integrated energy scenarios developer for Prince George, Canada.

It was sorted out that scenario analysis is also known as *transition analysis*. Used in Dutch planning, transition analysis is scenario planning with a greater emphasis on stakeholder engagement and creativity, specifically through the use of *backcasting* or working backwards from long-term targets. Forecasting is beginning in the present and working towards future milestones and targets.

⁸ <http://www.energy.gov.on.ca/en/municipal-energy/>

Backcasting and forecasting can be equally applied to the construction of scenarios using more quantitative techniques. Interestingly, to do transition analysis, Dutch planners invite stakeholders into the *transition arena*; it is much harder to bring people inside a quantitative computer-based scenario.

Going from the means to the ends, the *vision* is a long-term overarching vision of success defined collectively by community stakeholders. *Goals* are more specific objectives that support the vision, for instance *co-benefits* such as improving quality of life. The general goal of achieving *energy efficient low-carbon communities* is also shared by many. *Targets* are explicitly quantitative and long-term, for instance the target of achieving a 30% reduction in energy use in existing buildings by 2030 (from a 2010 baseline). The term *milestones* describes interim or short-term quantitative targets, sorts of fence posts on path to the long-term targets; looking at the 30% example above, a milestone might be to achieve a 15% energy use reduction by 2020.

Although targets can be set and later adjusted a persistent truth is that reaching energy and emissions targets requires leadership. In the Netherlands, leading municipalities are called *front-runners* and innovative projects are referred to as either *front-runner* or ground breaking. What are called *steering approaches* are otherwise understood as *leadership models*. Related to the idea of leadership is *management*, which may be better understood by some as control or steering.

With respect to stakeholders, what are described most accurately as (energy) end-users by some countries, are the *general public* in others. *Residents* may also be called *occupants*, *inhabitants* or *tenants*. The *municipality* refers to the local government; the *municipal administration* are its staff and *city councilors* its elected officials.

One discovery was that what is called *end-energy* in Germany is called *secondary energy use* (by source) in Canada, more commonly referred to as *energy use* or (improperly by those unfamiliar with the First Law of Thermodynamics), *energy consumption*. This would not pose much of a problem were it not for the fact that when Canadians say *energy end-use* they are really talking about *energy services* such as heating or lighting to meet *energy needs* such as the need for warmth or illumination. So as to avoid any mix up between end-energy and energy end-use, what is properly secondary energy use is simply called *energy use*. Energy services are called out individually as space heating, cooling, domestic hot water (DHW) and so on.

Ultimately, the myriad of technical approaches and decision making aside, local energy planning does come down to people working together towards the common goal of *energy efficient low-carbon communities*. Because knowledge exchange is a key strategy for advancing local energy planning, it is important to foster mutual understanding so that the most benefit can be derived from the experiences and lessons learned in other countries and jurisdictions. Anyone engaged in local energy planning encountering an unfamiliar term is urged to keep an open mind. Try carefully to understand its meaning be it by language or analogy, inference or intuition. Chances are the person may simply be calling something you already know by another name.

2 Local Energy & Climate Change Policy

The United Nations (UN) and the European Union (EU) have created legal and financial frameworks to mitigate climate change impacts and support social and economic sustainability. These frameworks create political commitments and CO₂ emissions reductions targets and set the context for national and local energy and climate policy and action. Based on the information input from Annex 51 participants, Chapter 2 surveys the local energy and climate change legal, policy and financial frameworks as implemented by participating countries following these requirements.

2.1 Local energy planning as a key factor in climate protection policy

Implementation of international climate frameworks must take place on the ground, on the local and regional levels. Cities and towns therefore play a crucial role in mitigating climate change due to their share of energy consumption and GHG emissions in the public, residential, commercial, industrial and transportation sectors. Some municipalities own local utilities providing energy supply and operating local energy networks enabling them to initiating programs both on the supply and demand sides. Furthermore, sustainable urban development can be promoted by municipalities a key means of mitigating climate change impacts and improving the quality of life in cities.

Figure 2-1 illustrates some of the factors influencing the local energy planning process. There are a great number of factors at play and so it would be a mistake to think that there is only one key to state-of-the-art LEP. Differences in geographic, climatic, architectural and cultural characteristics from country to country necessitate a variety of approaches. For example, with regard to countries in the EU there are major differences in energy standards although they are all based on the same EU directives such as the Energy Performance of Buildings Directive (EPBD).

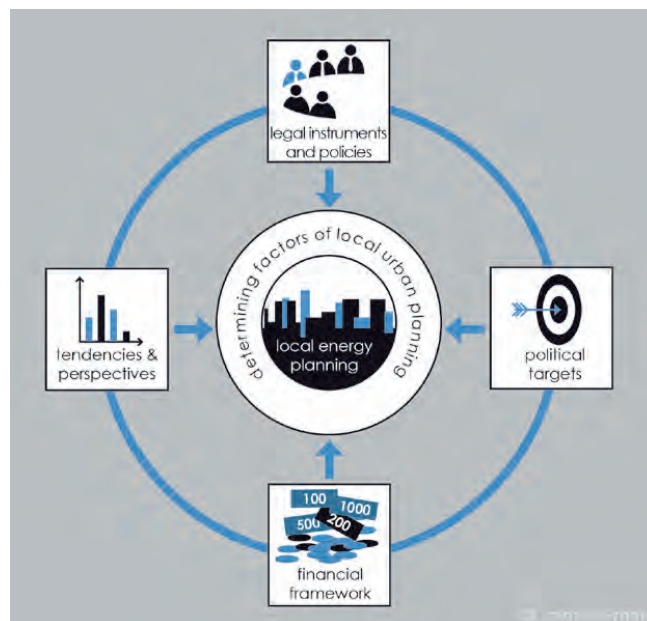


Figure 2-1: Factors influencing local planning. Source: pro:21 GmbH

European Union countries must adapt their national legislation and regulations to be in accordance with EU directives. As a result, national building legislation in Austria, Denmark, Finland, France,

Germany, the Netherlands and Sweden are similar. The following overview therefore focuses on different approaches taken by different countries, showcasing achievements and identifying challenges encountered. It is important to note that national legislation is modified frequently and descriptions found here are subject to change. It is nevertheless useful to look beyond national borders to compare the legislation that creates the context for local energy planning.

2.2 Legal and policy frameworks

To respond to the climate change challenge and to achieve GHG emissions reduction targets set by international treaties, countries have developed roadmaps and adopted and implemented policies and action plans. These create the legal context for energy and emissions planning on the municipal level. The following paragraphs outline national policies of greatest relevance for municipal energy policy and LEP. Differences in LEP approaches within participating countries are not presented.



For European Annex 51 partners, comprehensive directives have been adopted by the European Commission mainly derived from the Kyoto protocol. The EU approved an integrated energy and climate change policy in December 2008. Within the scope of this policy, several goals were established towards achieving a low-carbon and energy efficient economy. The main objectives of the EU are described in the so called '20/20/20 goal'. Starting with a 2005 baseline, this goal aims to achieve a 20% reduction in CO₂ emissions, a 20% share of renewable energy supply and a 20% increase in energy efficiency by 2020. Besides implementing measures to increase energy efficiency in transportation and manufacturing, energy use for heating and cooling in buildings has been the main focus of the EU. To increase energy efficiency and to harness GHG emissions reductions and cost savings in the building stock, the EU enacted the Energy Performance of Buildings Directive (EPBD). A central element of the EPBD is the obligation to issue energy performance certificates for individual buildings. These certificates rate either building energy demand or energy end-use using either modelling or measured end use. In May 2010, an amendment to this directive was passed announcing that by 2021 all new buildings will need to be built to be *near net-zero energy* standards. Near net zero energy buildings require the least possible amount of energy for heating and cooling, demands which are preferably met by renewables.⁹ By 2015, EU member states are committed to present strategic plans to comply with these requirements. To further illustrate different national approaches in the building sector various green building standards and codes for energy efficient buildings are described in Attachments A and B of Chapter 3.3.

To assure that a 20% share of energy is derived from renewable sources by 2020 (including a 10% share specific to the transport sector) the European Commission has passed the Renewables Directive (2009/28/EC). This directive mandates country-specific targets for the share of energy from renewable sources by 2020. For EU Annex 51 members these targets range from 14% for the Netherlands to 49% for Sweden. The directive also sets the legal framework for the generation of electricity from renewable sources and introduces sustainability criteria for biofuels.



Austria is taking several legislative approaches to comply with Kyoto targets and EU directives. The EPBD has been transferred into Austrian Federal legislation. Under the Green Electricity Act (*Ökostromgesetz*), uniform feed-in tariffs and surcharges aim at increasing the share of renewable energy sources, in particular

from hydropower. Another legal tool established in 2009 is the Combined Heat and Power (CHP) Act (*KWK-Gesetz*). It promotes CHP through the partial reimbursement of operating expenses for new and modernized CHP plants for public district heating and investment grants for new CHP plants, with the exception of those covered by the Green Electricity Act. Concerning district heating and cooling, the

⁹ For new public buildings this will already apply from 2019 onwards.

Law for the Development of District Heating and Cooling Networks was introduced in 2009 to provide financial support to deploy district heating and cooling technologies. Under this law, up to 35% of investment costs can be subsidised.

Spatial planning is regulated in Austria at the state level and each federal state has a Spatial Planning Law (*Raumordnungsgesetz*). A national coordinating platform known as ÖROK (*Österreichische Raumordnungskonferenz*) manages spatial planning nationally. This dichotomy allows federal states to set laws which respond to local and regional contexts. In 2012, due to air quality requirements in urban areas the federal state of Styria allowed municipalities to declare priority areas for district heating infrastructure and to enforce the requirement to connect to an existing district heating network. However, initial experiences show the difficulty of implementing such regulations.

 In **Denmark**, the Danish Energy Roadmap looks out to 2050 when total energy demand for electricity, heat, industry and transport must be met with renewable energy. Intermediate targets include that by 2035 the electricity and heat supply will be met entirely by renewable energy sources. This goal is supported by

reduced heating demand in buildings owing to tightening of building codes, refurbishment of the existing stock and legislative obligations around efficiency of energy production and its use.

The Danish Government's implementation of the EPBD set strict target figures of maximum thermal energy consumption and introduced a revised building code that mandates efficiency improvement requirements for new, renovated and existing buildings.

Danish Building Regulation BR10 sets requirements for heating energy use for all buildings heated to at least 15°C. See table 2-1, where A is the gross conditioned floor area in square meters (m²). New, more stringent requirements will come into force in 2015.

Table 2-1: Heating energy use requirements established in Danish Building Regulation BR10

Building type	Today	2015
Housing	52.5 + 1.650 / A (kWh/m ² /a)	30 + 1.000 / A (kWh/m ² /a)
Non domestic	71.3 + 1.650 / A (kWh/m ² /a)	41 + 1.000 / A [kWh/m ² /a)

BR10 requires total primary energy demand to be below 71 kWh/m² annually for buildings larger than 2,200 m² and 90 kWh/m² annually for smaller buildings. This value includes both thermal energy (heating, DHW) and auxiliary electricity for pumps, ventilation calculated according to total heated floor area¹⁰ and the number of heated floors. The requirements cover all habitable buildings including hotels. For offices, schools and other institutional buildings, the code allows a 20% increase in specific energy demands. Specific requirements apply to large renovations.

Two classes of low-energy buildings exist, as defined by municipalities. Progressive municipalities require that a certain number of buildings, typically between 25 and 250 dwellings, must be low-energy. Local authorities can designate areas, not including low-energy houses, to be supplied either by district heating or natural gas which increases investment security and economic viability.

Denmark's Heat Supply Act¹¹ empowers the Minister for Energy to ban electric heating in new buildings located within a district heating or natural gas supply network and requires existing buildings to switch from electric heating. The Minister made use of this power resulting in a decrease in the

¹⁰ Measured outside the building

¹¹ First established in 1979 and extensively revised in 1990, 2000 and 2005

number of electrically heated homes by over 9,000 between 1994 and 2008. For the public sector, Denmark imposed obligations including incorporating energy performance into procurement policies, mandatory implementation of energy conservation projects with a payback time of less than five years, and publicly reporting on energy and water consumption greater than 100,000 kWh per institution. Other provisions in the Heat Supply Act include the obligatory connection to the district heating or natural gas supply network, the principle of cogeneration of heat and electricity and the principle for heat pricing (see below). The opportunity to ensure that all buildings in a given area are connected to the district heating or natural gas network has increased the coverage of district heating considerably. Currently, more than 50% of Denmark's 2.7 million households are supplied by district heating. The long-term plan is that over 70% of building heating demand will be met with district energy.

About 80% of district heating is produced alongside electricity, due to the Heat Supply Act's provision that power plants larger than 1 MW must be operated as CHP plants. As a result, Denmark has the largest fraction of electricity generation provided by CHP plants in the EU; more than half of all electricity produced in the country is co-generated with heat. The principle for heat pricing stipulates that heat supplies must be priced according to actual reference costs on a non-profit basis. However, to increase the use of renewable energy resources and industrial surplus heat, heat from these resources can be sold at a profit, within limits set by the Danish Energy Regulatory Authority.



Finland passed the Building Code which represents a set of building regulations derived from the Land Use and Building Act. These include mandatory limits for the U-values of the building envelope and the air exchange rates of residential buildings (airtightness of naturally vented buildings max. 2 h^{-1} ; heat recovery efficiency of mechanically ventilated buildings at least 45%). With the exception of buildings with a floor area of less than 50 m^2 , traditional cottages for summer-only use and agricultural buildings with low energy use, as of July 1, 2012 all new buildings must adhere to new standards on their total primary energy requirements.

In addition to the Building Code, the Finnish government exercises energy conservation agreements in which companies voluntarily analyse their own energy consumption and draw up an action plan on implementing cost-effective efficiency measures. Accordingly, municipalities adhering to the "municipal sector agreement scheme" have committed themselves to similar measures.



In February 2000, the **French** government passed an electricity law that establishes fixed feed-in tariffs for the purchase of electricity from renewable energy sources and CHP plants. The law regulates the access of independent energy producers to the grid and lays the foundation for a new tender scheme to advance renewable energy production capacity. Another area of concern was the energy efficiency of boilers, which France tackled with two decrees that became effective in 2000. One imposes minimal thermal efficiency standards for the operation of boilers when their annual thermal energy production is between 400 kWh and 50 MWh. The second requires periodic retro-commissioning of boilers with a capacity greater than 1 MW.

Regarding the energy efficiency of buildings, advancements have been made through thermal regulations dependent on climate zone and building type. The thermal regulations (RT - *réglementation thermique*), were first established in 1975 and tightened periodically (RT2000, RT2005 and RT2012). According to RT2012, new buildings must achieve a primary energy consumption of less than 50 kWh/m^2 per year, a significant increase in efficiency from RT2005 which required new buildings to consume less than 150 kWh/m^2 annually. Included in this figure are heating, cooling,

domestic hot water, lighting, and other electricity for ventilation and pumps.¹² There are also a number of new eco-labels such as *Effinergie+*, based on RT2012. *Effinergie+* aims to go beyond the 2007 Low-Energy Building label (BBC - which also required primary energy consumption of < 50 kWh/m²/a) by requiring buildings to be air-tight. In addition, as of 2011 anyone seeking to sell a building must obtain an energy performance certificate and include the performance rating in real estate advertisements. The certificate is ranked on one of seven levels of consumption, enabling prospective buyers and tenants to make informed decisions.

As result of the 2007 Grenelle Environment Round Table (a national consultation process which addressed energy, transportation, urban planning, health and biodiversity governance), France developed a strategy for promoting renewable energy sources that includes a variety of operational measures, aiming to achieve the long-term goal of reducing GHG emissions by a factor of 4 by 2050. The strategy retains the official EU '20/20/20' target as a milestone target to be achieved by 2020. This strategy is reflected in a planning law called National Commitment to the Environment, (also known as the Grenelle II Law) enacted in July 2010. In addition to a specific roadmap for the transportation sector, the law introduces the following requirements with respect to local energy policy:

- The legal framework on urban planning and development
 - Requires each region and community with more than 50,000 inhabitants to have its own local energy action plan based on a quantitative local baseline inventory by 2012.
 - Requires planning documents called "Regional Patterns of Climate and Air Policy" to be co-led by state officials in the region and its communities. These are to include targets for energy efficiency by 2020 and 2050 (consistent with national targets) and targets to reduce air pollution. Land use climate action plans must take these plans into account.
- Concerning renewable energy development, the legal framework
 - Defines areas suitable for renewable energy development (wind energy development zones) and introduces monitoring and evaluation of results over time.
 - Stipulates that network operators must provide grid connections to renewable energy in accordance with the "Regional Patterns of Climate and Air Policy", benefitting both from renewable energy tariffs and the obligation of utilities to purchase electricity from renewable sources. Under certain conditions, departmental (or state), regional and inter-municipal cooperation can be achieved.
- Concerning risk assessment, it
 - Requires regional energy mapping to assess climate change related risks as well as air pollution and GHG-emissions risks and to determine domestic energy needs within the country. On this basis, adaptation strategies and monitoring instruments must be developed.
- Concerning local GHG emission assessment, it stipulates that
 - Companies with over 500 employees, as well as local and regional authorities with more than 50,000 inhabitants, must provide GHG emissions statements.
- Concerning funding of exceptional eco-projects,
 - best practices for eco-buildings, eco-neighbourhoods and eco-cities are supported using Grenelle Funds, established by each state.

¹² See also [www.rt-batiment.fr/batiments-neufs/reglementation-thermique-2012](https://doi.org/10.51202/6763616791232), which includes the definition of specific low-energy standards for buildings; RT2020 is currently under preparation.



Germany is pursuing more ambitious goals than requested by the EU Commission, adopted in the form of an integrated energy master plan in September, 2010; this was revised in 2011 to take into account the nuclear energy phase out. The energy and climate policy targets are a reduction of GHG

emissions by 40% by 2020 and by 80% by 2050, compared to a 1990 baseline. Additionally, by 2020 18% of the end energy use must be supplied by renewable energy sources. The share of renewable energy in Germany must reach 80% of total primary energy use by 2050.

The first German energy action plan, enacted in 2007, improved frameworks for the energy service market, financial services for energy efficiency measures implemented by building owners and marketing and education programs for energy conservation measures in the building stock. The Energy Conservation Ordinance *Energieeinsparverordnung* (EnEV) prescribes minimum performance standards for the thermal insulation of the building envelope and the heating systems of new buildings; EnEV has been revised four times since 2002. Energy performance requirements for new buildings are based on a so-called 'mirror baseline building' or reference building. Each building is compared with a reference building with the same geometry, occupancy profiles and defined thermal energy supply system (i.e. condensing gas boiler, solar collectors for DHW). The resulting calculation for the reference building determines the maximum primary energy use for the proposed building; different types of building envelope and system technologies can be used as long as the maximum primary energy is not exceeded. An additional requirement is set for the average U-value of the building envelope. For existing buildings, energy requirements must be met when more than 20% of the area of a given building element is being renovated, for instance more than 20% of the total wall area. The owner has a choice of either meeting the new building element requirements (which in 2010 were U-values of 0.24 W/m²·K for walls and roofs, 0.20 W/m²·K for flat roofs and 1.30 W/m²·K for windows) or demonstrating that the entire building does not exceed 140% of the requirements for a similar new building.

New buildings must employ renewable energy sources to cover a certain part of their thermal energy demand for space heating and DHW, unless they are connected to district heating or exceed the insulation requirements by at least 15%. At least 15% of the thermal energy demand must be supplied by solar collectors; if biomass or heat pumps are employed, at least 50% must be supplied by these sources. Individual states of the German Federation can set additional requirements, such as an extension of this regulation also to existing buildings upon refurbishment – a requirement that so far has been enacted only by the State of Baden-Württemberg.

The on-going tightening of norms and standards for buildings since 1984 has led to a reduction of energy use in new buildings by 50%. It is anticipated that another 50% reduction will be achieved by 2020, provided that available technologies are considered to be economically viable.

In order to avoid increased dependence on fossil fuels following the accelerated nuclear energy phase-out an increase in the use of renewable energy sources is required. In the electricity sector, the market share of renewable electricity must be increased to at least 35% by 2020; this would, in an annual energy balance, compensate for the reduction in nuclear energy. To achieve this target, construction of offshore wind farms and geothermal energy is supported by specific programs involving the German Development Bank *Kreditanstalt für Wiederaufbau* (KfW) as follows:

- Construction of the first ten offshore wind farms will be supported by an Offshore Wind Energy Program valued at 5 billion EUR. The purpose is to understand challenges associated with installations in deep water and far from shore.
- KfW and insurance company Munich Re have started a loan program for the development of geothermal energy, with 60 million EUR available to fund deep geothermal drilling projects. The specific purpose of this program is to reduce the risks associated with

exploration. Up to a maximum of 80% of eligible costs can be funded. If geothermal energy is not discovered, the investor is exempt from having to repay the loan. The exploration risk of the geothermal projects, and thus eligibility must be analyzed in detail before the loan is handed out.

The feed-in tariffs for electricity from onshore wind farms, biomass and PV panels have been reduced on the other hand, tracking the dynamics of cost development that can be observed here.

There is also a program to enable small and medium-sized businesses and utilities to gain access to KfW loans for specific investments on renewable energies or energy efficiency measures.

An incentive program for cogeneration plants smaller than 2 megawatts of electricity (MW_{el}) was first introduced in 2003 and amended in 2009 and 2012. This program provides a bonus in addition to the market price of 1.80 – 2.50 euro cents per kilowatt hours of electricity (ct/kWh_{el}), depending on the size of the cogeneration plant, for electricity fed back into the grid. The market price for cogeneration plants is defined by the EEX Stock Exchange in Leipzig. The purpose of the law is to double the share of combined heat and power generation from the current level of 12% to about 25% by 2020.¹³

In order to support national energy goals by providing best practice examples, four federal German ministries (the Economic Affairs/Technology, Research/Education, Agriculture, and Building Sector Secretaries) run energy technology research programs which address both basic research and technical applications. The programs cover most energy technology fields, from renewable energies to energy conservation in buildings and energy efficiency technologies in the industry and the automobile sector (batteries, fuel cells, electric cars). In addition, 'clean coal technologies' and Carbon Capture and Storage (CCS) are addressed. A special focus of the program is the building sector, currently expanding to the systemic consideration of communities and city-wide technologies rather than individual buildings. The practicality of corresponding planning approaches for neighbourhoods is currently being tested in pilot projects of the EnEff:Stadt program (research on energy efficient cities) of the Federal Ministry of Economics and Technology. The total volume of federal energy research programs is in the range of 1 billion EUR per year.



In **the Netherlands** building energy performance standards came into force in 1995. As a result of the EPBD a new national law was enacted, including the new building label Energy Performance Standard (EPN) and a flexible approach for planners to achieve the required performance standards. The requirements are no longer focused on individual measures or building components but on the total energy performance requirement of a building. Since 1995, building energy performance requirements have been tightened by 60%.

Since January 2008, an energy label has been mandatory for new sales and the rental of homes and buildings such as offices, shops, schools and hospitals. In addition to the energy performance certificate, the label provides information on possible energy saving measures in a building. It is planned that energy labels will play a bigger role in the country's energy strategy to reach national targets.¹⁴

Energy targets in the Dutch national policy for 2020 are:

- a reduction of 30% CO₂ emissions compared to 1990,
- 14% renewable energy share of total energy consumption (4% in 2011), and
- annual energy savings of 2% beginning in 2011.

¹³ For more details see [www.asue.de/themen/blockheizkraftwerke/broschueren/kwk-gesetz-2012.html](https://asue.de/themen/blockheizkraftwerke/broschueren/kwk-gesetz-2012.html)

¹⁴ <http://www.rijksoverheid.nl/onderwerpen/energielabel-woning>



Sweden has enacted a set of building regulations aimed at ensuring that new buildings meet essential technical requirements as well as environmental goals. The energy standard for residential buildings with direct electric heating has been tightened by imposing a maximum annual energy use threshold for heating and hot water of 55 kWh/m²/a in the southern climate zone and 95 kWh/m²/a in the northern climate zone, while houses using other heating systems have a limit of 90 kWh/m²/a in the southern climate zone, and 130 kWh/m²/a in the northern climate zone. These thresholds do not include household electricity. Non-residential buildings have somewhat lower standards.

Energy performance certificates provide information about a building's energy use, as required by EU regulation. Using reference values, a building's energy performance can be compared with that of similar buildings, a process known as benchmarking. The property owner is responsible for obtaining an energy performance certificate for a building. The data are entered into the Swedish National Board of Housing's registry for energy performance certificates. The registry contains information about the building including energy use, information on the surrounding area, technical systems, and proposals for cost-effective energy saving measures. Consumers looking to buy a certain building are given an identification number by their realtor that can be used to obtain information on the building. Since 2007, data on approximately 400,000 buildings have been entered into the register, representing around 10% of the total Swedish building stock.

In order to give consumers a greater role in the electricity and gas market, the Act on Guarantees of Origin for Electricity entered into force in December 2010. The purpose of the Act is to allow users to know the origin of electricity used. They can then decide on the source of energy they use, since electricity producers need to provide a certain amount of *green power*. Electricity derived from renewable energy sources is slightly more expensive: the retail price of electricity is about 0.02 EUR/kWh higher than electricity generated from conventional sources. All companies must be able to account for the source of the electricity they distribute. Guarantees of Origin are electronic documents that indicate the energy carrier and the power plant used for electricity generation.

Since 1977 all Swedish municipalities have been required by law to establish a local energy action plan describing how generation, distribution and use of energy are managed today and in the future. The law was not properly enforced however and the implementation of these plans has been slow. Nevertheless, by 2010 all large municipalities and the majority of smaller municipalities have developed such plans. According to Swedish and European regulations the local energy action plans must be updated regularly and the results must be evaluated.

Additionally, Sweden and Norway have come to an agreement on a common market for electricity certificates. The purpose of the common market is to improve market function, increase its cost effectiveness and give rise to a greater production of renewable electricity.



Building regulations in **Switzerland** are the responsibility of the Swiss states known as *cantons*. Since 2000 cantons have been harmonizing their building regulations according to Cantonal Model Building Prescriptions (MuKEn). Current requirements aim for improvements of the building envelope and an increased

use of waste heat and renewable energy to meet the remaining energy demand. The Swiss Federal Office for Energy has worked in partnership with cantons to determine a building standard (SIA standard 380/1-2009) and labelling system. According to this standard, the required maximum heating energy consumption for new residential buildings is 42 kWh/m² and 80 kWh/m² for renovated residential buildings. In addition, *Minergie* is a voluntary low-energy building standard for both new and renovated buildings, corresponding to the German *Passivhaus* standard. *Minergie* also includes standards for non-residential buildings (commercial and industrial as well as for hospitals, sporting

facilities etc.). It has become an important decision making factor when houses and apartments are rented or sold.

To encourage the purchase of energy efficient household appliances, the Swiss energy agency S.A.F.E. hosts a website (www.topten.ch). This website ranks household appliances and services according to energy consumption, environmental impact, usage properties, product quality, health safety and cost-benefit ratio.



Canada's target is to achieve a 17% reduction in GHG emissions compared to 2005 levels by 2020. A feature of Canada's energy policy making is constitutional division of powers between federal and provincial governments. The Canadian constitution contains one federal, ten provincial and three territorial governments. The direct ownership, management and regulation of most natural resources as well as the responsibility for land use planning fall under provincial jurisdiction. Issues of interprovincial, national or international concern, including energy R&D for the benefit of Canadians, fall under federal jurisdiction. Municipalities are granted authority or concurrent authorities in the areas of land use planning and building.

To provide a concrete example, the National Energy Code for Buildings (NECB, 2011) is developed as a model code at the national level by the federal government in collaboration with stakeholders. Energy provisions in the code are adopted or adapted and enacted into law through the building codes of the respective provinces and territories.

Through the Energy Efficiency Act, the federal government also establishes minimum energy performance standards (MEPS) for residential heating and cooling equipment and a broad range of household appliances and equipment. These standards are developed by NRCan's Office of Energy Efficiency in co-operation with industry, national standards organizations such as the Canadian Standards Association and the government of the United States.

The provinces enact legislation governing the generation, transmission or transportation and distribution of electricity and natural gas by public or private utilities. In Ontario, the Green Energy and Economic Act establishes a Feed-In-Tariff (FIT) to accelerate the deployment of renewable electricity generation; it has created 50,000 direct and indirect jobs relating to energy and energy services within the province. In British Columbia, where almost all of the province's electricity comes from hydro power, a strong emphasis is placed on *demand side management* (DSM) (also known as *conservation demand management* CDM), in particular through BC Hydro's Power Smart program. In the province of Manitoba where hydro-electricity is also predominant, ground source heat pumps have been promoted extensively. The province is home to more than one third of Canada's heat pump industry.

In the province of Nova Scotia, the enactment of the Environmental Goals and Sustainable Prosperity Act (EGSPA) is accelerating renewable energy generation projects. New Brunswick introduced the NB Energy Blueprint with 20 actions to accelerate uptake of efficiency improvement measures in district heating, the use of renewable energy for thermal energy generation, a renewal of energy infrastructure as well as the implementation of smart grids.

In British Columbia, the Local Government Act requires municipalities to include GHG emissions reduction targets, policies and actions in their Official Community Plans. This requirement is altering the nature of community energy and emissions planning in the province; municipalities are beginning to ask what combinations of actions will yield the emissions reduction targets they have set and at what cost. The provincial government works with utilities to create the Community Energy and Emissions Inventory (CEEI) reports on behalf of all local government in the province.¹⁵ The CEEI

¹⁵ www.toolkit.bc.ca/ceei

reports enable each municipality to automatically fulfill Milestone One of the Partners for Climate Protection (PCP) program.

In Quebec, the *Association Québécoise pour la Maîtrise de l'Énergie*, charged with the responsibility of promoting energy efficiency throughout the province, has developed a program called My Efficient Municipality (*Ma Municipalité Efficace*) that aids municipalities in developing and implementing energy plans. The program links energy efficiency and local economic development through the promotion of biomass as a fuel source.



In **Japan**, the law concerning the rational use of energy as part of the revised energy conservation law is continuously updated and represents the foundation of much of Japan's energy efficiency policy. In 2008, the Energy Conservation Act was revised to strengthen measures to enhance energy efficiency, including those for the commercial sector. Among the revisions, sectorial approaches and company-wide energy management have for the first time been introduced as a domestic regulatory measure. Currently, each factory and workplace is required to achieve on average a 1% reduction or more in energy intensity annually. The revision adds benchmarking indicators and associated targets in certain sub-sectors. Targets are set at the energy efficiency level of the best performing companies (top 10%-20%). The government may take action when it sees a substantial lack of efforts to achieve the targets. Potential measures could include providing the company with information and guidance, publishing the company's name and ordering the company to increase its efforts; a fine is imposed if the company does not adhere to the order. The indicators' average value and standard deviation for each sub-sector will also be published by the government based on company reports. On the other hand, the names of companies performing well beyond the target will be published as well.

Large-scale facilities with a total energy consumption of more than 30 gigawatt hours annually (GWh/a) in crude oil equivalent are required to file a long-term energy conservation plan with the government in collaboration with an energy conservation expert. Mid-size facilities that consume more than 15 GWh/a in crude oil equivalent are required to promote the rational use of energy in the same way as the large facilities and to submit energy conservation reports periodically to the government.

The Energy Conservation and Recycling Assistance Act for businesses was revised in May 2003 and the effective period was extended to 2013. With the latest modifications, the act now covers 3R (reduce, reuse, recycle) activities, additional financial assistance for overseas energy conservation or CO₂ emission reduction projects, and the use of Kyoto Mechanisms (the revised act covers CDM and JI projects). From its inception, this act has assisted business operators who voluntarily undertake activities such as the rationalization of energy use and the use of recycled resources, including the provision of financial incentives, such as low-interest loans.

In August 2011, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) issued Low Carbon City Development Guidance. It covers the residential, commercial and transportation sectors in cities. The Guidance offers technical advice as stipulated in the provisions of Article 245 of the Local Autonomy Law and accordingly, local authorities are free to adjust its application to their urban policy decisions. The Guidance is intended to be used for decision-making opportunities such as the master plan of city development. Target years are assigned to be consistent with the time frame of short (10 years), medium (20 years), and long-term (40 years) planning periods.¹⁶

The Low Carbon City Promotion Law was approved in August, 2012. This law encourages municipalities to develop a low-carbon community plan (LCCP). With the approval of the LCCP by the central government, a municipality can receive financial support for part of the plan's implementation.

¹⁶ http://www.mlit.go.jp/toshi/city_plan/teitanso.html

After the Great East Japan Earthquake in 2011, the Japanese government came to believe that it would need to review the national energy strategy it had previously promoted. The Energy and the Environment Council approved the Innovative Strategy on Energy and the Environment on September 14th, 2012.¹⁷ The Strategy's basic policy is to strive to reduce dependence on both nuclear energy and fossil fuels, by maximizing green energy solutions such as energy efficiency and renewable energy.



Although the **United States** did not ratify the Kyoto Protocol, the government has set targets to promote national energy goals. For example, Executive Order No. 13423 emphasizes energy conservation and environmental requirements by making GHG management a federal government priority. The Order defines reporting requirements with detailed targets and timelines for federal agencies with a focus on transportation, overall energy use, and procurement policies. While the order mandates that all federal agencies measure, report, and reduce their GHG emissions, it also calls for numerous federal energy requirements in a variety of areas such as sustainable buildings and communities, improved water efficiency, improved electronic products and service efficiency and stewardship.

Concerning the building sector, federal government agencies are required by law to eliminate fossil fuel use in new and renovated facilities by 2030 and to reduce overall facility energy usage by 30% by 2015. New buildings and buildings undergoing major renovations are required to reduce consumption of energy generated from fossil-fuels, both off and on site, as compared with energy use in a similar building in the 2003 fiscal year by 55% by 2010, 80% by 2020, and 100% by 2030. The baseline is established by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey and data from the Energy Information Agency.

The 2005 Energy Policy Act requires that federal facilities are built to achieve at least 30% energy savings compared to the 2004 International Energy Conservation Code (IECC) or American Society of Heating and Refrigeration Engineers (ASHRAE) Standard 90.1-2004 and that energy efficient designs must be life cycle cost effective.¹⁸

2.3 Financial frameworks

To achieve energy and GHG emissions reduction targets and related socio-economic objectives through legal frameworks requires significant financial resources. This section describes some of the fiscal instruments and financing approaches used in Annex 51 countries to facilitate energy planning and project implementation. Additional instruments used by participating countries, such as *white and green certificates*, will be examined further in Chapter 3.

2.3.1 Funds

One of the most commonly used fiscal instruments to promote and support environmental programs or projects are EU monetary funds. These offer favourable conditions for investors complying with the goals of a specific fund. The seven Annex 51 participating countries that are EU member states can make use of the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund. These funds are intended to promote territorial cooperation, regional competitiveness and improved conditions for growth and employment in the least-developed member states and regions. A total of 347 billion EUR are allocated for the January 2007 to December 2013 period, equivalent to approximately 40% of the EU's budget over that period. These large funding opportunities target infrastructure and development projects that are to be co-financed by specific

¹⁷ http://www.npu.go.jp/en/policy/policy06/pdf/20121004/121004_en2.pdf

¹⁸ Zhivov et al. (2012): "Energy Master Planning towards Net-Zero Energy Communities and Campuses".

eligible member states and the EU. The energy infrastructure components of these projects can be co-funded through the ERDF, thus supporting local energy investment.

Launched in 2004, the EU CONCERTO initiative has supported local communities in initiating activities and projects that are both sustainable and energy efficient. It primarily focuses on the environmental, economic and social benefits of integrating renewable energy sources through a sustainable energy-management system operated on the community level. In particular, CONCERTO aims to demonstrate that the optimisation of the building stock of whole neighbourhoods is more efficient and cheaper than optimising each building individually.¹⁹ The initiative has co-funded 58 communities in 23 countries. The CONCERTO initiative can be considered a first step towards the European Smart Cities program.

Another mechanism to achieve the EU's energy targets is the Intelligent Energy Europe (IEE) program. The premise of IEE is that although a wide range of technologies and methods already exist to improve energy efficiency and the use of renewable energy sources in the building and transportation sectors, these solutions are not realizing their full potential due to inefficient market conditions. In order to improve these conditions, IEE uses a funding scheme that supports the use of the technologies, their dissemination and European-wide knowledge exchange.

The current IEE funding period ends in 2013; in 2014 the IEE scheme will be integrated into a research program called Horizon 2020. The new IEE will be focused on supporting the rapid market launch of new energy efficient technologies. Horizon 2020 will include the Smart Cities & Communities Initiative which supports cities and regions in taking ambitious measures to achieve a 40% reduction in GHG emissions by 2020. Funding for this initiative will be awarded through annual calls for proposals; 365 million EUR in financing has been announced for 2013.²⁰



The **Austrian** National Energy Council has initiated the Climate and Energy Fund which is a means for the federal government to implement the Austrian Climate Change policy. To work towards a sustainable energy supply the program was endowed with a subsidy of up to 500 million EUR from 2007 to 2010. Since not all of the funds were used, the program is still in effect. Subsidies are particularly aimed at supporting innovative projects and awarding contracts which make an important contribution to national energy targets. The Fund covers three main program branches: research and development in sustainable energy technologies and climate change, local and regional public transportation projects, environmentally friendly freight traffic, as well as commercialization of climate-relevant and sustainable energy technologies. In addition, the Building of Tomorrow research program provides financial incentives for the research, development and deployment of components and demonstration buildings with innovative standards. Last but not least, the Climate and Energy Fund initiated the Smart Cities program²¹ in 2010. Calls for research and demonstration projects with a strong focus on cities are being issued by this program.



Denmark established a Danish Carbon Fund (DCF), which is managed by the World Bank. In cooperation with the Danish Ministry of Foreign Affairs and the Danish Environmental Protection Agency and five private sector participants²², the fund supports environmental projects throughout the developing world. The DCF seeks to contribute to the mitigation of greenhouse gases in countries with economies in transition and a portion of its overall capital is committed to the purchase of emission reductions through Kyoto Protocol Joint Implementation (JI) projects in countries in Eastern Europe and Central Asia.

¹⁹ <http://concerto.eu/concerto/about-concerto.html>

²⁰ http://ec.europa.eu/energy/technology/initiatives/smart_cities_en.htm

²¹ www.smartcities.at

²² In 2005: Elsam Kraft and Energi E2, Aalborg Portland, Nordjysk Elhandel and Maersk Olie



Since the 1990s, Berlin as a federal state of **Germany** has been accessing ERDF and ESF to refurbish parts of the city's infrastructure. Around 1 billion EUR have been used for more than 1,000 sponsored projects. In recent years retrofit of the public building stock has been the main focus; numerous nurseries, schools and municipal baths have been renovated. Some demonstration projects have focused on heritage buildings requiring special care in the remodelling process.



Until 2011, **the Netherlands** had the More with Less (*Meer met Minder*) program, aimed at helping building owners to conserve energy with the least possible effort. The process involved building owners receiving certified energy advice and support for the implementation of required energy efficiency

measures. It also provided a contact person intended to serve as guide to the building owner. Based on customized energy advice, measures that could be subsidized were determined. The cost was between 300 and 750 EUR, depending on the energy efficiency improvement of the building. From 2008 to 2011 approximately 500,000 buildings were made 30% more energy efficient. The program had a total budget of 10 million EUR.



Since 2010, **Sweden's** regional counties and municipalities have relied on national support for local energy efficiency planning. This instrument is a result of the EU's Directive for Energy Efficiency of 2011 which advocates a leading role for public institutions. Counties and municipalities may also on a voluntary basis access the European Energy Efficiency Fund (EEEF). The EEEF focuses on financing energy efficiency, small-scale renewable energy and clean urban transport projects by targeting municipal, local and regional authorities and public and private entities acting on behalf of those authorities.



In **Switzerland**, due to the independence of the cantons, financial approaches to support energy investments within the framework of local energy action plans differ widely from canton to canton. A leading example is the canton of Basel City which as early as 1999 introduced a tariff on electricity sales (*Tarife Elektrizität*). Revenues from the tariff are retained in an energy fund managed by the canton and used to finance investments in demonstration projects and soft measures intended to provide guidance to home owners looking to retrofit their buildings.



In **Canada** ecoENERGY initiatives provide funding to help Canadians use energy more efficiently, boost renewable energy supplies and develop cleaner technologies. ecoENERGY funding is available across multiple sectors including for energy efficient new and existing housing and buildings, aboriginal and northern communities, vehicles as well as research and development. For example, the highly successful ecoENERGY Retrofit for Homes program ran from 1998 until 2012 and disbursed over 934 million CAD. The program provided grants of up to 5,000 CAD to homeowners for eligible energy efficiency retrofits. A key component contributing to the success of the program was the Energy Rating System (ERS) that used housing energy simulation software to rate and label the energy performance of existing houses. Multiple provinces and some utilities continue to offer funding based on ERS ratings.²³

Canada's Gas Tax Fund provides funding to municipalities to help build and revitalize public infrastructure in the areas of drinking water, wastewater infrastructure, public transit, community energy systems, solid waste management and roads. The fund will have disbursed a total of 13 billion

²³ <http://oe.nrcan.gc.ca/residential/personal/retrofit/272>

CAD between by 2014 since its inception in 2005. Funds are allocated to each province and territory based on population; projects are prioritized according to local infrastructure needs.

Also endowed by the federal government is the Green Municipal Fund (GMF), a 550 million CAD revolving fund managed by the Federation of Canadian Municipalities. The GMF is aimed at supporting environmental initiatives and stimulating investment in municipal infrastructure. The fund provides both grants and repayable loans to the municipalities who propose projects that fall within five categories: water, energy, transportation, brownfields and waste. Communities must be part of the FCM's Partners for Climate Protection program in order to participate and must demonstrate through calculation and monitoring the beneficial impact of the project in terms of greenhouse gas reduction. They must also undertake the project as part of a longer term community plan. Since the GMF's inception in the early years of the millennium over 875 projects have been funded and an estimated 3 billion CAN of investment leveraged from public and private sector partners has been raised.

As noted earlier in the policy section, energy utilities have been delivering DSM and CDM programs using traditional marketing techniques to encourage participation. That these programs are increasingly important as mechanisms to reduce total energy demand is evident in terms of asset management, as many of the utilities are facing significant infrastructure investment in future years. To support provincial policy in British Columbia the electrical utility provided funding for communities to develop energy plans or to fund the position of an energy manager for the community.

2.3.2 Grants

Grants are non-repayable funds disbursed by a grant maker which may be a government department or a foundation. While grants originally were typically used by non-profit entities for educational purposes, they are becoming increasingly important in the environmental sector.



Finland has established a budget on state level that can be disbursed by The Housing Finance and Development Centre of Finland (*Asumisen rahoitusja kehittämisskeskus*) for improvements in the condition and quality of individual apartments and apartment buildings. Grants are aimed at reducing both energy consumption and GHG emissions and are also awarded for renewable energy sources. For individuals, this grant can cover up to 25% of the approved costs. These grants are administered by local authorities.



Sweden's Local Investment Programme (LIP) is managed by the Swedish Environmental Protection Agency (Swedish EPA) in order to support investments made by municipalities. The agency cooperates with local companies and organisations involved in ecological or sustainability projects, while the

municipality determines the nature and direction of the investment according to its opportunities and priorities. Thus, Swedish municipalities are responsible for allocating grant funding to different investors with the aim of enhancing ecological sustainability in the community. In doing so, they comply with the Ordinance on Support for Local Investment Programs aimed at Enhancing Ecological Sustainability in the Community (1998). The ordinance regulates the program to ensure that tangible results are achieved. Investments under the program can include a wide range of activities that promote sustainability, and comprise investments which aim to make more efficient use of energy and other resources, as well as those that make greater use of renewable raw materials. Of note is that LIP differs from other government grants in that there is no technical management. In other words, the Swedish EPA does not favour specific technological solutions. Instead, its focus is on environmental and employment impact.



In **Canada**, the Federation of Canadian Municipalities (FCM) manages the 550 million Canadian dollar (CAD) Green Municipal Fund (GMF) offering funding and knowledge to municipal governments and their partners for municipal environmental projects.²⁴ Plans, studies and projects in the areas of brownfields, energy, transportation, water and waste are funded through a combination of grants and low interest loans. In 2013-2014 up to 5 million CAD will be made available in grants and 45 million CAD in loans. Interest rates on the loans can be as low as 1.5%. Municipalities also traditionally obtain capital loans from their respective provincial or territorial governments that are disbursed proportionally according to population. GMF loans however are not restricted in this manner.



The **Japanese** Ministry of Economy, Trade and Industry (METI) and the New Energy and Industrial Technology Development Organization (NEDO) have implemented an incentive program for private companies or public sector bodies that invest in advanced new-energy technologies and facilities. They include PV systems, wind power, solar heat, cogeneration using natural gas, fuel cell demo-projects, the use of waste heat and production of waste fuel. The program provides grants of up to one third or one half of the installation costs for the private and public sectors respectively. In 2008, the program's budget was 37.8 billion Japanese Yen (JPY) or about 380 million EUR.



In the **United States**, Energy Efficiency and Conservation Block Grant (EECBG) Program, is intended to assist cities, counties, states, territories, and Indian tribes to develop, promote, implement, and manage energy efficiency and conservation projects and programs designed to reduce fossil fuel emissions and the total energy use, to improve energy efficiency in the transportation, building, and other appropriate sectors and to create and retain jobs. Funded for the first time by the American Recovery and Reinvestment Act of 2009, the program empowers local communities to make strategic investments to meet the nation's long-term goals for energy independence. Funding for the program totals 3.2 billion American dollars (USD). Eligible projects include:

- Development of an energy efficiency and conservation strategy,
- Financial incentive programs for energy efficiency such as energy savings performance contracting, on-bill financing, and revolving loan funds,
- Installation of efficient energy systems such as combined heat and power and district heating and cooling,
- Installation of renewable energy technologies for government buildings.²⁵

2.3.3 Feed-in tariffs

One policy mechanism meant to increase investment in renewable energy technologies that has become increasingly important during recent years is the feed-in tariff (FIT)²⁶. The goal of feed-in tariffs is to offer cost-based compensation to renewable energy producers, thereby providing price certainty and long-term contracts that, depending on the specific design, can help finance investments into electricity generation using renewables. An additional important feature is the commitment of local grid operators to feed electricity generated into the grid.



Based on **Austria's** Green Electricity Act there are feed-in tariffs for electricity from renewables, which are set by the Austrian Ministry of Economics.

²⁴ <http://www.fcm.ca/home/programs/green-municipal-fund.htm>

²⁵ www.eere.energy.gov/wip/eeecbg.html

²⁶ Also known as standard offer contract, advanced renewable tariff or renewable energy payments.

Additionally, there are financial incentives for the installation of small-scale PV systems. The feed-in tariffs have led to the growing implementation of PV systems in particular, since there is an attractive tariff which is guaranteed for a longer period of approximately 12 years. There is however an annual cap for subsidised projects determined by the total available budget which in 2012 amounted to 19 million euros for PV, wind power and hydro power, 8 million EUR of which were designated for PV.

While feed-in tariffs offer necessary incentives for the development of green electricity in Austria, the demand for available funding shows that the budget available in effect severely limits the effective implementation of renewable electricity generation facilities, in particular PV.



Denmark uses a feed-in tariff to promote renewable energy systems. The tariff is issued over a fifteen-year period and it is primarily used for wind power. As an example, onshore grid-connected wind power installed in 2008 benefits from a feed-in premium of 0.25 Danish kroner (DKK) per kWh (0.034 EUR/kWh) for electricity produced in the first 22,000 peak-load hours from the wind turbine; this is equivalent to about 10 years of operation, depending on location. The tariffs for wind power were essential for developing the successful Danish wind power industry. For electricity produced using biogas, Stirling engines or other specialized electricity production plants using biomass, the feed-in premium results in a total price of 0.745 DKK/kWh (0.10 EUR/kWh). A premium of 0.405 DKK/kWh (0.054 EUR/kWh) is granted for the share of electricity produced by power plants using biomass sources in addition to fossil energy carriers. The premiums and market prices are index-adjusted annually. For solar, wave and hydropower as well as other renewable energy plants (except for biomass and biogas), separate tariff provisions apply depending on the date of grid connection.



Finland plans to increase its annual electricity production derived from wind power to 6 TWh by 2020, to comply with the EU's directive to increase its share of renewable energy to 38% by 2020. To facilitate this increase, the country introduced a feed-in tariff in March 2011. The rate paid amounts to the difference between the target price of 83.5 EUR/MWh and the three month average spot market price. The duration of the FIT is 12 years after which electricity producers receive the spot market price. A similar regulation applies to biogas electricity: the producer is paid a tariff that covers the difference between the target and spot market prices. The target price for electricity from biogas is 83.5 EUR/MWh and the tariff is paid for 12 years. For electricity from CHP the target price is 133.5 EUR/MWh.



Due to **France's** planning law On National Commitment to the Environment or Grenelle II, administrative procedures for small solar systems have been simplified. Additionally, individuals can now install PV panels on their buildings and sell electricity produced to the grid, benefitting from a subsidized purchase

price. France also differentiates according to building type as well as type of installation; integrated PV systems receive more subsidies than conventional rooftop systems. Since 2011, rates are revised each quarter based on the number of projects submitted in the previous quarter.

Table 2-2: Feed-in tariffs for electricity produced from PV

Building Type		Power capacity (kW)	Purchase price (EUR/kWh)
Residential dwellings	Building-integrated photovoltaics (BIPV)	0-9	0.35
		9-36	0.31
	Simplified BIPV	0-36 36-100	0.184 0.175
Health and educational buildings	BIPV	0-9	0.25
		9-36	0.25
	Simplified BIPV	0-36 36-100	0.184 0.175
Other buildings	BIPV	0-9	0.21
		0-36	0.184
	Simplified BIPV	36-100	0.175
Other types of installation (PV-farm, non-integrated installations, etc.)		0-12 MW	0.11



Based on the Electricity Feed-in Act of 1991 (*Stromeinspeisegesetz*), **Germany** established the Renewable Energy Act (EEG) in 2000. The Act regulates the feed-in of electricity from renewable energy to the grid and guarantees feed-in prices oriented to technology-specific cost structures. The immediate goal was to offer sufficient incentives to achieve mass production, thereby decreasing costs of renewable energy making electricity from renewables competitive in the long term. The incremental costs of electricity generation are subsidized by an electricity price increase for private households, the public and commercial sectors and small and medium industrial operations with low electricity demand; large industrial operations are exempt to preserve their competitiveness.

An important component of this instrument is the identification of the correct feed-in price, which depends on the technology under consideration. A correct feed-in price is a decisive incentive for investors. Following an increase in the number of installations and mass production capacity, technology costs decreased. Since 2003 the feed-in tariff has been periodically adjusted to avoid inadequate compensation while maintaining sufficient incentive for potential investors.

As a result of the FIT and related legislation, renewable electricity supply increased from about 7% of total German electricity generation in 2000 to 22% in 2012. Of the 22% electricity supplied by renewables in 2012, 8.2% was generated from wind energy, 5.5% from biomass, 5.0 % from PV and 3.3% from hydro. The current generation of electricity from renewable sources in Germany amounts to 123 terawatt hours of electricity per year (TWhel/a).

As of June 2013, 34,500 MW of PV are installed. Of the 30,500 megawatts (MW) installed wind energy generation, 400 MW is from offshore wind parks²⁷. 2,000 MW offshore wind parks are currently in planning and policies envision a total of 10,000 MW offshore wind in the long run. Total renewable energy capacity achieved by 2012 means that, under certain favorable conditions, the total electricity demand of the country can be met exclusively with renewable sources.

In the case of PV, due to tariff reductions, aggressive pricing by Chinese manufacturers and low interest rates, the market has been flooded since 2009. A peak installation rate of up to 7,000 megawatts per year (MW/a) was achieved in Germany. Resulting electricity cost increases have been dominated by PV costs, leading to concerns about social acceptance of electricity price increases: In 2012, private households paid an extra EEG charge of 0.065 EUR/kWh (including VAT), a charge that

²⁷ The current EEG feed-in tariff for wind electricity is 0.145 EUR/kWh for offshore and 0.09 EUR/kWh for onshore wind parks; the current generation cost for conventional coal and nuclear power plants is between 0.04 and 0.06 EUR/kWh - externalities such as environmental costs not included.

is expected to rise to over 0.08 EUR/kWh in 2013²⁸. For this reason, an extra cut in PV tariffs to 0.019 EUR/kWh for small household PV panels and 0.013 EUR/kWh for large PV arrays was adopted in 2012. In addition, a cap of 52,000 MW in PV installed under the feed-in law was introduced.

The feed-in law can be considered successful in terms of mass deployment, acceleration of capacity building and cost reductions. Today however, certain limits have been reached around socio-economic costs, grid stability and supply security. While the target of 35% electricity from renewable sources by 2020 still stands to compensate for the nuclear phase-out, the optimal pathway to achieve this goal is in dispute. It is expected that the feed-in law will be redesigned after the German elections in 2013.



The Netherlands is running the SDE (*Stimulerend Duurzame Energie*) program, as authorised by the European Commission (EC), to stimulate the production of renewable energy and combined heat and power to reduce GHG emissions by 30% by 2020. In 2012, the SDE+ program made 1.7 billion euros available for

renewable electricity and heat from biomass, wind, solar, hydropower, geothermal and osmosis.²⁹ Energy producers get a subsidy for the produced energy, but not for the investment of the installation. The SDE+ program compensates the price difference between traditionally produced energy and renewable energy for 5, 12 or 15 years, depending on the energy technology used. The amount of the subsidy depends on the amount of renewable energy produced.³⁰



Switzerland runs a similar program under the new Electricity Supply Act that grants tariffs for remuneration of electricity from renewable energy sources, specified on the basis of reference facilities for each technology and output category. Depending on the technology, the grant applies for a period of between 20 and 25 years. In view of the anticipated progress and increasing marketability of renewable technologies, it is foreseen to periodically lower these feed-in tariffs.



In **Canada**, feed-in tariffs are relatively new. With the exception of Alberta, any electrical generation must be sold to the provincial grid operator or utility. In Ontario, the 2009 Green Energy Act included a feed-in tariff program to purchase wind power, photovoltaic power and biomass. The FIT program was divided into two streams: less than 10 kW and greater 10 kW with an associated pricing structure that encouraged smaller systems. The Ontario Power Authority who manages the FIT program has since developed the Community Energy Partnership Program (CEPP) to help fund the initial development of community-based projects.



In 2012, **Japan** introduced a feed-in tariff for renewable electricity from solar PV, wind power, geothermal power, biomass, and small and medium size hydro. It requires electric utilities to sign a contract to purchase electricity at a fixed price for a long-term period guaranteed by the government.³¹ For instance, electricity from solar power installations of less than 10 kW is to be purchased at

²⁸ In 2012, a total of about 7 bill. EUR was paid by private households in the form of renewable charges added to the normal retail price of electricity. The total costs of the current transition to renewable electricity sources, including costs of system adaptation and new transmission capacity, in Germany is estimated to be about 20 bill. EUR/a, which corresponds to about 0.033 EUR/kWh, if divided by the total electricity consumption in Germany (600 TWh/a).

²⁹ www.agentschapnl.nl

³⁰ A maximum basic amount of 0.015 EUR/kWh for renewable electricity, 1.035 €/Nm³ for renewable gas, and 11.78 EUR/MWh for renewable heat.

³¹ www.meti.go.jp/english/policy/energy_environment/renewable/index.html

a rate of 42 JPY/kWh (0.42 EUR/kWh, tax included) for 20 years. The cost of the scheme is covered by a monthly surcharge collected by electric utilities upon electricity sales which is calculated to be approximately 2 JPY (0.02 EUR/kWh) in 2030.

2.3.4 Subsidies

Subsidies are paid to a particular business or economic sector to stimulate additional action or to accelerate commercialization of new products. Historically, subsidies were used to control prices and exports or secure wages in a manner to safeguard the domestic economy. These payments have become an increasingly popular tool to support environmental projects. Subsidies can be reimbursed, as opposed to grants which are not reimbursed.



In **Austria** the most relevant financial support for the residential construction sector is provided by subsidy schemes for social housing administered by the federal states. These schemes define financial incentives supporting higher building energy performance. Most federal states introduced subsidy schemes

many years ago. Regular tightening of requirements leads to continuous improvements in energy standards within subsidized buildings. In addition, national and federal programmes known as *Sanierungsoffensive* support the refurbishment of commercial and residential buildings and energy supply such as solar thermal and district heating systems. This program, with an annual budget of 100 million euros, offers additional financial incentives aimed at increase the renovation rate of the building stock. While the legal framework determines minimum building standards, financial subsidies play an important role in achieving better standards. In particular, the high market penetration of the *Passivhaus* or passive house-standard (about 15,000 buildings), biomass-heating systems and solar thermal systems can be closely linked to available subsidy schemes.



In **Germany**, the state-owned Reconstruction Credit Institute (*Kreditanstalt für Wiederaufbau* - KfW) bank³² provides incentives for energy efficient buildings including owner-occupied buildings and landlords building new houses or refurbishing existing ones. It is based on the existing building energy standards using detailed definitions of various improved efficiency levels (KfW 70, KfW 55

and KfW 40).³³

KfW also subsidizes integrated local energy plans for redevelopment measures including employment of neighbourhood managers to assist with local energy plan implementation. There are a number of requirements that municipalities must fulfil in order to qualify for subsidies from the KfW, including: analysis of current neighbourhood energy use, providing an action plan that includes all stakeholders, developing a catalogue of measures considering potential energy supply synergies within and outside the neighbourhood and an evaluation of lessons learned. 65% of the costs of the neighbourhood manager can be subsidized, to a maximum of 20,000 euros per neighbourhood. Local authorities can apply for subsidies directly at KfW.

The *Bundesamt für Wirtschaft und Ausfuhrkontrolle* (BAFA) is another German institution offering subsidies. Two of its major goals are to increase CHP generation and to stipulate market incentive programs for renewable energy technologies. BAFA mainly subsidizes the energy sector and municipalities.

³² Created in 1948 after World War II as part of the Marshal Plan.

³³ KfW 70 refers to a maximum of 70% of primary energy regarding the current EnEV 2009.



Japan offers several subsidies as investment incentives for the installation of building equipment as well as housing and retrofit projects. This way, building owners installing high-efficiency air conditioning systems, water supply systems or efficient insulation materials that have been evaluated by the New Energy and Industrial Technology Development Organization (NEDO) are eligible for partial subsidies. Japan's subsidy program for state-of-the-art hot water systems (e.g. heat pumps operating with CO₂ as working fluid, latent heat recovery or gas engines) covers the price difference between innovative and conventional water-heating systems. Subsidies are also available to encourage the uptake of highly efficient air conditioning systems using heat pump technologies in commercial buildings.



In **France**, in conjunction with the implementation of the Grenelle process, a Grenelle Fund was established to support the implementation of innovative measures in the energy, building and transportation sectors. In the building sector, by 2012 about 3,000 buildings have been supported by a low-interest

loan program coordinated by ADEME. At the beginning of the program new buildings dominated however the focus has recently shifted to existing buildings, acknowledging that they are the main barrier to success. The pursuit of experimental or demonstration projects employing innovative technologies with the potential for nation-wide replication is the objective of this program. Smart-grid solutions enabling integration of intermittent renewable energy supply are included. 'Ecocity' projects that address holistic solutions for communities, infrastructure operators and industries are also targeted. Specific aims or technologies are identified by national experts in periodic calls of interest; applicants can provide their projects for approval by the *Agence de l'Environnement et de la Maitrise de l'Energie* (ADEME), which is also responsible for evaluation and dissemination of results.

2.3.5 Tax schemes

Tax models stimulate energy conservation among small energy consumers by offering a direct benefit through tax credits. In other words, home owners can pay less income tax in exchange for installing energy efficiency measures or renewable energy supply. Other taxes are used to create specific incentives or services for consumers to promote energy savings such as information campaigns or free energy consultations.



In **Austria**, a pact on tax revenue sharing was established between the Federation, the federal states and the municipalities in order to allow more flexibility for housing support schemes. The states receive an annual budget from the Federation called 'building support' which can be spent in accordance with federal state objectives. While this money can be spent on other improvements to infrastructure, environment and finance ministers of the state governments have declared their political willingness for part of the funding to support their climate change policy to achieve targets in the 2010 Austrian Climate Protection Strategy.



At the conclusion of the Green Tax Package scheme in 1999, **Denmark** revised the tax rates for industry and households. The resulting green tax system includes different tax levels, combined with certain reallocations to the sectors as subsidies for environmental projects and voluntary agreements to facilitate the shift towards increased energy efficiency and renewable energy use. A portion of the revenues is used for common state expenditures such as welfare. Between 2005 and 2009, Danish companies have received 19 million EUR in government subsidies to be invested in environmental projects. The grants were funded by national CO₂ tax revenues. Qualifying projects include company

investments in environmental improvements such as implementation of EU regulations and government strategies and R&D of alternative technologies.



As early as 1990, **Finland** introduced a carbon tax based on the carbon content of fossil fuels as an instrument for climate change mitigation. The tax rate evolved from 1.12 euros per tonne of carbon dioxide (EUR/t CO₂) in 1990 to 20 EUR/t CO₂ in 2010. The general structure of energy taxation in Finland changed in January 2011. Taxation of liquid fuels and coal now take into account both energy content and carbon dioxide emissions.

The tax rate for liquid fuels is largely based on energy content but is differentiated according to CO₂ emissions. For example, the rate was reduced for diesel but raised for other road transportation fuels. Since 2012, the CO₂ tax rate for road transportation fuels has been increased from 50 EUR/t CO₂ to 60 EUR/t CO₂; heating fuels are taxed at 30 EUR/t, with a 50% reduction for heating fuels used in CHP. The relative weight of CO₂ in the total tax for coal, natural gas and fuel oils was reduced, due to the introduction of the new energy component. Tax adjustments for natural gas will take place in steps until 2015.



France introduced a tax credit for energy conservation and renewable energy installations which primarily targets residential households. In order to promote sustainable development and energy conservation the scheme applies to purchases of low-temperature boilers, condensation boilers and heating regulation devices as well as the installation of the respective equipment, to a maximum of 8,000 euros per person (EUR/pp).

The sustainable development tax credit, which was created to accelerate smaller energy-efficiency renovations, allows the amount spent for the purchase of equipment or for retrofitting a principal residence to be deducted from income tax owed. The maximum allowable tax credit is 8,000 EUR per person or 16,000 EUR per couple, plus 400 EUR per dependent. To benefit from both support measures, a household's taxable income can be no higher than 45,000 EUR. These tax credits can be combined with a 0% ecological loan, established in 2009 it is meant to encourage home owners to improve their home's energy efficiency. The loan is for a period of 10 years, which the bank can extend to 15 years and can be for a maximum of 30,000 EUR.



In the **Netherlands**, a tax incentive scheme has been in place since 1997. The tax scheme known as EIA aims to save energy by stimulating investment in energy efficient assets and renewable energy technologies. It allows investment in certain technologies (including wind) to be deducted from taxable profit up to a certain percentage of investment costs.³⁴



In **Sweden** oil and coal use have decreased significantly since the 1980s in part due to increasing energy taxes. Sweden's CO₂ tax currently stands at about 100 euros per tonne (EUR/t). First introduced in 1991, an energy tax was introduced even earlier. Use of biomass (e.g. woodchips) was first promoted by taxes on fossil fuels and later also by green electricity certificates, making biomass-fired CHP plants more profitable due to the higher price of conventional fuels. Waste incineration is increasing because it is prohibited to dispose of combustible waste in landfill sites and district heating companies collect revenues for disposal of this waste. District heating has expanded rapidly in recent decades and reflects a political commitment to invest in infrastructure and reduce dependence on imported fossil fuels.

³⁴ <http://www.agentschapnl.nl>

December 2008 saw the introduction of the ROT deduction, financial incentives in the form of tax credits for renovation, maintenance, conversions and extensions of private homes. The main purpose of the ROT deduction is to reduce energy use through a number of energy saving measures such as installing solar heating or solar PV systems as well as heat recovery equipment and heat pumps. Home owners can apply for a tax credit amounting to 50% of the labour costs, to a maximum of 50,000 Swedish Krona (SEK) per year.



Switzerland introduced a CO₂ tax on fossil fuels used for energy purposes such as heating oil, natural gas or coal. The tax regulation will increase prices in order to encourage more economic and efficient use of fossil fuels and increased recourse to low-carbon energy carriers. Taxes received by the government are

redistributed to citizens and businesses in proportion to their payroll, thus the overall state tax rate is left constant.

A tariff on amounting to about 5% of the retail price was introduced in Basel in 1984. The Basel Electricity Savings Trust (*Stromsparerfonds Basel*/ SFB) pays the entire revenue back. Once a year, each citizen receives 72 swiss francs CHF (59.8 EUR) and each company receives around 0.5% of wage costs. The incentive tax motivates electricity savings: consumers using little electricity only pay a small amount in tax but get back the same amount of money as profligate energy users who pay higher taxes.



In **Canada**, accelerated Capital Cost Allowances (CCA) allows as a part of income tax regulations investors an accelerated write-off for certain equipment used to produce energy in a more efficient way or to produce energy from renewable energy sources. As an example a 50% accelerated CCA is provided for eligible

equipment that generates heat for use in an industrial process or electricity by using a renewable energy source, waste fuel or making efficient use of fossil fuels. Use of this allowance extends to district energy and several forms of renewable energy. To qualify, the proponent must submit the design to Natural Resources Canada for review and approval.

Several provinces utilise a Community Investment Fund as a mechanism for developing community-based projects. Investment in the fund allows public sector organizations to reduce their annual taxes.



In **Japan**, a tax incentive scheme is available for businesses investing in specified energy conservation and efficient equipment, providing a depreciation rate of 30% of the acquisition cost. For small businesses, the depreciation rate is coupled with a 7% tax deduction of the acquisition cost. Demand levelling devices benefit from a special depreciation rate applying to 50% of the

acquisition cost. Since 2006, preferential tax rates have applied to systems used in commercial and residential sectors, such as highly efficient air conditioning systems, high-insulation windows, LEDs and other energy efficient systems.



In the **United States**, the Department of Energy is working with Congress to redesign the current tax deduction for commercial building upgrades, transforming the deduction to a more generous credit that will encourage building owners and real estate investment trusts (REITs) to retrofit their properties. These changes could result in a ten-fold increase in commercial

retrofit uptake, leveraging investment and leading to job creation.

2.3.6 Additional options

Complimentary financial mechanisms such as Public Private Partnerships (PPPs) and low interest loans are also in widespread use. PPPs represent a powerful opportunity to establish environmental programs in co-ordinated with industry. A PPP is a government service or private business venture operated by a partnership of a government or other public body with one or more private companies. Examples of PPPs can be found in case studies Aarhus, Denmark and Tilburg, Netherlands.



In **Germany**, low interest loans have proved to be a helpful mechanism to encourage energy conservation and efficiency in the industrial and residential sectors. KfW also provides financial support for specific area development projects and acts by municipalities.



The **Dutch** Block by Block (*Blok voor Blok*) program aims to achieve large-scale energy savings in existing buildings by using existing energy technology in an innovative and large-scale approach. The program has initiated thirteen projects with market parties, municipalities and housing corporations – a minimum of

three stakeholders – working together as a consortium to implement a joint plan to make at least two thousand existing buildings in a given city energy efficient. The projects are planned to provide extensive energy savings in at least 23,500 homes. Between 2011 and 2013, participants share knowledge and lessons learned to possibly arrive at a nationwide introduction of this model. The maximum subsidy per project is 500,000 euros. The total investments by private investors, housing corporations and private owners will be much higher, the national subsidy intended to support costs associated with extra planning processes during the pilot phase.



The **Japan** Housing Finance Agency (JHF) provides low interest and preferential loans for owners of energy efficient houses. The Japanese government also has a low interest loan program aimed at energy conservation projects, services and advice delivered by Energy Service Companies (ESCOs). Another low interest loan program targets measures in buildings such as energy conservation and roof-top gardens. Based on the Energy Conservation and Recycling Assistance Law, low interest loans are available to support businesses voluntarily implementing projects to promote the efficient use of energy and natural resources.

Japan also introduced the Eco-Points System. In this system, the Government provides individuals who purchase eligible eco-friendly products such as home appliances with *eco-points*, which in turn can be exchanged for various goods and services such as exchangeable coupons and pre-paid cards that can be used anywhere in Japan. Organizations providing exchangeable products under this scheme are obliged to make some form of environmental-friendly donation.

2.4 Voluntary agreements and networks

Municipal energy master planning has become an integrated planning task which includes involving citizens and stakeholders and looks in a holistic manner over a long timeframe. Participation in networks such as the Covenant of Mayors (CoM) or the European Energy Award (eea) helps foster dialogue and knowledge sharing successes and lessons learned in past and current projects. An added benefit of participation in networks is greater regional collaboration.



The Covenant of Mayors

The Covenant of Mayors (CoM) is an EU initiative uniting local and regional authorities that commit to increasing energy efficiency and use of renewables and to implementing sustainable energy policies consistent with the EU's 20:20:20 goal. Covenant signatories agree to prepare a Baseline Emission

Inventory and submit, within a year of sign-on, a Sustainable Energy Action Plan (SEAP) outlining the key actions they plan to undertake. These actions serve as examples for others to follow by referring to *Benchmarks of Excellence*, a database of best practices submitted by Covenant signatories. The Catalogue of SEAPs shows the objectives set by other signatories and key measures they have identified to reach their objectives and targets. Promotional, technical and administrative assistance is provided by the CoM office, managed by a consortium of networks representing local and regional authorities. The Covenant benefits from comprehensive institutional support, including the Committee of the Regions, the European Parliament, and the European Investment Bank, which assists local authorities in unlocking their investment potentials. There are currently 4,212 CoM signatories from nearly all EU member states.³⁵



ICLEI - Local Governments for Sustainability

'ICLEI - Local Governments for Sustainability' was established in 1990, when more than 200 local governments from 43 countries convened at its inaugural conference, the World Congress of Local Governments for a Sustainable Future, at the United Nations in New York. It is an association of local governments and national and regional government organizations that have made a commitment to sustainable development. Today, ICLEI

has over 1,200 local government members from 70 different countries.³⁶ It works in partnership with regional, national and international organizations and institutions to ensure an international framework that supports local action and also provides technical consulting, training, and information services to support local governments in the implementation of sustainable development at the local level.

Canada has a number of municipalities involved in the Partners for Climate Protection (PCP) program, administered by the FCM. PCP is a network of Canadian municipal governments that have committed to reducing greenhouse gases and acting on climate change. It is the Canadian component of ICLEI's Cities for Climate Protection (CCP) network, which involves more than 900 communities worldwide. PCP is a partnership between the Federation of Canadian Municipalities (FCM) and ICLEI. PCP receives financial support from the Green Municipal Fund. Currently, 226 Canadian municipalities are voluntarily signatories in the Five Milestone PCP program. The program has been successful in building capacity and fostering actions totalling 200,000 tonnes of GHG emission reductions annually. Impact of the program over time is difficult to assess, however, owing to lack of consistent and complete data and a lack of municipal capacity to monitor projects.



Climate Alliance

Since its foundation in 1990, more than 1,600 cities, municipalities and districts in 20 European countries have joined the Climate Alliance of European Cities with Indigenous Rainforest Peoples association. Regional governments, NGOs and other organizations can join the Alliance as associated members. In order to achieve their GHG emissions reduction

targets member municipalities implement local climate strategies, in particular in the areas of energy and transportation. There are also measures to raise public awareness around rainforest protection and municipal procurement of tropical timber derived from destructive logging.

³⁵ A list of signatories can be found at http://www.eumayors.eu/about/signatories_en.html

³⁶ <http://www.iclei.org>.

By joining Climate Alliance, cities and municipalities voluntarily commit to:

- Reduce CO₂ emissions by 10% every five years;
- Halve per capita emissions by 2030, from a 1990 baseline;
- Preserve tropical rainforests by avoiding the use of tropical timber; and
- Support projects and initiatives of indigenous partners.

Among the Annex 51 countries of Austria, Denmark, France, Germany, Netherlands, Sweden and Switzerland a majority of cities are members of the Climate Alliance.³⁷



European Energy Award (eea)

An evaluation of municipal energy master plans carried out in the 1990s in the German federal states of Bavaria and North Rhine-Westphalia indicated that implementation rates of energy concepts were poor because they had not been linked with long-term municipal

planning. The apparent cause of a variety of challenges is the 'human factor' in the planning process; city and district structures involve a multitude of players with different and sometimes conflicting interests: tenants and landlords, public utilities, city administrations, manufacturers, developers, home owners, housing societies, etc. To optimize planning processes in view of complex participation processes, since 2002 municipal quality management systems have increasingly been introduced by municipalities (e.g. *Energiestadt* in Switzerland, and *e5* in Austria). These management systems, such as the European Energy Award (eea), based on the Swiss program *Energiestadt* and Austrian program *e5*, establish long-term energy planning in municipalities, guide process engineering and continuously monitor the implementation of measures. They help to establish the integral planning approach needed to ensure sustainable urban planning. The European Energy Award operates in more than 1,000 municipalities and administrative districts, representing 14 European countries and is particularly wide-spread in Germany, Austria, France and Switzerland, and most recently also in the majority of communities of the State of Luxemburg.

2.5 General conclusions on legal and financial frameworks

Countries participating in Annex 51 have created a variety of legal, financial and organizational frameworks to improve energy efficiency and the use of renewable energy sources in their cities. National strategies vary considerably in design, complexity and financial costs. Within the EU national legislative and financial frameworks are harmonized to a certain extent by directives issued by the European Commission. National legislators have, in certain cases, reacted to research projects results, (e.g. the Dutch *Blok voor Blok* programme, Danish demonstration projects located in Aarhus, Lystrup, Taastrup and Tilst or the German *EnEff:Stadt* initiative) and adapted their legal frameworks accordingly. In most participating countries energy performance requirements in standards and codes have increased over time, for some if not all sectors.

Strategies employed in participating countries can be generally characterized to:

- Increase the share of renewable supply
- Reduce energy end-use through energy conservation and efficiency
- Increase efficiency in the generation and transformation of energy.

While feed-in-tariffs for electricity fed into the grid from renewables can generally be considered to have a significant impact on renewable energy technology investments in many countries, variables such as rates and duration and inclusion of different sources, differ largely between technologies and

³⁷ A full list is available at http://www.klimabuendnis.org/our_members0.html

from country to country. A special case is PV, heavily promoted by Germany over the last several years through feed-in tariffs. This has led to significant PV growth rates and price decreases but also to a disproportionate electricity cost increase and exhausted grid capacities resulting in local transmission bottlenecks. Achieving technology maturity and market penetration requires an adapted FIT regime: when a certain degree of competitiveness is achieved, further growth can be left to market-oriented instruments. Challenges remain in system integration including back-up and storage capacities to ensure system resilience.

In contrast to electricity from renewable energy sources, no comparable legal instrument to support thermal energy generation from renewable sources or bio-fuels has been implemented in any of the participating countries to date. Thermal energy generation is more local in nature than electricity. It also has a very different market framework than electricity, easier for law-makers to influence the market rules. To foster thermal energy or fuels from renewable energy sources, entirely different instruments are necessary, such as a required use of solar thermal energy or tax exemptions for biofuels tailored to the individual technology to be deployed.

Concerning the legislative frameworks, major differences can be seen within participating countries in their approach and implementation strategies. For example in France, current energy regulations were developed during an extensive participatory process through the Grenelle Process. In order for such participatory processes to be successful, all stakeholders must be dedicated and successful outcomes can be difficult to predict.

France is one of the countries that have recognized the importance of a legal framework to facilitate municipal energy planning by prescribing energy action plans for every department (*department*). In Sweden and Denmark, all large and the majority of smaller municipalities are required to develop local energy plans that must be updated and evaluated regularly. Another example is the German Secretary for the Environment offering grants for communities to develop energy action plans as a pre-requisite to subsidies for investments in local energy measures. In British Columbia, Canada, municipalities are required to include GHG emission reduction targets, policies and actions in their Official Community Plans.

Japan has recently issued new guidelines on energy efficiency specific to corporations. Their enforcement is achieved differently than in other participating countries: companies that do not comply with requirements will have their company names published. This practice raises the general question of successful strategies to enforce energy regulations using carrots and sticks: even though local or municipal climate change policies have been advertised for years, their actual implementation is often still in its infancy. This is not always due to a lack of awareness on the part of consumers or corporations but rather can be attributed to political zigzagging and bureaucratic obstacles that lead to uncertainty and reluctance to make any long-term investments. Apart from the FIT strategy, there are other examples of successful policies such as the *Sanierungsoffensive* in Austria aiming to reduce the number of electric heating systems, or the Dutch *Blok voor Blok* initiative in The Netherlands as an integrated neighbourhood approach, that have yielded tangible results.

Financial incentives and programmes and their availability over a sustained period of time remain crucial to success in energy and climate change policies; and these do not always need to come in the form of subsidies. Participating countries generally employ a combination of standards and incentives to encourage the energy transition; simplicity and ease-of implementation of regulations is becoming an increasing issue for companies and other entities seeking to go beyond the minimum requirements. Fine-tuning and adapting regulations to specific needs results in a greater number of more complex regulations, which in itself can cause a barrier.

Since technical system integration in most cases leads to higher technical complexity even during the operating phase, more know-how is now required on the part of planners and operators than was

previously required for conventional energy supply projects. To avoid technical and economic failure, energy regulations should privilege contracting approaches, where the responsibility for the overall success of an integrated energy project remains with the contractor, in particular during the operating phase. Local legislation and procurement rules should promote this approach to successfully make use of the necessary expert knowledge, including mandatory performance management and operating strategies.

Due to very different legal and policy frameworks in Annex 51 participating countries and to the diversity of energy policy instruments that exists, a comprehensive appraisal of the effectiveness and cost/benefit ratio of the instruments found and their potential transferability to other countries could not be delivered by Annex 51. However after many years of experience, there is value in knowledge exchange and lessons learned for the design of future energy and climate change policy instruments. A more comprehensive analysis of national energy policy approaches within IEA Annex 51 countries and more profound energy policy conclusions should certainly be of great use and could be considered for future research by the IEA.

3 Local Energy Planning Methods: From Demand to Future-proof Solutions

Municipalities play a significant role in implementing global energy and climate policy. They actively contribute to reducing fossil fuel use and GHG emissions by translating international and national targets on the municipal level and, with support of stakeholders and the public, create locally appropriate strategies that lead to concrete action. Chapter 3 describes the local energy planning transition process and effective and successful methods.

Section 3.1 describes the transition process in general and different leadership models. Section 3.2 provides a high level overview of the step by step local energy planning transition process. Sections 3.3 – 3.9 discuss each of the seven steps in detail. Section 3.10 reviews policies and technologies available to planners and decision makers. Additional technical details are contained in the appendices. Because LEP differs in its scope and application at the municipal and neighbourhood scales, strategies and actions at both scales are described.

3.1 The transition process

Current urban design and development follows a linear pathway, where specific issues are dealt with by experts according to a defined set of procedures. This allows the municipality only minimal discretion to accommodate any non-conventional design approaches. The development of energy efficient low carbon communities is a cross-cutting endeavour requiring the coordination and cooperation of many types of expertise and team members and, in addition, new and innovative technologies and planning approaches. A permanent change in an existing process is called *transition*, while the regular way of working is referred to as *Business As Usual*, (Figure 3-1). Experience in local energy planning shows that a business-as-usual approach is insufficient for reaching community

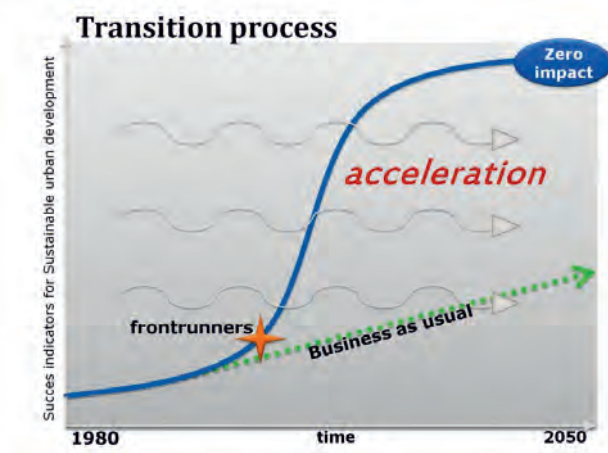


Figure 3-1: Transition process

energy and GHG reduction targets.

Previous research in technical and social systems shows that transition often follows an 's-curve' in three phases: pre-development, take-off and stabilizing. In the pre-development phase, frontrunners or leaders start new initiatives and distinguish themselves through a fundamentally different way of thinking. The take-off phase sees accelerated change in the system with an increasing number of initiatives and participants. At a certain point, the system stabilizes; the new way of working becomes standard practice and may be required by law. Those who at first did not want to change their approach are now compelled to do so.

Looking at municipalities who have successfully engaged in local energy planning identifies characteristics of effective local transition processes. These include political commitment and a vision and targets and co-benefits that are broadly understood and supported by diverse stakeholder groups. The municipal administration has the required knowledge and expertise, there are sufficient resources and organisational structures, management procedures are clear. The roles and responsibilities of everyone involved are also clearly defined. Targets and associated goals are integrated into existing municipal plans and policies and there is a continuous process from planning, project implementation and monitoring and evaluation. Failures are discussed and lessons learned are integrated into planning for future projects. The local energy planning transition is something that must be cultivated over the long-term rather than executed within a single electoral cycle.

To reach ambitious targets and become energy efficient and low carbon, municipalities must follow this transition path adapted to local boundary conditions and policy frameworks. It should be acknowledged that long lead times are required for transitions because new governance models are needed to support the radical shift away from incremental, project-oriented and short-term solutions. Fundamental changes will occur in the structure, culture and practices associated with future-proof neighbourhood developments. By starting early a municipality will be prepared for future challenges. Municipalities must acknowledge however the delay between the implementation of measures and financial pay-off; other co-benefits however may be realized in the short or long terms.

The benefits for municipalities are obvious: by taking an integrated and holistic approach to energy and quality of life, the community will benefit in times of higher energy prices. Communities with energy supplies independent from volatile market conditions will be more competitive. Energy efficient or net zero properties will be more easily sold or rented when energy prices are expected to increase. Organisations will depend on advanced and affordable mobility infrastructure and services to attract skilled employees. By laying the groundwork for a green future, municipal administrators and elected officials will free their cities from the constraints of reliance on expensive and unreliable fossil fuel supplies. From a marketing perspective they also label their community as progressive and smart, creating a valuable advantage over other cities.

3.1.1 Leadership models

Successful and effective energy transitions are not only characterized by a leadership model that uses stakeholder engagement. Although in many ways this leadership approach preferable, analysis of frontrunner projects shows that it is difficult to achieve in existing organisations in practice. It appears that different types of projects require different leadership models in order to be as effective as possible. In the Subtask C case studies identified as frontrunners, six types of leadership models can be identified:

- government-driven
- private sector driven
- end-user driven
- Public-Private Partnerships (PPP)
- the participatory model
- the transition model

A leadership analysis shows which stakeholders are involved and the linkages between them. The choice of the most suitable leadership model for a project or local context depends on many factors such as the organizations involved and the position of individuals within those organizations, the development phase and the diversity of stakeholder interests. For a municipality it is important to be aware of opportunities for smart management of the transition process to an energy efficient community. For example, the municipality does not always play the role of a developer but nevertheless is the approver of the proposed development's strategies and characteristics. Therefore

private-sector or PPP leadership models may be used to involve other stakeholders in the planning and implementation phases.

Figure 3-2 illustrates these leadership models as they relate to different planning contexts. At some point the models partly overlap because in some situations more than one leadership style can be useful. In reality there are also overlaps in the procedures associated with the different prototypical leadership models.

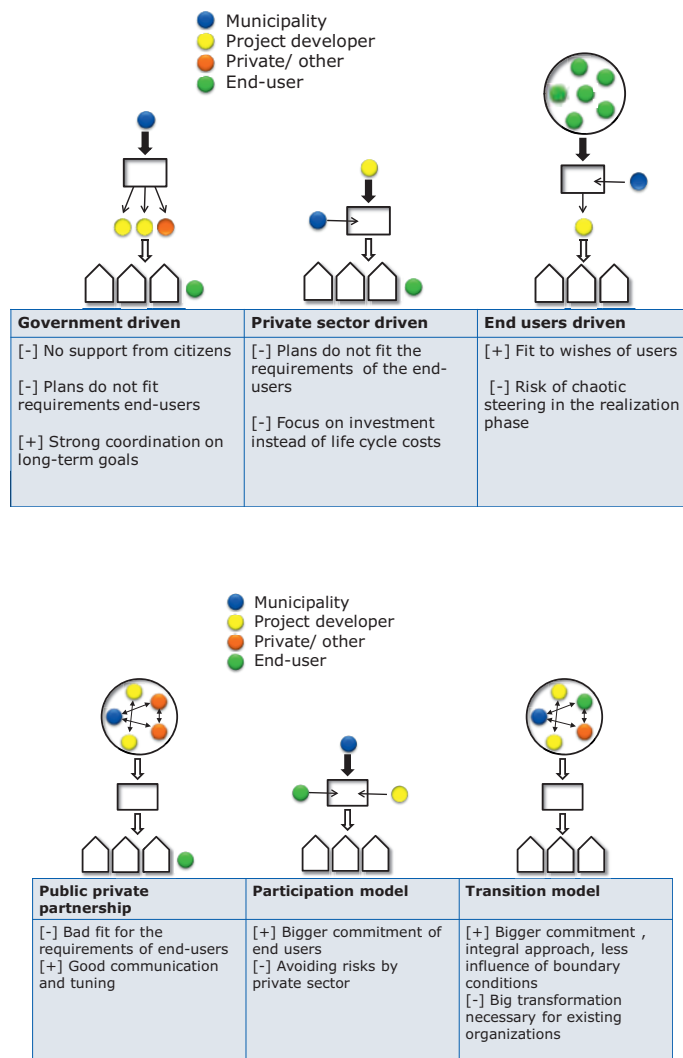


Figure 3-2: Leadership models

Leadership models are worthwhile to consider early in the planning process. Also, since municipal energy master planning processes and energy efficient neighbourhood development projects typically take a long time, the planning or project context will often change mid-course. For example, some project stakeholders will leave and others will become involved. It is probable that with these changes, leadership models and management procedures must also be adapted. Municipalities can

use the leadership models to reflect on how their plans and projects are currently organised and readapt them in order to reach the end goals. Detailed examples of such steering procedures have been described for the demonstration projects of the European CONCERTO initiative in (Di Nucci et al., 2010).

