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Energy Transition and Security of Supply: OECD Countries

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Abstract: For many decades, the production of industrial goods was concentrated in the Northern hemisphere, while energy resources were abundantly available in a limited number of developing countries and those with centrally planned economies. In this context, the security of energy supply was mainly understood as a secure procurement of cheap energy resources to the industrialised world. Military forces have been constantly upgraded and deployed to ensure geopolitical interests, including the control of energy resources. Nowadays, the depletion of oil and gas reserves, the growing concerns about global climate change along with the emergence of new energy demand centres in South and East Asia and the continuing political tensions in several major energy-exporting and -transit countries raise the question of possible alternative strategies to safeguard global energy security. It is vital to change the old paradigm. But what could be the new paradigm? This paper attempts to contribute to this debate.

Keywords: Energieverbrauch, Verwundbarkeit, Öl, erneuerbare Ressourcen
Energy use, vulnerability, oil, renewable resources

1. Introduction

The security of energy supply involves short-, medium- and long-term issues. In the short term, one of the main problems is related to the economic risks caused by highly volatile energy prices. A balanced portfolio of spot, bilateral and derivatives contracts, as well as other market-oriented risk management instruments can be used to alleviate these risks. In the medium term, there exists the possibility to adjust bilateral contracts, especially with the aim to diversify the origins and amounts of energy imports; however, little can be done to change overall energy supply patterns. A sustained change of the whole energy demand and supply system, while potentially offering more options, is more difficult to implement. In this paper, the security of energy supply is analysed in a long-term perspective, focusing on the OECD countries and on the necessity of transition from the present state to a global future where the share of oil in energy consumption is significantly reduced. It is argued that the current energy security paradigm should be changed for a vision of secure long-term energy supply. Such a new and peaceful paradigm of energy supply security is needed in order to avoid a frightening collapse.

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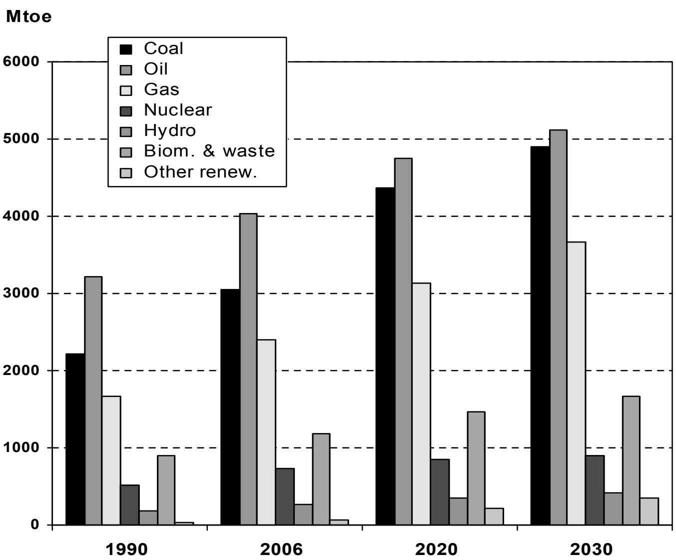
2. Challenges of energy transition

2.1 World total primary energy supply

According to the International Energy Agency (IEA)[1], the world total primary energy supply (TPES) amounted to 11.7 giga tons of oil equivalent (toe) in 2007 (1.8 toe per capita). In the IEA reference scenario (Figure 1), the world primary energy demand rises by 1.6% annually during the period 2006-2030, significantly above population growth (1% per year). The share of non-renewable energy (85%) and the contribution of fossil sources (81%) remain almost the same until 2030[2]. Oil continues to be most important, followed by coal and natural gas. Coal demand grows faster than that of other fuels due to its dominant share in electricity generation. The share of natural gas in electric power generation also increases fast, even though its contribution to the global energy demand grows slowly.

Figure 1: Projected Structure of World Total Primary Energy Supply



Source: IEA, World Energy Outlook. 2008 Edition. International Energy Agency, Paris, 2008.

With 18 % of the world population, but 76 % of the Gross World Product (GWP), the OECD countries were the highest energy consumer (47 % of the world Total Primary Energy Supply, TPES) in 2007. However, in the long term non-OECD regions will overtake OECD countries in economic growth, leading to an increased share of energy demand outside of today's industrialised countries. According to the IEA reference scenario, non-OECD countries account for 87 % of the incremental primary energy demand from 2006 to 2030 (more than 50 % solely for China and India); the Middle Eastern countries will also become an important energy demand centre. Accordingly, the main challenge for the energy security of industrialised countries in the coming decades is the loss of their present consumers' market power position to emerging economies, such as China, and the rise of other energy demand centres which will deeply change global energy geopolitics.

