Chapter 8: Sustainable innovations and transformation processes

Overview

In this chapter, you will become familiar with the requirements, difficulties and diffusion of sustainable innovations and their contribution towards a sustainable society. You will learn about the goals of sustainable development and innovation processes from a sociological perspective with a focus on how they emerge within networks and how they are implemented in everyday life. We will also present and discuss the multi-level perspective (MLP), a multi-level theory of sustainability oriented transitions.

Around the world, typical lifestyles and economic practices are too resource-intensive, too environmentally damaging and too unsustainable in socio-ecological terms to be continued without causing any problems. For this reason, modern societies are increasingly faced with the immense task of fundamentally changing their unsustainable practices and developing new ways to satisfy people's needs in all areas of activity. *Sustainable innovations* promise to fulfil the ecological, social and economic aspects of politically defined sustainability goals by means of new products, processes and arrangements. Beyond selective innovations to improve the ecological balance, the aim is to fundamentally reverse the current trends of using up finite resources, eradicating species, producing hazardous emissions and waste and thereby driving global climate and environmental change that jeopardises human life on planet Earth and could even wipe it out completely. Lifestyles and economic activity that do not pose a threat to the climate, environment or health, but will instead leave behind a habitable world for future generations, are considered future-proof, sustainable or "fit for grandchildren".

1. The guiding principle of sustainable development

The concept of *sustainable development* and its various dimensions, indicators and conflicts have been the subject of many studies in science and politics since the report "*Our Common Future*" (1987) was published by the World Commission on Environment and Development, which was set up by the United Nations in 1983. The report described development as sustainable if the needs of the present are met without risking the ability of future generations to meet their needs[27]. The commission, chaired by the Norwegian Gro Harlem Brundtland, therefore focused on the existential needs of all people worldwide and future generations and sought to harmonise economic development with the imperatives of sustainability. It focused on inter- and intra-generational justice in relation to the management of finite resources and the limited resilience of ecosystems and subsequently led to regional "agenda processes" worldwide that were designed to specify how the regulatory idea of sustainable development could be implemented

27 The concept of sustainability originally comes from forestry and was introduced by Hans Carl von Carlowitz three hundred years ago to ensure that the amount of wood taken from the forests did not exceed what could be regrown for mining and construction purposes. The term therefore focused on the use of resources and their natural regenerative capacity, with the aim of being able to meet future needs.

in an economically, ecologically and socially compatible way (→ chap. 7 on sustainable consumption).

To this day, the main obstacle on this path is the lack of consensus on how sustainability can be achieved, what a "good life" is, which "needs" have to be met to achieve it and how an ecologically "just fulfilment of needs" can also function socially and economically. In this respect, opinions differ not only in international comparisons, between North and South, East and West, but also between the social groups and milieus of individual countries. After much debate, the United Nations once again agreed on a series of ambitious political principles in the form of the seventeen *Sustainable Development Goals (SDGs)* that came into force in 2016. The goals have a stronger focus on simultaneously overcoming poverty and inequality, enforcing human rights and creating equal opportunities and resilience through international cooperation on the path to sustainable development. However, like the "Our Common Future" report, the SDGs contain many compromises and assume a consensus on common goals that does not exist and which is also thwarted by conflicting goals. In addition, the goals can be pursued in different ways and are partly dependent on factors that are beyond the scope of national and international strategies. For example, armed conflicts, forest fires and, in particular, the growth of the world's population thwart existing approaches. In view of these difficulties, innovations promise sustainable social change by taking a creative approach to the challenges of sustainable development and the establishment of new ways of satisfying needs. Innovations are usually sought primarily in the context of new technologies – less often in "social" contexts or in relation to fundamental systemic change (socio-ecological transformation).

Within environmental sociology is some doubt as to whether innovation and a primarily technology-driven search for new opportunities is the best way to achieve sustainable development, as this focus is often associated with growth and competition-oriented ideas about development and less with values such as solidarity, frugality or even the renunciation of certain goods and services, all of which appear necessary for global sustainability as per the sufficiency principle and in light of the planet's limited resources (Jungell-Michelsson & Heikkurinen 2022). The implementation of "innovative" forms of problem solving that are associated with fewer resources and emissions and are referred to as "sustainable innovations" is therefore only promising if it is accompanied by a corresponding change in awareness, and if these innovations actually help us to move beyond resource-intensive lifestyles instead of prolonging them or enriching them with additional unsustainable options (*e.g., buying an electric car as the family's third car*).