Leadership models

St. Johann, Austria

St. Johann uses a participatory leadership model to organize its energy and emissions planning processes. The initiative was established in the nineties by a member of the municipal administration, and individuals and municipal politicians soon joined. A working group was established in 1998, comprised of municipal policy makers including the Mayor, municipal administrators and individuals; developers are not generally involved aside from during specific projects. In total the working group has 20 members with around 10 participating in regular meetings. One co-ordinator is responsible for meeting invitations, agendas, moderating and taking minutes. Meetings are held between four and five times a year.

Ludwigsburg, Germany

It is difficult to identify which leadership model applies to planning activities in the City of Ludwigsburg. Looking at the urban development concept plan being led by the city's administration it would appear to be an example of a transition model. However a participatory model also applies since the city has a strong tradition of citizen and stakeholder engagement. Analysis of actors in Ludwigsburg reveals that the city council often tries to conform to the wishes of the general public and private investors, consistent with the end-user model.

Aarhus, Denmark

The municipality is leading a process to convert government-led urban planning into a climate partnership engaging the private sector and general public. Conforming to the Danish Planning Act the municipality acts as a leader in practice, including through its role promoting climate-related projects, while engaging the private sector and public, beginning with its own employees.

Nantes, France

The City of Nantes has a hybrid leadership model that is both public and private sector. The process is local government driven with state and private sector inputs and limited general public engagement.

Benefits of this model include good coordination between public and private sector actors and a consistent planning approach at the city scale, including with respect to target setting. Drawbacks include not having sufficient planning input from the public although a stronger role is foreseen in future. It is also difficult to mobilize all actors concerned by climate change mitigation with this approach.

Example Tilburg, the Netherlands

In Tilburg a transition is taking place in the leadership model from government-driven to the transition model. The municipality of Tilburg is initiating the process of target setting for 2045. At the moment the municipality has an executive and organizing role to achieve this target. Eventually the climate partnership and the climate office will take over this executive and organizing role and the municipality will become one of the participants.

3.2 The local energy planning transition process

The primary objectives of *municipal energy master planning* are to establish energy and GHG targets, identify concrete measures to achieve the targets and develop an implementation strategy for the whole town or city over the long term. This requires reliable, consistent and replicable quantitative methods and management processes to support evidence-based community energy and emissions policies and projects. Developing and implementing a city-wide energy strategy takes place over generally decades rather than years. Therefore, continuous monitoring and adaptation to changing legal, financial, political and social conditions is necessary.

Objectives of *neighbourhood energy planning* include assessing the feasibility of specific technologies, developing integrated energy solutions and implementing measures through policies and projects. Local stakeholder engagement and checking that measures proposed in neighbourhood projects and plans contribute to municipal targets are other features of energy planning at the neighbourhood scale.

The following general steps for a successful local energy planning transition process can be identified as follows:

Step 1 Develop an energy and emissions inventory

The energy and emissions inventory or balance characterizes annual energy use for the municipality as a whole by source or carrier and sectors. This enables the municipality and energy working group to assess current energy use and trends over time when the inventory is collected regularly. Additional data describing the building stock, population, renewable energy resources at finer spatio-temporal resolutions will further assist opportunity assessment and neighbourhood planning at later steps in the process.

Step 2 Engage stakeholders, create a vision and establish targets

By conducting a stakeholder analysis the municipality is able to invite participants to a transition arena where they work together to create a common vision and establish long-term quantitative targets. Key supporting indicators may also be identified in this step. The municipality also establishes an energy working group comprised of municipal officials from relevant departments, key stakeholders and a high profile energy planning champion.

Step 3 Assess opportunities and create future scenarios

Using the inventory, additional data and local and expert knowledge, energy efficiency, energy systems and renewable resource opportunities are assessed and key supporting indicators defined. Business As Usual (BAU) and alternative future energy scenarios are created, ideally employing both forecasting and backcasting approaches. Depending on available data and resources the municipality may take a collaborative and engineering approach, making use of best available estimates or leverage computer-based models to undertake a more robust quantification and optimization. The preferred scenario is identified in a roadmap outlining the strategy.

Step 4 Develop municipal energy master plans and neighbourhood energy plans

The municipal energy master plan is a strategic planning document that includes visions, targets and goals, selected baseline values and key indicators. A roadmap of the preferred scenario to reach the municipal target, with prioritized energy conservation, system and supply alternatives is listed, along with implementation and monitoring strategies. Neighbourhood energy plans provide additional technical details on energy demand characteristics of neighbourhoods, preferred supply alternatives, conservation potentials, optimized supply and demand and cost structures. These plans are iterative and should be updated periodically.

Step 5 Implement policies and projects, monitor, evaluate and adjust the process

The process co-ordinator uses integrated process management techniques and works with municipal departments and external stakeholders to implement and monitor measures in the plans, evaluate results, and communicate successes and failures back to the municipality and stakeholders and also as feedback for the purpose of updating the plans. Bottleneck analysis may also be performed to analyse and further improve the process.

It is important to note that this is a generalized local energy planning process that should be adapted to suit the context and needs of the local community. Some tasks may be accomplished in a different order, some new tasks may be added or others omitted entirely. These five steps are interconnected parts of a whole comprehensive process with iterations and feedback loops.

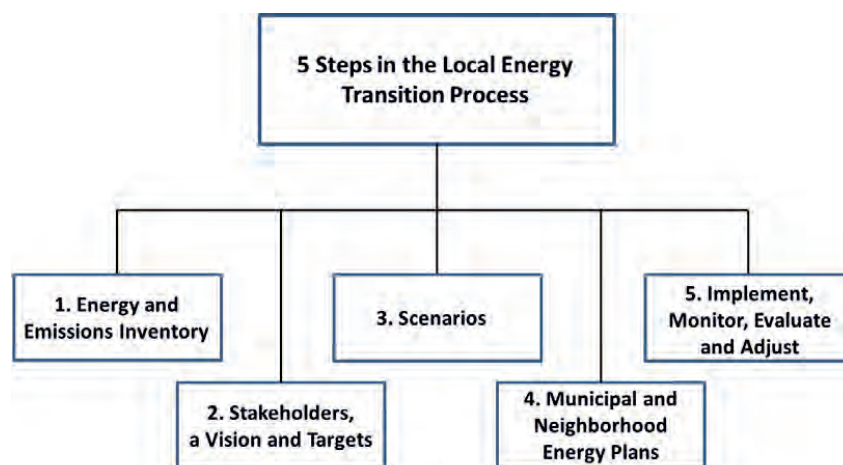


Figure 3-3: Overview of local energy planning transition process

3.3 Step 1 Create an energy and emissions inventory or balance

In jurisdictions where it is not yet mandatory, a municipality must voluntarily decide to engage in local energy planning. Typically this is achieved through a vote by the municipal council. For energy planners, municipal administrators or other community champions, this process can be assisted through various programs offered to municipalities, such as EU Covenant of Mayors (CoM), Klimabündnis, Carbone, or Partners for Climate Protection.

Following the political decision to embark on a local energy planning process, the first step is to create a *baseline municipal energy and GHG emissions inventory or balance*.³⁸ The purpose of compiling this is to:

- Recognize energy demand and supply structure of sectors and activities
- Identify opportunities
- Monitor the results of energy plan implementation
- Benchmark energy and GHG emissions against other communities.

3.3.1 A few words on data

Inventories and models require good quality data and transparent assumptions. Prior to listing the data required to compile an inventory, key terms related to data used in inventories and models are

³⁸ It appears that the main difference between inventories and balances is that inventories primarily characterize a city's energy demand whereas balances describe the energy demand as is met by supply.

described. Anyone creating an inventory or model should be familiar with these concepts both to optimize time spent compiling data and to ensure that the correct information is available at different steps in the local energy planning process.

Measured data is gathered through data logging devices from real world sources. Available for past or present conditions, examples of measured data include historical temperature data or metered electrical or natural gas consumption. Strictly speaking inventories should be comprised of measured data. *Modelled data*, as the name suggests, is output from models. It can describe current and future performance of a given system, be it for one building or a whole community. Examples of modelled data include energy end-use values simulated with building energy software. The distinction between the two is not always clear and modeled values are often used to adjust measured data, particularly when data are missing.

The data, assumptions and outputs of analysis that characterize physical properties of the urban environment and energy supply and use occur at different scales of time and space. At the lowest level of geography are the energy-using equipment or zones for space conditioning within buildings, typically described in square meters of conditioned floor space. Next are the *parcels* with the houses and buildings that occupy them. The parcel is the lowest common spatial denominator for land use planning and the integrated digital parcel fabric is a key data layer in the spatial cadaster. Larger geographical scales are *neighbourhoods* or *districts*, city-wide, regional, provincial or state. Energy use is described at these spatial scales as an absolute figure or more preferably as an intensity factor for example, 120 kWh/m². Data can be aggregated or disaggregated. An example of *aggregation* would be the accumulation of measured energy use in individual residential buildings for the residential sector of a community energy and emissions inventory. *Disaggregation* involves breaking a large number into parts. Both aggregation and disaggregation may be used to develop data at the appropriate spatial scales required for decision making.

Temporal scales, also called *time steps*, are annual, monthly, daily and hourly. The *timeframe* over which data are collected is also important. The performance of a solar domestic hot water system may be monitored on a five minute time-step over the course of a day, or on an hourly basis over the course of a month. A longer timeframe is the *planning horizon* or the number of years over which the local planning process looks out.

All of this is relevant because inventories are produced at the city-scale, on an annual basis for specific calendar years. Decisions made early in the planning process and over larger geographical extents can be based on less detailed information. The later in the planning process and for smaller planning areas, the greater the detail required for the design process. If data is available with finer resolutions, it may be worthwhile to obtain it since it could be useful at a later step in the process. For example, an energy planner can use annualized heating demand intensities from different energy carriers and figures on population and employment densities by city to generally support the case for a district energy subsidy program. However the engineer designing a district energy system requires operating schedules and heating demand of individual buildings down to daily use-profiles to ensure optimal sizing of boilers and piping.

3.3.2 A few words on inventories

Community energy and emissions inventories are based on inventory calculation methodologies referred to as GHG Reporting Protocols. Inventories report measured data on energy use and resources such as solid waste detailing the associated GHG emissions for a given year, for the whole community. Inventories for the community and corporate operations of the municipality are often calculated and presented separately. Community inventories cover typically residential, institutional,

commercial, industrial and transportation³⁹ sectors. A corporate inventory reports energy use and associated GHG emissions from municipal government facilities and operations including buildings, street lighting, water and wastewater treatment and fuel used in the municipal vehicle fleet. Solid waste may be reported in the community or corporate inventory depending on the local approach to waste handling and associated data availability.

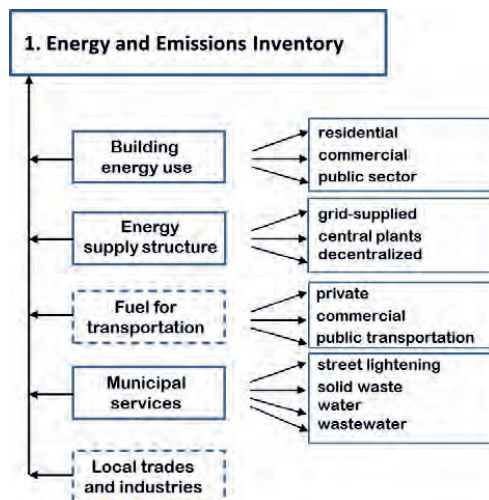


Figure 3-4: Step 1 - Compile a municipal energy and GHG emissions inventory or balance

GHG emissions are calculated on the basis of annual electricity and fossil fuel energy use in buildings, vehicle kilometres travelled and fuel types for transportation, and the quantity and composition of waste and disposal methods. Greenhouse Gas emissions accounted for include carbon dioxide (CO₂), nitrous oxide (N₂O) and methane (CH₄). By using appropriate global warming potential coefficients, GHG emissions from these various gases are reported together, expressed as equivalent tonnes of carbon dioxide or (CO₂e). Some inventories use emissions coefficients for site GHG emissions, calculated on the basis of energy end-use, waste composition and disposal occurring within the geographic boundaries of the municipality. Other inventory methods report GHG emissions by source, taking into account emissions resulting from upstream production, conversion and transportation of fuels or the generation, transmission and distribution of electricity. For the purpose of accurate calculation of GHG emissions, it is important to consult the appropriate database with emissions factors for specific processes and products. Examples are reviewed in Attachments A and F.

Inventories are most useful when they are transparent and compiled consistently over time. They can help municipal decision makers set targets, assess projects being considered for future implementation and observe trends, for example, comparing current emissions with those reported in 1990, the baseline year used in Kyoto Protocol and by communities participating in the EU Covenant of Mayors initiative (EU CoM, 2010). Comparison can also be made with other cities when the inventories have been developed using the same methodological approach; this is often referred to as city benchmarking.

As an assessment of total energy use and GHG emissions in the city, an inventory proves compliance with municipal or national targets. It is used to track the success of the implementation of measures to influence energy use or GHG emission. Since the results of project implementation are usually

³⁹ For information about the specifics of the transportation sector, which is not considered in this Guidebook, see (Praxisleitfaden, 2011).

estimated based on energy system models and simulation results, these must be validated and reported based on monitoring of a project post-occupancy performance. On a broader scale, the community's inventory should reflect the impact of measures and projects implemented to fulfil the municipal energy master plan. Figure 3-5 shows CO₂e emissions in the City of Freiburg, Germany over an 18 year period from 1992 to 2010. The projected trajectory of CO₂e emissions is depicted for two scenarios, Business as Usual (BAU) and the other established by a 1992 policy to achieve 30% emissions reductions by 2012. The lines in between illustrate actual emissions. A 2003 inventory showed that although CO₂e emissions were practically constant, they were better than the increase projected in the BAU scenario. Thus there was some success, but not nearly enough. As a result, the City Council stepped up its energy policy, revised its GHG target and required the inventory to be compiled on a bi-annual basis. This data is depicted by the blue line showing measured CO₂e emissions from 2006 to 2010. Figure 3-5 also shows the long timeframe needed to achieve emissions reductions and the importance of monitoring to assess progress towards targets.

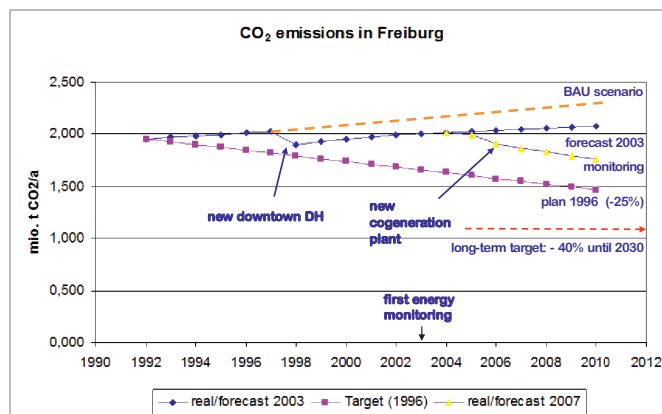


Figure 3-5: Projected and actual CO₂e emissions in Freiburg, Germany 1992 – 2010. Source: Erhorn-Kluttig

3.3.3 Data sources to profile energy demand

The main challenge in creating an inventory is to identify and access the data to describe energy use and supply in the various sectors. Compiling this data by sector and activity so that it may later be used for neighbourhood planning depends on the resolution of the data; detailed datasets describing buildings and equipment in the whole city can be aggregated to the neighbourhood scale, city-scale datasets cannot always be disaggregated. The following sectors and activities should be covered in a municipal energy and GHG emissions inventory.

The public sector

The public sector includes buildings belonging to the municipality and other institutions such as schools and hospitals. In the EU, following the EPBD each public sector building must have a building energy performance certificate based either on measured energy use or modelled demand. These certificates provide good coverage of energy use in public sector buildings. In addition, energy control and management systems are either already in place or are planned for most public buildings. Certain US states and the Canadian province of British Columbia are also requiring reporting of public sector building energy use and emissions data.

Municipal public or traffic lighting may be included as an activity, as recommended by the EU CoM framework (CoM 2010). Public lighting including street and traffic lighting is either managed by the municipality or outsourced to a service provider, in most cases the local utility. Electricity demand is obtained from monthly or annual electricity bills. Lighting measures often result in appreciable savings

achieved in a cost-effective manner. Other public sector services to include in the inventory are water and waste water treatment, solid waste and landfill emissions. Data are typically held by the relevant municipal department or private sector contractor.

The residential sector

Data on energy use in residential buildings including single family dwellings, row houses and low and high-rise apartment buildings can most often be obtained from local utilities or grid operators. Utilities and grid operators are required to track annual grid-supplied electricity, natural gas and district heating/cooling energy use by tariff group or rate structure (usually residential, commercial and industrial, and certified green electricity). This data is reported to federal and often also municipal authorities for statistical purposes.

Heating oil, coal and biomass are not covered by utility data. In Germany, Switzerland and Austria chimney sweep registries are the main data source. This registry lists installed furnaces, fuel type, year of installation, and design load for fire protection purposes. In many other countries the use of oil and biomass is small and suppliers can be approached directly. The annual energy consumption of these plants is usually not available however can be calculated using assumptions on annual residential building operating hours (see Attachment J), average boiler efficiency and boiler age. Seasonal temperature corrections must be made for heating and cooling energy use.

For multi-family buildings, local housing companies or energy contractors or condominium associations may be a reliable source of information. As for the owners of public buildings, within the EU housing companies are committed to compile energy certificates for their buildings and make them publically available.

The commercial sector

The commercial sector includes energy use in commercial, retail and other similar buildings; small and medium manufacturing facilities may also be included. For manufacturing and retail activities within the commercial sector, municipal statistical reports provide indirect information such as the number of businesses, employment by trade or retail floor area for shopping facilities. In many countries, average energy use in terms of kWh per workplace or kWh/m² is available from national statistical databases. These can be compared to any locally available data to support an educated guess on energy demand. Later in the planning process these numbers should be confirmed through additional data collection in the form of surveys.

Figure 3-6 exemplifies the graphical presentation of a typical inventory.

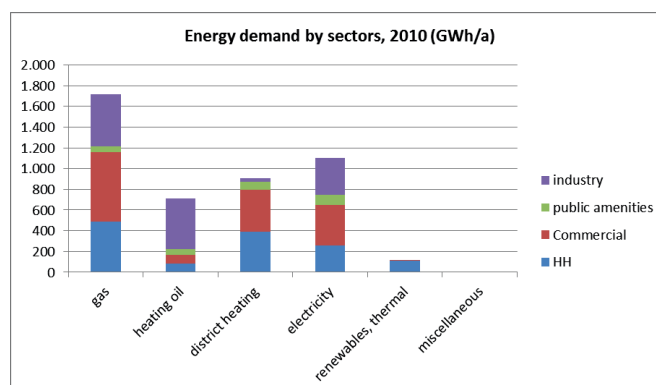


Figure 3-6: Total annual energy use in 2010 by sector and energy source or carrier for Freiburg, Germany (200,000 inh.). 'Renewables thermal' is primarily fuel wood and 'HH' indicates the residential sector.

The industrial sector

Although industrial operations and associated energy consumption may be within the geographic boundaries of the municipality, most of the commodities produced will not be used locally. The industrial sector is often omitted in the municipal energy inventory, an inventory which is correct for benchmarking purposes. If the intent is to compare different cities, industrial energy use and supply should be removed. If industry is able to provide electricity and/or waste heat to adjacent parts of the municipality, it must be considered in a similar way to local power plants, adjusted to the local context. For some kinds of industries, potential can be large. It is therefore important to identify such opportunities when compiling the inventory. Obtaining data on large industrial operations may be difficult in practice to protect commercial interests. Direct contact with plant operators – who in most cities are only a few in number and easy to identify – will be helpful. Co-operation may yield not only data but also the opportunity for local industry to contribute to achieving local energy targets.

Activities characterized as industrial should correspond to the definition used by a given country's statistical agency. Usually, central power plants or industrial processing plants receiving operating permits from regulators fall into this category. In the EU in the national emissions trade registry provides information on medium and large industrial energy and electrical power plants with a design fuel consumption of greater than 20 MW. Other manufacturing facilities such as metal processing plant that need operating permits for environmental reasons are also registered. Energy use for these facilities is often available in an aggregated form for the whole municipality, obtained from the local environmental authority.

To avoid double-counting, activities should be assigned to sectors consistently. For example, publicly owned residential buildings could be defined as belonging to either the public or residential sectors. Table 3-1 provides an overview of data sources for energy use compilation by sector for Germany; the context for Switzerland and Austria is similar.

	Energy from the Grid energy (electricity, gas, DH)	Heating Oil, Coal, biomass	Heat Pumps	Solar Collectors	Photovoltaics
Public Sector Buildings	municipal energy management	municipal energy management	municipal energy management	municipal energy management	municipal energy management
Public Sector Lighting	utility				
Residential Sector Buildings	utility grid operator building archetype library	chimney sweep registry	utility grid operator	local suppliers renewable energy program operators	utility
Commercial Sector Services	utility grid operator building archetype library municipal statistics office personal contact	chimney sweep registry local oil suppliers	utility grid operator	local suppliers renewable energy program operators	utility
Commercial Sector Manufacturing	utility grid operator building archetype library municipal statistics office personal contact	chimney sweep registry regulatory authority personal contact		support program registry direct survey	utility
Industrial Sector	utility grid operator regulatory authority emissions registry	emission trade registry			utility
Waste Processing	utility direct survey	utility direct survey			

Table 3-1: Overview of German energy and GHG emissions inventory data sources by sectors

3.3.4 Other types of data sets to contextualize energy demand and supply

Additional data on population, housing and building construction and demolition (i.e. total floor area, number of new units) and economic productivity must also be collected. These data will support analysis and interpretation of absolute energy and emissions figures contained in the inventory.

Spatial data is also useful for developing energy and emissions inventories or balances and carrying out subsequent energy planning tasks. Spatialized building attribute data may be available from the municipal land-registry department. City Geography Markup Language (CityGML) is an open data model in XML-based format for the storage and exchange of virtual 3D city models.⁴⁰ Introduced into law in the Netherlands and Germany, the standard specifies requirements for building attributes. The fourth level of detail (LOD4) may contain some of the attributes to support energy analysis. One attribute often missing are type and fuel source of heating or DHW systems. Another spatial dataset is

⁴⁰ <http://www.opengeospatial.org/standards/citygml>

Light Detection and Ranging (LiDAR) data, a 3-D point cloud. LiDAR data is also increasingly seen as essential for characterizing building geometry and vegetation. Municipalities may already have this data for watershed management or engineering purposes.

3.3.5 Data sources to profile conventional energy supply

To establish an energy and GHG emissions balance, the following data must be compiled to profile the current energy supply structure:

- Existing power and heating supply plants
 - design power (MW)
 - energy use input (MWh/a)
 - electricity, thermal energy or steam outputs (MWh/a)
 - age
 - efficiency
 - ownership
 - location
- CHP plants (subdivided by thermal base load and peak load facilities)
 - design power (base load, peak load; MW)
 - energy use input (MWh/a)
 - electricity and thermal energy outputs (MWh/a)
 - age
 - efficiency
 - ownership
 - location

How local electricity production and use is treated, and the resulting contribution to the municipal primary energy and GHG balance, creates some difficulty because it is necessary to distinguish between electricity imported from the grid into the community, local electricity generation and electricity exports outside the community. This export, which can be large, will influence the city's energy balance if not properly considered. For example, a major CHP plant supplies heat and a part of the electric power to the city, but exports a significant part of the electricity generated. In this situation, the correct fraction of the power plant's primary energy generation and use must be assigned to the city's energy and GHG balance. Conversely, electricity generated and consumed within the community, such as that distributed by local CHP plants, must be treated differently than electricity imported from outside. For electricity provided by the grid, the national electricity mix is used to calculate the primary energy demand. In cases where certified green electricity is procured, a specified emissions factor must be applied to this share of imported electricity. Consequently, local electricity supply must be split into electricity imported from the external high-voltage grid, electricity generated locally and electricity exports. This approach should be standardized so as to use the same process as for other cities' energy. This is discussed in further detail in attachment H.

3.3.6 Data sources to profile renewable energy supply

In addition to energy efficiency and conservation of conventional supply, renewable energy sources and technologies must also be characterized for the inventory. Several kinds of renewable energy sources may be available in a given city or town including:

- solid waste (incineration, landfill gas)
- biogas from green refuse or agricultural residues
- local biomass residues from landscaping, agricultural and forestry operations such as wood waste and sawdust used to create wood chips or pellets
- solar energy for electricity or hot water

- geothermal energy
- ambient air as a heat source for heat pumps
- hydrology and hydro-electric
- marine energy
- wind energy.

The availability of renewable energy sources will increase appreciably in the countryside surrounding any municipality. Additional biomass potentials (residual wood from forest thinning, wood chips, wood pellets, biogas from agricultural sources, and other biofuels from energy plantations), regional wind farms, and hydro energy might be potential sources for local renewable electric and thermal energy supply and can contribute significantly to the local energy inventory. Such regional potentials should ideally be identified in addition to the potentials of renewables within the geographic boundaries of the municipality.

For any renewable energy source, it is necessary to quantify the gross theoretical potential of renewable resources for policy and decision-making. Sources of renewable energy are highly site-specific, necessitating regional potential and site feasibility assessments. Once focus areas have been identified, a desktop reconnaissance study can be used to screen and identify potential sites for further investigation. It is important to consider the level of effort required to undertake the analysis versus the new knowledge gained. Simple estimates may suffice for sources such as solar – see calculation procedures for estimating solar potentials in Attachment I.

Where more detailed modelling is required GIS is an effective technology integrating information from various data sources for site identification and to assess the feasibility of various technologies. The use of GIS also enables analysis and evaluation of a variety of potential environmental impacts on habitat and aesthetic value. A main feasibility map and accompanying thematic maps can be produced for use in the decision-making process.

When individual sites have been identified, more detailed site assessments and preliminary designs can be carried out at the pre-feasibility and feasibility level, each with an increasing level of detail and cost. Of prime concern is the cost and accuracy of the required assessments - costly, detailed investigations cannot normally be justified for smaller-scale wind, solar and hydro projects. Typically, greater than 15% of site development costs are used for pre-feasibility and feasibility level studies, especially for small wind and small hydro developments.

To support estimation of theoretical potential of renewable energy resources of interest in the municipality, relevant spatial data should be obtained on for example hydrology, forest and vegetation cover and wind speeds. Additional geographical datasets describing elevation, roads, and electricity networks will also be required as will data layers describing areas of exclusion such as national parks, or areas of environmental or archaeological significance. These spatial datasets may be available from national, state or municipal governments in online databases and atlases, or utilities or private sector firms providing data and spatial analysis services.

For example, the International Renewable Energy Agency (IRENA) is developing the Global Renewable Energy Atlas which will include services such as technical potential for wind and solar, calculation of supporting indicators such as CO₂, ability to download maps and common GIS software and information on data quality.⁴¹ RETScreen is a popular Excel based pre-feasibility decision support software that contains databases of information on individual technologies and their performance characteristics. Additionally, cost data on grid electricity prices and locally applicable subsidies or FIT tariffs must also be collected. One example of a database that provides incentive information is the Database for State Incentives for Renewables and Efficiency (DSIRE).⁴²

⁴¹ <http://www.irena.org/globalatlas/>

⁴² <http://www.dsireusa.org/>

Additional spatial data useful for characterizing both energy supply options as well as energy demand in buildings include LiDAR data. LiDAR characterizes the community in a high resolution 3D point cloud. Since this dataset describes the orientation, slope and angle of building rooftops, it is indispensable for analysis of general technical potential for solar thermal or PV systems in urban areas (Klärle, 2011).

Solar atlases

Municipalities and states are making dynamic solar atlases available online. These maps show the locations and generation capacity of installed collectors and enable general resource analysis to assist home and building owners to determine if solar technologies are appropriate for their rooftop. Pre-feasibility financial analysis is completed by using the general technical potential of the proposed installation, its capital cost, electricity rates and available incentives to calculating approximate simple payback periods. In the absence of online solar atlases, data about existing solar collectors can be difficult to obtain. One source might be renewable energy technology grant programs. Installation type, year of construction and size are registered and generally available in aggregated form. Local housing companies, installers or the local utility may also provide this information.



Figure 3-7: Interactive solar map of a residential neighbourhood showing opportunities for rooftop solar energy installations⁴³

The real potential is smaller than the theoretical solar potential (according to the local irradiation); a lack of storage capacity is the main reason why solar thermal energy supply is negligible, even in cities with high insolation. For PV panels in countries with FIT schemes the situation is different. While due to limited overlay of solar insolation profiles and electricity demand, the potential for *direct use* of electricity generation by PV roof panels is below 10% of a household's annual electricity demand, using the public grid for electricity storage, balanced over a full year the potential PV coverage by

⁴³ Source: Solar Roof Cadastre Guidebook, Environmental Secretary of the State of Hesse, Germany; www.energieland.hessen.de/dynasite.cfm?dsid=17355

roof-installations of PV panels may approach 30% or more of the local household electricity demand under conditions observed in Germany.

3.4 Step 2 Engage stakeholders, create a vision and set targets

While it is important to use the right data and have robust quantitative baseline data, municipal energy planning is primarily a management task involving planners, decision makers and local stakeholders. The second step involves engaging stakeholders, establishing working groups, creating a vision and setting targets.

Insufficient support from stakeholders or groups of stakeholders typically results in failure, mainly due to the great effort required to overcome any barriers. Effective stakeholder engagement is essential for the success of local energy planning. Engagement should focus on stakeholder interests, motivation and perspectives. Fair rules must be established; each party has the right to participate and the opportunity to be heard. This implies stakeholders being involved alongside politicians in absence of any political interference. Ideally, stakeholder groups work to support policy makers such as the mayor or municipal council. By focusing on common value, the significant potential benefits of forging new coalitions and experiments will be obvious. Any successes achieved must be presented as a result of the collective effort.

Successful local energy planning therefore requires an understanding of stakeholder needs and an organisational structure responsible for the whole process. Stakeholder analysis and engagement techniques discussed here include stakeholder analysis, the transition arena, energy and emissions working groups and leadership models. Intelligent and efficient planning processes plan for stakeholder engagement from the outset and revisit specific engagement techniques during different phases of the process, or on projects in different neighbourhoods.

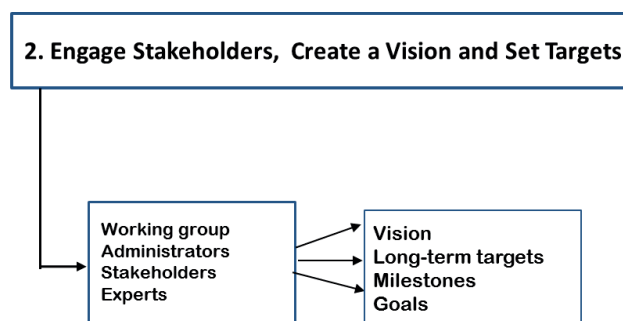


Figure 3-8: Step 2 - Engage stakeholders, create a vision and set targets

3.4.1 Stakeholder analysis

A *stakeholder analysis* aims to map the interests of and relationships between parties engaged in the transition process to an energy efficient low carbon community. Beyond understanding the stakeholders' own interests and economic and political clout, it is important to also identify strengths in innovation. Both a stakeholder analysis and a *force field analysis* are required to prepare the vision and strategy. These are techniques that can be applied both at the city-wide and neighbourhood scales.

A stakeholder analysis maps parties and interest groups and also considers specific individuals who can make a difference. External individuals who are active in the area but have never approached by the municipality ideally must be identified and included. The stakeholder analysis can be applied at both the municipal and neighbourhood scales and asks the following questions:

- Who will directly benefit from the transition to an energy efficient community?
- Who is able to positively influence the process or development?
- Who is able to bring innovation?
- Who is negatively influenced by the process or development?
- Who might oppose and try to block the process or development?
- What are the reasons why one stakeholder would oppose the process or development?
- How should anyone opposing the process or development be handled?

The stakeholders can be classified in different ways. For a transition process, stakeholders are clustered based on skills and vision instead of by interests or decision making power.

The *force field analysis* which looks at different focuses on the interests, interdependencies and decision power of the actors. It identifies which factors will need extra attention in the transition process. This analysis is used to inform the selection of working group members and stakeholders to create the long-term vision. It can also provide insight into what will be required for more detailed neighbourhood analysis and identify new forms of cooperation for project implementation and operation.

Governments, developers and occupants are examples of stakeholders groups. The Government sees the need for energy efficiency in terms of compliance with their overall policy priorities such as national or local GHG emissions reduction targets, residential occupancy rates or local economic development and may also request revised procedures or approval processes favouring, among other things compactness of design and diversity in urban form, social cohesion and quality of life.

The primary concern of the developer or contractor is on the profitability of the investment, with local market conditions and customer choice being highly important factors. The building as it is designed and built must comply with energy provisions in the building codes as well as other municipal by-laws. Energy efficiency is seen as meeting the code requirements through construction materials and techniques, energy using equipment and the provision of energy supply, at minimal cost.

Occupants are interested in energy efficiency or design improvement relating to appliances, lighting, heating and access to equipment. They seek to manage energy use while limiting capital costs for improvements and operating energy costs. For most occupants costs will dictate the degree of improvement possible. An increasing number of occupants are taking interest in the sustainability aspects of their properties and are becoming a driving force for change. Access to information on energy technologies, efficiency techniques and financing options will be increasingly important to the energy transition of communities.

It should be recognised that there will be very different stakeholder dynamics in different countries and regions, because the relationship between and involvement of each level of authority depends upon planning practices and expectations of the general public. For example, housing development in the Netherlands is predominantly driven by the builder or developer. Changes in design approaches would therefore reflect a *market push* and the public authority would focus any incentives, information, legislation, etc. on the builder or the developer. Development practices in Germany are more consumer-driven where the consumer will advise the builder or contractor on how to develop the building. This *market pull* would require the information presented here to be directed towards the consumer. In the United States and Canada both approaches exist. Consumers may define their needs for their own properties but it is the larger developers or *tract builders* who provide much of the new housing stock to meet market demand. This environment allows for both a market push to reduce overall technology costs and a market pull to raise energy performance standards in the sector. It is important for those co-ordinating any local energy planning process to understand the needs and motivations of local stakeholders.

3.4.2 The transition arena

A *transition arena* is a procedure to create collective visions and roadmaps to tackle local issues and problems. The transition arena can be used in different domains such as health care or leading towards energy efficient cities. Typically, the municipality organises the transition arena.

The method is characterized by selective participation, based on stakeholder analysis: a small but mixed group of innovators and change agents in and around the neighbourhood or community are involved. The transition analysis forms the basis for a discussion of the dynamics and potential of the transition to an energy efficient community. An important feature is the strategic link between vision and action: the vision is developed with a broad group to develop paths and an agenda for short-term actions, supported by those participating in the process.

The goal of the transition arena is to foster ambitious perspectives on the future. It is also the basis for creating a network of people who want to innovate. One of the main characteristics of a transition arena is bringing together selected participants who are able to renew, create change and bring together vision, strategy and action. Ideally participants do not safeguard certain interests but contribute their experience and network to the transition process. The process should be based on mutual trust, which is essential for the exchange of perspectives and the search for innovation. The participants are seen as a small but diverse support group, which works on dissemination and institutionalization at later stages.

3.4.3 The energy working group

An *energy working group* is essentially the same as a *transition arena*, only by another name. Many of the organizational features described below can be applied to transition arenas. And working groups could benefit from the ambitious perspectives characteristic of transition arenas.

An interdisciplinary energy team or working group should be established officially by the municipality. This helps to avoid potential conflicts within existing organisational structures. The working group needs appointed members, leadership, well-defined tasks and ideally an independent budget.

Working group members should be selected to represent a range of disciplines and various roles in the municipality, as representatives of stakeholder group or engaged members of the general public. Including the mayor or high-ranking members of the city's administration demonstrates the importance of the task. To be successful the working group needs the time and commitment of all participants.

Working group tasks can be directly linked to either the municipal or neighbourhood energy plans and related measures and projects. Following the process, discussing milestones and results as well as adapting the energy plans are typical working group functions. Approximately three to five meetings annually are necessary to achieve satisfactory results. Active team leadership is important. In particular, it is essential that each participant has the same status in the group, regardless of his or her function or role. Collective effort leads to collective results and being part of a successful team further motivates its members. The group leader must therefore also promote social interaction. Activities such as site visits, the opportunity to participate in training courses or awards distributed by the municipality are helpful to keep working group members engaged and motivated.

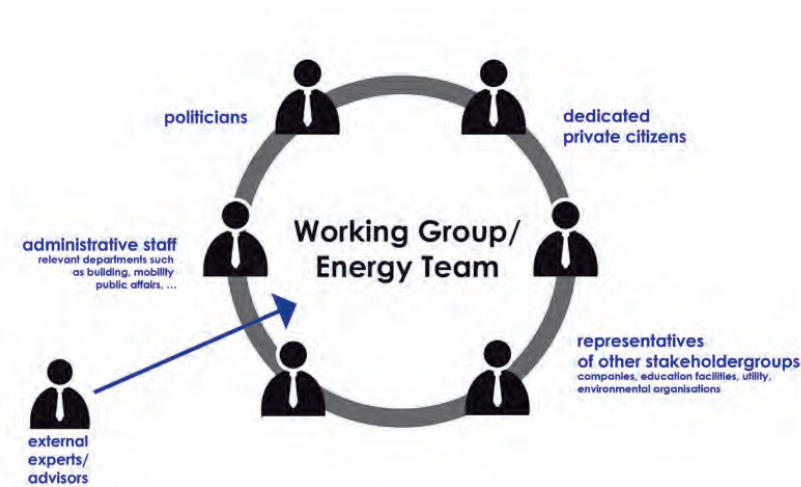


Figure 3-9: Interdisciplinary energy working group. Source: pro:21 GmbH

Municipal working groups

City of Aachen, Germany (250,000 inhabitants)

In Aachen a climate protection coordination office was established in the municipal administration in 2009. In 2010, activities of the coordination office and relevant municipal departments were optimized. The office plays a strategic leadership role to fulfil municipal policies through planning, monitoring and reporting tasks and organizing the energy and climate protection working group. The office is also responsible for several projects contained in the work plan, such as the CO₂ reduction programmes with schools and kindergartens. The office has two staff members and offers about 14 different services in total, including CO₂ Balancing, an energy efficiency programme and a climate alliance participation. The energy working group is formalised as the eea energy team for energy and climate protection. It includes 14 members representing municipal departments and public utilities and meets a minimum of four times a year. Regular development of work plans and overseeing their implementation is the working group's main task.

3.4.4 Create a vision

Although the mayor of a municipality likely already has an idea of his or her goals and objectives, what are the goals and objectives of other stakeholders? A common vision and targets must be developed in consultation with a broad group of stakeholders. Launching a process to develop an agreed-upon vision can be the starting point for the transition process in a municipality. Usually a vision covers a long timeframe (e.g. towards 2050). Describing a broad goal such as becoming energy efficient and low-carbon can be a powerful driving force for further activities. The vision is intended to create a common picture of the future. By bringing stakeholders into in a transition arena ⁴⁴ through the creation of a common vision helps to ensure that the transition process is broadly accepted and lays the foundation for actual policies and decisions.

⁴⁴ Rotmans et al., Erasmus University Rotterdam.

Characteristics of a successful vision statement include that it:

- is stated clearly and is easy to understand;
- looks out over the long term;
- can be linked to measureable targets;
- maintains a focus on local values;
- evokes emotion and is motivating;
- involves all stakeholders;
- has the commitment of local politicians;
- is included in policy and planning documents; and
- is communicated to everyone involved.

3.4.5 Set targets

Following from the vision; long-term targets are a quantitative definition of success to reduce energy or emissions or increase the contribution of renewable energy sources. Targets can be developed in stakeholder workshops or as a part of a broader visioning process. They should be set initially based on information in the energy and emissions inventory. Some municipalities may elect to assess energy opportunities and do preliminary quantitative modelling prior to setting the targets, however this is not necessary.

Targets are expressed as percentage reduction or increase (from a baseline year) achieved by the target year. For example a common GHG emission reduction target for European municipalities may be to reduce GHG emissions by 20% from 1990 levels by 2012. A common renewable energy target is for a 20% share of total energy demand to be met by renewable sources by 2020.

Besides creating a vision and defining long-term targets a municipality must set short-term milestones, defined for shorter periods of approximately five to ten years. Because achieving these milestones depends on actual knowledge and appropriate technologies, it is appropriate for the municipality to help define the most effective strategy considering local strengths and weaknesses. Short-term milestones should:

- contribute to the overall vision and long-term target
- be implemented using available local policy instruments and tools
- promote an intelligent combination of short-term actions to achieve long-term effects.

In addition to quantitative targets, goals can describe associated co-benefits that are desirable to stakeholders.

These targets, milestones and related goals must be integrated into the municipal energy master plan and other municipal policies as minimum standards. The creation of public awareness concerning the targets is crucial. Following additional analysis, implementation and monitoring of measures the municipality, city councillors or working group may seek to adjust the targets if those originally set were too ambitious or not ambitious enough.

Vision and targets

City of Stockholm (1,900,000 inhabitants)

Stockholm's "Action Programme on Climate Change" includes the vision of becoming fossil fuel free by 2050. This target is based on on-going reduction of greenhouse gases at the same rate as occurred between 1990 and 2005. The "Action Programme on Climate Change" involves the participation of several groups including: city departments, local businesses and those who live and work in the city.

In Stockholm GHG emissions from traffic, electricity and heating were reduced by an estimated 24% between 1990 and 2009. Based on the vision to become fossil fuel free, the city's mid-term target or milestone is to reduce GHG emissions to 3.0 tonnes per capita by 2015. The chances of reaching this target are good due to a detailed action plan covering all relevant sectors and municipal areas of action.

City of Copenhagen (600,000 inhabitants)

Copenhagen wants to become the world's first carbon neutral city by 2025.

The City has developed an ambitious action plan to reduce its CO₂ emissions dramatically within the next few years. All measures together would save around 1.5 of the 2.5 million tonnes of CO₂ produced in 2005. The action plan focuses on the city's strengths such as the district heating system and bicycle use for transportation. The remaining tonne should be delivered by promoting wind power production: the city wants to invest in 200 megawatts of wind energy capacity. Solutions are offered by politicians as well as cities, by private initiatives and by companies.

3.5 Step 3 Assess opportunities and develop scenarios

3.5.1 Assess opportunities

The objective of the opportunity assessment is to select a broad range of opportunities with sufficient quantitative information to inform the creation of scenarios and a roadmap for the municipality to reach its targets. Through compiling the baseline energy and emissions inventory, efficiency opportunities will have been identified in residential, commercial and public sector buildings. Energy supply switching may be supported by waste heat or surplus electricity from local industry. Opportunities to expand existing district energy systems or preliminary concepts for new systems may have been identified. Through the characterization of renewable energy resources, using either basic calculation or more advanced analysis, general technical potentials will have been quantified. Stakeholder support for technologies identified may have been assessed through the transition arena or working group and the visioning and target setting process. Importantly, opportunities can be either energy measures or urban development measures that result in energy improvement as a co-benefit, for example upcoming infrastructure or revitalization projects.

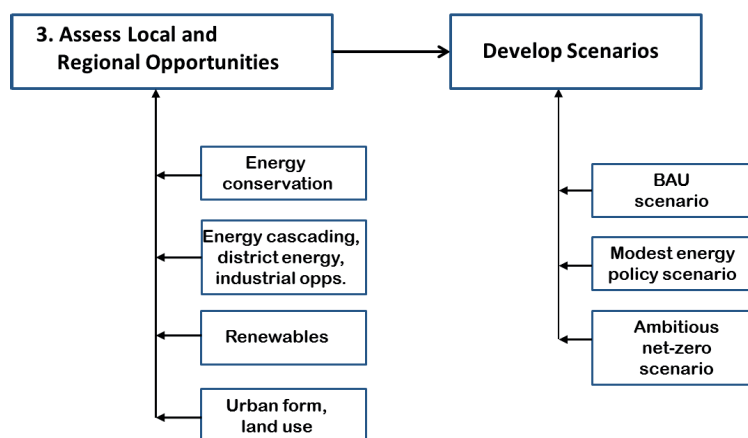


Figure 3-10: Step 3 - Assess local and regional opportunities and develop future scenarios

For each opportunity or potential measure identified the best available estimates of energy (saved or generated), emissions and costs as well as the capital cost of the proposed measure, should be assembled. If sufficiently detailed data are collected, including assumptions on future energy prices, it

may be possible to develop a CO₂ cost vs. abatement potential curve. As depicted in the chart in Figure 3-11, for every CO₂ abatement measure identified (numbered here from 1 to 18), the total abatement potential of each measure is estimated for the whole city. In addition, the average costs of these specific measures have been estimated and related to the abatement potential, resulting in specific CO₂ reduction costs (EUR / t CO₂e). A two-dimensional presentation of the CO₂ abatement potential of these measures (x-axis) sorted by costs (y-axis) provides a very informative illustration of the structure of available measures and connected costs that apply to a given city. These charts will typically look quite different from city to city. The CO₂ abatement potential would best be expressed as a percentage of the total CO₂ emissions of the city to allow a direct comparison with the targets established.

A large amount of information is necessary to create this type of chart. The resulting illustration provides an overview of measures available, their cost structures and saving potentials. Measures with large CO₂ abatement potential with negative or only modest positive costs should be prioritized in municipal and neighbourhood energy plans. Such a chart can serve as useful point of departure for strategic discussions of local energy scenarios by the City Council or the stakeholder working group.

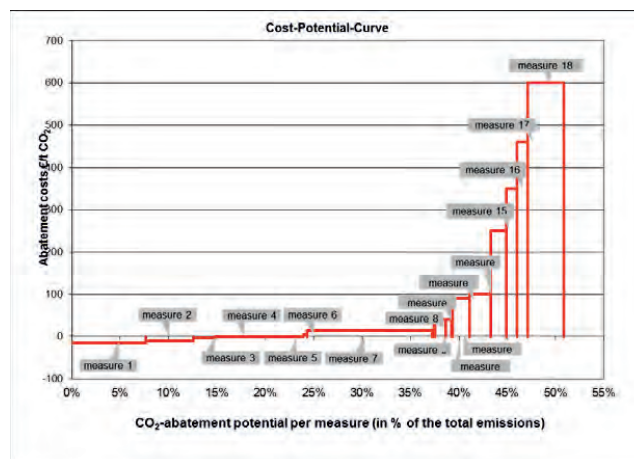


Figure 3-11: Example of a CO₂ abatement costs vs. abatement potentials curve

3.5.2 Supporting indicators

To further contextualize potential opportunities it is important to establish a set of supporting indicators. The performance indicators specified in Table 3-2 below are useful for a comparison with national or regional average values in statistical databases (see also District Energy Concept Adviser, Chapter 5). They can also be used to track progress towards long-term targets by evaluating changes in energy demand and supply structures in recent years, beginning with the baseline year. Indicators are also useful for benchmarking other municipalities.

Table 3-2: Key municipal energy performance indicators

	Key Performance Indicators
City-wide (industrial sector omitted)	kilowatt hours of electricity per capita ($\text{kWh}_{\text{el}}/\text{cap}$) kilowatt hours of thermal (non-electric) per capita ($\text{kWh}_{\text{EE}}/\text{cap}$) tonnes of equivalent carbon dioxide per capita ($\text{t CO}_2\text{e}/\text{cap}$) ⁴⁵
Public, Residential and Commercial Sector Buildings	kilowatt hours of thermal (non-electric) per floor area ($\text{kWh}_{\text{EE}}/\text{m}^2$) kilowatt hours of electricity per floor area ($\text{kWh}_{\text{el}}/\text{m}^2$)
Manufacturing Activities (trades)	kilowatt hours of thermal (non-electric) per work place (kWh_{EE}) kilowatt hours of electricity per work place (kWh_{el}) or per m^2 of floor area
Industry	megawatt hours of electricity per 1,000 EUR output (MWh_{PE}) megawatt hours of primary energy per 1,000 EUR (MWh_{PE})
Public Lighting and Traffic Lighting	kilowatt hours of electricity per meter street length ($\text{kWh}_{\text{el}}/\text{m}$)
Solid Waste and Wastewater Treatment	kilowatt hours of energy generated (thermal energy, wastewater/landfill gas) per capita ($\text{kWh}_{\text{gen}}/\text{cap}$)

3.5.3 Scenarios

As will be described in Chapter 4, it is increasingly common for municipalities, often supported by the academic and private sectors, to leverage simulation and optimization models. The typical procedure however, is to develop a customized Excel model for a specific energy plan or project. Common to both more advanced and Excel models, is the use of scenario analysis. Scenarios support assessment of the energy, emissions and financial implications of suites of measures and their ability to achieve the municipality's energy and emissions targets.

Energy scenarios describe the trajectory of energy demand and supply and associated emissions over a planning horizon. Quantitative assumptions are made on potential energy conservation measures, energy technology applications and their potential implementation rates within a defined policy context, in a manner coherent with anticipated land use planning and infrastructure development, population change and socio-economic trends.

A Business-As-Usual (BAU) scenario is established first. It describes the current context and its future development without an active energy or climate change policy. Alternative scenarios that are moderately or significantly more ambitious are also articulated and based on more aggressive policies, contain assumptions on higher implementation rates of energy efficiency measures or fuel switching, greater renewable technology availability or availability of grant schemes, among other things. To develop both BAU and more ambitious alternative scenarios, measures and their expected impacts must be identified, together with assumptions on implementation timeframes and cost estimates. For example, an assumption would need to be made concerning retrofit rates of future scenarios that would influence heating demand. Assumptions are often based on empirical evidence, averages,

⁴⁵ This indicator must not be confused with per-capita GHG emissions quoted for countries; these emissions contain all GHG emissions caused by the total national energy use, including transport, industry, embedded energies, imports and exports and, in addition, non-energetic sources and sinks.

personal experience or assumed future conditions. Care should be exercised in creating the assumptions since they play an important role in determining the results of scenarios.

3.5.4 Backcasting and forecasting

Scenarios may be developed using two distinct approaches. The traditional approach is forecasting which begins by looking at the current situation to determine what measures are needed to reach the long-term target. Generally, forecasting tends to be cautious, identifying measures that are incremental improvements over the status quo.

Using backcasting, concrete actions in the short term can be identified based on long-term targets. For example, assuming the goal is to achieve a net-zero energy built-environment by 2050, using a backcasting approach all new houses built starting today must be net zero energy. Backcasting, or working backwards from the long-term targets to today, enables stakeholders to get a feeling about necessary measures, according to what should be done *on principle*.

It is highly recommended that both forecasting and backcasting be used to determine the transition path. This approach can serve to make the roadmap or energy plan that is both as ambitious and as concrete as possible. Backcasting and fore-casting can also be used to monitor the transition process to the long-term targets.

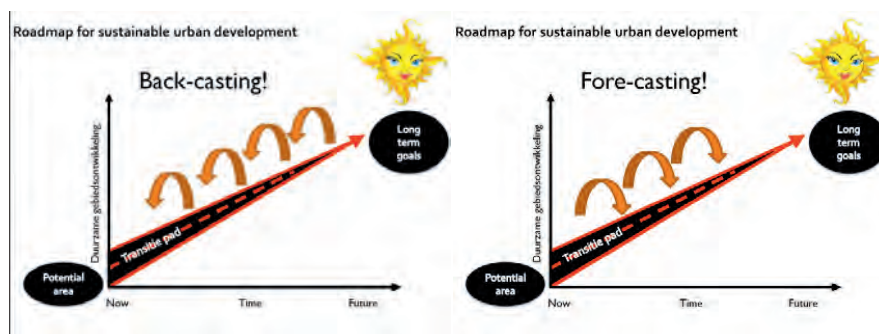


Figure 3-12: Forecasting formulates concrete actions from current values and tests them against long-term targets. Backcasting works backwards from long-term goals to formulate concrete actions.

Backcasting and Forecasting

City of Stockholm Climate and Energy Action Plan 2010-2020, Stockholm, Sweden

In this plan, measures and actions for this decade are described. The feasibility of this plan is underlined by backcasting development in Stockholm from 2020 to the present and back to 1990. The figure below illustrates achieved and anticipated reduction in CO₂ emissions from 1990 to 2020.

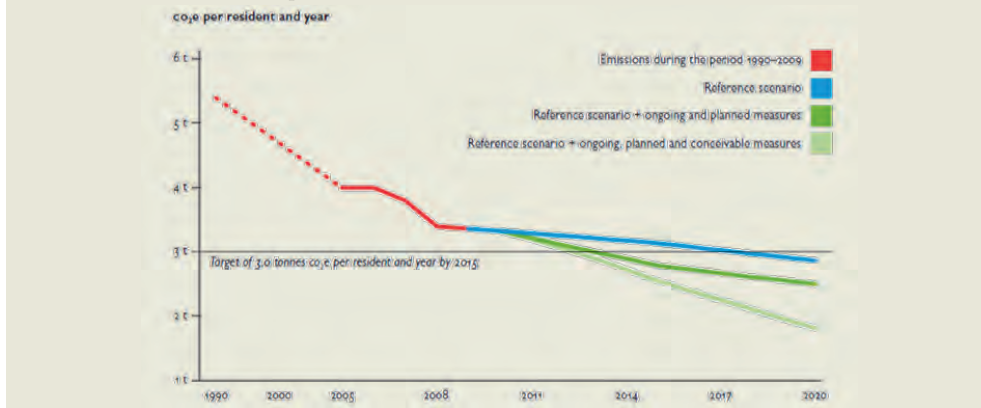


Figure 3-13: Different scenarios for greenhouse gas emissions in the City of Stockholm per capita between 1990 and 2020.⁴⁶

The building sector comprises > 50% of the Stockholm county energy use. This is to be reduced by 25% by 2030 and 40% by 2050. The use of oil and electric heating must both be phased out. Transport stands for 30% of the county's CO₂ emissions, 95% of which are caused by on-road transportation. The goal is to reduce the sector's total energy use by 20% by 2030. This will be done by more efficient vehicles, transportation system projects and behavioural change. An important indicator is the use of public transportation. Industry accounts for 12% of the county's energy use. The goal is to reduce energy use by 25% by 2020 and 35% by 2030. The agriculture and forestry sectors in Stockholm are small and only make a marginal contribution to CO₂ emissions. Energy use is to be reduced by 60% by 2020 and 80% by 2030. The most important measures are the phase out of fossil fuels and increasing the transformation of waste into energy.

⁴⁶ The rapid decrease between 2007 and 2008 (~123,000 tons) is attributed to a reduced GHG emission factor for electricity which the reference scenario assumes remains unchanged after 2008.

Backcasting and Forecasting

Nantes, France

The City of Nantes aims to be frugal in term of energy use and productive regarding renewable energies. In addition, it seeks to bolster its role as an organising authority in particular for heating networks and by awarding gas and electricity distribution contracts. Key energy-related strategies being pursued by the City of Nantes are:

- Reducing energy use city-wide and in city services as well as diversifying the sources of energy production.
- Burying electrical networks to improve quality of life and optimise electricity supply.
- Giving priority to district heating networks, a major tool in the Nantes City Climate Plan.
- Working towards the goal of installing 20,000m² of PV panels by 2012 and create an inventory of sites for the installation of PV panels, wind turbines (small turbines in particular) and heating networks.
- Restructuring NGE, a public-private company whose status has been expanded by the City of Nantes, enabling it to respond to new requirements and offer services to exploit energy opportunities as they arise.
- Providing information and raising awareness to encourage the general public to become active players in the Climate Plan by insulating their dwellings and changing their behaviour.
- Raising awareness regarding alternative transportation modes, correlating energy policy objectives with those of transport policy.
- Providing information and raising awareness among housing professionals on community and regional plans, to ensure a sufficient number of professionals are trained in the technologies required, able to respond to a sharp increase in demand.
- Coordinating industry and companies to be more energy efficient and reduce GHG emissions.

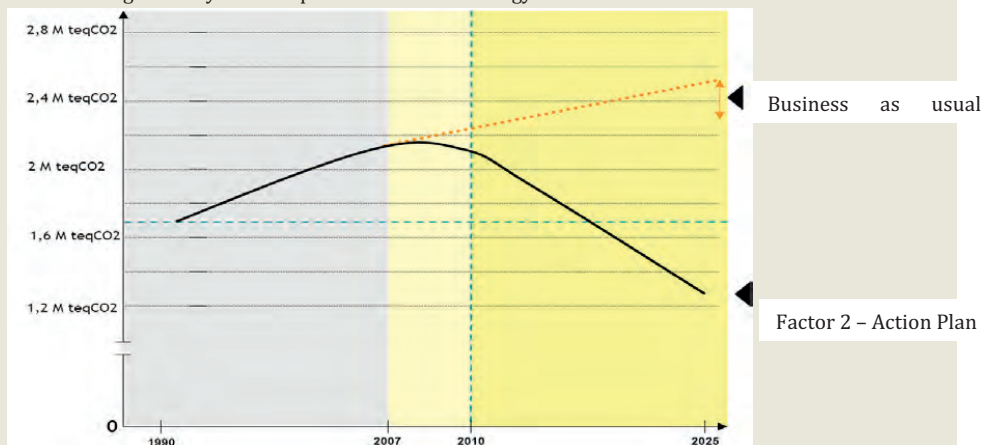


Figure 3-14: Forecasting CO₂ emissions reductions to 2025. Source: Nantes Métropole

3.5.5 Roadmaps

Roadmaps can be used to translate visions and targets into a framework of specific measures within a specific time frame. A roadmap document describes the steps to reach the goals. Instruments such as backcasting and forecasting can be used to translate the long-term targets into actions. The basis of

roadmaps consist of calculations on possible energy saving and production measures that can be taken by a city in a certain year. The local context is characterized using calculations from the baseline energy inventories and estimates of opportunities. ("What is the current energy use of residential and other buildings?" "How much potential energy can be produced from biomass?") The calculations are translated into a graph (see also Figure 3-15) which shows energy demand and renewable production curves. Where both lines cross, a net-zero energy community is achieved. In addition to the graph, a step by step implementation plan is developed.

To become a net zero energy city sooner, energy demand reduction measures should be considered before renewable energy sources. From the graph it is clear that the goal is reached at an earlier stage when energy use decreases sharply. When energy demand is not reduced, the target will not be achieved until much later, through greater effort to produce local renewable energy at a greater cost. By investing in both energy efficiency and in renewable energy production the target be reached sooner.

A mix of short and long-term measures should guarantee success and contribute to achieving targets. Concrete measures contained on the preferred scenario determine the roadmap's strategy and are the basis of the municipal energy master plan. At this stage, the municipality and stakeholders should be able to verify if the long-term energy and emissions targets and milestones established in Step 2 are realistic or should be adjusted. After measures have been implemented, the results of scenario modelling can be compared against measured energy and emissions contained in municipal inventories or balances.

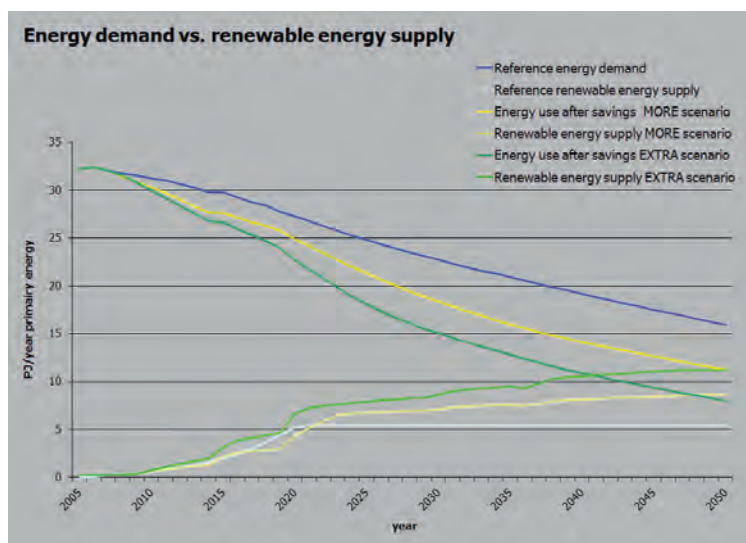


Figure 3-15: Reducing energy demand and increasing renewable energy production is required to become a net-zero energy city. Source: CO₂ neutral Tilburg, Builddesk 2008

Roadmaps

Tilburg, the Netherlands (210,000 inhabitants)

The municipality of Tilburg conducted a research study to explore what a carbon neutral energy supply system would look like in their municipality. This is done for the residential, commercial sectors (including industry) and mobility.⁴⁷

For Tilburg three scenarios were developed for energy demand reduction and the production of renewable energy:

- *Reference*: energy demand and renewables based on new energy technologies and market-driven by gov't policy.
- *More*: sees significantly more energy savings and more renewable energy than in the Reference scenario.
- *Extra*: significant increase in energy efficiency and in renewable energy production than in the Reference scenario.

The scenarios were based on extensive calculations based on a large quantity of data from the municipality of Tilburg and assumptions on future energy technologies (see figure 3-15; the graph is derived by adding renewable energy and energy demand reduction measures over time).

In Tilburg, the existing district heating network offers opportunities for a step by step implementation of renewable heat supply. The energy infrastructure is pre-existing and so only the heat source must be made renewable. Currently, heat comes from the *Amercentrale* coal-fired power station. This heating network also enables Tilburg to rapidly advance the building stock towards carbon neutrality by implementing renewable sources such as geothermal, bio-CHP and heat and cold storage; large scale thermal solar energy can also be integrated.

3.5.6 Charrette

A process similar to the transition arena or working groups is a *community energy charrette*, as was carried out in the Prince George, BC, Canada case study. The biggest differences between the working group and charrette approaches concern the duration of the process and the selection of participants. Transition areas or working groups consist of relatively small number of participants who meet periodically over a long timeframe. In the charrette process, a large number of participants are brought together for a short intensive period of anywhere from one to five days. A charrette can be used at various stages in the local energy planning process, to create a collective vision and a first draft of long-term goals or assist with opportunities identification, scenario development and road mapping. The charrette is an approach that can be applied at both the municipal and neighbourhood scales.

A charrette is a workshop that includes three parts:

- **Information Gathering**: the rationale and opportunities for a transition process towards an energy efficient community are identified. A field trip is usually conducted to the area. At this stage questions include: What are the characteristics and opportunities in the area? What expertise and knowledge can be gained from past projects?
- **Thematic Working Groups**: groups of stakeholders working on different parts of the plan. Ideas from different corners of expertise must be combined, which can lead to an integrated and innovative plan.
- **Preparation and Presentation of Detailed Plans**: results from the working groups are compiled and, depending on the objective, can inform a compelling vision or a detailed design plan at the neighbourhood or community scales.

⁴⁷ CO₂ neutrale steden, Builddesk 2008

Participants are local stakeholders and subject matter experts. It is important for the experts to remain on the side lines as advisors or there is the risk that they will dominate the workshop. Participants are brought together for a few days (or sometimes a few times for a few days). Everyone becomes well acquainted with the current context and perspectives offered in the various fields of expertise. Together they discuss, calculate and create a design concept for the development. By the end of the session, both the recommended development opportunities and broad direction of the plan are clear. The final output is a concept plan which addresses all important issues and contains strategies and actions broadly seen as being potentially feasible.



Figure 3-16: Discussion during the Smart Growth on the Ground charrette in Prince George, Canada. Source: Shana Johnstone

3.6 Step 4 Create municipal energy master plans and neighbourhood energy plans

3.6.1 Municipal energy master plan

The municipal energy master plan is a high level strategic document that identifies measures or combinations of measures expected to contribute most effectively to achieving the municipality's long-term energy or emissions targets. The investments and instruments necessary for implementation, including assigned responsibilities, resources, a clear timeframe and a monitoring plan, are other key features of the municipal energy master plan. Given the work already undertaken to create the inventory, bring stakeholders together, establishing a vision and targets, create scenarios and a roadmap, the plan should practically write itself.

The municipal energy master plan should contain a summary of the baseline energy and emissions inventory, the vision of success as defined in collaboration with stakeholders and the public as well as long-term targets. Anticipated co-benefits such as improvements to quality of life, health, and level of employment within the region should also be included in the form as goals to be achieved in the transition process. Clearly articulating social and environmental priorities alongside energy and economic benefits is often what creates common ground, bringing diverse stakeholders together and garnering their commitment to the local energy planning process.

Energy planning principles such as energy conservation, energy efficiency, re-use of waste heat, district systems and renewable integration can be briefly explained. These and other concepts such as flexible technologies and energy generating matched in scale and geographical distribution to end-use needs can provide background justification for the prioritization of specific measures.

The preferred scenario identified first through the opportunities assessment and backcasting and forecasting will set out the strategic roadmap for progress towards the targets. Sets of prioritized measures to reduce energy and emissions should be included for each of the residential, commercial, and public sectors as well as relating to any waste heat, district energy systems or preferred renewable energy technologies. Many municipalities will also identify measures for their own operations such as municipal buildings, vehicles fleets as well as water, wastewater and solid operations.

A brief description should be included for each measure identified. It can be effective to include one or more tables summarizing all measures and providing general details such as:

- Building characteristics
- Technology characteristics
- Capital cost of the proposed measure
- Cost savings after installation
- Estimated payback period
- GHG emissions reduced.

Another effective approach that helps to reinforce measures is to list quantifiable actions alongside qualitative process-type actions. This can be done for each sector and activity area. Examples of supporting qualitative measures include:

- Hold an inter-departmental meeting or public meeting
- Adopt a policy (e.g. relating to land use or municipal equipment purchase)
- Implement energy performance standards for new municipal buildings
- Increase public awareness for a specific topic or technology through public awareness campaigns
- Develop a strategy for a particular sector or activity.

Short-term projects to be implemented within four to five years should be included; this will help ensure success for local decision makers and all stakeholders within a manageable timeframe. Longer-term projects can also be included however it is important to balance being ambitious with being realistic. For longer-term projects, full cost accounting with an understanding of the trade-offs can help support choices that tend to be more 'whole-systems' in nature. Although the municipal energy master plan is high level, if available any specific sound integrated business case which takes the costs and benefits over the total life span of an energy system into account should also be provided.

Measures should also be organized to illustrate how they contribute to achieving specific long-term targets or goals. Each measure should be linked with a related goal, the corresponding key performance indicator, alongside the related baseline value and medium-term milestone; these can be both quantitative and qualitative indicators of success. This can assist greatly with monitoring and evaluation following implementation.

Responsibility for specific measures should be assigned to all relevant municipal departments that would be involved in implementing the measure. Associated information resources, linkages to other programs should also be included.⁴⁸

An approach to elaborating an implementation plan can consist of an implementation matrix indicating specific actions, specific municipal departments and roles or job titles of responsible individuals as well as timelines for completion. Supporting policies and by-laws, potential obstacles, financial resources,

⁴⁸ The Federation of Canadian Municipalities. Six Steps to a Sustainable Community: A Guide to Local Action Planning [www.fcm.ca/Documents/reports/PCP/Six Steps to a Sustainable Community A Guide to Local Action Planning EN.pdf](https://www.fcm.ca/Documents/reports/PCP/Six_Steps_to_a_Sustainable_Community_A_Guide_to_Local_Action_Planning_EN.pdf)

other resources (such as data, other human resources, collaboration with external stakeholders) and performance measures can also be very briefly summarized.⁴⁹

Unfortunately in many communities, active energy planning ends after completion of the municipal energy master plan. This is because once targets have been set, the general consensus articulated, it is assumed that implementation is a matter for investors or other local decision makers. Well-defined projects, assigned responsibilities and an established management structure are needed to support effective implementation.

3.6.2 Neighbourhood energy plans

Following from the broad strategies and measures identified in the municipal energy master plan, further work is required on the neighbourhood scale to identify the most promising energy conservation, efficiency or energy supply measures. Detailed analysis must be done on the neighbourhood level, using detailed energy demand data of individual buildings in the planning area. Only on this scale is it possible to make detailed economic comparisons of various technical options and explore an economically optimized solution of integrated demand and supply measures as a rational basis for a long-term neighbourhood energy design concept.

Neighbourhood energy plans will be developed iteratively with the municipal energy master plan being revisited and adjusted as required. Using communication and engagement processes it is important that stakeholders are made aware of the different types of planning required at the different geographical scales and phases in the process and the inherently iterative nature of local energy planning.

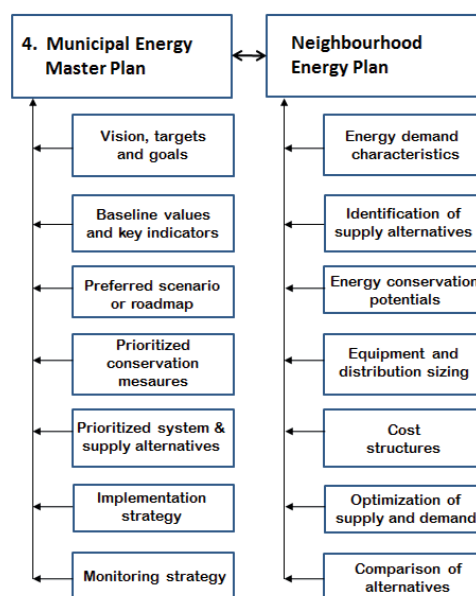


Figure 3-17: Selected key components of municipal energy master plans and neighbourhood energy plans

The objective of a neighbourhood energy plan is to develop a long-term plan for a combination of measures to achieve specific energy and GHG targets that can be implemented within a defined time horizon. Developing a neighbourhood energy plan is an extensive undertaking, requiring significant expertise and the involvement of local stakeholders (such as infrastructure operators, housing

⁴⁹ <https://doi.org/10.51202/6763616791232> - Generiert durch IP 216.73.216.80, am 23.01.2026, 22:51:17. © Urheberrechtlich geschützter Inhalt. Ohne gesonderte Erlaubnis ist jede urheberrechtliche Nutzung untersagt, insbesondere die Nutzung des Inhalts im Zusammenhang mit, für oder in KI-Systemen, KI-Modellen oder Generativen Sprachmodellen.

companies, local trades, public and private facilities, urban planners, local government administration and home owners). This constitutes a major barrier for neighbourhood energy planning, because there must be an organization willing to initiate, lead and finance the work. One finding from the Annex 51 case studies was that stakeholders had to understand that the success of their neighbourhood project depended on a resilient solution to this management issue. Although it is difficult to identify a generic solution, the municipality must take the lead on organizing and moderating the contributions of stakeholders involved.

Defining a management structure that supports the planning process was shown to be an essential part of the project. Since this planning process requires input from all stakeholders an agreement that defines the targets and responsibilities of the working group is of great benefit as a foundation of the common work. Such an agreement does not need to be a formal contract; a document describing the common understanding and moral commitment to the project held by the various stakeholders is typically sufficient. Because neighbourhood projects are of a very local nature, the social pressure on participants to follow ground rules agreed upon by the group can be more effective than a formal contract.

To develop a local energy plan for a neighbourhood or district, the work outlined below must be carried out. Similar to the local energy planning process as a whole, the neighbourhood planning process must too be understood as an iterative process with feedback loops, rather than a sequence of steps in a linear process.

- Describe the current context in existing neighbourhoods or the proposed new development in terms of energy demand and supply systems including:
 - measured data on energy use or energy demand calculations;
 - existing supply systems and their performance characteristics;
 - local energy resource opportunities; and
 - existing local initiatives or networks.
- Procedures for optimization and evaluation include:
 - opportunities to improve existing systems;
 - identification of alternative actions;
 - cost estimates for measures under consideration;
 - simulation or optimization of different alternatives including potential demand and supply measures and their integration into the local energy plan for the neighbourhood;
 - comparison with existing benchmarks and targets;
 - sensitivity analyses for energy processes, variability in demand, transition dynamics etc...; and
 - feedback with local stakeholders and investors.
- Definition of an implementation strategy including:
 - an action plan;
 - an investment and work plan;
 - delegation of responsibilities for actions;
 - a communications plan; and
 - monitoring strategy.

In the planning phase, there is a large difference between new developments and existing neighbourhoods:

New developments

New developments are based on a land use plan which establishes the sites, sizes and uses of buildings to be built, in addition to the timeframe over which they will be built. This information, in

conjunction with existing local or national building codes, define energy requirements for new construction and is sufficient to develop an initial estimate of projected demand for energy for heating, cooling, DHW, electricity (see also District Energy Concept Adviser, Chapter 5). This information is also needed to explore various energy or energy cost savings opportunities, either on building scale or on neighbourhood scale.

To assess the ability of the proposed development to meet the neighbourhood or city's energy or GHG targets, the two main questions to be answered are:

- *"Should energy performance requirements be implemented that are higher than those legally required by the building code?"*
 - This question is particularly relevant for European countries with already high building code energy requirements
 - For jurisdictions with unambitious energy requirements in the building codes, the answer to this question should be yes
- *"Which energy supply systems and which energy source should be selected to cover the heating/cooling demand, detached or central?"*

These questions can only be answered by an integrated consideration of demand and supply.

Existing neighbourhoods

There are three main reasons why a local energy plan would be developed for an existing neighbourhood:

- A conversion, brownfield or revitalization project is proposed where an existing neighbourhood, such as a military facility, a run-down residential area or an industrial area must be converted or revitalized to establish a new future-proof neighbourhood with favourable long-term prospects. One single developer or urban planner is usually responsible for design and implementation.
- A major individual construction project is proposed, such as the construction of a new or expansion of an existing neighbourhood facility (e.g., sport centre, school or hospital). These types of developments might trigger the creation of a local energy plan that integrates the development project into the broader framework of the surrounding neighbourhood.⁵⁰
- Construction of new or expansion of existing energy supply infrastructure network for a specific neighbourhood is planned by a local utility. For such an investment, a detailed investigation of the neighbourhood's demand characteristics and expected future development will be necessary as a pre-requisite for investment.

In contrast to new developments, there are two additional challenges associated with developing and implementing local energy plans in existing neighbourhoods:

- existing infrastructure must be refurbished or replaced; this is often a more difficult business case to propose than construction of entirely new infrastructure
- stakeholders such as investors and other decision makers or concerned members of the general public must be convinced to adapt their individual plans, for instance to retrofit a building, to be consistent with requirements in a local energy plan.

An energy plan for an existing neighbourhood must provide detailed information about demand characteristics for heating, cooling and DHW (peak load, base load, daily demand profiles) of buildings

⁵⁰ In the recent recast of the European Energy Performance of Buildings Directive (EPBD) of 2011, it is recommended to check for every major urban or municipal construction project if it can be embedded into a neighbourhood plan in order to find an optimized local solution.

in the neighbourhood. To gather such information, the same data from the energy and emissions inventory (Step 2) can be used. In addition, since only a limited number of buildings are being considered, direct contact with owners or local facility managers, in particular of housing companies, should be pursued.

Based on this data, an overview of energy conservation opportunities in existing buildings should be developed; this will influence anticipated future energy demand and supply requirements, and by extension the design of supply infrastructure. An important indicator for available conservation opportunities are the energy ratings of individual buildings, which can be benchmarked against high performance buildings. Combining anticipated savings with investment costs for energy conservation or efficiency measures, an estimate of anticipated implementation and expected efficiency improvements can be derived, which is important when considering feasibility.

In the pre-feasibility planning phase, average cost data for energy measures such as average specific investment costs usually available from publications are generally sufficient. For such an estimate, it is also important to consider existing energy prices and the anticipated energy prices in the future, which is decisive for the economic viability of investments energy efficiency measures or supply infrastructure.

Once the energy demand characteristics of a new or existing neighbourhood are known, identify local supply options. These must satisfy the energy and/or GHG saving targets pre-determined in the urban energy master plan. In addition, it should be confirmed that these options are broadly accepted by potential customers and residents. This represents a major difference between neighbourhood energy planning and the planning of innovative buildings. In the latter case, technical innovations or demonstrations may dominate the decision, perhaps subsidized by grants for specific technologies. This approach is not applicable to an entire neighbourhood, where economic viability and acceptance of the technology are among the important pre-requisites.

Supply options should be differentiated by detached or decentralized options for individual buildings and central options requiring a central generation and distribution network solution designed according to local energy demand densities. The availability of such options depends on local circumstances that must be evaluated in co-operation with local stakeholders. While local solar, biomass, biogas, bio fuels, geothermal, cogeneration opportunities are more or less immediately clear, local or nearby waste heat sources, such as industrial processes should not be forgotten. Evaluating local renewable technical potentials and costs compared to conventional energy supply sources and technologies will be decisive.

Total energy costs, for instance euros per megawatt hour (EUR/MWh) are a key indicator, however since energy conservation measures must also be included total annual cost per floor area per year (EUR/(m²/a) can be considered a preferable economic indicator. Total cost must include costs for investment, maintenance and operation, administration and operating energy as well as auxiliary energy and energy taxes. Since specific forms of energy, or energy conservation measures, may also be government-funded or are eligible for tax incentives, these must also be included in the calculation to make a correct comparison. In centralized systems, certain upfront capital costs must also be taken into consideration, since these costs, often underestimated, may not be offset by sufficient revenues in the first years of operation.

Although technical details are generalized in the design development phase, cost comparison of different options must be developed using complete and transparent economic calculations. It is important that the results can be understood by all decision makers, since they will inform strategic decisions with far-reaching implications. Key underlying assumptions, such as anticipated future energy prices, should accompany the calculation to enable a better understanding of the sensitivity of the results and any limitations of the approach.

The following chart depicts the complexity of the urban energy planning process for Karlsruhe, Germany where organising the urban climate change concept implementation strategy is currently underway. The chart illustrates the wide variety of individual activities interlinked. Important concepts that cannot be illustrated in the chart are appropriate timing of individual projects and the complexity of implementation processes. This is further described in Chapters 6 and 7.

... from planning to realization: a continuous process ...

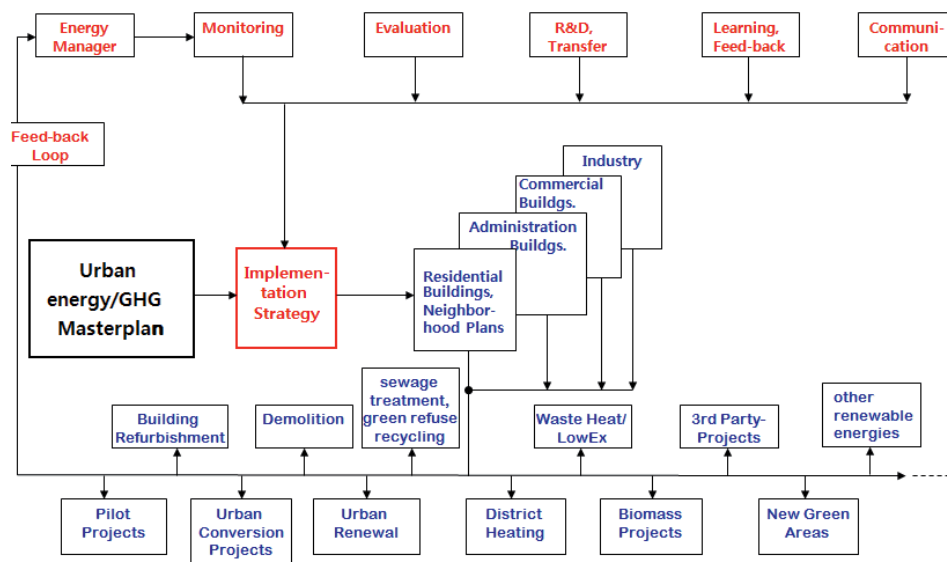


Figure 3-18: Overview of the energy master plan implementation strategy project structure for Karlsruhe, Germany (draft)

3.7 Step 5 Implementation, monitoring, evaluation and feedback

The key issue in municipal energy master planning is to transpose the visions, strategies and measures contained in the energy plans into other municipal policies that eventually lead to concrete actions with measurable results. How can the municipality translate the targets and goals into day-to-day politics and administrative procedures? How can the municipality initiate measures and projects? Are role and responsibilities as well as resources for implementation adequately defined? How can on-going adaptation be ensured over the long-term? These questions make it clear that municipalities must build management structures to operationalize implementation. Furthermore, instruments which ensure regular progress reports with the bigger picture in mind guarantee an on-going process that provides the feedback and maintains the momentum necessary to achieve the energy transition.

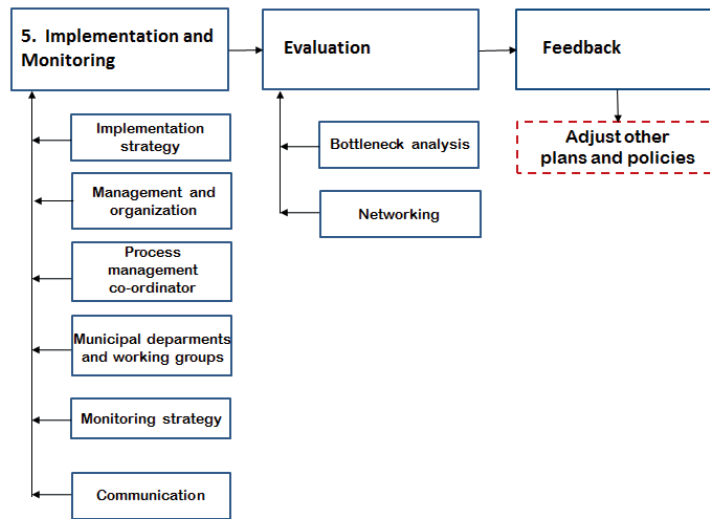


Figure 3-19: Implementation, monitoring, evaluation and feedback occurs for both municipal and neighbourhood plans

3.7.1 Process design instruments

Successful municipalities show that – besides clearly defined responsibilities and management structures – building and fostering processes is essential to establish a sustainable energy and climate protection policy. A consistent process should ensure:

- a strong linkage between planning, implementation and evaluation of projects
- a common vocabulary understood by all participants
- a common picture of the process including any changes required
- continuity which does not depend on a single individual
- close coordination between different areas of work to guarantee efficiency in the process
- linkages between different disciplines and stakeholders
- a scope that includes the potential for new approaches and coalitions.

Typically, a well-organized process is built on several recurring steps that broadly follow the four basic phases of management: plan, do, check and act, as illustrated in Figure 3-20.

Communal Management System for Energy and Climate Policies:

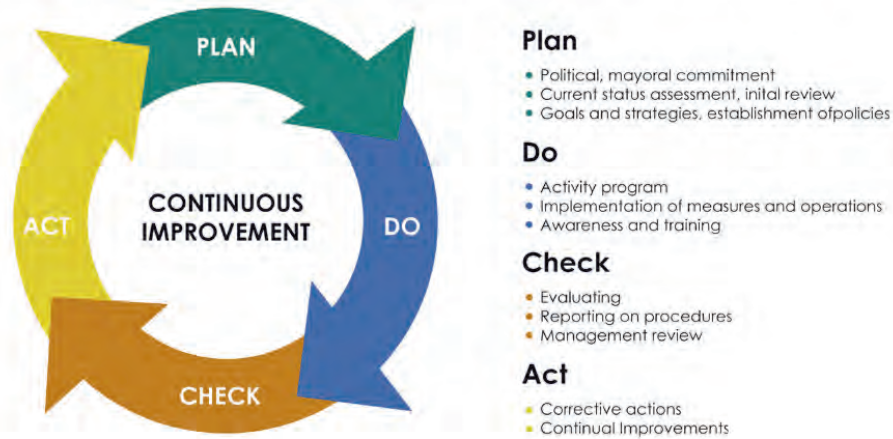


Figure 3-20: Once started, the implementation of energy and climate policies is an on-going process that must be continuously monitored, evaluated and improved. Source: pro:21 GmbH

Evaluation is the basis for the further planning of measures. Thus activities are repeating. This 'planning – implementation - audit – planning – implementation – re-audit' cycle generally has a time span of two to four years. Over longer periods evaluation should lead to a discussion and update of the strategy to include technical progress as well as changed framework conditions.

3.7.2 Integrated management strategies

An integrated approach covering all municipal departments is important to achieve high energy and emissions targets, although clearly many other people and companies also contribute to achieving the goals. Therefore it is necessary to adjust or merge their opinions in such a way that they all contribute in an optimal way to the targets.

Incorporating energy and climate protection targets and goals into local policy instruments means that adequate, integrated measures have to be worked out and implemented. Typically, these actions cover a wide range of disciplines. While they may be technology-oriented in the case of measures relating to municipal facilities, questions of mobility or public engagement must also be addressed. Thus, different kinds of knowledge and expertise are needed. The regularly updated development of strategies, the development and planning of measures as well as their implementation, the evaluation of and reporting on results, communication - internal and external - and financial management must be organised through clearly defined roles and responsibilities and dedicated financial and human resources.