2.2 Regional energy dependency

Due to the increase of energy demand in energy-producing countries, along with the progressive scarcity of proven oil and gas reserves and eventual under-investment in energy supply, infrastructures will inevitably change the world energy trade patterns. Accordingly, this will result in a declining number of energy-exporting countries and a larger number of net energy importers. This situation, accentuated by the risk of the formation of new oil and gas cartels, is prone to augment the strain on energy supply worldwide. It can be expected that the energy vulnerability of European OECD countries will be particularly increased.

According to the IEA[3], the total world demand for oil is projected to rise by 1% per year mostly due to emerging economiess, especially India (3.9% / year) and China (3.5% / year). Meanwhile, the share of OECD countries in global oil demand is expected to decrease from 57% in 2007 to 43% in 2030. In the reference scenario, the oil import dependency of OECD countries decreases from 58% in 2007 to 53% in 2030 mainly due to OECD-North America, where it drops from 44% in 2007 to 25% in 2030, thanks to the exploitation of Canadian non-conventional sources of oil. Conversely, oil import dependency of OECD-Europe increases from 65% in 2007 to 83% in 2030. The case of OECD-Pacific does not significantly improve with almost 92% oil import dependency in 2007 and 90% in 2030. The situation of OECD-Europe is worsened by the increase of the transport's share in the primary oil demand, from 53% in 2006 to 58% in 2030.

The world demand for coal grows faster than other fuels with a 2% annual growth mainly driven by electric power generation. While OECD-North America and OECD-Pacific are self-sufficient in coal, the dependency of OECD-Europe increases from 42% to 50%. However, the share of coal in the primary energy demand of OECD-Europe falls from 18% in 2007 to 15% in 2030, contrary to natural gas, which increases its share from 24% in 2006 to 29% in 2030. The OECD dependency on external natural gas increases from 24% in 2006 to 41% in 2030 with a highest dependency for OECD-Europe (2006: 44%; 2030: 69%).

2.3 Energy scarcity

According to the IEA reference scenario, the production of conventional crude oil and natural gas liquids will level off by 2030, and the increase in non-conventional oil output will be needed for meeting the world oil demand. Although natural gas resources are expected to be adequate for demand, they will be concentrated in a very limited number of countries. Proven reserves of coal are considered to be available worldwide. Meanwhile, several points should be mentioned: more resources

1 IEA, Energy Balances of OECD countries. 2009 Edition. International Energy Agency, Paris, 2009.
2 IEA, World Energy Outlook. 2008 Edition. International Energy Agency, Paris, 2008.
3 IEA, World Energy Outlook. 2008 Edition. International Energy Agency, Paris, 2008.

will be consumed in the energy-producing regions due to the industrialization of these countries; the strain on fossil fuels will be more and more severe due to a larger number of net energy-importing countries. The correlations between the prices of different fuels will grow due to their substitutability. If fossil fuels are not rapidly substituted by renewable energy, the world economy can continue to experience boom and bust cycles of energy prices, where low GDP growth and moderate energy prices will alternate with economic expansion and high energy prices. The most frightening risk resides in the potential spread of political confrontations and armed conflicts over energy procurement. However, the costs of such a strategy of violence are much higher than those of the alternative strategies of relying on goodwill, innovation and promotion of renewable energy.

2.4 Global warming

Due to the increasing concerns about global warming and climate change, the public opinion is expected to become more and more sensitive to the costs of negative externality effects caused by the emission of greenhouse gases. While the reference scenario of IEA depicts a business-as-usual projection, other scenarios limiting CO_2-equivalent concentration to 550 ppm (parts per million) or even 450 ppm lead to more demanding changes of the present energy supply system. The difference compared to the reference scenario consists in a wide-scale adoption of public policies aimed at increasing energy efficiency, especially in the construction and electricity sectors, as well as the promotion of fuel substitution in power generation and transportation. There is a significant uncertainty regarding the potential impacts of these policy measures on economic growth, energy and carbon prices. In comparison with the IEA reference scenario, the 450 ppm policy scenario leads to a 16 % reduction in world primary energy demand in 2030, a 51% reduction of coal demand, a 16 % and 20 % decrease respectively of oil and gas demand; and conversely 51 %, 34 %, 28 % and 95 % increases respectively of nuclear energy as well as hydro, biomass and other renewable energy.