2. Sustainable innovations

Unlike the concepts of sustainable or socio-ecological transformation (WBGU, 2011), talk of sustainable innovations often only refers to *technical* innovations without a simultaneous change in guiding principles. From this perspective, sustainable innovations promise the maintenance of today's lifestyle – and even

growing prosperity – while at the same time decoupling these goals from resource consumption. In the past, innovative technologies have often been able to improve resource efficiency and minimise harmful waste. However, the sustainability gains did not lead to a trend reversal, but were in many cases overcompensated by so-called rebound effects, for example when the introduction of more fuel-efficient cars led to more journeys as a result of the lower mobility costs and because drivers felt that the increased fuel-efficiency gave them a moral license to use their cars more (Sonnberger & Gross 2018). The rebound problem becomes most obvious when we look at global energy consumption, which is continuously increasing and for which coal – a particularly climate-damaging fossil fuel – continues to supply the lion's share. For this reason, many critics of growth view the hope that environmental consumption can be decoupled from growth ("*green growth*") as unrealistic and are instead thinking about post-growth societies with completely changed forms of economic activity and welfare production (Latouche 2006). They are therefore focusing more on *social* innovations and social reforms, including *exnovation* as a form of renewal through which unsustainable products, processes and thought patterns are eliminated without replacement.

In the following, we will use the term *sustainable innovations* to refer to such development and change processes to be sustainable innovations which facilitate, use and diffuse novel technical, organisational, practical, institutional and cultural solutions with the goal of facilitating lifestyle and business models that are transferable globally and in the long term, and contributing to social structures that promote health and fairness and protect the environment. They can only curb resource consumption harmful to humans and the environment and prevent dangerous emissions if they take effect on a "targeted basis" from the idea stage for sustainable options to the implementation and diffusion phase so that their use leads to sustainable routines that improve sustainability footprints as a result and they make an exnovative contribution to curbing unsustainable lifestyles and business models (Kropp 2018: 7).

In contrast to the everyday understanding of the term, "innovation" does not (only) refer to ideas or inventions, but also to their implementation as "new combinations" (Schumpeter 2021 [1911]: 62ff.), which *prevail* in the respective areas of activity and markets. Innovations or innovation processes are therefore more than just ideas – they change, supplement or replace what already exists. A good idea for sustainable solutions that is not taken up by anyone is irrelevant, both environmentally and in terms of innovation theory. The difference between an idea and an innovation lies in the realisation and diffusion of "the new", which sustainability innovations unfortunately fail to achieve in the majority of cases. They often remain unused or abide in ecological milieus and niches (e.g., grey water toilets or passive houses) (Fichter & Clausen 2016; Kropp 2023). Since the beginning of innovation research with the work of Schumpeter (2021 [1911]), the term innovation has therefore referred to a process that ranges from invention and testing (prototypes) to the introduction and implementation of innovations, and is influenced by many imponderables. The terms *invention*, *incubation*, *introduction* and *diffusion* are often used to describe the ideal type of innovative

process, which usually includes detours, setbacks and aberrations in terms of subject matter, time and location.

In the following, we examine three main directions of innovation research. They differ primarily in terms of the influencing factors they pay particular attention to, but also with regard to their assumptions about the malleability of innovation processes. What they have in common is that they reject reductionist and linear ideas that claim the realisation of innovations is a question of "better" ideas, technologies or strategies. Instead, sociological innovation theories focus on innovation networks and the different levels of innovation, and take into account the diversity and interconnectedness of technical, socio-cultural and economic influences in innovation processes.

3. Theories about the routinisation of innovation

Gabriel Tarde, a contemporary of Emile Durkheim (2012, first published in 1890), was one of the first to study the diffusion and routinisation of inventions and discoveries: In his view, social development is imitation. Tarde reflected on social change in the interplay between processes of contingent *inventions/innovations* and their *imitation*. According to his theory, innovations that arise in all areas of society are actively taken up and diffused, either partially or comprehensively, by individual agents of a group through acts of imitation in "imitation chains". For this to happen, however, the innovations must be compatible with existing values and structures, on which they in turn have an effect, making further inventions possible or impossible. What is special about this early sociological perspective is that Tarde's approach contains relational elements, i.e., it mediates between sociological theories of action at the individual level and macrosociological theories of structure: For him, social facts gain greater profiles as they are spread through individual imitation. Social facts are therefore not a necessary precursor for the explanation of social phenomena, as in the work of Durkheim, but are seen by Tarde as a temporary result of the routinisation of imitated practices. According to Tarde, this imitation spreads from an interior of high complexity and creativity, in which the new creation originated, to an exterior of stronger standardisation and imitative repetition. First the perceptions and interactions of individual imitators change, then the innovations manifest themselves in a more standardised way at the level of practices and institutions. For Tarde, this standardisation or "routinisation" at the level of customs, language, behaviours and economic forms enables the social linking of more or less voluntary acts of imitation, as well as their further differentiation in the area of tension between learning adaptation and modifying opposition. In his innovation-oriented view, the development of society is therefore always the provisional and fragile result of imitation processes through which inventions are stabilised, modified or discarded.