Integrated management

City of Zurich, Switzerland (380,000 inhabitants)

The City of Zurich has a long history of action on energy and climate. Based on two energy master plans issued 2003 and 2008, energy policy was approached in a strategic way. Qualitative and quantitative goals for energy consumption and CO₂ emissions reduction were defined in 2003. The measures identified involve 17 administrative departments and public utilities and initiated a wide range of activities and a

continuously improved process. After evaluation an adapted master plan with revised goals for the next decade was agreed to by city council. To implement the master plan a commissioner for energy issues was established. The commissioner formulates and evaluates energy-related goals and coordinates their implementation in Zurich and is charged with providing regular reports to city council. The energy commissioner is supported by an energy team involving 17 departments and utility representatives. The core and broader groups meet bi-weekly and monthly respectively.

Climate protection is seen in Zurich as a global challenge which needs common global strategies. Participation in several national and international networks reflects this mind set. As a member of the Swiss Energy Cities program (*Energiestadt Schweiz*) the City of Zurich has been evaluated regularly by external auditors. Zurich was twice awarded with the "European Energy Award Gold" and plays a leading role among energy efficient cities in Europe.

3.7.3 Process management co-ordinator

A key component of the implementation strategy is establishing a management structure to implement measures from the energy master plan over the long term. In the case of an overarching municipal program, overall energy saving and climate protection targets become the responsibility of the program coordinator. Any coordinating work has to be supported by a strong political commitment to involve all relevant departments. Sufficient time needs to be set aside as well as a budget for everyday activities. Concrete figures depend on the size of the municipality and the local context. Beside a high level of knowledge concerning all issues when it comes to energy saving and climate protection, the coordinator must possess leadership, communication, moderation, presentation and reporting skills. These qualifications have to be considered in choosing the appropriate candidates for coordination.

The coordinator is solely responsible for the integral and horizontal processes. He/she has sufficient authority to organise this process and reports to the alderman, mayor or another high ranked official. She has to fulfil certain competences, because she is the one to organise the integral process. She must have insight in different expertise in order to bring them together and must also be able to work on a broader and more strategic basis with a mandate to take decisions, so that not everything has to be proposed to a higher board level.

To appoint a single individual responsible for the process does not mean that only one person who knows everything about the project! Knowledge on various energy planning topics and projects should be widely shared. If the situation occurs where this project leader leaves the organisation, some of this knowledge is retained in remaining staff and stakeholders. The responsibility should also be shared between different departments. A good starting point is regular communication between departments about new and on-going plans and projects related to energy planning.

3.7.4 Responsibilities of municipal departments

Municipal departments should support the vision and targets and be involved by being partly responsible for implementation of measures in their domains of expertise. These target-oriented responsibilities must be clear, since there may be differences between overall goals and internal department specifications.

The overall responsibility for achieving municipal targets involves fulfilment of the roadmap and its strategies including the definition of priorities and day to day planning of measures. Concrete actions and tasks with objectives, timeframes, available budgets and individuals responsible for implementation must be defined. While large municipalities define responsibilities according to domains to be addressed by staff, smaller municipalities assign individuals to single measures. In smaller communities, responsible individuals are not always civil servants, in which case their

commitment is voluntary. In assigning responsibilities, it is worthwhile to identify which measures are mandatory or those which are voluntary. Regardless of the priority or working arrangement, due to time-constraints it is essential for everyone to work in parallel. Assigned responsibilities are usually formalised through votes by the municipal council. This level of detail allows for subsequent evaluation as a basis for further planning.

For efficient project management, engaging stakeholders in both decision making and operations ensures common knowledge of roles and responsibilities, different skill sets and know how as well as information and data resources. The responsibility for managing the implementation of the energy master plan should however stay with the municipality. As indicated in the right hand portion of Figure 3-21, the whole local energy planning process includes implementation activities both on the neighbourhood or project scales and broader strategic planning at the municipal level. Over time these must be adjusted to maintain a process that is enabling, coordinated and properly promoted.

3.7.5 Co-ordinating the energy working group

Leading and coordinating the transition arena or energy working group can be done by city's administrative staff. Smaller municipalities with less capacity often draw on qualified external facilitation support from private contractors or universities.

The quality of the process and its outcome depends upon the knowledge and capacity of team members. Although co-operation is a must, training can also benefit the municipality and the process. Knowledge transfer should therefore be organised by the municipality. Courses should include specialised technical training as well as energy and climate change issues more generally. Facilitation, mediation and communication are also areas in which capacity can be built to support the process. Offering regular training courses in the municipality itself or supporting participation in courses offered by external providers are two useful options.

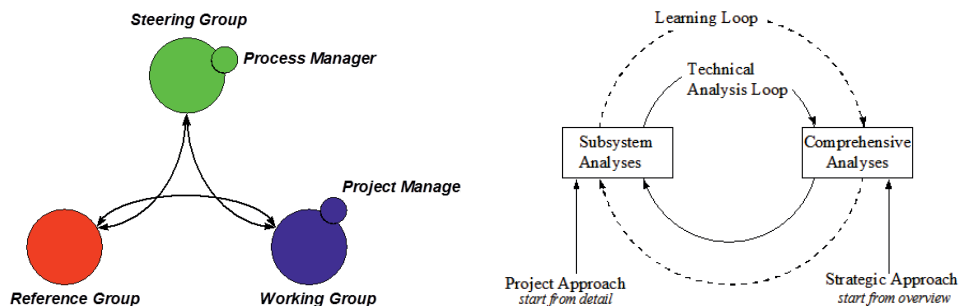


Figure 3-21: Organisational setup for energy master plan project management and a sketch of the iterative working and learning processes necessary over the course of the implementation process (both charts from Annex 33, 2000)

Process management

St. Johann, Austria

In St. Johann, the **energy coordinator** is a member of the municipal administration sitting in the department of environment. The energy coordinator is responsible for all energy-relevant issues concerning the municipality such as municipal buildings and street lightning. The energy coordinator leads the e5/eea team and is responsible for communication between municipal departments through the e5/eea team platform.

Prince George, Canada

Within the City of Prince George, the environmental coordinator was responsible for leading the development of the initial energy and emissions inventory and the management plans. To achieve internal energy demand reduction goals, with the support of BC Hydro the provincial electric utility, the city hired a corporate energy initiatives manager in 2008, with the mandate to measure energy use in the City and reduce demand. In November 2010, the city added a **Community Energy Program Manager (CEPM)**, whose task was to engage the citizens of Prince George in reducing their energy consumption and GHG emissions through policy and programs. In December 2010, City Council approved a Corporate Carbon Neutral Plan. Funding for the CEMP position was limited to two years and the position was eliminated when the funding ran out.

3.7.6 Monitoring

Criteria and key performance indicators to support effective monitoring of technical and financial results and processes should be defined in advance. Energy and CO₂-balances or inventories must be updated regularly requiring an adequate database. Additional data should be systematically collected and spread sheet, models and methods adopted and customized to support the systematic monitoring of selected criteria and indicators. Seeking to collect the same data, using the same methods over time for selected indicators is the most helpful approach for readily showing trends and progress towards milestones and targets.

Certain tools and technologies are facilitating easier data collection and monitoring than was the case previously. For example, the province of British Columbia, Canada works with utilities to develop Community Energy and Emissions Inventory (CEEI) reports on behalf of all local governments on a bi-annual basis. On the building scale, automated reading of energy use via smart meters can be useful. In the EU, energy control systems are required for municipal buildings; automated energy control systems with integrated alarm messages are useful for municipalities owning and reporting on a large number of buildings.

The use, maintenance and sometimes further development of inventories, supporting datasets and models can be defined as an individual project in itself, typically requiring a significant amount of resources. Larger municipalities may be able to assign a dedicated staff person to this work, or may include it in the job description of the energy manager or co-ordinator. Another option is to split responsibilities between different municipal staff with specialized expertise; for instance building inspectors, city engineers and GIS analysts may be required to report on different items associated with individual projects or neighbourhood or municipal plans. Temporary employees or students may also be enlisted for certain tasks or to track down new or difficult to obtain datasets.

It is also highly recommended to explore what services are offered by networks supporting municipal energy and climate planning. Resources to support monitoring could include templates for data collection, training and methods. Some may also offer financial support specifically geared to enabling improved monitoring. As discussed below, other types of organizations who can provide monitoring

and modelling support include private planning and engineering consultancies and academic institutions.

In addition to maintenance of quantitative data, the responsibility for monitoring also implies evaluating qualitative criteria associated with planning and implementation processes and making adjustments to the energy master plan and related planning documents. This iterative process allows for continuous learning from implementation and subsequent optimization of management processes as illustrated in Figure 3-21.

3.7.7 Evaluation and feedback

Bottleneck Analysis

A bottleneck analysis is an important method for evaluating the local energy planning process that can be applied at either a municipal scale or to an individual project. It is carried out by engaging relevant stakeholders, forms the basis for exchange of knowledge and lessons learned. Once bottlenecks are identified, possible solutions can be identified, often inspired by frontrunners. Instead of 're-inventing the wheel', communities and municipalities should be open to learning from relevant past experience. Also, stakeholders may be more willing to consider solutions that have worked elsewhere and to adjust their own boundary conditions, such as their idea of a good payback period, accordingly.

Bottlenecks commonly occur in the areas of financing, planning, procurement, quality control, and collaboration between different trades. A lack of expert knowledge aside, barriers are often characterized by short-term thinking, separation of implementation and operation, a lack of incentives to achieve targets (including a lack of negative consequences for energy inefficiency), fragmentation of management, organization and working methods in different sectors and a lack of coordination between different projects executed within the same community.

Removing a bottleneck or barrier generally requires fundamental changes to the underlying planning processes. Experience from pioneering or leading cities shows that fundamental changes in how energy planning stakeholders think, work and organize are required for success in the energy transition process.

Networking

Basic transition arena principles are already being put into practice through various climate and energy networks. For example EU CoM signatories⁵¹ commit to developing a Sustainable Energy Action Plan (SEAP)⁵² which also emphasizes the importance of obtaining stakeholder commitment. This is required to establish "...a common vision for the future, [defining] the paths that will make this vision come true, and [investing] the necessary human and financial resources".⁵³ According to the procedure proposed in the Covenant of Mayors, stakeholder engagement must happen in different ways during the different process phases (initiation, planning phase, implementation phase, monitoring and reporting phase). Different opportunities to engage in stakeholder participation should be considered such as information and education, information and feedback, involvement and consultation, extended involvement.

By June 2012, over 4,000 mayors have signed the Covenant of Mayors and therefore engaged in providing and implementing a SEAP by following the Covenant of Mayors guideline. Nearly 1,500 SEAPs have been submitted by June 2012, meaning that 1,500 European cities have already undertaken such stakeholder involvement processes. The other cities are currently in the planning phases of their SEAPs.

⁵¹ www.eumayors.eu

⁵² European Union, How to Develop a Sustainable Energy Action Plan (SEAP) – Guidebook, 2010.

⁵³ Citation from SEAP

External consultants

External experience can contribute know how and experience needed to tackle complex issues. This does not only pertain to technical know-how in support of individual projects; external assistance can be useful throughout the whole local energy planning process. The requirements described for coordinating stakeholder engagement are challenging. External support offers independent advice that can help to stay the course. These external advisors are often best equipped to lead and moderate processes both within the municipality and those involving stakeholders. Being independent and neutral they can facilitate dialogue, ask tough questions and ensure everyone is given a voice in the process thereby helping the group to do its best collective thinking.

Figure 3-22 provides an overview of the municipal energy master planning process, illustrating its circular nature involving many stakeholders with no defined timeline for individual steps.

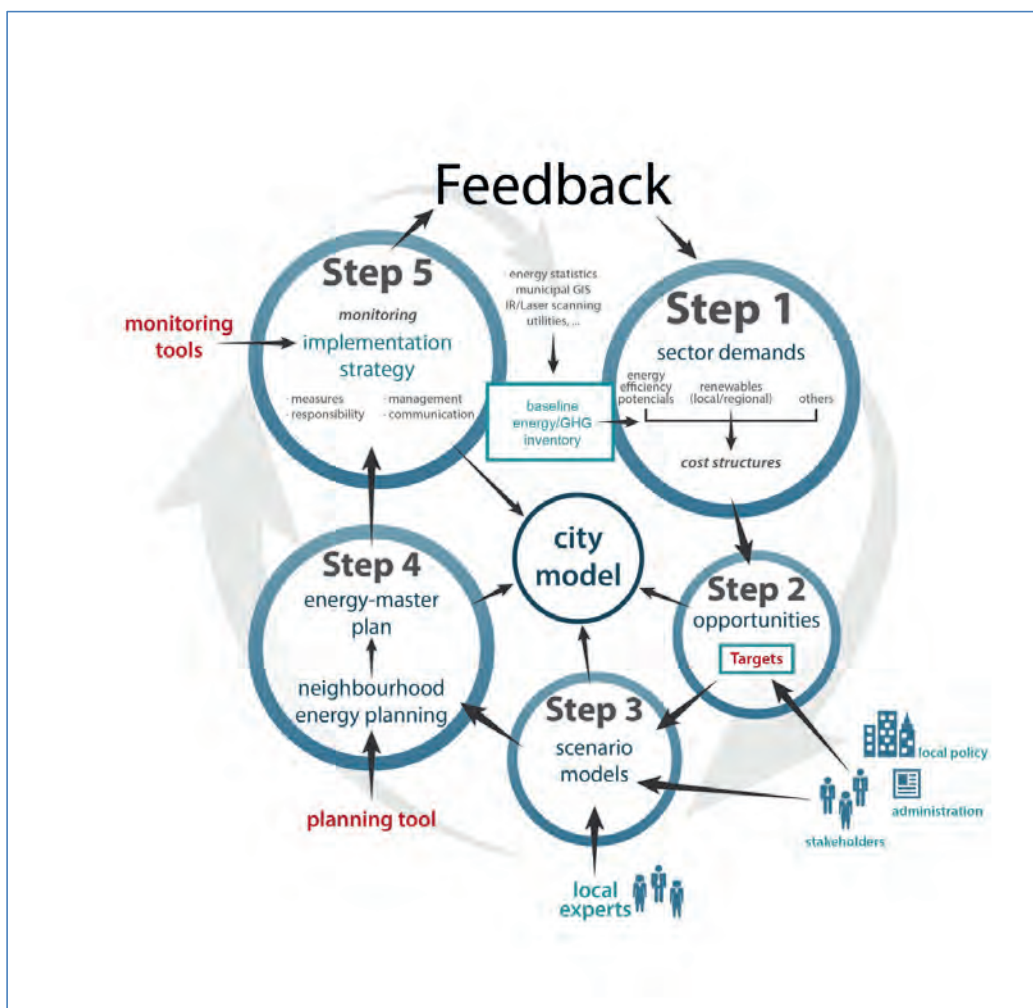


Figure 3-22: Local energy planning processes with linkages between different steps and stakeholders. Source: pro:21 GmbH

3.8 Technical improvement options, economic feasibility

To address the impact of technical options and their economic feasibility, this section asks:

"What improvements can be made to the design and implementation of local energy infrastructure to improve the energy performance of a development and contribute to a reduction of the community's overall energy demand?"

Traditionally, this question would result in a discussion on the application of engineering practices or technological hardware to reduce the need for the input energy, provide the energy through some alternative means or control and manage energy conversion from primary sources to secondary uses. Rarely would the response reference the impact of the urban planning and design process, municipal policies or financial instruments used in neighbourhood development. The various policy and technical instruments discussed here can support the municipality in the implementation phase.

3.8.1 Technology and policy approaches available to governments

Municipalities and senior governments have two courses of action by which they may achieve their energy reduction targets: they can *direct* or otherwise require action through legislation, standards, permits and bylaws or they can *incent* action through the use of negotiation, offsetting and moral suasion. Legislative and policy frameworks on a country-by-country basis are found in Chapter 2.

Directing compliance through legislation

GHG emission limits

A top down approach prescribed by senior government (e.g. federal) based upon regional attributes and presented as an aggregated value or as a value associated with particular technology. For example emissions limits are set by the Canadian federal government for large industrial emitters, power generation and transportation according to CO₂e t/a. While this addresses the production of goods it ignores the impact of their use e.g. natural gas, electricity, diesel fuel oil and petroleum. Instead, the reduction requirements are assigned to the user (municipalities). In this way the municipalities are enabled to define activities to achieve the necessary reduction. This approach must necessarily be accompanied by authority at the municipal level (e.g. the ability to impose bylaws, tolls, tariffs, etc.).

Community plan / official plans

Communities are required by law to provide official community plans to senior government that describes their proposed growth pattern and future activities. Communities are including principles of sustainability in their planning policy statements; depending on the region this community plan may reference energy use or emissions reductions targets. Whether legislated or not, the development of an energy plan is an ideal tool for gaining a greater appreciation of the demand for energy as well as the manner in which that energy is required to be supplied or used.

Codes & standards

Codes for construction or operation of housing or buildings are normally established by the federal government. Developers comply with these codes while the municipalities monitor or enforce their use. To the municipal government building codes represent the minimum standard required for safe, reliable occupation. However, for many developers the codes represent the maximum requirements for any property. To address this, in North America and most European countries municipalities may, through by-laws, exceed National Building Code standards in areas where they have authority. However, they must provide technical proof to justify the need for improvement as well as the necessary inspection and approvals. In municipalities with restricted budgets or lacking appropriate expertise, this additional responsibility is rarely assumed.

Local service area bylaw

A local service area enables a municipality to provide and charge for any localised service deemed necessary, including energy infrastructure. This can be done either directly by the municipality or through another public authority or organization.

Emission limits in specified areas

A municipality can dictate emission limits or specify fuel types in a specified area within a community. This mechanism could be used to promote specific technologies or activities where permitted by senior government. An example is the rezoning of a neighbourhood to encourage solar PV or DHW.

Future energy upgrade bylaws

Solar Ready Bylaws require new buildings to be built to accommodate the installation of solar hot water heating equipment at a later date. In practice, this influences building orientation and size and slope of rooftops. Inside, conduits and rough-ins are installed during construction.⁵⁴

District Energy Ready Bylaws can require buildings of a certain size and type to undergo a district energy pre-feasibility study in the design phase. They can also require new buildings to include the appropriate infrastructure to support connection to a district energy system at a later date.

Net Zero Ready Bylaws require buildings to achieve high levels of thermal efficiency and include infrastructure to support either stand-alone or district renewable energy systems. High efficient building practices, combined with renewable energy can eventually lead to the building producing as much energy it consumes, thereby being net zero energy.

Building energy labelling, green building rating systems

Green buildings standards address developments designed for maximum energy efficiency (low-energy buildings) as well as reduced water consumption, materials and impact on health and environment. Standards vary by country, describing the approach to the design of such properties along with a grading procedure to encourage and qualify participants. A list of green building standards and energy efficient building codes may be found in Attachment B. Building labelling has been shown to be an effective mechanism for influencing consumers and effecting energy efficient retrofits (Attachment E).

EnerGuide for houses

The EnerGuide label introduced in Canada gives an estimate of the electricity, natural gas or oil that is expected to be consumed each year. At the time of writing in 2012, the labelling process and format is currently under review.⁵⁵

Building energy quotient (ASHRAE)

The program provides buildings with a rating from A+ to F; the former reserved for facilities that are net zero (- meaning they produce as much energy on site as they consume) and the latter for those that are “unsatisfactory.” The labels provide an easy-to-understand metric for owners and tenants to compare with other, similar buildings

www.buildingeq.com.



⁵⁴ <https://doi.org/10.51202/6763616791232> - Generiert durch IP 216.73.216.80, am 23.01.2026, 22:51:17. © Urheberrechtlich geschützter Inhalt. Ohne gesonderte

⁵⁵ <http://oee.nrcan.gc.ca/residential/new-homes/upgrade-packages/4998>

Energy performance certificates

As a result of EU EPBD, certificates were introduced in England and Wales in 2007 for domestic properties with three or more rooms. Similar certificates have been developed in the other EU member states, examples can be seen in Figure 23:⁵⁶

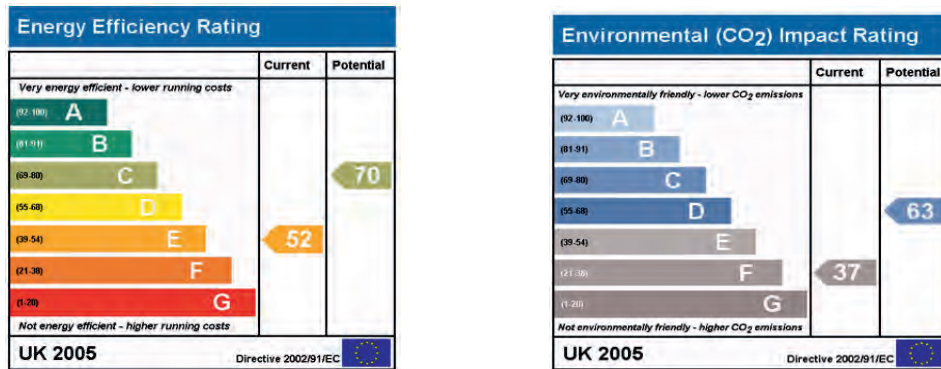


Figure 3-23: Building energy and GHG certificates in the UK

Local improvement charges

Municipalities have traditionally used Local Improvement Charges (LICs) or similar other instruments to help cover the costs of infrastructure investments that benefit a specific neighbourhood - for example the construction of residential sidewalks or grants to support business improvement areas. Landowners whose properties benefit from improvements are assessed a charge that is added to their property taxes each year until their share of the improvements has been paid. The same concept might be applied to energy infrastructure, for example to finance district heating schemes.⁵⁷

Purchasing guidelines / green procurement

Many municipalities, because of their size, wield significant purchasing power and are able to adopt green standards to support their principles. The use of these standards sends a strong message to the retail sector that environmental performance has value within the community. One such example is the ability for communities to purchase bulk green power or green electricity certificates from energy distributors. While a municipality with institutions such as school boards might purchase green power⁵⁸ for their buildings there may be potential for instructing local energy distribution companies, through bylaws or other mechanisms to purchase and sell renewable or low-carbon emitting power and heat. This would provide, at least on a temporary basis, a significant opportunity to reduce the overall carbon footprint of the community at a relatively low incremental cost.

⁵⁶ http://en.wikipedia.org/wiki/Directive_on_the_energy_performance_of_buildings) and www.direct.gov.uk/en/HomeAndCommunity/BuyingAndSellingYourHome/Energyperformancecertificates/DG_177026

⁵⁷ www.ontariocanada.com/registry/view.do?postingId=6982

⁵⁸ www.bullfrogpower.com

Incenting compliance

Programs

Public funds and loan guarantees

A public endowed fund is a fixed amount of funding set aside by a local government to provide loans for development that combat global climate change and improve air quality. The Toronto Atmospheric Fund⁵⁹ is one example of this approach. Many other funds exist for financing thermal renovation measures. A loan guarantee however is essentially a pool of capital retained by a bank to provide itself with a guarantee for private sector loans. It is only used if there is a default on the loan, in which case the lender is reimbursed by the fund.

Feed-in tariffs

A policy mechanism designed to accelerate market uptake and penetration or other policy decisions. As previously described, it has been used extensively in Europe for the promotion of renewable energy technologies (e.g. photovoltaic) within the electricity generation sector. In Canada only Ontario has implemented FIT program to date. Although these programs focus on electricity generation, there is no technical reason why the same principle cannot be applied to smaller thermal networks regionally to encourage uptake.

Tariffs typically provide three key provisions: 1) they provide guaranteed access to the energy grid, 2) they offer long-term contracts for the energy produced and 3) purchase prices are based on the cost of alternative generation. Different tariff rates would be set for different supply technologies, possibly linked to the cost of the resource development in each case (see Chapter 2 for details).

Under a thermal feed-in tariff, a centralised distribution system would offer eligible supply technologies a premium price for their thermal energy. Unlike electricity feed-in tariffs, thermal feed-in tariffs are more difficult, due to the lack of a public grid that is involved. No functioning solution for thermal feed-in tariffs has emerged thus far.

White & green certificates

White Certificates, also called Energy Savings Certificates or Energy Efficiency Credits, are documents that certify specific reductions in energy use have been achieved. They are used in Italy, France and Denmark where energy producers and distributors undertake energy efficiency measures for the final users consistent with a pre-defined percentage of their annual energy delivery. They are marketable in that the certificate owner can use it for his own compliance or sell it to those who cannot meet their targets. Penalties encourage the meeting of targets resulting in a guarantee of energy saving at minimum costs. Moreover, white certificates stimulate the activities of Energy Service Companies (ESCOs).⁶⁰

Green Certificates in Europe and in the United States are a tradable commodity similar to white certificates but are related to the generation of electricity from renewable energy sources. They represent the environmental value of renewable energy generated and can be traded separately from the energy produced. Several countries use green certificates as a support for green electricity generation within a market driven economy and without grants, feed-in tariffs, etc...⁶¹

⁵⁹ www.toronto.ca/taf

⁶⁰ www.encharter.org

⁶¹ http://en.wikipedia.org/wiki/Green_certificate

Planning approvals

Zoning for sustainability

Urban zoning designations may be reconfigured to accommodate the needs of a more sustainable or low-carbon community. Literature identifies many factors that can be considered while developing urban zones that will maximize the potential for energy savings.

Development permit area (DPA) guidelines

Within DPA areas, as a condition specified in the permit guidelines (or similar instruments such as legally binding land-use plans or neighbourhood development schemes), local governments can now require consideration of specific features within the development, including machinery, equipment and systems external to buildings and other structures. This makes it easier for local governments to require building systems that are supportive or compatible with renewable energy systems (e.g., solar hot water heating) or district energy systems (e.g. hydronic building heating).

Development cost charges (DCC)

Local governments may now waive or reduce development cost charges (DCCs) for developments with low environmental impact or for a subdivision of small lots that is designed to result in low GHG emissions. As with previously allowed DCC exemptions, the requirements that must be met to receive a DCC reduction must be clearly stated in the DCC bylaw or regulation.

Tax exemptions

Depending upon location, local governments may have the opportunity to use tax exemptions to encourage particular forms of revitalization, including environmental revitalization, primarily because long-term lower energy costs can help achieve local government revitalization objectives. Tax exemptions can represent a significant financial benefit, and are an attractive incentive to the developer of a district energy system, particularly to help offset capital costs during the early stages of the project.

Density bonusing

Density bonusing allows local governments in certain circumstances to exchange increased density for amenities. Thus a developer may be allowed to build more units than normally permitted in the zone (increased floor space ratio, site coverage or number of buildings per parcel, etc.) in exchange for amenities such as recreation centres, public squares, or pedestrian or bicycle paths. Europe has examples where local authorities grant bonuses to developers, based on the application of specific measures during building renovation (Bolzano, Italy) or the achievements of specific energy performances (Nantes, or Mulhouse - Quartier Franklin, Salzburg) (for more information see the Annex 51 Subtask B Final Report).

Performance bonds

Performance bonds are common practice for many construction projects but rarely implemented on housing and building projects where the developer has little control over the operation of the property after completion. One example, in a performance bond implemented in Victoria, Canada the development agreement between the City and the developer required the developer to achieve certain LEED standards on the various buildings. To ensure compliance, a performance bond was required, repayable on attaining the required LEED certification.

3.8.2 Technologies available to the developer / contractor

The developer works within the constraints of the municipal authorities with the aim of maximising his return on investment while remaining within budget and within the proposed operating performance. The design process involves integrating the appropriate construction technologies with those for

energy generation and distribution. Typical buildings utilize energy in a variety of ways, some being the responsibility of the building designer and some that of the occupant.

Integrated energy design process

The expression 'integrated energy design of buildings' describes a design process that minimizes the building's energy demand by maximizing the efficiency of the technical building services in order to assure architectural quality, thermal comfort, indoor air quality and total economy. The process is considered essential when designing passive houses, low-energy buildings and zero-energy buildings since it reduces the risk of capital-intensive interventions afterwards in the life cycle of energy use. It does this by focusing on the design of the building envelope and of any energy conversion and distribution system, for the individual buildings of the neighbourhood as well as for the neighbourhood as a whole.

Integrated energy design focuses on making quantitative analysis so that the design work is based on facts and not on design criteria, construction traditions and materials that are outdated.⁶²

Modelling & indicators

The use of dynamic modelling tools to support the design of communities has been advanced by academic institutions and leading municipalities, increasingly with the support of the private sector. Their widespread application has been limited however due to the quantity of input data and level of expertise required to develop and maintain these models. Single buildings have been modeled for compliance with building codes, incentive programs or for performance analysis while models using GIS have been utilised to map renewable energy supply and model community-wide scenarios for building demand and conventional and renewable energy supply.

The impact of human behaviour on building typologies is the focus of much research where those interactions have been developed employing human factors through approaches such as 'agent-based' modelling or simulation. The intent of the research is to evaluate the behaviour patterns within existing communities and then apply these observations to new system design.

Models in common use are described in detail in Chapter 4 while details of the District Energy Concept Adviser developed within this Annex 51 are in Chapter 5. At the building level several commonly used design models are then listed in Attachment C.

Training / education programs

Recent surveys by Natural Resources Canada (2010) indicated that a major barrier to the implementation of district energy or other sustainable design is the lack of technical understanding of the processes and procedures. As most of the Case studies discussed in Subtask A and Subtask B demonstrate, training may be provided to construction personnel when new generation technology is proposed but project related training for design is rarely included within a development contract. The lack of training or continuing education of designers inevitably leads to a reversion to "business as usual". This may be true for technical innovations in the buildings sector in general.

Construction materials

Many of the building technologies mentioned below are covered by various IEA EBC Annexes in the form of state-of-the-art reports or design guidelines. These can be downloaded from www.ecbcs.org.

Envelope

Exterior walls commonly consist of one or more of the following: claddings, drainage planes, air barrier systems, vapour retarders, insulation layers, and structural elements. Exterior wall types are all classified as: cavity walls, barrier walls, or mass walls.

⁶² <https://doi.org/10.51202/6763619791232> - Generiert durch IP 216.73.216.80, am 23.01.2026, 22:51:17. © Urheberrechtlich geschützter Inhalt. Ohne geordnete Erlaubnis ist jede urheberrechtliche Nutzung untersagt, insbesondere die Nutzung des Inhalts im Zusammenhang mit, für oder in KI-Systemen, KI-Modellen oder Generativen Sprachmodellen.

- *Cavity walls* - partially or fully concealed air space and drainage plane to resist rainwater and to improve the overall thermal performance.
- *Barrier walls* - weather-tight at the exterior wall surfaces and construction joints so as to resist rainwater and/or moisture ingress.
- *Mass walls* - solid construction and more common in Europe than Canada, the UK or Japan.

Fenestration

Fenestration elements include: windows, doors, skylights, and curtain walls. All are designed to permit the passage of air, light, vehicles, or people. Fenestration with glass is not only part of the building shell but provide daylight and heat from sunlight. Orientation of fenestrated areas should consider the solar radiation as both light and heat that complement the building heating demand and maximise the natural light entering the indoor space (example *Passivhaus*). Improved fenestration efficiency involves multiple layers of glass panes, coatings, or fillings between the panes with an inert gas or vacuum.

Ventilation, heating, cooling & dehumidification

Well-insulated, air-tight buildings require active ventilation to remove used air and introduce fresh air for occupant health. Mechanical ventilation with efficient heat recovery is a standard solution and, where the requirements of air quality are high, such as in commercial buildings its energy use can be reduced by the introduction of natural ventilation or by creation of a mechanical / forced hybrid ventilation system.

Space heating (SH) and domestic hot water (DHW) for the building is supplied through a variety of individual technologies such as electric heaters, heat pumps, individual boilers, solar thermal collectors, micro-cogeneration units, or from collective systems such as district heating or cooling.

As with heating systems, the provision of cooling can be from building based equipment or from a community based district cooling system. Air tightness is more important for building cooling than for heating since air leakage can substantially impact the effect of mechanical cooling. Examples of district cooling exist that use natural cooling sources (seawater or lake water) and demonstrate the significant benefits of this approach.⁶³

To maximize a building's lifespan in humid climates and in buildings producing much humidity, such as indoor swimming pools, baths, etc., humidity needs to be removed from the inside air. Several techniques are available, both passive and active. In mechanical systems dehumidification is integrated into the air conditioning systems and adds a further energy-intensive process. In passive systems a desiccant is used to remove the moisture content from the air.

Domestic hot water (DWH)

DHW is required for hygiene, food preparation, cleaning and commercial purposes. Several approaches are available to produce the hot water, either instantaneously or through the use of a storage tank. Storage temperature and conditions are critical to avoid the development of legionella bacteria within the system. The quantity of energy required for DHW production is dependent upon user lifestyle. Due to permanent high temperatures of the distribution system, appreciable distribution losses can occur that are in the range of up to 50% of DHW generation. For that reason, a careful insulation of pipes, armatures, fittings and storage tanks is important. Inline circulation pipes further reduce the losses to a reasonable amount (< 30% of DHW preparation).

Lighting

Energy consumption for lighting could be dramatically reduced by efficient lighting technologies, adequate controls, and better use of natural daylight. Lighting requirements are a function of building

⁶³ www.enwave.com

design and the need for lighting during daytime depends not only on the external conditions but also on the size and placement of fenestration and its geometry. The design therefore should not ignore the relationship between natural and artificial lighting. Widespread phasing-out of incandescent lamps is under way, replacing them with compact fluorescent lamps (CFLs), advanced halogen lamps or light emitting diodes (LED). Of these, LEDs have a superior efficiency (> 80% saving). Currently, LEDs are at the beginning of market adoption, still expensive, but allowing additional savings of about 30% compared to CFLs.

Orientation

Passive solar buildings utilise windows, walls, and floors to collect, store, and distribute solar energy as heat in the winter (Passive Solar Heating) and reject heat in the summer (Passive Solar Cooling). The term is 'passive' solar because, unlike 'active' (solar heating, photovoltaic, etc.) solar systems, it involves no mechanical or electrical fans or pumps.

Active solar systems include: solar water heating, solar space heating, and photovoltaic panels, all of which are flexible in their application making them ideal for retrofitting existing buildings or in any new construction.

Energy generation

In-house

In-house generation of heat and/or electricity is generally limited to solar thermal, heat pumps, solar photovoltaic panels, building integrated wind turbines and micro-generation. The use of biomass in stoves remains widespread and contributes to a major share of renewable energy, despite concerns over combustion efficiency and air pollution. As an indication Europe has seen significant interest in automatically fed pellet boilers between 15 and 300 kilowatt thermal (kW_t), increasing the biomass thermal market beyond that of solar collectors.

PV panels convert solar radiation into direct current (DC) electricity through the use of semiconductors. Extensive work has been undertaken to integrate the photovoltaic modules into roofing and other envelope materials. Because of recent mass production and installation of PV panels, system prices have decreased to below 2,000 \$/kW_p for major installations. Further significant technological improvements are still to be expected.

Stirling engines are external combustion engines driven thermally by cyclic compression and expansion of air or other gas. The conversion of this heat to mechanical work produces electricity. Stirling engines are generally limited in power (maybe less than 25kW_e) by their ability to transfer heat rapidly through the cylinder walls. This technology is still under development.

Community scale renewable energy

The availability of renewable energy at the community level supports energy efficient heating and cooling systems. Energy strategies may therefore be developed to address three areas of activity: demand side management, supply side generation efficiency and fuel switching to renewable energy sources.

Communities that wish to convert entirely from fossil to renewable energy from solar or wind face a fundamental challenge, that of converting intermittent supply into a stable energy system. The primary mechanism for thermal energy is the use of bore-hole storage where the ground is used as a heat sink, where excess heat is stored in times of low demand and drawn upon in times of high demand. Limited storage is available for electricity although chemical batteries are being developed. Short-term localised alternatives do exist, although they can be expensive such as plug-in hybrid vehicles. Research is underway into cost effective strategies for 'transition towns' or communities

intended to be 100% dependent on thermal renewable energy. However, the notion of a 100% renewable energy scenario, covering both thermal and electrical energy needs, remains to be developed.

Control strategies of renewable energy-based supply systems

As noted above, the use of an intermittent renewable energy supply on a continuous or unpredictable basis requires collaboration between neighbourhood communities, local, regional and national governments and utilities to facilitate access to electricity and thermal storage options. Energy infrastructure has a long lifespan and today's decisions impact communities for decades to come. Agreement on energy supply and distribution infrastructure is required between parties with a transparent decision making process. Each project should be seen as part of a plan, thereby avoiding short-term tactics that may lead to inefficient use of capital resources.

Two approaches exist to develop effective renewable energy systems: technical regulation and economic regulation. This terminology has been taken from the operation of combined heat and power plants, but it can readily be applied to renewable energy technologies more broadly.

- Technical Regulation: energy plants are operated according to heat demand, ensuring optimal balance between supply and demand of both heat and electricity.
- Economic Regulation: generation is undertaken to maximize the economic profitability within the market constraints. In North America this option is referred to as operating a 'merchant' plant.

A system that is economically regulated tends to have technical capacity that is oversized for local requirements. Thus excess can be sold to the surrounding grid, relying upon neighbouring systems to balance energy supplies & demands and hence define the energy pricing within the centralised network. This approach impacts the potential for deep renewable energy technology penetration, since the economically regulated system places a heavy emphasis on availability.

In a technically regulated system, 'thermal load following' is the most common option. A system has a smaller capacity based on the community's minimum electrical demand and draws the remaining energy from the existing electrical grid. This is also referred to as the 'connected-island mode'.

Passive and active renewable energy networks

In many buildings that incorporate passive heating and cooling techniques thermal gains can lead to occupant discomfort and natural resources such as water or the ground must be used to reduce the need for mechanical cooling systems. Alternatives include free cooling during the night-time, natural ventilation or other phenomena. Passive heating and cooling is not restricted to small buildings: offices or commercial buildings can use natural ventilation but require consideration during the design phase along with the building shape and circulatory elements such as solar towers, earth tubes, etc.

The cost of implementing renewable energy technologies at the community scale depends on a variety of factors including the energy characteristics of the community itself, its demand profile and the choice of renewable energy technology. Table 3-1 illustrates generic cost figures for a range of community scale renewable energy technologies.

The data, cost figures and technological description reported in the Attachment D are derived from the literature and recent IEA publications in the renewable energy sector (www.iea.org).

Smart energy networks

Smart electric grids

The Smart Grid concept describes an intelligent integration of demand and response of all connected electric power users. This allows both suppliers and consumers to efficiently deliver reliable and

sustainable electricity services. Smart grids incorporate monitoring, control, communication, and self-healing technologies in order to better facilitate the connection and operation of electricity supplies of all sizes and technologies. This allows consumers to dynamically optimize the operation of the system by collecting and monitoring information and options. While individual technical components of smart grids have been developed, the whole idea of a smart grid is still in a pioneering status. In particular, in conventional energy supply systems the business case of such smart grids still has to be identified.

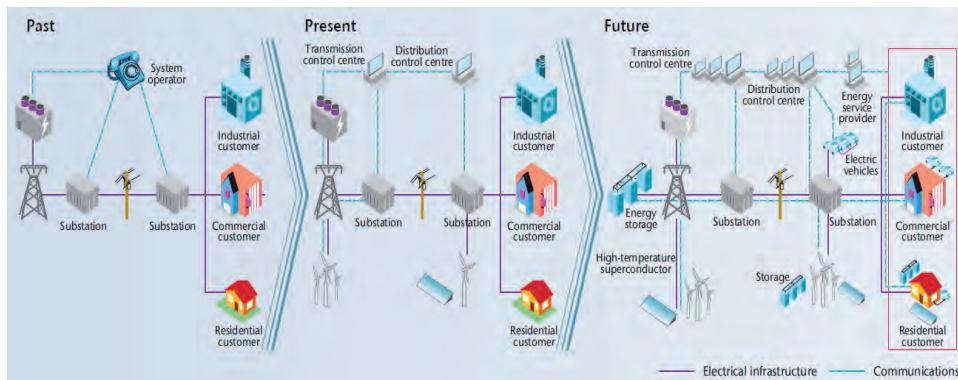


Figure 3-24: The evolution from traditional electric grids to electric smart grids. Source: IEA Smart Grid Roadmap, 2011⁶⁴

Low-exergy systems

A conventional utility's primary focus is on the production and distribution of energy. District Energy reverses the perspective, focusing instead on the comfort requirements of the end-users to provide the most-economic mechanism to satisfy this demand. This is often achieved through efficient distribution and supply systems based on renewable energy, waste-to-energy or surplus heat.

For long-term sustainability, DH systems must consider the improvements to building standards that drive towards net-zero construction. In this case the building heating demand would be only for domestic hot water ~25% of the original level. An economic impasse would be created where the heat loss from the supply piping might equal or surpass the demand from the buildings. This is a case of integrated energy planning, where demand reduction and supply systems must be optimized simultaneously to find the economic optimum of a future-proof energy system.

Reducing the supply temperature within DH network is an effective mechanism to reduce the system heat loss. Based on the Annex 51 case study in Denmark, a supply temperature of 50-55°C and the return temperature to 20-25°C could provide heating and domestic hot water (DHW) in central and northern European climates. The peak supply temperature during the heating season would be increased so as to limit the size of the distribution pipelines. The typical supply temperature for these peak load periods could be 65-75°C.

⁶⁴ http://www.iea.org/publications/freepublications/publication/smartgrids_roadmap.pdf

Technology	Energy characteristics	Levelized thermal energy costs [US¢/kWh]	Levelized electrical energy costs [US¢/kWh]
Power generation			
Small hydro	Plant size: 1–10 MW		5–12
On-shore wind	Turbine size: 1.5–3.5 MW		5–9
	Blade diameter: 60–100 meters		
Biomass power	Plant size: 1–20 MW		5–12
Solar PV (module)	Cell type and efficiency: crystalline 12–18%; thin film 7–10%		n.a.
Rooftop solar PV	Peak capacity: 2–5 kilowatts-peak		20–50
Utility-scale solar PV	Peak capacity: 200 kW to 100 MW		15–30
Hot water/heating/cooling			
Biomass heat	Plant size: 1–20 MW	3–6	
Solar hot water/heating	Size: 2–5 m ² (household); 20–200 m ² ; (medium/multi-family); 0.5–2 MWth (large/district heating); types: evacuated tube, flat-plate	12–20 (household) 10–15 (medium) 7–10 (large)	
	Plant capacity: 1–10 MW; types: heat pumps, direct use, chillers	0.5–2	
Geothermal heating/cooling			
Rural energy			
Mini-hydro	Plant capacity: 100–1,000 kilowatts (kW)		5–12
Micro-hydro	Plant capacity: 1–100 kW		7–30
Biogas digester	Digester size: 6–8 cubic meters	12 - 20	
Biomass gasifier	Size: 20–5,000 kW	8–12	
Small wind turbine	Turbine size: 3–100 kW		15–25
Household wind turbine	Turbine size: 0.1–3 kW		15–35
Village-scale mini-grid	System size: 10–1,000 kW	25–100	
Solar home system	System size: 20–100 watts	40–60	

Table 3-3: Levelized energy costs for energy generation from renewable sources (various sources)

Using low supply and return temperatures offers major advantages to the operator:⁶⁵

- Reduced network heat loss – a lower temperature level, increased insulation allows the use of twin pipes.
- Reduced pipeline thermal stress - lower supply temperature, more even temperature gradient and reduced pipe leakage.
- Reduced heat loss in thermal storage units.
- Improved power to heat ratio in the CHP units – improved economics for grid sales.
- Improved capacity for using RE and waste heat – more energy sources available (flue gas condensation, geothermal and solar thermal).

To initiate movement in this area, Public Works and Government Services Canada has developed and issued guidelines to require federal buildings to use low temperature (70°C) heating. In this way federal properties will more readily accept the use of renewable and district energy.

The district energy sector has often opposed Net Zero Energy developments due to the potential for low-energy density “ghettos”. Using a lower temperature energy supply reverses this situation since energy conservation measures provide the opportunity to make intelligent investments and place a higher value on the energy. Use of low-temperature district heating in neighbourhoods of sufficient energy density is very often the most cost-effective solution when the community is assessed holistically. Municipalities and policy-makers must prepare effective heat plans to identify opportunities for energy networks and other technologies. Low-temperature DH draws together both interests; those of the energy suppliers and those of the consumers, and provides for both their needs.

Commissioning

As with the lack of specific training for the installation of new technologies, the omission of comprehensive commissioning plans is often seen as a cost saving measure. However, savings of 15% of the energy used can be possible in existing buildings when correct commissioning is undertaken.

3.8.3 Technologies available to the occupant

The occupant does not always have influence to the design of a new building and often inherits the decisions of municipality, developer and energy utility. Regardless of the intentions of the designer, the performance of the building depends upon the occupant’s understanding of the technologies.

Standards

Partly due to the rebound effect of improved component efficiency, the consumption of electricity by lighting and appliances is increasing rather than declining. Implementation of energy efficiency measures, minimum energy performance standards and mandatory labelling are critical to the management of building energy consumption. Electrical appliances provide unwanted heat gains to building interiors and therefore increase the need for mechanical cooling. Standards are available for the development of efficient appliances as are labelling programs. These allow consumers to select appliances based upon estimated energy consumption. For more information - see Attachment F.

Operations / lifestyle

- ***Energy conservation techniques***

Many energy utilities implement Conservation Demand Management (CDM) or Demand Side Management (DSM) programs that focus on aspects of household design, replacing appliances or

⁶⁵ www.Annex49.info

upgrading equipment. These not only encourage the reduction of energy demand within the household but, on a larger scale reduce the demand at the plant and the wear and tear on transmission infrastructure. The impact on national electrical systems of sudden spikes in demand is well known, for instance during the half time break in a football match or hockey game. The two kilowatt demand of a kettle is small but when many thousand people demand this simultaneously the surge current is significant and the resulting transient requires infrastructure to be sized accordingly to prevent damage.

Peak load management is an opportunity for utilities and developers to work together. In summer when peak demand is highest in North America, electrical utilities can remotely set back the temperature or completely deactivate residential air conditioners. When undertaken on a large enough scale this prevents brownouts or the need for additional expensive generation. A developer could include such control mechanisms within the property with the minimal additional cost being provided by the utility. This kind of measures would be one component of future smart grids necessary to enable a safe operation of grids under much more unstable conditions than it is the case today.

Other opportunities include the provision of a guidebook for homeowners or tenants that explains the operation of many of the non-traditional appliances. An understanding of the operation and limitation of some of the equipment will enable homeowners and developers to work together in minimising the energy demand.

4 Community Energy and Emissions Inventory and Modelling Tools to Support Local Energy Planning (LEP)

4.1 Introduction

Computer-based energy and GHG emissions inventory and modelling approaches can provide effective decision support enabling science based policy making. Although challenges still exist around data quality, data access and interoperability of systems and services, measured inventories and modelling are increasingly used to explore future scenarios to support identification of cost-effective low-carbon energy strategies and accelerate project implementation. Ideally, LEP processes are informed by accurate building, energy and emissions inventory data, balancing tools and models, resulting in neighbourhood energy plans and projects that work to implement strategies and actions contained in the municipal energy master plan.

Numerous computer-based energy and GHG emissions decision support applications are available. They range from Excel spread sheets developed and used by municipal staff or private sector practitioners to complex urban energy system models developed and used by academic institutions. Furthermore, a variety of databases and software applications, broadly in use for purposes such as building energy modelling can be helpful for LEP. The aim of Chapter 4 is not to provide a comprehensive overview of inventories, models and their practical applications, since this has already been done by other authors (Province of British Columbia, 2012, Bertoldi et al., 2010, Connolly D. et al., 2010, Condon et al., 2009; Keirstead et al., 2012). Rather, by presenting key concepts and describing selected inventories and models and experiences gained in their practical application, the aim is to foster a general appreciation of the types of inventories and selected examples of models available and their benefits for the LEP process. Although inventories and models can describe activities within a number of sectors in the economy, this chapter will highlight applications for buildings and energy systems, consistent with the focus of Annex 51. The chapter also anticipates developments around open data, cloud computing and the general increase in the interconnectedness of systems and processes that will provide more computing power to respond to local energy planning needs.

4.2 The scope of LEP and the need for inventories and models

Local energy planning (LEP) is carried out at the municipal and neighbourhood scales. Generally strategic planning takes place at the city-wide scale and operational planning at the scale of a neighbourhood or building cluster. Principles of strategic planning include taking a long-term perspective, considering the needs of a range of stakeholders and working towards energy, greenhouse gas and economic development goals by advocating for energy efficient buildings and systems. Operational planning at the neighbourhood scale implements strategic planning done at the municipal scale. It considers the impact of a development project on the specific area and provides detailed technical specifications for planning alternatives. Some distinctions can be made regarding the policy and decision processes, the level of detail of information and modelling approaches required by each.

At the community-wide scale, LEP activities include establishing GHG emissions or energy targets, creating long-term plans, developing policy and enacting by-laws. LEP processes for whole cities or towns typically require energy, emissions and cost information on a community-wide scale and on an annual basis, although sometimes monthly figures are used. It is common for long-range planning activities to look out over planning horizons of 25 years or more. Municipal energy master planning activities have generally been guided by community energy and emissions inventories, often further enabled by computational methods. To guide long-term planning and questions such as "*we set a target, now how do we achieve it?*", increasingly sophisticated future scenario and backcasting

analyses are being conducted, sometimes leveraging the power of whole system simulation or optimization models that characterize energy demand by sector, source and end-use, alongside associated GHG emissions and costs. Geographical information system (GIS) supported spatial analysis techniques are increasingly seen as offering opportunities for local energy planning since mapping is traditionally used by land use planners and can support tasks such as characterization of energy use in buildings and assessing local availability of renewable energy resources. Integrated modelling approaches (using several purpose-built models in combination), is another valid approach increasingly used by academic institutions (Eicker, 2012) and some jurisdictions e.g. British Columbia, Canada.

Planning activities for new or existing neighbourhoods can involve creating or updating local area plans, and developing and implementing revitalization programs or energy technology projects. Strategic visions and community engagement provide the framework; detailed technical analysis first explores a range of measures, then prioritizes selected measures and finally determines suitability based on site, building and financial considerations. While modelling can inform policy analysis and selection of options for implementation, monitoring is an empirical measurement approach that verifies the real energy, emissions and cost savings achieved. Figure 4-1 provides an overview of this decision making process and the application of modelled and/or measured data collected from inventories.

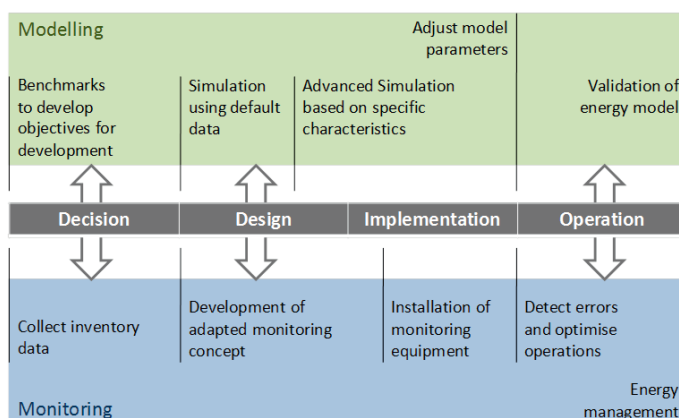


Figure 4-1: Parallel steps in modelling and monitoring. Source: Koch and Kersting, 2011

In current practice, housing and building energy use is the principal focus of community and neighbourhood energy and emissions modelling. LEP usually considers houses and buildings on an individual or archetype basis, often accomplished through a housing or building energy simulation. In addition to building characteristics, weather conditions and detailed occupancy profiles help determine building energy use. Depending on the scope of the study, thermal and electrical demand profiles are calculated on a monthly, daily, hourly or even sub-hourly basis. GHG emissions, operating energy costs and proposed capital expenditures data are required to assess proposed solutions.

Targets, policies and strategies guided by general technical potentials are broader topics examined at the city-wide scale. Technical feasibility and cost effectiveness are the criteria that determine whether a project will be approved and ultimately implemented at the neighbourhood scale.

4.3 Energy and GHG emissions inventories

4.3.1 Selected examples of inventories and balancing tools in practical application

The Greenhouse Gas Protocol is an accounting framework for GHG standards developed by the World Resources Institute and the World Business Council for Sustainable Development. Endorsed by the International Standards Organization, it is the most widely-adopted GHG accounting framework, forming the basis of the majority of GHG standards and emissions reductions programs worldwide. In addition to enabling GHG accounting for products and by business sectors, it also provides the accounting framework for many of the community GHG inventories implemented nationally. ICLEI – Local Governments for Sustainability, leverages the Greenhouse Gas Protocol in the United States in its Community Protocol for Accounting and Reporting Greenhouse Gas Emissions, recently released. In Europe, different approaches have been developed, an example being the ECORegion model advanced by the European Climate Alliance in collaboration with the European Economic Area (EEA) or Bilan Carbone (see below for more details).

In Canada, the Partners for Climate Protection Program is the Canadian component of ICLEI's Cities for Climate Protection (CCP) network. The Community Energy and Emissions Inventory (CEEI) reports are compiled by the Province of British Columbia and its utilities for use by municipalities in the province (Province of British Columbia, 2012b). The CEEI reports allow municipalities to fulfill Milestone One in the five milestone PCP program – the creation of a GHG emissions inventory. The CEEI report outlines energy consumption and greenhouse gas (GHG) emissions from municipal activities, including on-road transportation, residential, commercial and industrial buildings and solid waste. Note that energy and emissions from municipal corporate operations and other public sector organizations in the province are reported separately through SMARTTool. First compiled for the year 2007 and repeated in 2010, the CEEI process will be updated bi-annually. The Community Energy and Emissions Inventory is the first of its kind in North America, enabling all local governments and regional districts in British Columbia to achieve their legislated requirement to include GHG targets, policies and actions in their Official Community Plans and also to meet the Climate Action Charter commitment to measure and report on community GHG emissions profiles.

Energy Balance

Energy Balance is an Excel-based tool, developed in Denmark by engineering consultant PlanEnergi. It contains survey data on fuel consumption, energy transformation, energy distribution, end use, greenhouse gas emissions and energy from renewable resources. Two balances are developed: the municipal energy balance and the energy balance of the municipality. The former covers all energy use and associated GHG emissions within the geographic boundary of a municipality, while the latter reflects the energy and GHG emissions from the municipal corporation and its buildings including associated municipally owned and operated institutions such as schools and nursing homes. It enables analysis for fuels, technologies for energy conversion, distribution (both electricity and district heating) and end use. Fuels are divided into different types according to the objectives of the study. Power and/or heating plants are also defined according to their fuel type, efficiency and end-use. Efficiency is divided into efficiencies for electricity production, energy for processes, heat, and efficiencies in the electric and district heating grids. Distribution systems for electricity and heat are described. The last section in the model defines the energy end-users.

Energy Balance has been used as an energy accounting tool since 1997 by a number of Danish municipalities to calculate CO₂e emissions at the municipal level and define strategies for future energy supply. From 2005 to 2010 the tool was applied in more than twenty Danish regions or municipalities as well as in the United Kingdom, Italy and Thailand. Engineering consultants usually explore general statistical data describing community activities and compile the community energy balance or inventory. The municipality provides their own data and if possible, updates the general

data available for the community. Data for input may have been collected in monitoring by utilities or from statistical datasets developed from surveys. If reliable local measurements are available they can be used in place of more generalized datasets; for example, local smart meter data is preferable to energy end use values derived from a larger, national survey.

After the local data have been incorporated, the calculated energy balance or inventory is passed to the municipality together with a report explaining results and suggested action items. Using these results, the municipality can begin to develop action plans. In recent years, municipalities such as Samsø and Aalborg in Denmark have re-applied the tool a decade after the first evaluation, to monitor the results and plan for further corrective measures where necessary.

The strength of Energy Balance is that it offers a complete analysis of fuel consumption, energy transformation, distribution and consumption, greenhouse gas emissions and renewable energy of a whole region or municipality. Its main disadvantage is that it requires a large quantity of input data, some of which is not always available, accurate or otherwise difficult to obtain.

Bilan Carbone® Collectivités

Bilan Carbone®, initially created by the French Energy Agency (ADEME) in 2004, has been in further development by the Association Bilan Carbone (ABC) since 2011 (www.associationbilancarbhone.fr). Future development of the tool is assured by involving members of the organisation in four committees for research, public bodies, local administration and industry. The approach provides communities with an Excel based tool to assess their GHG balance and describes the process to reduce GHG emissions for municipalities. It considers both direct and indirect GHG emissions as required by the Kyoto Protocol and provides transparency regarding input data and GHG emission factors used. The approach covers a variety of local energy activities including space heating, combustion for manufacturing processes, freight shipments, passengers travel, production of raw materials and waste and water treatment. The assessment allows urban decision makers to calculate emissions, identify and prioritize projects and work towards incremental emissions reduction over time. It is therefore suited as a basic tool to develop the energy and GHG inventory for the Territorial Climate Plan required for communities with more than 50,000 inhabitants by the Grenelle directives.

Bilan Carbone® is based on existing emissions data, default values are provided when no other data is available, as well as guidance on how to relate processes in the municipality to GHG emissions.⁶⁶ The version for cities essentially targets all processes or activities within the geographic boundary of the municipality.

Between 2002 and 2009, Bilan Carbone® was used by over 200 communities in France. An estimated 20 to 30 days is required for an ADEME accredited consultant to develop a GHG balance or inventory for a local community; the consultant is usually assisted by a municipal staff person. A list of more than 1,500 accredited experts is available on the ADEME website.

In conjunction with the Bilan Carbone® assessment, ADEME provides grants to local authorities and companies of up to 50% of the cost of the service, up to 30,000 EUR (ADEME 2011). While this estimation includes the assessment process, the licence fees range from 150 EUR to 1,100 EUR for local authorities or companies. While the Bilan Carbone® approach is recognized as a standard in France, the documentation is also available in English and Spanish. ABC maintains and updates the tool.

⁶⁶ www.bascarbhone.fr

ECORegion

ECORegion is a web based inventory software that enables municipalities and companies to monitor their energy use and associated GHG emissions. It was developed by ECOSpeed, a spin-off of the Swiss Federal Institute of Technology in Zurich (ETH Zurich). The software calculates a municipality's energy balance, considering a variety of sectors such as public facilities, households, commerce and trades, and transportation. It requires only basic statistical data such as number of inhabitants and workplaces in local trades/industries. It autonomously fills in data gaps using a top-down approach. The more localized and specific the information input into the software, such as data developed using a bottom-up approach, the more precise the community's energy inventory will become.

Being internet based, the tool offers its users a number of benefits: no software installation is required and the tool's country-specific databases that account for a number of environmental factors, such as primary energy factors for electricity generation, are updated automatically. The standardized methodology promotes reliability and continuity in balances and comparability of inventories of different municipalities.

The software was launched in 2008 with versions for Germany and Switzerland; it is now being used by more than 300 towns and cities in Switzerland, Germany, Italy and Austria and is endorsed by the European Energy Award (eea), the European Climate Alliance and the EU Covenant of Mayors initiative. It operates on a fee for service basis, compiling community inventories for a fee determined according to the size of a municipality.

All versions of the tool are also available as regional versions which facilitate the creation of consolidated balances of a number of individual balances, for example for cantons, counties or different departments of a company. The German federal state of North Rhine-Westphalia has acquired a license to enable all of its municipalities to use ECORegion without further costs.

GEMIS

GEMIS has been under development since 1989 by *Öko-Institut* Darmstadt, Germany. GEMIS utilizes national databases for energy balancing in different European countries, the United States and some developing countries. The most recent version 4.81 was released in August 2012 by *Institut für Nachhaltigkeitsanalysen und -strategien* (IINAS) Darmstadt⁶⁷ the follow-up organization that has taken over the periodic updating of GEMIS since 2012. An English language version using US energy data is available under the name Total Emission Model of Integrated Energy Systems (TEMIS).

GEMIS is a computer-based decision support system designed to evaluate energy systems and scenarios with regard to primary energy consumption, environmental impacts and direct and external costs. Transportation and materials are also tracked including those associated with embodied energy. GEMIS is primarily a complex database used to derive primary and emission factors (CO₂ and a number of pollutants) for simple or integrated energy systems, computing flow of energy and materials from source to end-use. Concerning non-energy related data, it is linked with EcoInvent, an authoritative Life Cycle Assessment (LCA) database of raw materials and chemicals.

GEMIS is the recognized standard for energy and emission factors for energy technologies of all kinds. It is used primarily for neighbourhood level planning but, given the extensive database, it is also used at the community scale as a calculation tool for mandatory GHG reporting of EU member states to the European Union Commission. Particularly, in the field of detailed neighbourhood planning, GEMIS can be used for the detailed analysis of the energy characteristics of complex energy systems. In addition, cost functions for a variety of energy systems, such as solar collectors, wind turbines, cogeneration or biomass plants etc. are provided. GEMIS 4.81/2012, together with

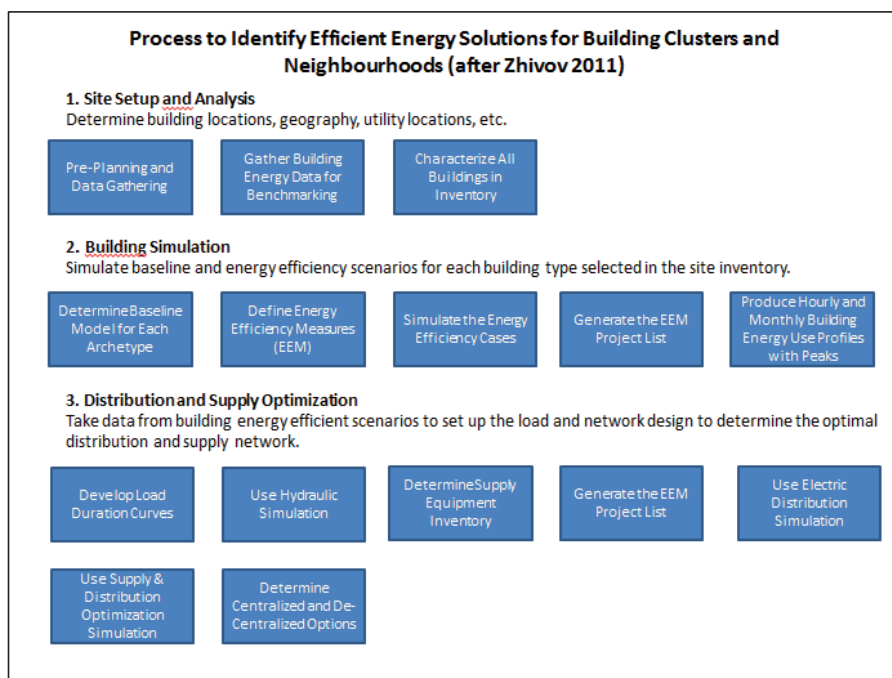
⁶⁷ www.iinas.org

numerous backup and tutorial material and a comprehensive user guide, can be downloaded free of charge from www.iinas.org.

4.4 Energy modelling approaches

Energy system models enable assessment of the behaviour of a technical system based on input data and a physical or statistical description of the energy system. As a practical differentiation from GHG inventories or balancing tools, energy system models usually allow for a more detailed description of specific parts of the energy system, whereas GHG inventories rely on simple mathematical relations of activities and emissions. Energy modelling for local energy planning is interdisciplinary in nature and so a diversity of types of modelling are performed based on data availability, resources and user needs. LEP models generally include representations of energy use in buildings as well as the supply and distribution infrastructure. Results are usually provided with a more or less structured reporting and an economic assessment. The description of the individual steps is based on Zhivov et al., 2010. Similar conceptualisations are described in ASHRAE, 2005 or by Hayashi et al., 2009.

This section describes different modelling approaches taken and outlines key concepts including simulation and optimization modelling, deterministic and data-driven modelling and spatial modelling. These general concepts usually relate to individual steps in the described process (e.g. development of load duration curves), as described in chapter 3.



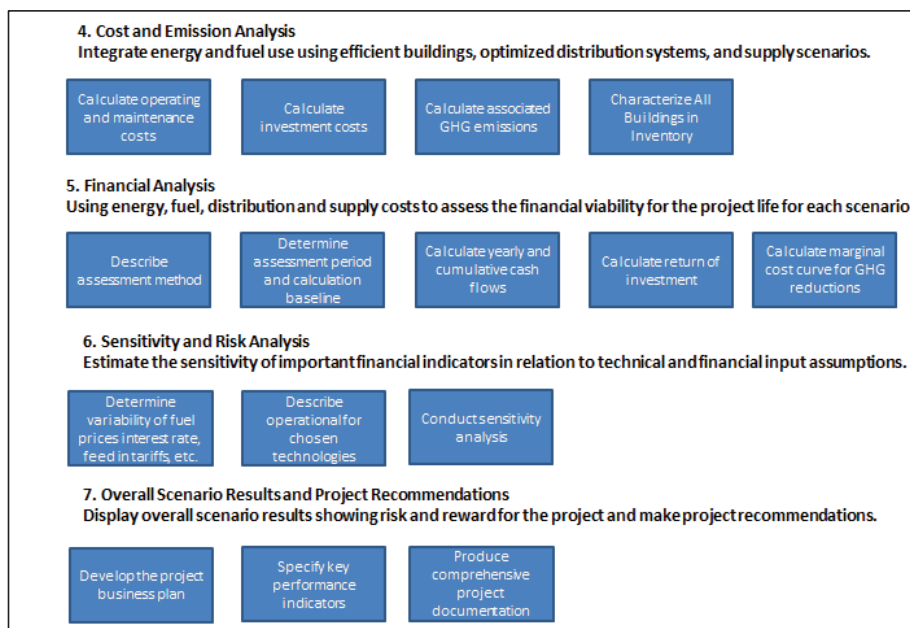


Figure 4-2: Steps in Local Energy Planning for neighbourhoods or building clusters

Simulation models

In the case of simulation models, output data can be used to compare different solutions which were simulated using a specific set of parameters in the model. Simulation models usually apply a bottom-up approach to describe the energy system by describing individual conversion processes or process chains. Ignoring the great variety and complexity of simulation models, the general process of estimating energy requirements begins by calculating energy needs which are then translated into a system or secondary equipment load that incorporates distribution and auxiliary system losses. Finally, primary energy requirements for conversion from fuel or electricity are calculated. Adding economic data to the model enables economic analysis of the system.

The deterministic approach is based on a physical model and measured or known input variables are applied to predict the output variables. With advances in computing power, increasingly complex models have been developed to include natural phenomena and interactions within a given system, delivering reasonably comprehensive representations of the physical world. This is the most common approach to describe and predict building energy use. This category of model includes dynamic thermal simulation models such as EnergyPlus, DOE-2 and TRNSYS as well as steady-state or quasi steady-state models in the European context specified by EN ISO 13790. While these examples might relate specifically to the building scale, the calculation core can translate input data collected at other levels. In this way a steady-state building simulation such as ISO 137090 can be used to calculate energy needs on the district scale. Such an application was pursued in connection with structured input data in the CityGML format (Bahu, 2012). Similarly, the calculation procedure of the German DIN 18599 which initially was developed for the calculation of energy needs of buildings is used as a calculation core of the District Energy Concept Advisor (D-ECA) described in detail in chapter 5.

On the other hand, the amount of available input data and complexity is growing with the scale of application for bottom-up simulations. The physical representation of buildings for larger urban areas

therefore will likely be simplified by using either archetypical buildings (see D-ECA) or 3D geometry in a standardised format (e.g. CityGML).

For the assessment of existing neighbourhoods, however, detailed information on building conditions and previous energy retrofits is preferred and sometimes becomes a limit to accurate physical representation. To overcome this constraint for a large number of buildings, the data-driven approach uses measured input and output variables to mathematically describe the system. This approach of course requires that a similar system has been built elsewhere and performance measurements have been taken. In practice, data-driven models tend to be simpler to use, and require less expert knowledge to run a simulation. On the other hand, data-driven approaches are limited when it comes to changing the properties of the modelled objects, such as comparing different retrofit measures. A widely used data-driven approach is, for example, to use regression functions for determining heating energy needs dependent on outdoor temperature. Figure 4-3 illustrates an example of an energy signature (Φ mean power per time step, Φ_0 power at 0°C, Φ_b base load [e.g. domestic hot water] provision, θ_L limit temperature for space heating, θ_e mean outdoor temperature per time step).

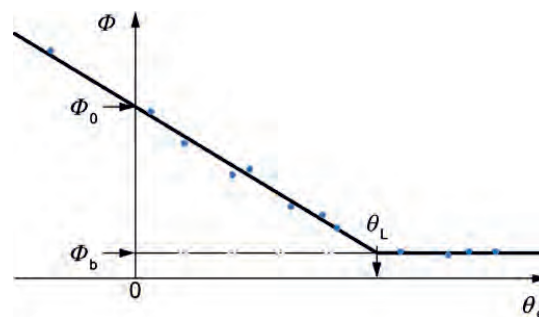


Figure 4-3: Linear regression model (energy signature, DIN EN 15603:2008)

Traditionally, these models are used to predict energy needs at the scale of gas distribution networks. In the UK and in Germany, standard models are provided to estimate 'day ahead' gas demand for a given zone. More recently, such models have been tested at the district and neighbourhood scales. Two examples developed at the EPFL and at EIFER are described below (Girardin et al., 2010 and Koch, 2010).

This is only a first approximation, since the heating demand of a building is not only a function of the outdoor temperature, but also of solar irradiation, wind velocities and user behaviour. Measured over a longer period of time, these influences have a tendency to cancel each other out, as it is demonstrated by the two examples of a building situated in the neighbourhood of the case study Karlsruhe-Rintheim, Germany. Taking mean values over one full month, a clear linear dependency between heating demand and outdoor temperature can be observed (left hand chart below). For daily values, this linear relationship is much less strict; even the inclination of the straight line is different, probably due to many sunshine hours in February 2013. Therefore, this approach is only a first approximation that has limitations when used for shorter periods of time.

Figure 4-4 illustrates the linear relationship between outdoor temperature and heating load, for a well-insulated building in the City of Karlsruhe on monthly and daily time scales. The graph on the left shows average monthly temperatures in the 2012-2013 heating period and the corresponding average heating demand (kW). The graph on the right shows average heating demand per day over average daily outdoor temperature.

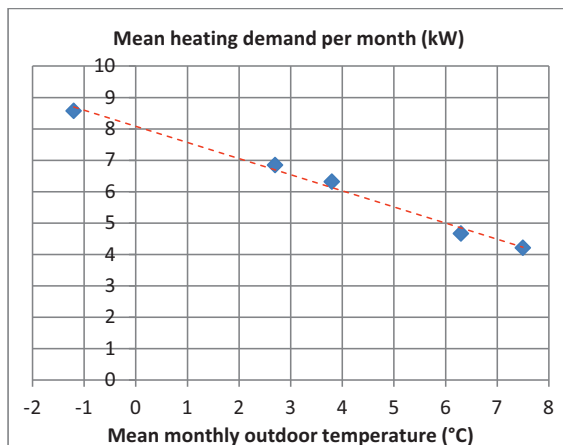
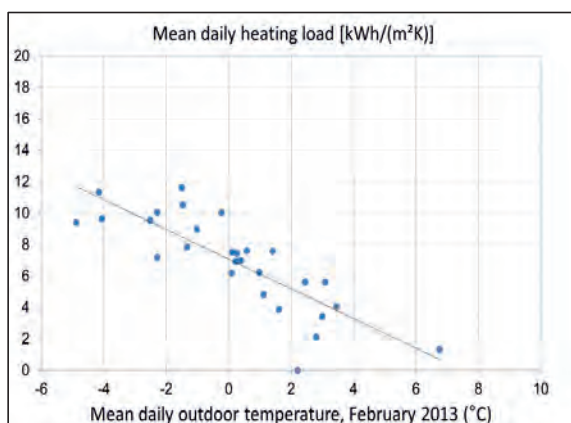


Figure 4-4: Measured average heating demand in relation to temperature on monthly and daily scales, Karlsruhe, Germany



Optimisation models

Optimisation models describe technical, economic and environmental aspects of an energy system, usually on both demand and supply sides. The resulting equilibrium system is then optimised towards a target function using a mathematical approach (Koch et al., 2003). Usually, the total system costs are used as a target function. It is preferable that optimisation models be designed using a bottom-up approach providing a detailed description of technical components of the system. Typically, a number of additional boundary conditions, such as the availability of technologies, set constraints on the optimization. The definition of boundary conditions is of vital importance for the relevance of modelling results, as is their documentation for the transparency of the overall modelling process.

While optimisation models tend to focus on the cost function, simulation models are usually applied to quantify the technical or techno-economic potential for energy savings or emission reductions (Koch et al., 2003). An example of an optimisation model is POLIS which uses a linear programming approach to identify optimal solutions for energy distribution networks; it uses a linear objective function based on linear constraints (see below for more details on POLIS).

Spatial models

Already in widespread use in support of feasibility assessment for renewable energy projects, geographic information systems and spatial data in general are increasingly used in community energy and emissions modelling. Both deterministic and data-driven models can integrate a wealth of measured and modelled inputs derived through spatial analysis. Models are also developed using GIS as a central data handling and modelling platform. These take an explicitly bottom-up approach built from the parcel or building scale, overlaying of datasets such as modelled or measured energy data, satellite imagery and 3D layers derived from LiDAR (Light Detection and Ranging) applications. Importantly, spatial modelling enables aggregation and analysis at any level of geography, making it a flexible technical platform for planners and utilities to answer a range of questions at the building cluster, neighbourhood or larger scales. Future scenarios are being explored through simulation of type, number and location of new construction, retrofits and renewable energy technologies. Spatial models also support visualization through graphics, maps and 3D renderings of streetscapes and other landscapes. The need for spatial databases or models varies according to the different type of decisions at the neighbourhood and municipal scales. Information produced using spatial analysis can be used in interoperability with building and equipment energy simulation models, although further improvements are required to more fully automate these processes.

4.5 Examples of models in development and practical application

Energy monitoring, modelling and simulation activities described in Annex 51 subtask B and C case studies cover a wide range of applications. Many of the tools or modelling approaches are focused on modelling and simulation of energy system design. Advanced energy simulation was conducted for individual buildings or end-uses; integrated models simulating building energy use and energy system efficiency were also found to be in use.

This section provides a brief overview of some of the models in development in Europe, Japan and Canada. They include both those in practical application and those developed on a research basis.

POLIS / URBS

POLIS (formerly URBS) (Richter, Hamacher, 2003) was developed at the *Max-Planck-Institut für Plasmaphysik* (IPP) and the University of Augsburg, Germany. Today it is used by GEF Ingenieur AG (Zhivov et al., 2010) to perform simulation of the energy distribution system at the scale of building clusters and neighbourhoods. It describes the whole energy system including conversion systems such as boilers and generators as well as the grid or network. Energy demand is described by representative hourly values for electricity and thermal energy. Individual entities are then connected to represent the complete local energy system. Each component has associated cost parameters for identifying cost optimal solutions. A linear programming approach is used to calculate different system alternatives, by describing components of the system in linear equations. Therefore different solutions for co- or tri-generation can be compared; however, demand-side efficiency measures cannot be optimized against efficient supply-side solutions within the frame of the model as the latter is represented by static curves.

In the planning of energy infrastructure for clusters of military buildings, POLIS was applied to assess the lifecycle costs and the greenhouse gas emissions for centralized energy systems (Zhivov et al., 2010). In this case POLIS was coupled with a hydraulic flow model, using results from a system optimization process with realistic distribution system capacity in order to study optimized solutions for local district heating systems.

BHKW Plan

BHKW-Plan is an Excel model developed by the Centre for Solar Energy and Hydrogen Research (Zentrum für Sonnenenergie- und Wasserstoff-Forschung) of the state of Baden-Württemberg and the Institute of Technical Thermodynamics of the German Aerospace Centre (DLR). Further development and on-going updates to the model are provided by Steinborn Innovative. BHKW-Plan uses archetype buildings and associated annual hourly load curves to describe load profiles for typical building types aggregated to the total annual duration curve. The overall system description follows a deterministic approach to calculate system losses (due to the length of distribution lines) in the assessment of district heating systems. Solutions implementing combined heat and power units are compared to a reference case of a central boiler system. A simplified estimation of solar thermal potentials is included as well. While the technical system description uses a relatively simple model, BHKW Plan enables a detailed economic assessment based on various tariff systems adapted to the German regulation on feed-in tariffs (KWKG and EEG). BHKW-Plan is a simulation tool and, as such, provides no optimisation function. BHKW Plan is in relatively widespread use in Germany.⁶⁸

Energy demand modelling of the housing sector based on 3D geometry city models

Energy balance models (e.g. ISO 13890) are widely used and tested for calculating the energy balance for individual buildings based on their physical properties and geometry, orientation, etc. More recently, such balance models have been used to calculate energy demand of buildings based on urban morphological information in the form of 3D building data in the context of Annex 51 applications by the University of Applied Sciences Stuttgart (*Hochschule für Technik Stuttgart* - HfT) and the European Institute for Energy Research (EIFER).

Annual and monthly energy balance models use actual geometric data for all buildings of a district area and further semantic information stored in the spatial database. The 3D city models are based on the CityGML (Geography Markup Language) standard defined by the Open Geospatial Consortium (OGC). The 3D data is structured in five different levels of detail (LOD0 – LOD4) allowing, for example, the study of roof shapes or simple block structures. In addition to building geometry, this approach considers building orientation and enables calculation of solar irradiation on horizontal, inclined and vertical surfaces. The latter can be used to calculate the potential for PVs or assessing passive solar gains in the buildings' energy balance based on urban form.

The application takes a comprehensive approach to develop an energy balance for urban areas and enables the city to understand and communicate an energy assessment of its building stock based on a spatial data model. Applications on the district scale using building attributes have delivered promising results. Having detailed information on the properties of building envelopes is essential, however, and applicability is limited where little or no data is available on the actual condition of renovated buildings.

HfT successfully used a 3D geometry model based on the CityGML standard in connection with a steady-state energy balance method which considers ventilation and transmission losses as well as internal and solar gains. The case study used in Strzalka, A., Bogdahn, J., Coors, V., & Eicker, U., 2011 was the 150 ha development area Scharnhäuser Park located in the south of Stuttgart, Germany. Here, different temporal resolutions of the energy balance were tested against measured data from individual buildings. Further application cases include the assessment of the potential for the active use of solar energy (Strzalka, A., Alam, N., Duminil, E., Coors, V., & Eicker, U., 2012).

In cooperation with EDF, EIFER is working with the City of Lyon. Here, an existing 3D model of the city's building stock was connected to an energy balance model. To assist in the further development

⁶⁸ www.ihr-bhkw.berater.de

of the local climate plan, 3D building geometry was used to classify the city's building stock, calculate heating needs for residential buildings and assess the active solar potential for roof areas.



Figure 4-5: Annual calculated space heating needs [kWh/m²/a] for residential buildings in the Greater Lyon metropolitan area (Bahu, David, 2012)

Figure 4-6 describes the energy flow – the supply, conversion, consumption and discharge of energy - in Osaka, Japan in 2005 as developed by researchers at Osaka University. A detailed end-use simulation model was used to develop estimates for the residential and non-residential sectors. For the residential sector, households and building types were considered. For the non-residential sector, energy consumption was estimated according to district or neighbourhood characteristics such as central business districts and commercial areas. For the industrial sector, 1997 data was used including information on blast furnaces and power plants. For the transportation sector, available statistical data was incorporated into the model. The estimated energy flow chart of Osaka City for 2005 was compared with energy flows in 1997. Such energy flows are useful for gaining an understanding 'at a glance' of energy sources, heat losses and end use in a community and can be used to derive values to calculate a variety of sustainability indexes. Energy flows also identify thermodynamic efficiency, or exergy, that can support an optimized use of waste heat (Shimoda et al., 2008; for further reading see Shimoda et al., 2004 and Shimoda et al., 2007).

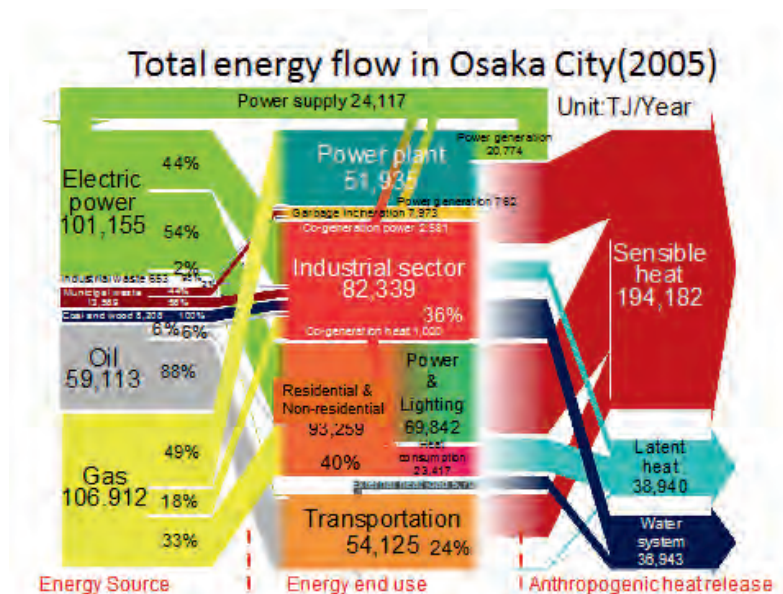


Figure 4-6: Total energy flow in Osaka, Japan (2005)

City-Scale Residential Energy End-Use Simulation Model

The City-Scale Residential Energy End-Use Simulation Model developed at Osaka University enables evaluation of various mitigation measures such as occupant behavior, energy efficiency of appliances, building insulation, conservation of standby power loads and integration of solar hot water heating, photovoltaic and micro-cogeneration in one single platform while considering the diversity of households and building types in the city. Its intended audience is municipal policy makers and the research community. The modelling approach involves coupling of a number of individual models including occupant behavior, dynamic heat load simulation, air-conditioning, and distributed generation of water heating. Inputs include weather data, occupant schedules and use profiles, configuration of model buildings, energy efficiency and ownership of home electric appliances and equipment. Outputs include electricity, city gas and kerosene use in 5 minute intervals for 8,760 hours per year (hr/a) at the district, city and national levels. The model calculates the impact of each GHG mitigation measure considering interactions between electricity load curve changes by dissemination of PVs, fuel cells and energy efficient buildings. It supports the evaluation of community-scale impacts of energy saving measures, large scale dissemination of fuel cells, heat pump water heaters and PVs. It also enables electricity load curve prediction for smart grid design including required capacity of batteries and demand response impact on substations. Developed on a research basis, it is not available for widespread use; however, it was used to evaluate the impact of daylight savings time and electricity saving measures during the 2011 electricity crisis in Japan.

SPREEM

Simulation Program for Regional Energy and Environment Management (SPREEM) was originally developed by the Japanese Ministry of Land, Infrastructure, Transport and Tourism to simulate the energy performance in individual buildings. It has since been used to improve district-scale energy supply systems operated by utility companies. For example, Tokyo Gas Co. Ltd. which owns district cooling and heating plants in the Annex 51 Shinjuku Area case study, recently used SPREEM, an

extended version of an Excel-based simulation tool for individual public buildings. (Shinjuku is a commercial district in Tokyo). SPREEM contributes to the conceptual design phase when options such as installing district-scale cogeneration, interconnecting neighbouring district heating and cooling plants are assessed to clarify which of them can effectively meet the recent energy directives issued by the Tokyo Metropolitan Government in 2010.

SUN-AREA 3.0

The basic idea of using GIS data bases for local energy demand mapping is applicable to map renewable energy sources and their local potential as well. A first tool has been developed during recent years by M. Klärle (Klärle, 2011), using high resolution airborne laser or photogrammetry data together with ground data of building cadastres and local weather statistics to attach a detailed solar energy potential to every building roof of the investigated area.⁶⁹ This tool, labeled SUN-AREA, first applied in 2008 for the City of Osnabrück, Germany, is now generally applicable for all cities with access to the required scanning data, which is increasingly the case: SUN-AREA is provided in the form of an interactive web site which enables home owners to check their homes for any existing solar energy potential and 'returns' the roof area suited for solar energy installations, the potential annual yield and an estimate of the investment costs necessary⁷⁰. In addition to individual solar energy potential data, a scan of the total solar energy potential of a given built area can be done, which can also be used by local utilities to check the available or required transmission capacities of the local grid.

The same approach can be pursued in determining local wind energy potentials. In this case, unlike the roof topography interesting due to its solar energy potential, the land surface is important for its impact to the statistical distribution of wind velocities as a function of the height over ground. This is currently under development by Klärle and others, using high resolution geo-data, local wind energy statistics and an air-flow simulation model. Such a tool would be valuable to determine the regional wind energy potentials and their economic viability in the surrounding country side of a city.⁷¹

RETScreen

An Excel-based model is the RETScreen Clean Energy Project Analysis Software. RETScreen is developed by Natural Resources Canada's CanmetENERGY in collaboration with numerous experts from government, industry, and academia. This Excel-based software can be used to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of renewable energy and energy efficient technologies (RETs). The software includes default data representing product, project, hydrology and climate conditions including local degree days for a very large number of locations world-wide. There are five modules that include the energy mode, cost analysis, GHG analysis, a financial summary and risk and sensitivity analysis. Technologies that can be evaluated on a pre-feasibility basis using RETScreen include those for solar collectors, PV, heat pumps, cogeneration, district heating and cooling and refrigeration. The software also contains a library of default values that can be accessed to support manual engineering calculations or input into other models.

The software is free of charge and is available in multiple languages. It includes an online user manual; additional support is available in the form of a case study-based college/university-level training course which includes an engineering e-textbook. At the time of writing, RETScreen had over 388,000 registered users in 222 countries. Between 1996 and 2012, use of the software resulted in

⁶⁹ www.sun-area.net

⁷⁰ www.frankfurt.de/solkarkataster

⁷¹ www.wind-area.de

the implementation of an estimated 320 MW of clean energy projects in Canada, and 1000 MW worldwide.