One of the possible spillovers of such an environmental policy might be the improvement of security of energy supply due to a decrease of energy imports in absolute and in relative quantities. Furthermore, the levelling of international energy prices due to a relaxation of the strain on fossil resources would contribute to a steady economic growth, particularly in less industrialised countries. However, because of limited geographical availability, inferior technical performance and higher costs of renewable energy, such a strategy includes a significant share of nuclear energy, which in turn requires a high reliability of nuclear power plants in all countries, a strong international regulation in order to avoid nuclear proliferation and a high level of social acceptance of peaceful nuclear use. For the moment, these conditions are not totally fulfilled in all OECD countries.

3. Vulnerability of energy supply in OECD countries

3.1 Benchmarking

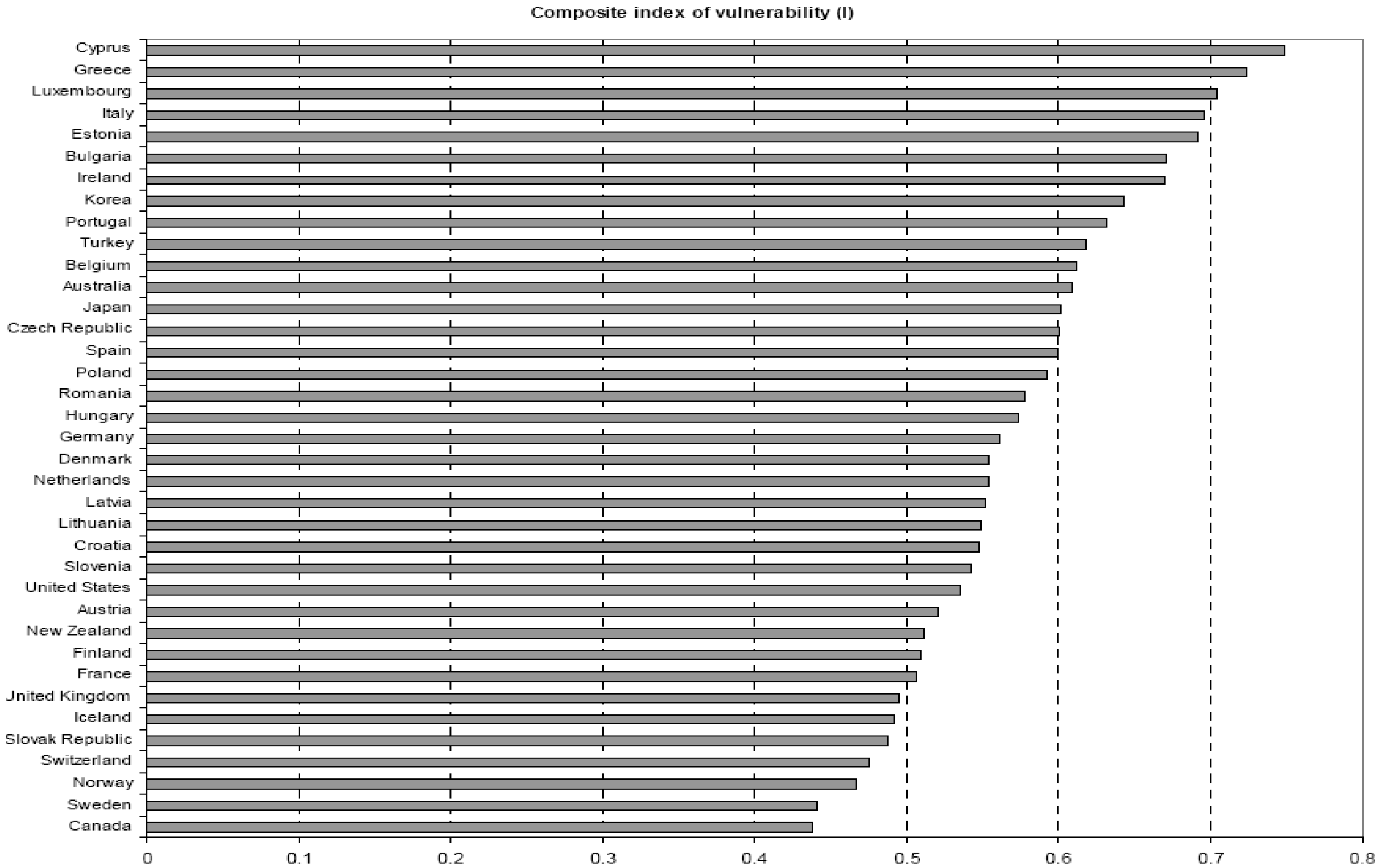
In order to ensure security of their energy supply in the long term, the OECD countries have the choice of either following an autarchical strategy or contributing through international fair governance to the promotion of a secure energy trade. The former orientation consists in developing even more expensive renewable energy resources; the latter relies on secure energy imports and maintaining the required peaceful international environment. However, peace is a challenge to all parties and it is never certain. Therefore, developing a resilient energy supply system with a larger proportion of indigenous, renewable energy resources and, at the same time, promoting sustainable international energy trade may be a good policy.