Tarde would probably not have been surprised that sustainability innovations such as car-sharing, grey water toilets, vegan diet or attempts to create a circular economy are not copied in the way they were envisioned, but instead interact

with the simultaneous spread of unsustainable innovations and lose their sense of direction, are modified, dumped or become the subjects of incomplete imitation and end up having unsustainable consequences. Therefore, for environmental sociologists the fundamental question about sustainable innovations is: What conditions are required for the routinisation of sustainable innovations so that they can make a substantial contribution towards the creation of a sustainable society?

From the point of view of diffusion research and in particular its best-known representative, Everett M. Rogers, communication processes play a decisive role here. Through communication processes, information about the innovative novelty is diffused in social communication channels and networks and then successively adapted by other social groups or spread as positive deviations via their networks (Rogers 2003, first in 1962; Rogers et al. 2009). Diffusion research is particularly interested in the time required for this to take place and how amenable different social groups are towards innovation, as these factors make it possible to estimate the required diffusion effort.

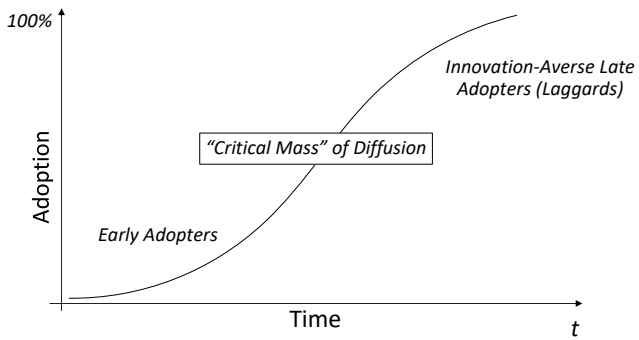

Figure 10: Diffusion process, depicted as an S-curve according to Rogers; source: own illustration based on Rogers et al. (2009: 427)

The faster an innovation is adopted and establishes itself, the faster it reaches the "critical mass" and leads to financial gains for entrepreneurs, prestige for pioneers and the need for later imitators (*adopters*) to follow suit. This process leads to a routinisation of the innovation in the respective area of activity until it is no longer perceived as an innovation at all. Empirical studies on diffusion processes have often shown that younger, more highly educated people and men are more open to innovations than less qualified people and women, who usually adopt innovations later. Even back in Tarde's days, inventions tended to be made by a small number of prestigious players, while repetitive (but also creative) adoption took place among the broad majority. Sustainable innovations are also more likely to be adopted by younger and better educated people, although women are statistically more orientated towards sustainability than men. Overall, however, all externally induced changes that represent a deviation from the familiar and a break with routine are initially met with little approval by those affected, even though modern societies supposedly have a strong orientation towards innova-

tion. In contrast, a number of inertia forces mean that incremental innovations, which only require minor changes to existing routines and skills, have a better chance of being implemented than radical innovations. In addition, innovations are adopted and changed in a context-specific manner throughout the course of diffusion, as Tarde already pointed out.

Sociologically, the delayed and stubborn adoption of innovations can be explained by the fact that they – like social deviation in general – dissolve the predictability that previously facilitated social behaviour and provided orientation. Innovations cause uncertainty and require organisational and socio-technical adaptation measures to overcome the fact that they do not fit with the old and familiar. In this respect, all innovations require the development of new competencies and devalue existing experiences and skills. Innovation and transformation processes are therefore rarely met with spontaneous acceptance, but are instead fended off at various levels of society or only adopted gradually or after some form of adaptation. This situation gives rise to the aforementioned supposed paradox that the innovations that diffuse most successfully are those that deviate the least from the status quo or whose level of innovation is characterised as low. Their incremental novelty is easier to integrate into existing everyday practices and behavioural expectations than radical changes that "violate" the established social order. The sale of fuel-efficient cars is therefore easier to organise than the spread of forms of shared mobility (*ride sharing*), which require people to say goodbye to their own car and the routines of individual mobility (Clausen & Fichter 2016). This highlights the fundamental problem of sustainable innovations: They not only require the replacement of individual products or processes with other technologies that function in a similar way, but usually deviate so strongly from the status quo in terms of their orientation that they also require a change in the interpretive patterns that guide people's actions (automotive freedom of private transport), ingrained practices (flexible patterns of movement and planning) and corresponding structures (forms of housing, infrastructures, regulations).

General innovation research focuses less on the significance of system innovations for social change than on the significance of individual product and process innovations for the economic development of a country and its companies or – viewed the other way round – on the consequences of a lack of innovative capacity for economic development. According to Schumpeter (2021 [1911]), who is regarded as the founder of innovation research, innovation processes are primarily determined by entrepreneurial personalities and the possibility of obtaining loans for innovation development. Both factors determine whether a potential innovation (*invention*) can be successfully established in a company and, based on this, in society or on the markets (*diffusion*) in order to initiate a "process of creative destruction" through which the existing is intermittently replaced by the new. The innovation drivers or "promoters" in the organisations must succeed in presenting the innovation as a convincing improvement and then initiate an adaptation process through which the new becomes so adaptable with the old that it changes the old.