SCEC³ model

Another model developed by Natural Resources Canada's CanmetENERGY is the Spatial Community Energy Carbon and Cost Characterization (SCEC³) model. Created to characterize energy, GHG emissions and cost opportunities in the residential sector in the City of Prince George, BC (an Annex 51 case study) the SCEC³ model supported municipal energy and emissions target setting, policy development and advanced Canadian research in the area. Users included researchers and City of Prince George staff, with the intended audience being municipal policy makers and the research community.

The model uses an integrated, bottom-up spatial modelling approach leveraging housing and building simulation and renewable energy technology assessment. Built at the building scale using annual information, analysis can range from the building to the community scale. Existing housing and energy technology software including HOT2000 and RETScreen are leveraged, as well as of-the-shelf software Excel and ArcGIS models developed in parallel with Excel Dashboard and ArcGIS Application versions. Input data includes tax assessment data, housing energy audit records, emissions factors, utility rates and assumptions around future growth scenarios. Output includes numbers, graphs and maps for energy, GHG emissions, and operating and capital costs at the neighbourhood or municipal scale.

Analysis of the final scenarios run for Prince George, Canada revealed that after capital costs are repaid, an estimated 120 million CDN in operating energy costs could be saved by taking a downtown infill or high efficiency scenario approach that would see new apartments served by the biomass district energy system built in the downtown, a combination of retrofits undertaken on just under half of all existing residential dwellings and modest integration of solar domestic hot water systems. Figure 4-7 illustrates total residential energy use scenarios⁷² looking out to 2040, broken out by efficiency measures (solid lines at the top) and renewable measures (dashed lines at the bottom). This graph tells a cautionary tale about the actual work required to achieve net-zero communities, given current incremental planning approaches.

⁷² Developed in 2011 for the community design charrette. This was one year prior to the downtown infill results yielding an estimated 120 million CDN in cost savings. The data and assumptions, however, are largely the same.

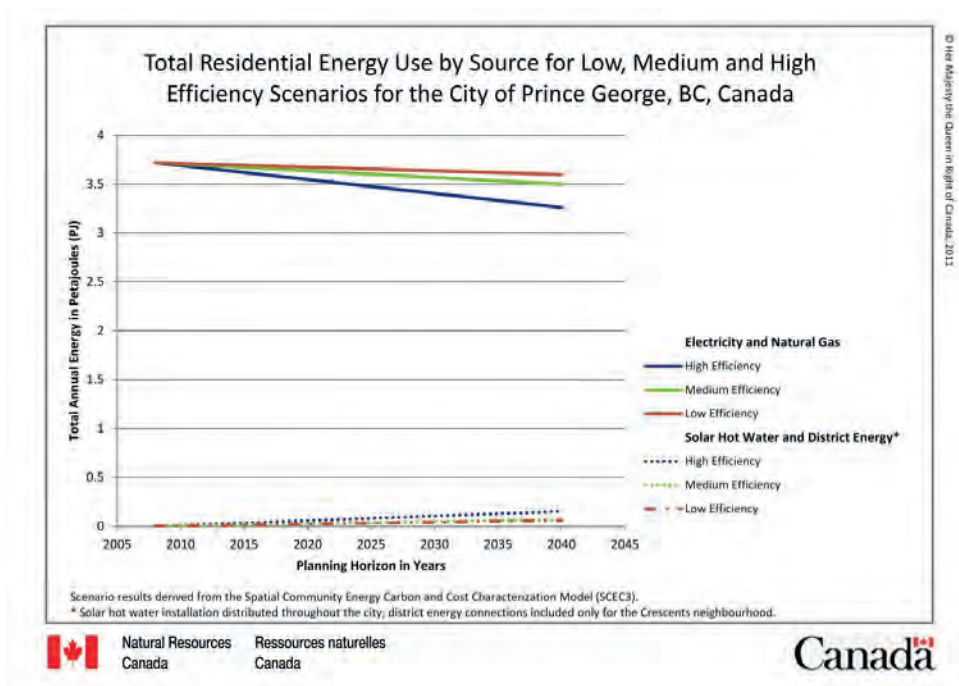


Figure 4-7: Total residential energy use scenarios developed for Prince George, BC (2011)

Model development paralleled community energy planning processes in Prince George including Smart Growth on the Ground, myPG, the City's Integrated Community Sustainability Plan and an update of the Official Community Plan. Developed on a research basis, the model was transferred to the City of Prince George; the data integration method was shared with the province of British Columbia, contributing to improvement of the Community Energy and Emissions Inventory (CEEI) reports through the Tract and Neighbourhood Data Modelling project.

Policy Impact Estimator

The Policy Impact Estimator, developed by the Pembina Institute and improved and promoted by BC Hydro, is an Excel-based model designed to assist in estimating the energy and GHG emission savings of community-wide building policies for residential and commercial sectors in British Columbia, Canada. Working on the community scale, the PIE model can be used to estimate the community-wide energy and greenhouse gas (GHG) impacts of one building-related policy at a time. The PIE is based on building energy use data derived from building energy modelling studies. Current and future building energy stock data and associated energy use is developed for four BC regions: the Lower Mainland, Vancouver Island, the Southern Interior, and Northern Interior (NI).

The PIE model, along with modelling support, is made available free of charge to BC Hydro-supported Community Energy Managers working in BC municipalities. It is also available upon request to organizations supporting municipalities in their energy and GHG emissions planning activities. The model is updated on an annual basis.

EnerGis

Building upon the work of the AGS Tokyo, EnerGIS is developed at the École Polytechnique Fédérale de Lausanne at the Laboratory for Industrial Energy Systems (LENI). To describe the energy needs, EnerGIS uses a classification of building types per use and building age to aggregate surfaces per

area defined in a coupled GIS system. Energy requirements are based on measured data or, in cases where no measured data is available, on the SIA Norm 380/1 (2001). The distribution of the annual heat demand over the year is based on a data-driven model using a linear correlation with the outdoor temperature (Girardin et al., 2008). Figure 4-8 shows the linear functions also referred to as energy signatures applied in the context of EnerGIS. The gradient reflects the energy requirements and insulation standard of different buildings.

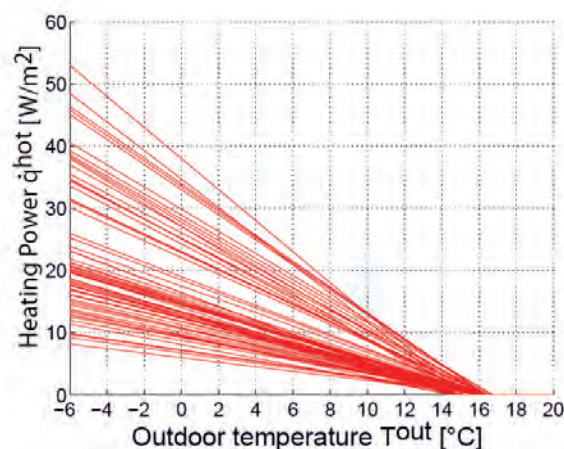


Figure 4-8: Heating signatures for different buildings used in EnerGIS. Source: Girardin et al., 2010

By estimating the heating system, the model extrapolates temperature levels and compares composite curves for districts (Girardin et al., 2010). The curves are then used in an approach based on a pinch analysis. In this form of analysis, temperature and enthalpy of cold and hot processes are combined to form cumulative curves (Linnhoff, 1982).

GENY District Energy Tool

The GENY District Energy Tool is an example of a model developed by an engineering consultancy.⁷³ Municipalities and district energy developers need a tool to support the assessment of trade-off of demand and supply-side measures. GENY is an Excel-based tool developed to assess, in the early planning phase, the degree of energy conservation in a district that can be achieved by measures on the existing buildings and neighbourhood scale measures. The operating costs for the buildings in the neighbourhood can be calculated as well as the total capital costs for the considered measures.

GENY supports planning of measures on both the building and neighbourhood scales. Inputs include the number and types of houses, number and gross floor area (m²) of office buildings, energy design concept (including thermal storage, boiler, heat) and investment costs of installations. In addition to building parameters, renewable energy sources to supplement the district system can also be entered. These include large and small wind turbines and PV. Considering small wind turbines ('urban wind') the wind velocity characteristics of the site must also be indicated. The software assumes that the entire project will be implemented in a logical order, with investments made at the beginning of the project and provides total annual costs beginning one year after implementation of the planned measures.

⁷³ Cauberg-Huygen Raadgevende Ingenieurs B.V., the Netherlands

Simulation and Monitoring for Neighbourhoods

The Simulation and Monitoring for Neighbourhoods approach has been developed since 2009 at European Institute for Energy Research (EIFER) and provides predictions for daily and hourly space heating needs at the scale of a neighbourhood or building cluster (Koch et al., 2003). The objective is to provide a solution to the building owner or operator that can be used to describe the annual duration curve in an early planning phase and also to provide for a continuous benchmark at a high temporal resolution to monitor actual operation data.

The underlying model is based on an energy signature approach originally developed for the prediction of gas demand in regulatory zones. It is currently adapted and tested for use at the scale of 10-50 individual users to provide an easy but robust description of heating needs that can be compared to measured hourly, daily or monthly values. The model is currently used in two case studies to test the minimal spatial and maximal temporal resolution for the application of such a data-driven approach.

4.6 User needs

For effective inventory and model development, it is worthwhile to take a user needs-perspective and consider the roles of individuals involved. The audience is ideally engaged both in providing inputs to the models and communicating the modelling outputs as is discussed below.

Municipalities use energy and GHG emissions inventories and modelling to support the development and review of GHG targets, policies and actions in community or regional plans, and in the design, implementation and verification of programs or projects. Local government planning departments are central to these efforts. Planners and developers benefit from community energy and emissions modelling to explore the GHG and energy implications of future land use development, and to actively engage their colleagues in the financial and engineering departments. The audience outside the local administration can be considered to be decision makers, key stakeholders and the general public.

Utilities traditionally rely on engineering models for various technologies and macroeconomic analysis; they also routinely carry out integrated resource planning. There is an increasing understanding that new methodologies are required to model the increasingly complex nature of energy supply and demand in communities (Fortis BC, 2010). Those undertaking load forecasting standards development and local energy planning are all concerned with modelling issues to one degree or another. In Canada, utilities have supported research initiatives into the development of more focused decision support tools, such as BC Hydro's Policy Impact Estimator.

The degree to which a municipality or utility is required to respond to provincial or federal legislation often influences its demand for inventories and modelling approaches. For example, changes to the British Columbia (Canada) Local Government Act require municipalities and regional districts to set GHG emissions targets, policies and actions in their Official Community Plans. This legislative change has prompted an increased demand for decision support in the form of improved data, inventories and modelling support. The European Energy Performance in Buildings Directive (EPBD) which makes building labelling mandatory and also requires consideration of the local or neighbourhood context to derive action opportunities is another example of a requirement for improved modelling, measurement, labelling and disclosure of the energy performance of buildings. Following these requirements, senior governments are potential users of community energy inventories and modelling approaches to inform policy and program development.

A summary of the main types of users, their roles and specific decision support needs is presented in table 4-1.

Table 4-1: Users, their roles and needs

User	Roles	Needs
Community Energy Managers Sustainability Planners	users who pull together numbers for enablers who direct model development and use by others	- good quality data and assumptions - information on energy use, costs and other key performance indicators to justify energy-related policy, programs, projects, report results of monitoring or progress towards targets to elected officials or other city staff
Land Use Planners (long-range)	- data providers who make estimates of types, number and location of new construction in future land use scenarios - enablers who direct model development and use by others	information to evaluate and provide justification to elected officials on energy implications of land use policies or projects; may require community, neighbourhood and household-scale information
GIS Analysts	- developers who create and use models or on-board models developed by others - users who perform data integration, analysis and develop outputs	- detailed parcel-level data - direction on creation of outputs
Elected Officials	political decision makers, i.e. the audience for final outputs of models to support evaluation of proposals for land use and energy policy, programs and projects	easy-to understand numbers, graphs and maps on energy use, costs and other key performance indicators to evaluate land use and technology options
Housing Agencies	housing owners and operators, either direct users of building energy modelling or enablers who retain these services from others	cost-effective building energy optimization, retrofit and renewable options towards maintaining a comfortable living environment for their tenants.
Developers	business decision makers, enablers and audience who may retain a consulting firm to develop models of proposed housing and building designs demonstrating code compliance	easy-to understand numbers, graphs and maps to evaluate technology options from cost-optimization and building code compliance perspectives; typically require building-scale information
General Public	constituents and decision makers who provide input into model development and are an audience for interim and final outputs	- understanding of role of modelling in overall process - easy-to understand numbers, graphs and maps
Engineering and Design Firms	developers and users who provide modelling services for clients, calculating energy use and costs, as well as key performance indicators	- good quality data and assumptions, at detailed spatio-temporal scales - understanding of planning goals, direction on creation of outputs
Academic Organizations	developers and users of models to answer research questions; provide support to local government or other organizations	- good quality data and assumptions - Defining key questions and conducting research to answer them

4.7 Selecting a modelling approach

The choice of an appropriate modelling approach depends on the objectives of the task at hand, on data availability, and on having time and resources to prepare the model and subsequently test alternative hypotheses for improving energy performance. There is inherent tension between the

desire for detailed, context-specific and accurate modelling results and 'getting it right now'. In essence, what is the amount and accuracy of information required for a particular plan or project as compared to the time and financial constraints associated with policy and project work plans?

Two forms of modelling approaches exist: optimization and simulation. Both employ different strategies to develop their solution. Optimization models help to assess and compare a large number of technical options against specific criteria, for example costs and emissions. Employing simulation models, expert knowledge replaces the 'automatic' approach pursued by optimisation models. A simulation approach is therefore more suitable in cases where multiple strategic targets are set at the outset that shall be analysed. Optimisation models can be more useful when a number of technical options are assessed with no prior preference for the solution.

A further choice in the framework of modelling concerns the representation of the energy system or its sub-systems. The components of a system (e.g. buildings, plant system, etc.) can be described based on their physical properties or on their overall performance. While the prior choice is pursued by deterministic models, the latter is related to the data-driven (black box) approach.

Several aspects should be considered when selecting an energy modelling approach. The decision support solution should be as simple as possible but avoid over-simplification. It should be tailored to the specific problem, and selected with the user and resources available in mind. It must also be precise enough to generate meaningful results in the specified context. A modelling approach should relate to the chosen indicators and, as far as possible, be scalable in order to link the outcomes with every key variable taken into account and to answer the initial question. The modelling approach should also address the interests of stakeholders involved in the local energy planning process. Additional considerations are addressed in table 4-2.

Table 4-2: Criteria to select an energy model

Model applicability	Model flexibility and robustness Study framework definition Ease of use
Approach selection	Purpose of study and design criteria Capital versus life cycle costs Environmental standards Model flexibility and adaptability
Quality and accuracy	Modelling assumptions and methodology Design stages and quality of data Validation of results and simulation procedures
Data availability	Access to relevant sources of information Appropriate and high-quality input data Climate data, internal heat gains, material and construction
Desired outcomes	Parameter sensitivity Key design messages, transparency for communication

Based on the chosen planning objectives, a modelling structure must be developed, taking into account the optimisation or simulation requirements and the level of resolution required to achieve the planning objectives. This structure identifies the specification of information needed to run the models or software for the given approach and the sequence of assessments necessary to evaluate

the model's performance. Further to this specification, a check can be made of available modelling tools and their applicability for the specified tasks. This evaluation can be made in co-operation with the users / planners involved (see table 4-3). In general, it will be necessary to use several programs or modelling platforms or possibly a single program that could run a range of simulations contained within a common reporting tool.

Table 4-3: Objectives and means of municipal and neighbourhood LEP

	Objectives	Applications	Means	Examples
Municipal LEP	Strategic guidance to develop municipal planning policies	Municipal Emission Inventory	Bilan Carbone	Case studies Subtask B, A
		Local energy efficiency strategy	SCEC ³	Case study Subtask C
	Identify economic effects of LEP alternatives	Development of local planning regulations or bylaws	SCEC ³	Case study Subtask C
	Monitor compliance with national targets	Assessment of local renewable energy resources		
Neighbourhood LEP	Guidance for specific project development	Total GHG emission, primary energy or final energy balance for a project	D-ECA	Subtask B and A
	Develop optimal systemic solutions for the local energy system	Comparing planning alternatives	Building-based energy assessment	
	Prove compliance with municipal or national regulations	Cost optimisation for the different solutions		

4.8 Communicating the modelling concept

Modelling concepts and results have to be carefully tailored for effective communication to expert and non-expert audiences. Communication involves describing the inventories or models and their roles in a given energy planning process, soliciting inputs for scenario development and then communicating the results of analysis to municipal staff, decision makers and the community.

Despite the huge numbers of numeric and graphic outputs that can be generated using models, a 'less-is-more' approach is more effective with decision makers and the public. Although the objective of the modeler is to characterize conditions associated with baseline and future scenarios as accurately as possible, as the term decision support suggests, modelling and the data required, are merely the means to an end.

At the outset of a local energy planning process at a neighbourhood or municipal scale when input is sought from stakeholder groups, the stakeholders must be assured that a rigorous scientific approach is being taken. Explanation of the names of the inventories and models used, diagrams of the overall process and description of key datasets and assumptions should be sufficient to provide the level of comfort required.

To solicit input for the modelling approach, a range of visualization types is helpful in engaging non-expert stakeholders and the public. Visual techniques might include photos of representative housing and building types in district or renewable energy technologies under discussion. Diagrams of renewable or district energy systems labeling the major components can also be helpful as are hands-on techniques such as map usage to help identify key technology themes within the community. Architectural renderings and neighbourhood visualizations for assessing residents' preferences for densification strategies or the placement of renewable energy technologies is common practice (Sheppard et al., 2012, Salter et al., 2009). In a group or workshop format the use of audience response systems common in planning processes has also been piloted to generate inputs for modelling (Webster et al., 2012).

The scale at which information is presented is also important. While planners and politicians seeking long-term decisions or community-wide targets require information summarized at the community-scale, the public relates more to information presented at the household-scale. Therefore the importance of a careful design of the communication process cannot be over-emphasized: presenting information at different scales of geography, on different time frames, over different planning horizons, all supported with appropriate visualizations. It is worth noting here that this large and small scale resolution approach will be understood differently by different professions, all of whom may be engaged in aspects of the local energy planning process. Large scale for example means one thing to an architect yet the inverse to a spatial analyst. Upon hearing the term 'resolution', elected officials will immediately think of a political commitment and not the spatial or temporal scale on which data or results are presented. Such semantics are not trivial when attempting to effectively convey information to the audience member or a reader.

Just as the use of plain language is highly recommended, so too, is the role and use of color in the design, to separate and define outputs.

Traditional pie charts, bar graphs, histograms, line graphs and scatter plots are recognizable to almost everyone. Tables of numbers should be avoided if possible in presentations; although engineers can glean useful information from tables, a general audience will likely find them too technical. Regardless, key datasets, assumptions and calculation of different scenario outcomes, can and should be made available upon request. It could be that a specific group of energy experts might gather around in a break out session to review and discuss the numbers. Among planning experts GIS based maps are commonly used to show geographic distribution or patterns of energy use or installed technologies.

Multiple modelling outputs need to be described separately, providing energy use, GHG emissions, and cost implications of each. This facilitates a better understanding of trade-offs in a way that the community might understand and use better to achieve their goals.

4.9 Perspectives on future directions

While some urban models are in widespread use, others continue to be under development within academic institutions and government agencies. Both approaches are required so as to provide practical decision support to ongoing projects and conduct research to advance modelling approaches.

Integrated community energy mapping is emerging as a systematic approach to local energy planning, leveraging different technologies and energy modelling techniques, as well as enabling collaboration between domain experts. Spatial models have the potential for rapid incremental improvement through further data manipulation and additional modelling. Further research prospects include the integration of energy relevant building attributes into the CityGML standard, thus making the data more accessible to local energy planning.

The ability to develop and use inventories and balancing tools and a range of energy and emissions models, and to check progress against targets is a key approach to identifying improvements in energy efficiency, reducing emissions and optimizing costs. Further calibration and validation of models and measured data, and improved interoperability between modelling platforms, will accelerate the value of this research, through efforts by academic institutions, government research labs or institutes, non-governmental organizations and private sector planning and engineering consultancies.

Multi-national companies have recently begun to develop competencies in urban modelling. Under the broad heading of Smart Cities a number of different sector specific applications are being developed, especially by companies in the IT sector who are engaged in assessing and structuring the ever growing amount of data.

Trends to watch include the increasing involvement of utilities in demand-side management (DSM), integrated energy contracting and other local energy planning activities. The development of DSM programs to achieve increased levels of energy conservation and efficiency and accelerate the use of renewables has become a way of business for utilities, particularly when they are regulated to meet established targets for energy conservation or GHG emissions reduction. With respect to utility decision support, while current efforts are largely focused on asset management, the application of these systems to questions of a longer-term strategic nature, including their application to assist municipalities in their energy planning efforts has the potential to significantly accelerate the achievement of energy targets. Utilities are currently facing a paradigm shift, as some of their customers no longer simply use energy but now also generate electricity and heat. This places an increased emphasis on the need for two-way communication between utilities and their customers and real-time decision support to facilitate load balancing in the grid.

Continuing developments can be expected in data collection, availability and best practices. Emerging trends include those of open data, where energy-related datasets are made available online in an open and accessible manner. One example in the United States is the Open Energy Information (Open EI) initiative developed by the National Renewable Energy Laboratory. The Government of Canada maintains an open data portal and supports and builds the Canadian Geospatial Data Infrastructure. However, most of the information contained on these sites is not relevant for local energy planning purposes. Similarly, the enerGEO portal, a product of the European Earth Observation for Monitoring and Assessment of the Environmental Impact of Energy Use project, is "...a gateway to web-based geospatial resources that enables users to discover, view and access geospatial information, services and applications." With the collection of data, the harmonisation of data structures emerges as well; in the European context the Infrastructure for Spatial Information in the European Community (INSPIRE) initiative is pursuing the objective of a common geo-data infrastructure for the European Union.

Due to the ever increasing amount of data generated by utilities, governments and other organizations, data analytics techniques to handle and mine this 'big data' can provide valuable insights to support decision making. With open data there also comes the need for interoperability standards including electro-technical engineering and spatial data standards. For example, the International Electrotechnical Commission (IEC), the International Institute of Energy Engineers and

the Open Geospatial Consortium (OGC) along with key utilities and consultants, are working to develop interoperable standards for the smart grid of the future.

'Hackathons' are another emerging trend capitalizing on open data, meaning that developers and interdisciplinary teams are provided with open datasets and given 'problem sets'. Using 'out of the box' thinking, these co-operations facilitate rapid prototyping development of various information technology applications to advance energy efficiency.

One promising practice is the identification of 'use cases' for gathering requirements. Common practice in software engineering, a use case tells the story of a user's interaction with a software or system being designed. Use cases ensure that modelling tools are developed in a way that makes them most effective for the purpose for which they are intended.

To build on past experiences and take advantage of emerging trends, local energy planning will be successful if inventory and modelling efforts - both in practical application and for research purposes - are supported on a consistent basis by senior levels of government and enabling organizations including utilities. The co-ordination of these efforts to learn from past projects, develop best practices and standards, is a central challenge for the discipline. This must be completed by state-of-the-art user interfaces and software documentation, the lack of which is most often a serious barrier to the widespread use of otherwise useful and ingenious planning tools.

While in the framework of Annex 51 many innovative technical projects for energy efficient communities were described, no consistent energy system model that addresses all the necessary process steps in LEP could be identified. Often solutions were targeting individual sectors or performing a special task in the complete modelling workflow. Even though current models often include a wide range of expertise and detailed default data, the combination of models often necessary with an increasing complexity of energy systems highlights the need for expert advice on the application of energy models in Local Energy Planning.

In the fields of urban energy simulation and the simulation of buildings many connections can already be seen that combine the different expert knowledge and develop common tools for specific tasks in urban energy simulation. In contrast to this, there still seems to be a lack of integration of know-how from urban planning and energy systems planning in the field. This missing link is of particular interest for municipalities to better address the assessment of policies related to the urban development.

Web-Sources for Information on Municipal Energy Inventory Tools

www.ecospeed.ch (in German)

www.ademe.fr/bilan-carbone (in French)

www.miljoportal.dk/CO2-beregner/ (in Danish)

www.climatealliance.org

www.climateregistry.org

www.grip.org.uk

www.project2degrees.org

www.toolkit.bc.ca/ceei

5 The District Energy Concept Adviser (D-ECA): Software from IEA EBC Annex 51 to Support District Energy System Planning

5.1 The tool in brief

Within the framework of the German research initiative EnEff:Stadt, launched by the German Federal Ministry for Economy and Technology, Fraunhofer Institute for Building Physics (IBP) has developed a computer software program to support urban planners in the early stages of energy efficient district or neighbourhood planning. This software was developed in collaboration with international partners from IEA-EBC Annex 51 *Energy Efficient Communities* and comprises a set of individual supporting tools.

The core of the software is a tool for the energy assessment of districts or neighbourhoods. It uses archetypes and other pre-established configurations to allow simple and quick input of data for buildings in the district. Only a few steps are required to identify the energy saving potential of building construction, technical building systems and central supply system strategies.

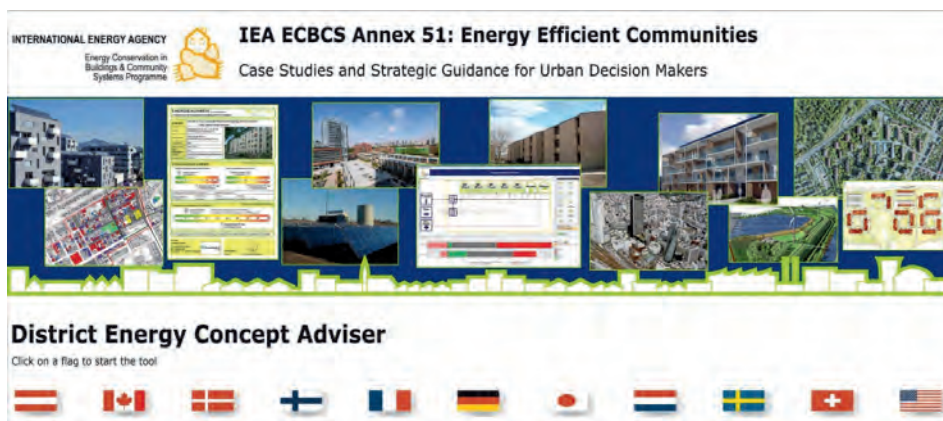


Figure 5-1: Welcome screen of the District Energy Concept Adviser

This chapter describes the District Energy Concept Adviser (D-ECA) planning tool in detail, including practical examples. The software can be downloaded free of charge (registration required) from www.district-eca.com/index.php?lang=de.

5.2 Background and aim

As described in Chapter 4, a variety of computer tools are available for different applications to facilitate the task of planning. Some focus on simulation of central energy supply systems (local district heating and district heating); others examine detailed solutions for individual buildings and their energy supply. Some of the tools are partially based on data from geographic information systems (GIS) and are capable of mapping and modelling entire cities or districts in great detail. Be they custom Excel spreadsheets or advanced map-based models, many have complex data preparation and input procedures.

The District Energy Concept Adviser aims to support urban planners, housing societies, developers and local political decision makers in the early stages of planning, providing strategic guidance both for the energy supply of new districts and for retrofitting and re-designing the energy supply of existing districts. The early planning phase in which most important decisions are made, will have the

greatest impact on the energy needs of a district. Given this context, the aim was to provide tools that are easy to apply, requiring only minimal building information and producing a reliable potential assessment of different measures of buildings, their energy demand and energy supply. The District Energy Concept Adviser is not intended for designing the individual technologies in detail; although this will be required in the later stages of planning. The D-ECA allows for a quick comparative evaluation of diverse options pertaining to building energy performance and to centralized and decentralized energy supply.

The main advantage of the D-ECA tool is that the user interface is full of useful default values starting with the different building archetypes (single-family houses, multi-family houses, offices, school buildings, shops, etc.), the pre-configured quality of the building envelope is dependent on the building age and the choice of building supply systems. In many cases default values can be adapted by the user to the real situation (if values are known), however it is not necessary to have very detailed knowledge about each building prior to beginning the calculation. Of course the better the information is on the existing or planned district, the more accurate the calculated result of potential energy savings from improvement measures will be.

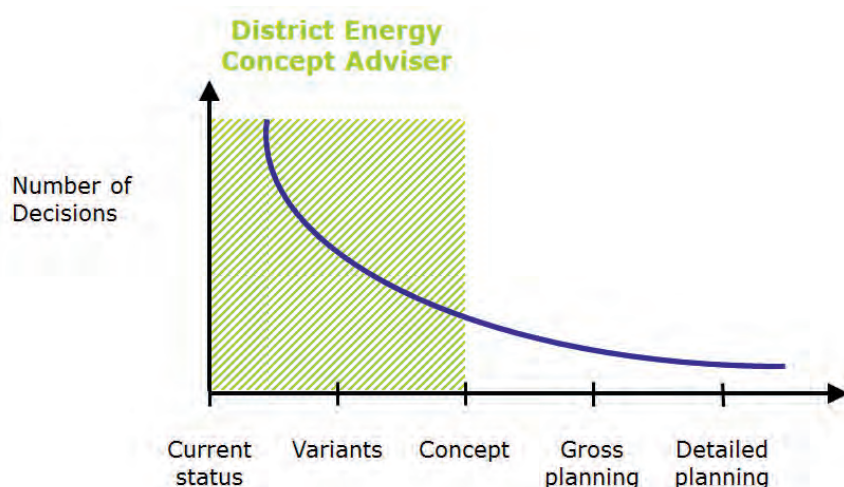


Figure 5-2: The D-ECA as a tool for early stages of planning

The program comprises four different applications. The **Energy Assessment of Districts** enables the quantitative assessment of energy needs of a proposed or existing district. **Case Studies** or international examples of energy-saving and eco-friendly districts are presented in a structured form. **Strategies and Technologies** for minimizing the district energy consumption are described. A **Performance Rating Tool** enables the user to compare energy consumption data to the national average of similar districts.

The tool was internationalized in conjunction with Annex 51. Among other features, the selection of national archetypes, national climatic data and the presentation of results were localised for the respective countries. This allows a useful and simple application in participating countries for which national parameters are included in the tool.

Before starting an application, the user chooses which national boundary conditions shall underlie the performance rating and numerical assessment of district energy needs, by clicking on a flag. It is not possible to transfer input data from one country to another, as this would not be reasonable due to the different national boundary conditions and divergent approaches adopted. It is however possible

to subdivide a heterogeneous country such as the United States for instance, into different climatic regions.

5.3 Tool sections

The screenshot of the navigation in 5-3 shows the different sections included in the District Energy Concept Adviser:

- The **Performance Rating** tool enables the user to compare the energy use of a certain district with the national average of a similar district
- The **Case Studies of Energy Efficient Districts** have been provided by Annex 51 national representatives. Studying the 19 exemplary Case studies of energy efficient new and existing renovated districts or quarters provides the user with inspiration and information on lessons learned.
- **Strategies and Technologies** gives a short overview of applicable measures and includes links for further information, including to specific IEA annexes and tasks that deal in detail with certain technologies.
- The **Energy Assessment of Districts** enables the user to calculate the energy performance of various energy concepts on demand and supply sides. Supply can be central such as a local district heating system or distributed such as detached boilers or heat pumps alone or in combinations. Results are presented as delivered energy, primary energy and CO₂ emissions.
- The **Basic** section contains references including links to download international and national reports on energy efficient districts or quarters.
- The last section **Contact** lists participants of Annex 51.

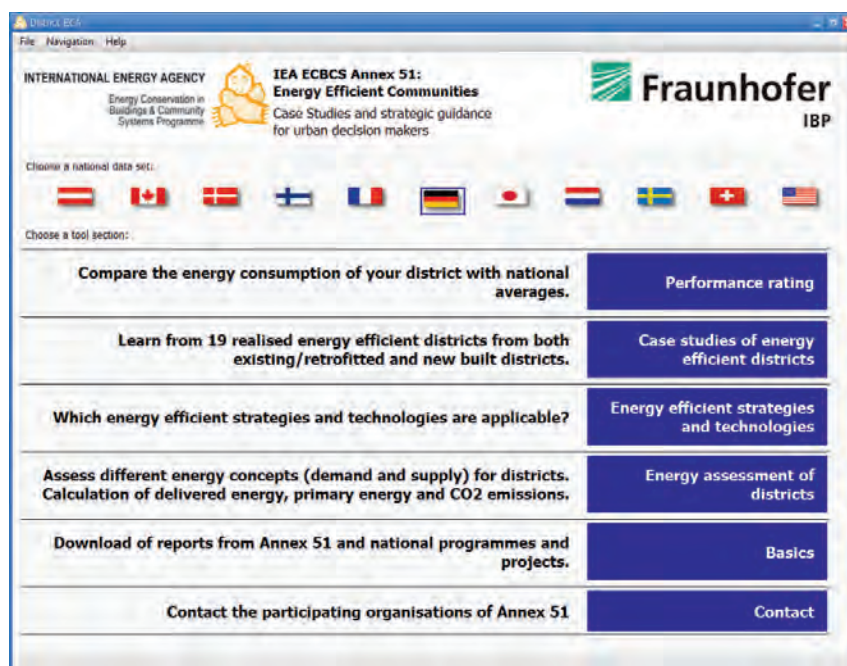


Figure 5-3: Navigation through the different sections of the D-ECA

5.4 How to use the main sections

The following presents the Performance Rating, the Case studies, the Strategies and Technologies and the Energy Assessment of Districts in more detail, specifically developed for the use in the District Energy Concept Adviser. The other sections are based on other more general work within Annex 51, other national program or contain information on participating organizations therein.

5.4.1 Performance rating

The **Performance Rating** section enables the user to compare energy consumption parameters of a district to the average district or neighbourhood values for her/his own country and thereby determine whether a particular district is relatively energy efficient or rather less efficient. Whereas data input is the same for every user in each country (i.e. specific data on energy consumption, subdivided into energy carriers such as heating oil, gas, biomass, electricity from the public grid, electricity generated from PV, wind, etc., divided into heat and electricity) the comparison values or benchmarks vary widely from country to country. This is not only true for the average values in an absolute sense, but also for the source of the parameters and the possibility to subdivide analysis by groups of buildings. Some countries offer various options for making comparisons.

The Swedish version, for example, provides three different options for comparison:

- Average energy demand for single-family houses, other residential buildings and non-residential buildings compared to results of a national survey (SABO, 2008). Total delivered energy for heating and electricity and primary energy use are displayed.
- By three climactic regions compared to the Swedish Passive House / Low Energy Standard for Residential Buildings (2012). Presented results are weighted for heating, electricity, and cooling.
- Residential buildings and non-residential buildings and buildings with and without electric heating or with cooling for three climactic regions are compared to the Swedish Standard for detached buildings. Results will indicate weighted heating energy.

The tool calculates a comparative value based on the proposed district's overall mix of buildings; this value is computed on the basis of the net floor areas of the various buildings types.

Figure 5-4 shows the screenshot of the input for the heating energy need for Sweden. The bar diagrams each compare the total delivered energy for heating, the delivered electricity and the primary energy use with the respective mean values established by the SABO study.

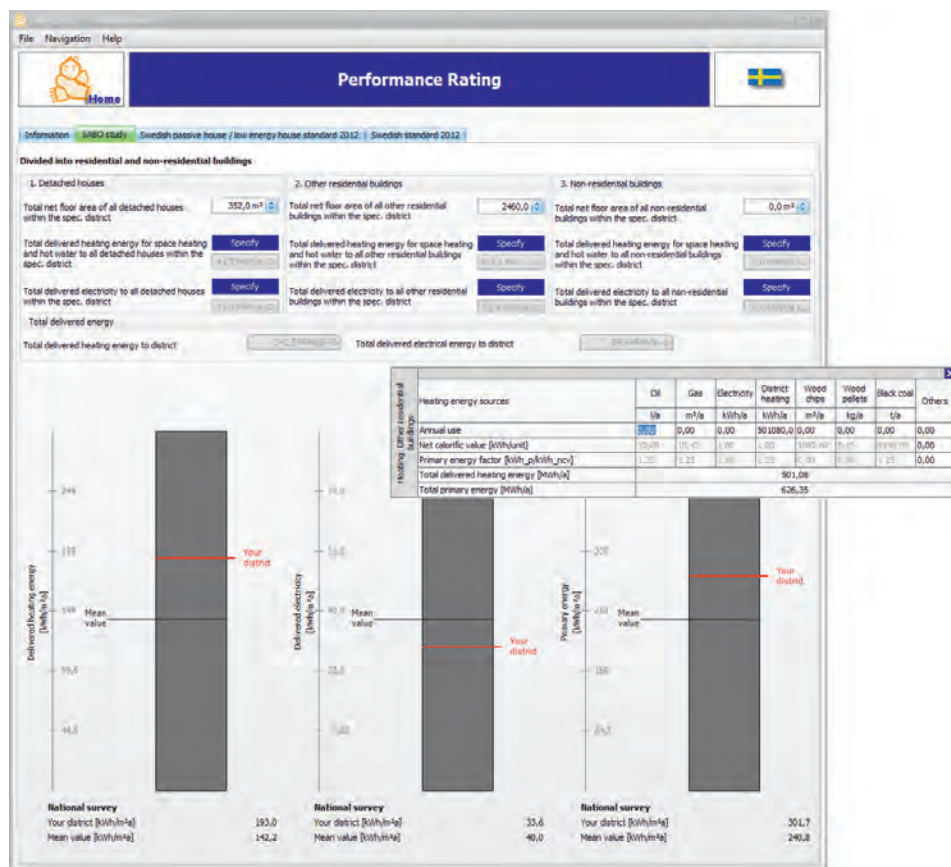


Figure 5-4: Screenshot of an exemplary input in the Swedish Performance Rating system

The following national performance rating systems are included in the tool:

Table 5-1: Description of available national versions in the D-ECA Performance Rating Tool

Country	Source of benchmark data	Division into	Results presented as
Germany	Basic: • BMWi <i>Projektgruppe Energiebilanzen</i> 2007 (table 7), <i>Statistisches Bundesamt</i> (2005)	• Residential buildings • Non-residential buildings	• Delivered energy for heating and hot water • Delivered electricity • Primary energy
	Detailed: <i>Bekanntmachung der Regeln für Energieverbrauchskennwerte und der Vergleichswerte im Wohngebäudebestand</i> (BMVBS) and <i>Bekanntmachung der Regeln für Energieverbrauchskennwerte und der Vergleichswerte im Nichtwohngebäudebestand</i> (BMVBS) both of 30.July 2009	• 2 types of residential buildings • 32 types of public residential buildings • 28 types of private non-residential buildings	• Delivered energy for heating and hot water • Delivered electricity
Denmark	Basic & Detailed: • Kim B. Wittchen, "Heating Energy Savings in Buildings", <i>Statens Byggeforskningsinstitut</i>, 2006. • Kim B. Wittchen, "Potentielle energibesparelser i det eksisterende byggeri", <i>Statens Byggeforskningsinstitut</i>, 2009:05. • Jesper Kragh, Kim B. Wittchen, "Danske bygningers energibehov i 2050", <i>Statens Byggeforskningsinstitut</i>, 2010:56. • Energy Statistics 2010, Danish Energy Authority, www.ens.dk	Basic: • Single-family residential buildings • Multi-family residential buildings • Offices and commercial and public buildings	Basic & Detailed: • Delivered energy for heating and hot water • Delivered electricity
		Detailed: • Single-family houses (detached, row house, farm house) • Multi-family house • Offices and commercial and public buildings divided into 7 age periods	
Sweden	SABO study: • <i>Miljövärdering av energianvändning i fastighetsbestånd</i> (Environmental assessment of energy use in the building sector, SABO 2008)	• Detached houses • Other residential buildings • Non-residential buildings	• Delivered energy for heating and hot water • Delivered electricity • Primary energy
	Swedish passive/low energy house standard 2012: Jansson, U.: Passive houses in Sweden - From design to evaluation of four demonstration projects. Division of Energy and Building Design, Department of Architecture and Built Environment, Lund University, Faculty of Engineering LTH, Doctoral Thesis 2010, Report EBD-T--10/12. Specification of energy demands in zero-energy, low-energy and Passive houses in Sweden. LTH rapport EBD-R-12/36. 2012.	• Residential buildings/Other buildings • Buildings with no electrical heating/Buildings with electrical heating and possibly cooling	• Supplied energy
	Swedish standard 2012: <i>Boverkets byggregler</i> BBR 18, BFS 2011:6. (Swedish Building Regulation by National Board of Housing, Building and Planning). With the addition of BBR 19 valid for 2012 (BBR 19, BFS 2011:26).	• Residential buildings • 3 Geographical/ climate zones	• Supplied heating and cooling energy

5.4.2 Case studies of energy efficient districts

The **Case Studies** section contains practically implemented, exemplary energy concepts for districts, which were contributed from all countries participating in Annex 51. It differentiates between completed and on-going projects, corresponding to Annex 51 Subtask B and Subtask C respectively. Figure 5-5 provides an overview relating the projects appearing in the left column to the strategies applied as they appear along the top row. Distinctions are made among:

- New high performance buildings
- Energy efficient retrofit of buildings
- Energy efficient decentralised supply systems
- Energy efficient centralised supply systems
- Decentralised energy generation from renewables
- Centralised energy generation from renewable

Case Studies	New high performance buildings	Energy efficient retrofit of buildings	Energy efficient decentralised supply systems	Energy efficient centralised supply systems	Decentralised energy generation from renewables	Centralised energy generation from renewables
Canada	✓					✓
Japan				✓		
USA	✓	✓	✓	✓	✓	✓
Denmark		✓			✓	✓
Japan		✓	✓			
Austria				✓	✓	
Netherlands	✓				✓	✓
Denmark	✓		✓	✓		
Germany	✓			✓		✓
Sweden	✓			✓		✓
France	✓	✓	✓		✓	

Figure 5-5: Screenshot of the overview matrix presenting exemplary international districts

The case studies are presented in a clear, concise structure and are displayed on several pages in the *Case Study Viewer*. In addition, PDF files of case study reports are available for download. The idea behind presenting the case studies is to inspire tool users on their own projects and allowing users to benefit from experience gained so far.

Information on each case study includes project objectives, energy design concept, the decision-making process, planning schedule, implementation phase, measurement results, costs incurred, and experience gained or lessons learned, along with further links and reports.

Stadtwerk Lehen, Salzburg

Open PDF-Report

Objectives

Technical info

Energy and environment

Decision processes

Design/planning

Realization phase

Monitoring/evaluation

Costs

Lessons learned

Additional information

Lessons learned

Holistic approach of modernisation of communities offers a chance for reduction of energy demand and integration of renewable energy in urban areas. Project of Stadtwerk Lehen comprises aspects like implementation of sustainable urban development plan, new buildings and renovation, integration of solar energy in urban district heating system, instruments for implementation of optimized solutions and initiating and steering of processes. Effort for new buildings areas has to be put on optimization of whole systems, ecological and economical benefits. System optimization has also to consider ecological quality of local supply of electricity and district heating to achieve further improvements. New building areas can additionally give impulses for further improvements for existing neighborhood around. E.g. modernization and renovation activities can lead to higher living quality of whole community. But integration of existing building stock causes several further questions for planning such like:

- Figures about actual heat demand
- Figures about expected heat demand after renovations/modernizations
- Schedule of renovation process

Furthermore communities often mean complex structure of ownership with different interests. Thus implementation of optimized energy concepts will be successful if there is a successful steering of the implementation process. Energy optimization and integration of renewable energy in communities need optimized technologies and tools for optimization. Likewise innovation is in the process and its organisation.

Residential buildings

SWOT analysis

	Helpful to achieving the objective	Harmful to achieving the objective
Internal origin	Quality agreement with defined targets ,quality criteria were binding for all involved parties. Being the basis for getting EU-fundings quality criteria became very important in whole process. Project was steered by a steering group with members of all involved organizations (politics, city planning department, involved housing associations, energy supplier, ...), with regularly meetings. These helped to overcome a lot of barriers during the development process (e.g. energy concept based on solar energy/heat pump/district heating and own low-temperature-micro-net was not compatible with existing regulations for social housing) Engagement of energy supplier to realize a innovative energy concept	Although goals were clear from beginning (quality agreement) it was difficult to motivate architects to achieve better thermal standards than required (e.g. passive house standards)
External origin	Participation in funding program motivates for reaching energy related targets as described in funding contract resp. quality-agreement	Discussion / decision for renovation of existing building stock around took a lot of time and was not only based on technical facts but also on social issues (renovation or demolition and new build) with participation of politics and public medias.

Figure 5-6: Presentation of lessons learned from the Austrian *Stadtwerk:Lehen* project in the D-ECA Case Study Viewer

5.4.3 Energy efficient strategies and technologies

In the **Energy Efficient Strategies and Technologies** section, the classification previously used in the case studies of energy efficient districts is revisited. For each of the six different building options (new building / retrofit) and supply options (centralised / detached and efficient / renewable) a short description is given, including an explanation of possible energy efficiency or supply options and advancements. This information is supplemented with links to specific IEA-related projects from various Implementing Agreements.



Figure 5-7: Screenshot of the Technology Viewer, here the section on energy efficient retrofit of buildings with many links to specific IEA annexes or tasks dealing with this topic in details.

5.4.4 Energy assessment of districts

The **Energy Assessment of Districts** function allows users to evaluate a large number of buildings on the basis of the CEN-compatible, standardised EU Energy Performance of Buildings Directive (EU-EPBD) assessment methodology with regard to:

- Net energy
- Delivered energy
- Primary energy
- CO₂ emissions or CO₂ equivalent emissions and
- Share of renewable energy supply.

Calculation principles are taken from German standard DIN V 18599 (DIN 2009). In Germany, this standard is the mandatory standard prescribed in the Energy Saving Ordinance (EnEV) for calculating the energy performance of individual residential and non-residential buildings.

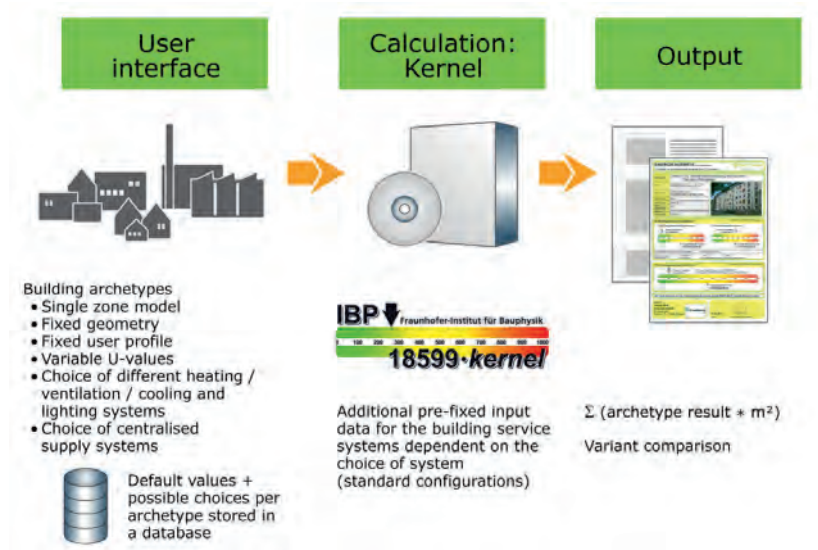


Figure 5-8: D-ECA software architecture comprised of user interface with databases of archetype buildings, user profiles, a choice of centralized service systems, the calculation kernel and outputs as tables and diagrams

To facilitate easy and fast data input for districts consisting of many buildings, national archetypes are provided in libraries. Each of these archetypes has a fixed geometry, a usage or occupancy profile and building envelope U-values (related to building age), any of which can be overwritten by the user. Additionally, a wide range of technical system options for space heating, hot water generation, ventilation, cooling and renewable energy technologies are included. The user selects the appropriate building archetypes, and in seven steps adapts them to the building stock of the proposed district or neighbourhood. The energy parameters for the entire district are generated as an output.

The number of archetypes is determined by the user. Buildings with similar characteristics are to be grouped into one archetype. For example, all multi-family houses with the same type of energy supply requiring retrofitting can be represented by one archetype in the assessment box. As for the living space or net floor area, this archetype must be assigned the total floor area of all multi-family houses, which must be input by the user.

Parameters for subdividing the building stock in a neighbourhood or district into archetypes include:

- Building type. Depending on the country, differentiated between:
 - Detached single-family houses (small, medium or large - if appropriate)
 - Row houses (S, M, L - if appropriate)
 - Multi-family houses in block form (S, M, L)
 - Multi-family houses in tower form (S, M, L - if appropriate)
 - Non-residential buildings. In Germany, for example, categories include:
 - Office buildings (fully glazed or regular window area)
 - Schools
 - Nursery schools
 - Hotels
 - Sports halls
 - Food retailers
 - Production/manufacturing buildings
 - University buildings

- Building age. Described by:
 - building envelope U-value or
 - thermal insulation standard.
 - A well-insulated building envelope (in the range of a passive house) is also offered in most countries.
- Energy supply:
 - Heating
 - Hot water
 - Ventilation
 - Cooling
 - Lighting
- Renewable energy sources.

Regarding energy supply (both heating and cooling supply), both centralized (local and external district heating or local and external district cooling) and decentralized solutions (various types of boilers, heat pumps, micro-CHPs, split units, etc.) can be modelled.

Local district heating and cooling are assigned to the district that is going to be assessed and may be based on different generation types. Available energy carriers include oil, gas, remote district heat, remote district cold, electricity, biomass, biogas, bio-oil, solar power, wind, waste, waste heat, ambient heat, and geothermal energy.

When generating energy from renewables, electricity can be fed into the grid, which will be compared to the district's energy consumption in the energy balance. In this way it is possible to determine whether the respective district is neutral with regard to delivered energy, primary energy, or CO₂ emissions or if it is even a surplus energy district (delivered energy or primary energy). With regard to heat, contributions generated from renewables can only be assigned (or credited, respectively) up to the amount of local consumption. At present, the tool is not capable of simulating energy being fed into an external district heating network. Renewable energy can be used for individual buildings or in the area of a virtual electricity node (like a large central PV field or a wind power plant) or as local district heat (e.g. solar thermal field, waste heat from industry or a large geothermal heat pump).

When generating alternative scenarios by duplicating existing variables, it is possible to create a mix of several buildings and/or building standards (such as before and after retrofitting) and/or energy supply concepts (e. g. decentralized solutions and centralized solutions such as a local heat supply concept) for comparison. It is also possible to duplicate the building types after configuration by the user, allowing for subsequent further modification.

The following options may be selected to visualize the results:

- Instant preview of delivered energy and primary energy, divided into energy carrier, CO₂ emissions and the renewable energy ratio (share of renewables contributed to the energy supply in the district under investigation), immediately below the input box
- Tabular comparison of the variant scenario results. This option provides a great number of results for the total of buildings and the entire district, like net energy, delivered and primary energy and CO₂ emissions, including a balance recording input and output to/from local district heat, local district cold, and the electricity node. The tables can be exported as PDF or Excel files.
- Graphical comparison of the most important results of the variant scenarios.

Working with the tool is user-friendly. The archetypes are drawn into the district from a library using the 'Drag and Drop' function, the right-hand mouse key is used for editing (edit = adaptation by the user, copy or delete an archetype). Double-clicking the left-hand mouse key will also open the screen for editing the archetype. Depending on the selected type of supply, there will be automatic links to the energy carriers, or to the local district heat or cold network. The local networks can be defined more precisely when opening the input box by using the right-hand mouse key (or by double-clicking). The same applies to the energy carrier parameters.

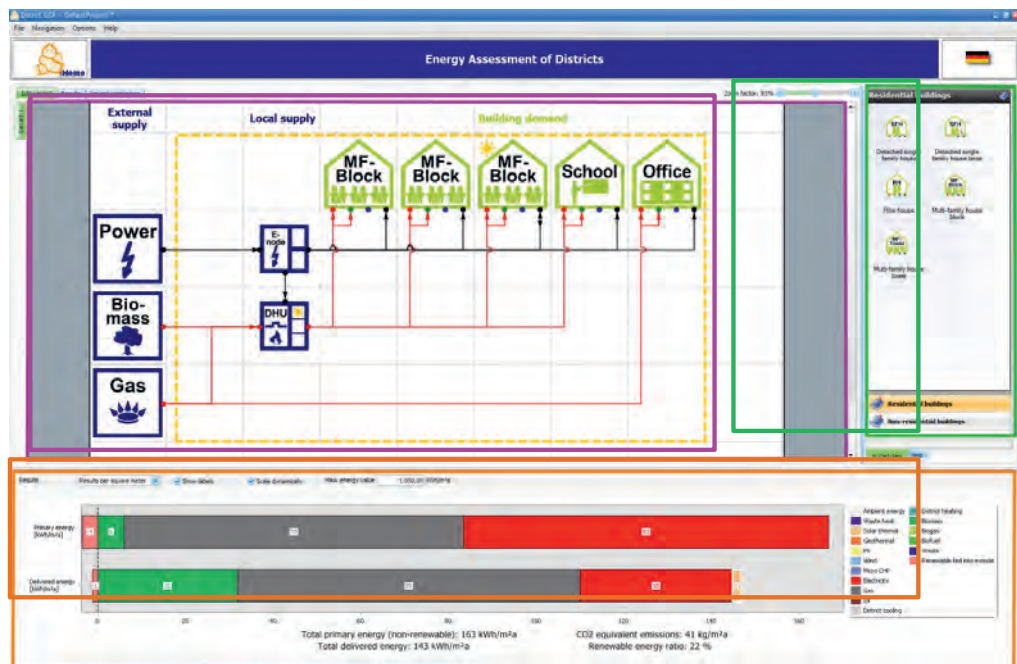


Figure 5-9: User interface of the energy assessment tool⁷⁴

Due to the assignment of energy from renewables (credit method) and depending on the complexity of the respective district, when interpreting detailed simulation results users can refer to the D-ECA manual and may also need experience in practical application. Efforts were made however to reduce results to an absolute minimum, in favour of giving a concise presentation of results in the instant preview. The presentation of results depends on the country, as it was envisioned to produce parameters comparable to the ones used in building energy certification, by analogy with national EPBD procedures.

⁷⁴ The green frame marks the library of archetypes, which can be dragged into the assessment box framed in pink. The assessment box shows the archetypes with their energy supply solutions and enables the user to edit components of buildings, technical building systems, and supply systems. The bottom section of the screen framed in orange, presents the instant preview of results for a variant scenario.

Building parameter

General U-/g-values

(1) Building information

Name: My office no. 1

Building type: Office building with regular window size

File with detailed information: Open pdf-file

Year of construction/ insulation level: 1984 to 1994

Net floor area: 7.924,36 m²

(2) Heating + hot water systems

Space heating system: Condensing boiler

Energy carrier of space heating: Gas

Hot water generation: Central in combination with space heating

Energy carrier of hot water:

(3) Solar water heating

Type of solar thermal system: No solar thermal system

Collector area: m²

Collector orientation: South

Collector inclination: 30°

(4) Ventilation

Type of ventilation: Window ventilation

(5) Cooling system

Share of cooled area: 60 %

Cooling delivery system: Split

Cooling generation system: Compression

Cooling energy source: Water

(6) Electricity consumer

Lamps: Fluorescent lamps with elect. ballast

Equipment: Standard

(7) Renewable electricity generation

☒ PV system available

PV collector area: 90,00 m²

PV collector orientation: South

PV collector inclination: 15°

☐ Wind power generation available

Disk area: 0 m²

Hub height: 0 m

Use of renewable electricity: Feed-in only

Results for the buildings represented by this type building

Energy	Unit	Heating	Hot Water	Ventilation	Cooling	Lighting	Equipment	Total
Total delivered energy	MWh/a	1.315,6	81,8	0,0	18,4	220,4	168,4	1804,6
Delivered energy related to floor area	kWh/m ² a	166,0	10,3	0,0	2,3	27,8	21,3	227,7

Close and undo changes Close and apply changes

Figure 5-10: Screenshot of the editing procedure. In seven steps, the user can refine the specified building and building service system data.

Table 5-2 shows the national versions and boundary conditions that are included in the energy assessment tool.

Table 5-2: National and international versions available in the D-ECA Energy Assessment Tool

Country	Archetypes	Climate data	Main results for the district
Germany	4 residential types (detached single-family houses, row houses, multi-family houses block, multi-family houses tower) 12 non-residential types (school, sports hall, medical centre, nursery school, university canteen, university institute building, university lecture hall, office building with regular window area, office building with glazed facades, work shop, supermarket, hotel) - Age-dependent U-values + passive house level	Potsdam (reference data for energy performance certificates of single buildings)	- Delivered energy - Non-renewable primary energy - CO₂ equivalent emissions - Renewable energy ratio
Austria	7 residential types (detached single-family houses in 3 different sizes, row houses, multi-family houses in 3 different sizes) - Non-residential buildings (2 school types, nursery school, 2 office building types with regular window area, 2 office building types with glazed facades, supermarket) - Age-dependent U-values + passive house level	Climate data derived from test reference years (TRY) of - Graz - Innsbruck - Linz - Salzburg - Vienna	- Delivered energy - Total primary energy - CO₂ emissions - Renewable energy ratio
Denmark	3 residential types (detached single-family houses, row houses, multi-family houses block) - Age-dependent U-values	Climate data derived from test reference year Copenhagen	- Delivered energy - CO₂ equivalent emissions
France	8 residential types (detached single-family houses, row houses, small apartment buildings, standard apartment building, slab housing (the last three are represented as detached type and as row-type), towers; - Age-dependent U-values + passive house level	Climate data derived from test reference years of - Orleans (zone H1), - Rennes (zone H2), - Nimes (zone H3)	- Delivered energy - Total primary energy - CO₂ equivalent emissions
Inter-national (all remaining participating countries in the IEA ESCBC Annex 51)	Same archetypes as for Germany, incl. the user profiles and age-dependent U-values + passive house level	Climate data derived from test reference years (TRY). - For Canada: Ottawa - For Finland: Helsinki - For Japan: Tokyo - For the Netherlands: Amsterdam - For Sweden: Stockholm - For Switzerland: Geneva	Delivered energy (All other values can be derived from the delivered energy using primary energy factors and CO ₂ factors)

National assessment versions for the USA, Canada and Japan have been suggested and might be realised after the Annex 51 project phase.

Examples of the use of the Energy Assessment for Districts

The tool allows for the assessment of decentralised energy supply systems such as boilers, heat pumps or centralised energy supply systems (e.g. district heating systems or local district heating systems). The two simple examples presented below represent both cases.

- a) Decentralised supply system: New city quarter with high performance buildings and building specific ground coupled heat pumps or biomass boilers with solar supported domestic hot water system.

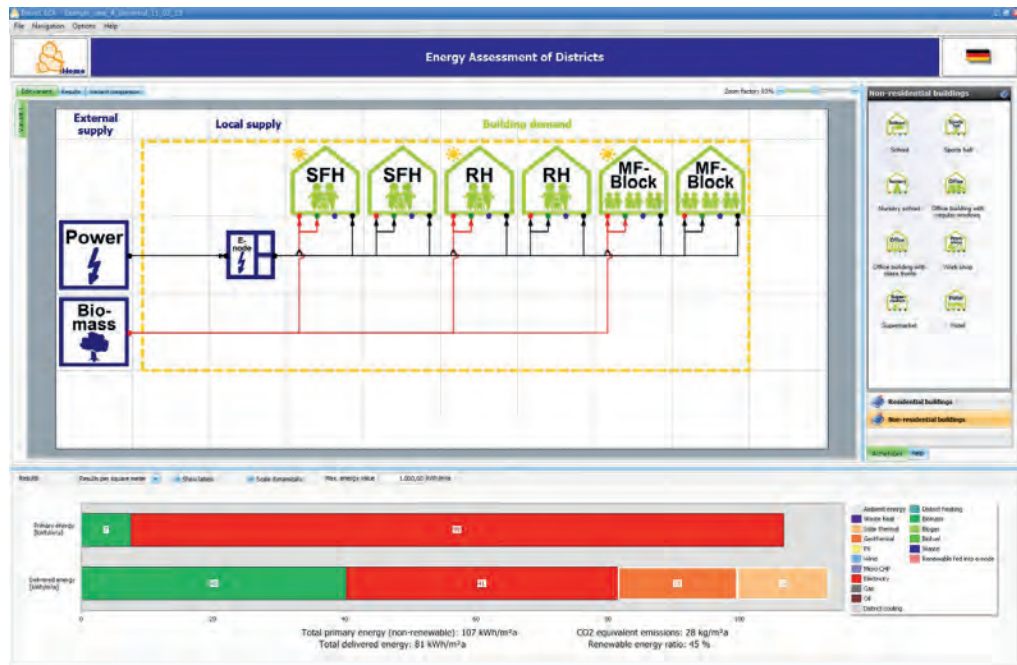


Figure 5-11: Screenshot of example case a) detached supply of a newly-built high performance city quarter

Figure 5-11 shows six archetype icons in the assessment box. For each of the three different archetypes single-family house, row house and multi-family house in block form, two different supply systems were configured: biomass boiler in combination with a solar supported domestic hot water system (first icon) and ground-coupled electric heat pump (second icon). The small text shows a fly-over with the mouse, in this case the user-defined name of archetype 3. The supply icons are power (for the electrical heat pumps and all electricity consumers) and biomass (for the boilers in archetypes 1, 3 and 5). The archetypes represent all buildings built in the same way, therefore the living area or net floor area was input based on the sum of all buildings belonging to a specific archetype. The quick result diagram at the bottom of the screenshot presents the delivered energy to all buildings in the district of 40 kWh/m²/a biomass (green) and 47 kWh/m²/a electricity (red). The renewable energy generated and used on the district site is 18 kWh/m²/a geothermal heat from ground-coupled heat pumps (orange) and 14 kWh/m²/a solar thermal. Both renewable energy uses are usually not shown on energy performance certificates for single buildings and are therefore not included in the total sum of delivered energy (87 kWh/m²/a) and presented in white frames instead of black frames in the bar chart. The upper bar chart shows the primary energy use calculated by multiplying the delivered energy with the primary energy factor, in this case for Germany, the non-renewable primary energy factor. This leads to 121 kWh/m² primary energy need (7 kWh/m²/a biomass and

114 kWh/m²/a electricity). Information on the CO₂ equivalent emissions and the renewable energy ratio completes the quick results.

- b) Centralised supply system: Existing city quarter consisting of various archetypes and being supplied by an upgraded local district heating system consisting of a cogeneration unit and a peak load boiler. Waste heat is added to the local district heating.

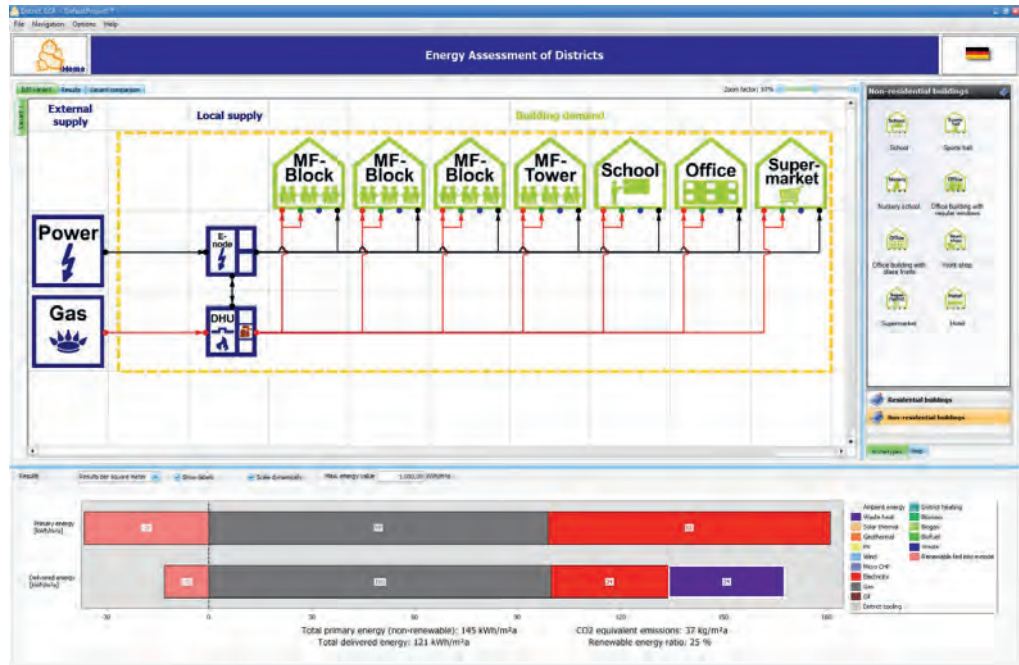


Figure 5-12: Screenshot of example case b) central supply of an existing city quarter with a local district heating

Figure 5-12 presents mixed archetype icons, specifically four different residential archetypes comprised of three types of multi-family house blocks (according to age or insulation level), an archetype of a multi-family house tower, a school archetype, an office building archetype and a supermarket archetype. All buildings are connected to the local district heating unit (DHU). The DHU consists of a cogeneration unit with a peak load boiler, both using gas as energy source. Additionally some waste energy is added to the energy mix, represented by the small brown symbol within the DHU icon. The results in the bar charts show the energy use of gas (grey), electricity (red) and generated electricity by the cogeneration unit (pink, presented to the left of the bar chart and violet for the waste heat). Waste heat is interpreted to be similar to a renewable energy source as it is described as waste from another building or building process. Therefore it is presented with white frames and only visible in the delivered energy bar chart. Total delivered energy for the district is 172 kWh/m²/a, consisting of 143 kWh/m²/a gas, 48 kWh/m²/a grid electricity and -19 kWh/m²/a electricity generated by the cogeneration unit. The waste heat contributes another 63 kWh/m²/a to the district. The total primary energy of the district amounts to 204 kWh/m²/a taking into account the -52 kWh/m²/a electricity generated by the cogeneration unit of the district heating central.

5.5 User guide

The District Energy Concept Adviser contains a user guide with more detailed information on the individual tools and how to use them. The user guide combines step by step procedures for all the different tool parts with reference data on how the defaults have been chosen, and a list of national contributors to the tool.

The user guide can be found in the task menu under 'help'.

5.6 Test calculations to assess the accuracy of the calculation tool

The accuracy of calculation and simulation tools can be assessed in several ways:

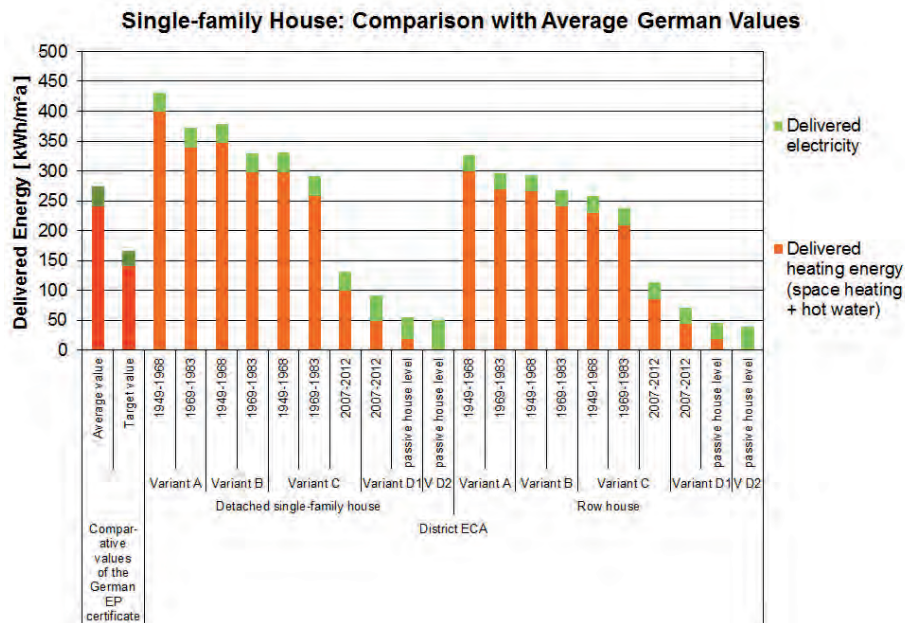
- Comparison of the results with those of similar tools
- Comparison of the calculated results with measurements in real buildings
- Using defined test methods for simulation tools such as the BestTest method (Judkoff & Neymark, 1995) which was developed in an International Energy Agency (IEA) project. In the end it is a comparison of a black box model result with several other simulation tools. Since the District ECA cannot be used for black boxes, but only for pre-defined archetypes this method cannot be applied.

If calculation tools for the energy performance of buildings are compared with real energy use measurements, it must be taken into account that it is rarely possible to include the occupant behaviour in the calculation tool. Deviations in results may be based on ventilation rates, internal temperatures, internal heat sources, manual control of building service systems, etc. Often, occupant behaviour is assumed by tools according to an average profile. In the case of the District Energy Concept Adviser, it is derived from the national user profiles of the German standard DIN V 18599-10 "Energy efficiency of buildings – Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting – Part 10: Boundary conditions of use, climatic data". This standard includes user profiles for 2 residential building types and 33 non-residential building types. For the other national versions, adaptations of user profiles were possible. Most of the European countries have adopted the assumptions contained in the German standard.

When other national assumptions were available, the country representatives in IEA Annex 51 made test calculations and sent their feedback to the main developer, Fraunhofer Institute for Building Physics (Fraunhofer IBP).

The evaluation of the tool by Fraunhofer IBP was performed in several ways:

- Comparison of single building tool results with the result of the calculations obtained by the tool ibp18599, which uses the same calculation kernel. Here deviations in the pre-configurations of the building service systems have been analysed and corrected.
- Calculations of several demonstration projects comprised in the German programme "EnEff:Stadt", including Karlsruhe-Rintheim, Munich Lilienstraße and Stuttgart-Burgholzshof. The results were found to be within a very good range when compared to measured values. The calculations and comparison with measured values for Stuttgart-Burgholzshof are presented in chapter 5.6.1.
- Comparison of the calculations for the archetypes with average measured energy use data of German buildings based on (BMVBS 2009). Extracts from the results are shown in Figure 5-13 and Figure 5-14.



Comparison values for electricity are derived from 4000 kWh household electricity per single-family house (average value) and 3000 kWh household electricity per single family house (target value)

Variant A: Constant temperature gas boiler, hot water in combination with space heating, window ventilation, mix of incandescent and energy saving lamps, standard equipment, no renewables from solar or wind, standard household equipment.

Variant B: Low temperature gas boiler, hot water in combination with space heating, window ventilation, mix of incandescent and energy saving lamps, standard equipment, no renewables from solar or wind, standard household equipment.

Variant C: Condensing gas boiler, hot water in combination with space heating, window ventilation, mix of incandescent and energy saving lamps, standard equipment, no renewables from solar or wind, standard household equipment.

Variant D: Geothermal heat pump with gas, hot water in combination with space heating, mechanical ventilation with heat recovery, solar supported hot water (5 m² of collectors, 45 ° inclination), energy saving lamps, class A household equipment. D1: gas driven geothermal heat pump; D2: electrical geothermal heat pump.

Figure 5-13: Comparison between average values used in the German energy performance certification and results of calculations using the District ECA for single-family houses with various building service systems and building ages (envelope qualities)

A comparison between the average values for German single-family houses and a specific calculation of one District Energy Concept Adviser archetype together with one combination of building service systems and one level of the building envelope quality is not meaningful. The average values for Germany are comprised of measurements of numerous single-family houses from all available building age periods and with installations of various combinations of building service systems. However, the calculation of different building service system variants and different building age

periods gives an overview of the range of calculation results. Here, both District ECA archetypes, namely 'detached single-family house' and 'row house' have to be analysed as they belong to the upper-level grouping 'single-family house'. The results of the District ECA had to be recalculated to make sure that they are related to the same reference area as the values of the energy performance certificate (A_N , an artificial area dependent on the gross volume V_{gross} ($A_N = 0.32 \cdot 1/m \cdot V_{\text{gross}}$).

The results presented in (Erhorn, 2002) show that a single-family building built in the periods that represent the biggest share of the German building stock (1949-1968 and 1969-1983) provided with a conventional combination of building service systems at that time (Variant A with a – rather inefficient – constant temperature gas boiler) will result in values that are significantly higher than the German average on the heating side. Yet, it has to be taken into account that the vast majority of these older buildings have already experienced one or two rounds of upgrades of the heating generation system; most also have had the windows replaced and undergone other types of thermal renovations. With a new heating system (Variant C with a condensing boiler) the results are rather close to the average; some insulation measures will further improve them. Additionally, it has to be considered that many new buildings have been constructed in the meantime, which also lowers the average heating energy demand considerably. Examples of this development are the results for a new building (2007-2012) equipped with a condensing boiler or even a heat pump (Variants C and D). The results for the variants featuring passive house level show how low the heating energy demand can be when state-of-the-art insulation levels and building service systems are provided.

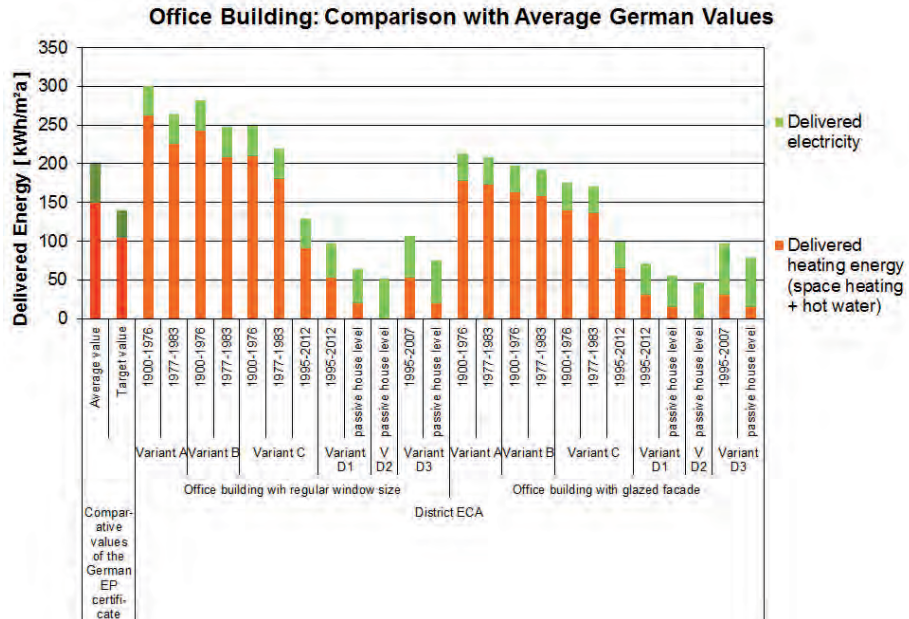
Comparing the electricity use with the average values is easier as it is neither greatly influenced by the age of the building nor by most of the building service systems. Exceptions are the electrical heat pump, the mechanical ventilation system and, to a small degree, the solar thermal system, all of which are included in variant D2. This variant also features more efficient lighting and household equipment which mitigates the impact of these end-uses. The variants with standard electrical equipment and standard heating systems resulted in electricity demands that correspond very closely to the average electricity use of German single-family houses. As a general outcome of the comparison it can be stated that calculated values of the District Energy Concept Adviser correspond well to the measured average values of single-family houses in Germany.

The results of the calculation of the archetype office buildings in Figure 5-12 should be interpreted in a similar way as the single-family house calculations. Again, no direct comparison is possible between the comparative value and one variant since both District ECA archetypes, the office with regular window sizes and the office with a glazed façade, belong to the upper-level grouping office building of the database of measured energy consumptions. Also, the building stock comprises all building ages and numerous building service system combinations. Most buildings were built between 1900 and 1976 but again the majority of the buildings have undergone renovations including heating system upgrades, window replacement and insulation measures. The average measured heating energy use is therefore adequately covered by the results of the different variants calculated using the District Energy Concept Adviser.

Again, calculated electricity use corresponds well to the average value. Variants D3 include 100% cooling of the building. The chosen cooling system is based on an electrically driven compressor cooling machine and thereby significantly increases the electrical energy use of the building if compared to mechanically ventilated office buildings (as in variants D1 and D2).

The calculation kernel itself is used by more than 20,000 users in Germany within several EPBD calculation programmes. A general test of all these programmes has been realised within a project initiated by the German Federal Office for Building and Regional Planning (BBR) in 2007. The specified project aims were to check calculation and energy certificate issuing procedures and the development of quality assurance methods with the aim of creating transparency regarding the software solutions available on the market. Fifteen software programs for office buildings and thirteen

software programs for residential buildings were examined with regard to the determination of energy demand according to DIN V 18599 and with regard to energy consumption. Further information can be found in Fehlauer, 2009.



The comparative values for heating and electricity are taken from the BMVBS guideline *Bekanntmachung der Regeln für Energieverbrauchskennwerte und der Vergleichswerte im Nichtwohngebäudebestand* July, 2009.

Variant A: Constant temperature gas boiler, hot water in combination with space heating, window ventilation, fluorescent lamps with low level ballasts, standard equipment, no renewables from solar or wind, standard equipment.

Variant B: Low temperature gas boiler, hot water in combination with space heating, window ventilation, fluorescent lamps with low level ballasts, standard equipment, no renewables from solar or wind, standard equipment.

Variant C: Condensing gas boiler, hot water in combination with space heating, window ventilation, fluorescent lamps with low level ballasts, standard equipment, no renewables from solar or wind, standard equipment.

Variant D: Geothermal heat pump, hot water in combination with space heating, mechanical ventilation with heat recovery, no renewables from solar or wind, energy saving lamps, class A equipment. D1: gas driven geothermal heat pump; D2: electrical geothermal heat pump, D3: gas driven geothermal heat pump and compression cooling of the entire net floor area.

Figure 5-14: Comparison between average values used in the German energy performance certification and results of calculations using the District ECA for office buildings with different building service system variants and building ages (envelope qualities)

5.6.1 Evaluation results of the exemplary district Stuttgart-Burgholzhof

Stuttgart-Burgholzhof is a district built in the north of Stuttgart prior to the year 2000. The project is included in IEA Annex 51 Case studies and the Case Study viewer of the District ECA. It consists of 36 different buildings in multi-family block type and tower type and a school building. When the city of

Stuttgart sold the land to more than ten different housing developers, the contract required the buildings to be built to energy performance requirements 30% higher than the national energy performance regulation at that time. Thus the building envelope quality is considerably better than typical buildings built before the year 2000. The energy supply was developed by a local district heating network with support by 1,750 m² of solar thermal panels installed on the roofs of some of the multi-family houses. The electricity bills of all buildings have been gathered and analyzed together with total gas consumption and the contribution of solar collectors. The results are presented in a report (Erhorn 2002). A photo of the district is presented in Figure 5-15.



Figure 5-15: Photo of the low-energy district Stuttgart-Burgholzof. Source: Heike Erhorn-Kluttig

For the evaluation of the District Energy Concept Adviser the quarter was inserted, using five different building archetypes:

- Multi-family house block with window ventilation
- Multi-family house block with exhaust ventilation
- Multi-family house tower with window ventilation
- Multi-family house tower with exhaust ventilation
- School building

The total floor area of buildings belonging to each archetype was aggregated. 2007-2012 was chosen as the age category to represent building envelope quality, corresponding to a 30% improved building envelope quality at the time of construction. All five archetypes are connected to a local district heating unit with gas boilers and a centralized solar thermal collector field of the correct size has been added. Distribution losses of the local district heating were set at 25%, as determined by monitoring data. The whole configuration is presented in Figure 5-16.



Figure 5-16: Screenshot of the configuration of the Stuttgart-Burgholzshof district in the D-ECA

The comparison of the results is only possible for the heating and domestic hot water energy use since the project report does not include electrical energy bills. Figure 5-17 presents measured data and the calculated results. The calculated results are slightly higher than the actual measurements. The range of results is however very adequate for all components, the energy use of the building, the gas consumption and the solar contribution. This is explained in part by the monitoring report which indicates that the weather was slightly warmer than usual during the monitoring year.

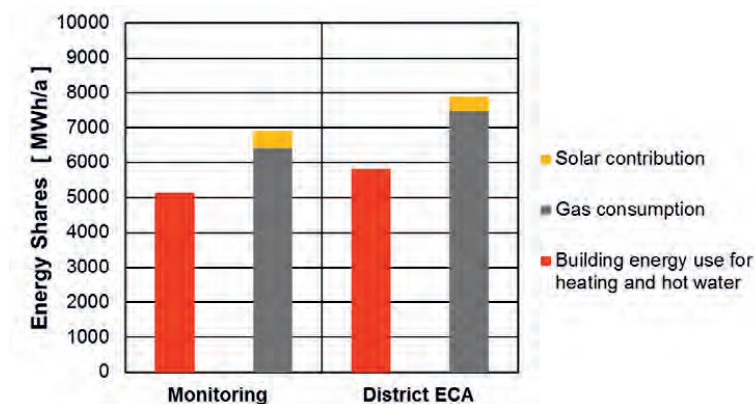


Figure 5-17: Comparison of measured results (left) and calculated results with the D-ECA (right)

5.7 Download source

The English version of the District Energy Concept Adviser (in English) is available as a free download upon registration (www.annex51.org). A German version has been issued; French and Austrian (in

German with Austrian boundary conditions) versions are also under development and will be available until end of 2013.

6 Energy Efficient Neighbourhood Case Studies

6.1 Neighbourhood case studies

A common theme in the neighbourhood development case studies analyzed as a part of Annex 51 Subtask B was that stakeholders had a vision that went beyond the normal horizon of city architects or city planners. Although most neighbourhood development projects reviewed in Annex 51 are primarily aimed at sustainable and efficient energy use, some also work towards sustainability in a broader perspective through projects on transportation, material flows, air and water quality and so on. However, these cases remain mostly in the planning phase and far from implementation. Table 6-1 presents an overview of Subtask B projects. The case studies are described briefly in attachment A6-1. For more details see the corresponding Subtask B case study report (Zinko, Moshfegh, 2012; pages 190, 203) and the Annex 51 case study viewer in the District Energy Concept Adviser, Chapter 5). The examples from which useful lessons and practical experience can be derived are those where detailed planning and/or partial implementation have taken place and where recent energy conservation regulations such as the EPBD or related national directives have been enacted. Therefore the main emphasis in this Chapter is on *energy conservation measures* in either revitalization projects or new development projects. Other aspects of sustainability are discussed when applicable.

Three types of case studies are analyzed in the context of this guidebook:

- Revitalization/retrofit of buildings and/or revitalization of neighbourhoods including renovation of existing or implementation of new energy supply systems.
- Construction of new buildings with emphasis on energy conservation and advanced energy supply technologies using equipment and appliances in both green field and existing neighbourhoods, including former industrial brownfields.
- Neighbourhoods or districts with a mix of refurbished buildings and new building development, often involving new heat supply technologies.

6.2 Successful neighbourhood developments

6.2.1 Energy efficiency is profitable

Participating countries were free to choose projects they judged best fulfilled the basic criteria mentioned above. The resulting group of case studies presented a broad spectrum of possible ways to achieve economically viable neighbourhoods in both revitalization/retrofit and new construction contexts. Also, despite different technologies and methods, featured projects have one important factor in common: *Energy efficiency pays for a part of what has been added to the tenants' quality of life through increased comfort, increased neighbourhood security and increased sustainability of housing.* Although energy conservation measures in most cases resulted in higher capital investments and fixed rent (in comparison to market levels), the total monthly costs for rent and purchased or operating energy for tenants are often the same or only slightly higher. Additionally, building owners reduce their risk and benefit from a more predictable Return on



Figure 6-1: Process structure of neighbourhood development projects

Investment (ROI). Significantly, all projects resulted in large reductions in both primary energy use and GHG emissions.

Process structure

Figure 6-1 depicts a general neighborhood development process that can be deduced from Annex 51 case studies. Similar findings were also derived from the European CONCERTO initiative (Di Nucci, 2010). Generally, a development starts with a problem. Groups with common interests act as driving forces toward a decision to solve the problem. At the point the decision is made to proceed, the planning phase starts, followed by an implementation phase. If a project is a showcase or demonstration, it will be evaluated, with feedback made available for future projects.