In order to perform a benchmark assessment of the energy supply security of selected OECD countries, a vulnerability index was built based on five distinct dimensions[4]: Energy intensity of the Gross Domestic Product - GDP (X_1); Energy import dependency (X_2); Ratio of energy-related CO_2 emissions to Total Primary Energy Supply - TPES (X_3); Electricity supply vulnerability (X_4); Non diversity in transport fuels (X_5).

- X_1 is supposed to give an indication of the efficient use of energy to produce goods and services. However, several factors are hidden in this dimension. For less industrialised countries, low energy intensity could indicate the pre-eminence of low diffusion of energy-consuming technology. Furthermore, the energy embodied in imported goods is not accounted for in the statistics, i.e. substitution of inland production of goods by importation may result in improvement of X_1.
- X_2 is limited to oil and natural gas imports in this benchmarking exercise because these fuels are the most challenging. As far as energy vulnerability is concerned, the values of positive net exports are not considered, inasmuch as a high reliance on energy export may cause economic vulnerability, i.e. the Dutch disease.
- X_3 is supposed to show the environmental dimension of energy use. However, only a limited aspect of that dimension is represented. Local impacts on conversion sites, such as in the case of Canadian oil sands, may induce significant environmental burdens.
- X_4 mainly denotes self-sufficiency in electricity coupled with a well balanced electricity generation mix. Thus, electricity net importing countries get low scores. The same is true, to a lesser extent, for countries with a high share of risky electricity options, e.g. nuclear power.
- X_5 rewards efforts for diversifying the energy mix in the transport sector. The variability within the countries is not expected to be high on this dimension for the base year. However, in the future, variability may increase depending on the countries' strategy of introducing alternative fuels in transport.

4 See Edgard Gnansounou, Assessing the energy vulnerability: Case of industrialised countries. Energy Policy 36 (2008), 3734-3744.

Figure 2: Energy Vulnerability Rating



Source: Edgard Gnansounou E., Assessing the energy vulnerability: Case of industrialised countries. Energy Policy 36 (2008), 3734-3744.

For each dimension i, a *relative indicator* I_i was estimated that was finally used to compute a composite index I[5]. The relative indicator of X_1 is estimated by using a scaling technique where the minimum value is set to 0 and the maximum to 1. The energy import dependency is estimated in relation to oil and gas net import. Net exports are set or adjusted to zero. The net import ratio to TPES is then adapted by taking into account the concentration factors in oil and gas import origins and geopolitical factors. The ratio of energy-related CO_2 emissions to the total primary energy supply is scaled in the same way as X_1.

The electricity supply vulnerability is defined in terms of three sub-dimensions: the net import of electricity; the concentration and risk of non-acceptance by the public of a chosen dominant technology of electricity generation; and the non diversification of an electricity generation. The indicator of non-diversity in transport fuels is derived from the Shannon-Wiener diversity index (originally developed to measure bio-diversity). Finally, a composite index of vulnerability was computed as a function of these relative indicators using the following method: (1) The composite index was defined as the Euclidian distance (ED) to the best energy vulnerability case represented by the zero point. (2) When the relative indicators are significantly correlated, the ED is estimated in the orthogonal system defined by the principal components. (3) The ED is standardised in order to get a value between 0 and 1. This energy vulnerability index (I) was estimated for the year 2003 for 37 industrialised countries.

As Figure 2 shows, Cyprus (0.749) and Canada (0.439) were found to have the highest and the lowest vulnerability respectively. The mean value and standard deviation of the composite index of vulnerability were 0.576 and 0.080, respectively.