As a branch of business administration, innovation management is dedicated to overcoming internal and external barriers to innovation by providing strategic support for innovation processes and their promoters in order to move quickly from initial ideas to successful market penetration. However, the challenges of supporting sustainable innovations are greater: Not only must they be successfully promoted and implemented, but they must also remain true to their original aims, i.e., they should *not* adapt particularly well to the (unsustainable) existing situation, but rather continue to pave a transformative path forward towards greater sustainability. This objective often requires the deliberate disregard of short-term success factors in favour of long-term transformation goals, which, considered individually, are radical, uncertain, controversial and volatile, as illustrated by the debate surrounding electric cars. Within this debate it is even considered a success if an electric car is purchased as a second or third car (regardless of the overall ecological impact), which stabilises rather than transforms unsustainable lifestyles.

This may be one reason why sustainable innovations are rarely driven by large market players and established research and development laboratories, but mostly by explicitly ecologically motivated industry newcomers, start-ups, niche players and so-called eco-pioneers. At the same time, these two contexts tend to result in different types of sustainability innovations. In established companies and organisations that develop technologies, the incentives for innovation processes are guided by commercial considerations, so that their output is dominated by incremental adaptation and innovations that improve the sustainability of existing technologies – typically in response to new regulations or changes in market demand. "Radical" innovations, which are associated with high costs and a major risk of failure, are avoided. More fundamental innovations dedicated to sustainability are therefore typically driven by government interventions, a high level of commitment and clear sustainability objectives (Fichter & Clausen 2021), or by "change agents", "visionaries" and innovative user communities, including private individuals from the civil society sector (Ornetzeder & Rohracher 2013). They specifically strive for sustainable change and generate alternatives as a response to a development model that is perceived as threatening.

Fichter and Clausen (2016, 2021) consider the role of market power, compatibility, policy- and path-related factors (economies of scale, capital commitments, lock-in effects) and industry effects from the perspective of evolutionary economics in order to explain the different the degrees to which sustainable innovations are successfully diffused beyond communication processes. They identified different types of diffusion and sustainability paths and found that efficiency-enhancing and easy-to-understand improvement innovations developed by established companies lead to faster market penetration and tend not to be dependent on government support, but are associated with higher ecological rebound risks. In contrast, the diffusion of more radical and fundamental environmental innovations is lower and slower, especially if they are associated with a high need for behavioural change and place higher demands on users. However, their potential for ecological change is greater. As a result, while fundamental key innovations

for sustainable development are more likely to come from exogenous drivers and players, sustainability innovations from actors with experience in the sector and tried-and-tested sales channels will achieve better market penetration.

In most cases, sociological research is not only interested in individual processes that lead to the development, diffusion and establishment of new technologies or social arrangements, but also in overarching innovation processes, as well as the systems, milieus, regimes and networks involved in innovation, and their socio-cultural prerequisites and social effects. The sociology of innovation is not limited to the economic sphere, but encompasses all social fields of action and their various innovation processes and groups of actors. In the following section, we therefore continue our exploration of the opportunities for sustainable innovation with a focus on network formation in scientific and technological innovation processes from the perspective of *Science and Technology Studies (STS)*.

4. Innovation networks and alliances

Disney's *Gyro Gearloose* characterised the image of the ingenious but naive (garage) inventor for entire generations: While he could build a faster-than-light spaceship within a few days if necessary, innovation processes are rarely the result of the genius of individual actors. Rather, they require cooperation across organisational boundaries and involve existing instruments, technologies, financing options and connecting factors. This cooperation results in innovation networks that are sometimes implicitly and sometimes explicitly used. If an innovation process is successful, all the actors involved in the network change their (starting) positions, motives and criteria, and existing material and technical artefacts are reshaped in favour of an innovative "new combination" in the words of Schumpeter or "new composition" in the words of Latour. This process of transformative network formation requires the modification and reorganisation of all components, both human/social and technical/material. Actor-network theory (ANT) traces how these processes develop along a meandering *trajectory* and uses the concept of "translation" to consider the individual modification steps (Callon 1984). The concept of "translation" indicates that innovation processes do not seamlessly transform an initial state into a new state, but rather, as with translations from one language into another, they are associated with adjustments, changes and new meanings that do not necessarily correspond to the original intentions (→ chap. 3 on society-nature relations). Reductionist notions of scientific "discoveries", individual "ideas" or technical "improvements" and their subsequent "application" or "implementation" are thus rejected. Instead, ANT ethnographically traces how new scientific interpretations, social arrangements and technical possibilities emerge in a heterogeneous web of relationships and assert themselves as innovative socio-technical networks – or don't (Latour 1996). On the one hand, this approach takes up the findings of research on the *social construction of technology (SCOT)*, which has used many individual case studies to examine how the processes used to create technologies are influenced by relevant social groups and their ideas and expectations (Bijker et al. 1986). On the other hand, as part of its "symmetrical" approach, it also takes into account the role of technological influencing factors,

material effects and natural resistance: "The social 'material' and the technical 'material' are both relatively malleable and the successful innovation is the one which stabilises an acceptable arrangement between the human actors (users, negotiators, repairers) and the non-human actors (electrons, tubes, batteries) at the same time" (Akrich et al. 2002a: 210).