Table 6-1: Case studies from low-energy projects in neighborhoods

	Location	Main goal	Type of buildings	Number of buildings/ dwellings	Start of planning	Construct. time Start/end	Expected energy/CO ₂ reduction	Special features
AT	Stadtwerk Lehen, Salzburg	new development of former industry and stadium area near city	new and refurbished residential and commercial buildings	dwellings 550 refurb. 623 new	2005	2009/2014	30% - 75% Prim. energy	micro DH net with solar energy
CAN	Petite Rivière, Montreal	equilibrium community initiative – (Sustainability)	new buildings, 2 - 4 stories in a park landscape	56/1461 4600 m ² commercial area	2007	2012/2020 ⁷⁵	energy reduction 50% CO ₂ not decided yet	not decided yet
DEN	Laerkehaven - Lystrup	low-energy district heating system	new detached houses	105/122	2004	2008/2010	annual use: 45 - 55 kWh/m ²	PV, low-temp DH 55/25 °C
FI	Peltosaari	integrated revitalization project	existing residential buildings and neighbourhood redevelopment	125 buildings 103.000 m ² flats, 2 comm. buildings, school	2008	2012/2020	energy 50%	DH
FR	Franklin-Mulhouse	revitalization of degraded buildings in a historic area	2- 4 stories historical residential buildings	dwellings /120	2005	2007/2012	primary energy by 90%	indiv. boilers
DE1	Rintheim	urban renewal by refurbish. and new construction	refurbished residential buildings + some new	dwellings 36/1350 refurb., 3/110 new	2008	2009/2012	80% CO ₂ reduction	cost-optimized energy supply
DE2	Bad Aibling	revitalization of abandoned military area	new and refurbished residential and commercial buildings	52/183 refurb. 21/60 new	2006	2009/2015	target 0 (net-zero)	Show-case for various energy saving projects
JA	Kumagaya	replacement of ineffective energy system	office building and hotel/ restaurant	2 buildings, 10,340 m ²	2008	2009/2010	primary energy by 77%	Solar heat and PV, Micro CHP
NL	Mine water Heerlen	LOWEX - district heating system based on mining water	new and exist. resid. buildings, detached houses and commercial buildings	330 + 110 dwellings+ 120000 m ² commercial /office area	2006	2009/2012	30- 40% primary energy	HP assisted low-temp DH
SE	Brogården	revitalization towards Passive house standard	existing residential mass produced buildings	18/300	2007	2009/2012	80% energy 53% CO ₂ reduction	DH assisted air heating
US	Fort Irwin	pre-study of net-zero energy renovation	renovation objects at military training area	5/ 16,000 m ² incl. dining room	2009		50% for refurbish. 100% with biomass plant	CHP, PV

⁷⁵ Project delayed

Color code explanation: New development



Neighbourhood development



Revitalization project



Multiple goals

Generally, the larger the area of the neighbourhood to be developed the more complex the tasks that need to be addressed simultaneously. In neighbourhood development or revitalization projects, energy conservation and reduction of CO₂ emissions are often only one part of a project's vision. Very often, the primary goal is not saving energy but improving quality of life by revitalizing the area which, for different reasons, has fallen into disrepair. In other projects, sustainable new development is the main aim. In such cases, sustainability in a broader sense is of importance, including waste treatment, water and air quality, transportation, land use and recreation, personal and economic security, in addition to energy conservation and supply issues and opportunities.

Secure investment

In the view of a housing company or city planning office, a major reason to develop and implement a long-term neighbourhood strategy is that an integrated sustainability plan helps to increase investment security in contrast to single, ad hoc improvement measures. Facing demographic and economic uncertainties (for example those that could result from fluctuating populations) it is understood that an attractive urban development that serves the needs of prospective tenants and ensures a good quality of life, will provide the lowest risk for the major investments required in certain districts.

In summary, the interwoven dependencies for urban development projects should be underlined: energy is but one part in a bigger framework of urban renewal, leading to revitalization and opportunities for an improved quality of life for residents and business owners in formerly rundown neighbourhoods.

6.2.2 The decision making process

A vision emanates

The decision to implement a neighbourhood project can originate from a vision or idea either from an identifiable individual or an anonymous person or group. This vision or collection of ideas is further developed in working groups, steering committees or the like. Regardless of where the idea comes from, they gain traction sooner or later and undergo further technical and economic analysis by a planning group. Over time, this task group assembles a number of stakeholders for the project, every party having legitimate interest in the implementation and outcome of the project and able to contribute to the initiative.

The implementation of a detailed showcase project can be very helpful to demonstrate certain type of renovations and options for the overall revitalization/retrofit of a district. Early in the decision-making process it is very important to identify the main objectives of the development and prioritize the many different aspects of sustainability. Energy conservation will very often be only one of a number of objectives that are promoted by stakeholders and sometimes it will not be the highest ranked.

Stakeholders

Urban development is a complex process, more so if there are a large number of stakeholders.

When a neighbourhood development project is in discussion and on the path to implementation, the number of actors as stakeholders grows.

Because the cost of neighbourhood development or revitalization projects can run into the tens or even hundreds of million euros or dollars, a diversity of interests and concerns must be brought together on common ground. Since stakeholders are very important to the success of a project, an intensive communication engagement and consultation effort must take place. Sometimes undesired lobbying activities may occur.

A typical organizing approach is to form a steering committee and/or working groups that meet on a regular basis to discuss stakeholder concerns and interests. These working groups report to controllers, boards of shareholders, regional administrations, investors or similar actors who are responsible for financing. Because of the large budgets involved in development projects of neighbourhood or city size, efficient leadership and quality control are important preconditions in the decision-making process.

It is important that the roles and responsibilities of those in leadership positions are well defined and that a budget is available to support stakeholder consultation. On this point, public authorities can play an important role.

The role of public authorities

Legislation is an important prerequisite for development and revitalization projects with a long-term vision of sustainability. International and national regulations and directives are the most important instruments used in sustainable planning. Projects that view profit in the broader social context and not only in a strict economic sense need political support.

For obvious reasons, public authorities, especially municipalities, play a key role in urban development. Since development planning is the core business of municipal governments, it is also one of the main things by which voters will judge politicians. Also, municipalities are often the owners or shareholders in public housing companies and political will can guide investment and development decisions, for better or worse. Local administration can do much through long-range planning to stimulate the low-energy sector by energy conservation initiatives and sustainability planning measures.

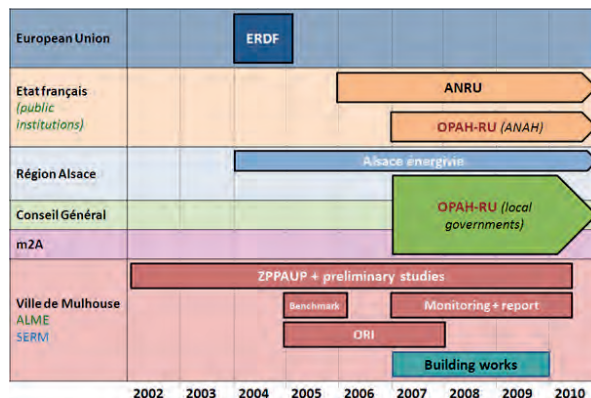


Figure 6-2: Example of subsidies from different organizations in the French case study project Franklin, Mulhouse

In the French example of the quarter Franklin in the city of Mulhouse, as illustrated in Figure 6-3, six types of public institutions support a project through subsidies, regulations and technical support.⁷⁶

⁷⁶ The city of Mulhouse delegated the project's implementation and management to SERM, a local mixed enterprise for developments in the Mulhouse region. This entity was mandated by the city of Mulhouse to carry out the operation in strict

In some cases, municipalities take the lead and support pre-feasibility studies or showcase projects to assess alternative solutions or direct public opinion on certain types of measures. Engineering and planning offices can play a major role in formulating targets and objectives. Political decision-makers can be involved in order to set planning priorities. In some development projects, municipalities co-ordinate all the stakeholders and consultants involved in the planning process. This is described further in the section on leadership and organizational structures.

The driving forces

In general, in an urban development project, among stakeholders there will be a group of actors who take the lead in pushing the case forward (see Figure 6-4). These are the drivers of the project and their actions constitute the driving force. Evidently, those drivers represent organizations that have economic resources and influence in decisions. In the Annex 51 cases studies, the most important drivers were investors, often private developers and/or public housing organizations, and municipal planning offices. In some cases utilities were active participants, especially when district heating was envisioned as a heat or cooling supply option.

Subsidies or other assistance from national or internal funding are an important component in many of the projects reviewed. Annex 51 projects are often showcases for revitalization or new development using technologies in an early stage of development, where technology applications are high risk, or not yet commercialized. In most cases public funds were granted for pre-feasibility studies and start-up projects.

However, in future widespread applications market drivers will favor economically viable solutions for consumers including tenants and property owners. Viable solutions will be influenced by expected future energy prices and by the development and costs of energy conservation technologies. Neighbourhood revitalization, building retrofits or new housing and commercial developments will also influence market decisions.

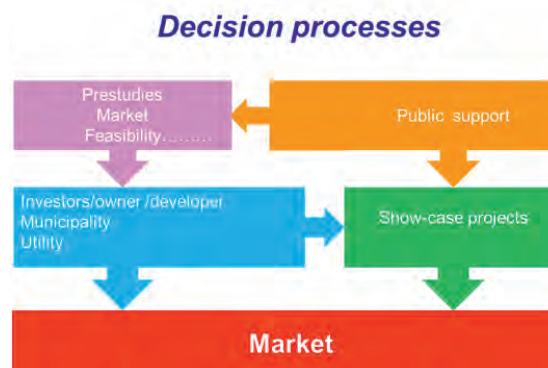


Figure 6-3: Flow of decision processes during project development

collaboration with the local energy agency ALME. Within the framework of the available financial sources, SERM offered to help the owners for free: Firstly, by providing a dossier allowing all available subsidies to be claimed. Secondly, by transferring the part directly subsidized to companies in the form of an upfront capital fund so that the owner would not have to pay in advance.

The project management succeeded in receiving support from several public funds:

- EU contributed via FEDER research and benchmarking.
- The National Agency for Urban Renovation (ANRU) contributed funds for similar urban revitalization projects.
- Renovation organization OPAH (in form of a partnership between districts, local authorities and the state) dedicated funds for renovation of buildings hazardous to health.
- Finally the municipality demarcated an architectural and urban heritage protection zone (ZPPAUP) which made it possible for owners to deduct a part of the cost of the renovation work from their tax bill.

Leadership and organizational structures

In the case of neighbourhoods and districts, most case study projects presented are either coordinated by housing and development companies or public administrators such as city or military planning offices. In some projects, housing companies are municipally owned, directed by their shareholders to ensure that social housing is available for low-income residents. In many countries, such housing companies are no longer not-for-profit organizations, however, their earnings are defined by the municipality. In most cases, these companies have the capacity to undertake neighbourhood planning and development projects.

ORGANIZATION	
Initiator	Owner/Housing company/association City – Planning office
Investor	Owner/Housing company/association Developer Grants/ funds administration
Coordinator	Owner/Housing Company/Association City – Planning office Development/Planning agency
Other	Constructor, Utility Customer/Tenants organization

Figure 6-4: Main actors in neighbourhood development projects

In larger projects, a project-coordination organization directs the course of action in the overall decision-making and planning process (Figure 6-4). This coordination can be done by the city planning office or by a third party planning office such as a private sector planning consultancy or an ad hoc planning committee. Builders, utilities and tenant organizations are important third party partners in this committee.

This planning process must be supervised or controlled by a responsible person who is in charge of the whole process and who is able to delegate duties and subtasks to other stakeholders. It also requires either a voluntary or formally defined commitment by all stakeholders to common targets and transparent co-operation throughout the planning and construction phases. In some cases, these project leaders must be courageous, defending decisions that may appear economically questionable in the short term but offer good longer-term business opportunities.

Quality agreement

One important issue for the planning team during the project initiation and implementation phases is a common understanding of the quality assessment required. Similar to lessons from earlier projects, case studies revealed that rigorous goals such as those regarding energy standards and sustainability might not be met if a quality agreement was not established among all parties. It is important to ensure that contractors and workers are provided with the necessary specifications and quality assurance information and confirm that they know what it means for their work. In some cases, especially where Passive house technology is involved, all responsible craftsmen had to sign a quality contract to achieve energy performance consistent with design specifications; this was found to be particularly important with respect to

airtightness of buildings. Figure 6-5 is the last page of the quality agreement used in Lehen, showing signatures of project partners.



Figure 6-5: Example of the quality agreement established in the Austrian case study project Lehen, Salzburg. Source: Salzburger Institut für Raumordnung und Wohnen

6.2.3 Planning urban development projects

Planning approaches

At some stage in the decision making process, the planning team will come to a point where it can quantify project objectives and targets. Very often, multiple objectives are defined. Hence the planning process is normally not carried out focused only on a single objective.

To quantify targets and strategies, specialized software tools are used for building construction and energy simulation, energy system simulation, traffic and spatial planning, and so on. Alternatively, optimization tools can be used in which energy simulations are done at a lower resolution to create an optimized economic overview of the system for the whole area. Other objectives such as sustainability or neighbourhood development are often addressed with traditional planning instruments such as priority lists, exergy factors, life-cycle factors, etc. A comprehensive planning tool for neighbourhood development was not used in any of the Annex 51 case studies.

In most cases, the planning procedure involves using several planning tools in combination with traditional planning methods based on decision guidelines.

In modern integrated planning, several interlinked software tools are used where the output from one tool produces the input for another. In the case studies, we can distinguish between two basic planning approaches:

- Tool-supported planning: based on traditional decision procedures, but important decisions are supported by specialized calculation processes including simulations and optimizations. Commonly used tools were building simulation tools such as Pleiades, IDA, e-QUEST or system simulation tools such as TRNSYS, SPREEM and POLIS to name a few (see Chapter 4).

- Integrated planning: Tools are used for guidance towards cost-optimal decisions taking a whole system perspective on buildings, energy supply systems, and other sustainability issues. The use of tools is in this case iterative. Some view a single tool for this task as highly desirable, others are more reluctant. (See Chapter 3 for planning methods and Chapter 4 for planning tools).

Policy instruments

Most Annex 51 projects for neighbourhoods and districts are influenced by national or EU policies and directives for energy saving or reduction of CO₂ emissions. However, in some projects, targets have been set that reach far beyond these energy policy requirements. They involve measures for the use of renewable energy or for improved sustainability as a whole, for social housing, for revitalization of urban areas, development of brownfields, and so on. Hence national policies are often merged with local or regional policies concerning the welfare of the inhabitants of the area (see Chapters 2 and 3).

Larger projects often combine multiple targets, which together seek to improve residents' quality of life and contribute to rising value of real estate. To achieve these goals, different *carrots* and/or *sticks* must be applied. Among the carrots used were several national funds for pre-feasibility studies, building conservation, quality assessment, sustainable cities, environmental clean-up; subsidies and special interest rates for revitalization projects were also observed. Sticks include legislative and regulatory frameworks such as building codes and energy standards for buildings, performance standards and certificates, maximum costs limitations, and the like.

Policy instruments

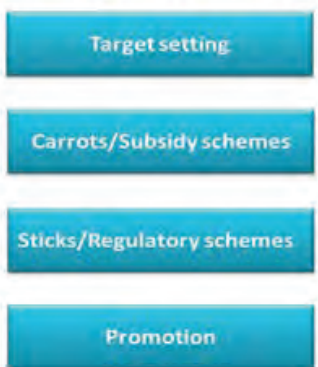


Figure 6-6: Family of policy instruments in neighbourhood development projects

Promotions are an important factor in many projects. Promotion can be accomplished through demonstration or pilot projects to test and prove technologies or methods to achieve economic viability, or in the form of showcase projects in combination with different public relation and marketing activities that disseminate project information to the public. PR activities have also been shown to be important for selling a refurbished or revitalized area to potential inhabitants. Publicity can be one way for tenants to understand their role in an important development and can increase their self-esteem.

Social aspects

Urban development projects dealing with neighbourhood and district revitalization are often governed by the pillars of sustainability (as formulated originally in Brundtland, 1992).

Renovated buildings are a precondition for revitalization, but renovated buildings in the case of Annex 51 projects also set a standard for lower energy use, improve the neighbourhood image and help to

Pillars of Sustainability (Brundtland)

Economy: In total, the project must be economically sound, otherwise the company will not survive and the tenants will be the loser. Or the tenants will move out and the housing company will be the loser.

Ecology: Environmental sustainability is one of the main issues which has become fashionable for many projects, but in the long term will be a requirement in all construction projects.

Social welfare: The housing companies are either legally or morally obliged to keep the rent for tenants at an affordable level.

Figure 6-7: Pillars of Sustainability. Source: the Brundtland report

contain future living expenses. Over a 30-year period, energy costs were found to be a very large proportion of regular tenant expenses. *To rehabilitate a neighbourhood without a significant reduction of energy end-use is virtually unthinkable today.* In the long term, a revitalized neighbourhood is a win-win situation for most people, except perhaps for those with extremely low incomes. The quality of life increases and the residents' experience of living in an attractive area supports their self-esteem. The tenants have better control of monthly living expenses, with fewer cost fluctuations during the year because of lower and more predictable operating energy costs. In most of the revitalization projects, residents may also experience improved indoor comfort, because of a better-controlled indoor climate. They may also feel that the municipality and/or building proprietor cares; this can contribute to an increased perception of security. From some projects it is known that some social benefits achieved through the revitalization of their neighbourhoods serve as essential arguments for tenants to accept a moderate increase in their monthly rent after revitalization.

6.2.4 Implementation

Most neighbourhood case studies reviewed in Annex 51 are currently under construction, which means that the learning process is ongoing. From these projects information is available on the experience with the transition from planning to implementation. These experiences can be generalized and may be informative to future projects.

Education of tradespeople and quality assurance

Including low-energy retrofits in the revitalization of existing buildings or new construction deviates substantially from conventional construction methods. Thermal bridges, airtightness, insulation levels, air flows, low-temperature heating and many other features become much more important. For example, in Passive Houses, it matters how and where you place a nail or put a feed through in a wall assembly. Experienced workers must understand and accept a new way of thinking and implement new construction techniques.

Information and education are important and necessary preconditions for successful low-energy building performance. Therefore, planners and architects have an educational task of transferring basic knowledge associated with a new technology to the tradespeople who will execute the job to attain the desired performance and building rating.

One approach taken in some projects was to organize work in a modern horizontal structure with broad responsibilities for employees. In this scenario, planning is done together and documented in a table visible to everyone. This inclusive process requires each worker to take responsibility. Many details must be developed by the workers on-site, something which is only possible if there is a common understanding of design principles and project goals. In the case that only a few buildings are under construction or are being refurbished within a year, the project team has an opportunity to adjust its methods by learning from experience and at the same time reducing costs associated with the learning curve.

In general, for construction work a tender is issued and contracts are awarded based on the best value for money. If new technologies are used where little practical experience is available, assistance from the manufacturers is requested. In some instances, although a principal decision to implement revitalization for the whole neighbourhood was made by an executive board, detailed decisions for individual buildings were made consecutively, making use of the experiences from previous projects to improve quality and efficiency of work (as was done in Rintheim and Brogården).

Planning groups have also had to learn to solve competitive problems which may occur during the construction phase by finding compromises; for example the allocation of space for different equipment such as solar system components, heat exchangers, fans or other energy equipment is often a highly debated issue.

Involving residents

Residents are the broad stakeholder group to whom most of the efforts described in this section pertain. Their roles vary considerably, according to tenure, the stage of a project in which they will be involved, through to the rental or purchase process.

Conventionally in new development, future occupants are not involved in the planning process. This is different in revitalization projects. Refurbishing or retrofitting an occupied building has a serious impact on everyday lives of residents. They either have to live with the inconvenience of having construction work and workers all around them or move out of their own dwelling into temporary accommodation. In any event, the housing company will need to compensate and engage the residents to keep them happy. One way is, through consultation, to identify desirable future living conditions and assist them in envisioning their improved quality of life after they have moved back into the refurbished dwelling.

An important feature of successful projects is continuous feedback from the housing company to residents. In one case, this was done by means of regular information folders and information meetings with residents (Figure 6-8). The Internet can also be used for information sharing purposes. There, developers and planners can easily provide information on the new technologies and techniques used in the revitalization process. A demonstration apartment (virtual or, better still, real) could be created, to allow residents to visit and understand how their apartments will be redeveloped. Tenants can also be provided with specific advice on energy-saving potentials to improve their energy use behavior.



Figure 6-8: Feedback group in one of the case study projects for neighbourhoods. Source: Alingsåshem

In another case study, the competition process for the revitalization project could be accessed by residents on the Internet which enabled them to see entries and understand the selection process. The residents could post comments and the jury could see the opinions expressed online during the evaluation process. A number of resident seminars were also organized. The seminars focused on presenting all the results achieved in various studies and on obtaining on-the-spot feedback from residents.

Results also find their way into the local media giving residents the feeling that they have participated in an important project.

From these projects, it is obvious that modern information technologies (IT) offer a broad spectrum of opportunities to support and inform residents. However, as a pre-requisite, the residents must be used to using Internet and other data base tools.

Caring for residents

In some projects, renovations were so extensive that it was necessary to temporarily move residents to empty apartments. This had to be carefully planned and full support and compensation for the inconvenience provided. For many tenants, this move is a turning point in their lives and when they move back, they expect to move into a new, improved living situation. It is very important for the success of the revitalization project that the move back in goes as smoothly as possible and that the situation lives up to residents' expectations (Figure 6-9). For example, in some cases with Passive House revitalization, the indoor temperatures were felt to be too low in some apartments, which resulted in a very negative attitude amongst the tenants with respect to the whole revitalization process.

In some cases, an energy portal was created, where the energy use for heating and DHW is individually measured and evaluated on a monthly basis and presented to the tenants. Using a password, tenants are able to open their individual accounts, where graphics illustrate energy use for space heating, hot water, cold water, and electricity, on a monthly and annual basis.

In summary, knowing the specific interests of the residents, either renters or owners, is essential for investors and planners; this became an important focus for the research. The prospect of improved quality of life is an important motivation for tenants to tolerate inconveniences during renovations and for many establishes expectations concerning a new period in their lives.



Figure 6-9: Moving back of temporarily evacuated residents in a revitalization project to the refurbished building. Source: Alingsåshem

Potential replicability

Many of the neighbourhood development projects in Annex 51 were also undertaken to serve - when successful - as showcases in their respective countries. This holds true both for new construction and revitalization projects. Revitalization projects are often carried out in neighbourhoods with similar types of houses, for which a successful reconstruction method can be replicated elsewhere in the neighbourhood, city, region, and nation-wide in some countries with similar mass-produced buildings. This is the case for example with postwar construction in several countries or for 18th and 19th century heritage buildings similar to those in the French case study. Another special case is the revitalization of military barracks studied in United States, the results of which could be applied to thousands of similar barracks.

New construction also shows potential for replication, as demonstrated by projects in Germany and Denmark. The Danish project of Lystrup and multifamily buildings in Bad Aibling in Germany both serve as showcases for low-cost, low-energy buildings of the future. These projects are examples of how long-term energy and emissions targets in the buildings sector (e.g. 50% energy savings by 2050) not only create the conditions for implementation but can also be achieved using available technologies. As mentioned, the challenges of replication are predominantly organizational in nature.

6.2.5 Barriers

Since most Annex 51 case studies deal with new or partially new techniques or methods of energy supply and energy use, it is obvious that lack of experience on the part of builders, owners and

occupants, can lead to problems. These can only be overcome by identifying the challenges and opportunities for their resolution. Some examples are described below.

The role of tradition

Tradition plays an important role in our everyday lives and energy conservation sometimes means that we must give up habits, a change which is difficult for most people, and impossible for others.

Traditional behaviors can be found everywhere, in the construction business, at the political level, and on the consumer side. Education, communication and information can be means to overcome barriers to implementing new objectives, development techniques and technologies. For basic requirements legislation such as energy conservation directives are also helpful.

For example in new building construction, even experienced tradespeople must accept new ways of thinking and working and assimilate information regarding new technologies. In some countries for example neighbourhood heating supply systems are common whereas in other countries individual systems are prevalent. From a sustainability perspective, when energy and CO₂ emissions are key indicators (instead of energy end use) modern district heating technology is advantageous in areas with high energy density. Hence a new approach means a paradigm shift. In many countries, however, it can be difficult to establish the necessary know-how, infrastructure and acceptance. This holds true not only for new construction techniques, or district heating, but other forms of renewable energy supplied by local networks, as well.

Another challenge relates to day-to-day life in a Passive House followed by 'do and don't' instructions that presume a certain level of technical knowledge and education. Many people, especially the elderly, experience a life change when moving into a Passive House; some take longer to adapt than others. Several Annex 51 case studies showed that a lack of occupant awareness around required behavior change when using new technologies resulted in considerably higher than anticipated energy use. This could be overcome through information and communication. In one project (Peltosaari), a web-based information system provides feedback to tenants; this is an action seen as necessary to reach energy and emission reductions targets. A key question for older people may focus on the acceptability of having daily life controlled by the Internet or other feedback system. This may not however be a major issue for younger generations.

Legislative and political barriers

Legislation is often seen as a prerequisite for development and revitalization projects. Local municipal administration through long-range planning can stimulate the low energy sector. Municipalities have the opportunity to support low-energy construction through initiatives and planning measures. Especially important is the elimination of barriers and restrictions caused by local vested interests. For this reason, a well-defined regulatory structure is seen as helpful, particularly in countries where legislation is not in sync with the needs of development projects. The development of a common understanding amongst the key stakeholders as to their commitments and anticipated benefits can help to avoid political disputes which can cause delays in any development project.

Obviously, local conflicts based on political disputes and misunderstandings impact on neighbourhood development projects, through delays, changing priorities, or by stopping the project in part or in whole. Sometimes, managers are not familiar with the type of projects involving a large group of stakeholders or customers and energy and sustainability issues may not be among the municipality's priorities or core tasks. In such cases, it would be better to involve the municipal planning office whose staff members are likely more experienced to handle all issues and contact project partners.

Additional measures lead to additional costs

In multi-stakeholder initiatives the opposite of diffuse engagement can also happen when local interest groups try to add objectives not originally part of the project. This will generate additional costs. In some cases, projects have had to be delayed until new funding was identified.

Whatever the reason for delaying development projects, it inevitably costs money which would be better spent on the project itself. Therefore, investing in effective planning tools is highly recommended for improved efficiency in the project implementation phase.

6.3 Lowering energy demand efficiently

6.3.1 Single buildings or whole neighbourhoods?

An important conclusion from some of the Annex 51 neighbourhood case studies is that it is preferable economically to develop or revitalize a whole neighbourhood instead of retrofitting individual buildings. In particular, it is beneficial to develop an overall energy strategy for the whole area with a focus on stakeholder engagement and communication between planners, building developers and other engineering and design professionals. Improving a whole district or neighbourhood means increased flexibility in the design, attractiveness of the area, quality of life of residents, and represents a more secure capital investment.

An example is the German case of Rintheim, where shareholders of the municipally-owned housing company raised the question regarding future cost for energy supply in their housing stock and, in particular, about the investment risk if a large scale, ambitious revitalization program were to be initiated. In 2006, the housing company initiated an optimization study for total lifecycle costs and included an assumption that future energy prices would increase by a factor of 2 (Figure 6-10). When the local utility offered to build a transport pipe from the city-wide district heating system to Rintheim to increase the demand capacity for industrial waste heat, it became clear that the revitalization program had to be accelerated to accommodate the rate of connection of buildings in Rintheim to the new heating grid. Therefore, instead of a step-by-step revitalization approach of individual buildings over many years, rapid implementation was initiated, involving a comprehensive neighbourhood upgrading plan with a retrofit standard optimized according to assumed long-term energy prices (incidentally the price rose to this level the following year).

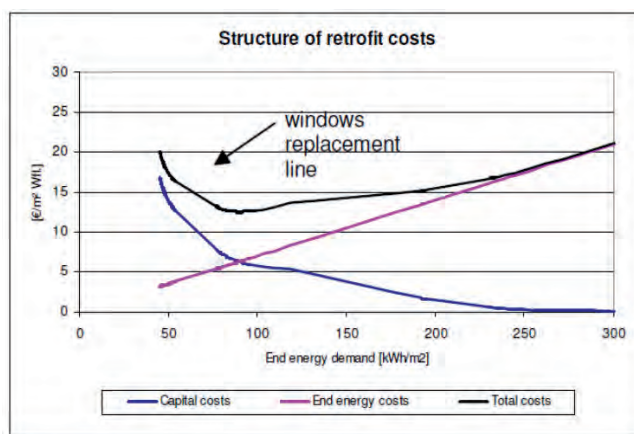


Figure 6-10: Cost optimized energy demand for a building when the choice is between high investment for insulation or high operational costs

Rintheim to the new heating grid. Therefore, instead of a step-by-step revitalization approach of individual buildings over many years, rapid implementation was initiated, involving a comprehensive neighbourhood upgrading plan with a retrofit standard optimized according to assumed long-term energy prices (incidentally the price rose to this level the following year).

Similar conclusions can be made for many revitalization projects where the main objective is neighbourhood revitalization. The revitalization of a single building would not have helped to revitalize the area, occupants would in the best case only pay less rent and the social aspects and quality of life would not have improved on the whole. A whole neighbourhood solution, including green areas, blocks of buildings, annexes, public spaces, commercial areas, a waste handling system and

transportation facilities increases the attractiveness of the area and real estate values and creates a positive dynamic for both tenants and owners. Affordability should not be forgotten for the broad public, but in many societies this problem is solved by public subsidies such as housing allowances.

In new development projects, developing a whole neighbourhood is a common approach, due to infrastructure investments which need to be made at the same time. One or several developers will develop a plan from scratch, containing sustainability strategies reflected in the community master plan and neighbourhood or area plan. Here, different visions can be applied, including areas for different types of clients and purposes. One limiting factor is the affordability of the neighbourhood in question. In the Danish case of Lystrup/Lærkehaven, the upper specific costs of the buildings were limited by a Danish law on cost of social housing. In spite of this law, some of the buildings were constructed according to the Passive House standard.

6.3.2 Increased comfort paid for through energy efficiency

As mentioned previously, most of the projects reviewed had two distinct goals: to let energy efficiency pay for a portion of revitalization costs and to improve occupant comfort. This is a straightforward approach, in which uncertain future costs of energy are paid for through investments in energy savings. This tendency has been observed in many projects: reduced energy use in retrofitted buildings translates into lower and more predictable future operating costs and rents.

The principle of most projects was that the total monthly cost for residents should not be much higher than market rates. This also implies that the cost for the investor is not higher than what would be paid to raise capital in typical market conditions. In projects including energy efficiency measures, the economic value of energy savings can be paid for through incrementally higher levels of investment. Skilled planning and optimization efforts are required to find the trade-off between energy conservation and investment. In principle, this will generally be different for revitalization and new development, depending on the capital tied up in existing real estate and energy savings achieved through potential conservation and technology integration measures.

The results differ widely from project to project and from country to country, despite the fact that all these countries have similar economies. This has to do with traditional national structures such as the role or existence of municipally owned housing companies, interest rates for the building sector, subsidies both open and hidden and so on. What was also found is that revitalization of neighbourhoods can cost nearly the same as new development, and costs of different energy standards in buildings (normal, low-energy or Passive House) are not always discernible.

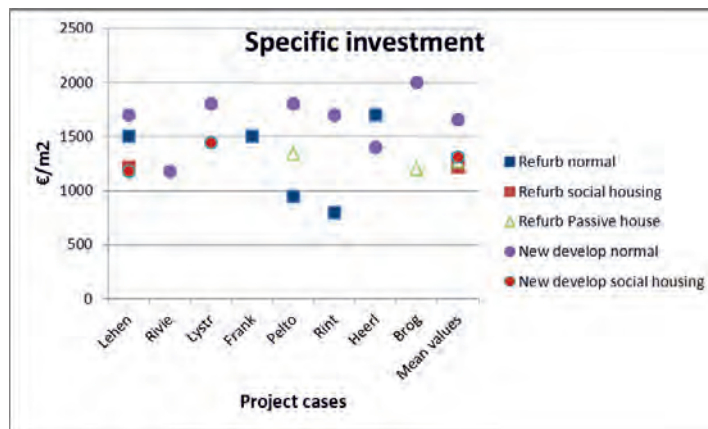


Figure 6-11: Specific investment costs for residential buildings in development projects⁷⁷

In all the case studies analyzed (see figure 6-11). It can be seen that revitalization costs were in general 80% of new development costs, with large deviations amongst the countries. It could also be seen that in some countries the costs (and therefore building standards) for social housing are considerably lower than the average on the open market.

Revitalization costs

Investment costs range between 1,200 and 1,400 EUR/m² for ambitious revitalization to low-energy standards and complicated planning contexts (for example the older, more culturally valuable buildings in Franklin). For less ambitious modernization, costs of between 800 EUR/m² and 1,100 EUR/m² should be anticipated.

These total costs can be differentiated according to the goals of the revitalization. A general distinction can be made using the following cost categories:

- maintenance
- modernization (increase in comfort)
- energy conservation and energy use measures (building-related)
- energy supply-related measures

Maintenance means that the measures were necessary to retain the function of the building and its equipment at a minimum acceptable standard for occupancy. However, with increasing standard of living, occupants often demand an increased level of comfort and modern appliances. Furthermore, part of the revitalization deals with improving energy efficiency, i.e., improved insulation, windows, heat recovery, heating systems, and so on. And finally, part of the investment includes the heat and electricity supply system, for instance renewable heat supply such as solar energy and biomass, piping for heat distribution systems, heat pumps, PV systems, and so on. In figure 6-12 cost examples for some of the projects are depicted. It can be seen that energy-related costs are in general only a minor part of total revitalization costs, with modernization and maintenance costs dominating. Since most of the revitalization projects shown here belong to the social housing segment, the total height of the bars in the diagram indicates the upper level of what revitalization

⁷⁷ The costs represent the investment cost in EUR/m² living area in residential buildings for the Subtask B Case Studies performed in the different countries. The cost level is that from the beginning of 2010. See Zinko, Moshfegh, 2012.

was allowed to cost. This also controls the level of modernization and ambition of the respective projects.⁷⁸

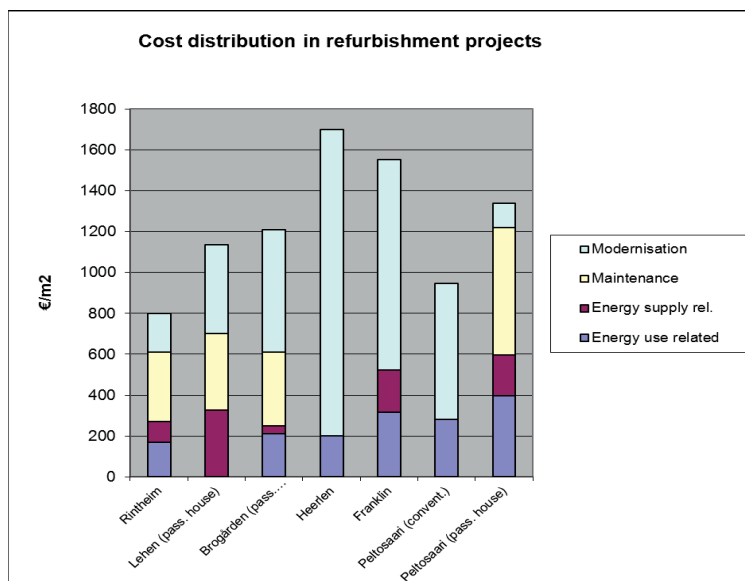


Figure 6-12: Example of cost allocation in revitalization projects in 2010

New residential building costs

As would be expected, new construction costs are generally higher than building revitalization costs. However, as shown in figure 6-13 the costs derived from the case studies are not extremely different from that for revitalization, the difference in costs for new development and revitalization being on average about 20%.

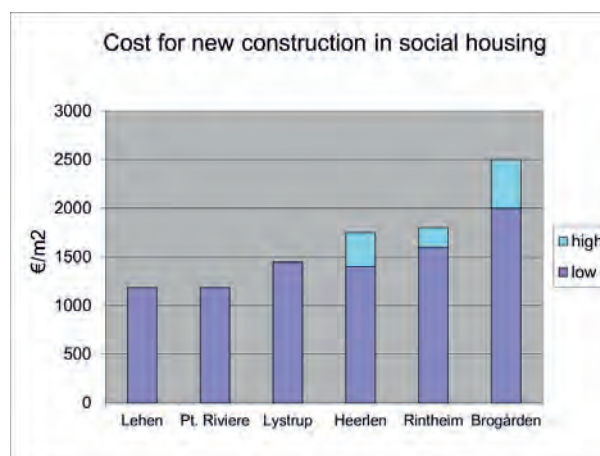


Figure 6-13: Example of cost distribution in new-construction projects (cost level 2010)

⁷⁸ A new EBC Annex was created on this topic in 2011. Annex 56 - Cost-Effective Energy & CO₂ Emissions Optimization in Building Renovation www.EBC.org

For instance, in the Lystrup project, the construction costs of new buildings represent a maximum allowed level for social housing, and are kept low by various subsidies. The case is similar in Lehen, where the allowed cost for new construction is about 25% higher than the planned revitalization costs with moderate energy reductions, but roughly equal to the costs of an ambitious revitalization. Similar low costs for new construction were also shown in the Canadian study for Petite Rivière.

From this review it is difficult to draw general conclusions from the limited number of projects in different countries about which type of energy conservation measures should be recommended. Planners and others engaged in building development and revitalization projects must draw their own conclusions depending on local conditions, costs, energy prices, building materials, goals and values, in order to find an optimal solution for the development.

In some cases it was shown that profit margins can be quite small. In order to make a return on investments in renewable energy systems the system owner must sell energy; for projects with renewable energy technologies this means too much of a focus on energy conservation can be counterproductive. This might be difficult to accept for some administrations or planners, but it is nonetheless an important lesson learned from Annex 51 case studies.

Are energy efficient buildings affordable?

Despite the often very large initial capital investments, total rent including energy costs paid by occupants did in most cases increase, however, only by a small amount. Future cost increases resulting from increasing energy prices will be largely offset by the investment. A limited increase in the rent can be fully justified by the increase in occupant comfort and improved quality of life and neighbourhood. In most of the projects with revitalization of existing buildings, between 50% and 70% reduction was achieved in electricity, gas or biofuels. The investment costs for such optimized systems vary from 800 to 1600 EUR/m² depending on the technology. This is in contrast to capital costs of energy conservation investments amounting to between 200 and 300 EUR/m² on average. The remaining amount is for improvement of occupant comfort and other building amenities.

The Passive House standard can also be met in revitalization projects. The costs, however, will be higher than for economically optimized buildings and will result in additional costs of between 100 and 200 EUR/m², in addition to the costs mentioned above. Depending on the economic terms in the respective country, these extra costs might not always be acceptable either for occupants or investors or both.

Energy plus systems

Energy plus systems supplying renewable energy from a local energy production system to nearby buildings can successfully increase the use of renewable energy while fostering local economic development. Utilities and developers have shown interest in such solutions, as shown by certain projects in Germany, Japan and the United States.

Another alternative to larger district heating systems are local heating supply systems for a few users, as shown by the Japanese case study. Small heating systems feeding local grids with renewable energy derived from sources including biomass, solar and geothermal sources can be more efficient than individual systems. Furthermore, they might work well in locations where district heating is unavailable. Such systems can be owned and operated by one of the building owners or a third party company.

In some countries such as Sweden, the pros and cons of third-party connections to existing district heating systems are being debated. The main risk concerns non-optimized solutions, for example replacing one kind of renewable with another. No matter the technology or ownership model, one

trend is quite clear: in the future, neighbourhood district heating systems will rely less on central heating systems and more on smaller decentralized electrical and thermal energy supply systems.

6.3.3 Monitoring and evaluation

At the time of writing, monitoring results from only a few Annex 51 neighbourhood case studies are available. This is because the projects were either studies or are still early in the implementation phase, preventing monitoring of the final outcome.

In the context of these guidelines, understanding energy savings achieved in a typical revitalization case and energy use in a typical new development is of interest. For example in the Salzburg case study, smart meters collect hourly data on heating, cooling, hot water demand and electricity for each customer. This information is displayed to the customer who can control both his or her behaviour and the operation of a very sophisticated energy supply system. The data is sometimes also made available to the utility or the municipality. In some projects, additional information on user behaviour, climate control and equipment performance is collected for analysis by university research projects.

In the Swedish Brogård project, at the time of writing, about ten buildings have been refurbished or are under revitalization. Of these buildings only one with 16 dwellings has been monitored for a whole year from April 2010 to April 2011 (Zinko, Moshfegh, 2012). Figure 6-14 shows the results, enabling evaluation of different energy use before and after revitalization. Household electricity is also presented but should, according to the Swedish regulation, be excluded in the energy rating process.

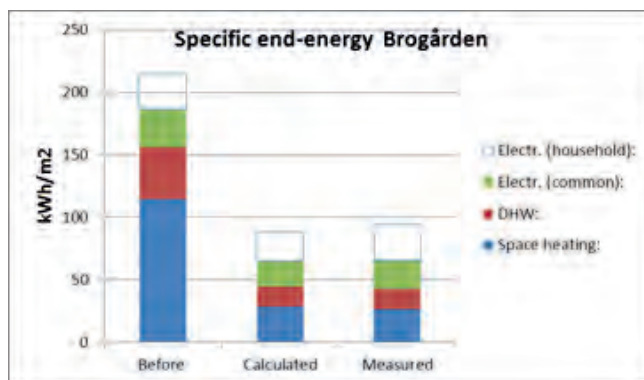


Figure 6-14: Specific energy end-use in Brogård before (2004) and after revitalization

Therefore measured and calculated or modelled results are comparable in this case. Energy end-use is reduced by more than half.

Figure 6-15 shows energy use before and after retrofit for six revitalization projects. In these projects, results are based on measurements or calculations from single objects, i.e. they are believed to be typical for the total neighbourhood. Results for neighbourhoods are at the moment available only for the case of Rintheim. The energy end-uses include heating, domestic hot water, and electricity for lighting and equipment in common areas but not household electricity.

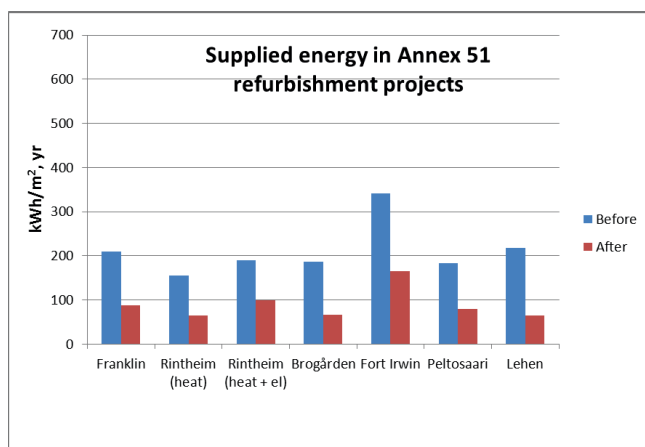


Figure 6-15: Measured energy use before and after revitalization in six Annex 51 projects (typical values)

Corresponding primary energy savings are shown in figure 6-16. These savings are based on individual primary energy factors applied to the energy use by the case study projects of each country. For this reason, savings in mostly fossil-fuel based energy supply of Fort Irwin, United States⁷⁹ is predominant in the diagram.

In some cases, the use of primary energy is reduced by energy conservation in the buildings as well as by renewable energy supply such as solar (Lehen, Kumagaya) and geothermal energy (Heerlen). For these projects, energy saving through a combination of measures is presented in figure 6-17.

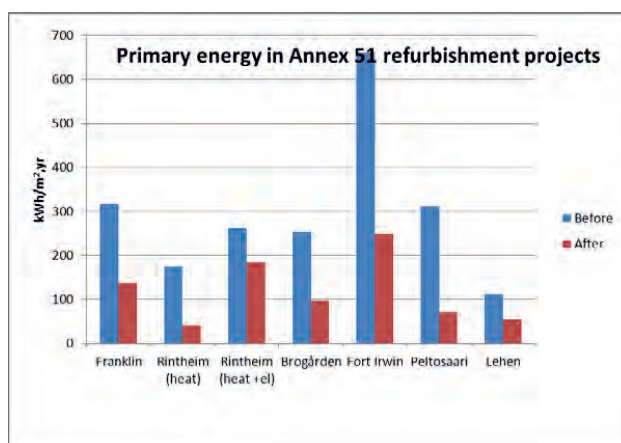


Figure 6-16: Specific primary energy savings in the projects of Annex 51 neighbourhood case studies

In Heerlen, cooling is also supplied by the same heat delivery system based on geothermal energy from abandoned flooded coal mines. The cooling energy delivered to an office building during one year is about half of the heating energy supplied.

⁷⁹ Fort Irwin is a military camp with about 1600 buildings, located in California. It accommodates recruits and provides facilities for military training. Electrical energy is supplied via the grid and heating energy is mostly supplied via Liquid Gas (LPG), therefore the high amount of fossil fuel and primary energy in this case.

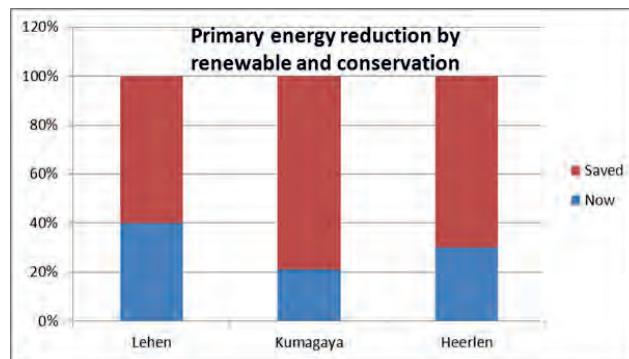


Figure 6-17: Primary energy reduction by conservation and renewable energy supply in three Annex 51 projects

Two cases (Lystrup, Petite Rivière) describe new development projects. In these cases, the use of primary energy is reduced by 50% – 60% compared to a reference neighbourhood. This corresponds in both cases to around 70 - 80 kWh/m² primary energy including electricity for operation of buildings energy equipment.

Verification essential for project implementation

One important finding is that monitoring and subsequent evaluation of the anticipated energy goals and cost structures should be an essential component of energy conservation projects. A good idea is to start energy monitoring very early in neighbourhood projects to get feedback on the effectiveness of the measures implemented. This early evaluation in larger projects can result in changes to the methods initially chosen and lead to cost savings and/or quality improvements that finally secure the projects' anticipated success, as was the case in Franklin and Brogård.

Monitoring is also important for the verification of planning, design and optimization tools. In some projects it was shown that although tools were detailed and carefully developed, the coincidental influence of one parameter, for example temperature sensors exposed to sunshine, can lead to malfunction of the whole system. Only verified qualified monitoring can provide clues in such cases.

6.4 Lessons learned from neighbourhood case studies

6.4.1 Why districts or neighbourhoods?

An important conclusion that can be drawn from the case studies is that it is more economically viable to revitalize a whole neighbourhood than to refurbish individual buildings. In particular, it is beneficial to develop an overall energy plan for the intended area, with an emphasis on communication and collaboration between planners and multiple stakeholders. The revitalization of a whole district or neighbourhood can increase the local attractiveness of the area and the quality of life of residents. Reduced risk associated with capital investments is an important co-benefit for investors.

6.4.2 An integrated planning approach

The most effective way to reach project targets was shown to be an integrated approach for a whole neighbourhood, district or quarter. In this approach, many aspects of development, such as energy efficiency, security, affordability, mobility, and the like are treated simultaneously in order to provide optimized quality of life for the tenants and a secured return on investment (ROI) for the shareholders' capital. Such an integrated approach shortens the development timeline and clears the path for advanced technologies and methods to be applied (e.g. connection to district heating).

Numerous advantages can be observed when taking an integrated approach. These include:

- A paradigm shift allowing for technology selection that aims to reach long-term climate targets instead of incrementally improving existing technologies or approaches
- Accelerated implementation of local energy policies
- Increased security of investments
- Supportive, innovative financing conditions
- Fostering a synergistic and holistic approach to city planning
- Accelerating the pace of retrofits for the benefit of residents and landlords (in contrast to uncoordinated or step-by-step revitalizations taking place over longer periods of time)

6.4.3 Organization

The experiences of the Annex 51 projects show that in general, two important groups of actors take the lead in neighbourhood planning and revitalization initiatives: municipal administration departments and investors and owners, including both public and private organizations. Other stakeholders such as tenant organizations and utilities play a less dominant role in project initiation, but can still exert an influence. These stakeholders must therefore, from the very beginning, be involved in a transparent decision-making process that leads to a consensus. This process should be organized by a responsible leader who is in charge for the duration of the process and who has the power and the budget to delegate duties and subtasks to other stakeholders. It is necessary to require a commitment from all stakeholders to common targets and transparent co-operation throughout the planning and construction phase.

Many case studies revealed tensions between the visionaries advocating drastic energy-saving principles and the clients paying for the investments (ultimately paid by tenants). Hence it is meaningful for future research on neighbourhoods to address the following important questions:

- What policy instruments do cities have to make committed targets binding for the participating parties?
- Who is ordering and paying for common tasks such as energy planning and optimization, for a whole neighbourhood or community?
- Who defines the practical boundaries of community projects and by what criteria?

6.4.4 Quality agreement and control

An important issue for project stakeholders during not only the project planning process but also during and following implementation is quality control. Lessons from Subtask B projects demonstrated that rigorous goals regarding energy standards and sustainability might not be met if a quality agreement was not established with all partners. It was also important for the members of the project steering committee to make sure that contractors and vendors receive the necessary quality agreement information and understand what it means for their work.

6.4.5 Policy instruments

It is quite obvious from the case studies that policy instruments influence the outputs and outcomes of the project contract. In many countries, funding schemes are available which might be applicable to projects that comprise novel approaches or interesting issues such as approaching sustainability from multiple perspectives. It is important that project managers should eagerly pursue the accessibility to such funding opportunities, partly because the novelty of the project increases the chance of its success and partly because it is a promising way to increase the interest of tenants/residents in the project.

The availability of subsidies and other policy instruments such as tax reductions or simply local or national regulations have been important factors of success in many projects. For instance, external stakeholders can at times influence investors to fulfill additional requirements, for example energy targets, innovations, evaluation and learning processes and to obtain subsidies.

It should be remembered, too, that these policy instruments are independent of the local or national context and may not be accounted for in all cases of neighbourhood development.

6.4.6 Planning for lowest cost

Since the widespread market adoption of ambitious neighbourhood or district energy concepts will in general receive little public funding, economic optimization including long-term life cycle assessment will be required. Otherwise, there will be no implementation. That means that energy demands may not be reduced as far as technically possible, but rather only as far as it is economically viable. In addition, energy supply should be integrated into an integral system optimization. Here, either utilities or local ESCOs may be involved, who have the flexibility and practical know-how to handle low energy demand density or high capitalized costs.

Important efforts in the planning process are directed towards the well-being of the tenants/residents. Most of the case studies contributed to Annex 51 are/were organized by social housing companies or similar entities. This implies that the tenants are a target group for which regulations regarding the upper limit of their monthly rent are effective. This means further a tradeoff between how much can be paid for the amortization of fixed costs and how much for operating (energy) costs. This arrangement limits the amount of investment that can be spent on housing projects.

6.4.7 Planning tools

While computer-based planning tools for buildings are available and widely used by planners and architects, planning tools for neighbourhoods are not. It would be helpful to have additional tools for neighbourhood planning in the early planning stages, similar to the District Energy Concept Advisor described in Chapter 5. Of course, any energy pre-planning must be integrated with broader neighbourhood targets, for example on water and air quality and transportation. Following this line of thinking, models supporting multi-criteria optimization looking at all aspects of sustainability are desirable. In practice, the approach is modular insofar as energy planners are using specific purpose built models to support quantitative assessment in different domains, combining the outputs to assess results in an integrated manner. This supports municipalities and stakeholders in understanding the quantitative implications of certain scenarios but also in making tradeoffs by prioritizing certain measures over others. Research into integrated modelling approaches is ongoing in universities and governments. See chapter 4 for more information on planning tools.

6.4.8 Information and education

Planners and architects will have an educational task to transfer the basic knowledge of new technologies to the workmen who in the end have to execute the job with the desired quality label. In some projects, the information, education and training of the labor force was an important initial phase for the whole task. The work was often organized in a modern horizontal organization with broad responsibility for the employees. Weekly planning, done as a group, is visualized in a table and available to everybody. This made everyone part of the progress.

The same holds true for all work with new developments where new methods and technologies are used. Even experienced workmen have to accept new ways of thinking and information and education of all participants are important and necessary preconditions for a successful low-energy execution of the construction.

6.4.9 Involving residents

Energy-effective systems, such as presented by low-energy buildings or Passive Houses, need a good deal of involvement from the tenants. Partly they have to understand the systems and control equipment to some degree to enable them to check that it works properly, and partly they must consciously follow the instructions that result in a successful energy-saving strategy. Therefore, information and education are part of the owner's strategy towards the tenants.

Furthermore, in revitalization projects, it is very important that the owner and the tenant build a relationship of mutual trust. The revitalization work often implies a drastic impact on the life of the tenants which must be met by the owner with a shrewd mixture of empathy and incentives in order to maintain a positive attitude by the tenants. Increased housing costs might be an impediment. Continued regular information and accessibility for proposals and ideas on the part of tenants is an important ingredient for successful projects. Every measure and every instruction must be comprehensible to the tenants in order to be able to achieve tough energy-saving goals. The latter is very important in cases where reduced energy costs have been used to compensate for accepting increased rent.

Information to the public, reported via the mass media, also gives the tenants a sense of the importance of their housing and their living situation. In many cases it was recognized that the awareness of being a part of a new and innovative system which received public attention also increased the self-respect of the people involved.

6.4.10 Energy efficiency

When planning for a reduction of energy use in neighbourhoods, low-exergy concepts that take advantage of energy cascading and low temperature applications will become increasingly interesting. Such systems, however, must be carefully planned even in the first steps of building and energy system design and discussed with the other stakeholders of the project in detail. In fact, the identification of the optimum between reducing energy demand to allow low-energy solutions and the possibility of amortizing the investments made for energy conservation measures by selling enough energy can often be quite narrow and is not very stable.

As a rule, an integrated planning approach considering energy conservation, low CO₂ emissions aspects of heat supply and demands (by means of renewable energy) and advanced building constructions measures, will result in the most economic solutions. Integrated planning is therefore a method which can be further recommended for neighbourhood development tasks. It is also important to coordinate short-term planning with the municipalities' long-term strategies in order to avoid local sub-optimizations for neighbourhoods and ensure coordination with the master plans.

6.4.11 Technological achievements and solutions

Energy efficiency may be achieved by applying non-conventional methods at the time of construction. In most projects it was common to increase the insulation in walls, ceilings and windows. In some cases, advanced types of prefabricated façade elements could successfully contribute to reduction of costs and energy demand. In Passive Houses and in some low energy buildings, air tightness and ventilation air heat recovery systems are the important building envelope and mechanical components. Solar or geothermal heating and heat pumps make important contributions to the reduction of non-renewable energy. While none of these systems are novel, they become economically viable in current market conditions. Local district heating systems, often at lower than normal temperatures, contribute successfully to energy efficient system solutions. PV systems are also applied, but still require high financial subsidies.

The greatest differences between conventional project implementation and that seen in the case studies are the ways to plan and implement energy efficient solutions: i.e. how to establish energy targets, stick to them at every step along the way and finally monitor and evaluate building and system energy performance to see if the targets were attained in reality.

6.4.12 Monitoring

In most of the case studies, monitoring is seen as a separate endeavor and not as an integral part of the energy conservation project. This is because most Annex 51 case studies were showcase projects with evaluation and monitoring being carried out by universities or similar institutions. Instead it is recommended that verification of anticipated energy targets and cost structures should be an essential component of any energy conservation project.

When discussing the energy optimization of neighbourhoods and districts, monitoring results should be presented by using relevant figures and supporting indicators. Since community projects involve multiple aspects, there must be a set of parameters indicating overall energy quality. Such parameters can include: average energy performance of buildings, non-renewable primary energy demand and share of local energy production. For the time being, there is no standardized and accepted set of key parameters and indicators for monitoring of energy and emissions in communities.

New development case studies show that it is possible to plan and build areas with low energy buildings or Passive Houses at essentially the same costs as conventional new construction. In the two new development cases in Canada and Denmark, the costs for dwellings in new buildings are 1,265 and 1,445 EUR/m², respectively, at the low end of costs for new construction.

In revitalization projects it was shown that essential saving of both primary energy and end-energy by more than 50% can be achieved at costs which, depending on the envisaged standard, are only slightly higher than conventional revitalization projects. The typical range of revitalization costs in the Subtask B cases studies were 1,200 -1,300 EUR/m², but with values as low as 800 and as high as 1,700 EUR/m², depending on standard, ambition and national cost levels.

APPENDIX to Chapter 6

	Austria	Stadtwerk:Lehen – revitalization of a city district in Salzburg	
Project vision and objective		Revitalization of a rundown urban area with the intention to improve quality of life by creating a district aimed at sustainability as far as environment, energy, and social life is concerned.	
Location		47°48'15" N, 13°02'6" E	
Time frame		2005 - 2014	
Type		Neighbourhood development	
Number of residential buildings		60 existing, 40 new	
Number of dwellings		550 existing, 623 new	
Other buildings		Not specified	
Description		The <i>Stadtwerk:Lehen</i> case study is a midtown area in Salzburg just northwest of the city center. It is home to approximately 15,000 inhabitants. Most buildings are owned by the City of Salzburg. Increasing traffic had reduced the area's attractiveness and changes in the socio-economic and ethnic makeup of residents led to reduced social cohesion. The purpose of the case study was to revitalize the neighbourhood through a combination of revitalization, new buildings and a new district heating system based on solar and biomass which supplies thermal energy. Where the former utility once stood, new residential and commercial buildings have been built to high energy efficiency standards. Because existing buildings were mostly erected after World War II and had not yet been renovated, an integrated energy concept has been applied that includes both demand and supply side measures.	
Achievements		The following projects have been implemented so far: - <i>Fallnhauser Areal</i> : Residential buildings with focus on architectural design. - <i>Neue Mitte Lehen</i> : Residential buildings and municipal library on the area of the former football-stadium, developed with the approach to define a new Centre of Lehen. - Establishment of a train-station as part of the new city-train concept.	
Lessons		- Holistic approach of simultaneous retrofit, energy switching and neighbourhood development offers an opportunity to increase attractiveness and security of investment. - Community development often means complex ownership structures with different interests. Implementation of optimized energy concepts is only successful if there is successful leadership of the implementation process. - Energy optimization and integration of renewable energy in communities need optimization of technologies and operation control.	

Figure 6-18: source: SIR

Figure 6-18: source: SIR

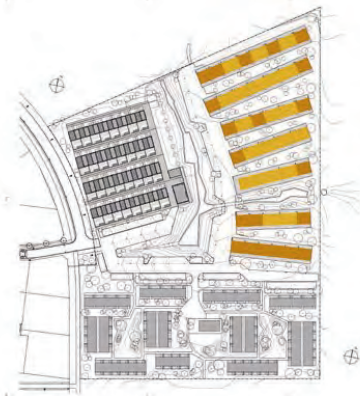
	Denmark	Low-energy neighbourhood Laerkehaven in Lystrup, near Aarhus, North Jylland	
Project vision and objective		Integrated sustainable building, district heating network and energy supply solutions to accommodate future residents.	
Location	56°14'57" N, 10°14'57" E		Figure 6-19, source: Ringgården
Time frame	2004 - 2011		
Type	New development		
Number of residential buildings	105 new		
Number of dwellings	122 new		
Other buildings	Activity Building (new)		
Description	Lystrup is a suburb of Aarhus, the capital of Jylland, Denmark. The neighbourhood is located 10 km north of the city. The project deals with planning, implementation and evaluation of a sustainable housing area. In total 122 low energy dwellings in 105 buildings have been built according to three design types in different parts of the development area. The buildings are either detached houses or row houses for one or two families. The buildings are connected to a low-temperature district heating network operating at around 40°C.		
Achievements	<i>Laerkehaven</i> is the result of an international architectural competition. Precise sustainability targets and requirements were prescribed in the call for proposals. The buildings have either Passive House standards with annual heating energy demand of no more than 15 kWh/m ² or a low energy standard of 30 kWh/m ² .		
Lessons	- This national showcase project required extensive collaboration between housing associations, industrial partners, architectural and engineering consultants. - Increased capital investment was required during the construction phase to achieve the development's energy goals. - Project partners analyze residents' energy usage behavior through a wireless data collection system which is available to tenants on the internet.		

Figure 6-19, source: Ringgården

	Canada	Revitalization plan for Petite Rivière, Montreal⁸⁰	
Project vision and objective		Development of a former recreation area for true sustainable living	
Location	45°30'18" N, 73°40'12" W		
Time frame	2007 - 2020		
Type	New development		
Number of residential buildings	46 new		
Number of dwellings	1461 new		
Other buildings	4,600 m ² commercial	Figure 6-20, source: Equilibrium for Communities	
Description	The project is situated near the city of Montreal and envisions a neighbourhood of 24 ha (former curling arena and golf course) and is planned to achieve 70% reduction in the ecological footprint through the application of good land use practices and renewable technologies. Meadowbrooke Groupe Pacific, a private developer, and the City of Montreal share the vision that sustainable development is possible from both the building and community perspectives. The Petite Rivière development will be a 'living laboratory' to further develop the design with modelling, design and optimization of energy systems in the built environment. The buildings are a mix of two to four storey structures.		
Achievements	The neighbourhood design plan aims towards zero carbon and zero waste in general. For residential buildings an annual heating load of 18 kWh/m ² and a cooling load of 11 kWh/m ² are anticipated. Hot water demand will be around 2,000 kWh (19 kWh/m ²) and total electricity demand around 4,500 kWh (42 kWh/m ²) per dwelling annually.		
Lessons	- The local electricity supplier delivers hydropower specified as renewable. - Low natural gas prices and a low cost monopolistic electricity market create a challenging business climate for renewable energy technology providers. - Electric heat pumps are therefore a viable short-term option and biogas from a sewer plant is considered as a future solution developed as a municipal-industrial symbiosis project.		

⁸⁰ Project delayed

	Finland	Eco-efficient renewal and revitalization of a neighbourhood, Riihimäki, Peltosaari	
Project vision and objective	Eco-efficient renewal and revitalization of a neighbourhood by technical, architectural and socio-economic development		
Location	60°44'8" N, 24°47'6" E		
Time frame	2009 - 2020		
Type	Neighbourhood development		
Number of residential buildings	65 existing, 60 new		
Number of dwellings	~800 (53,000 m ²)		
Other buildings	50,000 m ² 2 commercial, 1 school		
Description	The Peltosaari neighbourhood was built during the 1970s and 1980s next to Riihimäki city center, about 70 kilometers north of Helsinki. The largest concentration of social housing owned by the City is located in the western edge of the neighbourhood. Centralized social housing has caused social problems. The unemployment rate in the neighbourhood is approximately 27%. As socio-economic problems have increased property values have decreased. This situation requires radical action to prevent further social exclusion and segregation. Today Peltosaari has some 2,800 residents compared to the 3,600 previously.		
Achievements	An 'ideas competition' on the renewal and revitalization of Peltosaari was organized by the City of Riihimäki with the Finnish Architects Union and The Housing Finance and Development Centre. A total of 61 entries were submitted. During the evaluation process the jury could follow public comments about the entries online. The aim of the competition was to prove different possible solutions. The competition entries served for decision-making and planning of the new Peltosaari neighbourhood.		
Lessons	By looking at market rents for apartments in neighbourhoods nearby, the lost value of real estate in Peltosaari is an estimated 77 million EUR. If all existing buildings were to be renovated according to model building solutions, energy savings would total 11 GWh per year. This corresponds to between 1 and 1.5 million EUR in cost savings in the existing building stock. By renewing the neighbourhood's master plan through demolitions, infill development and extensions, new offices and recreation buildings and effectively creating a new image of the neighbourhood, the value of the existing building stock is estimated to increase to 100 million EUR. Increased urban comfort and connections to the city center across the railroad tracks will be emphasized. The whole renewal process of the existing building stock will cost between 80 and 90 million EUR, corresponding to roughly 1,350,000 EUR per building or 850 EUR/m ² ; approximately one-third of these costs are attributable to energy efficiency improvements.		

	France	Low-energy building renovation in a historic area of the city centre of Franklin, Mulhouse	
Project vision and objective	Rehabilitation of rundown buildings within a historic preservation area with an objective of a substantial reduction of energy use		
Location	47°44'76" N, 7°19'52" E	 Figure 6-22, source: Andreas Koch	
Time frame	2005 - 2012		
Type	Revitalization		
Number of residential buildings	300 renovated and around 100 demolished		
Number of dwellings	120		
Other buildings			
Description	The Franklin district was built by the leaders of the Mulhouse textile industry between 1880 and 1910 to house their workers. The area was economically depressed and as the buildings became more run down there was a corresponding fall in occupancy. In 2004, the city started a revitalization process. The local authority wanted to preserve the strong working-class identity of the area while implementing extensive renovations which would have a practical impact on the urban environment and on the inhabitants' quality of life. The low energy building standard (BBC1) was set as a target by the Local Energy Agency (ALME). It was given the mandate by the City of Mulhouse to optimize energy use partly based on renewable energy. It also coordinated and led the operation, being responsible for accompanying contractors and project managers in applying their energy measures.		
Achievements	The primary energy demand was reduced from 450 kWh/m²/a to the set target of about 50 kWh/m²/a. To achieve this, several main tasks were defined: - Insulation was increased for walls and windows (triple glazing), taking summer comfort into account. External insulation was preferred where possible with the exception of historical façades or the encroachment onto the sidewalks. - The existing heating distribution system including the radiators were maintained but supplied by new wall-mounted condensing gas boilers. - Air exchange was ensured via mechanical ventilation with heat recovery, centralized for each building. - Domestic hot water (ECS) was taken care of by solar water heaters, from 5 to 7 m² per building, meeting about 40% of the hot water demand.		
Lessons	- Monitoring of energy use beginning in the construction phase is very important to reach targets.		

	- Information and education on new energy technologies are an important precondition for the success of an energy efficiency project. - Misunderstandings or noncompliance with instructions lead to higher energy use which could be detected through monitoring. - The acceptance of new technologies by tenants and their energy usage behavior is part of the success of a project.

	Germany	Future-proof development concept for the residential sub-district Karlsruhe-Rintheim	
Project vision and objective	Development of an economically viable retrofit and energy supply concept by minimizing fossil energy use while ensuring future attractiveness for inhabitants and investors		
Location	49°01'44" N, 8°26'44" E		
Time frame	2008 - 2015		
Type	Revitalization		
Number of residential buildings	40 existing, 3 new		
Number of dwellings	1,350 existing, 110 new		
Other buildings			
Description	Karlsruhe-Rintheim is an urban housing estate located in the northeastern part of the City of Karlsruhe. This residential neighbourhood consists of 40 buildings, 90% of them multifamily dwellings, of which 30 buildings are owned by the municipally owned housing company VOLKSWOHNUNG. The total area is 250,000 m², with a total residential area of 77,000 m². The buildings are a mix of four to five storey low-rise apartments and high-rise apartment buildings of up to 17 stories. Four of the buildings have been demolished and will be replaced by new buildings. According to a detailed optimization, economically optimal energy conservation targets for heating demand are in the range of 40 to 50 kWh_{th}/m², post-retrofit, corresponding to an average heating demand reduction of 65%. In combination with efficient district heating, an 80% reduction in primary energy consumption and associated CO₂ emissions will be achieved after the project is completed.		
Achievements	Technical achievements include: - Application of new planning approaches and tools. - Introduction of a neighbourhood-wide energy monitoring system including feedback to the tenants. - Application of innovative technologies such as vacuum insulation elements and sunlight shading equipment in the revitalization of two of the multi-family buildings. - Results of analysis in the planning phase corresponded closely to		

Figure 6-23, Source: VOLKSWOHNUNG GmbH

	measured energy use in buildings following revitalization. - A detailed assessment and evaluation study collected project experiences, the results of which can be applied to future projects.
Lessons	By using conventional yet integrated energy retrofit measures for typical post-World War II construction in Karlsruhe, a 60% decrease in heating demand is both possible and economically feasible.

	Germany	A former military base on its way to a zero energy city, Bad Aibling
Project vision and objective	Revitalizing a former military base by refurbishing existing buildings and building new energy efficient residential and commercial areas.	
Location	47°52'12" N, 12°00'36" E	
Time frame	2008 - 2014	
Type	Neighbourhood development	
Number of residential buildings	52 existing, 21 new	
Number of dwellings	183 existing, 60 new	
Other buildings	40,000 m ² of offices and hotels.	Figure 6-24, source: B&O Wohnungswirtschaft / Schankula Architekten
Description	The former Bad Aibling military base was built in the 1930s, serving as a US airbase and barracks. Following German reunification in 1990, the base lost its importance and was abandoned in 2004. The B&O real estate management and construction company acquired the estates (700,000 m²) in 2006. The vision is to create a zero energy city. This objective will be achieved by implementing high energy standards, innovative technologies and modern project management and planning instruments. Furthermore, the neighbourhood's energy system will be monitored systematically. Several projects inside the development serve as show cases.	
Achievements	- Refurbished buildings exceed current mandatory new building standards: low-exergy and Passive House standards will achieve energy savings of significantly over 50%. - The local heating plant has been completely renovated, incorporating renewable biomass and solar energy sources and using the existing distribution network with improved thermal insulation. - In addition to the 3,500 m² of PV systems already installed on commercial buildings, a field with approximately 15,000 m² ground-mounted solar cells and a small hydro power plant are planned. - The energy supply of the development will be completely based on renewables. Feed-in of excess solar electricity into the public grid is anticipated. - Several demonstration projects have been built as show-cases for	

	further development projects. One is a wood frame multi storey mixed-use building; load-bearing wood construction over several floors is novel in Germany (see above).
Lessons	- The investor had the capacity to manage both planning and implementation. Working groups were formed for the different project tasks. - The main objective was to achieve net-zero energy over the entire development; all sub-projects had to serve this purpose. - The neighbourhood is promoted as a normal property development offering a regular return on investment. It also acts as a technical innovation demonstration site for building construction and technical equipment.

	Japan	Inter-building thermal transfer system for extended use of solar heat, Kumagaya, Tokyo
Project vision and objective	Solar energy for heating and cooling purposes, for both own use and export to neighboring buildings	
Location	36°08'24" N, 139°23'24" E	
Time frame	2008 - 2012	
Type	Neighbourhood development	
Number of residential buildings		
Number of dwellings		
Other buildings	Hotel and offices	Figure 6-25, source: Tokyo Gas Co., Ltd.
Description	Kumagaya City is well known for its hot summers; it is where the highest recorded temperature of 40.9°C was set in 2007. The city is also ranked first for the annual number of sunny days in Japan. The Kumagaya building is an office building of Tokyo Gas Co. On an annual basis, it only has a small heat demand for hot water supply; its solar collector system produces surplus solar heat. The Maroudo Kumagaya Inn, a hotel across the street has large thermal energy demand and a different thermal energy load profile than the office building. Recognizing the different load characteristics of these two buildings, Tokyo Gas designed an inter-building heat transfer system to maximize the use of solar heat.	
Achievements	- The system includes the following components: - Evacuated tube solar thermal panel, 47 kW - Heating and cooling system: solar heat absorption chiller, 35 kW (cold); gas-fired absorption chiller, 141 kW (cold); domestic hot water	

	heater: condensing gas boiler, 87 kW - Thermal heat transfer system: hot water circulation pipes, water storage tanks 1,000 + 450 l - PV-system: 5 kW polycrystalline silicon cells - Micro cogeneration system (natural gas): 25 kW; heat recovery 35 kW; fuel input: 75 kW.
Lessons	- A 78% reduction in primary energy was achieved through use of renewables instead of natural gas. - The project serves as a showcase for similar projects in highly populated areas of Japan.

	The Netherlands	Low-exergy systems through re-mining abandoned coal mines, Heerlen	
Project vision and objective		Demonstration of the use of mine water, a locally available low-value renewable energy resource, for heating and cooling of buildings.	
Location		50°54'36" N, 5°59'12" E	
Time frame		2006 - 2012	
Type		Neighbourhood development	
Number of residential buildings			
Number of dwellings		110 existing, 330 new	
Other buildings		Offices and public services, 120,000 m ²	Figure 6-26, source: Cauberg Huygens
Description		This project demonstrates the use of low-temperature heat taken from abandoned coal mines. For heating, 35°C water is available at a depth of 800 m. For cooling, water of between 16 and 18°C can be obtained in another well at 250 m. The quality of the heat or cold is further improved by heat pumps or boilers. Existing buildings have been refurbished and new buildings have been designed including low-energy systems. Water is returned to the mine in a separate well around 25°C 400 m deep. Three areas are supplied with different heating and cooling supply systems: - Heerlerheide Centre: 330 new residential dwellings with a total area of 33,000 m² and 20,000 m² of commercial and public floor space. - Stadspark Oranje Nassau: The load comprises 110 apartments, 14,000 m² of commercial building floor space, a 4,000 m² hotel, 40,000 m² of new office space and refurbished office buildings covering another 43,500 m². - ABP head office: the ABP head office with 41,000 m² of floor space has been refurbished. It will be connected to the mine water system. Post-processing takes place in a building-integrated energy center	

	using heat pumps.
Achievements	This development was done using an integrated design approach. The energy efficient building is combined into one integrated energy efficiency design concept with an optimized indoor climate, thermal comfort and occupant satisfaction.
Lessons	- When planning water distribution in low exergy (LowEX) district energy systems, a distinction should be made between the design temperatures for heating, cooling and DHW and any seasonal variations. - For efficient energy use in neighbourhoods, low exergy concepts will become increasingly interesting. Such systems, however, must be carefully planned from the beginning and discussed with the other stakeholders of the project in detail. - Identifying the optimal balance between reducing energy demand to allow low exergy solutions and selling enough energy to recouping capital expenditures for energy conservation measures can be quite narrow and is not very stable.

	Sweden	Revitalization of multi-family houses to the Passive House standard in Brogården, Alingsås
Project vision and objective	Revitalizations of municipally owned buildings by letting reduced energy costs pay the restoration	
Location	57°56'12" N, 12°32'24" E	
Time frame	2008 - 2014	
Type	Revitalization	
Number of residential buildings	18	
Number of dwellings	300	
Other buildings		
Description	Brogården comprises 300 dwellings in 18 buildings built in 1973 through the Swedish 1 Million apartment Program (<i>Miljonprogrammet</i>). Each building is three storeys high, has two or three entrances and between 16 and 18 dwellings. The buildings in the quarter of Brogården are for pure residential applications, i.e. service and commercial locals are not foreseen there. The dwellings consist of a suitable mixture of two, three and four bedroom apartments, each with their own kitchens, bathrooms and hallways. The project is based on economic, environmental and social sustainability. Costs paid by the tenants after the renovation should not deviate much from the costs paid prior. Energy cost savings pays a	

Figure 6-27, source: Alingsåshem

	portion of the cost of renovating the buildings to the passive house standard.
Achievements	- Annual energy use for heating and hot water supplied through the district heating system was reduced by 90 kWh/m² to 55 kWh/m². Annual electricity use was reduced by 19 kWh/m² to 40 kWh/m². - An important feature of this project was the on-going communication between the property owner Alingsåshem and the tenants. Alingsåshem publishes a bi-monthly bulletin and holds regular information meetings for tenants. - A demonstration apartment was also created in the first completed building, which allowed Brogården residents to visit and understand how their apartments were to be renovated.
Lessons	- Communication and cooperation with residents is a vital component of the project as the redevelopment involved relocating residents to temporary accommodation while their apartments were being renovated. - The cooperation between housing company, architect and entrepreneur was quite successful in establishing working methods and working schedules. - Politicians, management and technicians are cooperating with the same strategy. - A win-win contract was established between owner and general contractor stimulating cost reductions due to the learning curve during the construction process; it took five years to renovate 18 buildings. - Tenants had to learn how to live in the new Passive House-designed buildings which required changes in heating usage behaviors.

	USA	Working towards Net Zero Energy, Fort Irwin, Barstow, CA
Project vision and objective	Revitalization of military facilities with the long-term goal to reach net-zero energy and zero GHG emissions.	
Location	34°53'18" N, 117°1'48" E	
Time frame	2008 - 2014	
Type	Revitalization	
Total number of buildings	1,600 existing	
Study sample	5 barracks and 1 dining room, totaling 16,000 m ²	
Description	Fort Irwin, the home of the National Training Center, is a U.S. Army installation located 37 miles northeast of Barstow, CA, in the High	

Figure 6-28, source: Alexander Zhivov

Figure 6-28, source: Alexander Zhivov

	Mojave Desert midway between Las Vegas, NV and Los Angeles, CA. The energy required to serve the needs of more than 1,600 buildings located on the installation is conveyed over long distances. Electric power is transmitted from distant generators through the power grid. Liquefied petroleum gas (LPG) for heating and DHW is trucked to Fort Irwin in bulk. Primary energy use on the installation is very high at over 600 kWh/m². The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) conducted an energy study with a focus on a representative group of buildings located in close proximity to one another. The building cluster investigated comprises five barrack buildings, each with about 2,900 m² of living space and a dining area of 1,200 m².
Achievements	It was found that it is possible to reduce the energy used to heat, cool, and ventilate the building cluster by between 44 and 49% for electricity and between 30 and 59% for heating with payback of six to ten, depending on the alternative chosen. The remaining energy is supplied by electricity from the grid and LPG. The following measures were included in the analysis: - Envelope retrofits - HVAC retrofits - Upgrading the chiller plant If energy supplied is produced by on-site renewables such as biomass, solar energy and PV, a net-zero energy system could be achieved, but at a higher cost.
Lessons	Since the proposed energy efficiency efforts include the implementation of a dedicated outdoor air system (DOAS) and high efficiency dehumidification systems that would dramatically reduce the potential for mold, the lifecycle cost of these systems is far lower than that of alternative systems. The cost savings associated with reducing mold are difficult to quantify, however, in many climates the costs and associated savings are not trivial; costs associated with mold remediation and manpower displacement and relocation can far exceed the life cycle energy costs of the facility.

7 Energy Efficient City Case Studies

7.1 Introduction

Many municipalities have the vision of becoming more energy efficient and climate-friendly. Energy efficiency, energy exchange between buildings and renewable energy are currently high on the political agenda of many municipalities. It can be seen in the case studies, however, that it is difficult to achieve this vision in reality. Necessary processes such as integrated design, organization and collaboration, financing and contracting are often hindered by fragmented, short-term thinking and conflicting objectives among different stakeholders.

Many municipalities develop local energy planning processes on their own, often making the same mistakes made by other municipalities. There appears to be little knowledge transfer between municipalities about how to achieve long-term targets. Effectively working towards energy efficient cities requires a process that is managed in such a way that all ongoing opportunities are identified and stakeholders are involved. This makes it possible to grasp opportunities and advantages of synergy to the maximum, so that energy efficient cities and towns are not only an ambition, but become a reality.

In order to achieve an energy efficient city, a new way of working is required: not only new energy design concepts but innovative combinations of technological, strategic, financial and organizational solutions must be introduced. Knowledge and lessons learned on energy efficiency have been gained through practical experiences by frontrunner projects. These frontrunner projects have been evaluated in terms of bottlenecks encountered, how these bottlenecks were addressed and what strategies were successful. Investigating the best practices in different countries not only provides access to the best international examples, but also shows how different boundary conditions, such as policy, legal or financial frameworks, influence the results in the various countries. In the ideal transition process the boundary conditions are levers which can be pulled to optimize the process.

This chapter presents a top-down approach for energy efficient cities, based on Annex 51 case studies. Top-down approaches occur when municipalities take the lead for the transition to an energy efficient low carbon community and actively engage in various initiatives. This approach emphasizes strong coordination of the transition process, the need for a steering process and priority placed on reaching the long-term goals. To derive short and mid-term milestones, the backcasting method is used. In a multi-level governance context, other levels of government may be actively involved. In addition, bottom-up approaches might involve local community groups interacting in different ways with the municipality.

Other municipalities can learn from the experiences of these frontrunners when undertaking their own local energy transition processes. Using them, these municipalities will be able to identify and lead new initiatives effectively and successfully. It is necessary to understand the transition process on two levels: components of the process and solutions to case study-specific problems and their boundary conditions.

7.2 Case studies

Within Annex 51, the collection and analysis of experiences from frontrunners is based on seven cities around the world. The selected case studies are frontrunners in dealing with long-term goals and implementation plans for their city. The cities in the case studies ranged in size from St. Johann, Austria with 10,000 inhabitants to Stockholm, Sweden with 850,000 inhabitants.

These cities have ambitious long-term targets, as can be seen in the tables below. The targets define energy efficiency differently and use different indicators such as: energy autonomy, energy neutrality, greenhouse gas emissions, CO₂ emissions and the reduction of fossil fuels. Three cities – Ludwigsburg, Stockholm and Tilburg – defined targets on a long-term basis, envisioning the year 2050.⁸¹ Others such as St. Johann and Aarhus have very ambitious targets to be achieved in a shorter period, looking out to 2025 or 2030. Both of these communities are able to gain a significant amount of renewable energy from biomass and wind from their surrounding environments.

⁸¹ A fourth city, Prince George, established a short-term target, but was also required to adhere to a more ambitious long term target established by the province.

Table 7-1: Overview of Energy Efficient City Case Studies (Subtask C)

	Vision and targets	Important bottlenecks	Reasons for success
St. Johann, Austria 10,000 inh.	100% energy autonomy by 2020	- Involving the public and key stakeholders with binding instruments	- Standardized process - On-going process since 1998 - Knowledge transfer with other experts and municipalities - Established e5/eea team
Prince George, Canada 72,000 inh.	A 2% reduction in community-wide GHG emissions from 2002 levels by 2012 A provincial target of 80% reduction in GHG emissions by 2050	- New strategic priorities due to a change in political direction: focus on supporting energy resource extraction and trade, away from energy efficiency and renewable resources and technology integration	- Informed and engaged Mayor and Council - Knowledgeable city staff across various departments - Ability to change public opinion regarding the introduction of energy technologies
Aarhus, Denmark 311,000 inh.	CO ₂ neutrality by 2030	- Lack of backcasting: the targets and strategy are set and projects are launched, but it is not fully clear if the planned measures are enough to reach the targets.	- Frontrunner in CO₂ mapping - Highly committed municipal administration - Political commitment at the highest level - Introduction of Climate Partnerships
Nantes, France 580,000 inh.	50% reduction of GHG emissions by 2025	- Awareness-raising beyond single events - Mobilizing all stakeholders and the public in the community	- Precise knowledge of problems (Carbon Assessment) - Provision of tools and management methods for communities and population - Engaged council members as leaders - Introduction of exchange places between all actors and population (climate workshop) - Long-term commitment and climate plan

Table 7-2: Overview of Energy Efficient City Case Studies (Subtask C)

	Vision and targets	Important bottlenecks	Reasons for success
Ludwigsburg, Germany 87,000 inh.	Energy neutrality by 2050	- Initial skepticism from municipal councilors	- Most actors within the municipal administration support the process - Mayor as leader - Broad commitment from an extended stakeholder engagement process
	100% GHG emissions reduction by 2045	- No organization that owned the issue of implementing city-scale energy infrastructure	- Broad commitment within the municipal administration and councilors - Know-how within municipal departments - Targets institutionalized in municipal policies - Municipal department benefits included in financial models - Partnerships with business and residents through the Climate partnership
Tilburg, the Netherlands 205,000 inh.	Fossil fuel-free by 2050	- Enabling population growth while also improving the environment and public health - Being a small city region but an international leader - Making the region more secure despite increasing global uncertainty - Minimizing climate impacts despite economic growth	- Political support for the process by all parties
	850,000 inh.		

It can be concluded from the case studies that both trivial and structural types of bottlenecks can hinder progress towards energy efficient low carbon cities. Solutions for many of the bottlenecks do exist, but knowledge transfer and implementation is not well organized. What is missing in particular is a focus on the process. Many problems can be avoided through proper organization of the process at the beginning, by anticipating potential bottlenecks and finding the right person to manage the process and also having the right people with the right knowledge in the right place at the right time.

Because achieving energy efficient low carbon cities is a complex task, the following sections present a few suggestions to successfully engage in this process.

7.3 Vision and targets

7.3.1 Realistic vision and targets

As seen in vision statements found in the case studies, cities formulate different types of targets, the exact definitions of which are often not clear. System boundaries are also often not well-defined and politicians and other stakeholders often do not understand the implications of the targets selected. As a result, the targets are 'wishful thinking' and it can be hard to determine the most appropriate actions to take. For example, a few demonstration projects are supported in the hopes that in the future, the market will adopt and multiply these projects in such a way that the city's energy or GHG emissions targets will be achieved.

Few municipalities use backcasting methods to find out what they should do on an annual basis to reach their targets. If municipalities were to use backcasting, they would see that in the short term, a greater collective effort is required to create boundary conditions and policies on which specific projects can be initiated and planned.

Vague ambitions

City of Aarhus, Denmark

The aim of Aarhus is to be CO₂ neutral by 2030. In the beginning, the exact target definition and system boundaries or scope within which the target would be achieved were not clear. There was also a lack of backcasting: the overall target and strategy was established and projects had been launched but it was not clear if the projects and activities would be enough to reach the target. Another bottleneck was a lack of understanding of the potential for GHG emissions reductions and which sectors had the highest emissions. This was solved by CO₂ accounting and mapping.

Another theme that emerged from the case studies is that although many members of the public may not identify with the targets, they still play an important role in achieving the targets. To improve the public's commitment, they would need to be involved in defining or visualizing the targets and understand how achieving the targets would benefit them personally. Regular communications aimed at the general public on progress towards the targets, including on a selection of projects, can help to overcome this problem.

Despite efforts to develop clear definitions of key concepts applicable to every municipality, the case studies revealed the use of different terminology and sometimes different interpretations of the same terms. Therefore it is important at the beginning of the process for the municipality to clearly define key concepts. For example:

- What is meant by *long-term* and *short-term*?
- What is meant by *energy neutrality*, *carbon neutrality* (also referred to as *net zero energy* or *net-zero emissions*) or *independence from fossil fuels*?

- What are the *system boundaries*? In other words, what sector or activities are in scope or out of scope?
- Who is responsible for which actions?

Clear definitions

Tilburg, the Netherlands

Target: Tilburg is climate neutral and climate proof in 2045:

Steps on the roadmap:

- 2012 5% reduction greenhouse gases
- 2020 30% reduction greenhouse gases
- 2030 60% reduction greenhouse gases
- 2045 100% reduction greenhouse gases

With current projects described in the local Climate Program, the Tilburg region will be able to achieve energy savings of 8% in the built environment and SME's and a 2.7% contribution of renewable energy sources in the overall energy balance. The implementation of these projects strongly depends on the Midden Brabant development company for energy and sustainability (MOED).