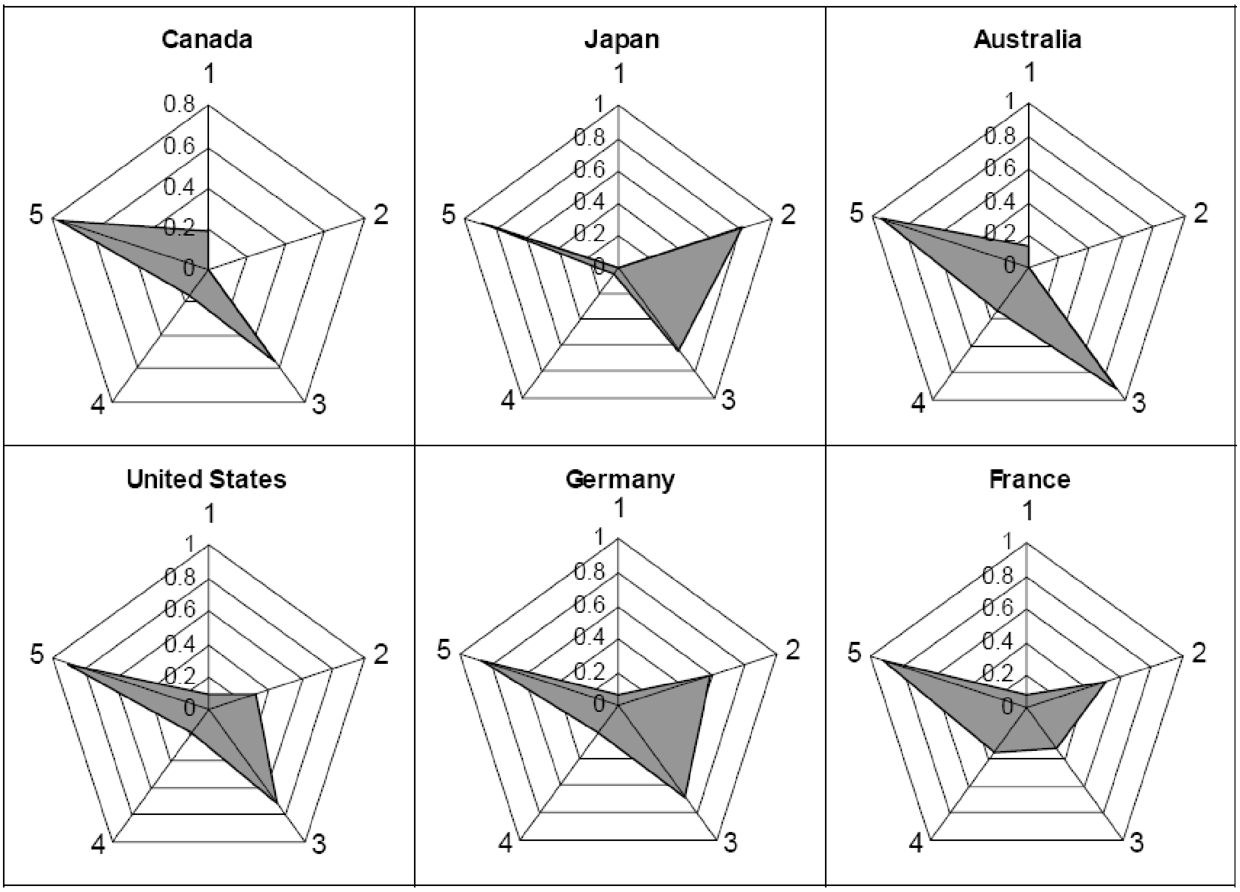
3.2 Discussion of selected country cases

In order to illustrate the concept of vulnerability proposed in this paper and to point out its limits, the cases of six countries are discussed (Figure 3). These cases also highlight the sensitivity of the composite index to indicator variations as well as the influence of geopolitical factors.

With regard to the composite index, *Canada* is the least vulnerable among all 37 countries analysed. The strength of this country is in I_2 and to a lesser extent in I_4. Canada is a net energy exporter. Three deposits provide the core of Canadian oil production: the Western Canada sedimentary basin (WCSB), the oil sands deposits of Northern Alberta

5 The details of the mathematical formulae are given in Gnansounou (note 5).

Figure 3: Energy Vulnerability Indicators of Selected Countries



The figures 1 to 5 correspond to the five dimensions discussed in the text.

and the offshore fields in the Atlantic Ocean. The WCSB also provides most of the natural gas production (EIA, 2007). In 2003, the net exports of oil and gas of Canada amounted to 49.32 Mtoe and 75.35 Mtoe respectively. Over 99 % of the total oil and gas exports of Canada were for the U.S. However, the fact that Canada is considered to be independent for its supply of oil should be interpreted with caution. Although being a net oil exporter, Canada imports a significant amount of oil and refined petroleum products. In 2003, 44.5 million tons of crude oil was imported, representing 56 % of the intake of the country's refineries[6] (IEA, 2007). This is due to the long distance between the Western most productive regions and the most populous locations in the Eastern part of the country. Another consideration is the private nature of the Canadian oil sector with a growing share of ownership by foreign companies including from China. The proven oil reserves of Canada are second in the world, only behind Saudi Arabia. However, over 95 % of these resources are oil sand deposits.