From this perspective, an innovation appears as an interdependent process that connects several components, in which the formation of scientific descriptions (e.g., of electricity), technological applications (electricity grid, lightbulb) and arrangements for their use (electricity consumption) are mutually co-constructed. The focus of the investigation is therefore on how it is possible to stabilise an evolving network in which different actors, interests and abilities to act are linked (Latour 2005). It is only through successful connection that "*collaborative*" new "associations" of a shared world can emerge, whereby the roles of nature and technology, innovators and users, network and actor, innovation and adaptation cannot be clearly separated from one another. Michel Callon (1984) described this process of relational inclusion in a much-cited study on the emergence of a new process for the cultivation of scallops: Relational inclusion is the result of moments of translation in a heterogeneous innovation process, through which the human and non-human actors, communities, identities and affordances involved are connected and modified until a new process gradually takes shape through the networking and modification of all elements. Callon describes the initial emergence of a common problem and the naming of relevant groups as the *problematisation* of the status quo, which must be followed by the integration of relevant perspectives, materials, technologies and actors (*interessement*) into an alliance in order to successively establish mutual relationships and define roles (*enrolment*), which ultimately leads to the *mobilisation* that is critical for the successful further "representation" (i.e., stabilisation) of the innovative arrangement (cf. Figure 11). Other case studies also show that this network formation does not proceed in a linear fashion, but via detours and crossroads, and is often not successful – it is hindered or prevented by the failure of shared visions and alliances, as well as by the opposing strategies of individual "dissidents".

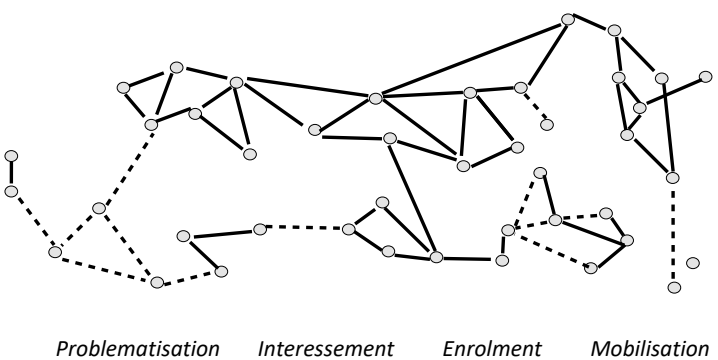

Figure 11: Network-like innovation processes; source: own illustration based on Callon (1984) and Akrich et al. (2002b)

The work of technology historian Thomas P. Hughes (1983) is similarly structured. His comparative study of the electrification process in major cities in the United States, Great Britain and Germany and the resulting infrastructure systems is considered an important work of innovation research. Hughes examines how gas lamps in private households were replaced by Edison's lightbulb and electricity, not because the technology was superior or because Thomas Edison was a brilliant inventor, but because he was a skilful "*system builder*". In addition to developing technically useful devices, he also succeeded in initiating corresponding supply systems, organising financing options and winning over relevant decision-makers. Edison problematised the risks of gas lamps, gathered together the relevant people, mobilised social, material and financial resources for the new infrastructure and successfully stabilised his supply system by also "representing" the needs of companies, consumers and the authorities – all before developing the technical applications. By assembling these heterogeneous components, which John Law characterised as "*heterogeneous engineering*" (Law 1986), Edison enabled the development of a new, relational network ("*seamless web*") of electrification and helped to stabilise the emerging infrastructure system in the face of resistance and alternative proposals through continuous adjustments that were not only technical, but also financial, discursive and legal (Hughes 1986). In this way, he initiated a complex socio-technical system that not only interdependently changed the lighting technologies, but also the legal norms, political power relations, billing models and other components in support of a new, common system goal. In the ambiguous title of his book, Hughes (1983) describes the emerging supply systems as "*networks of power*" and thus links the development of technical infrastructure systems with the associated emergence of political spheres of influence. Innovations, he tells us, are not a question of technically or socially superior ideas, but must, in order to be successful, transform social reality and rearrange socio-technical configurations through the formation of innovative alliances.