Climate neutral: no net production of CO₂ or other greenhouse gases within the municipal boundaries calculated on a yearly basis, possibly compensated by sustainable energy generated elsewhere. This includes transportation.

Climate proof: protect and adjust the built environment to adapt to climate change, like floods, long dry periods, and urban heat effect.

Studies show that, without taking into account transportation, this goal can be achieved in Tilburg in 2030.

A vision should be presented in a way that explains what it means to be *energy efficient*. This rather abstract concept can be further defined by asking questions such as: "*what does an energy efficient city look like?*" and "*what are the implications for the city, its infrastructure and residents?*" The vision should be an inviting prospect that is visually appealing and engages and motivates stakeholders by being based on core values that are already understood. Developing a long-term vision should involve a diverse group of stakeholders to ensure broad support. Stakeholders should be invited to engage in the transition process to 'break away' from conventional and short-term problems and to be open to new and unconventional solutions. The win-win situation for market players includes the development of new markets and new robust future-proof projects. Embedding energy efficiency into the broader context of sustainability and linking it to co-benefits such as social cohesion, sustainable employment and mobility of residents and drivers such as environment and health is another important way to ensure continuous progress towards the targets.

The following recommendations can be made based on frontrunner communities who have successfully developed visions and set targets:

- Create a vision as a plan on the horizon
 - Formulate an inspiring and guiding vision.
 - Ensure flexibility in the scope to account for unanticipated developments.
 - Translate long-term values into guiding principles as a touchstone for future developments with enough flexibility for new initiatives and new technical developments.
 - Involve all political parties and key municipal stakeholders to ensure continuous support, even if policies change.

- Formulate targets that are acceptable to different stakeholders and are realistic at various geographic scales and phases of the plan
 - Translate the long-term vision into short-term actions by using forecasting and backcasting.
 - Determine short-term actions which contribute to realizing the long-term vision.
 - Integrate, coordinate and combine different targets:
 - Organize processes in which energy efficiency / sustainability is incorporated in all types of plans and projects, early in the process.
 - Develop energy efficiency / sustainability targets at various scales and phases of plans and make them specific and measurable.
 - Stay focused, giving highest priority to achieving the targets.
- Safeguard the vision and targets in policy and the organization
 - Ensure that the vision and targets transcend short-term operating cycles by incorporating them into various policies and organizational functions. This helps to ensure that every role, position and action contributes optimally to achieving the targets.
 - Incorporate the vision and targets into all policy documents, structure plans and zoning plans on land-use. The vision and targets must provide a framework for both short and long-term developments.
 - Make the goals part of the organization. Energy efficiency / sustainability should be a way of thinking and working in every department. When sustainability becomes part of the organization, institutionalizing the vision and targets becomes much easier. Because the organization as a whole will not change every four years, continuity and momentum towards the long-term vision and targets can be maintained.
 - Make the vision and targets a part of the strategic agenda of key stakeholders.
- Monitor progress towards the vision and targets
 - Test short-term actions against the long-term vision and targets. Ensure these actions contribute to the long-term goals and do not impede other beneficial actions or lead to sub-optimal solutions.

A municipality's definition of its energy and GHG emissions reductions targets must make sense in a local context. Instead of applying standard solutions which almost always lead to untapped local potential, plans for an energy efficient low carbon city should be developed on the basis of the city's own characteristics. For example, what are the opportunities in the existing building stock? What are the opportunities for energy generation from renewable sources within the city's geographic boundaries (see also A3-6)? How can local businesses contribute to achieving the targets? Which solutions that are technically and economically feasible are also culturally appropriate?

Defining long-term targets must also build on a city's strengths. By establishing an energy transition or strategy on the basis of a city's core values, the city's infrastructure and buildings can be strengthened, supported by local actors. Residents and other stakeholders can be asked to help define the city's core values thus engaging them in development planning. Synergies between ongoing programs and actions should be exploited. Parallels should be drawn between past and future development projects, in order to learn from past projects and apply this knowledge to future developments.

Core values

Stockholm, Sweden

The Office of Regional Planning seeks to achieve a shared vision on how the unique assets and strengths of the Stockholm region can best be managed and developed. The issues dealt with include land use, housing, the environment, nature conservation, energy, sparsely populated areas, the archipelago, integration, social perspectives and international cooperation.

7.3.2 Linking short-term actions with long-term targets

Although difficult in practice, maintaining consistent policy and management throughout the transition process is desirable. Although establishing a long-term vision seems easy at first, it will become clear that the majority of stakeholders primarily have a short-term focus. Their short-term plans are often inconsistent with the long-term vision and objectives. One challenge is a changing local political landscape which, depending on the country, can happen every four to five years; politicians are therefore focused mostly on the short term. This is also true for the codes and standards used in building community planning. The site planner who approves development plans must stick to the rules. If these rules do not allow certain building types, the dreams of the planner thinking in the long term will not become a reality. It is difficult to institutionalize a long-term vision in organizations with a short-term focus.

Short-term focus

Tilburg, the Netherlands

Tilburg's current Climate Program is focused on achieving long-term targets. The disadvantage of this long-term focus is that there are only a few concrete projects that will be carried out within the political term of the current city council and mayor. The municipal administration tries to involve the elected officials as much as possible in the projects for political support and involvement.

Ensuring short-term measures are consistent with long-term targets requires significant effort. Standards must be changed, new ways of working are needed and organizations themselves must change. The first plans must be strong to maintain momentum. For example, even if cities adopt a long-term goal of carbon neutrality, current local building energy performance requirements for new buildings that have not been changed will mean that any new buildings will not go beyond current energy requirements. This means going back to these buildings at a later date to implement additional measures, which is inefficient.

Not only should short-term actions contribute to long-term targets, but different long-term goals must match as well. Municipalities consist of many departments, many of which may include long-term goals in their own plans. Annex 51 case studies show that the long-term goals of different departments often do not match. This is due to a lack of coordination between departments engaged in goal setting.

Another challenge is to include both long-term and short-term goals in development plans. If energy efficiency is not anchored in the core values of the organization, there is a risk that energy efficiency requirements will be included in the plans when it is already too late. Another scenario sees sustainability criteria and requirements being taken into account in early planning phases and becoming less important or 'watered-down' along the way. The biggest reasons for this are a lack of budget and investor support. Municipalities also struggle to maintain a high level of interest and engagement over extended periods of time.

Long-term targets

St. Johann, Austria

The City of St. Johann aims to be energy autonomous by 2020. A city can be considered energy autonomous if no net import of energy is needed from outside the municipality over the course of a year. This means that energy used within the municipality is equal to the amount of renewable energy produced within the municipality.

In St. Johann, energy autonomy is understood as an effort by the municipality as a whole to become independent from fossil fuels for heating, electricity and transportation and to control energy costs for community members. St. Johann is a relatively small city with large renewable energy generation potential in the form of biomass from the surrounding forests. Therefore the goal of being energy autonomous by 2020 is more realistic in St. Johann than for other communities reviewed in the case studies.

The benefit of translating the long-term vision into short-term actions which contribute to the long-term target is that short-term actions are tangible. Politicians are elected for short terms and are more likely to commit to projects which can be implemented in shorter timeframes. Investors also have an interest in short-term projects and seek short payback periods to maximize returns on their investments. It is important to gain the commitment of politicians and investors because both actors play key roles in reaching long-term energy and GHG emissions reductions targets.

Step-by-step implementation

Stockholm, Sweden

The City of Stockholm is planning the road map to achieve a clean future at several scales. At the highest level, the Regional Planning Office (RPK) prepared a study on regional energy future for the 2010 to 2050 timeframe. In this respect, greenhouse gas emissions will be reduced by 90%, despite a 40% increase in population.

In a parallel initiative, the City of Stockholm is working on a strategic study of the city called Vision2030. It examines every aspect of sustainable development including energy and climate goals and can be used as a high level visionary plan to guide city development.

7.4 Process and organization

7.4.1 Continuous process

The transition towards an energy efficient low carbon city is a long-term task that takes between 15 and 40 years to achieve. The transition process involves many supporting processes; for example, the activities of a main individual responsible for the transition within the municipality. Numerous 'micro-processes' or individual activities and tasks must be adapted or introduced to enable the process as a whole. This involves many stakeholder groups and requires many decisions to be made. Consequently, it is difficult to maintain an overview of the whole process. Often there is a lack of knowledge about how these processes work and how best to apply and organize them.

In many cases, part of the problem is that no one person is responsible for the whole transition process within a municipality, including managing stakeholders and dealing with the various issues on different levels. Decision makers are not always clearly identified. Often no decision is made with each stakeholder waiting for another to decide.

No owner of the whole process

Tilburg, the Netherlands

In Tilburg there was no actor or organization with the responsibility to implement energy infrastructure on the city scale. A traditional partner would have been an energy supply company or a Distribution System Operator (DSO) which may be found within a municipal or regional (energy) utility. However, no investor was interested in the business case for a large-scale renewable energy plant. The solution developed consists of a public-private partnership (PPP) model, involving the municipality, an energy supply company as the main investor and other shareholders such as building owners who help minimize investment risk and thereby guarantee the success of the business case.

Part of the organizing process is to get an overview of the bottlenecks or barriers and issues at an early stage. This is to ensure the bottlenecks are addressed early-on, enabling everyone to stay focused on the same long-term targets. It is clear from the case studies that this can be challenging. Each stakeholder has his or her own priorities (be they professional or personal) and assignments they must complete. Getting all stakeholders and priorities aligned and everyone 'rowing in the same direction' requires significant resources. Due to the fact that different stakeholders may be engaged in different phases, strict attention must be paid during *transfer moments* where responsibilities and information are transferred from one stakeholder to another. Transfer moments are critical because they represent points in the process where there is an increased risk that information may be lost or misunderstood; momentum can also be lost if a new stakeholder is for whatever reason less capable or committed to a task than the individual previously in the role. The lack of communication which happens in many projects is also detrimental to keeping people together and motivated. Inadequate communication occurs in every phase, on every level from engineering activities to governance roles, reducing the effectiveness of all actors from the elected official to the builder on site.

More attention must be paid to how development processes are organized. The municipality can develop a standardized process which can be followed for each development. This standardized process should contain:

- Rules of the game. In the organizational and legal context of the municipality, what policies must be followed to ensure an energy efficient development?
- Step-by-step procedures. What are the step-by-step procedures that must be followed to achieve energy efficient development? Functional definitions, specific tasks, monitoring methodologies and much more should be clearly documented in a manual.
- Roles and responsibilities. Which organizations are involved? What are the individual roles? Who is responsible for what?

The city should monitor each project during its implementation in order to identify changes to the process, individual steps, roles, tasks, responsibilities and rules of the game. Standardizing the process⁸² as much as possible implies that every stakeholder in the municipality knows what to do, when and how. If correctly implemented, the process should become a routine procedure for all stakeholders. Besides a clearly defined, organized process it is essential that any successes are attributed to everyone involved and not only to one person or political party.

⁸² For an accurate description of the different processes see the results of the CONCERTO-project

Standardized process

e5/ eea methodology, St. Johann, Austria

The main elements of the e5/eea quality management system are:

- Total quality management system (TQM) for a community's energy-related activities.
- Certificates and awards for energy-related achievements in defined award categories (5 and 2 categories in the e5 and eea programs respectively) and monitoring of progress through regular audits.
- Networking within the community and between communities through increased cooperation, communication and training.

Based on this quality management system, the target of the e5/eea program is the identification of relevant potentials for energy saving and renewables within a community and the implementation, documentation and evaluation of savings measures. Therefore a community's action program is developed and adopted annually. All energy-related municipal activities (development & planning, municipal buildings & facilities, transport, energy supply, internal organization, communication & co-operation) are considered. Internal structures are set up, suitable for guiding the process and including all relevant players in the community (politics, administration, citizens, enterprises etc.).

The following tools are used in the eea program:

- eea catalogue (audit/assessment tool) including all possible actions in municipalities
- Guidebook, check-lists
- Report of the audit
- Benchmarking with indicators
- Good practice catalogue
- Training, excursions
- Information exchange

Municipalities are audited regularly (every 3 or 4 years) by an external auditor and awards are given depending on the result of the audit. In the Austrian e5 program the success of a community is measured by 'e', the best communities achieve up to 'eeee'. 'eee' corresponds to the European Energy Award (50% of all possible points) and 'eeee' to the European Energy Award Gold (75% of all possible points). Communities attaining this designation can be seen as belonging to the 'European Champions League' of energy efficiency.

To ensure that the process of energy efficient city development is followed, a coordinator for the whole process can be assigned. This person is solely responsible for the realization of the integrated process within the municipality. This person must have sufficient authorization to organize this process and is under command of the alderman, mayor or another high ranked official. This person has to fulfill certain competences, because he is the one to organize the integral process. He or she has to have insight in different areas of expertise and must be able to bring them together. He or she must be able to work on a broader and more strategic basis and be mandated to take some decisions. An integral coordination of the process has to cover two important core issues: coordination of activities and projects, and coordination of the integral process, consisting of involving the relevant stakeholders (including end-users if necessary) and ensuring political commitment. The process coordinator has to be aware of both requirements to be successful, but his main task concerns the second issue.

The knowledge about certain subjects, issues and about the project should be widely shared. Therefore the process coordinator should not be the only one who knows everything about the project. The responsibility of the project is shared in a team. The responsibility should also be shared between different departments. Starting point is a regular communication between these departments

about plans they are making and projects which are ongoing and the role of sustainability in these projects.

Central coordination

MOED, Tilburg, the Netherlands

The task of the process leader for MOED (the development company for Energy and Environment in the Province of Central Brabant), is to work together with entrepreneurs, educational system representatives and government to support large scale renewable energy generation in Central Brabant.

St. Johann, Austria

The e5/eea team is responsible for the implementation of measures and projects. Members of political parties, municipal administrators and members of the general public are all part of the team. The e5/eea team was involved in development and discussion of general principles and is responsible for implementation of identified measures. Usually there are about four meetings per year. The e5/eea team has the responsibility for achieving the energy targets.

Activities of the e5/eea team follow normal planning procedures: planning, implementation and management. Planning is understood as defining concrete actions within the next year. The activity plan is managed by the e5 team, leading to an action implementation plan. An external audit is done at least every four years, based on documentation of measures implemented.

The energy coordinator is a member of the environmental department within the municipal administration and is responsible for all energy-related issues concerning the municipality (e.g. municipal buildings, street lighting ...). The energy coordinator is also the leader of the e5/eea team. Communication between departments is managed by the energy coordinator, supported by the e5/eea team.

The central objective of energy efficient urban development is to achieve a sustainable city with a high standard of living. To create this, it is essential to involve all kinds of expertise and perspectives not only those belonging to municipal employees. Input from and consultation with all stakeholders is important, beginning in the early stages of development. Working together with insight and respect for the perspectives of others is essential. However, it must also be clear that not all issues will be resolved – giving up some of one's own expectations or wishes is also part of realizing joint goals. Working together in this way develops plans that are broadly supported and get a 'high score' both on the drawing board and in real life.

Joint responsibility

Stockholm, Sweden

Stockholm assembled a steering committee to coordinate project implementation and achieving the city's climate and energy goals. Organizations represented on the committee included the Stockholm County Association of Local Authorities, the County Administrative Board of Stockholm, and the regional planning office.

Working together as described above does not always avoid problems that may occur in the many transfer moments. In large-scale projects such as new urban development or neighbourhood renovation projects, the municipality can choose to issue a tender which includes not only design and construction but also financing, maintenance and operation. This approach is referred to as Design-Build-Finance-Maintain-Operate or DBFMO. These tasks are then executed by companies. The consortium as a whole is responsible for the results. It is in their interest to take an integrated approach to working together and to make as few mistakes as possible. These tenders should

preferably ask for solutions rather than list specifications. In this way, the consortium can fulfill the goals and vision the way they think is best. Often this approach leads to more innovative and future-proof projects.

It might be obvious, but arranging these types of processes takes time and effort. The individuals working on energy efficiency in the city have to be strong and determined. If a regular development project takes a lot of time, working together with many people to achieve an energy efficient development project takes even more time. Working on these kinds of projects requires perseverance and goodwill to negotiate and discuss things over and over again until everyone around the table is content with the results.

7.4.2 Integrated approach

Taking an integrated approach offers the biggest chance for success. In the case studies, however, it can be seen that a lot of municipalities and stakeholders are organized vertically in 'silos'. This segmentation makes it difficult to work using an integrated approach. Departments are not used to working together or thinking about the situation in other departments. In many cases, communication between persons in the different departments does not take place very often. Coordination between decision makers in different departments is also difficult.

Difficulties in cooperation between different departments

Salzburg, Austria

At the start of a stakeholder dialogue intended to define a long-term vision and a roadmap for becoming a smart city, a steering group was established on the highest political level. Members include the Lord Mayor, city councilors representing departments of financing, planning, mobility, buildings and social issues, and the managing director of the local utility. This steering group creates the conditions for better cooperation between administrative departments.

An integrated and broadly supported vision starts by embedding it horizontally across the municipal organization. The vision becomes a part of existing or new structures and procedures that allow departments to work together. Working this way prevents fragmented planning, making it possible, for example, to bring mobility plans and ecological plans together to be examined through the lens of the vision. *"What aspects of the plans correspond closely to the vision and each other?" "Where are the problems and how should we solve them?"*

Horizontal embedding

Ludwigsburg, Germany

To implement Ludwigsburg's Urban Development Strategy, the entire municipal administration was reorganized. An interdepartmental unit for sustainable urban development (*Referat Nachhaltige Stadtentwicklung*) was founded to address energy and climate-related topics in all relevant fields. It ties together activities in sustainable urban development and organizes processes to link them to all administrative processes in the city. The importance of the sustainability strategy is reflected in the fact that the unit reports directly to the Lord Mayor. In addition, the Centre of Competence for Energy, Climate Protection and Ecological Design (*Energetikom*) was established. The new center creates a network for experts and users in energy conservation, energy efficiency, climate protection and eco-design.

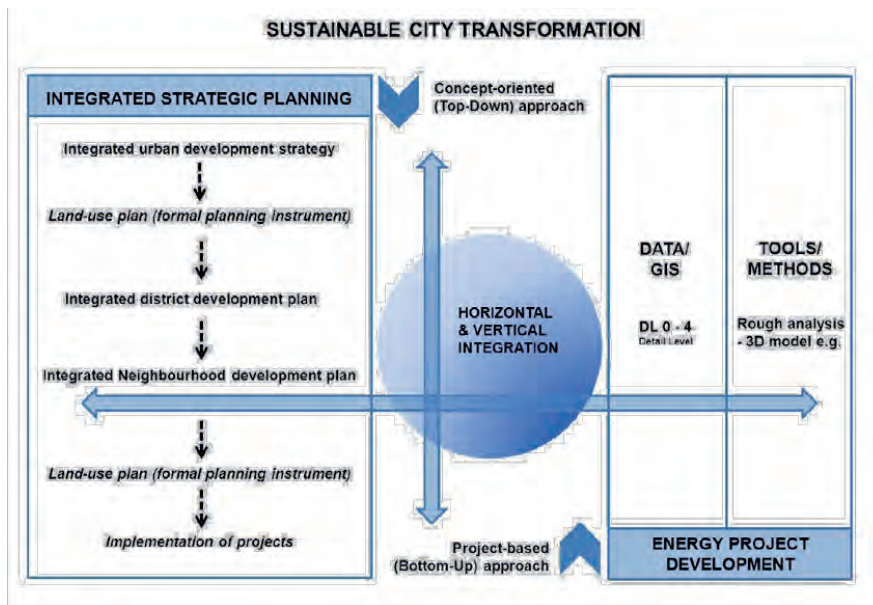


Figure 7-1: Horizontal and vertical integration, Ludwigsburg, Germany

Another important advantage of this integrated approach is the institutionalization of sustainability in the organization; working in this network starts with asking departments what they can contribute to the end goal. However, cross-pollination between disciplines and actors should also be encouraged in practice. People should work side-by-side on given projects. In multidisciplinary teams they can test policies and plans against sustainability goals. It is also sometimes difficult to achieve full-scale cooperation between departments when they are competing for the same funding. The objectives of the individual departments often win out over the common good.

Integrated approach

Prince George, Canada

The Smart Growth on the Ground (SGOG) process was a sustainable community planning and engagement program run by the former Vancouver-based Non-Governmental Organization (NGO), Smart Growth BC. This unique program helped BC communities to prepare more sustainable neighbourhood plans that included land use, transportation, urban design, and building design components. Following an application process, Prince George was selected as the first northern community for Smart Growth on the Ground (SGOG).

The focus of the engagement in Prince George was to develop a concept plan for the revitalization of the city's downtown. The scientific themes of the engagement were energy and climate change. In addition to broad-based participation from city staff, elected officials and community stakeholders, numerous researchers from government, academia and the private sector contributed science-based information on a range of energy and climate change issues. The resulting Concept Plan for Downtown Prince George was approved in September 2009.

Community engagement in the SGOG process enabled the incorporation of cutting-edge research and new innovations on the linkages between energy use, greenhouse gas emissions, and urban form into neighbourhood planning processes. Participants learned how urban development decisions are directly related to climate change, and used this information to inform their land use and infrastructure decisions for downtown Prince George. The process included public information sessions known as open houses,

foundation research bulletins, a design brief and a four-day community design charrette. The resulting Concept Plan reflects good energy planning principles and practices for land use, building design, sustainable transportation and district and renewable energy technologies. Information produced in the SGOG process was made available on the project website.

7.5 Support and involvement

7.5.1 Creating support

In any city there are stakeholders and members of the general public who often do not completely trust each other. Amongst other things, this lack of trust is caused by people with hidden agendas and by people who do not say openly what they want or do not want. Even if only a few parties act this way in a process, others involved tend to adopt the same behavior; a lack of trust is like a vicious circle.

Information sharing can also pose a problem. In contrast to strict technology to market intellectual property development, where corporations intend to patent and profit from a product or process, in the development of innovative technical concepts in municipal energy master planning, the best case scenarios occur when information is shared. Parties are afraid, however, that another actor might 'steal' their idea or that their position in the hierarchy might diminish. Since there is often competition between municipalities for the same national or federal grants, another scenario would involve a municipality using a 'borrowed' concept to their advantage to obtain funding.

Individuals or organizations not fulfilling promises is another cause of distrust. This has been observed on a national level concerning subsidies: for example, a government issues a subsidy or grant for solar panels and three or four years later it is eliminated despite several developments counting on it for a viable business case. Policy changes on the national level put a stop to projects or at least reduce expectations and momentum. On a local level, not acting as promised only feeds distrust between stakeholders, distrust that may have been pre-existing. This will make people more reluctant to collaborate, making the achievement of energy and climate goals even harder.

In response to a lack of trust, people tend to protect themselves and not 'show their cards'. This creates a situation in which it is unclear what is going to happen and the process becomes slow, with every decision being a struggle. Not sharing knowledge also makes it harder to achieve innovation, because cross-pollination cannot take place.

Another challenge relating to a lack of information is that developments are sometimes planned by policy makers or others with little connection to the city. A lack of knowledge of local problems and opportunities can result in a development that does not effectively respond to other social issues. The city's residents and business owners may therefore not understand the added value of the development and may be reluctant to accept it. In many engagement processes the right people are not always involved and those who do participate do not necessarily reflect the needs and interests of the average resident or business owner.

Involving many different actors implies new challenges. Having many stakeholders introduces a large number of different ambitions, different requirements, and, especially, different interests that often don't mesh well. This creates a problem in establishing a commitment to collaboration and a common vision. If the ambitions don't match up in the beginning, it is almost impossible to come to a good conclusion.

The CONCERTO report *Policy Recommendations Publications–European Communities* (2010) states that the involvement and proactive attitude of stakeholders is a key factor contributing to success.⁸³

⁸³ <http://concerto.eu/concerto/library.html>

An important first step to achieve proactive stakeholder engagement is to create a safe and open environment that encourages people to trust one another. Trust makes it possible for all participants to share their ideas and perspectives – all participants should have the opportunity to ‘score’. Creating a safe and open environment begins with sharing and not immediately asking for something in return. Trust is also fostered by acting as promised. To help create trust, one needs to work together with all participants to create ‘the rules of the game’. These rules should include principles for engagement and describe the roles of all stakeholders. Importantly, it must be clear who is leading the process and who is making the decisions. It must also be clear to participants that the decisions made may not always correspond to their own views or interests. Decision makers must also understand that they have the responsibility to clearly explain their reasons for choosing a particular course of action. Write the rules down in a document to be signed by all participants. And don’t forget to make sure the rules aren’t changed during the game!

Creating support

Ludwigsburg, Germany

Energy has been discussed in Ludwigsburg since the 1990s, however, the topic was not prominent in political debates. To make sustainability obvious in political conversations, the Lord Mayor started an urban development process. Eleven urban sustainability planning themes were developed, of which energy was one theme. A management circle was implemented to ensure these themes were evaluated and adapted on an on-going basis.

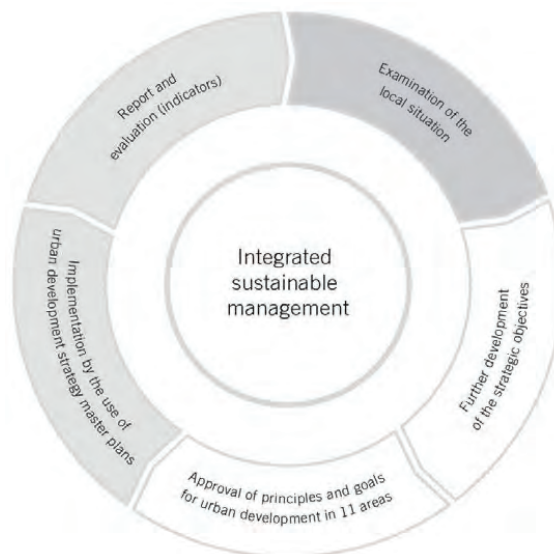


Figure 7-2: Management system for the Ludwigsburg urban development strategy. Source: City of Ludwigsburg

A safe and open environment creates room for new roles and new partnerships. New partnerships and a new division of roles can promote cross-pollination between disciplines and actors. Parties that work together make each other and the group stronger. Many different types of partnerships exist for many different reasons. Always begin by identifying the goal of the partnership. The tasks required to achieve those goals can be determined by using the backcasting approach. This will help to identify

which skill sets are required on the part of the stakeholders and to guide stakeholder selection. Assess possible actors including stakeholders which otherwise would not be involved – sometimes their perspectives can be the most useful. Dare to do things differently and learn from it. Keep in mind the goal of creating a group of people who are intrinsically motivated to achieve sustainability. Connecting these individuals creates a strong group which is able to set ambitious objectives and involve others in achieving the group's goals. In doing this, it is important to secure the commitment of managers, policy makers and other decision makers.

New partnerships

Aarhus, Denmark

The municipality of Aarhus tries to facilitate collaboration between companies and knowledge institutions on development projects and new use of existing solutions. Climate Partnership is a framework for creating concrete cooperation and preparing binding agreements between business entities, knowledge institutions and public organizations. Each agreement is tailored to the specific partnership so that all parties profit. The municipality has decided to focus on the 2012 to 2015 timeframe and entering into partnerships with leading companies in the energy and climate technology, as well as big businesses with many employees or a large production, which typically have significant energy efficiency or CO₂ reduction potentials.

Climate partnerships have been chosen as a major method because:

- Climate partnerships create growth and company results.
- Relevant results cannot be achieved without the involvement and commitment of the private sector.
- All parties achieve a mutual off-exchange. The first part of a climate partnership agreement obliges companies to reduce their internal energy demand.

The second part of a climate partnership agreement commits the companies to participate in innovative projects to develop new concepts and products that can create a green growth in the community. Climate partnership agreements commit Aarhus Municipality to help create the necessary framework for actors' cooperation, including e.g. influencing the legislative and infrastructural framework that is needed for the development of commercial climate solutions.

Aarhus Municipality has signed partnership agreements with knowledge institutions (University of Aarhus, Engineering College of Aarhus, VIA University College), private companies (Agro Food Park, Alectia, COWI, DONG Energy, Energy Service of Central and East Jutland, Grontmij, Midttrafik, NCC, NRGi, Ramboll, Siemens, Sondrup Bilcenter, Vestas).

Another possible opportunity to achieve an energy efficient city is through collaboration with local renewable energy companies. Their aims often include not only to increase renewable energy production but, for instance, also to decrease energy demand through measures in the existing building stock. An important bottleneck mentioned in the case studies is the struggle between municipalities, the big energy companies and the network or transmission and distribution management. Another bottleneck is the unclear and often changing national government policies on sustainable energy. Municipalities want to obtain inexpensive renewable energy for their residents at the same time as achieving established goals. However, national government legislation and regulatory frameworks often do not support these objectives. Other important motivations for setting up local renewable energy companies are energy autonomy and local economic development. Last but not least, local renewable energy companies can be used to engage inhabitants in the implementation of renewable energy; when residents or businesses participate they will receive the revenues from energy generated or saved due to the measures. This will increase the support and involvement of local residents and businesses.

Local renewable energy company

Ludwigsburg, Germany

In recent decades, many German communities privatized their municipal utilities or sold them via cross-border-leasing arrangements. Within the last few years, this trend has reversed, favoring municipally owned facilities due to their importance for strategic planning and security of supply. Municipal utilities are an important prerequisite for the implementation of city-wide energy concepts. A city that owns an independent and decentralized energy supply infrastructure is powerful in decision making, especially in regard to energy conservation, energy efficiency, renewable energy supply and new supply concepts such as district heating. Municipal energy utilities should allocate a budget for innovation and develop pilot projects. The involvement of the municipal utility of Ludwigsburg-Kornwestheim shows that a municipally-owned energy supply is an important factor for success in promoting innovative energy strategies and projects.

7.5.2 Involving the right people at the right time

An integrated approach does not consist of involving all stakeholders in all phases and consulting everyone on each issue. The challenge is to understand who should be involved, when and how. For that, a stakeholder analysis is required.

Not all the stakeholders in a city have the same priorities concerning energy efficiency. Stakeholders often regard energy codes as a maximum rather than a minimum effort. Instead of seeing it as a small effort to set higher targets, they view energy codes as a reason not to do anything extra. If not broadly supported it is very hard to achieve energy efficiency.

Within the municipal administration, sustainability is regarded as an additional layer of difficulty since it adds extra work to the normal work load. If there is no team that can convince the stakeholders to cooperate, it is difficult to get the municipal administration to join.

No intrinsic motivation

Ludwigsburg, Germany

The aims of the city administration and the Lord Mayor were more ambitious than those of the city council. So the city council did not give their consent in the beginning. This was solved by downsizing some targets, other objectives the city administration tried to reach by developing its own land and creating higher standards (for themselves).

At first, a lot of people in the administration also found that sustainability was too much work in addition to their everyday workload.

St. Johann, Austria

In the beginning St. Johann's city council was less motivated than the Lord Mayor and parts of the administration. As a result, long-term goals were difficult to establish. But within the e5/eea group, permanent involvement of all persons could be achieved. At first there was no discussion about visions and overall targets but only on commitment to single projects. The projects themselves, regular evaluation and awards led to visible results which in turn led to a higher level of commitment. Not, however, before years of work was there a need to define goals as a basis for further work.

By using selective participation through stakeholder mapping and analysis at the very beginning of a project, a network of intrinsically motivated people can be built. Selective participation is about selecting a small but diverse group of people to analyze and formulate strong integrated goals and

targets. Preferably these people are individuals with the ability to think in an integrated and innovative way and who dare to think and act differently. When selecting these people, the actors who are always involved and whose points of view are already known should not necessarily be selected. Invite actors whose points of view are not known and who might have different but useful ideas.

For energy efficient city development, new working methods and ways of thinking are needed to achieve an innovative and effective approach. It is important to 'let go' of conservative methods and stakeholders for energy supply and be open to new methods and new parties. In taking a broader look at who can benefit from the city or who may affect the city, new forms of collaboration and roles can be adopted.

It is necessary to understand, for example, stakeholders' motivations behind investing in renewable energy and energy efficiency. What is important to them? What values do they see? The aim is to build coalitions to unite fragmented interests, making stakeholders owners of the development and, above all, to integrate and respond to other social issues and needs. Creating a group of selected participants increases the chance of establishing a commitment to collaborate and achieve common value. However, there is still quite a big chance that unwilling parties need to be convinced to support that motivation. It is necessary, therefore, to have a strong leader who is able to pull unwilling parties into achieving energy goals. This leader might be the mayor or an investor, but can also be the project leader or energy coordinator. This group of participants can and should also be relied on to strategically work towards energy and GHG visions and targets.

A strong leader has a personal commitment to stay focused on the objectives and bring stakeholders on board; he or she also deals effectively with setbacks and comes up with creative solutions. Visionary ideas can very often be traced back to one person. Someone with authority and the capability to persuade who generates an idea will eventually see it adopted by organizations or committees for further planning and implementation.

Strong leadership

Prince George, Canada and Ludwigsburg, Germany

- Prince George achieved many of its energy and climate change successes due to an informed and engaged mayor and council. A former mayor was co-chair of the organization Community Energy Association (a BC-based NGO), and was a great supporter of energy and emissions planning activities such as the Downtown District Energy System and energy mapping.
- In Ludwigsburg, the initiators of the sustainable urban development strategy were the mayor and the head of the department of sustainable urban development who had earlier been head of the building department. They also initiated the energy concept, together with persons from the urban agenda department. The initiators have a steering and controlling role. The Lord Mayor is a convincing leading figure.

A strong leader needs a motivated team to support him or her in achieving objectives – a fact apparent in most of the case studies.

Motivated municipal teams

- Engaged persons and team (St. Johann, Austria)
- Dedicated city staff across various departments until 2011 (Prince George, Canada)
- New sustainability office (*Nachhaltigkeitsreferat*) responsible for convincing most actors to participate in the process (Ludwigsburg, Germany)
- Broad commitment within the municipal administration and elected officials (Tilburg, the Netherlands)

→ Highly committed municipal management staff (Aarhus, Denmark)

7.5.3 Involving the public

Bottlenecks or barriers to public engagement can be attributed to a combination of organizational, communication and technical issues. The public can contribute a significant amount of local knowledge to an energy planning process. For example, a member of the public might identify ample green space as a local strength while pointing out that there are too few playgrounds. This type of local knowledge is very useful when making plans for a revitalization of the city. However, communication with the public is typically difficult. Public engagement is often not done properly and the value of public comments not fully realized. It is necessary to develop smart management approaches to ensure measures are properly implemented, focusing on current residents while considering the needs of future residents. Taking the public seriously and making their contributions visible, engages them in the decision-making process.

Local energy planning decisions that are made will be more readily accepted if they are understood by the public. Most members of the public do not know a great deal about energy systems. People think sustainable energy systems are more expensive, unreliable and difficult to maintain. Many times this is not the case, but because people prefer things that are guaranteed, they may object to a proposed energy planning measure or not buy a property. An accurate, easily understood explanation of a technique or technology and its potential impacts (financial, maintenance, disturbance) is needed.

The media play an important role in the creating of public perceptions about energy technologies. They often show cases where something went wrong. Collective sustainable energy measures can also scare people. Their fear may be based on the assumption that collective measures are inflexible. Depending on the measure this may be true, but often it is not. A good communications strategy to accompany the local energy planning process is therefore essential. The media is a tool to be managed; their job is to sell airspace or newspapers. If the only information they have is bad news, they will use it. Bad news is sold with pictures. Good news is sold with numbers, preferably financial numbers, accompanied by numerous facts.

It is important to ensure that the language used is on the same level as that of the people who are being addressed. Communicate in different ways through both mass and individual channels using both direct and passive approaches. For example, providing information via a website is a collective passive approach whereas a letter addressed to a member of the public explaining what is going to happen is an individual and direct approach. It only takes one unhappy member of the public to create a negative buzz which can be very difficult to reverse. Proactive communications and careful implementation of measures are important to prevent negative publicity. A related point is that it is important to act as promised, even if policies change.

The lack of a single contact person is one reason why communications can be a mess. The public needs to be able to call someone with their questions. If a different person answers every time and the same points are repeated or if people are sent from one organization to another without positive results, it will cause frustration to grow and support to decrease. Designating a single contact person within the municipality to whom the public can turn is important. This person can make sure that the public knows what is going to happen and when.

Another communications challenge is that the public may also not feel connected to long-term targets, finding them too abstract. They may not be interested in what measures are required to reach the targets if they cannot understand how achieving them benefits themselves or their families. Greater public awareness about the targets, in a way that is meaningful to the public, will make the targets easier to reach.

Residents will become more aware of energy issues when energy is generated visibly in the city and if energy use by residents is made visible in real-time on an individual or collective basis or both. Using

smart meters to monitor residential energy use can provide insights into potential efficiency measures. Clear feedback and comparison with other local residents is essential. Time of use electricity rates provide an incentive for the public to shift their energy use to times when green electricity is available.

Involving the public

Nantes, France

To foster citizen engagement, a climate workshop was set up that brought together 150 households representative of the wider population who had agreed to take part in a consultation process. Over the course of one year, the households benefitted from advice on how to live in a more ecologically-friendly manner and reduce their emissions. At the same time, they were consulted as a source for new ideas to develop.

Downtown District Energy System: Prince George, Canada

When initial plans for a bioenergy Downtown Energy System (DDES) were released, residents of Prince George expressed opposition, wary of adding additional particulate matter to an already compromised air shed. Strong public opposition stalled the approval of the DDES in late 2007. A renewed effort by a new mayor and city council was made, and included a revised technical approach and a stronger communications strategy that outlined the benefits of the new system. The city was successful in addressing issues, particularly through an improved design that will result in fewer air pollutant emissions than are currently occurring and is now developing the DDES with the support of the community. The new system included situating a proposed heating plant designed to use waste wood at the site of Lakeland Mills, a local pulp and paper operation.

Spreading negative views was a key factor in the initial opposition to the Downtown District Energy System. Citizens, organized in a community coalition, communicated their concerns regarding air quality through websites and the media. An improved system design that accounted for the citizens' air quality concerns and improved communications strategy including an innovative approval process, were all key aspects of knowledge management. Eventually this contributed to the development of a superior design, achieving economic development and revitalization objectives from an environmental perspective.

Instead of putting the question to the public in a referendum, the city pursued an innovative alternate approval process known as the 'approval of the electors', consistent with requirements in the provincial Community Charter. The new design and proposed by-law to purchase waste heat from the pulp mill⁸⁴, was communicated through the development of an information brochure, staff reports to the council and through articles in local newspapers. Those 'electors' eligible to vote, were provided with a form that could be submitted to the city showing their opposition to the proposed heat supply purchase by-law; residents were also able to participate in the federally-regulated Environmental Assessment (EA) process. In 2010, after having received not one single complaint through the approval of the electors process, or through the EA process, after three readings by council, the proposed by-law to purchase waste heat was approved, signaling the city and community's formal decision to proceed with the construction of the Downtown District Energy System.

Public Participation: Ludwigsburg, Germany

Becoming an energy efficient low carbon city not only requires great commitment, but also significant behavioral change. Public engagement is a time-consuming process. Therefore shorter, focused forms of participation such as roundtable discussions, expert workshops or 'future conferences' are used; several-day workshops are only rarely conducted. The group of participants should not be too small and include different representatives. Public participation allows the public to identify with their municipality. It allows the public to identify opportunities and integrate them into planning. Yet it is sometimes seen as controversial: Councilors fear to lose decision making power, and the public are afraid of not being taken

⁸⁴ Lakeland Energy Supply Agreement Bylaw No. 8296, 2010

seriously. Therefore, trust building must take place on all levels. The municipal council should acknowledge the benefits of public participation. It must be communicated to the public that their concerns are being taken seriously, but that ultimately the municipal council makes decisions based on the public good.

During the Urban Development Strategy, the City of Ludwigsburg organized an intense public participation with positive results. A department for community volunteer services (*Fachbereich Bürgerschaftliches Engagement*) was established in 2004 and the public is involved on an ongoing basis.

7.5.4 Involving the real estate industry

While some private investors are convinced of the urgency of sustainability, many still think it is just another obstacle in the development process. The construction and development industry is a conservative sector in which changes are not easily made. Legal requirements set by governments, for example building energy performance requirements, are most often seen as a maximum of measures to be taken, instead of as a minimum.

Municipalities have few options when choosing innovative private investors for energy supply systems or municipal development projects. Furthermore, European contracting law makes it difficult to favor innovative parties. In many cases there simply is no choice, because investors have already purchased land which they intend to develop.

One of the central challenges for energy efficient low carbon cities is to reduce energy use in the building stock. Much of the existing building stock is owned by the private sector and owners and landlords play an important role in this process. Currently there are few instruments to promote working with these actors to reduce energy use, in particular with buildings that are co-owned. Often owners see no need to renovate and their objectives differ from those of the municipality. To move forward, a majority of the owners and tenants must agree to undertake renovations.

Building or renovating in a way that is energy efficient should be common practice. Considering occupants, it is desirable to keep their energy costs as low as possible, which means the building must be energy efficient by definition. It is helpful, however, if energy efficiency is presented as a challenge and not a requirement; not prescribing which exact requirements must be fulfilled gives parties room to create their own innovative solutions. Using innovation and a building's energy efficiency as something to showcase can be used as a selling point.

Innovative private sector actors can also influence other investors to become more innovative. By allowing private sector actors to work together in new coalitions, everyone will learn various techniques, how they work and how to organize the process.

Municipalities can increase collaboration with innovative parties by, for example, initiating a competition. Another way to challenge the private sector to be more innovative is to award a bonus: for every energy efficient dwelling built or renovated a builder may be permitted to either build an additional unit or more floor area. This is sometimes called a *density bonus*.

Innovative contracts

Kerkrade West, the Netherlands

Involve companies, such as builders and installers as early as possible in the process to maximize creativity. Consult with these companies so that they may contribute their socially innovative or efficient ideas. Encourage these companies by including other criteria in addition to price in the tender, such as sustainability, energy efficiency and user friendliness; don't forget to also include these criteria in the contract!

During the renovation of 153 houses built in 1974 in Kerkrade West to *Passivhaus* standards, Hestia, the social housing corporation, consulted with companies to identify optimal solutions for the project. A consortium of companies was responsible for the renovations and therefore all parties were involved from the beginning. In this way, integrated approaches for the companies to work on together became a reality.



Figure 7-3: 153 houses renovated according to *Passivhaus* standard, Kerkrade West, the Netherlands. Source: Hogeschool Zuyd

7.6 Knowledge and risk management

7.6.1 Sharing knowledge

Conventional planning and building construction methods are standardized to such a degree that it is very difficult to change them. Building codes are created to ensure that a building meets certain safety standards. The *modus operandi* of contractors has, over time, become to ensure that construction costs are minimized for the developer. If an alternative construction approach can be shown to provide a greater financial or business benefit for the developer, only then will the method be changed. And even if a developer decides to adopt a new process or technology, implementing changes on the job site poses a further not-insignificant challenge: effectively communicating required changes across multiple trades, sub-contractors and work crews, to workers who may speak several different languages.

These types of changes are necessary, however, to be able to achieve energy efficient low carbon cities. Problems begin with a lack of knowledge by any participant at any point in the sustainable urban development process. This could apply equally to the mayor, the civil servant or to the builder on the building site. If the mayor is demanding that targets be set and it is not known if these targets can be reached, the municipal energy master planner must provide advice to guide the process. Similarly, the builder on site makes changes along the way if needed for a new technology or technique to fit in. When making the case for energy efficiency and the need for system optimization, this learning by doing approach might change the whole energy outlook of the building.

Next to basic knowledge, certain roles demand certain skills and competences as well. The best example is the process leader. In many cases this person is technically educated but not necessarily capable of bringing people together to achieve an integrated approach. The potential consequence of this lack of knowledge and skill is a process that is less than smooth and an increased risk of failure.

A lack of knowledge is due partly to not sharing lessons learned from past experiences. While successes are widely communicated, mistakes are kept quiet despite the fact that they are often the experiences from which the most can be learned. In many cases the wheel is reinvented over and over again and the same mistakes are made even though they could have been prevented. Not sharing mistakes makes scaling-up innovative processes and technologies much more difficult.

There are, however, places to make mistakes and other places where mistakes are not welcome. For example, in a litigious environment it is not always advantageous to admit to mistakes. Also, when

public money is involved mistakes are generally not welcome nor are the people who make them. On an individual level, people are wary of making mistakes out of fear of being judged. This is a paradox of innovation: creating new concepts requires making mistakes. Risk management is a way of handling the impact of the mistakes.

As shown before, certain roles must be fulfilled to steer urban development in the right direction. The person fulfilling this role needs to have certain knowledge and skills to properly fulfill the role. One of the most important roles is the process leader. This person must have insight into different kinds of expertise but must also be able to work on a broader and more strategic basis. This process leader can be in charge of organizing the process needed to reach the goal of an energy efficient low carbon city. The task is to coordinate the different departments of a municipality, as well as the stakeholders, to achieve this goal.

By paying attention to knowledge management, on an internal and external level the individuals involved – mayor, civil servant or builder—are empowered to develop the knowledge necessary to do their job. By organizing workshops and training sessions for all relevant persons throughout the whole process the amount of knowledge will increase. By creating a network of stakeholders (institutions, experts or advisors) and projects, knowledge can be shared. Sharing knowledge on a higher level between cities is also important. On many occasions the successes of developments are shared, but only on few occasions is the knowledge shared of how to achieve those successes and which route was followed. Failures are also often not shared. The failures and the route to success are the things we can learn from each other.

By sharing knowledge, people can learn, mistakes can be prevented and sustainability can be scaled up. It is important to create a situation in which making mistakes is a way to grow instead of something to be ashamed of, thereby giving scope to experiment and learning from it. In fact, we can talk about three levels of knowledge management:

- within organizations (the most common)
- between stakeholders in a city (very rare, because of potential competition, individual interests etc.)
- between cities (for example as is done in the framework of European projects)

Knowledge management

Ludwigsburg, Germany

The basic knowledge concerning the sustainable urban development strategy as well as the energy concept comes from the initiators and the staff members. But there has been a lot of knowledge transfer through international research projects like “Managing Urban Europe” or “Sustainable Now”.

Experiments by frontrunner cities or projects can be learned from. These types of projects are meant to develop and to test alternatives and innovative solutions on a small scale. Although it is desirable that the goals and targets as stated are achieved, learning from the results and the process is more important. In fact, in some cases learning is the main goal of the project: “*What bottlenecks turn up in legislation?*” “*What challenges were encountered in financing the project?*” A frontrunner project can be used to show that innovative concepts do work and to stimulate more innovation and discussion. To deepen, broaden and scale up sustainable solutions is the purpose of breakthrough projects. The concept must work on the project scale before it can be used on a bigger scale.

Breakthrough projects/ 'living labs'

District of Tomorrow: Heerlen, Netherlands

The District of Tomorrow is an innovative program in which educational institutions, researchers, businesses, and public authorities join together to create an exciting environment for the transition to a sustainable built environment. It takes place at Avantis, the European Science and Business Park in Heerlen, the Netherlands and Aachen, Germany. This innovative program involves designing, studying, and testing sustainable technologies so that they can be used 'tomorrow' in towns, neighbourhoods and buildings within the Meuse-Rhine Euregion. The District of Tomorrow is a driving force for sustainable development within the region and a venue for collaboration between vocational schools and universities of applied sciences. The District of Tomorrow is a project of Zuyd University, where bachelor students design very sustainable buildings for their thesis projects, supported by professors of RiBUILT and their research. The best design will be built on-site at Avantis. The city is both a learning company where students receive training in professional roles and the trades and also a research and practice test platform for the professors. Financial and substantive cooperation is also achieved with 60 private sector organizations. Next to this site there is an existing District of Tomorrow: Kerkrade West. With the working cooperation of housing corporations, new energy saving techniques are tested and completed in what is a 'living lab' for the existing building stock.



Figure 7-4: Breakthrough project District of Tomorrow, Heerlen, the Netherlands. Source: De Wijk van Morgen B.V.

Monitoring takes place on two levels: at municipal level for the whole city via top-down approach using aggregated statistical data and at the building or project levels using bottom-up monitoring approaches. In this section, city-scale monitoring of progress towards energy efficiency and low carbon goals and targets are further described.

Monitoring on a building or project level is taking place more and more, but consistent monitoring of progress towards targets at city level is established in only a few cases. The result is that each municipality must create or reinvent the process. This takes a lot of effort, time and money. Perhaps most importantly, chances are that mistakes will be made that have already been made by other municipalities. Even when a municipality is willing to monitor, it often lacks the most useful instruments since the indicators monitored are most often quantitative results and not the qualitative aspects of the process. It is questionable if monitoring will change the way of working if results are seen as data and not as a signal to change. Without monitoring, there is no translation from short-term actions to the long-term vision, goals and targets. Monitoring is used as an instrument to check whether the goals and targets are being achieved and to identify corrective actions if necessary.

Monitoring should start with the willingness to learn, the willingness to share these learning moments and the willingness to change. People should be aware that regular monitoring is essential to achieve

long-term goals and targets. Monitoring is not only done by learning from mistakes but also by observing the process. Results must be transferred to any ongoing development and to new developments. Redefine short-term actions if required.

To effectively monitor the process, a skilled team must look critically at the path taken, make corrections and transfer lessons learned to other developments. Anchor the monitoring process by establishing who is responsible for monitoring and who is going to pay for it. Ensure several people involved in the vision and target-setting phase are also engaged in monitoring; these individuals can relate to the rate of implementation of the vision and strategy and understand underlying arguments for choices made earlier. Monitor not only whether plans have been implemented, but also whether they have been implemented in a manner consistent with the process' guiding principles. Finally, start processing data as soon as the data is provided. Do not wait before all data is available because it might be too late to do sufficient analysis or make any corrections.

Monitoring

Freiburg, Germany

The municipality's aim is to move away from nuclear energy towards the use of renewable energy sources. The graphic below (among others) is used to monitor their short-term results towards their long-term target.

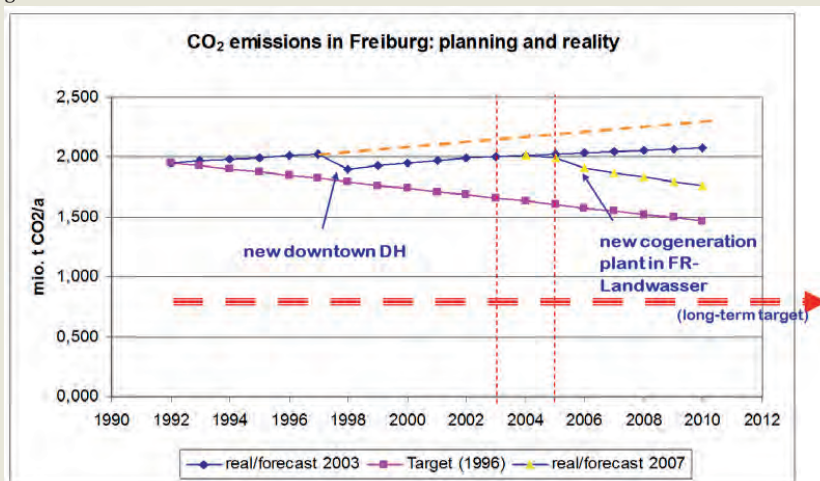


Figure 7-5: monitoring CO₂ emissions in Freiburg, Germany. Source: Erhorn-Kluttig et al., 2011

7.7 Co-benefits

From the different frontrunner cities and breakthrough projects around the world it can be seen that achieving energy efficiency will be more successful if it can be linked to other key issues. Achieving energy efficient low carbon cities will also make significant positive contributions to economic, social and environmental sustainability.

For example, improving the insulation of the existing building stock will provide more jobs for contractors, in industry and in transportation. Also, properties will increase in value which benefits owners through resale values and municipalities through increased property taxes. Producing new products locally can contribute to local economic development and a more increased economic stability regionally. All of these things are positive externalities; however, co-benefits are not usually taken into account when making the business case for energy efficient development.

7.7.1 Economic benefits

Stable energy costs

Energy costs for households are increasing. In social housing projects many residents have problems paying their energy bills. Their houses are often poorly insulated so the energy bill can represent a significant part of a household's living expenses. Rising energy prices are causing increasing problems in this regard. By making the building stock more energy efficient, energy costs are a smaller part of the household's expenses. Also, a city can generate its own local renewable energy. As a result the residents become less dependent on or completely independent from importing fossil fuel from less stable regions. As a result of these two actions people have lower energy bills, which, not determined by increasing oil prices worldwide, are stable for a longer period of time. There will be fewer problems with people who can't afford to pay their rent or mortgage due to rising energy costs.

Green jobs

Research by the International Labor Organization (ILO) published for the Rio+20 conferences summarizes results of a survey on green jobs in different countries.⁸⁵ 700 British business leaders indicated that "...a shortage of sustainable business leadership skills would represent one of the most pressing challenges facing UK firms over the next 5 years." Changes in employment were also explored: in each country employment in the service sector will increase, at the expense of industry and agriculture. Only Indonesia shows a different picture. The shift to services is essential to a green economy and it appears to be a trend that is already in motion. In Germany, an estimated 74% additional workers are required for recycling and 55% for renewable energy.

Other organizations have also made estimates of potential green jobs. The European Insulation Industry (EURIMA) calculated the number of jobs required to implement the existing EU energy saving policy. For example, an increase in housing renovations of 1% per year would result in an additional 150,000 jobs. In the glass industry for high performance glass alone, renovating all houses in the EU with energy efficient glass ($U = 1, 2$) over a period of ten years would create 126,000 new jobs.⁸⁶ In another report, Renovate Europe estimates that a deep, two-stage retrofit of European buildings of all types would result in 71% energy savings across Europe by 2050 and create 800,000 clean energy jobs.⁸⁷ Architects' Council of Europe (ACE) concludes that "...revitalization is therefore part of the solution."

Green jobs

Aarhus, Denmark

The greater Aarhus area has the world's most dense concentration of wind energy companies and represents as much as 87% of Denmark's entire economic output from wind energy. Additionally, almost 60% of all chief executives in the wind turbine industry and more than half of all other high-ranking employees in the industry are concentrated in the greater Aarhus wind cluster.

Ludwigsburg, Germany

During times of structural change, it is worthwhile to consider energy efficiency and economic development together. Competence in energy-related trades is a competitive asset, creating jobs in trade and contributing to the economy's export strength in a new market that is growing globally. Therefore, educational facilities and universities must be included in local economic strategies. Economic development is one of the three themes in Ludwigsburg's interdepartmental unit *Referat Nachhaltige Stadtentwicklung*. The city's initiatives to develop *Energetikom*, the energy competence center, and the Weststadt district demonstrate that it is worthwhile to cross-link stakeholders from the energy sector, trade, industry, associations and advanced training and research.

⁸⁵ <http://www.uncsd2012.org/rio20/index.php?page=view&type=400&nr=103&menu=45>

⁸⁶ <http://www.eurima.org/>

⁸⁷ <http://www.euractiv.com/energy-efficiency/energy-savings-deal-pushed-back-2012-news-509206>

7.7.2 Social benefits

When a neighbourhood or district is made more energy efficient through large-scale revitalization, social problems can also be addressed. Sustainable renovation can remodel and rebrand the neighbourhood, increase property values and create a more secure atmosphere. Investments are repaid through higher rents and lower energy bills. In areas with high unemployment, individuals can gain work experience on renovation projects. They can learn skills and improve their chances of finding jobs in the future.

Often these neighbourhoods have been neglected for many years, have numerous social problems and are not attractive to potential new residents. People moving out of these areas are typically not replaced by new residents moving in. Eventually, buildings will become abandoned and even more neglected which aggravates the problem further. Through revitalization, the district becomes a more attractive place to potential residents and the population will become less transient and more stable.

In a large proportion of the existing building stock, indoor air quality is often poor. Ventilation is poor, making moisture problems and mold quite common. When these buildings are renovated, these problems can be addressed and solved together, along with the energy efficiency measures. An integrated climate plan is therefore needed. By improving indoor air quality, people will have fewer health problems, will need to visit the doctor less and need less medication. This in turn has a positive effect on the health care system through cost savings. Furthermore, residents do not call in sick for work as often resulting in savings for both their employers and insurance companies.

In *CONCERTO: Socio-Economic Impact Assessment Report, European Communities* (2010)⁸⁸ a socio-economic assessment is made based on several indicators:

- degree of satisfaction and acceptance by inhabitants, tenants and owners
- active and proactive householders' behavior
- level of information and direct participation

The analysis shows that socio-economic actions carried out have had a positive effect on the implementation of CONCERTO demonstration projects. In order to rise to the challenge of integrating social, economic and environmental considerations, it is necessary to take an integrated approach encompassing methods, processes and data streams; only through a holistic approach can interactions in complex systems be understood and acted upon.

7.7.3 Environmental benefits

Improving the energy efficiency of a city can address numerous issues simultaneously, often saving costs by taking all measures at once. Examples of environmental issues that can be addressed in tandem are land use, nature conservation and waste water treatment. Climate adaptation is becoming an important issue in countries such as the Netherlands and Denmark. In the Netherlands, an increasing number of high intensity rainfalls and longer dry periods in summer are causing problems in the built environment. In Denmark, sea level rise is one of the focal points for climate change adaptation efforts.

Energy efficiency clearly helps the environment in and of itself. Taking this thinking a step further, it also helps to reduce air pollution from transportation, for example. Renewable energy can help the environment in unexpected ways. Contrary to what was expected, research has shown that off-shore wind farms are a safe harbor for fish and other marine life.

⁸⁸ <http://concerto.eu/concerto/library.html>

APPENDIX to Chapter 7

	Austria	City of St. Johann
Long-term goal	To be 100% energy autonomous by 2020	
Population	10,714	
Heating degree days	3,573	
Description	Energy autonomy is understood as an effort of the municipality to become independent of the need to import fossil fuel for heat, electricity and mobility. St. Johann is also a member of the Climate Alliance, a commitment that means achieving a 50% reduction in CO₂ by 2020 compared to 1990 levels. The target is supported by the following goals also to be achieved by 2020: - Increase energy efficiency in all sectors - Use local renewable energy resources - Create visible examples of active mobility - Support the economy and tourism through the community energy strategy - Consider nature and the environment	
Important bottlenecks	Involving the population and other stakeholders in binding instruments and opposing trends and policies such as tourism and new business development.	
Reasons for success	- Standardized process - On-going process since 1998 - Knowledge transfer with other experts and municipalities - Establishing an e5/eea team responsible for achieving the municipality's goals with different stakeholders as members.	

Figure 7-6, source: Atelier Oczlon

	Canada	City of Prince George	
Long-term goal		Province-wide target to reduce GHG emissions by 80% by 2050 compared to 2007 levels. Short-term milestones: the city shall reduce corporate GHG emissions by 10%, and reduce community GHG emissions by 2% compared with 2002 levels.	
Population	72,000		Figure 7-7, source: City of Prince George
Heating degree days	4,727		
Description	The strategic vision of the city council, in charge until late fall 2011, was: - Creating a better downtown: focusing on energy alternatives - Improving Health and safety: addressing future energy supply and cost risks - Taking care of air, water and land resources: managing community forest and reducing GHG emissions - Strengthening and diversifying the economy: exploring bio-energy alternatives for fiber supply - Increasing civic pride: promoting local clean innovation - Continuing progressive and responsible fiscal management: lifecycle and full cost accounting		
Important bottlenecks	- A change in political direction. A new mayor and council were elected in the late fall of 2011. The new council has removed most environmental measures from its priorities and eliminated the city's environmental division including the position of the community energy manager - Council's priorities have shifted to focus on economic development by supporting energy resource extraction and trade		
Reasons for success	Prior to 2011 reasons for success included: - Having an informed and engaged mayor and council. - Knowledgeable city staff across various departments - Justifying energy planning through a focus on priority areas such as economic development and public health. - Engaging residents in various processes considering energy and GHG and demonstrating the ability to change public opinion regarding the introduction of energy technologies, specifically the Downtown District Energy System		

Figure 7-7, source: City of Prince George

	Denmark	City of Aarhus
Long-term goal	To be CO ₂ neutral by 2030.	
Population	311,000	 Image: Cees van Roeden
Heating degree days	3,503 Kd	
Description	The City of Aarhus has been working on climate issues for a number of years, through environmental action plans, energy management systems, wastewater plans, green accounts and environmental impact assessment of construction projects. Furthermore, Aarhus is one of the leading cities in Denmark when it comes to district heating supply, public transportation options and extended bicycle path network.	
Important bottlenecks	- A lack of backcasting. The overall target and strategy have been established and projects have been launched, but it is not clear if the effort is sufficient for the city to reach its target. A main part of the Climate Plans is the implementation of successive projects, which are assessed afterwards. It is uncertain, however, if those plans and actions are really in line with the goal of being CO₂ neutral by 2030.	
Reasons for success	- Having both a highly committed municipal administration and political commitment at the highest level - Introducing Climate Partnerships - Available proven climate-friendly technologies and businesses on site (e.g. district heating and wind energy) - Establishing a good monitoring plan: Climate Plans are versatile and are revised every two years.	

	France	City of Nantes
Long-term Goal	To achieve a 50% reduction in GHG emissions by 2025.	
Population	580,000	 © Sabine de Villeroy
Heating Degree Days	2,483 Kd	
Description	The challenge for the city of Nantes is to establish adapted objectives. Those objectives must be in line with international commitments (the factor 4 reduction required by Kyoto) and national targets as required by the Regional Climate-Air-Energy Plan (SRCAE - <i>Schéma Régional Climat-Air-Energie</i>). These regional plans have been the main energy planning tool in France since 2006. Climate plans are required by the State and the local community must establish realistic quantitative targets in relation with national goals. Although many municipalities have already implemented energy policies and actions in their jurisdictions, for example in the areas of public building consumption and waste management, the development of local objectives is new. Several innovations occurred simultaneously and influenced the process of energy policy for 10 or 20 years.	
Important Bottlenecks	- The need to go beyond individual events to raise awareness more broadly - Engaging all stakeholders in the region	
Reasons for Success	- Having a precise understanding of the problems through the <i>Carbone Assessment</i> - Providing tools and management methods for communities and the public - Engaging one or more people from city council as champions - Creating opportunities for stakeholder engagement and promoting interaction between actors and the public population, for example through climate workshops - Generating broad, long-term commitment to the process	

Figure 7-9, source: Sabine de Villeroy, MRW ZEPPELINE BRETAGNE

	Germany	City of Ludwigsburg
Long-term goal	To be energy neutral by 2050.	
Population	87,000	
Heating degree days	3,239 Kd	
Description	On the basis of the integrated Urban Development Strategy a municipal energy and climate protection concept called the Citywide Energy Strategy (CES) is currently implemented via numerous projects. The CES gives priority to a holistic, city-wide perspective. Heat, electricity and the transport sectors were analyzed regarding their present and future contribution to energy efficiency and opportunities for renewable energy generation and climate protection. The CES does not contain specific targets but is aligned with the goals of the city's Urban Development Strategy (UDS). Results and proposed measures were discussed during the citizen participation process. The UDS is the dynamic foundation for the long-term development of Ludwigsburg. It also aims to be equitable for all generations, consistent with the guiding principles, objectives and conceptual framework for sustainable urban development. In the course of the process, the strategy is reviewed, further developed and updated.	
Important bottleneck(s)	Members of Ludwigsburg city council were skeptical in the beginning.	
Reasons for success	- Securing commitment to the process on the part of the majority of actors within the city administration - the Lord Mayor acting as a leading figure and champion - engaging in an extended stakeholder process resulting in a broad commitment	

Figure 7-10, source: City of Ludwigsburg

	Sweden	City of Stockholm
Long-term goal	To be fossil fuel-free by 2050.	
Population	850,000	
Heating degree days	5,433 Kd/HDD	
Description	Energy use and energy supply targets for Stockholm County are distributed across the building, transport, industry, agriculture and forestry sectors. The associated energy and climate long-term vision is to achieve a fossil-free Stockholm area based on energy savings and renewable energy by 2050. While district heating plays an important role in reaching this target, in order to achieve the vision and make the region fossil fuel free, transport is the biggest issue.	
Important bottleneck(s)	- To enable population growth while improving the environment and public health - To be a small city in a large region and an international leader - To make the region more secure in times of growing global uncertainty - To minimize climate impacts while supporting economic growth - To address existing shortfalls and needs while continuing to grow - To open up the region whilst minimizing exclusion	
Reasons for success	- For now the biggest success is political acceptance across all parties for the process. It is unclear however how long this situation will last.	

Figure 7-11, source: City of Stockholm

	The Netherlands	City of Tilburg	
Long-term Goal		To achieve a 100% reduction of GHG emissions by 2045.	
Population	205,000		
Heating Degree Days	2,902 Kd		
Description	Tilburg has been on the road towards sustainability and energy efficiency for many years. It is one of the frontrunners in municipal climate policy in the Netherlands. While efforts in Tilburg have resulted in many attractive projects and programs, these alone are not enough to achieve an energy transition and the city's ambitious GHG target. Tilburg believes in an alternative governance approach. This is exemplified by the creation of a regional network organization that is grown organically with the Climate Board as a focal point. The Climate Board consists of a multi-sector network where climate alliances and consortiums are established to initiate projects based on green deal agreements. For example, an innovative approach for existing privately owned homes is carried out according to the philosophy of the Climate Board through local private companies. The municipality participates in this newly established consortium. Other energy achievements include implementing district heating, waste heat recovery, as well as bicycle lanes and routes throughout the city to encourage a reduction in car dependence.		
Important Bottleneck(s)	An important bottleneck is that big energy companies will not take the risk of investing in large-scale sustainable energy infrastructure. There is therefore no 'issue owner' to lead implementation of energy infrastructure on the city-wide scale.		
Reasons for Success	- Broad commitment on the part of municipal administration and politicians - Having expert knowledge within municipal departments - Institutionalizing GHG emissions reduction targets and related goals in municipal policies - Partnerships between companies and citizens, for example climate partnerships		

Figure 7-12, source: Wikimedia Commons / Platonides

8 Summary and Conclusions

Currently available standards of individual buildings, residential or others, such as “green” buildings, zero-energy buildings, CO₂-neutral buildings and the like, promise very large reductions in fossil energy consumption and GHG emissions, from “factor 4” to “factor 10”. Considering all of the existing building stock in neighborhoods, municipal quarters or towns, the achievement of such ambitious targets is both easier and more difficult than it is for individual demonstration buildings: while on neighborhood scale there may be more technical and economic possibilities, it is much more challenging to find an agreement with the involved stakeholders about the best local energy plan and its implementation. Therefore, issues of decision-making processes, organization and implementation strategies have much more weight compared to mere technological or planning issues for individual buildings. Another important difference lies in the fact that contrary to single demonstration buildings, the aim of neighborhood scale energy plans must be to find an economically optimized solution *for the whole neighborhood* rather than the latest technical solution for few show-case buildings, otherwise comprehensive implementation will not be achievable.

Due to economies of scale, a number of technologies, like cogeneration or combined heat and power, waste heat utilization, biomass, geothermal energy, solar heating (and cooling), and others, are more efficient – in technical and economic terms – when used in large installations instead of small ones. Taking advantage of these technologies, if locally available, the effective primary energy consumption achieved by an integrated system may fall even below best available standards for new buildings, but with lower cost and with the advantage of feasibility in large scales. While the necessity to improve technical components – and to reduce their costs – on the level of individual buildings, new or existing, still remains and often is the only available option, in compact built areas a centralized approach may offer better economic options. A successful urban energy and climate change policy will only be available if such options can be found and realized whenever possible; otherwise, it will be too expensive.

The appropriate planning level to achieve this is the neighborhood or district level: planning for individual buildings often cannot benefit from potentials of their surroundings; municipal energy planning on the other hand will in general provide only a theoretical scheme for the whole city that cannot be implemented in a straightforward manner in the concrete case of a neighborhood project.

However, a city consists of several districts or neighborhoods. Their local energy plans must be consistent with the overarching municipal energy master plan. Therefore, there is the parallel task of optimizing the neighborhoods of a city in a bottom-up approach and of finding an overarching plan for a future-proof development of the whole city.

On this scale, energy issues are only a subset of many other topics that have to be considered in order to achieve a true “sustainable urban development”. This interaction of different decision levels and activity fields is described in figure 8-1, illustrating the simultaneous actions required on the ‘strategic’ level and on the ‘operative’ level that interact with the general urban (economic) development in an iterative way over many years.

The resulting complexity will require an appropriate approach towards a holistic planning and implementation strategy to achieve the transition to a future energy-efficient and low-carbon city. As a consequence, to plan a ‘future-proof’ energy system, to a larger extent than in the past a *systems approach* is necessary, by which interactions of and feed-back processes between different parts of the urban system must be considered adequately.

To respond to these challenges, Annex 51 *Energy Efficient Communities* presents the results of case studies at the neighbourhood and city-wide scales and identifies strategic guidelines for decision makers and stakeholders engaged in local energy planning. The purpose is to further refine the local energy planning methodology with the hope and intention that communities will learn from the

experiences documented and apply some of the approaches in their own energy planning processes. To assist with this, common bottlenecks have been identified and solutions proposed variously in municipal administration and management, design and management of energy systems, and financial instruments used to fund energy projects. Chapter 8 provides a concise overview of the results of Annex 51, beginning with key results in the form of broad challenges and solutions. The five steps in the local energy planning process are summarized along with selected observations. Eight guidelines for energy transition success are distilled from the case studies for the benefit of decision makers and stakeholders.

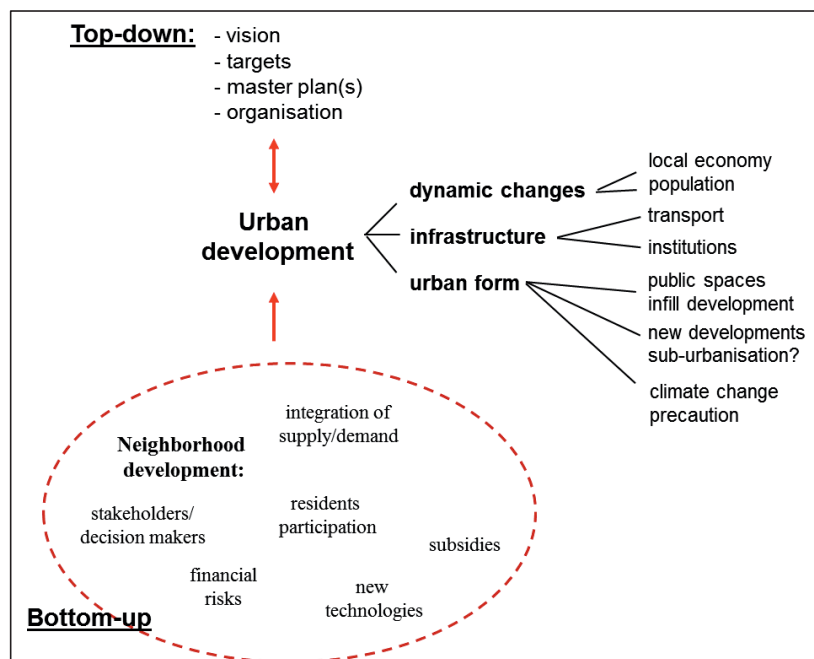


Figure 8-1: Urban energy planning requires both bottom-up and top-down approaches to be successful.

While the main focus in this chapter is laid upon the municipal energy transition process, methods and approaches of neighborhood energy planning are broadly discussed in chapter 3 and in the Attachments of the Guidebook.

8.1 Key results and implications

8.1.1 Neighborhood energy planning

With respect to technically advanced neighbourhood projects (solar thermal, biomass, heat pumps, cogeneration, LowEx-technologies, novel building embedded systems ...), new thermal energy supply technologies in many cases still proved to be too expensive compared to conventional systems and thus required subsidies for their implementation. However, there was consensus amongst the experts that there exist unused potentials for cost reductions, for example due to suboptimal planning because of lacking experiences.

The most important barrier, however, was poor performance of the installed technologies, which often resulted from poor system integration of the various technologies employed in a specific project. Due to lacking or insufficient (control and) monitoring equipment (which in conventional technologies is

less important), active 'retro-commissioning' and continuous optimization of system operation is difficult and requires expert knowledge. Poor performance does not only prevent the achievement of project goals – be it economic or energy goals – but will seriously step down the market penetration of new technologies.

The lack of sufficient technical capacities, planners or suppliers, is another problem often experienced in advanced neighbourhood energy projects. There is a need to disseminate lessons learned from practical experiences to local craftsmen and industries, which currently is done in an insufficient way.

While both the technology and the interest of potential investors is apparently there, due to the increased system complexity the real problem to be solved is to find qualified planners and system operators. One solution of this problem would be a pronounced co-operation with experienced contractors, for instance for integrated residential neighbourhood projects, who should be better capable of finding optimized technical and operational solutions and thus could be more cost efficient. To avoid technical and economic failure, energy regulations should privilege such contracting approaches, where the responsibility for the overall success of an integrated energy project remains with the contractor, in particular during the operating phase. For integrated neighbourhood energy planning, this would reduce the planning risks and the implementation barriers significantly.

8.1.2 Municipal energy planning

Designing this Annex, the initial assumption was that

- insufficient know-how on strategic planning,
- insufficient management ability during the implementation process, and
- insufficient availability of tools and instruments for decision making, planning and monitoring

would be the decisive 'technical' barriers that prevent communities from a successful municipal energy and climate policy. Evaluation of the case studies addressing municipal energy master planning revealed that the technical energy planning problems – on the municipal level (!) – were not the decisive bottleneck. The management problem, in particular the problem of initiating and steering the necessary transition processes on all levels of local decisions, is the real problem faced by the persons in charge of implementation of the municipal energy policy.

While most of the investments necessary to guide the local energy systems into the aspired energy future must be made by private investors on neighborhood level making use of adequate business models, a certain degree of *coordination* is necessary on city level that enables the market participants to take the right decision at the right time to make the intended energy transition happen with least possible transaction costs. This coordinative task requires an overarching long-term strategy of the local government – the *municipal energy master plan*, which every city should have in the first place.

To ensure a successful implementation, adequate organizational structures must be established and maintained either in the city administration or assigned to it, for example in the form of a local energy agency, over the whole time that is needed for the transition process. There are costs caused by the provision of such an organization, but they can be considered to be small compared to the decrease of transaction costs of the municipal energy transition that can be achieved.

Thus, an important conclusion is that the most prominent barrier to achieve municipal energy goals is not given by inadequate energy technologies or planning tools (though these should still be further developed and costs reduced during increasing application experiences), but by

- a lack of access to the relevant knowledge (energy systems analysis, process management),
- missing municipal management structures and personal capacities,
- missing consciousness within the local governments about the importance of such structures,
- and a lack of sustained commitment on the part of the important local stakeholders.

Estimates have been made in Case Studies about the order of magnitude of costs to be expected by the required energy transition process of whole cities, which amount to 10,000 EURO per inhabitant and more. While this seems to be a very large investment, it must be compared with the substantial investments into infrastructure and the building sector of a community that are continuously ongoing anyway. The aim must be to use these ongoing change processes to steer the urban development into the right direction.

Beyond reasons of local climate change impacts, which are still not fully understood in the broad public, there are additional reasons to support such a policy that include

- increase of energy supply security by reducing dependence on imports from politically unstable regions;
- reduction of economic disruptions caused by rising energy prices;
- cost savings for energy users by improving energy-inefficient buildings or equipment;
- local economic advantages by capitalizing on local investments in energy conservation or renewables;
- modernization of local infrastructure;
- promotion of sustainable urban development in general.

These co-benefits of working towards energy and GHG emissions targets should be emphasized in the communication with stakeholders and the broad public to increase awareness and acceptance of the consequences of the local energy policy.

8.1.3 Computer-based planning tools

Evaluation of the Case Studies and the practical experiences of the Annex experts have shown that

- simulation tools, both for buildings and for single energy system components, such as solar collector arrays, cogeneration plants or district heating networks, are available and widely in use by planners,
- tools to compile energy and GHG inventories for whole municipalities have been developed and are currently also widely used by city administrations (and are increasingly assisted by offices for statistics to ease the tedious task of data gathering).

Tools that support automatic energy mapping for neighbourhoods or communities by combining GIS data with airborne scanning data to provide 3D city models including energy demand estimates of the neighbourhood's buildings are still in their infancy. However, due to the ongoing development of powerful computer hardware and software it can be expected that such tools will be available and broadly in use in the near future.

In contrast, energy system models describing the behaviour of 'integrated' energy systems (i.e. demand and supply), for instance on neighbourhood scale, with sufficient time resolution and providing both simulation and optimization calculations, are still used more or less by academia only. Such models are complex and difficult to use. In combination with GIS models, they could be very powerful for LEP. It is concluded that this is still an area of basic research that should be fostered more effectively than it is currently the case.

8.1.4 Legislative frameworks

The overview of the existing legislative boundary conditions in the participating countries that are relevant for LEP has disclosed a variety of legal, financial and organizational frameworks: National strategies vary considerably in design, complexity and financial costs. Periodic fine-tuning and adapting regulations to specific needs results in more complex regulations, which in itself can cause a barrier. A comprehensive appraisal of the effectiveness and cost/benefit ratio of the instruments found

and their potential transferability to other countries is not available. After many years of experience, there would be value in enhanced knowledge exchange concerning the design of future energy and climate change policy instruments. A more comprehensive analysis of national energy policy approaches within IEA countries and more profound energy policy conclusions should be considered for future research by the IEA.

Feed-in-tariffs as a powerful instrument to promote electricity generation from renewable energy sources are used in several of the participating countries in various designs – in contrast to renewable thermal energy, where a comparable instrument has not been found. In two countries, Denmark and Germany, the expansion of volatile sources (wind energy, PV) has meanwhile reached a degree causing challenges in system integration and back-up and storage capacities. Besides necessary FIT changes in these countries towards more market orientation, the potential role of the building stock as a whole as active constituents of the energy system (storage, detached generation, DSM, smart buildings) must be more strongly pronounced in the future, also within the legislative frameworks. It is this transition to 'smart cities' – in a very comprehensive sense – that will be the key to success in the long term.

In several participating countries it is mandatory for municipal administrations to provide local energy or GHG action plans. The methods and quality of such plans vary from country to country. It would be useful for every country to stipulate such a basic planning instrument to be a mandatory constituent of urban development plans because it would foster the necessary integration of energy issues into the traditional urban planning procedures. At the same time, it would add to the planning know-how and capacities needed if communities are expected to contribute their part to a successful national energy policy.

8.2 Municipal energy transition process

This evaluation has investigated the approach of pioneering cities in IEA member countries towards energy efficiency in order to develop a roadmap of the ideal transition process for reaching energy efficiency targets; state of the art and leading edge neighbourhood scale projects were evaluated. Investigating the best practices in different countries gives access to leading examples and demonstrates how the different limiting conditions in the individual countries influence the results. In the ideal transition process, any limiting factors can be adjusted to optimize the process. The five basic steps in the local energy planning transition process and some of their essential features are illustrated in figure 8-2.

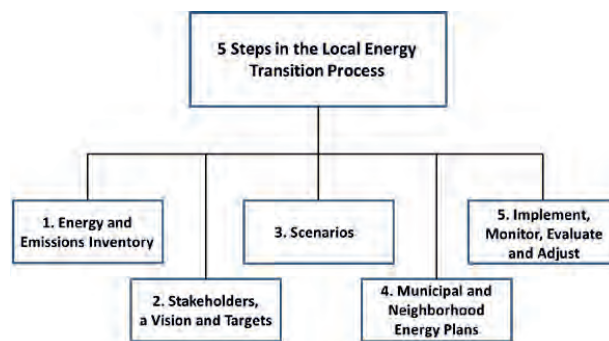


Figure 8-2: The five steps in the local energy planning process - the steps are more circular and iterative than this diagram suggests.

Step 1 Develop an energy and emissions inventory

Following approval by the municipal council to embark on an energy planning process, the first step is to develop an energy and emissions inventory or balance. Characterizing annual energy use for the municipality as a whole by source or carrier and sectors enables the municipality and stakeholders to assess current energy use and trends over time when the inventory is collected regularly. Additional data describing the building stock, population, renewable energy resources at finer spatio-temporal resolutions assists opportunity assessment and neighbourhood planning later in the process.

Chapters 3, 4 and 7 provide context on the nature of energy and emissions inventories and approaches to energy system modelling, their developers, enablers and the audience for their outputs. Several examples of practical application of inventories and models are described and their effective communication discussed.

Step 2 Engage stakeholders, create a vision and establish targets

The municipality conducts a stakeholder analysis and invites participants to a transition arena where they work together to create a common vision and establish long-term quantitative targets. Key supporting indicators may also be identified in this step. The municipality establishes an energy working group comprised of municipal officials from relevant departments, key stakeholders and a high profile energy planning champion to assist with further planning and implementation over the long-term.

Many Annex 51 case studies show that cities are defining ambitious targets to decarbonize their energy systems. Achieving these requires both substantial energy savings and an increased use of local or regional renewable energy resources. This in turn requires restructuring of existing energy supply systems and energy use patterns. Frontrunner or leading cities have demonstrated that not only barriers but also benefits exist for these transition processes: for example, increased investment budgets resulting from energy cost savings, increased quality of life for city inhabitants, and local economic incentives. If local energy policy targets are not realistic however there is the risk that they will remain wishful thinking. Problems can arise from a lack of technical and organizational knowledge, a lack of coordination, a fragmented approach, or not taking account of conflicts between different goals or dissenting local stakeholders.

The transition to an energy efficient low-carbon community requires a wide range of technical, economical, architectural, financial, legal, and behavioral requirements to be met. Because these requirements are interlinked, care must be taken to avoid contradictory or sub-optimal measures arising from conflicting goals. Problems can be mitigated by taking a holistic perspective and using an inter-disciplinary approach to develop and work towards a vision of the intended future state of the community.

Step 3 Assess opportunities and create future scenarios

Using the energy and emissions inventory, additional data and local and expert knowledge, energy efficiency, energy systems and renewable resource opportunities are assessed and key supporting indicators confirmed. As soon as municipal long-term targets and related objectives are established, backcasting and forecasting techniques can be applied to define the steps and processes leading towards the energy and GHG emissions targets. As depicted in Figure 8-3, *backcasting* denotes the process of working backwards from future goals to determine concrete steps or actions and associated impacts to achieve the goals. In contrast, *forecasting* works forward from the current context and identifies concrete actions and compares their impacts with milestones and long-term targets developed through the backcasting process.

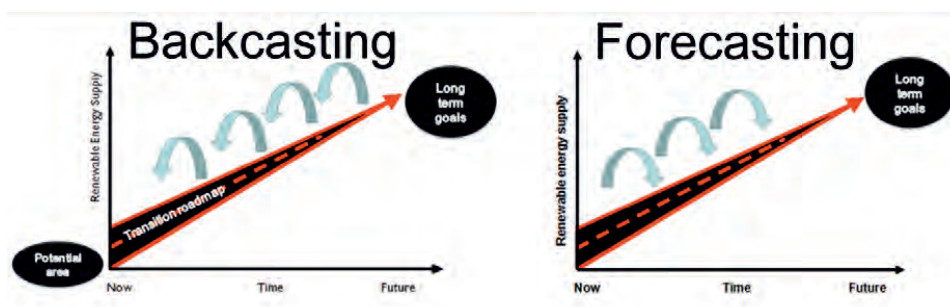


Figure 8-3: Backcasting and forecasting approaches for achieving long-term goals or targets

Both backcasting and forecasting are necessary to determine the transition path and to develop the roadmap or energy strategy as concrete as possible. Depending on available data and resources the municipality may take a collaborative and engineering approach, making use of stakeholders' ideas and creativity and the best available quantitative estimates on hand. Other municipalities may choose to work with stakeholders and also leverage computer-based models to undertake a more robust quantification and optimization. Often a Business As Usual scenario and two or more alternative future energy scenarios are created initially. When the preferred scenario is identified a roadmap outlining the strategy is created to reach the long-term targets; it includes prioritized measures and medium-term quantitative targets milestones. The calculation models used for backcasting and forecasting can also be used to monitor the transition process in relation to long-term goals. The building blocks of this transition process are described in the roadmap in figure 8-4.

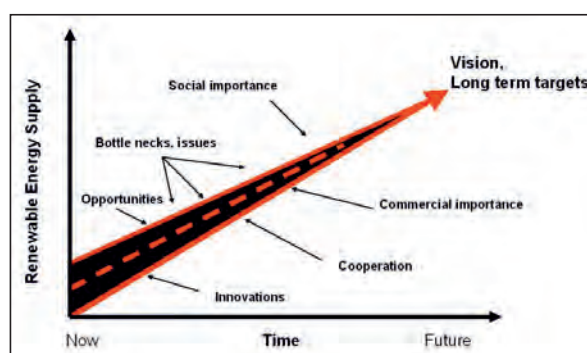


Figure 8-4: Transition management involves designing a roadmap towards a vision

Step 4 Develop municipal energy master plans and neighbourhood energy plans

The municipal energy master plan is a strategic planning document that includes visions, targets and goals, selected baseline values and key indicators. A roadmap of the preferred scenario to reach the municipal target, with prioritized energy conservation, system and supply alternatives are listed, along with implementation and monitoring strategies. Neighbourhood energy plans provide additional technical details on energy demand characteristics of neighbourhoods, preferred supply alternatives, conservation potentials, optimized supply and demand and cost structures. These plans are iterative and should be updated periodically.

Step 5 Implement plans and projects, monitor, evaluate and adjust the process

Integrated process management techniques are used by a process co-ordinator who works with municipal departments and external stakeholders to implement and monitor measures in the plans

and evaluate results. Successes and failures are communicated back to the municipality and stakeholders. Feedback is obtained for the purpose of updating the plans. Bottleneck analysis may also be performed to analyse and further improve the process.