Two important conclusions can be drawn with regard to the development and implementation of sustainable innovations: Firstly, innovation processes cannot be planned and "implemented" by individuals, but require supra-individual networks and successful stabilisation: "Innovation is perpetually in search of allies. It must integrate itself into a network of actors who take it up, support it, diffuse it" (Akrich et al. 2002a: 203f.). It is therefore not enough for environmentally conscious scientists or activists to develop sustainable solutions to problems; the new compositions must assert themselves within a network of socio-technical components and require a variety of adjustments and mutual compromises. Secondly, innovation processes cannot be intentionally designed from one perspective, but depend on these successful links – they and their contexts change unpredictably and interdependently throughout the multi-branched introduction, implementation and stabilisation phases. Many sustainable innovations, such as meat substitutes for vegetarian lifestyles, are therefore disappointing in terms of their sustainability balance when they ultimately end up as industrially manufactured consumer goods in supermarket refrigerators. ANT refers to this comprehensive process that is full of surprises as "socio-technical transformation"

(Akrich et al. 2002b: 212). However, neither Hughes, Callon nor Latour were initially specifically concerned with sustainability innovations, although all three authors later turned their attention to this problem and emphasised the need to take non-human actors into account for the successful long-term interaction of everything on Earth.

Research on non-technical innovations, such as the introduction of the first paper currency and the establishment of voluntary fire brigades by Benjamin Franklin (Mumford 2002) or the current emergence of municipal, sustainable energy supply systems (Smith et al. 2016), also emphasises the necessity of successful network formation and the mutual adaptation of technical and social systems. In particular, innovations that deviate from the established social order and question its frameworks that guide action (as is generally the case for sustainable innovations) face the problem of having to build a countercultural network and assert themselves against the powerful existing alliances. To do this, they are usually dependent on windows of opportunity during which established approaches are called into question, and on protected spaces in which sustainable solutions can first be trialled before they are exposed to competition with the non-sustainable mainstream. These insights are summarised in the multi-level perspective presented below, which has been taken up primarily in *transition research* over the last ten years.

5. Innovations and the different levels involved in the transformation of unsustainable practices

Transition research refers to a variety of research approaches that examine ways of supporting the transition processes which will lead to sustainable societies. They adopt different perspectives to describe, evaluate and promote transitions in the energy, agricultural and transport industries and their possible contributions towards social change that will lead to greater sustainability (→ chap. 10 on transdisciplinarity). This broad field is also not interested in individual innovation processes. Instead, it focuses primarily on the innovation-relevant interactions between the established, non-sustainable systems and the various sustainability-oriented or "transformative" approaches and strategies and their socio-economic and institutional frameworks.

In the Netherlands, a widely recognised heuristic method called the *multi-level perspective (MLP)* has been continually developed since the late 1980s (see Figure 12). It incorporates concepts from actor-network theory, evolutionary and institutional economics and governance research (Kemp et al. 1998). It analyses opportunities for sustainable innovation and transition processes, viewing them as relational, co-evolutionary and long-term processes that result from multifaceted changes in the configuration of socio-technical systems (Geels 2002; Grin et al. 2010). It sheds light on the interactions between groups of actors from different sectors and disciplines, from the societal micro-level to the societal macro-level, as well as the possibilities for these interactions to fundamentally change the established socio-technical system. The MLP thus also pursues a decidedly

non-deterministic perspective that understands technologies as a place for the organisation of social change, not as its driver, even though it has addressed the implementation of innovative, technological problem-solving processes in great depth. Drawing on studies about innovation trajectories – i.e., the specific trajectories of innovation processes (see section 2.) – the multi-level perspective instead assumes three interlinked levels of innovation development with different cycles of change, between which a multidimensional interplay of radical niche innovations, stabilised problem-solving patterns and long-term change evolves (Grin et al. 2010).

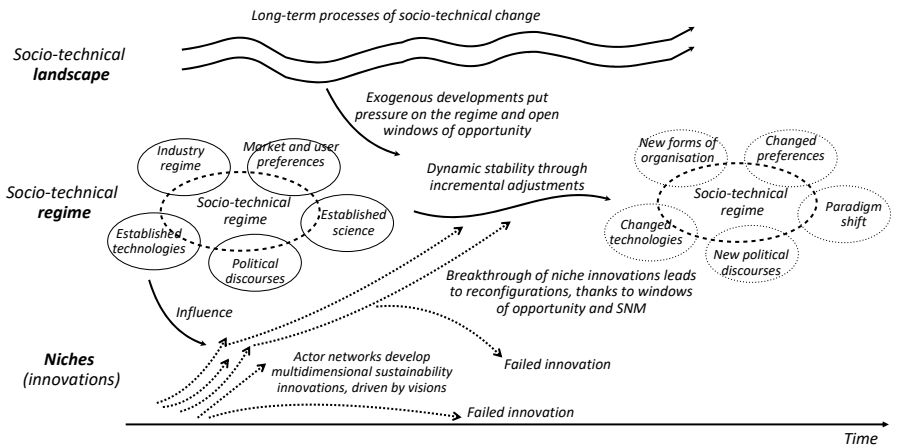

Figure 12: Transition processes from the multi-level perspective (MLP); source: own illustration based on Geels (2002: 1263)

- The concept of the *regime* lies at the centre of this perspective. It describes a stabilised socio-technical system of actors, products, technologies, specialist knowledge and corresponding routines and cultures related to demand, as well as political lobbying networks. In regimes, the various interests are balanced and the necessary organisational processes are firmly established. The existing infrastructures are adapted to suit the regime, as are the formal, moral, and cognitive rules. Examples of such regimes include the automotive industry or the mainstream food system, the various dimensions of which are all consolidated and therefore almost impossible to change.
- In contrast, promising sustainability innovations can only emerge at the lower level in *niches*, i.e., on the fringes of established problem-solving patterns. In these niches, the aforementioned *change agents* consciously experiment with alternative, countercultural strategies and initially allow their results to circulate in the protected space of ecologically oriented milieus or neighbourhoods until they are capable of competing with mainstream strategies. Examples include the early days of solar and wind energy development, mobility pioneers, and organic farms.

- The exogenous, socio-technical *landscape* is the overarching level of analysis that looks at societal trends and developments that characterise the use of resources in the long term. At this level, crises and disasters can call the status quo into question, opening up the windows of opportunity that are necessary for change. However, this level remains conceptually diffuse and forms the weakest part of the MLP.

The concept of regimes has long played a role in diffusion research. It has been used to describe different configurations of conditions in which innovations are implemented. Two examples of this include "routine regimes" in highly concentrated markets with strong path dependencies, in which large capital-intensive companies in particular have an advantage in relation to innovation, and "entrepreneurial regimes" in which smaller, fast-learning companies (e.g., in the music and culture industries) enjoy special innovation opportunities (Acs & Audretsch 1987). This research has also shown that the handling of knowledge and the strategic organisation of new forms of knowledge are important for the success of innovations. If these findings are transferred to sustainable innovations, it becomes clear that so-called *incumbents* (i.e., the well-established regime actors) avoid the necessary handling of uncertainties and complexities. However, they have sufficient resources to take up challenges such as following the guiding principle of sustainable development, primarily symbolically, without actually initiating a comprehensive and continuous sustainability process (Blättel-Mink 2006: 90). Instead, by continuously launching incremental innovations, they contribute to dynamic stability within the established socio-technical system, in which the prevailing frameworks that guide action change only gradually. New knowledge for sustainability innovations, on the other hand, tends to be contributed from external sources by "eco-pioneers" in niches (Blättel-Mink 2006: 89), as mentioned in the first section.

The MLP focuses on analysing the complex innovation and transition processes, which are characterised by intended and unintended interactions with the established nexus of prevailing infrastructures, habits, thought patterns, logics that guide action, actor configurations, policies, economic practices, and forms of regulation. For this reason, its scope of investigation goes beyond the organisational level of individual innovations and primarily encompasses the significance of high degrees of institutionalisation and how this shapes relevant path dependencies, legal and financial framework conditions and their historical development. The socio-technical status quo's forces of inertia – together with their institutional anchoring in market power, standards, consumer preferences and educational content – are countered by sustainability-oriented visions, learning processes and alliances that cannot emerge in the mainstream, but only in niches that are more strongly shielded from these institutions. With the *strategic niche management* (SNM) approach, the authors of the MLP were interested in exploring how sustainable innovations from the "green" pioneer milieus can successfully penetrate the dominant regime network of industrial market and actor configurations, canonised knowledge, established solution expectations, economic

and consumption patterns and the unquestioning continuation of unsustainable relations with nature.

This approach emphasises that compatible "co-evolutions" are needed to support the success of sustainability innovations – for example, corresponding political regulatory impulses that open the door to sustainability goals within existing legal and cultural regulatory systems. The basic thesis of the multi-level perspective is that as long as overarching processes of change do not create pressure to adapt within the regimes or windows of opportunity for the development of sustainable innovations within the niches, the regimes will cause sustainable innovations to largely adapt to the established modes of problem solving. For a few years now, this research heuristic has also been further honed with concepts from political economy regarding the resilience of dominant actor configurations in industry and politics (*incumbent actors*) (Geels 2014): Since then, increased attention has been paid to the close capitalist alliance of decision-makers in politics and business and the well-resourced, definitional, techno-economic, governmental and regulatory ways in which they assert their interests to ensure the system remains profitable for them.