A bottleneck analysis carried out by engaging relevant stakeholders forms the basis for exchange of knowledge and lessons learned. When bottlenecks are identified, possible solutions can be identified, often inspired by the experiences already made by frontrunners (figure 8-5). The case studies in this Annex 51 illustrate a number of bottlenecks which often make the transition to energy efficiency difficult for cities and towns. Conventional processes such as urban planning, local energy and traffic planning, procurement and cooperation are characterized by fragmentation, short-term thinking and a focus on individual interests.

For a municipality to work effectively towards energy efficiency, it must utilize a controlled process which identifies all ongoing opportunities and stakeholders concerned. This will make it possible to take full advantage of all opportunities and benefits of synergy. Unfortunately, in many cases municipalities assume that their situation is unique and re-invent the wheel as a result. It appears that knowledge transfer is difficult, except in situations where very specific bottlenecks in one project are linked to specific solutions elsewhere. On the basis of the solutions developed by leading cities, specific advice can be given to different municipalities. Removing a bottleneck or barrier generally requires fundamental changes to the underlying planning processes. Experience from pioneering or leading cities shows that fundamental changes in how stakeholders think, work and manage are required for success in the energy transition process.



Unrealistic goals and targets

- Vague ambitions
- Wishful thinking
- Inability for individuals to identify with targets
- Conflicting municipal priorities and goals



Ambitions not widely supported

- Lack of trust
- No common goal and vision
- Ambitions not supported by municipal departments
- No intrinsic motivation
- Area residents do not support proposed development
- Poor communication with the general public



Non-integrated approach

- Difficulty co-ordinating municipal departments
- No common vocabulary
- Organizational processes and working methods are segmented or 'siloed' within each sector
- Split incentives
- Implementation and operation separated
- No monitoring, evaluation or feedback



Non-continuous process

- Short-term focus
- Vision and targets insufficiently anchored in policy
- No problem-owner for the process as a whole
- Lack of coordination between projects within the municipality
- Lessons learned are not shared
- National policy not continuous
- No monitoring
- Lessons learned are not shared

Figure 8-5: Typical reasons for bottlenecks

8.3 Eight guidelines for local energy planning success

The following eight guidelines for success summarize the knowledge and experience gained in the Annex 51 case studies and the methodological conclusions drawn in this Guidebook. These build on the five energy planning steps outlined above (see Chapter 3). These guidelines are formulated to be useful for municipal decision makers seeking to overcome bottlenecks when initiating and implementing an energy transition process.

Guideline #1 Create an inspiring vision!

To achieve long-term energy and GHG emissions targets, a clear vision of a desirable future community and energy system must be created. A diverse group of opinion makers, end-users, officials from different municipal departments, local businesses representatives, politicians and external experts should work together to create inspiring visions upon which everyone can agree. Developing such visions in a workshop is a good way to encourage stakeholders to free themselves from conventional thinking. Questions could include: *"What will the 'energy efficient city' look like after the energy transition?" "How will people live in it?" "How will people move in and through it?"*

Guideline #2 Cultivate an integrated approach to management, process and organization!

An approach that integrates various stakeholder perspectives and relevant municipal administrative departments offers the greatest chance for success. However, Annex 51 case studies revealed that horizontal segmentation and vertical or hierarchical organizational structures make efficient co-operation difficult. Municipal departments are organized independently of each other and employees are not accustomed to consider the situation in an overarching perspective. In many cases, communications on a working level between departments are insufficient which in turn complicates coordination between decision makers.

This integrated approach must be institutionalized within the municipal administration in its plans and policies and ensure that necessary communication and collaboration between departments takes place systematically, based on what each can contribute to the targets and goals. Cross-pollination between disciplines and actors should be encouraged in practice. People should work alongside each other in the same workspaces in on-going projects. Multi-disciplinary, interdepartmental teams can test policies and plans against the transition roadmap contained in the municipal energy plan established at the beginning.

Because many departments, companies and individuals contribute, it is important that participants adjust their attitudes and expectations so that everyone is able to contribute to achieving the targets. Since the implementation process takes a long time and involves many stakeholders and decision makers, there must be the possibility of checking the results intermediately, learning from mistakes and re-adjusting the strategy. This is a continuous process employed in many complex management tasks and industrial performance programs. It can be characterized by the 'plan-do-check-act' rule, as depicted in figure 8-6.

Communal Management System for Energy and Climate Policies:

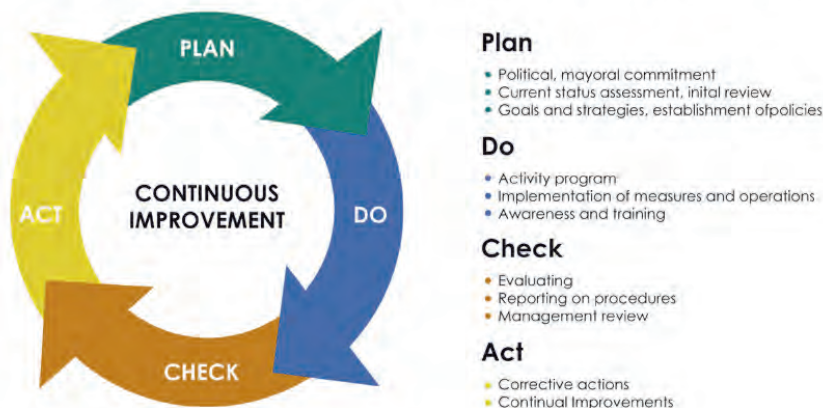


Figure 8-6: The design and implementation of energy and climate policies is an on-going process that must be monitored, evaluated and continuously improved. Source: SIR / pro:21 GmbH

Guideline #3 Evaluate the local context in your city and make a transition analysis!

Achieving an energy-efficient, low carbon city requires a combination of energy demand reduction, energy supply switch or cascading, local renewable energy production, local energy storage potential and appropriate energy infrastructure. An energy concept must be developed which considers the local energy demand, the system boundaries, and the available energy resources of the city and which also corresponds to the existing economic and social situation.

Incorporating local sources of renewable energy is an important task for urban planners. City buildings and infrastructure and the energy system are interdependent: density determines local energy opportunities, and energy systems affect buildings and infrastructure. Examples include roofs optimized for orientation and slope to maximize solar energy generation, energy infrastructure for the supply of heating and cooling, energy storage opportunities and even buffer zones around wind turbines.

Transition analysis is used to create an inventory of the potential opportunities within the city, relevant for the development of the energy strategy and urban and local energy plans. Creating a baseline inventory of the current context and developing scenarios is described in Chapter 3. The spatial, economic, ecological and socio-cultural characteristics, including heritage buildings, landscape characteristics and broader socio-economic dynamics are mapped. Emerging trends, internal and external influences are also included. First, the area and their characteristics are defined, data on the area is collected and existing studies, interviews and other relevant materials are examined to characterize the current context. Local stakeholders must be involved to perform the analysis. This process provides general information that forms the basis for the conceptual framework. Opportunities for cooperation between different stakeholders can also be identified. This analysis provides the starting point for further discussion about future energy concepts for the city.

To develop an integrated energy strategy for the city, an opportunities assessment of future energy demand must be compiled based on the existing potential for energy demand reduction. Topography, climate, land use, surface and local elements need to be taken into account. Then the available renewable energy sources can be determined: sun, wind, hydro, biomass, geothermal, waste heat,

etc. These energy sources are mapped in terms of heating and cooling and electricity potentials. This can identify waste energy sources and required adaptation of the energy infrastructure to allow use of the existing potentials. The combination of energy demand reduction, energy supply from renewable energy sources and switching between energy carriers can then be optimized.

When interpreting the results, it is important to pay attention to interdependencies, timeframes and the potential for uncertainties and setbacks. Rapid technology change means a large chance that new strategies can be developed over the course of the municipal energy transition. It is generally prudent to develop clear targets and a clear vision at the beginning of a project while avoiding strict definitions of the technologies to be used.

Guideline #4 Exercise smart leadership!

Because a city cannot become energy efficient by continuing with a Business-As-Usual approach, smart leadership is needed to ensure that the municipality avoids sub-optimal solutions while trying to achieve its energy and GHG emissions reduction targets. One component of smart leadership is having an influential person such as a mayor, elected official or municipal administrator to act as a champion for the process. This person must be personally motivated to maintain focus and must generate enthusiasm among stakeholders and the general public. He or she must propose creative solutions and react effectively to setbacks when they occur.

In addition to having a champion, smart leadership also involves appointing a coordinator responsible for the entire transition process. This person would be in charge of the implementation process and coordinating activities and projects within the municipality and involving stakeholders and the public. She or he must be given the authority to organize the process directly, to work on a broad strategic level and make decisions without approval from upper management. This coordinator must report directly to the mayor, council, or other high-ranking official. This person should possess certain competencies such as insight into different areas of expertise, from administration to urban planning and energy issues. Since the process coordinator and the city's energy champion cannot achieve the targets on their own, a strong team is necessary, possessing expertise in specific areas that should be widely shared. This is illustrated in figure 8-7.

Guideline #5 Ensure participation and create new coalitions!

Insufficient stakeholder support can be a powerful barrier to success, mainly due to the great efforts required to overcome this as an obstacle. Successful stakeholder involvement requires fair rules. The involvement of stakeholders must be based on their own interests, motivation and perspectives. Each stakeholder group not only has the right to participate but also needs the opportunity to bring their issues to the fore. Although this also implies engaging politicians, their participation should not involve any policy-driven interference. Ideally, stakeholder groups work to support decision makers such the mayor or municipal council. The significant benefits of coordination and co-operation have to be made clear. Success must be presented as a result of the combined effort of all stakeholders.

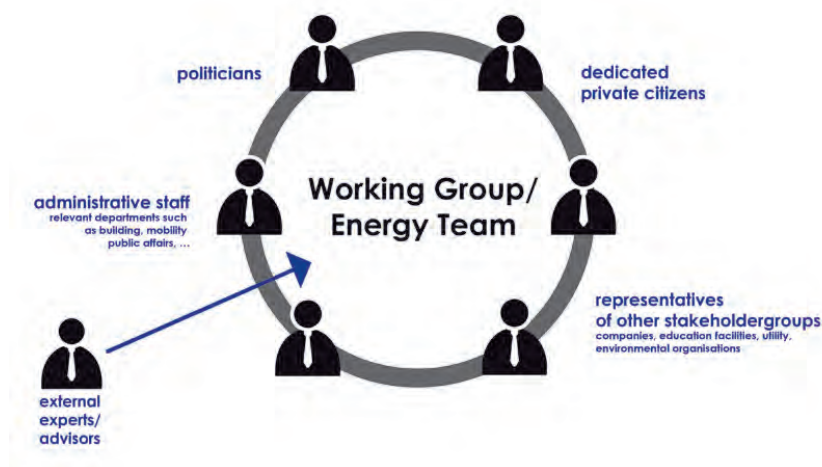


Figure 8-7: Structure of an interdisciplinary energy working group. Source: SIR / pro:21 GmbH

A clear understanding of the interests and motivations of stakeholders who play or should play a role in the process is essential. Taking a broader look at who can benefit from or affect the development can create new collaborations and new roles to emerge. Stakeholders can be involved building a broad network of motivated individuals across all sectors of the municipality. Policy makers, energy companies, developers, homeowners and other stakeholders should be involved early in the process, making a clear commitment to the goals of the local energy policy and their role supporting it.

This approach is even more effective if the public are involved in the decision-making processes with regard to energy conservation and the use of renewable energy sources in the city. Many case studies show that members of the public often come up with initiatives and unconventional ideas for local renewable energy use projects. When involving the general public, particular emphasis should be put on communication, technical information and financial aspects.

Guideline #6 Enhance skills and know-how within the municipal administration!

The success of the energy transition process is dependent upon the experience and skills of team members. This knowledge is usually based on the specific background of each member. Although cooperation is a must, improving the knowledge of individuals is also important. Training courses should include expert on technologies as well as general knowledge on energy and climate policy issues and soft skills such as moderation and communications.

Leading and coordinating the energy team should generally be done by the city's administration staff, which requires skilled employees. Smaller municipalities with fewer capacities often must draw on qualified external support.

In the context of municipal energy transition, three levels of knowledge management must be considered:

- Within institutions, the most common
- Among stakeholders in a city, uncommon due to potential competition, self-interest, and a lack of organization
- Among cities, as done in the framework of EU projects.

By paying attention to knowledge management internally or including external know-how, those involved such as the mayor, municipal staff or other stakeholders or members of the public can improve their own knowledge and better do their jobs. By creating a network of stakeholders, experts, advisors or project managers of partner communities, knowledge can be shared between cities as well. While the successes of developments are often shared, only on rare occasions are details of the journey to success shared as well. The route to success and the reasons for failures are the things that can be learned from each other.

Guideline #7 Emphasize monitoring!

Monitoring criteria have to be defined in advance. Criteria or key performance indicators can be defined according to several themes related to milestones in the municipal energy plan and energy and emissions targets. These could include energy targets, financial requirements, and organizational goals. In particular, monitoring of energy use employing smart meters and automatic data logging is important. Notably, sophisticated energy management systems are obligatory for municipally-owned public buildings.

Continuous evaluation of monitoring results provides feedback required on progress towards the milestones and targets. Thus regular updates of energy inventories or balances must be developed, supported by an adequate database. Creating such monitoring instruments can be a project on its own, since it needs sufficient staff resources. Based on the data logged, time series of selected indicators can illustrate performance trends. The City of Salzburg has determined that the cost of monitoring public building stock is lower than the cost savings achieved through energy conservation measures. Although promising, this finding may or may not apply elsewhere depending on local energy prices among other factors influencing monitoring costs and cost savings.

Beyond project-related energy monitoring, monitoring the energy transition process of the city as a whole is important. As for all complex projects, continuous monitoring of the results achieved and their comparison with the milestones is a most important management strategy to guide the process, receive feedback and adjust the strategy if necessary.

Guideline #8 Create a realistic financing plan!

Annex 51 case studies demonstrate that financial considerations often prevent cities from achieving their energy policy goals and targets. The projects carried out by frontrunner cities show that financing becomes less of an obstacle when energy projects can be integrated into other municipal development projects. Co-benefits make projects possible by not only improving energy performance but also providing motivation such as low and stable local energy prices, increased occupant comfort, cleaner air and reduced GHG emissions. Financial considerations concerning the revitalization of the existing housing stock include job creation to reduce unemployment and costs of social welfare. In disadvantaged neighbourhoods, revitalization projects improve the social infrastructure, leading to fewer social problems, which reduces the demand for social services in the long term and increase the real estate values in the neighborhood.

These and other external co-benefits must be incorporated into the business case analysis. Presently there are only a few relevant experiences describing these kinds of financial considerations, largely because to do so requires a new way of thinking and cooperation from many disciplines.

8.4 Concluding remarks

This Guidebook has attempted to collect existing knowledge on local energy planning in neighbourhoods and cities from countries participating in Annex 51 *Energy Efficiency Communities: Case Studies and Strategic Guidance for Urban Decision Makers*. It also aims to present an integrated overview of energy planning as a discipline, combining technical, organizational and policy aspects. It was found that a broad range of multidisciplinary activities are required to create energy efficient communities. The experiences and expertise exist but are dispersed and not always available to practitioners. This Guidebook, and its comprehensive overview of approaches, methods and existing sources for information, is made available in order to support planners and decision makers in the energy transition process in communities.

The Annex 51 case studies have illustrated an abundance of existing technical solutions for neighbourhoods and cities. There exists also a broad spectrum of planning instruments with focus on city-wide and neighbourhood energy planning. Created within Annex 51, the District Energy Concept Adviser (D-ECA) is a decision supporting tool that can be used in the pre-planning phase, when existing energy system models are too complex and need more data than is available early in the project.

With regard to the availability of suitable modelling tools for urban planners, accelerated model development has been observed in recent years. Municipal energy inventory or balancing tools are in widespread adoption. More advanced scenario modelling and optimization tools have not enjoyed broad uptake for a variety of reasons. It is expected that in the future there will not be one comprehensive Local Energy Planning computer tool, but several purpose-built models that are used in combination. Improving the interoperability of existing models is required to achieve broader application.

8.5 Where should we go from here?

To further accelerate the momentum towards energy efficient cities and communities, increased awareness for comprehensive and sustained efforts rather than showcase projects is required. In addition, intensified co-operation among cities, at least on a national level, is necessary.

The leap must also be made from showcase projects to broad implementation of innovative approaches in general municipal planning practice through transfer of the accumulated findings, technical solutions and planning models into the daily *modus operandi* of municipalities.

In the future, combining fragmented approaches still employed in most municipalities today with the holistic approach of a sustainable urban development plan will enable long-term visions and goals to become a reality embraced by all involved in this process.

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Attachments

As a part of their day-to-day work professional energy engineers, building energy modellers and architects develop and review detailed design calculations for buildings and building energy systems using design software referencing standards or codes. Less frequently are these professionals engaged in the design of integrated energy concepts for neighbourhoods or cities. Early in local and urban energy planning processes, when local energy opportunities are identified and assessed for their general technical potential and economic pre-feasibility, the quality and availability of data is often poor. It is therefore necessary to make the best of available data, supplemented with empirical figures based on past studies and educated guesses. This process can be daunting for any professional unaccustomed to energy planning at the neighbourhood or city scales.

In support of local and urban energy planning when only limited data is available, the attachments to Chapter 3 can serve as references for any professional or energy planner responsible for developing recommendations for decision making.

The attachments cover the following topics:

A.	Primary Energy and GHG Performance of Energy Systems
B.	Green Building Rating Systems
C.	Low-Energy, Passive House and Net-Zero Energy Buildings
D.	Energy Generation from Renewable Sources
E.	Economics of Energy Retrofitting and Energy Performance Contracting
F.	Energy Benchmarking of Neighbourhoods
G.	Energy Performance of Typical Cogeneration Systems
H.	Municipal Energy Balancing
I.	Municipal Energy Improvement Potentials/ Efficiency Opportunities
J.	Planning Methods in Neighbourhood or District Energy Planning

Attachment A. Primary Energy and GHG Performance of Energy Systems

Calculating the energy performance of an energy system supplying energy to meet end-use needs is done in two steps. The first step considers the end-use efficiency of the energy system under consideration and the second step the effort required to supply the energy to the point of use. Definitions of the different types of energy and calculation steps are important to follow to avoid introducing sources of error.

For example, in the case of an oil boiler generating thermal energy for heating and domestic hot water:

Step 1. Evaluate the energy performance of the system (e) by determining the secondary energy (E_{EE}) required to generate the usable energy required (E_U).⁸⁹ Usable energy can be either thermal or cooling energy, distributed to the point of use.⁹⁰ The energy performance of the system (e) is therefore defined by:

$$e = \frac{E_{EE}}{E_U} \text{ (kWh}_{EE}/\text{kWh}_U\text{)}.$$

For example, the seasonal efficiency of an oil boiler (η_B) is defined by:

$$\eta_B = \frac{E_{th}}{E_{Hi}},$$

where E_{th} represents the usable thermal energy generated and E_{Hi} the inferior heating value of the heating oil consumed. The energy performance (e) of the boiler is in this case simply the reciprocal value of the boiler's seasonal efficiency (η_B) given by:

$$e_B = \frac{1}{\eta_B} = \frac{E_{Hi}}{E_{th}} \text{ (kWh}_{Hi}/\text{kWh}_{th}\text{)}.$$

Calculation methods for energy performance of more complicated energy systems are addressed in attachments F and G.

Step 2. Calculate the amount of primary energy P_{EE} (kWh_{PE}) required to deliver E_{EE} by considering the upstream energy losses for the supply of E_{EE} by multiplying E_{EE} with the corresponding primary energy factor f_{PE} ($\text{kWh}_{PE}/\text{kWh}_{EE}$), which varies for different kinds of end-use energies E_{EE} (and also for different countries):

$$pe_{EE} = e \cdot f_{EE} \text{ (kWh}_{PE}/\text{kWh}_U\text{)},$$

with f_{EE} being the primary energy factor of the specific secondary energy EE used in the process under consideration. Thus,

$$PE_{EE} = pe_{EE} \cdot E_U \text{ (kWh}_{PE}\text{)}.$$

In the simple oil boiler case above, pe_B is calculated from

$$pe_B = e_B \cdot f_{oil},$$

with f_{oil} being the primary energy factor of heating oil (in Germany: $f_{oil} = 1,11 \text{ kWh}_{PE}/\text{kWh}_i$). Thus in this case the total primary energy use of the boiler, PE_B , is given by

⁸⁹ The term *secondary energy* (E_{EE}) or end-energy in German, means *delivered energy* billed by a local supplier, such as heating oil, natural gas or electricity, or thermal energy supplied by a district heating network. This must be distinguished from the *primary energy* (PE) required to deliver this secondary energy, which covers the upstream energy expenses, and from *energy end-use* (E_U) or usable energy or the energy service for the user.

⁹⁰ In this definition, the losses occurring by distributing the usable energy to the point of use are not included.

$$PE_B = p_{e_B} \cdot E_{th} = \frac{1}{\eta_B} \cdot f_{oil} \cdot E_{th} = 1.28 \cdot E_{th} \text{ (MWh}_{PE}/a),$$

if the boiler's seasonal efficiency η_B is assumed to be 0.87 kWh_{th}/kWh_{EE}.

Two peculiarities must be noted:

Natural Gas

In cases where the end-energy is natural gas, it is billed by utilities using the superior (higher) heating value H_s (in kWh_s) of the delivered gas instead of the inferior (lower) heating value H_i , which is used for all other fuels. The (lower) energy content of the delivered gas (H_i) must therefore be calculated using $H_i = h_i/h_s \cdot H_s$, where h_i and h_s are the specific inferior and superior heating values of natural gas, which vary to a certain extent for different gas sources. For the gas quality used in most supply areas in Germany, $h_i/h_s = 0.89$ kWh_i/kWh_s.

In the case of a gas boiler, $e_{Gas} = 1/\eta_{Gas} = H_i/E_{th}$, with η_{Gas} being the gas boiler efficiency related to the inferior heating value H_i (kWh_{Hi}/kWh_{th}). This can be inserted into the formula $p_{e_{B\_Gas}} = e_{Gas} \cdot f_{Gas}$, where for gas qualities used in Germany, $f_{Gas} = 1.12$ kWh_{PE}/kWh_{i, Gas}. To determine the primary energy use PE_{Gas} ,

$$PE_{Gas} = 1/\eta_{Gas} \cdot f_{Gas} \cdot E_{th} \text{ (MWh}_{PE}/a),$$

according to the oil boiler above.

Note that using the definition of η_{Gas} given above, the efficiency of the gas boiler is related to the inferior heating value H_i of gas, which means that in the case of condensing gas boilers, where the thermal output E_{th} is increased by the condensing heat of the steam generated by the burned gas, η_{Gas} can be larger than 1!

Electricity

Since electricity from the public grid is generated using a mix of different energy carriers and technologies, the utilities (or grid providers) publish two annually averaged primary factors f_{el} for the electricity delivered to the customers: The first, f_{el_total} a factor which considers the mix of all primary energies in all power plants of the utility and the second, f_{el_fossil} which includes only the *non-renewable* amount of primary energy used, comprised of both fossil fuels and nuclear energy.

Using the public electricity grid in Germany as an example, $f_{el\_total} = 2.74$ kWh_{PE}/kWh_{el} and $f_{el\_fossil} = 2.27$ kWh_{PE}/kWh_{el} due to a fraction of about 17% renewables in the electricity mix of 2011.

Thus the primary energy PE_U (total or fossil) for a process using electricity (for instance a circulation pump or a compressor driving an air-conditioning system or an electric heat pump) to provide the desired usable energy E_U is

$$PE_U = e_{el} \cdot f_{el} \cdot E_U \text{ (kWh}_{PE}),$$

with e_{el} (kWh_{el}/kWh_U) being the specific electricity demand to deliver 1 kWh_U of usable energy.

If in a given case different sources of electricity are used, other than that from the public grid, the corresponding primary energy factor f_{el} is the weighted average of the f_{el} -factors for all electricity sources used over a certain period of time.

The calculation of corresponding GHG emissions, M_{CO_2} , is done in the same way, for the second step using GHG factors f_{CO_2e} (kg CO_{2e}/kWh_{EE}) instead of primary energy factors f_{EE} . Again, upstream effects

and greenhouse gases other than CO₂ are included into the f_{CO_2e} -factor used to determine the emission of CO₂-equivalents as demonstrated in step 2 above from

$$M_{CO_2e} = e \cdot f_{CO_2e} \cdot E_U \text{ (kg CO}_2\text{e)}.$$

To ensure consistent methods and calculation factors are applied, specific regulations and databases are available for different countries or regions that should to be used by planners. These are outlined briefly:

European Union

Throughout the European Union, the principles to define and use primary energy and GHG factors are determined by the EN 15603 – Energy Performance of Buildings standard. This code requires the calculation of energy ratings for buildings in a standardized way and distinguishes between renewable and non-renewable primary energy sources such as fossil and nuclear in electricity generation. However, the concrete primary energy factors to be used within specific member states are not prescribed by this standard. It remains in the responsibility of the member states to define valid factors for their respective countries, because depending on the existing energy system and specific energy sources, significant differences in primary energy factors can occur, notably for electricity. In addition, electricity exhibits changing primary energy factors over time due to changes in the generation mix of the country, which requires periodic updates.

With regard to GHG factors, EN 15603 refers to the IPCC Guidelines for National GHG Inventories (see reference below), where a large number of energy carriers, far beyond those that are of interest for building or neighbourhood energy planning, are addressed. These factors are used to determine the national GHG factors, e.g. for electricity, which are available in publications (see below) and can be used by energy planners thereby avoiding independent and possibly tedious investigation. It is sufficient to make use of these factors, with the exception of

- local electricity generation and district heating,
- bio-fuels, bio-gases, solar energy (thermal and photovoltaic) and waste (used as a fuel),

In these cases, the correct PE and GHG factors are heavily influenced by local energy sources and technologies used. These cases must be analysed on an individual basis.

North America

In North America a greater diversity of fuels are in use than in Europe. In addition, there are several separate electricity grids which use different primary energy sources. Nation-wide PE or GHG factors are therefore not possible. An overview of current PE and GHG factors for US regions is provided by the National Laboratory on Renewable Energies, which contains a detailed overview for the fuels used in the US. This database is updated periodically (see references below).

In addition, a Climate Registry Information System is operated in California. It is a system that can be used for energy and GHG balancing by municipal environmental departments. In the corresponding handbook, detailed coefficients also for unconventional energy carriers are presented and continuously updated on a scientific basis. This Climate Registry was founded in 2007. About two thirds of the US states and all Canadian provinces and territories are participating.

For British Columbia, in addition to the factors, Community Energy and Emissions Inventories (CEEI) reports are provided by the provincial government as a service to local governments (including municipalities and regional districts). Energy and GHG emissions reporting for public sector organizations in BC takes place through the Climate Action Reporting Incentive Program (CARIP) and a tool called SmartTool.

A similar service is offered by the European Energy Award (eea) and the International Climate Alliance in some EU member states. This is described in more detail in Chapter 4.

As a result, primary energy and GHG factors for *fossil fuels* are clearly defined, regularly updated and easily accessible for energy planners.

The situation with *renewable energy sources* is more complicated. For a detailed assessment of concrete cases, the reader is referred to the following data sources that can be used to explore primary energy and GHG factors both for fossil and renewable energies within the participating countries.

References on Primary Energy and GHG Factors

International Data Sources

IPCC GHG inventory factors - www.ipcc-nggip.iges.or.jp

The CO₂ Monitoring Tool - www.climatealliance.org

EU Covenant of Mayors Emission Factors Instruction Document - www.eumayors.eu

National Data Sources

Austria

Austrian Institute for Civil Engineering (Österreichisches Institut für Bautechnik), Guiding Instruction #6: "Energy Conservation and Thermal Insulation", Vienna (2011) www.oib.or.at/RL6_061011.pdf (in German)

Canada

Toolkit for energy and GHG reporting municipal administrations of British Columbia (last update from February (2012) - www.toolkit.bc.ca

Denmark

Energy factors for calculating energy use of buildings are presented in:

http://w2l.dk/file/155699/BR10_ENGLISH.pdf

France

BASE CARBONE ADEME (2012) - Base nationale de données publiques contenant un ensemble de facteurs d'émissions et données sources. Elle est destinée à la réalisation réglementaire ou volontaire de bilans Gaz à Effet de Serre - www.basecarbone.fr

Note de cadrage sur le contenu CO₂ du kWh par usage en France (2005) - ADEME - www.ademe.fr

Calculation methods to verify the French Thermal Regulation requirements for buildings:

www.rt-batiment.fr/batiments-neufs/reglementation-thermique-2012/

Germany

GEMIS 4.8/2012 – Gesamtemissionsmodell Integrierter Systeme, U. Fritsche, IINAS – Int. Inst. f. Nachhaltigkeitsanalysen und Strategien, Darmstadt and Öko-Institut Freiburg (2012); www.iinas.org

Univ. Stuttgart/IER, Lebenszyklusanalyse ausgewählter Stromerzeugungstechniken, O. Mayer-Spohn et al. (2007) www.ier.uni-stuttgart.de

Emissionsbilanz erneuerbarer Energieträger 2007. UBA (German Federal Environmental Authority), Dessau (2009) www.uba.de

U. Fritsche et al., Welche Rolle für Biokraftstoffe?, Study commissioned by Shell Germany, Darmstadt (2012); www.shell.de

Japan

Primary energy conversion factors:

Rational Use of Energy Act - periodical primary energy consumption report mandatory for specified businesses:

www.eccj.or.jp/law/revised/rue_2.pdf

Primary energy consumption calculation sheet for periodical reports mandatory for specified business operators (only in Japanese): www.eccj.or.jp/law06/xls/03_00.xls

GHG emission factors:

GHG Emission Calculation, Reporting and Publication Protocol, published by Japanese Ministry of Environment (MOE); periodically updated since 2006 (in Japanese):

<http://ghg-santeikohyo.env.go.jp/calc>

National GHG Inventory Report of Japan, supplied by Greenhouse Gas Inventory Office, National Institute for Environmental Studies (NIES): www-gio.nies.go.jp/aboutghg/nir/nir-e.html;

For grid (mix) power, the marginal GHG emission factor is still argued. Some calculations refer to the report published by the Central Environmental Council of Japan as below (in Japanese):

www.env.go.jp/council/06earth/r062-01/index.html.

Switzerland

Schweizerischer Ingenieur- und Architektenverein (SIA), Technical Specification 2040: "SIA Energy Efficiency Path" (Effizienzpfad Energie), Zurich (2011): www.sia.ch/SIA_2040, (in German and English, including calculation methods).

Sweden

Miljöfaktaboken 2011: Uppskattade emissionsfaktorer för bränslen, el, värme och transporter (Environmental facts 2011: Estimated emission factors for fuels, electricity, heat and transport in Sweden); in Swedish; Authors: J. Gode, F. Martinsson, L. Hagberg, A. Öman, J. Höglund, D. Palm; VÄRMEFORSK Service AB, Stockholm (2011); ISSN 1653-1248.

Miljökommunikation med nyckeltal och indikatorer - Fjärrvärme och Fjärrkyla (Environmental communication with key factors and indicators – District heating and Cooling); in Swedish; Authors: J. Gode, J. Höglund, E. Särnholm, F. Martinsson, M. Lindblad, E. Bingel; Svensk Fjärrvärme AB (2012); ISBN 978-91-7381-085-2

The Netherlands

www.emissieregistratie.nl/erpubliek/bumper.nl.aspx

[www.broeikasgassen.nl/docs/Vreuls%202011%20\(NL\)%20Ned%20brandstoffenlijst%20januari%202011.pdf](http://www.broeikasgassen.nl/docs/Vreuls%202011%20(NL)%20Ned%20brandstoffenlijst%20januari%202011.pdf)

www.ecn.nl/docs/library/report/2012/b12005.pdf

USA

National Renewable Energy Laboratory (NREL), M. Deru and Torcellini, P. (2007): Report TP-550-38617

"The Climate Registry Local Government's Operations Protocol": www.theclimateregistry.org

Attachment B. Green Building Rating Systems

Leadership in Energy & Environmental Design (LEED®)

The predominant green building rating system in North America, LEED® is administered in the United States by the US Green Building Council (USGBC): www.usgbc.org/leed

In Canada, LEED® is administered by the Canada Green Building Council (CaGBC): www.cagbc.org

BuiltGreen

Built Green™ offers certification for new single family homes and row homes to members of Home Builders' Associations including builders, renovators, product suppliers or manufacturers, service providers, community developers and municipalities. www.builtgreencanada.ca

BOMA BEST

BOMA BEST is the leading environmental certification program for commercial buildings. Launched in 2005, it addresses an industry need for realistic standards for energy and environmental performance of existing buildings based on accurate, independently verified information. www.bomabest.com

Building Research Establishment Environmental Assessment Method (BREEAM)

Used to assess any type of building (new or existing) against a set of criteria and provides an overall score which corresponds to a rating (Pass, Good, Very Good or Excellent). The French CSTB institute and the United Kingdom's Building Research Establishment (BRE) have been working since 2009 to develop a pan-European building environmental assessment method based on BREEAM. This will eventually result in the development and promotion of a common assessment method throughout the European Union. www.breeam.org

Eco-Quantum

Eco-Quantum converts the range of information on the environmental performance of buildings into information usable by professions and trades within the construction industry. Industry supplies information on building materials and technologies and related environmental matters, tested on the basis of the environmental fact sheet with lifecycle cost assessment (LCA) information. Eco-Quantum is used as a policy instrument to determine environmental targets for housing programmes. Architects use the programme to optimise the environmental sustainability of their designs. www.ecoquantum.com.au

LiderA

LiderA is intended to: 1. support the development of sustainable plans and projects, 2. evaluate sustainability performance and position in the design, construction and operation phases, 3. support environmental management, 4. assign a trademark certification, verified by an independent evaluation, and 5. be a distinctive brand for businesses and customers who value sustainability. www.lidera.info

Teri-GRIHA

Teri-GRIHA uses qualitative and quantitative assessment criteria to rate a building according to its degree of 'greenness'. The rating is applied to new and existing commercial, institutional, and residential buildings. A building is assessed on its predicted performance over its entire life cycle from preconstruction, building design and construction, and building operation and maintenance. www.teriin.org

SBAT

SBAT® was designed to support sustainable development in developing countries, as reflected in the assessment criteria and how the tool is to be used. Buildings should aim for 15 sets of objectives in economic, environmental and social domains. The tool suggests the extent to which these objectives are achieved in buildings, providing a simple, yet reasonably effective measure of sustainable development. www.csir.co.za

Green Star

Green Star supports sustainable property development in Australia by encouraging the adoption of green building practices and supported by both industry and governments across the country. It moves the property industry towards sustainability by certifying and promoting green building programs, technologies, design practices and operations as well as the integration of green building initiatives into mainstream design and construction as well as building operations. www.gbca.org.au

Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)

CASBEE is a Japanese tool for assessing and rating the environmental performance of buildings and the built environment. www.ibec.or.jp

Gütesiegel für Nachhaltiges Bauen (DGNB)

This recently-developed standard for sustainable building certificates in Germany is directed primarily to commercial buildings and neighbourhoods. 49 criteria are evaluated within five areas of sustainability. www.dgnb.de

HQE High Quality Environmental Standard

A green building standard developed and maintained since 1992 by the *Association pour la Haute Qualité Environnementale* in France. www.assoHQE.org

EcoNeighbourhoods Label

Resulting from a successful call for award applications for sustainable neighborhood projects carried out in France in 2009, a label called EcoNeighbourhoods was developed. It includes all aspects of sustainable urban development. www.ecoquartiers.developpement-durable.gouv.fr

Attachment C. Low-Energy, Passive House and Net-Zero Energy Buildings

For a comprehensive comparison of building codes refer to the IEA publication *Energy Efficiency Policies for New Buildings*: www.iea.org/g8/2008/Building_Codes.pdf.

Energy Performance of Buildings Directive (EPBD)

The European Parliament (2003) committed the EU to reduce GHGs by at least 20%, to reduce energy consumption by 20% and to increase to 20% the share of renewable energies in energy consumption by 2020. The EPB-Directive is the main legislative instrument at EU level to achieve energy performance in buildings. Member States apply minimum requirements regarding energy performance of new and existing buildings; ensure the certification of building energy performance, and require the regular inspection of boilers and air conditioning systems. The most recent EPBD (2010) calls for a near net-zero energy building standard to be introduced by the EU member states by 2020 for new buildings.

German Building Energy Conservation Ordinance (*Energieeinsparverordnung - EnEV*)

Energy performance requirements for new buildings are based on a reference building. Each building is modelled as a building with the same geometry and user profiles before a defined set of technologies is applied. The result of the calculation gives the maximum allowed primary energy for the building which can then be planned and achieved with different types of building envelope and building service system technologies.

An additional requirement is set for the mean U-value of the building envelope. For existing buildings, energy requirements must be met when more than 20% of the area of a building element (e.g. a wall) is renovated. In this case, the owner has a choice to either meet special requirements for the new building elements (in 2010: U-value of 0.24 W/m²·K for walls and roofs, 0.20 W/m²·K for flat roofs and 1.30 W/m²·K for windows) or prove that the entire building does not exceed 140% of the requirements for a similar new building.

New buildings must have a certain portion of their energy for heating and hot water met by renewable sources, unless the building is connected to district heating or has low energy demand at least 15% below standard requirements. For buildings with solar heating at least 15% must come from solar, for building using biomass, heat pumps or geothermal energy, at least 50% must come from these sources. The EnEV allows federal states to set additional requirements (see also Chapter 2).

Danish Building Code

Denmark's building code (2006) requires total primary energy demand to be lower than 71 kWh/(m²·a) for houses with more than 2,200 square meters⁹¹ of usable area and 90 kWh/(m²·a) for smaller houses. This value includes both hot water as well as electricity for pumps and ventilation. The requirements extend to all habitable buildings including hotels; for offices and schools the code allows a 20% increase in specific energy demands. Requirements also apply to major renovations.

Progressive municipalities require that a certain development (typically 25-250 dwellings) must be low-energy. Local authorities can dictate which houses use district heating or natural gas, except for low-energy houses.

The code also defines formulas for calculating the maximum annual specific primary energy use for space heating, DHW and ventilation in low-energy buildings:

$$\begin{aligned} E &= 30 + 1000/A \text{ [kWh/(m}^2\text{·year)]} && \text{(residential and hotels) and} \\ E &= 41 + 1000/A \text{ [kWh/(m}^2\text{·year)]} && \text{(offices, commercial buildings, schools, institutions),} \end{aligned}$$

where E is the specific annual energy use and A is the heated floor area and the primary energy factor for district heating is set to 0.80 kWhPE/kWhth.

⁹¹ The product of total heated area of building (measured outside the building) and the number of heated floors.

Minergie

Minergie is a quality label for new and refurbished low-energy buildings in Switzerland (see also Chapter 2). For all buildings (except new single-family homes) end use energy consumption per usable area must be declared and verified. For new single family homes and apartments the value is 42 kWh/m² annually including DHW. The value increases at elevations above 800 m. The exact conditions depend on building typology. Five simplified standards are available:

- heating and DHW using ground source heat pump
- biomass heating and solar hot-water
- biomass pellet heating and DHW
- district heating using waste heat
- air-water heat-pump-based heating and DHW

Passive House (*Passivhaus*)

Passive House buildings are heated predominantly with passive solar gain and a mechanical ventilation system with heat recovery employing compact heat pumps, making a traditional (hydronic) heating system redundant. To meet the *Passivhaus* standard a building must fulfill the following conditions:

- Heating demand equal to or less than 15 kWh/m² per year
- Heating load equal to or less than 10 W/m²
- Air leakage rate equal to or less than 0.60 h⁻¹
- Total (primary) energy use for space heating, DHW and electricity equal to or less than 120 kWh/m² per year.

In practice this means meeting certain construction standards. For example:

- Insulation U-values of between 0.10 and 0.15 W/m² K
- Triple-glazed low-emission coated windows with overall U-values of between 0.70 and 0.85 W/(m² K)
- For thermal bridges, a heat transfer coefficient of less than 0.01 W/(m K)
- Air exchange rate of between 0.40 – 0.60 h⁻¹
- A compact heat pump for air ventilation heat recovery.

The typical payback period for the incremental costs to build a new residential building to a *Passivhaus* standard is around 20 years. *Passivhaus* is a feasible and mature technology in central and northern Europe.

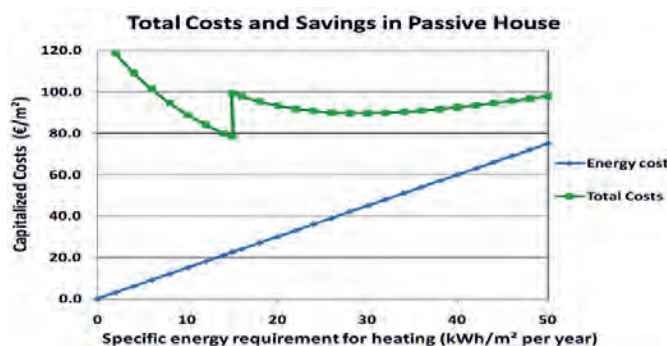


Figure C-1: Example of capitalized costs for typical single-family houses in central Europe, assuming a time frame of 30 years and an oil price of 90 EUR/barrel. Source: www.passiv.de; [7].

Zero-Energy Buildings

While *near-zero energy buildings* are discussed in Chapter 2 in the context of the EPBD, *net-zero energy buildings* can be defined in a variety of ways, including:

- **Net-zero energy buildings** deliver as much energy to the grid as they use from the grid.
- **Stand-alone net-zero energy buildings** can be either off-grid or use the grid only as backup. Stand-alone buildings are energy autonomous, having the capacity to store energy on a daily or seasonal basis.
- **Energy plus buildings** deliver more energy to the grid than they use from the grid.
- **Zero-carbon buildings** do not use energy that produces carbon dioxide emissions.

The various net-zero building concepts are subject of IEA EBC Annex 52 *Towards Net-Zero Solar Energy Buildings* which investigates net-zero buildings and their design.⁹²

Energy Surplus Buildings

In 2011 the German Ministry of Transport, Building and Urban Development (BMVBS) launched a support scheme for owners of houses that generate more energy than they consume in an annual balance. The Efficiency House Plus pilot project built in Berlin⁹³ is now monitored and evaluated by a research team together with 30 other energy plus buildings throughout Germany. Financial support is offered for integrated planning, innovative technologies and monitoring. Energy surplus or energy plus buildings are defined as producing more energy than delivered and primary energy used on the building site on an annual basis. The calculation method is the German standard used for the energy performance calculation of buildings DIN V 18599; in comparison to the energy decree the total energy generated on the building site can be taken into account, not only what is used by the building. The same approach is also planned for non-residential buildings and city quarters or neighbourhoods.

French building energy code (*Règlementation Thermique*)

Besides the general requirements defined in this building code (updated on an ongoing basis to reflect the EPBD) several low energy building standards are defined, applicable to new and existing buildings in France.⁹⁴

⁹² www.ECBCS.org/annexes/annex52.htm

⁹³ <http://www.bmvbs.de/SharedDocs/EN/Artikel/B/energy-plus-house-my-house-my-filling-station.html>

⁹⁴ www.rt-batiment.fr/batiments-neufs/reglementation-thermique-2012

Attachment D. Energy Generation from Renewable Sources

Renewable energy technologies may be integrated into the building sector in a variety of contexts. For example, solar thermal may be integrated within an individual building or used as a renewable heat source for a district energy system. Renewable energy may also be sourced from nearby communities; biomass gasification for example may come from nearby rural areas.

Solar Thermal Energy

Solar thermal collectors capture heat from the sun and transfer this heat to a liquid to either pre-heat domestic hot water or store it for space heating. Large-scale applications can be *direct* or *indirect*, *active* or *passive*.⁹⁵

Direct or open loop systems circulate potable water through solar collectors. These systems are the least expensive and offer superior heat transfer from the collectors to the storage tank. These systems do not contain mechanisms to protect from overheating or freezing or scaling in areas with hard water.

Indirect or closed loop systems use a heat exchanger to separate the water circulating in the building from the solar panel. Though they are more expensive, indirect systems offer protection against freezing and overheating.

Active systems use pumps to circulate water and/or heating fluid in the system. *Passive systems* rely on heat-driven convection or heat pipes to circulate water or heating fluid in the system. Passive solar water heating systems have lower maintenance costs but are also less efficient.

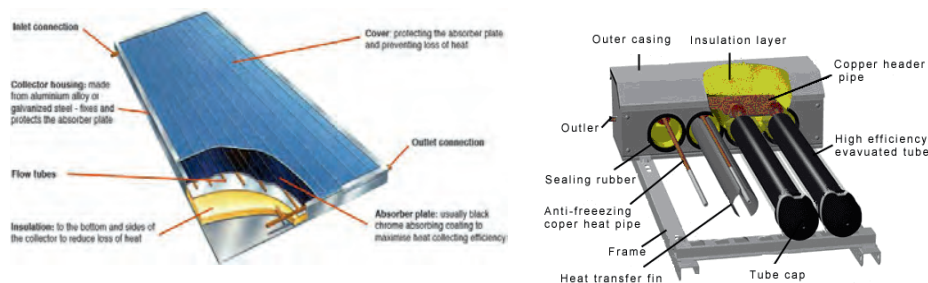


Figure D-1: Flat plate collector (left) and evacuated tube collector (right).

Source: <http://www.buildinggreen.com/menus/>

Solar collectors are categorized as follows:

- *Batch collectors* - Reduce heat loss with the water tank in a thermally insulated box.
- *Flat plate collectors* - Horizontal header pipes at the top and bottom connect to smaller vertical risers. The risers often have thin absorber fins, aiding in the collection of heat.
- *Unglazed or forced* - unglazed collectors are neither insulated nor protected by a glass panel. These are less efficient for DHW heating but excellent for pool heating.
- *Evacuated tube collectors (ETC)* - Vacuum between two concentric tubes acts as an insulator. Equally efficient than flat plates in full sunshine however function better than flat plates in cloudy or extremely cold conditions. Higher costs.

⁹⁵ For example, see Drake Landing Solar Community www.dlsc.ca

Photovoltaic Power

Photovoltaic technology (PV) converts solar radiation to DC electricity using semiconductors. Emerging technologies include advanced thin films and organic cells. Concentrating systems are also under development, using an optical concentrator system to focus solar radiation on a small high-efficiency cell (Würfel, Physics of Solar Cells, 2009).

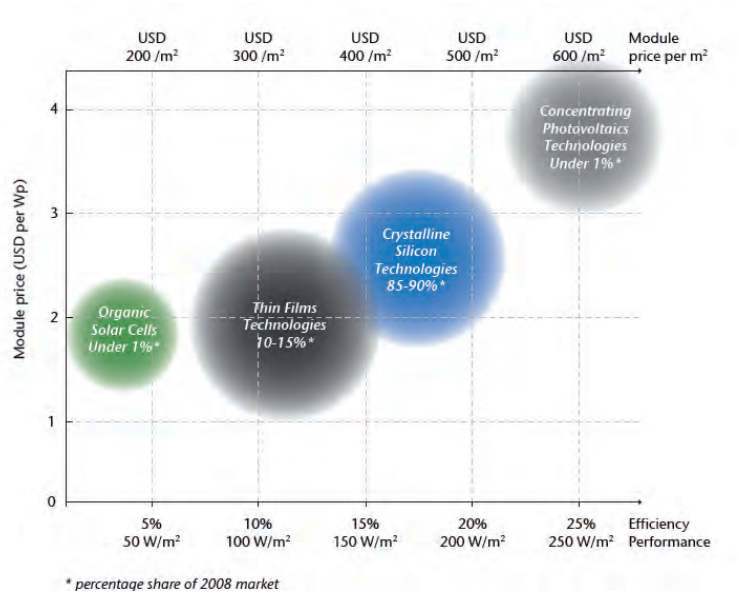


Figure D-2: Price and efficiency of PV systems. Source: Technology Roadmap: solar photovoltaic energy OECD/IEA, 2010

Bioenergy

Bioenergy is derived from biological matter other than fossil fuels. Technologies used to convert biomass into usable energy include anaerobic digestion, pyrolysis, combustion and gasification. Matching the available resource with the energy carrier guides selection of the appropriate conversion technology.

Biomass feedstock	Ligno-cellulose materials - municipal solid waste, forestry, wood process residues, crop residues, vegetative crops, starch crops , sugar crops, vegetable oils, animal fats from meat processing, sewage sludge, animal manures, wet process wastes, green crops
Conversion processes	Direct combustion, thermochemical processes including pyrolysis, carbonisation, gasification, catalytic liquefaction, biochemical processes including anaerobic fermentation, methane production in landfills, ethanol fermentation, biodiesel
Bioenergy carriers	Biogas, landfill gas, methane, synthesis gas, process steam, methanol, ethanol, biodiesel, synthetic gasoline, synthetic diesel

Table D-1: List of the main biomass feedstock, conversion processes and energy carriers for bioenergy purposes.

Bioenergy conversion technologies:

- *Combustion and co-firing* - For feedstock with moisture contents <65%. Three main furnace technologies: grate firing, suspension firing, and fluidized bed.
- *Grate combustion* - Very robust, flexibility in fuel source (wood, straw).
- *Suspension firing* - Large facilities where the fuel is ground and blown into the furnace. Good economy can be achieved in converting coal-fired power plants to suspension firing plants based on biomass.
- *Fluidized bed combustion* - Solid fuel suspended in an upward-blowing jet of air, creating effective combustion, heat transfer, and emission control. Requires a large amount of inert bed material (sand). Co-firing of biomass can be undertaken with another fuel, typically coal.
- *Thermal gasification* - Solid biomass is converted into syngas, to be used elsewhere.
- *Anaerobic digestion* - Biomass is treated in an anaerobic (oxygen starved) process, to generate biogas. The digested biomass may be used as fertiliser. Digestion is either mesophilic (35-40°C) or thermophilic (50-55°C). Biogas may also be produced from the organic fraction of household waste or sewage water. The biogas may contain between 60 and 70% methane (CH₄) and between 30 and 40% carbon dioxide.
- *Landfill gas* - Landfill gas (CH₄ and CO₂) collected through vertical or horizontal pipes, cleaned and connected to the end-user (typically electricity generation). Typical landfill contains between 40 and 60% CH₄.

Geothermal and Earth Energy

Geothermal energy can be used for either thermal energy electrical power production, depending upon its temperature. Only a few countries have sufficient geothermal resources close enough to the earth's surface where geothermal energy has a sufficient temperature to heat a fluid, drive a turbine and generate power. The majority of so-called geothermal systems may be more accurately described as collecting earth energy, since they use heat from the earth's crust to prime a heat pump for space heating. Typical earth temperatures lie between 10°C at the surface to 35 - 45°C at depths of 1,000m.

Hydroelectricity

Hydroelectric energy is the energy derived from flowing water, either from the potential energy of water reservoir or from the kinetic/potential energy of rivers. The generation capacity depends on a combination of water flow and pressure drop. Primarily a regional undertaking, three types of hydroelectric projects exist:

- storage schemes, incorporating a dam and reservoir
- run-off-river schemes using the natural river flow
- pumped storage installations utilising flow between reservoirs at different elevations (of increasing importance with surging PV and wind electricity).

Heat Recovery from Organic Waste (Sewers)

Valuable heat can be extracted from sewer trunk lines before the sewage reaches the waste treatment facility. Care must be taken in extracting only a certain amount of heat since lower temperature adversely affects the ability to break down the sewage within the digesters. Heat exchanger design is critical as is the material and location.

Concentrated Solar Power (CSP)

Concentrated solar power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight onto a small area. The concentrated light is then used as heat or as a heat source for a conventional power plant. Typical sizes of such plants are in the range of 50 MW. Ideal sites are deserts or elevated plateaus with long periods of sunshine. Cooling for steam condensation is required, which limits the energy performance. The technology has advantages compared to PV technology due to possible high temperature storage using liquid salts, by which the available power is increased. Because of recent decreases in the market price of PV panels, very large PV arrays may become competitive with CSP plants in the medium term.

Wind Power

With the exception of hydro power, wind energy has become the world's largest source for 'new' renewable energy. In 2011 240 GWel of wind turbines had been installed, with production of 460 TWh/a. Contrary to solar electricity, wind energy has – on favorable sites – total costs of between 0.06 – 0.09 USD/kWh, competitive with conventional power plants. Denmark already has almost 30% of its total electricity generation from wind and is the country with the largest percentage of wind energy. Other European countries have between 10 and 20% of energy from wind. In the United States 3% of the electricity is currently generated by wind turbines.

Modern on-shore wind turbines have design sizes of up to 3 MW, while off-shore turbines (which are increasing in importance) generate 5 MW and more; off-shore wind parks are usually between 50 and 500 MW size. Small-scale wind turbines of between 5 and 50 kW are increasingly available, but are only useful in remote off-grid locations, rather than in neighbourhoods or cities where unfavorable wind conditions, high generation costs and non-acceptance by residents reduce their effective potential in comparison to detached PV panels (Heier, 2012).

Unconventional Renewables

More sources of renewable energy are conceivable, such as tide or wave power, algae biomass produced using CO₂ and solar energy, or 'second generation' biomass. These renewables are either restricted to specific sites with favorable conditions or still in a state of research and development that at present does not allow any prediction of their future availability.

Attachment E. Economics of Energy Retrofitting and Energy Performance Contracting

Renovation of Existing Buildings

The lifecycle of a building typically exceeds 50 years, making periodic upgrades necessary to maintain the quality of the building envelope and technical equipment. Major renovations⁹⁶ usually take place between two and three times during a residential building's lifecycle; renovations occur more frequently in commercial buildings. Minor repairs or refurbishment often include energy conservation measures (ECMs); these are generally favored since their costs are recovered through energy cost savings following renovation. Economic feasibility should therefore be calculated using a method that compares renovation options and energy efficiency improvements.

Regional, national and international surveys identify the building sector as a potential source of major energy savings. In Europe alone, 55% of building energy use in the 15 original European Union member states could be avoided through cost-effective energy-efficient building envelope measures.⁹⁷

⁹⁶ Typically defined as those exceeding 25% of property value or covering more than 25% of the property's surface area.

⁹⁷ www.eurima.org

When including new EU member states, the potential reduction in energy use increases to between 65 and 80% for single family houses and between 55 and 70% for multi-storey buildings. Further savings could be obtained through improvements to heating, cooling and ventilation systems and by increasing the use of district energy and solar collectors.

Economy of Renovation

It is essential that economic feasibility studies are performed according to a consistent methodology to identify cost-optimal renovations. Because energy efficiency potentials associated with renovations can be either over or underestimated, and so does the economics (Hermelink, 2009). The key issues in the calculations are identified as:

- *Use of semi-static calculations* - Finance costs are excluded by keeping interest rates zero.
- *Energy price increase* - Predicts unrealistic energy prices when calculating long-term energy price development by using small equal annual rates of increase.
- *Payback period* - Calculations based on the pay-back period may tend to focus on short-time investments. Net-Present-Value (NPV) calculations are preferred for long-term investments.
- *Interest rate* - Energy improvements are often financed by mortgages or loans. Interest rates are often overestimated with a corresponding underestimation of benefits.
- *Capital investment* - Energy savings must balance the real share of the total investment in the property and not the investment of the whole project, which might include also the expenditures for aesthetic, functional, structural or maintenance purposes.
- *Residual economic value* - Studies often have time horizons that are shorter than the lifecycle of building components (e.g. insulation); therefore the residual economic value of the investment must be taken into account.
- *Neglecting co-benefits* - Energy efficiency measures have additional positive monetary value, e.g. energy security, abatements of energy import, mitigation of global warming, improved thermal comfort and better indoor air quality; in the case of rented buildings also better marketability (Subtask B Final Report).

To realize the full potential energy conservation potential there is a need to set, enforce and regularly update building codes for energy efficiency in new and existing buildings. Requirements should refer to the least cost over time (through-life) and not only the incremental cost of installation.

With regards to new construction, best practice examples and demonstration projects should be encouraged and supported to ensure these buildings will have high visibility and lead to subsequent market penetration.

Strict energy requirements should be developed for all major renovation and refurbishment projects, regardless of type or size. Finally, energy certification and the labeling of building energy use make the advantages of energy conservation visible in the market and should be widely promoted.

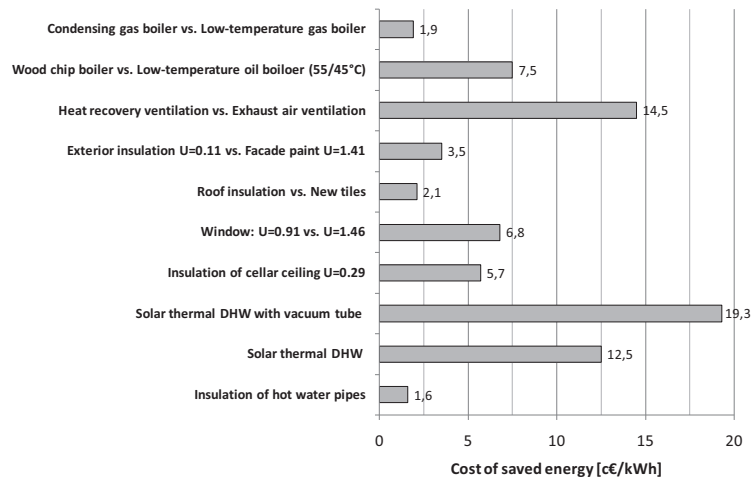


Figure E-1: Costs of energy saving measures for typical energy renovations in Germany. Source: Hermelink, 2009

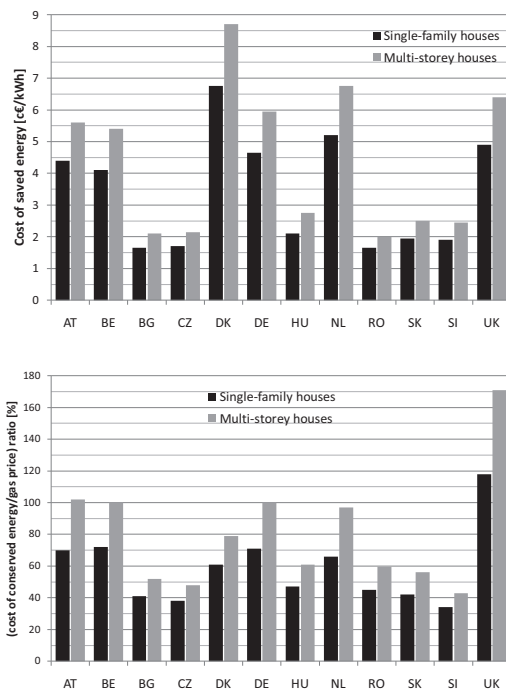


Figure E-2: Major renovation projects: Estimation of energy cost savings (top) and comparison between energy cost savings and natural gas supply prices (bottom) in 12 EU member states. Source: Hermelink, 2009

Figures E-1 and E-2 suggest that 'shallow' energy renovation projects in Germany and major renovation projects in 12 EU member states are economically feasible at today's energy prices. Only in the case of low natural gas prices, as is the case in the UK and North America, does the cost of energy renovations outstrip the cost savings resulting from the renovation. The study was carried out using a conservative methodology, which considers current energy prices and excludes financial subsidies. Rising energy prices suggest that, even in countries that currently have low energy prices, demand side policies will be more cost-effective than those on the supply side.

Energy Performance Contracting

Energy Performance Contracting (EPC) provides energy services at minimal lifecycle cost to occupants, while ensuring worthwhile profit margins to contractors. It focuses on the total lifecycle cost of integrated energy conservation measures, by linking energy supply with demand side efficiency measures to guarantee the functional performance of the system. This is done by outsourcing most of the technical and economic risk and incorporating incentives and guarantees. Three types of EPC exist:

- general contractor
- general planner
- energy service corporation (ESCO).

Which EPC model is selected depends upon who is responsible for the implementation of the energy service package. Characteristics, advantages and disadvantages of each EPC model are listed in Table E-1. Experience with the application of novel technologies in buildings and distributed energy supply show that the increasing complexity of these systems requires increased technical and management know-how by the operator. Therefore, it can be expected that the demand for EPC will grow in the marketplace in the future.

	General Contractor, EPC model	General Planner, EPC model	EPC model 'light'
Example measures	Deep renovation or Public-Private-Partnership projects	Deep renovation projects, including facade and building technology	Building conservation measures: windows, heating/cooling system, roof insulation
Building construction measures	> 50% of total project costs	> 50% of total project costs	< 50% of total project costs
Project specifications and tendering	Negotiated procedure, if the functional specifications are > 50% of the project volume	Construction Company and detailed specifications: standard procurement ESCo and functional specifications: negotiated procedure	Negotiated procedure, if the functional specifications are > 50% of the project volume
Overall project management, optimization and planning	General contractor (individual company or consortium)	General Planner	Energy Service Company (ESCo)
Execution of measures	General Contractor (individual company)	Construction company and ESCo	Energy Service Company (ESCo)
Financing	Combination of individual EPC-savings guarantee, investment cost allowance, third party financing, subsidies	Combination of individual EPC-savings guarantee, investment cost allowance, third party financing, subsidies	Individual EPC-savings, guarantee subsidies
Advantages	Integrated solution Bonus-Penalty system for the contractor Comparison performance-contract possibilities of financing	The building owner/general planner controls the planning and implementation phases No general contractor surcharge Clearly defined building measures	Possible interest of ESCos companies Less capital intensive Standard know-how
Disadvantages	Dependency on the general contractor Pressure on subcontractors Conflicts between general contractor and subcontractors	Cost for the general planner The general planner is not responsible for the long-term performance No incentives for innovative solutions	High share of functional specifications Sub-optimal energy efficiency solutions

Table E-1: Comparison of energy performance contracting models in the renovation of buildings. Source: adapted from IEA-DSM 2009.

Attachment F. Energy Benchmarking of Neighbourhoods

Using the energy performance factors referenced in Attachment A neighbourhood energy performance (pe_{NB}) can be calculated. Neighbourhood energy performance is generally understood as the (primary or secondary) energy by source or carrier required to meet the total end-use demand of individual buildings located in a neighbourhood. The various end uses heating, cooling, DHW, electricity for lighting, appliances and auxiliary uses are summed in total kilowatt hours (kWh) and most commonly expressed as a function of floor area. In the case of residential buildings, usable or total floor area (A_u) refers to the total floor area conditioned with heating and/or cooling. Total building energy use by floor area (kWh/m²) is also referred to as building energy intensity or specific energy demand. The primary energy performance (pe_{NB}) of a whole neighbourhood, containing a given number of buildings, is the total annual building energy consumption divided by the total building floor area (kWh_{PE}/m²).

The values obtained for the specific 'total primary energy', the 'non-renewable energy' (i.e. fossil and nuclear energy) and the specific GHG emissions (kg CO₂e/m²) are the indicators that characterize neighbourhood energy performance. Using the method described in Attachment A, these indicators can be derived by inserting the corresponding primary energy or GHG factors. To do that, the energy performance values (e) of the various energy systems installed in the neighbourhood must be calculated. This is demonstrated in this Attachment F.

In neighbourhoods for which no detailed building attribute information is available, building archetypes may be used. Building archetypes describe the building attributes and energy performance values of buildings representative of those in the overall building stock. As long as basic data on the number of buildings, their type and floor total floor area (m²) is known in a neighbourhood, the entire building stock can be classified according to the k building archetypes (BT_k) that exist in this neighbourhood. Energy performance (pe_{BT}^k in kWh_{PE}/m² by building archetype (k)) is calculated according to total annual megawatt hours of electricity per year (MWh_e/a) and total megawatt hours of fossil energy per year (MWh_{PE}/a). Total annual building energy use (PE_{NB}) for the neighbourhood can then be calculated by adding the total energy use per building archetype PE_{BT}^k (Pol, 2010):

$$PE_{NB} = \sum_k pe_{BT}^k \cdot A_{BT}^k.$$

In some countries, data on local or regional building archetypes specifying average values for size, construction year, U-values etc.) are available, which can be used for a quick energy demand assessment (IWU 2011).

Energy Benchmarks for Buildings

Buildings can be supplied by their own energy systems such as boilers or heat pumps, by district heating or cooling systems, or by a combination of decentralized and centralized systems. The following sections describe how to evaluate the energy performance of such systems. The formulae presented are applied in worked examples to demonstrate the method. Results are presented that may be useful for comparison purposes. An overview of the energy performance calculations for the examples can be found at the end of this Attachment.

Energy benchmarks for buildings or building archetypes are widely in use today, often in connection with energy certificates or sustainability rating systems (see Attachment B). In the EU, the legal requirement for building energy certificates has led to the creation of detailed national certification calculations or modelling approaches. In the context of urban or local energy planning and design concepts, it is typically not feasible to conduct building energy modelling on a building-by-building basis. A simplified approach is

therefore necessary, one that leverages the principles and modelling approaches used in building energy codes and delivers plausible results with a modest level of effort.

The building codes define the following energy indicators that can be generally used to evaluate the building performance.

- The thermal energy demand (or thermal energy intensity)

$$q_{th} = q_H + q_W,$$

where q_H denotes the annual specific heating energy demand and q_W the DHW energy demand in kWh per m² of floor area.

- The *energy performance of the technical building equipment*, e_{EE} in kWh end energy use per kWh of usable thermal energy, kWh_{EE}/kWh_U, as defined in Attachment A.
- The *specific cooling demand*, if applicable.
- The *electricity demand for lighting and appliances*, and *auxiliary uses* e_{el} in kWh_{el} per m² of floor area.
- The resulting (*primary*) *energy demand* pe in kWh_{PE}/m².

In most neighbourhood or local energy planning projects, the main energy-related question is: "*What is the total (primary) energy (pe_{th}) needed for supply of thermal energy for space heating and hot water uses of the buildings in the neighbourhood?*" This is discussed in the following sections in detail.

For example, if a residential building's thermal energy requirements (space heating and hot water needs) are met by a stand-alone natural gas boiler, the primary energy use pe_{th} of this system is calculated according to the methods outlined in Attachment A, step 2, using formula (F-1):

$$(F-1) \quad pe_{th} = q_{th} \cdot (e_{Gas} \cdot f_{Gas} + e_{aux} \cdot f_{el}),$$

with $q_{th} = (q_H + q_W) \cdot (1 + v_D)$, i.e. the thermal energy that has to be generated in the building's heating central including distribution losses v_D . The different terms of the formula above have the following meanings:

Term	Unit	Definition	Typical Values for a Retro-fitted Multi-Family Residential Building (Germany)
$q_H + q_W$	$\text{kWh}_{\text{th}}/\text{m}^2$	specific thermal energy demand (related to the total dwelling area)	$50 + 15 = 65$
v_D	$\text{kWh}_{\text{th}}/\text{kWh}_{\text{th}}$	net losses caused by buffer storage and heat distribution within the building	0.15
q_{th}	$\text{kWh}_{\text{th}}/\text{m}^2$	total thermal energy produced by the boiler	$65 \cdot (1 + 0.15) = 75$
e_{Gas}	$\text{kWh}_{\text{Gas}}/\text{kWh}_{\text{th}}$	energy performance of gas boiler	$e_{\text{Gas}} = 1/\eta_{\text{Gas}} = 1/0.87 = 1.15$
e_{aux}	$\text{kWh}_{\text{el}}/\text{kWh}_{\text{th}}$	auxiliary electricity for boiler and pumps	$8 \cdot 10^{-3}$
f_{Gas}	$\text{kWh}_{\text{PE}}/\text{kWh}_{\text{Gas}}$	primary energy factor of natural gas	1,11
f_{el}	$\text{kWh}_{\text{PE}}/\text{kWh}_{\text{el}}$	primary energy factor of electricity	2.74 (Germany, 2011)
pe_{th}	$\text{kWh}_{\text{PE}}/\text{m}^2$	primary energy performance of thermal energy supply	97.0

Table F-1: Variables to calculate the specific primary energy performance ($\text{kWh}_{\text{PE}}/\text{kWh}_{\text{th}}$) of a stand-alone natural gas boiler using values for a retrofitted multi-family building in Germany.

The fossil primary energy demand and corresponding GHG emissions can be obtained by replacing the primary energy factors in (F-1) with the corresponding fossil primary factors or GHG factors.

For different energy supply systems such as condensing boilers, solar collectors or heat pumps, the energy performance e_{EE} ($\text{kWh}_{\text{EE}}/\text{kWh}_{\text{th}}$) must be calculated on a per-technology basis. For example, for a ground source electric heat pump with a co-efficient of performance (COP) of ε , $e_{\text{HP}} = r/\varepsilon$, where r includes the effect of the auxiliary pumping demand of the pump's heat exchangers (typical values: $\varepsilon \sim 3.5 - 4.0$ ⁹⁸ and $r \sim 1.10$), the term $e_{\text{Gas}} \cdot f_{\text{Gas}} = 1.28 \text{ kWh}_{\text{PE}}/\text{kWh}_{\text{th}}$ in (F-1) should be replaced with $r/\varepsilon \cdot f_{\text{el}} = 0.82 \text{ kWh}_{\text{PE}}/\text{kWh}_{\text{th}}$ (for $\varepsilon = 3.7$ and $f_{\text{el}} = 2.76 \text{ kWh}_{\text{PE}}/\text{kWh}_{\text{el}}$). The primary energy performance of this heat pump is then given by $pe_{\text{th}}^{\text{HP}} = 62.5 \text{ kWh}_{\text{PE}}/\text{m}^2$, which indicates that the energy performance of this heat pump would be 35% better than a conventional gas boiler (last line in Table F-1).

These figures for the *thermal energy supply* can be compared with the primary energy demand pe_{el} due to household electricity demand e_{el} , which is typically $30 \text{ kWh}_{\text{el}}/\text{m}^2$; hence $pe_{\text{el}} = e_{\text{el}} \cdot f_{\text{el}} = 82 \text{ kWh}/\text{m}^2$, which means that electric household appliances and the thermal energy demand of well-insulated buildings cause similar amounts of *primary energy use*, assuming the primary factors used here are valid.

In neighbourhoods with existing or planned district energy systems the energy conversion factors and distribution losses must be calculated for central generating plants supplying heating, cooling or electricity. To assess the energy performance (pe_{NB}) of a neighbourhood heating system, the whole energy chain from import to conversion and distribution to energy end-uses within buildings must be considered. This is illustrated in figure F-1.

⁹⁸ This is a typical empirical COP value for a well-designed air-to-water heat pump. ε depends on source and sink temperatures, T_D and T_S , according to the Carnot factor f_C : $\varepsilon = f_C \cdot \eta_{\text{HP}} = (T_S - T_D) / T_D \cdot \eta_{\text{HP}}$, with η_{HP} the mechanical efficiency of the heat pump (η_{HP} is in the range of 0.45 – 0.65).

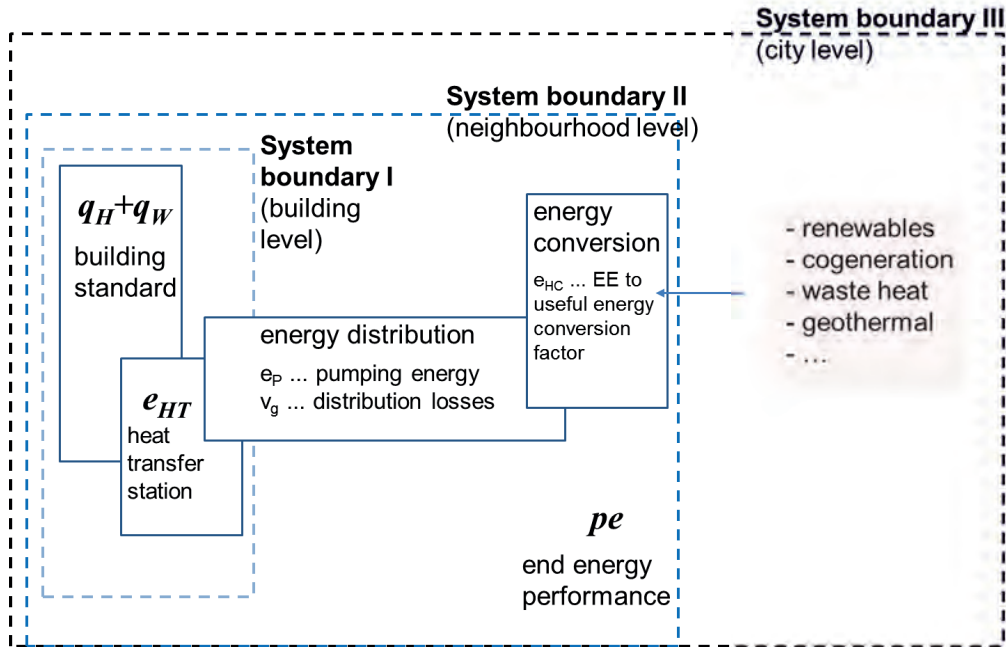


Figure F-1: System boundaries of neighbourhood energy supply

In this case, the thermal energy demand ($q_{th} = q_H + q_W$) of neighbourhood buildings is supplied by a central heating plant with a performance of e_{HC} ($\text{kWh}_{EE}/\text{kWh}_U$). Also taken into account is building heat exchanger performance (e_{HT}), a distribution grid with heat losses (v_g) and pumping demand (e_P) of the district heating system.

If such a district energy system were to use cogeneration, a large heat pump, waste heat recovery, or large scale renewable energy sources (as indicated in Figure F-1) it would only be feasible if it was found to be a significant advantage over conventional building heating systems in terms of both economics and energy quality. In this section, a method to quantify this energy quality is described.

As for individual buildings, a (primary) energy performance (pe_{DH}) for the district heating system must be calculated that can be directly compared with various alternatives be they centralized systems or conventional single-building solutions. To do that, equation (F-1) must be transformed into (F-2):

$$(F-2) \quad pe_{DH} = q_{th} \cdot [e_{HT} \cdot (1 + v_g) \cdot e_{HC} \cdot f_{HC} + (e_{aux} + e_P) \cdot f_{el}] \text{ (kWh}_{PE}/\text{m}^2),$$

where the natural boiler performance is supplanted by the performance of the central heating plant (e_{HC}), and additional grid losses (v_g) and grid pumping demand (e_P) are taken into consideration.

To evaluate (F-2), the energy performance of the central heating plant (e_{HC}) must be determined. This depends on the technology and energy source employed. Three examples of calculating central heating plant energy performance (e_{HC}) are discussed here:

(1) Natural Gas Motor-driven Heat Pump, Using Groundwater as Heat Source

In this system, exhaust gas heat and waste heat from the engine are recovered in addition to the thermal energy generated by the mechanical heat pump process, using ground water as an energy source for the evaporator (Figure F-2). Compared to electrical heat pumps, a higher system supply temperature is possible. If the capacity of the ground water source is large enough, this system can serve as a base load supply of a small neighbourhood scale district heating system, backed by a conventional peak-load natural gas boiler.

The system is characterized by the engine's mechanical efficiency $\eta_M = M/EE$ (see Figure H-2 for the meaning of the variables used), the total energy efficiency of the engine, $\eta_g = (M+Q_M)/EE$, the mechanical-to-thermal energy output ratio $s = M/Q_M$ (kW_{mech}/kW_{th}), and the heat pump's COP, which is defined by $\varepsilon = Q_{HP}/M$. With these notations, the performance of the gas driven heat pump is given by (F-3):

$$(F-3) \quad e_{GHP} = \frac{1+s}{\eta_g \cdot (1+s \cdot \varepsilon)} \quad (kWh_{Hi}/kWh_{th}).$$

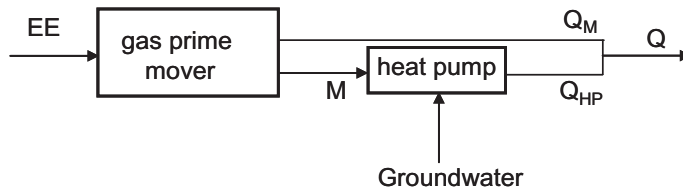


Figure F-2: Energy flow scheme of a gas driven mechanical groundwater heat pump: end energy input EE, engine/exhaust heat recovery Q_M , mechanical energy output M , heat pump heat generation Q_{HP} , total thermal energy output $Q = Q_M + Q_{HP}$.

Inserting plausible values, for example $s = 0.70$, $\eta_g = 0.88$ and $\varepsilon = 4.0$, the result for e_{GHP} is 0.51 kWh_{Hi}/kWh_{th} . This value of e_{GHP} must be inserted into eq. (F-2) for e_{HC} . Since the heat pump is operated with gas, f_{HC} must be replaced by f_{Gas} to finally achieve $pe_{GHP} = 53 \text{ kWh}_{pe}/m^2$ for the gas heat pump process only.

However, an economic optimization will show in most cases that the heat pump should only be designed for base-load supply (delivering, say, $p_{BL} = 85\%$ of the total annual supply), the remaining peak load to be generated by a low-cost gas boiler, characterized by e_B . Therefore, e_{HC} must be the weighted average of e_{GHP} and e_B , that is

$$e_{HC} = p_{BL} \cdot e_{GHP} + (1 - p_{BL}/100) \cdot e_B.$$

Inserting into eq. (F-2), the result for such a district heating system operated with a base-load gas driven heat pump is $pe_{DH}^{GHP} = 63 \text{ kWh}_{pe}/m^2$ (and is thus practically equal to the detached electric heat pump discussed above, considering the current electricity mix in Germany).

(2) Cogeneration Plant

A cogeneration plant consists of one or more internal combustion engines that generate electricity and usable thermal energy from the exhaust gas and the gas-engine. The usable heat is recovered at a temperature of between 65 and 75°C, for instance, and fed into the local district heating network. Cogeneration plants most often use natural gas as fuel.

Typically, the cogeneration plant is operated in base-load mode (such as the gas heat pump above), achieving approximately 5,000 hours of annual operational time and serving some 80% of the total thermal energy demand of the neighbourhood scale district heating network. Figure F-3 illustrates the energy flows through the cogeneration unit, indicating the fuel (= end energy) input EE and the output of usable energy, i.e. thermal energy Q and electricity E.

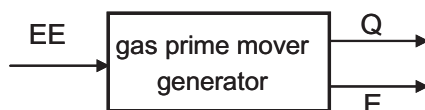


Figure F-3: Energy input EE (natural gas or biogas) and thermal and electric output, Q and E, of a cogeneration plant.

Cogeneration systems entail complex considerations and their economic viability is strongly dependent from several different parameters. Therefore, every application requires special consideration of the specific local frame conditions, which is discussed in more detail in Attachment G. Inserting the result derived there for the performance of the cogeneration plant, $e_{HC} = 0,20 \text{ kWh}_{EE}/\text{kWh}_{th}$, for one specific system (large cogeneration base-load plant with peak-load boiler serving a local district heating scheme of 1 MW_{th} design load) into eq. (F-2), the ensuing primary energy performance of this system is $pe_{DH}^{Cog} = 38 \text{ kWh}_{PE}/\text{m}^2$. This value would be significantly better than the corresponding value pe_{DH}^{GHP} of the gas driven heat pump discussed above.⁹⁹

The results derived from the (F-1) and (F-2) equations above for several supply systems are summarized in Table F-2 and Figure F-4:

Supply system	$pe_{th} \text{ total}$	$pe_{th} \text{ fossil}$	GHG
	$\text{kWh}_{PE}/\text{m}^2$	$\text{kWh}_{PE, \text{fossil}}/\text{m}^2$	$\text{kg CO}_2\text{e}/\text{m}^2$
conventional detached gas boiler	97	95	22
detached ground-coupled electric heat pump	63	51	14
district heating with centralized oil boiler	116	116	31
district heating with wood chip base-load boiler	120	26	12
district heating with cogeneration base-load supply	38	38	8
gas engine base-load heat pump using ground water	63	63	14
district heating system Case Study Rintheim ¹⁰⁰ (40% industrial waste heat, combined heat and power, peak-load boiler)	35	35	10

Table F-2: Comparison of primary and GHG performance for detached and centralized systems, assuming an average thermal energy demand of the supplied buildings given by $q_H + q_W = 50 + 15 = 65 \text{ kWh}_{th}/\text{m}^2$ (characteristic energy numbers of Germany)

⁹⁹ Under the frame conditions of electricity supply underlying the specific example discussed in in this attachment. This result cannot be generalized because of its strong dependency from the given specific frame conditions, which are different from country to country.

¹⁰⁰ See Chapter 6.

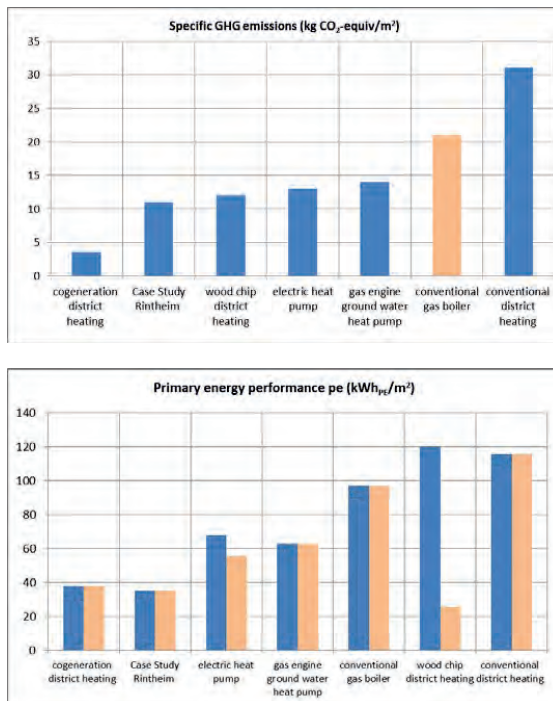


Figure F-4: Graphical illustration of the energy performance coefficients presented in Table H-1:
- top: specific primary energy (total primary energy, blue bar, and fossil primary energy, yellow bar);
- bottom: GHG performance sorted by emission rate.

Figure F-4 illustrates that district heating operated with a conventional heating plant uses significantly more primary energy (and emits more GHGs) than conventional detached boiler systems, due to extra pumping energy and heat losses from the grid. However, efficient systems such as cogeneration or a gas-driven heat pump can compensate for excess energy requirements due to their excellent energy performance factor in supplying the thermal base load. Due to the small fossil primary energy content of wood chips, this energy carrier, as expected, has the lowest fossil energy consumption of all technologies considered here, but the advantage over other efficient district heating systems is not large. While heat pumps, electrically or gas driven, are both in a good midfield, cogeneration systems have more or less the best energy performance (a result however, that depends heavily on the existing energy economic frameworks of the country under consideration. In addition, the *economic viability* of gas driven cogeneration plants is strongly dependent from the monetary return for the generated electricity, and cogeneration plants are prone to rather volatile gas prices, making this technology risky in economic terms.

Figure F-4 also shows that the combined effects of energy efficient (or renewable) supply and moderate building energy conservation measures (in this case a refurbished residential building) can yield a fossil primary energy rating of about 40 kWh_{PE}/m² for thermal energy supply. This outperforms even the excellent energy performance of buildings that comply with *PassivHaus* standards, but with lower total costs, if the neighbourhood heating density is sufficiently large to enable an economic operation of a district heating supply grid.

(3) Large Scale District Heating

In the examples described above, a small-scale local district heating system was assumed. In large district heating systems of several hundred MW_{th} design load, as operated in many major central or northern European cities, usually medium or large combined heat and power plants are installed, very often operated with coal, solid waste or even wood chips as energy carriers. More recently, also combined-cycle gas and steam turbines have been brought into operation, demonstrating cutting-edge energy efficiency capabilities. These plants produce base and medium-load electricity and thermal energy at a temperature of around 100 °C during the heating season.

Combined heat and power plants are capable of operating with varying thermal output, down to pure condensation operation during summer time. Contrary to the cogeneration system described above, there is no fixed relationship between electric and thermal output. Instead, increasing thermal output during winter time will result in decreasing electricity output. The thermal energy supply performance of this CHP plant is then characterized by the reduction of electricity output that the thermal output entails, dubbed as *specific electricity loss* σ (kWh_{el}/kWh_{th}). Multiplying with f_{el} , the primary energy performance ratio pe_{CHP} can be derived for this process also, because $pe_{CHP} = \sigma \cdot f_{el}$ (kWh_{PE}/kWh_{th}) is the amount of primary energy needed to supply 1 kWh_{th} of thermal energy by the CHP plant.

σ depends strongly on the thermodynamic quality of the CHP plant under consideration. Modern CHP plants exhibit values around $\sigma = 0.13$ kWh_{el}/kWh_{th}, corresponding to

$$pe_{CHP} = \sigma \cdot f_{el} = 0.13 \cdot 2.74 = 0.36 \text{ MWh}_{PE}/\text{MWh}_{th} ,$$

a very favourable value, which is comparable to the cogeneration plant discussed above.

As in the case of neighbourhood scale heating schemes, only the base-load is covered by the CHP process. Unlike those neighbourhood systems, there are large scale urban heating schemes where the CHP plants are not operated during summer. In these cases, the fraction of thermal energy covered by a central boiler is much higher than 15%. Such systems must be assessed on a case-by-case basis in terms of their energy and GHG balance (or economic viability). Operators of such large plants, usually municipal utilities, publish annual system energy balances to derive the annual energy performance and GHG emissions. This can be used for energy benchmarking of a city-wide heating scheme.

Final Remarks

As a result, the different technologies of energy supply discussed display a wide variety of energy and GHG performance ratings, measured as (fossil) primary energy input to thermal energy output ratio. Depending on the local conditions, the best system in terms of economics, economic risks and long-term supply security can be selected. These energy and environmental characteristics can be determined along the calculation methods outlined here. In specific applications, the local conditions (availability of energy sources, applicability of technologies, energy density, demand-side measures etc.) need to be carefully considered in the evaluation.

In the foregoing discussion, no consideration of cost or economic features has been made. This would require *integrated system optimization* employing concrete cost curves, encompassing also energy conservation measures within the buildings, which would be strongly dependant from local or national boundary conditions.