For this reason, research on transition processes initially examined the development of sustainable innovations by strategically looking at the provision of protected spaces in learning niches, in which the innovations can be successfully developed and tested through network-like support outside the established regime (Kemp et al. 1998). Accordingly, the strategic niche management (*SNM*) approach investigates how sustainability experiments can improve the performance and diffusion of potentially transformative innovations through networking, the development of visions and social learning that reinforces positive expectations (Kemp et al. 1998; Schot & Geels 2008). It is argued that the progress of sustainable innovation processes can be supported and stabilised by anticipatory decision-making in the political arena that is geared towards long-term goals, as well as by the articulation of sustainability visions that guide action, the formation of overarching networks, and comprehensive training and learning processes (Kemp & Loorbach 2006; Grin et al. 2010). However, this research has made it increasingly clear that strategic niche management alone is not enough to establish sustainable innovations in the face of the existing regime. Transformative sustainable innovations are also dependent on political support (*niche policy advocacy*), accompanying forms of advocacy from intermediary organisations and convincing transformation discourses (Smith et al. 2016), as well as the targeted delegitimisation of unsustainable solutions and the forging of subversive innovation networks, which are often instigated by civil society (Smith et al. 2016; Köhler et al. 2019). Above all, however, it is becoming increasingly clear that these kinds of innovations benefit from the deliberate "destabilisation" of existing regimes by means of transformative political instruments at a superordinate level (Kivimaa & Kern 2016).

In recent years, the multi-level perspective approach has often been applied to energy transitions, the successful implementation of which requires not only innovations in renewable energy generation and storage technologies, but also

far-reaching political, financial, organisational and social changes, including innovative forms of governance and control. The implementation of these innovations and changes has been far too slow, which illustrates not only how difficult such far-reaching transformation processes are, but also the long-term obstacles facing the multitude of interlinked transformations that are required before a project like the energy transition actually leads to measurable sustainability changes. A transformation can only be considered socially accepted and routinised when the established approaches and institutional orders have been replaced by newly created socio-technical regimes. This involves a change in thinking, acting and regulating, because the transformative practices must go beyond the "semantic" level of discursive and symbolic changes and reach the "pragmatic" level of new practices and routines, and also change the "grammatical" level (Hutter et al 2015: 37) of the (infra)structures and rules that guide action. From a multi-level perspective, a *transition* to a different, more sustainable regime configuration is therefore synonymous with changes across all the levels in one sector (energy supply, mobility), from the innovating niche (photovoltaics, electric cars) through to the entire socio-technical regime (energy or mobility systems) and the overarching social macro level (post-fossil fuel society).

6. Outlook

As innovation research has taught us, even individual innovation processes for sustainable development are far-reaching and complex projects that have to contend with considerable "initial disadvantages" compared to (unsustainable) innovation processes in the established socio-technical system. A transformative breakthrough that will contribute to the general development of sustainable innovations and a sustainable society is necessarily made up of many small and some fundamental transformational steps. The transformation will involve both incremental and radical innovations: Some will be deliberately designed to address perceived risks or changed demands, while others will be the surprising results of the networks that are formed in response to the constraints and disasters caused by environmental and climate change (→ chap. 5 on risk and conflicts about risk). It should be emphasised that the effects of innovation and transformation processes cannot be predicted. They are made up of direct and indirect, intended and unintended changes and adoption processes, and are accompanied by social upheavals that result in further innovation and adaptation processes. After decades of social science restraint in relation to intentional societal transformation, researchers are increasingly interested in the targeted management of long-term transformation processes and the associated imagined futures (→ chap. 10 on transdisciplinarity). This raises questions about the legitimacy of the competing futures, their subjects and objects, the transformation regimes, as well as ideas about transformation goals and justice from a global perspective. To date, transition research has primarily focused on the structural barriers to sustainable innovation and transformation processes in Western industrialised countries; despite the SDGs presented in the introduction, these barriers have not yet been sufficiently investigated in conjunction with the living conditions and scope for action in the global South.

It is incredibly important that environmental sociologists continue to research sustainable innovations. The need for contributions from sociology will become ever clearer as modern societies increasingly recognise how comprehensively we need to think about sustainable innovation and transformation processes, and how small the contribution of technological innovations is (even though it is important that technological innovations are anchored in socio-technical transformation processes and connected with processes of social change). Sociologists can also help to correct the "*innovation bias*" of the engineering sciences in favour of further research into exnovations. This would require working out not only how sustainable approaches and supply systems (e.g., renewable energy sources) can be introduced, but also how unsustainable practices and technologies (e.g., the generation of electricity from coal) can be simultaneously abolished, in order to make society truly sustainable (Kivimaa & Kern 2016; Davidson 2019).

What students can take away from this chapter:

- Knowledge about innovation processes and their trajectories
- Knowledge about sustainability goals and the difficulties involved in related innovation processes
- Knowledge about diffusion research
- An understanding of the characteristics of innovation processes and networks
- Knowledge about sustainability-orientated transformation processes
- Knowledge about the multi-level perspective (MLP)

Recommended reading

Kivimaa, P. & F. Kern, 2016: Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *An article worth reading that uses the energy transition strategies in the UK and Finland to show why sustainable innovations are not enough and why unsustainable regimes must be destabilised at the same time.*

Rogers, E.M., 2003: Diffusion of innovation. *A classic of diffusion research that explains the importance of different communication and diffusion channels.*

Schot, J. & F.W. Geels, 2008: Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. *A presentation of how the diffusion of sustainable innovations can be specifically supported.*

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