Attachment G. Energy Performance of Typical Cogeneration Systems

The Characteristic Performance Indicator of Cogeneration Plants

A cogeneration plant is an internal combustion engine that generates electricity E and thermal energy Q by recovering heat from the motor or generator and waste heat at a temperature suited for space heating and DHW pre-heating preparation (Figure F-3). Cogeneration plants are often operated in facilities such as hospitals or leisure centers or as central heating plants in neighborhood-scale central heating systems with operating temperatures of 65 – 75 °C. A cogeneration central heating plant usually consists of one or more cogeneration engines to provide the thermal base load, and a peak load boiler plus a heat storage with a thermal capacity of one or two hours of base load operation. To operate the cogeneration engines in an economically optimal way, annual operation hours of 5,000 hours or more must be achieved.

As a first approximation, base load cogeneration engine(s) are in most cases sized between 25 and 50% of peak-load demand (the thermal energy demand on the coldest day of the average heating season), supplying between 65 and 90% of the annual heating demand, depending on the demand profile. Any electricity generated is either used within the building, in a local network or fed back into the grid.¹⁰¹ In any case this will displace electricity that would otherwise have been produced by conventional (e.g. coal or nuclear) power plants operating on the public grid.

The efficiency of the cogeneration system is characterized by the efficiency of its electricity generation, η_{el} (kWh_{el}/kWh_{EE}), and its overall energy efficiency (η_{Cog}), defined as useful energy output ($Q+E$) related to (secondary) energy EE used, which very often is natural gas:¹⁰²

$$(G-1) \quad \eta_{Cog} = \frac{Q+E}{EE}.$$

For natural gas driven engines, η_{Cog} ranges between 0.84 and 0.88 independent of the size of the engine.¹⁰³ Typical electrical efficiencies of small cogeneration plants with an electricity output of between 5 and 25 kW_{el} are in the range of $\eta_{el} = 0.20 - 0.25$ kWh_{el}/kWh_{EE}; medium-sized cogeneration engines of between 100 and 300 kW_{el} have efficiencies of $\eta_{el} = 0.33$ to 0.37 kWh_{el}/kWh_{EE}; very large diesel units generating several megawatts of electricity (MW_{el}) have efficiencies $\eta_{el} \geq 0.40$ kWh_{el}/kWh_{EE}.

An important indicator for the quality of a cogeneration engine is given by the electricity-to-heat ratio s :

$$s := \frac{\eta_{el}}{\eta_{th}} \text{ (kWh}_{el}\text{/kWh}_{th}\text{)}.$$

From this definition, since $\eta_{Cog} = \eta_{el} + \eta_{th}$,

$$(G-2) \quad s(\eta_{el}) = \frac{\eta_{el}}{\eta_{Cog} - \eta_{el}},$$

yielding the $s(\eta_{el})$ -curve presented in Figure G-1. Thus, typical values of cogeneration engine quality (s) range from about 0.40 for small engines to 0.75 kWh_{el}/kWh_{th} and higher in very efficient large engines.

¹⁰¹ Since the monetary value of the electricity fed back into the grid is usually smaller than the price of electricity purchased, the economic viability of such a system is strongly influenced by the fraction of cogeneration electricity that can be used locally.

¹⁰² The energy content (EE) of the fuel used is defined here by its inferior heating value (H_i).

¹⁰³ Cogeneration plants can also be operated in condensing mode. Then η_{Cog} can take a value of 0.90 or even higher. This requires low temperature heat supply (≤ 60 °C), which in district heating schemes is often difficult to achieve.

Because cogeneration plants output useful energy in two forms (electricity and thermal energy), a cogeneration plant makes more out of the fuel when compared to separate thermal energy generated by a boiler (with a thermal efficiency (η_B) of $\sim 0.88 \text{ kWh}_{th}/\text{kWh}_{Hi}$) and electricity generated by a condensing power plant (the electric efficiency (η_{el}) of a large modern coal power plant is about $0.44 \text{ kWh}_{el}/\text{kWh}_{Hi}$). That is to say that cogeneration is more energy efficient. This must be quantified to compare the energy performance of cogeneration plants with traditional energy supply systems, which is the objective of this Attachment G.¹⁰⁴

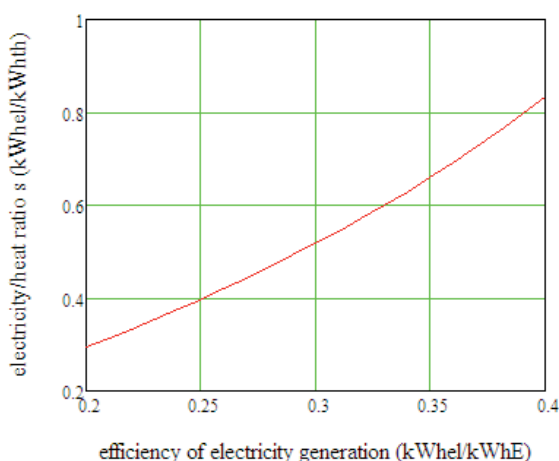


Figure G-1: Dependency of s from η_{el} (with $\eta_{cog} = 0.88 \text{ kWh}/\text{kWh}_E$)

System Energy Performance of Cogeneration Engines

Generally it is not known which one of the public power plants generation is replaced (in whole or in part) by the electricity output of the cogeneration plant. Therefore, it is typical to assume that a small part of the overall generation mix of all public power plants is replaced by the operation of the cogeneration plant. This mix is characterized by an average efficiency η_{Mix} , either expressed in $\text{kWh}_{el}/\text{kWh}_{PE}$ or in $\text{kWh}_{el}/\text{kWh}_{PEfossil}$, the latter of which only considers the fossil part of the energy demand.¹⁰⁵ The average efficiency of the generation mix (η_{Mix}) in a modern electricity grid, operating a number of different power plants of different size and age, is approximately $0.36 \text{ kWh}_{el}/\text{kWh}_{PE}$.

Thus on average 1 kWh_{el} produced by the cogeneration plant will result in the (primary) energy replacement of $1/\eta_{Mix} = 2.74 \text{ kWh}_{PE}$, which otherwise would have been burned in the overall generation mix of all power plants in the public grid. This is called the primary energy bonus b_{PE} that can be assigned to a cogeneration plant producing $s \text{ kWh}_{el}$ for every kWh_{th} of useful thermal output: $b_{PE} = s/\eta_{Mix}$.

Because cogeneration plants are usually operated close to end-users, electricity losses are avoided that would otherwise have occurred in high voltage transmission from public power plants to end users. This is characterized by the transmission efficiency η_T which is in Germany currently around 0.96. Therefore,

¹⁰⁴ Involving the First Law of Thermodynamics only and thus neglecting *exergy* considerations.

¹⁰⁵ It is assumed here that the energy use of the power plants is indicated as *primary energy* (or fossil primary energy) rather than end use energy.

the cogeneration bonus b_{PE} of a cogeneration unit with an electricity-to-thermal energy ratio s is given by $b_{PE} = s/(\eta_{Mix} \cdot \eta_T)$ kWh_{PE} for every kWh_{th} thermal energy output of the cogeneration unit.

Using the definition of η_{Cog} given in equation (G-1), the amount pe_{Cog} of primary energy kWh_{PE} required by the cogeneration plant to produce 1 kWh_{th} is given by:

$$pe_{Cog} = \frac{1+s}{\eta_{Cog}} \cdot f_{Gas} ,$$

With $s = 0.60$ and $\eta_{Cog} = 0.86$ as plausible figures for a 50 kW_{el} cogeneration unit, $pe_{Cog} = 2.08$ kWh_{PE}/kWh_{th}, which is larger and thus inferior in terms of (primary) energy performance, compared to a simple natural gas or oil boiler ($pe_B \sim 1.27$ kWh_{PE}/kWh_{th}). However, the primary energy bonus b_{PE} achieved by generating s kWh_{el}/kWh_{th}, as discussed above, must be subtracted. In this example, $b_{PE} = 0.60/(0.36 \cdot 0.96) = 1.74$ kWh_{PE}/kWh_{th}. Thus the true value of $pe_{Cog} = 2.08 - 1.74 = 0.34$ kWh_{PE}/kWh_{th}, a value much better than the boiler performance pe_B .

The general formula to calculate the (primary) energy performance pe_{Cog} of a cogeneration plant, as discussed above, is thus given by:

$$(G-3) \quad pe_{Cog}(s) = \frac{1+s}{\eta_{Cog}} \cdot f_{Gas} - \frac{s}{\eta_{Mix} \cdot \eta_T} \text{ kWh}_{PE}/\text{kWh}_{th}.$$

Figure G-2 provides a graphical representation of pe_{Cog} as a linear function of s , which is illustrated together with the boiler's (primary) energy performance ($pe_B = 1.27$ kWh_{PE}/kWh_{th}), the blue dotted horizontal line:

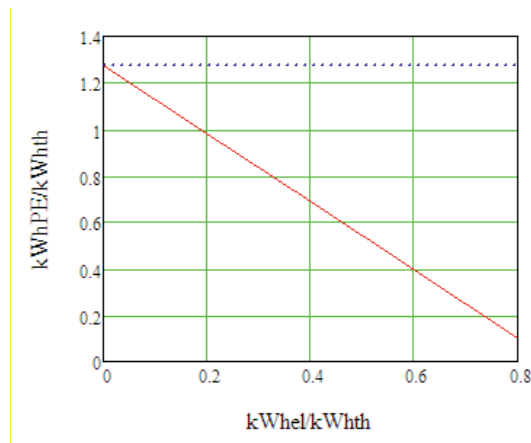


Figure G-2: Primary energy performance pe_{Cog} (kWh_{PE}/kWh_{th}) of a cogeneration engine as a function of s , the electric-to-thermal energy ratio (kWh_{el}/kWh_{th}), and of a boiler, pe_B , (dotted horizontal line), both operated with natural gas.

As Figure G-2 illustrates, the primary energy performance of the cogeneration plant, pe_{Cog} , is decreasing (that means improving) with increasing s . Thus s is an indicator of the cogeneration engine's energy performance. Small cogeneration units have typical s -values of about 0.40; medium and large units, due to their improved electric efficiency, have s -values of between 0.65 and 0.80 or higher.

Energy Performance of a Neighborhood District Heating System

To consider the energy performance of an entire neighbourhood heating system supplied by a cogeneration base-load plant and a peak-load boiler, three adjustments must be made to the formula given in (G-3):

1. Calculate the *average of pe_{Cog} and pe_B* , weighted by fraction of base-load p_{BL} and peak-load, p_{PL} , of the total annual thermal energy supply ($p_{BL} + p_{PL} = 1$). p_{BL} is typically 85% of the annual thermal energy production.
2. *Pumping energy p_{el} (kWh_{el}/kWh_{th})* required by the heating system reduces the net electricity production of the cogeneration plant (s) to $s - p_{el}$. The electricity demand for pumping is often in the range of $p_{el} = 10$ kWh_{el}/MWh_{th} (or 0.010 kWh_{el}/kWh_{th}).
3. Comparisons with other energy systems are related to the sum of the primary energy demand of individual buildings (Q'). To cover *the grid losses v_L* (typically 12%), the central heating plant must supply $Q_0 = Q' \cdot (1 + v_L/100)$ kWh_{th}/a.

By making these adjustments to equation (G-3) outlined above, the total primary energy performance of the local cogeneration district heating system (pe_{DH}) as a function of s may be calculated using the following formula:

$$(G-4) \quad pe_{DH} = \left[p_{BL} \cdot \left(\frac{1+s}{\eta_{Cog}} \cdot f_{Gas} - \frac{s - \frac{p_{el}}{p_{BL}}}{\eta_{Mix} \cdot \eta_T} \right) + (1 - p_{BL}) \cdot pe_B \right] \cdot \left(1 + \frac{v_L}{100} \right).$$

The corrections resulting from these changes are illustrated in Figure G-3:

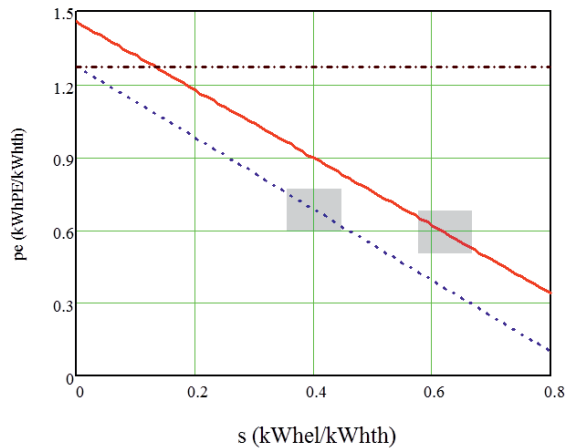


Figure G-3: Primary energy performance pe_{Cog} (kWh_{PE}/kWh_{th}) of a single cogeneration unit (dotted blue line) and the increase of pe_{DH} caused by the corrections made in eq. (G-4), see red line. pe_B for a gas boiler is also indicated (dotted horizontal line). The two grey squares indicate the range of s for small detached (left square) and medium sized (right square) central cogeneration (district heating) units.

Three Application Cases

Using equation (G-4) above, it is easy to compare a large variety of different cogeneration systems, small or large, with natural gas, diesel engines or Stirling engines, gas turbines, back pressure steam turbines, or even fuel cells. Other energy supply systems can also be readily compared, if the correct expression for pe_{th} (see formula (F-1) or (F-2)) for this specific system is derived.

Since numerous parameters must be defined to describe a given system, this guidebook uses only three typical cases as examples of the approach:

Case 1

For the supply of a multi-family residential building with 50 apartment units and 150 kW design heating load, compare the energy performance of a small cogeneration plant (30 kW_{el}, 75 kW_{th} base-load) with a neighborhood scale district heating system of 1 MW peak load with a cogeneration plant (240 kW_{el}, 400 kW_{th} base-load). In both cases, natural gas peak-load boilers are operated.

Assuming the grid mix efficiency mentioned above in formula (G-4), the comparison of these two systems is indicated by the grey squares in Figure G-3. Compared to a conventional natural gas boiler, energy use is reduced by 48% in the building cogeneration case and by 65% in the district heating case. It can be concluded that in terms of energy use both cogeneration alternatives are much better than a gas boiler and that the central system due to the larger value of s has a better energy performance than a building unit, despite the fact that there are no distribution losses in latter case.

Case 2

It can be argued that a new cogeneration system should be compared with technically more advanced systems, such as a new combined-cycle gas power plant ($\eta_{el} = 0.60$) and a new condensing boiler ($\eta_{CB} = 0.97$, for instance) rather than with the separated generation of electricity by the existing mix of power plants and a detached conventional gas boiler.

If this improved parameter for separate electricity and thermal energy generation, by which the cogeneration electricity bonus (b_{PE}) is reduced, is inserted into equation (G-4), the pe_{DH} -value of the district heating cogeneration system is converted to 0.97 kWh_{PE}/kWh_{th}, while the condensing boiler's pe_{CB} -value is 1.15 kWh_{PE}/kWh_{th}. Thus the advantage of the cogeneration system is in this case significantly decreased to about 16%. The small cogeneration building unit, however, does not have any advantage in terms of primary energy performance compared to this optimized separate generation of electric and thermal energy.

However, it is not reasonable to expect that an existing large scale electricity system will be fully replaced by the newest power generation technology within a short timeframe. In a large scale system consisting of existing power plants supplied by fossil fuel, cogeneration systems will maintain their advantage in energy terms as long as the existing infrastructure is not largely replaced. This is due to the fact that electricity generated by cogeneration will preferably replace electricity generated in older, less efficient and more expensive power plants.

Case 3

In Germany, a fraction of 17% of renewables was used in the public electricity mix of 2012. The remaining electric energy demand was supplied by fossil fuel fired power plants and a current fraction of about 19% of nuclear energy. Germany's energy policy requires the fraction of renewables in public electricity generation to increase continuously. For that reason, it is of interest to ask how the *fossil*

primary energy savings by natural gas cogeneration will develop in the future, assuming an increasing replacement of fossil energy by renewables (neglecting the diminishing generation of nuclear electricity for the sake of simplicity here).

The fraction of renewables in the electricity mix shall be expressed by a coefficient r . With 100% renewables ($r = 1$) the fossil primary energy bonus (b_{PE}^{foss}) will be zero. Extending the definition of the *fossil primary energy bonus* (b_{PE}) of the cogeneration electricity s , as given above, by

$$b_{PE}^{foss} = \frac{s \cdot (1-r)}{\eta_{Mix} \cdot \eta_T}$$

and, although this is not realistic, assuming that η_{Mix} and η_T will remain constant, and taking a fixed cogeneration value of $s = 0.72 \text{ kWh}_{el}/\text{kWh}_{th}$, this adjusted value for b_{PE}^{foss} inserted into (G-4) leads to a dependence of pe_{DH} from r as depicted in Figure G-5:

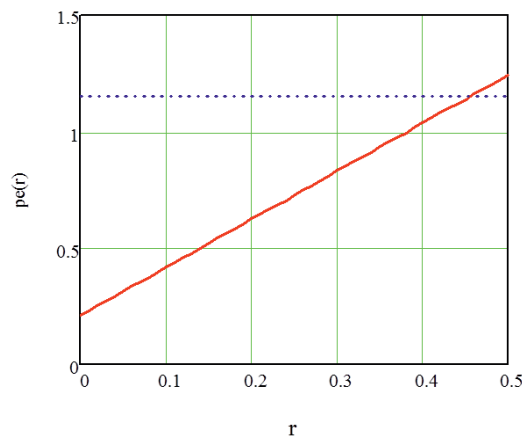


Figure G-5: Fossil primary energy performance $pe_{foss}(r)$ of a cogeneration base load system ($s = 0.72$) as a function of the fraction r of renewables in the primary energy mix of the public electric grid (red tilted line), compared with a conventional boiler (dotted horizontal line).

As depicted in Figure G-5, with r increasing beyond $\sim 45\%$, the primary energy advantage of the cogeneration system when compared to a natural gas boiler is reduced to zero, assuming that the calculation the fossil primary energy bonus (b_{PE}^{foss}) according to the varying electricity mix is correct.

German energy policy currently intends to meet 30% of the electricity demand with renewables by 2022, at which time nuclear energy will have been phased out. This means that the former carbon neutral nuclear electricity will have been fully replaced by renewable electricity. According to the official policy goals, this fraction of renewables shall be increased to 50% by about 2050. Assuming that other characteristics of the public electricity system remain constant (an assumption which is unrealistic due to required structural changes and uptake of new technologies such as flexible gas turbines to replace coal-fired generation) in the long run, natural gas fired cogeneration systems will gradually lose their anticipated advantage in terms of fossil energy savings.¹⁰⁶ These losses could only be offset by future

¹⁰⁶ Due to replacement of outdated power plants with more efficient ones, this development will be accelerated. On the other hand, transmission losses will increase in the future due to long-distance transport of renewable electricity, more frequent voltage transformation and storage losses, which will counteract this acceleration.

significant improvements in the electrical efficiency of cogeneration units (and hence increased s) achieved possibly by transition to a new generation of fuel cells, or if renewable fuels (such as biogas) were to be used in cogeneration plants.

This leads to the question: which alternative strategies such as extreme energy conservation in buildings, increased use of heat pumps or increased use of renewables for heat supply or in the gas mix (e.g., using biogas upgraded to methane) will be more advantageous in the long run? This requires a complex systems analysis that will yield different answers in different countries, depending from the local framework conditions, and goes beyond the simplified considerations adequate in this guidebook. The calculation methods presented above however can be used for such analyses.

In Austria, Sweden, Switzerland, France or regions in Canada with a large share of hydro-electric generation (and also nuclear energy with the exception of Austria), the question of the advantage of cogeneration in terms of fossil primary energy performance (and GHG performance) is even more critical. Thus, the value of the cogeneration technologies depends on the answer to the question, which kind of electricity generation would be substituted by the operation of a cogeneration or combined heat and power plant.

Attachment H. Municipal Energy and Emissions Inventories

Standardized procedures for compiling national CO₂ inventories are published by IPCC (2008). All CO₂ emissions within a country must be accounted for, that is from all national uses of (fossil) primary energy, but also emissions and sinks from agriculture, forestry and other land uses and from other chemical compounds not related to energy supply. Such a compilation is neither feasible nor relevant for municipalities. Relaxing the IPCC rules for municipal inventories creates more direct relationship between energy use within a municipality and identification of local opportunities for action.

Local energy planning requires, at a high level, energy use within the city described by source or carrier and sectors and activities. This is illustrated in Figure H-1 below and Figure 3-6 in Chapter 3. The energy and emissions inventory or balance enables the municipal energy working group to assess current energy use and understand trends over time. Monitoring the impact of energy measures that have been implemented as a result of municipal or neighbourhood energy plans is the core function of an inventory that is updated consistently.

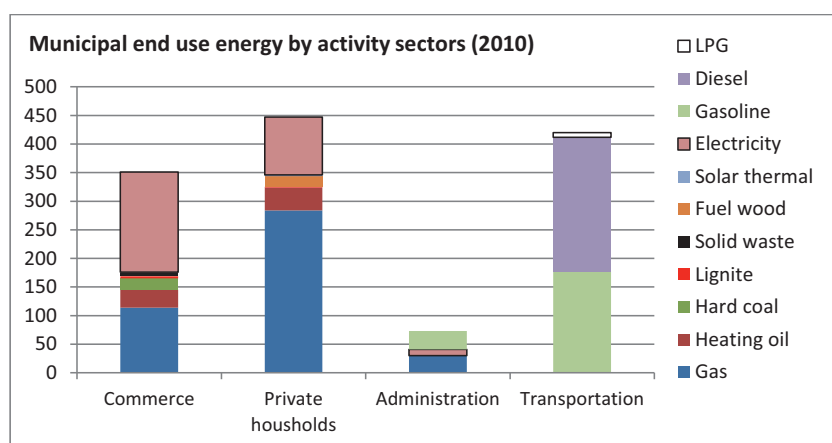


Figure H-1: Structure of energy use within a municipality, by energy source or carrier and sectors (example)

When establishing the municipal inventory or balance, energy use and GHG emissions from local electricity generation must be properly allocated. There are several examples of energy use that should not be included in the inventory, as for instance, energy used by local inhabitants that occurs outside the municipality. Embodied energy in buildings should also not be counted, since it is energy that was used in the past. Electricity generated within the municipality but delivered to customers outside the city should also not be included in the inventory.

With respect to local cogeneration plants, four distinct cases can be identified where guidance is required on attribution of energy and associated emissions to the municipal inventory.

Case 1

Electricity generated by a local conventional condensing power plant used locally should not be included in the municipal inventory, because it is already part of the general electricity mix.

Case 2

A local (CHP) plant in mixed mode (condensing mode and heat extraction mode)

(a) Heat extraction mode:

According to Attachment F, assign the primary energy use PE_{CHP} of the CHP plant exclusively to the CHP's output of thermal energy Q_{th} , but subtract the quantity $PE_{el} = Q_{th} \cdot \sigma \cdot f_{el-Mix}$ from PE_{CHP} (with σ being the electricity output loss caused by the thermal energy output of the CHP plant in kWh_{el}/kWh_{th} , and f_{el-Mix} the primary energy factor of the electricity mix). The resulting primary energy consumption $PE = PE_{CHP} - PE_{el}$ provides the amount of primary energy assigned to the thermal energy production Q_{th} of the CHP plant.

(b) Condensing mode:

Treat this operation mode like case 1.

Case 3

For electricity produced by *local cogeneration plants* (or local back pressure steam turbines) with electricity-to-thermal output ratio s (kWh_{el}/kWh_{th}), use equation (G-3) in Attachment G to evaluate the primary energy balance of the cogeneration plant.

For example, using this approach Figure H-2 can be created by using the data used to create Figure 3-2 in chapter 3.2 and assuming 6% of total municipal electricity use would be generated by several local cogeneration plants operated in multi-family buildings, commercial facilities and public buildings. The primary energy PE bonus can be subtracted from the total measured natural gas consumption: Figure H-2 then shows the overall contribution of cogeneration projects towards the municipality's energy and GHG targets.

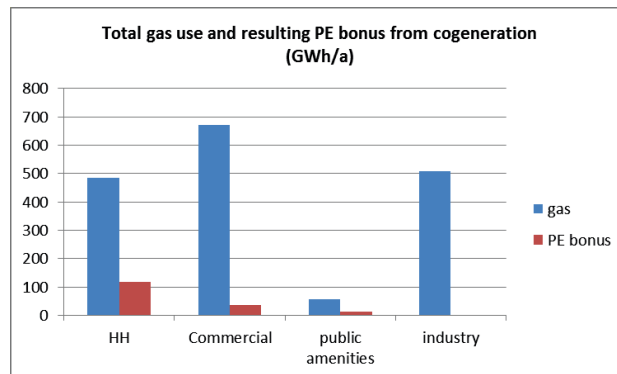


Figure H-2: Gas use in Freiburg, Germany (left column) and the primary energy bonus from cogeneration plants (right column), which can be subtracted from the gas use to adjust the energy balance correctly, by sector

Case 4

Local operation of renewable electricity plants should be treated similarly to local cogeneration plants. Electricity E_{el} generated from renewable sources causes a fossil primary energy consumption $PE_{ren} = E_{el} \cdot f_{ren}$, where f_{ren} characterizes the specific source of renewables employed. This is compensated for by substituting the *electricity generation bonus* for electricity from the grid, $E_{el} \cdot f_{Mix}$. Thus the total primary energy bonus is given by $PE = E_{el} \cdot (f_{Mix} - f_{ren})$, which can be subtracted from the primary energy

associated with electricity use by the sector and activity under consideration. Calculate GHG emissions in an analogous way.

Attachment I. Municipal Energy Improvement Opportunities

Three principles of the local energy planning transition and energy systems of the future are:

- Reducing energy use through energy conservation
- Reducing energy use through energy efficiency
- Increasing the use of energy from renewable sources

Application of these principles to achieve the transition to energy efficient low carbon cities is a long-term process. To inform opportunity assessment and scenario development in the early planning stages, with absence of precise data or advanced models, an energy planner should be prepared to estimate the *general technical and economic potential* associated with these three kinds of measures and the implementation rates required over the planning timeframe. Numerous explicit or implicit assumptions about technology availability, energy prices, behavior of potential investors, legal frameworks, incentives and so on will need to be made. To keep the level of effort minimal, existing statistics and studies available locally or on a regional or national basis should be used. In addition, the planner must draw upon his or her own practical experience and make reasonable guesses. This Attachment I provides some practical examples.

Local Renewable Energy

Concerning renewable energy supply, apart from potential biomass, hydro or wind electricity imports from surrounding regions into the municipality, it is a good idea to focus on existing *local potentials*. While imports can hardly be influenced by municipal energy policy, the use of local renewables can be encouraged.

Local Solar Energy Potentials

Solar thermal energy (solar collectors) and solar electricity (PV panels) are the most popular renewable energy supply options in local energy policy. Most often, the *technical potential* is the largest of locally-available renewable energy sources. However due to a lack of economic feasibility, a mismatch of demand and supply and a lack of local technical capacity, solar energy technologies are capturing far less than the technical potential of the solar resource in most if not all cities. This situation is changing gradually. In the mid to long term, it will be necessary to increasingly exploit the local technical potential to achieve a successful local energy policy. Hence it is important to make a reasonable estimate of the size of this potential and a plausible guess of the long-term implementation rates, and realistic expectations about future technical developments and economic optimization potentials.

The technical potential of solar energy in cities depends on the available areas for solar installations, that is: *roof areas on buildings*, since other areas within cities very often are either not accessible or too expensive.¹⁰⁷ There may be additional potential installation areas, such as roofs on public buildings, but to make a coarse estimate, these can more or less be neglected compared to the roof areas of residential buildings.

¹⁰⁷ This situation may be different in the surrounding country side, but this would mean 'import' of solar energy, which is not considered here.

Three levels of precision to estimate the available roof area can be considered:

- estimate by local building archetypes,
- estimate based on the number of flats or residential areas within the planning region, recovered from local statistics,
- GIS building cadaster data bases and area scanning technologies (see also Figure 3-7 and Chapter 4).

To derive a rough first estimate of local solar energy potentials, the first two methods are adequate.

The first method (classification of local settlement archetypes with characteristic solar potentials) is illustrated by the photograph below (Figure I-1), where the structure of several adjacent settlement types in the north of Karlsruhe, Germany, can be observed. From this picture it can be imagined that it is possible to elaborate characteristic numbers, such as available collector area per dwelling area or floor area per settlement area (floor area ratio), for different settlement archetypes. Knowing the area of every settlement archetype within the city, a rough first estimate of the available solar energy potential can be derived.

This method requires the availability of a '*settlement archetypes library*', developed on a national or regional basis – a planning method that has already been developed in several countries. Employing this approach, it is assumed that the districts of a city can be classified into homogeneous neighbourhoods ('settlement archetypes') that can be characterized by typical building styles and typical urban forms. Investigating a number of such typical settlements, characteristic empirical properties, such as the typically available solar roof area, have been derived in the literature. Using the floor space of the existing settlement archetypes of a given neighborhood or city, the characteristic data of the settlement archetypes can be converted into corresponding data for the settlement under investigation.

This method was developed in detail already in 1980 in Switzerland by U. Roth and updated later by M. Blesl in 1998 (Roth 1981, Blesl, 2002). A current update, employing GIS based tools, is under way by Hegger (Hegger 2012). To make use of it, prevalent settlement types in the city of consideration must be assessed.



Figure I-1: Typical residential areas in Karlsruhe, Germany: Mixture of single/double family buildings and small multi-family buildings in the north and east, large multi-family buildings in the center and medium-sized multi-family buildings in the south of the area (at the bottom of the photograph). Source: VOLKSWOHNUNG GmbH.

The second method can be used when only statistical data on the residential building stock of the city is available. This statistics usually provides the numbers of single family buildings, two family buildings (duplex) and multi-family buildings. Knowledge of the existing number of buildings with a given number of storeys would be more useful, but is rarely available.

A quick estimate of the available roof area for solar installations on residential buildings of a given city can be made using the following approach:

The southern oriented roof area A_{S_Roof} of a *one-storey building* (pitched roof, oriented from west to east), which can be used for a solar installation, is proportional to the building's residential area A_{Res} : $A_{S\_Roof} = f(\alpha) \cdot A_{Res}$, where the proportionality coefficient f is a function of α , the roof inclination angle. For geometric reasons the ratio of the southern oriented (symmetric) pitched roof area A_{Roof} to ground area A_{Res} is given by:

$$\frac{A_{Roof}}{A_{Res}} = f(\alpha) = \frac{1}{2 \cdot \cos \alpha}.$$

Figure I-1 depicts $f(\alpha)$ for roof inclination angles between 15 and 45 degrees, illustrating that $f(\alpha)$ varies between 0.5 and 0.7 for plausible roof inclination angles of 15 – 45°. For an angle of $\alpha = 30^\circ$, which might be the most frequent roof angle, $f(\alpha) = 0.58$.

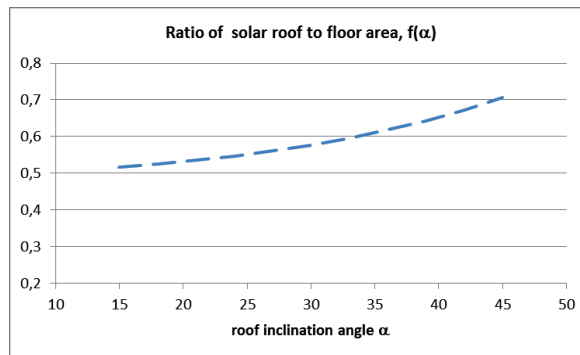


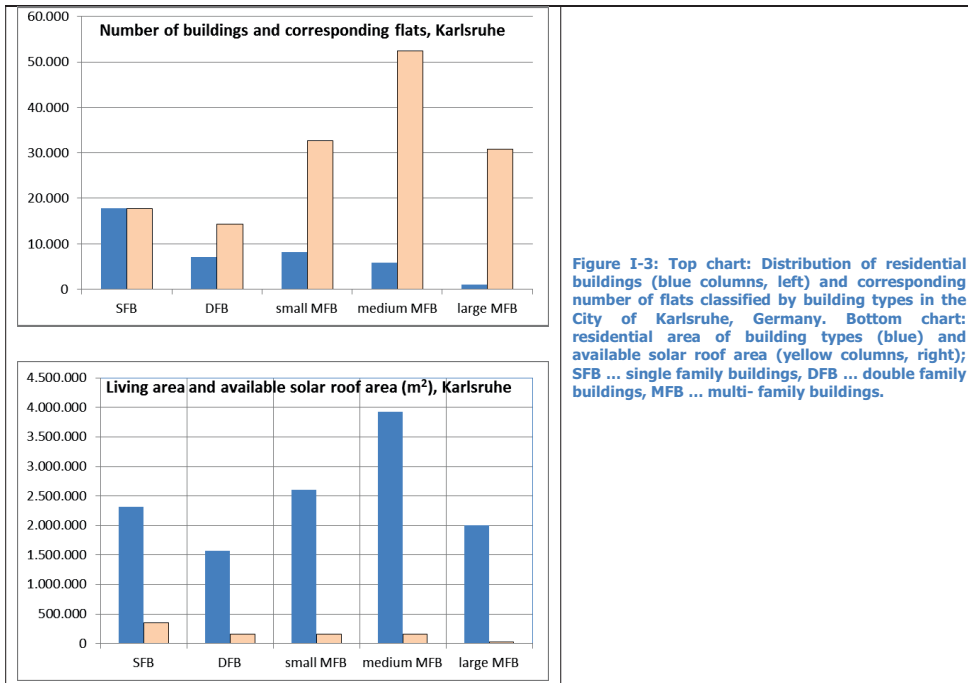
Figure I-2: The ratio $f(\alpha)$ of the area of the southern oriented part of a pitched roof to the residential area of a one storey building as a function of the roof inclination α .

However, it is not possible to use the total available area for the solar installation. We estimate the usable fraction of the available roof area to be 85%. Since the buildings of a city have more or less statistically distributed geographic orientations, only about 50% of all roofs will be suitable for solar installations. Thus for the average of *all 1-storey buildings*,

$$A_{S\_Roof} = 0,58 \cdot 0,85 \cdot 0,50 \cdot A_{Res} = 0,25 \cdot A_{Res} \text{ m}^2 \text{ of available roof area per m}^2 \text{ dwelling area.}$$

For a building with n storeys, this term must be divided by n .

Under these very rough assumptions and using the building statistics of a neighborhood or city, a rough estimate of the solar potential of the residential buildings of a city can be made. The result is shown for a concrete example below, using the data of the City of Karlsruhe (300,000 inhabitants, 40,000 residential buildings with 146,000 flats).



To estimate the resulting local potential for solar energy, a mixture of thermal and electric energy can be generated using the available solar roof areas. It is reasonable to assume that *solar energy for DHW* is prioritized over electricity generation: the remaining area not used for DHW can be used for PV panels. Thus, the solar energy that can be harvested by collectors is estimated first:

If d is the average specific DHW demand of a flat (kWh_{th} per m^2 living area) and the (economically) optimal DHW coverage by solar energy is c_{Sol} , the efficiency of DHW distribution within the building is η_{DHW} , and the specific solar yield is s_{th} (kWh_{th} per m^2 collector area), the required collector area a_{coll} to supply a fraction of c_{Sol} of the DHW demand is given by

$$a_{\text{coll}} = \frac{d \cdot c_{\text{Sol}}}{\eta_{\text{DHW}} \cdot s_{\text{th}}} \quad \text{m}^2 \text{ collector area per m}^2 \text{ residential area.}$$

With typical figures, like $d = 18 \text{ kWh/m}^2$, $c_{\text{Sol}} = 0,60$, $\eta_{\text{DHW}} = 0,70$ and $s_{\text{th}} = 400 \text{ kWh per m}^2$ collector area for flat plate collectors, **$a_{\text{coll}} = 0,04 \text{ m}^2 \text{ collector area per m}^2 \text{ dwelling area}$** .

The annual electricity yield e_s of PV panels ($\text{kWh}_{\text{el}}/\text{m}^2$) can be calculated, using the specific PV solar power yield a_{PV} in kW_p per m^2 panel area (which depends on the cell efficiency) and the annual electricity yield e_p in $\text{kWh}_{\text{el}}/\text{kW}_p$, which depends on the local solar irradiation, yielding

$$e_s = e_p \cdot a_{\text{PV}} \quad (\text{kWh}_{\text{el}}/\text{m}^2)$$

for the potential solar electricity production e_s . Typical figures are $a_{\text{PV}} = 0,14 \text{ kW}_p/\text{m}^2$ and $e_p = 950 \text{ kWh}_{\text{el}}/\text{kW}_p$ for solar average irradiation conditions observed in Southern Germany. Thus an annual electricity generation of **$e_s = 135 \text{ kWh}_{\text{el}} \text{ per m}^2 \text{ of PV area}$** results for this example. With this value for

e_s , the electricity generation by PV panels on residential buildings can be calculated using the available roof area of Figure I-3 (right hand side chart) after subtraction of the area of 0,04 m² collector area per m² dwelling area required for solar DHW supply.

As a result, about 20% of the total household electricity demand and approximately 50% of the DHW demand can *technically* contribute to the provision of solar energy in Karlsruhe, making use of about 35% of the total roof area. A further result is that given the specific distribution of building types in Karlsruhe, 70% of the total solar energy generation comes from one and two family buildings – which is very reasonable, since the ratio of roof area to dwelling area in multi-storey buildings is much smaller. For one and two family buildings, on average between 35 and 55% of the household electricity demand can be *technically* met with PV in addition to up to 60% of the DHW demand, when balanced over one year and when the public grid can be used for electricity storage. However, this storage capacity is limited and therefore such a 'PV strategy' will not be possible without significant changes to the existing electricity system (not considering economic implications).

It is left to the planner and his or her expertise to estimate a realistic value for a specific case and the implementation rate that can be assumed, considering such factors as future installation costs, future energy prices, future legal frameworks, or demand (or acceptance) by potential users, when making up an energy scenario for a specific community.

Local Biomass

In each city there is a limited biomass potential for thermal energy generation from local scrap wood and landscaping waste. In the past decade there has been a revolution in municipal waste management and waste processing technologies in industrialized countries, introducing material recycling systems and waste to energy or sewage/biogas generation by fermentation on the other. This has resulted in a massive reduction of the volume of final (inert) to be disposed. The municipal biomass potential mentioned above can be technically almost entirely recovered making use of existing municipal waste processing systems.

Considering the current average waste disposal structure in Germany, in the average about 1.1 MWh of primary energy per inhabitant (i.e. 2% of the total average primary demand of about 50 MWh_{PE}/inhabitant) can be recovered by modern municipal waste processing systems.

A biomass strategy can play a significant role in the local energy plan, since fuel wood, either wood chips or wood pellets can be transported economically over 100 km. Thus, available potential is regionally determined, but must include other competitive uses. There is no general method to determine existing regional potentials, except by identifying forestry areas and using the statistical annual harvest yields per hectare from forests or energy plantations for the determination of solid biomass or biogas harvest quantities. By multiplying these values with the available forest and agricultural areas in a region and subtracting the fraction used for conventional purposes such as timber for furniture, an estimate of theoretical potential can be made. The usable quantity for a neighborhood or city will depend on existing or new district heating grids, central heating plants and economic competitiveness of alternative energy sources, which must be examined on a case by case basis. Therefore, unlike solar energy, no generally applicable figures for biomass utilization potentials in cities can be derived.

Other Renewables

Renewable electricity from local hydro or wind energy sources requires available sites, which generally do not exist in urban areas. In some cases the potential may be there, but their feasibility must be evaluated

on a site by site basis. Though wind and hydro energy may be the most important renewable energies on regional scale, in local energy planning they will likely play only a minor role (see, however, Klärle, 2013).

The only renewable source that, like solar energy, is available ubiquitously is 'environmental energy', that is ambient air and – with limited availability – geothermal energy of the near-surface thermal capacity of the earth, in both cases to be used by heat pumps. Only areas that need individual supply systems are candidates to tap this source, since in areas with central heating schemes, for economic reasons these are preferred for building thermal energy supply. For detached systems, there will be a competition between conventional (fossil) supply systems, small biomass (wood pellet) systems and heat pump systems, involving solar energy where applicable, and the potential will depend on individual availability and economic optimization considerations and/or individual preferences (see Chapter 3.8 for technical details). Increasingly, geothermal mapping is available in cities, which is useful in identifying local sites with useable geothermal potentials.

Waste Heat

Waste heat refers to heat produced by machines, electrical equipment and industrial processes for which no useful application within the individual manufacturing process is found. Internal waste heat recovery within industry and buildings is profitable depending on energy prices. Use of waste heat from a local industrial facility in a district heating scheme may have a large potential, but is often difficult to organize given security of supply concerns and economic risks.

The biggest potential point sources of industrial waste heat originate from basic industrial processes, such as steel or glass or paper production or chemical processes, or from large industrial machines. Heat recovery or electricity generation from waste heat (e.g. using absorption heat pump processes or ORC turbines) can be technically and economically feasible when industrial processes have generation capacities ranging from a few to many MW and produce heat at temperatures of between 100 and 400 °C - although to identify the business case might be more difficult.

Waste heat sources in buildings include internal appliances, such as air-conditioning or exhaust air from ventilation systems, or tap water. Heat recovery within the process for re-use within the same building is often technically easy, however local energy prices will dictate whether it is economically feasible.

Sewage water in high density areas is often considered as possible source of waste heat employing heat pumps, however this technology faces technical and economic barriers and its energy potential is generally small.

Methods for Estimating Energy Conservation Potential in Buildings

Innovative energy efficiency building components and energy technologies have been developed in recent years and rising energy prices have accelerated their market adoption. It is generally assumed that significant energy saving potentials exist in the building sector, if these technical innovations could be implemented on a large scale (see Attachment E). Saving potentials of up to 50% of the existing thermal energy demand or even more are suggested.

Considering whole cities, only a statistical approach combined with a 'building archetype' data base is possible to quantify energy conservation potentials as input into a specific municipal energy demand scenario. The key numbers required to determine this potential are:

- current energy performance (heating/cooling demand, performance ratio) of the building stock by building types and construction years
- the difference between supposed 'optimal' performance that is economically viable and existing technical potential after implementation of latest state-of-the-art technologies (that must be identified)
- the supposed implementation rate r
- the timeframe or planning horizon Δt of the scenario that is provided (for instance, 25 years).

Example: Energy Conservation Potential of Household Refrigerators

To take *household refrigerators* as a very simple example, in a specific energy planning project it has been found that N_{HH} households had an average electricity use of 3.300 kWh_{el}/a. From statistical studies it is known that refrigerators have an average electricity consumption of $e_e = 462$ kWh_{el}/a, approximately 14% of the average household electricity use. It is assumed that households replace refrigerators after $n_L = 14$ years of use. If the current best technology refrigerators (A⁺⁺⁺ devices in the current EU energy classification scheme) have a demand of $e_T = 220$ kWh_{el}/a, the average annual savings (total amount of kWh_{el}/a saved by refrigerator replacement within the planning area) would be

$$\Delta E = N_{HH} \cdot (e_e - e_T) / n_L.$$

In reality, this approach is too simplistic because not all devices are replaced by best available technology, in a number of cases the old device is not taken out of operation (the worst case) and the best technology will be improved in future. Consequently, this assessment method must be adjusted according to assumptions made by the planner concerning real conditions of the case under consideration.

Such an approach can be applied in principle for most potential conservation technologies that may contribute to an overall energy conservation scenario, including energy retrofit of buildings, if sufficient statistical information is available. This can be integrated into a scenario model describing the assumed development of energy uses within the planning horizon.

As a result, scenarios to describe development trajectories that realize existing energy conservation and renewable energy potentials at certain implementation rates can in a first step be based on coarse estimates as described above. During the development of more planning details on neighborhood level, this estimate can be adapted and refined in several steps in an iterative manner, which will continuously improve the quality of the scenarios, making them a useful tool for both planning and monitoring over time.

Attachment J. Planning Methods in Neighborhood or District Energy Planning

Methods and approaches in neighbourhood or district energy planning are rarely addressed in the education of architects, urban planners or technical building equipment engineers. Urban energy system planning is rarely taught as an established academic discipline. Rather, the required knowledge foundation must be gained in specialized disciplines, such as district heating planning or energy systems analysis. While this existing substantial knowledge is still confined to subject matter experts, there is comprehensive literature available in most countries providing up-to-date planning know-how and practical results.

For pre-feasibility studies in neighbourhood or district planning, detailed design planning is not necessary. Rather, a good estimate of existing alternatives, supply or demand side, is required based on the existing data on building structures and energy systems relevant for the neighbourhood under consideration. In this attachment, the key steps necessary to elaborate neighbourhood concepts on the basis of pre-feasibility considerations are described, in combination with typical key indicators useful in this phase of planning. Conventional methods and key figures are outlined that are useful for the planner in the early design phase of neighbourhood projects, without employing software planning tools. Useful information about pre-feasibility methods can also be found in RETScreen, 2011.

A number of software tools have been developed over the past years that provide additional support in neighbourhood planning, albeit they can be difficult to use. Such computer-assisted planning tools are discussed in Chapter 4. In addition, in Chapter 5 a new energy balancing tool for neighbourhoods, the District Energy Concept Adviser (D-ECA), is presented that has been developed in the context of Annex 51 by Fraunhofer-IBP, Stuttgart, which is also useful in the pre-planning phase of neighbourhood concepts.

1.1 Thermal Energy Demand Data for Neighbourhood Planning

(1) Heating and DHW Energy Demand of Individual Residential Buildings: a Proxy Approach¹⁰⁸

(a) Design load: Full-load Hours Approach

For a pre-feasibility study of thermal energy supply concepts of a neighbourhood, key energy indicators are:

- the peak or design load Q_D (kW_{th}) of the neighbourhood, being the sum of the design loads of individual buildings plus grid losses, corrected by a simultaneity factor; and
- the annual demand Q_a (MWh_{th}/a) for thermal energy, $Q_a = Q_h + Q_{ww}$, (Q_h ... heating demand, Q_{ww} ... DHW demand).

Both indicators are connected by the 'equivalent full hours' of operation, h_e , which is the time in hours that the central heating plant would have to operate at full load to deliver Q_a : $h_e = Q_a/Q_D$ or, using values related to the floor area, $h_e = q_a/q_D$, with q_a in kWh/m² per year and q_D in kW/m².

Knowing the annual thermal energy use Q_a (or q_a and the floor area of the buildings), this is a simple way to estimate the design load Q_D of the planning area using empirical full-load hours (see below for examples).

¹⁰⁸ Local low temperature thermal energy needs, such as laundries, are potential district heating customers, for which demand characteristics must be captured individually. Such customers may improve the economic viability of a district heating system appreciably.

(b) Design load: U-value Approach

If no reliable data for the overall annual thermal energy demand is known, Q_D can be calculated using a simplified (steady-state) heating demand approximation for the neighbourhood's building archetypes:

For residential buildings with an envelope/volume ratio $v = A_H/V_e$, (A_H ... area of the building's envelope, V_e ... external volume of the building), air exchange rate n (for instance 0.50 h^{-1}) and no heat recovery from ventilation exhaust air, the heating design load Q_D at the coldest day (the day with the local 'design outdoor temperature' T_D^{109}), can be approximated by

$$(J-1) \quad Q_D = (U_m \cdot A_H + n \cdot V_n \cdot c_A) \cdot \Delta T_D \text{ (W)},$$

with

U_m ... average U-value of the building's envelope in $\text{W}/(\text{m}^2 \cdot \text{K})$ and $\Delta T_D = T_h - T_D$, with T_h being the temperature below which the building must be heated, the 'heating limit temperature', for example 17°C for buildings with poor U_m -value,¹¹⁰

V_n ... net volume of the building (m^3): a plausible estimate is $V_n = 0.80 V_e$;

c_A ... specific heat capacity of air: $c_A = 0.34 \text{ Wh}/(\text{m}^3 \cdot \text{K})$.

Inserting these values, the design heating load Q_D is given by

$$(J-2) \quad q_D = (U_m + 0,14/v) \cdot \Delta T_D \text{ (W/m}^2\text{)},$$

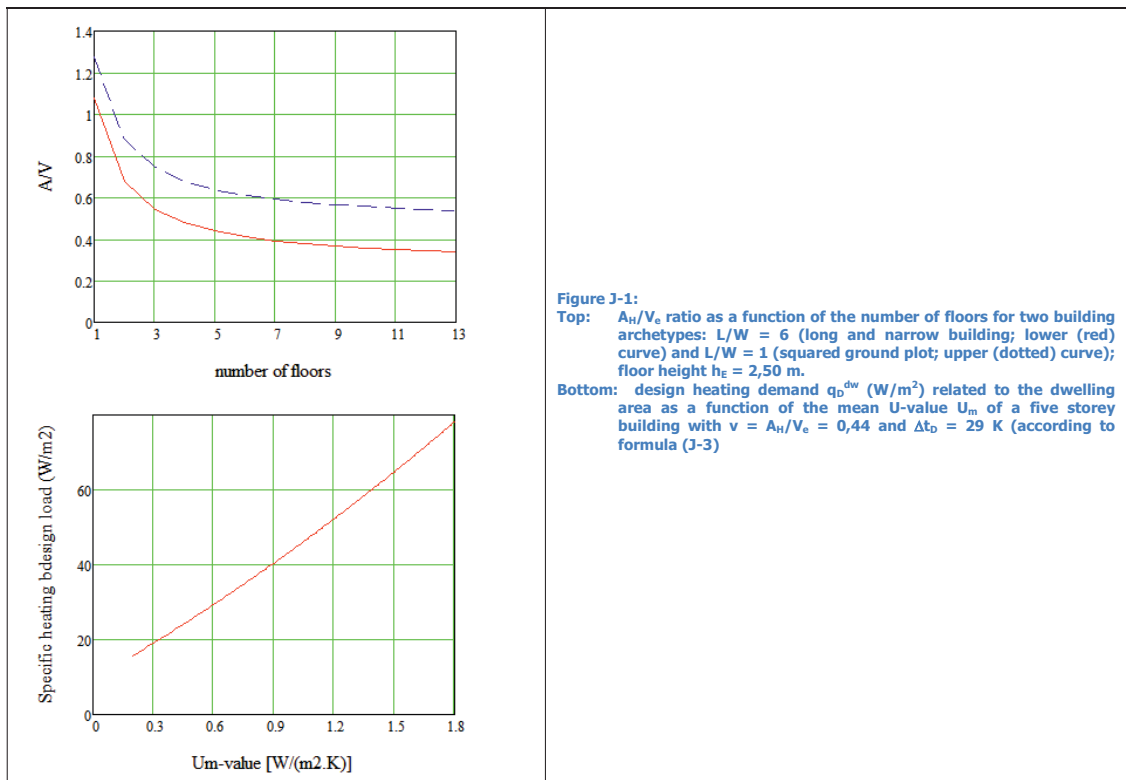
the specific heat design load q_D of the building, related to the building's external envelope area A_H . However, the specific heating design load q_D^{dw} (kWh/m^2), related to the building's dwelling area A_{dw} , is more useful, since A_H is very often unknown, while A_{dw} is generally available. Since $q_D^{dw} = Q_D/A_{dw}$ per definition, and $A_{dw} = 0,8 \cdot L \cdot W \cdot n_E$ (L and W being the length and width of the building, an n_E the number of floors; 0.8 is a proxy factor to estimate the dwelling area from the building's geometry), and $V_e = L \cdot W \cdot h_E \cdot n_E$, A_{dw} can be written as $A_{dw} = 0,8 \cdot V_e/h_E$. Assuming for the floor height $h_E = 2,50 \text{ m}$ and inserting into (J-1), we arrive at

$$(J-3) \quad q_D^{dw} = (3,13 \cdot v \cdot U_m + 0,44) \cdot \Delta T_D \text{ (W/m}^2\text{)},$$

where the parameters in (J-3) should be all known. Thus, for a given ΔT_D , for example $\Delta T_D = 17 - (-12) = 29 \text{ K}$, q_D^{dw} is dependent from the shape of the building, defined by the envelope-to-volume ratio $v = A_H/V_e \text{ (m}^{-1}\text{)}$, which in turn depends from the ratio of the building length L to its width W , L/W , and the building's height $H = n_E \cdot h_E$. v is depicted in Figure J-1 (upper chart) for two different building archetypes. The lower chart of Figure J-1 illustrates the resulting specific heating demand q_D^{dw} according to formula (J-3) for a multi-family building with 5 floors as a function of the U_m -value, from "not refurbished" ($U_m \sim 1,80 \text{ W}/(\text{m}^2 \cdot \text{K})$) down to 'PassivHaus'-standard ($U_m \sim 0,20 \text{ W}/(\text{m}^2 \cdot \text{K})$).

¹⁰⁹ Depending on the local climate, T_D is between -10 and -20°C in northern climates.

¹¹⁰ T_h depends on the internal loads, solar gains, thermal inertia and insulation; it is often assumed to be 17°C . With a decreasing U_m -value, T_h is drops from 17°C to 10°C for extremely well insulated buildings such as *PassiveHaus* standard buildings.



On the upper chart in Figure J-1, a decrease of T_h with decreasing U_m was assumed according to Table J-1, which results in a slightly nonlinear shape of $q_D(U_m)$, because with improving (that is decreasing) U_m , the calculated 'heating limit temperature' $T_{h,r}$ is decreasing, since solar energy gains and internal heat loads increasingly compensate for the difference between the required comfortable room temperature, say 21 °C, and the outdoor air temperature (T_h) at which point heating must be switched on.

The U_m -values of the buildings under consideration are often characterized empirically in previous studies or may be found in a building archetype database. Reasonable U_m -values of medium-sized multi-family buildings and the corresponding heating design load (q_p) are displayed in Table J-1.

	U_m-value (W/(m ² ·K))	T_h (°C) (plausible values)	Heating design load q_D^{dw} (W/m ²)
Existing post-war buildings: double-glazed windows, no retrofits	2.10	17	92
Existing buildings: modest retrofits	1.50	17	65
Existing buildings: recent retrofit, corresponding to new building standards	0.60	15	36
low energy building (new)	0.40	15	22
<i>PassivHaus</i> standard (new)	< 0.30	12	16

Table J-1: Plausible heating design loads of a multi-family building (T_D = -12 °C) for different insulation standards with n_E = 6 and v = A_H/V_e = 0.44.

An estimate of the annual heating demand q_H (kWh/m²) is then achieved using the full load hours approach mentioned above, using empirical full heating load hours (h_H)¹¹¹ defined by h_H = q_H/q_D^{dw} (h/a). Thus, with an empirical value for full heating load hours the annual heating demand (q_H) can be calculated from q_H = h_H · q_D^{dw}/1,000 (kWh/m²). Since heating systems are usually over-sized by between 10 and 15% to guarantee supply including DHW, the empirical value for h_H must be increased by between 10 and 15% to calculate a realistic value of q_H. The annual heating demand is then given by Q_H = q_H · A_{dw} (for a calculation of h_H based on local weather data see DD approach below).

(c) Annual heating energy demand: Degree Day (DD) Approach

If full-load hours are not known, q_H can alternatively and more reliably be calculated using the Degree Days (DD) method:

For a given day (k) with mean outdoor temperature (T_k) the heating demand (Q_D) can be calculated using the formula

$$Q_k = A_H \cdot (U_m + 0,14/v) \cdot (T_h - T_k) \cdot 24/1000 \text{ in kWh/d.}$$

Summarizing Q_k over the z days of the heating period delivers the annual heating demand of the building, Q_a:

$$Q_a = A_H \cdot (U_m + 0,14/v) \cdot \sum_{k=1}^z (T_h - T_k) \cdot 24/1000 \text{ in kWh/a,}$$

or using the term:

$$\text{HDD} := \sum_{k=1}^z (T_h - T_k), \text{ the 'heating degree days' (Kd),}$$

$$Q_a = 24/1000 \cdot A_H \cdot (U_m + 0,14/v) \cdot \text{HDD.}^{112}$$

Exemplary HDD values for the cities of Karlsruhe and Stockholm are provided in Table J-2.

To make use of this formula for an estimate of the total heating demand of the neighborhood under consideration, the specific heating demand (or heating energy intensity) for every building archetype

¹¹¹ The equivalent full hours (h_{eq}) as defined above, contains both heating and DHW, while h_H covers heating demand only.

¹¹² The relationship between Heating Degree Days (HDD_h) and Degree Days (DD), where it is assumed that the heating limit is equal to t_i, is given by DD = HDD + (t_i - t_h) · z, with t_i ... room temperature (usually, t_i = 20 °C).

must be calculated, which can then be multiplied by the total floor area (A_{dw}) of the various building archetypes to calculate their respective portions of the neighborhood's heating demand. Summing up the total heating demand of all building archetypes within the neighborhood delivers the total annual neighbourhood heating demand (Q_{NB}). Using the same considerations as presented above, with the specific annual heating demand $q_a = Q_a/A_{dw}$ in kWh per m^2 of dwelling area and $A_{dw} = 0,80 \cdot V_d / (n_E \cdot h_E) \cdot n_E = 0,32 \cdot V_{er}$, we arrive at:

$$(J-4) \quad q_a = 24/1000 \cdot (v/0,32 \cdot U_m + 0,44) \cdot HDD \text{ (in kWh/m}^2\text{)},$$

with $v = A_H/V_E$.

The result of this calculation of q_a as function of U_m is illustrated in Figure J-2 for Karlsruhe and Stockholm:

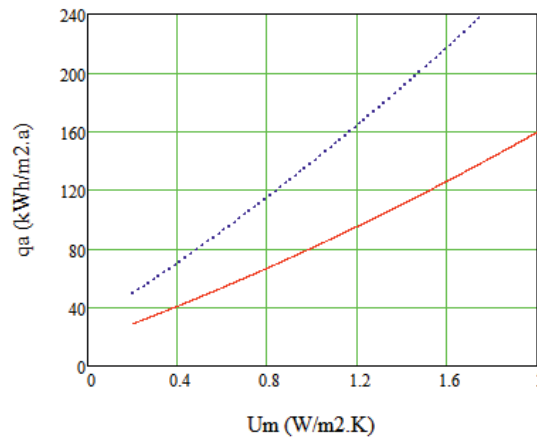


Figure J-2: Annual specific heating demand as function of the mean U-value U_m for Karlsruhe (red line) and Stockholm (dotted line), using the HDD-values given in table J-2.

This is a simplified approach that considers temperature differences as drivers of heating demand while neglecting the dynamic effects of weather variations in sun and wind, day and night, heating capacity of the building and user behaviour. However values for q_H illustrated in Figure J-2 have been empirically verified in the Annex 51 Karlsruhe-Rintheim Case Study for residential buildings both pre-retrofit ($U_m \sim 2.0$) and post-retrofit ($U_m \sim 0.40$), showing that these effects have a tendency to cancel each other out (see Figure 4-5 in chapter 4).

As alternative to using HDD values, average outdoor temperature over the heating period, T_m , can also be used to calculate q_H according to:

$$(J-5) \quad q_H = 24/1000 \cdot (v/0,32 \cdot U_m + 0,44) \cdot z \cdot (T_h - T_m) \text{ (kWh/a)},$$

if T_m is known from local weather statistics (see also footnote on the previous page). Since both approaches must yield the same value for q_H , the number of heating days (z) can be calculated by:

$$Z = \frac{HDD}{(T_h - T_m)},$$

and the full-load heating hours h_H from

$$h_H = 24 \cdot \frac{HDD}{(T_h - T_D)}.$$

The examples of Stockholm and Karlsruhe illustrate the resulting key heating indicators (using $T_h = 15^\circ\text{C}$):

	DD (Kd) ¹¹³	T_D (°C)	T_m (°C)	z (d)	h_H (h/a)	HDD (Kd)
Stockholm	4,967	- 19.4	2.4	285	2,470	3,542
Karlsruhe	3,277	- 12	6.6	245	1,820	2,052

Table J-2: Comparison of key heating demand the climates of Stockholm and Karlsruhe

(d) Estimate of DHW demand

The DHW demand of dwellings varies appreciably. In the literature, consumption of 30 to 60 litres per person per day are quoted, corresponding to between 380 and 760 kWh per year. In addition, there are appreciable losses in the range of up to 40% of the DHW demand that occur during storage and DHW circulation. Thus, between 600 and 1,100 kWh per year per user must be generated by a heating central plant to meet DHW needs. However, the number of users per dwelling is not known in most cases. Therefore, an empirical demand figure related to floor area rather than the number of occupants is often used, gathered from DHW demand measurements. In the Karlsruhe-Rintheim Annex 51 case study, an average of 25 kWh/m² per year DHW generation by the heating plant was measured over two years for around 1,000 flats with an average size of 70 m². Since distribution losses from basement to flats are in the range of 40%, the average DHW demand of the flats is about 15 kWh/m².

Together with the estimate of heating demand data as described above, these values can provide a reasonable initial estimate of thermal energy demand ($q_a = q_H + q_{W,r}$) of residential areas that can be used in the design phase of neighbourhood energy planning projects.

(2) Archetype Approach

As previously mentioned, countries such as Germany, Switzerland and Canada make building or neighbourhood archetype data available; these enable the user to estimate energy demand of the building or neighbourhood under consideration. The archetype buildings or neighbourhoods are characteristic of the architecture styles and settlement structures of the country or region where they are located. For building archetypes, attributes such as building type, average floor area, year built, typical U-values, average occupancy and average energy use are included. Neighbourhood archetypes may include total number of buildings by type, their floor area, residential or occupational densities, street lengths and thermal energy demand density. Archetype data will need to be customized by the energy planner. Using the full load hours approach, peak load estimates can be made. Using characteristic load duration curves it is also possible to develop initial lay-out configurations of supply alternatives (see below).

(3) Thermal Energy Load Curves

In many cases an economically optimized district energy system for a neighbourhood consists of two or more different supply systems, for example a wood chip boiler or cogeneration base load plant operated

¹¹³ The local value for the degree days (DD) can be downloaded from RETScreen which supplies weather data for locations in many countries around the world.

with a peak load natural gas boiler. In this case the base load system requires a high up front capital investment but allows for low operating costs and vice versa for the peak-load system. This raises the question of optimizing the whole heating central to achieve the lowest total heating costs over a full year. For such bivalent energy systems, apart from the design load (q_D) and annual energy use ($q_{a,r}$) also temporal variations in energy demand (daily, monthly, yearly) are important, influencing the operating characteristics of bivalent supply systems and thus the economic viability as a whole.

Since extensive input data and calculations are necessary to fully describe and optimize a bivalent central heating plant and distribution network, planners use simulation software packages to solve such optimization problems. Examples include BHKW-Plan, a German energy system planning tool used to optimize the design of cogeneration plants (see Chapter 4). However, for pre-feasibility studies with little data on hand, a simplified approach can be applied using sorted load duration curves; used in the 'pre-computer age' they are still used by planners due to the useful information that they provide.

Load duration curves can depict, for example, the daily load of residential buildings supplied by a district heating network, sorted by size. The load consists of various demands for heating and DHW and grid heat losses. Figure J-4 illustrates a load duration curve constructed on a monthly basis using a proxy method described in (RETSreen, 2010), with degree days that determine the monthly heating load of a user in Ontario, Canada. This curve is compared with the result of a computer simulation, using an annual outdoor temperature data base ('test reference year', TRY, see (DWD 2013)) as driver for the heating demand of a location in Germany.

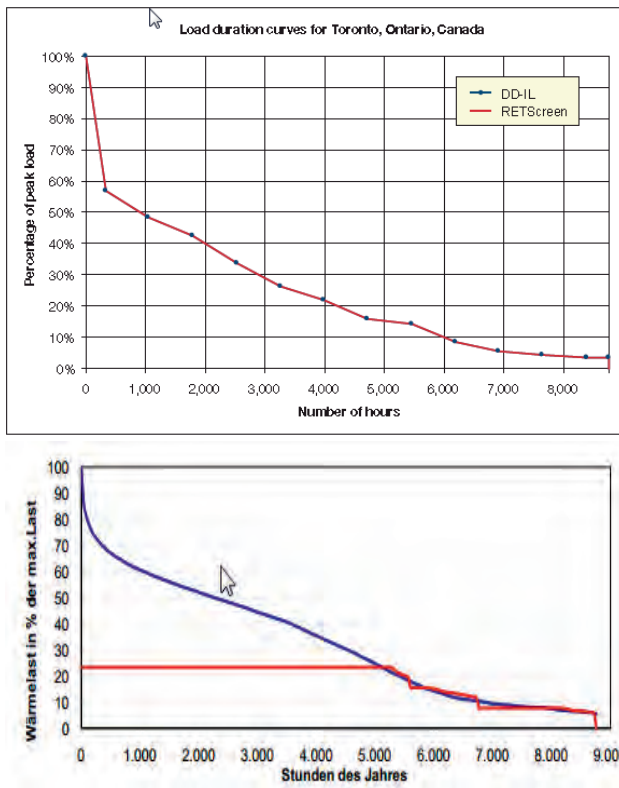


Figure J-3: Examples for sorted load duration curves (heating, DHW) with a point wise approximation (upper chart) for a location in Canada (RETScreen 2010) and using a software package for a 8,760 hours simulation using TRY data for a location in Germany (BHKW Plan, 2011).

The lower chart of Figure J-3 illustrates one use of such load duration curves: to determine the economically optimal base load lay out, in this case a cogeneration plant, which is depicted by the horizontal red line. The effect of small thermal energy storage capacity on the operation of the cogeneration system is also indicated.

The total annual costs of a bivalent heating central depend on the ratio of base load to peak load, which determines the annual full load hours of the base load system. A low base load means long annual full load operation, which is good, but also a lower percentage of the annual supply, which is not as good in terms of economics. Using a computer simulation tool, the optimal combination can be identified in iterative steps of base-load designs, from 15% up to 60% of the full load, to determine the lay out that yields the lowest total costs.

As the total area below the duration curve represents the annual amount of energy delivered, it can be estimated by inspection that a base-load design of 23% of full load (Q_b) represented by the red line in the lower chart of Figure J-3 can supply about 50% of Q_a and exhibits an annual full load operation of about 6,500 hours. In turn, a base load lay out of 60% would enable the supply of about 90% of Q_a by the base load system, but with less than 4,000 hours at full load.

As illustrated by Figure J-4, load duration curves can be used to quickly and graphically depict the relationship of annual base load to peak load supply for a given base load sizing in % of the design load.

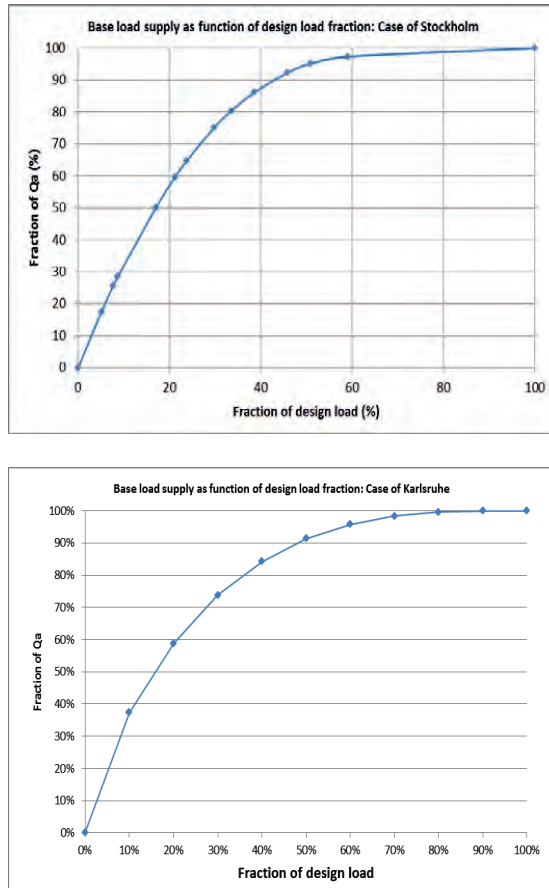


Figure J-4: Graphical estimate of the base-load supply fraction of Q_a , as a function of base-load lay out: example for residential supply of Stockholm (up, RETScreen 2010) and of Karlsruhe-Rintheim (Annex 51 Subtask B Report) on the bottom.

The two charts in Figure J-4 compare results for Stockholm and Karlsruhe. These cases are remarkably similar despite the differences in heating requirements in the Swedish and German climates.

Using the result of estimates illustrated in Figure J-4, with case specific energy prices and investment cost structures an iterative optimization of base-load and peak-load lay out can be carried out graphically without employing simulation software.

To perform a detailed calculation of the economic viability of *cogeneration plants*, the monetary return from electricity generation is most important. This requires also day and night use profiles such that different electricity tariffs can be included. When such detailed calculations are required, the use of simulation software is inevitable.

1.2 Thermal Energy Distribution

District heating, the technology for central thermal energy supply in neighbourhoods or districts, is well established in many countries. For residential heating and DHW supply, optimal temperatures are 70°C for supply and 40°C for return. These temperatures best meet space heating and hot water needs because they enable thermal disinfection of tap water and require minimal installation of equipment in a house or flat to manage the return temperature. At these temperatures, thermal distribution losses and pumping energy losses can also be minimized. While lower grid temperatures are technically feasible, they are generally only justified when using specific heating sources (e.g. solar thermal energy or heat pumps) or in other specific cases (for a Danish example, see Dalla Rosa, 2012).

The standard piping technology used in district heating is isolated steel pipes with plastic jacket pipes. For diameters below 80 mm, medium pipes made of plastic are also used, sometimes as double pipes with supply and return pipe contained within one larger insulated pipe; stainless steel pipes with pre-fabricated insulation are also used. The different materials have different cost structures and are used for different purposes including distribution mains, sub-distribution and building connections.

While there is a significant amount of knowledge on planning and operating large scale district heating networks in many European countries, it is still the domain of subject-matter experts. Through co-operation with manufacturers district heating systems are planned and installed that guarantee optimized and long-term operation. Software are used for detailed system engineering design planning and many use GIS-based models for network planning. In the pre-feasibility phase however, rough estimates about investment and operating costs described below are generally sufficient

The distribution costs for thermal energy are a function of pipe diameter selected for a given thermal distribution capacity (kWth):

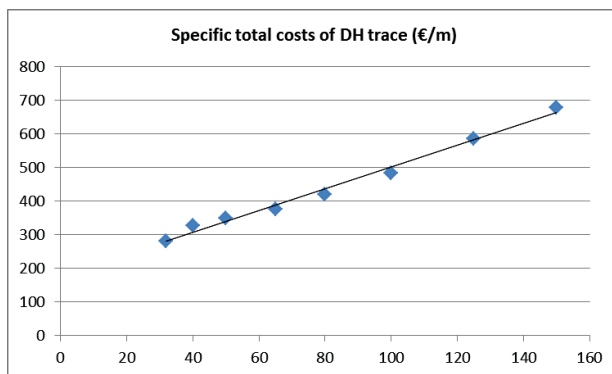


Figure J-5: Total specific costs of district heating traces (EUR/m) as function of the pipe diameter (mm), German conditions, prices of 2011. Source: Richter, 2008

In pre-feasibility planning stage, a few empirical parameters can be used to develop an initial cost estimate: the difference between forward and return temperatures (ΔT), the flow velocity v (1 – 2 m/s) that determines the required pipe diameter to transport a certain thermal capacity, the specific heat distribution losses q_v (16 – 30 W/(m·K) per double pipe), and the expected specific pressure losses Δp (80 – 110 Pa/m) of the pipes (Dötsch, 2001).

Using these parameters, for a specific case with a given heating pipe load Q_p an investment and operation cost estimate can be made using the following equations:

$$(J-6) \quad d(Q_p) := 17,4 \cdot \sqrt{\frac{Q_p}{v \cdot \Delta T}}$$

to calculate the pipe diameter $d(Q_p)$ (in mm) as a function of the required pipe capacity Q_p (in kW) and of the difference ΔT of supply and return temperatures, $\Delta T = T_s - T_r$, for a given water flow velocity v (m/s). This dependency of d from Q_p is illustrated in Figure J-6. Practice shows that for small pipe diameters a typical velocity v with acceptable pressure losses Δp_{eff} of about 100 Pa/m is in the range of 1.2 – 1.7 m/s.

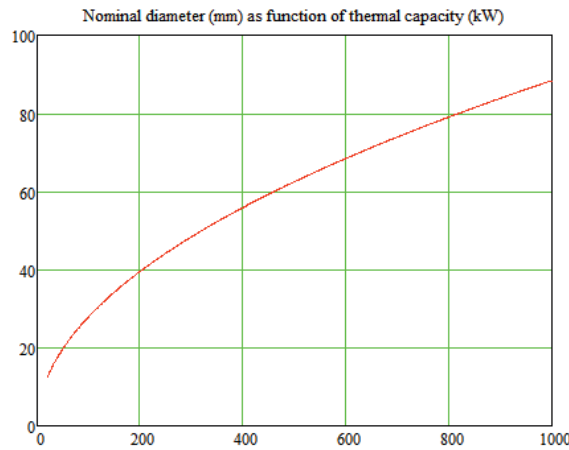


Figure J-6: Interior pipe diameter (mm) as function of the transport capacity (kW), with $\Delta T = 30$ K and $v = 1.3$ m/s.

The electric power required for the water circulation, E_{el} (in W) is given by

$$(J-7) \quad E_{\text{el}} = \frac{1}{\eta_p} \cdot V \cdot \Delta P$$

with η_p being the electric efficiency of the circulation pump, V the volume rate of the hot water pumped (m^3/s) and ΔP the total pressure difference over the grid (Pa): $\Delta P = L \cdot \Delta p_{\text{eff}}$ (Δp_{eff} is the total pressure loss of the heating pipes divided by the length of the pipes in Pa/m).

Using the specific mean thermal loss q_v (W/(m·K)) of the supply and return pipes of total length L and the mean temperature difference ΔT_U between pipes and surrounding earth, the heat loss Q_v (in W) of the district heating grid is given by

$$Q_v = q_v \cdot L \cdot \Delta T_U.$$

In the practical planning case, the total grid length must be determined from the neighborhood's local energy plan, but geographical information systems (GIS) populated with local cadaster data should be

used to calculate the length of the grid, if available. Pipes lengths and diameters in different sections of the grid must be estimated using the equations and empirical parameters given above, which delivers L and the average pipe diameter (d_m).

With suitable assumptions about the operating temperatures and operating hours per year, the annual thermal losses Q_v and pumping electricity consumption E_{el} can be estimated. The circulation pumping energy can be obtained by multiplying E_{el} from formula (J-7) with an estimated annual full load operation time. A typical value for district heating grids is a specific pumping energy of $e_{el} = 6 \text{ kWh}_{el}$ per MWh_{th} supplied.

The total costs of district heating pipes c_{Tr} including supply and return pipe, pipe fittings, thermal expansion compensations, trench excavation, and civil works are usually assumed to be a linear function of the pipe diameter d_p : $c_{Tr} = a + b \cdot d_p$ (EUR/m). Typical empirical values for the coefficients a and b in a documented German case are $a = 178.5$ and $b = 3.24$. Figure J-5 compares the costs offered by different manufacturers (Richter 2008). To adjust for costs in 2011, an inflation rate of 1.5% per year was used. The costs of piping material in this case were in the range of 20% of the total costs. Therefore, impact of pipe material choice on costs is not significant.¹¹⁴

The contribution of the district heating grid to the total specific costs of thermal energy supply can be estimated using the total length (L) of the grid, the mean diameter of the pipes (d_m) with corresponding costs $c_m = a + b \cdot d_m$ (EUR/m) and determining the total annual thermal energy demand Q_a (MWh/a). This yields the line density $d_l = Q_a/L$ ($\text{MWh}/(\text{m} \cdot a)$). From this, annual costs c_{DH} (EUR/ MWh) of thermal energy distribution are given by:

$$c_{DH} := \frac{c_m \cdot a}{d_l},$$

with the annuity a :

$$a := \frac{q - 1}{1 - q^{-N}},$$

using the discount factor $q = 1 + p/100$ (p ... interest rate in %) and the depreciation time of N years.

In selecting pipe sizes, it is important to consider the simultaneity factor that arises when a number of users (n) of similar type are supplied by one supply pipe. This can reduce the estimated investment costs for the grid and the central heating plant appreciably. An empirical formula to derive this factor $g(n)$ as the function of the number of users (n) with similar demand characteristics (such as residential users) was quoted by (Hackner, 2004):

$$(J-7) \quad g(n) := a + \frac{b}{1 + \left(\frac{n}{c}\right)^d}$$

¹¹⁴ The density of in-ground infrastructure services such as electricity/telecommunication, water, sewage beneath roadways can influence capital costs. In the case of high infrastructure density, piping costs can be 50% higher, whereas in low density new developments costs can be 50% lower than those indicated in Figure J-5.

with empirical values for $a = 0.45$, $b = 0.55$, $c = 53.8$ and $d = 1.76$. This yields the following curve:

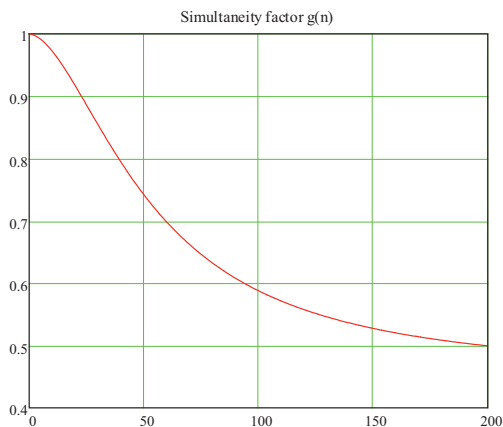


Figure J-7: Simultaneity factor $g(n)$ as a function of a number of users with similar demand characteristics

As a result, the simultaneity factor of, for example, 50 residential buildings would be $g(50) = 0.75$. Using this factor, the assumed sizing of the main pipes can be reduced accordingly.

Example to demonstrate the approach described above:

A new neighborhood with 50 low energy buildings with an average floor area A_B of 300 m² per building and a thermal energy demand q_a equal to 80 kWh/m² per year has an annual thermal energy demand of $Q_a = q_a \cdot A_B \cdot n = 80 \cdot 300 \cdot 50 / 1000 = 1,200$ MWh/a. Using an empirical value of full load hours of $h_e = 1.700$ h/a, the nominal peak load (sum of heating and DHW demand of individual flats, employing a simultaneity factor of $g_{(50)} = 0.75$ is $Q_p = 530$ kW (see equation (J-7)).

Not including the pipes between the distribution grid to individual buildings, L was measured to be 550 m. Thus the total specific line density (d_l) is given by $d_l = Q_a/L = 2.18$ MWh/m. With an estimated mean diameter of $d_m = 50$ mm, mean specific costs of $c_m = 350$ EUR/m (Figure J-5) and an annuity factor of $a = 0.06$ ($p = 4.5\%$, $N = 20$ years) the specific capitalized costs of the thermal energy distribution grid (c_{DH}) yield $c_{DH} = (c_m \cdot a)/d_l \sim 13$ EUR/MWh. This is a typical figure for new neighbourhoods with modest energy demand densities.

The pipe connection from the main pipe to the building is usually be paid by the building owner. With an average length of 9 m per building, the total length of these connections is 450 m, leading to a total length $l_{total} = 1,000$ m. Using an average specific thermal loss of double pipes of 18 W/m, the total annual pipe losses are approximately 150 MWh_{th} or 12% of the annual thermal energy demand.

With an energy price of 45 EUR/MWh_{th}, the losses cause extra costs of 6,750 EUR per year or 5.6 EUR/MWh_{th}. Assuming an electricity demand of 6 kWh_{el}/MWh_{th}, pumping costs are 1,620 EUR per year, resulting in extra costs of around 1.4 EUR/MWh_{th}. Thus the total heat distribution costs are in the range of 20 EUR/MWh_{th}, which must be added to the heat supply costs (energy plus capital cost plus maintenance) of the heating central plant. These costs can be compared with alternatives such as

detached boilers, to assess the economic feasibility. Additional cost components such as administration, planning, or initial uncovered costs due to delays in connecting buildings must be estimated accordingly.

J.3 Neighborhood Archetypes Approach

Using the neighborhood archetype approach mentioned in Attachment I, the structure of the distribution costs for 11 defined neighborhood archetypes in Germany (ST 1 – ST 11; where ST stands for *Siedlungstyp*) has been determined by Blesl (2009). Figure J-8 illustrates examples derived for typical line densities and resulting thermal energy distribution costs of these neighborhood archetypes.

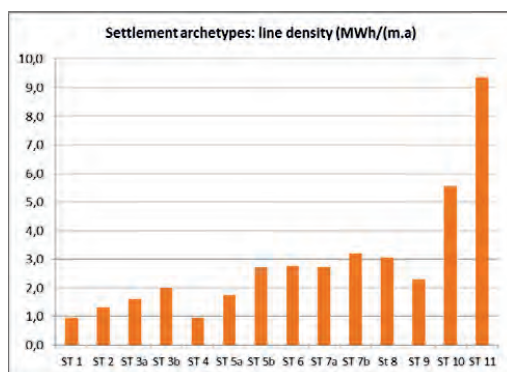
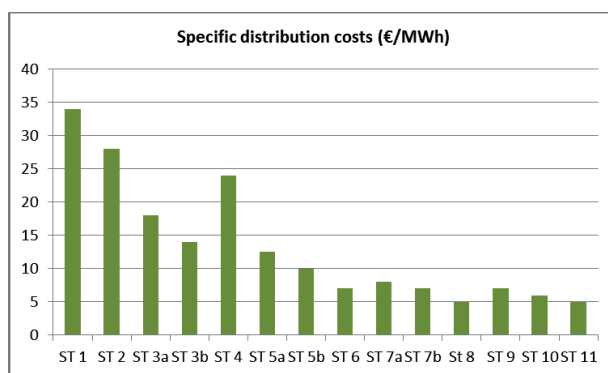


Figure J-8: District heating line density (MWh/(m.a)), up, and specific distribution costs (EUR/MWh) of thermal energy for 11 settlement archetypes (called ST for 'Siedlungstyp') according to (Blesl 2009).



As Figure J-8 illustrates, for distribution costs to be less than 15 EUR/MWh the line density of the neighbourhood archetype should be ≥ 2 MWh/m. For this reason, it can be concluded that for neighborhood archetypes ST 1 to 4 in Figure J-8, implementing a centralized solution will not prove to be economically viable due to the low density energy demand in single family dwellings and other low density residential areas. This is valid for existing neighbourhoods seeking to replace existing stand-alone supply units with a central solution. New developments present greater opportunities for district energy integration; however, up front capital costs and the time required to make new connections and generate revenue may prove to be deterrents.

Results of the neighborhood analysis as illustrated in Figure J-8 are only initial estimates to provide information about the potential economic feasibility of a central heating system. These must be further

investigated in more detail as a next planning step. Only if positive results are obtained from this pre-feasibility assessment of the general technical and economic potential, further detailed planning is justified.

IEA ECB Annex 51 „Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers“ was carried out from the perspective of communities, towns or cities: Considering the large energy conservation and Greenhouse Gas reduction potentials in our cities and the disappointing results of municipal energy policies in almost all cities, what are the barriers that prevent us from achieving our long-term energy goals in cities or, more generally, in our built environment? What can be learned from successful Case Studies in neighborhoods, districts or cities? Given the great advancements in building physics and energy technologies made during the last 20 years, is there any economically viable way to apply these advancements to whole cities? If we seriously want to achieve the goal of reducing the consumption of fossil primary energy carriers by a factor of four and more, as stipulated by most of the governments of industrialized countries, we must find answers to these questions that are of immediate use for decision makers in our cities.



This Annex 51 wants to provide such answers, based on the evaluation of over 20 Case Studies carried out within the 11 participating countries and elaborated in the form of this guidebook on successful local energy planning. In eight chapters and several detailed attachments a manual to derive municipal energy master plans for towns or cities on one hand, and local neighborhood energy plans on the other is presented, which serves as a guideline for municipal decision makers, real estate developers and urban planners as well. The guidebook also describes the methods to derive energy and emissions inventories, energy scenarios and suited implementation strategies for energy master plans. One additional focus are proved methods how to involve local stakeholders into the decision making process. The aim is to provide the user with the capability to understand how to design and implement a realistic energy plan for their city or neighborhood, based on existing experiences and lessons learned from pioneering communities all over the participating countries.

The following countries have participated in Annex 51 with the following research groups:

Country	Research Group	Participants
Austria	SIR - Salzburger Institut für Raumordnung und Wohnen; AIT Austrian Institute of Technology GmbH, Vienna	<i>H. Strasser; O. Pol</i>
Canada	Natural Resources Canada (NRCan), Ottawa	<i>K. Church, J. Webster</i>
Denmark	Danish Technical University, Copenhagen	<i>S. Svendsen, A. dalla Rosa</i>
Finland	VTT Technical Research Centre of Finland, Helsinki	<i>J. Nieminen</i>
France	EIFER European Institute for Energy Research, KIT Karlsruhe	<i>P. Girault, A. Koch</i>
Germany	Fraunhofer Institut IBP, Stuttgart Fraunhofer Institut UMSICHT, Oberhausen; pro:21, Bonn; Volkswohnung GmbH, Karlsruhe	<i>H. Erhorn-Kluttig, H. Erhorn, C. Beier; A. Dütz; R. Jank</i>
Japan	Yokohama National University; Tokyo Gas Co., Ltd.	<i>S. Sadohara; R. Kuzuki</i>
Sweden	University of Linköping	<i>B. Moshfegh, H. Zinko</i>
The Netherlands	Hogeschool Zuyd (Heerlen); Cauberg Huygen b.v. (Maas-tricht)	<i>J. Kimman, W. Broers; E. Willems</i>
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