The *United States* ranked 12th among all 37 countries and 1st among the medium range of less energy-vulnerable countries. Compared to Canada, its weaknesses are on I_2 to I_5, the major difference being on I_2. The U.S. is a net oil- and gas-importing country. In 2003, its net imports were 594.7 Mtoe and 76.1 Mtoe respectively. Oil and gas imports amounted to 29.8 % of the total primary energy supply. The imported oil came from various geopolitical regions: Commonwealth of Independent States (CIS) 2.6 %, Middle East (ME) 21.7 %, Africa (AF) 15.6 % and OECD 60.2 %. With 96 %, the importation of natural gas is mostly from the OECD. In the baseline calculation, risk factors were attributed to the various geopolitical regions - CIS (30 %); ME (50 %); AF (20 %); OECD (0 %) – resulting in a value of 0.302 for I_2. A change of the risk factors such as CIS (15 %); ME (60 %); AF (15 %); OECD (10 %) would result in a slight increase of I_2 (0.315).

Japan ranked 25th and its major weakness was on I_2. In 2003 the net imports of Japan were 260.7 Mtoe and 68.4 Mtoe for oil and gas respectively. The origins of oil imports were CIS (0.9 %), ME (80.5 %), AF (2.2 %), OECD and others (16.4 %); and for gas ME (23.1 %), OECD, Indonesia and others (76.9 %). The high dependency of Japan on the ME region for oil import is its major energy vulnerability concern. The strength of this country is mainly on energy intensity (rank: 1st) and electricity supply (rank: 3rd).

France ranked 8th and *Germany* 19th. France outranked Germany on I_2 and I_3, while it was the contrary for I_1, I_4 and I_5. The main difference relates to I_3, i.e. 0.295 for France and 0.614

6 IEA, Energy Balances of OECD countries 2004-2005. 2007 Edition. International Energy Agency, Paris, 2007.

for Germany. This is due to the high adoption of nuclear power in France and the higher share of coal in Germany. However, this is moderated by a higher risk of public non-acceptance attributed to the French electricity mix that could follow after a nuclear accident somewhere in the world.

Australia ranked just after Japan. Australia outranked Japan for energy independency, while Japan outranked Australia on all other indicators. Australia performed particularly low on the intensity of CO_2 emissions due to its high reliance on coal. Fossil fuels represented 94 % of the TPES in 2003, compared to 84.4 % for Japan. The difference is mainly due to the use of nuclear energy for electricity generation in the latter country.

4. Conclusions

Most of the OECD countries cannot only rely on domestic energy production. Thus, the questions are how much energy could be produced internally, and how much should be imported from secure regions. The questions were answered in the old paradigm as follows:

1) Take the resources wherever they are; take them at the lowest possible direct price.
2) Add value on the resources and increase welfare inside the country.
3) Continue as long as the resources are available.
4) Use all your power to get access to the resources everywhere in the world.
5) Be peaceful as long as your own interests are safe.

This paradigm based on power games may no longer be effective in the future because of the distribution of power among several countries. A possible new paradigm could be as follows:

1) Be really cooperative and peaceful
2) Take care of the human well-being everywhere in the world
3) Strive for improved energy efficiency and rational use of energy
4) Work to assure the capability of future generations to use some part of the non-renewable resources
5) Super power is vulnerable; collective intelligence is more sustainable
6) Be a part of a fair and peaceful international governance of natural resources.

Rethinking the energy supply security of industrialised countries in light of this new paradigm means that interdependence in access to natural resources must be the rule. The need of fair international governance taking into account the strategic interests of all parties is a prerequisite for a peaceful and collective energy security. On the way towards such a new paradigm, which could be envisaged beyond 2050, several options should be discussed, including the following examples:

Oil and natural gas. A radical substitution of oil and natural gas by alternative sources should be promoted especially in industrialised and leading emerging economies. Oil and gas should be preferably used in the chemical industry. In order to achieve a good allocation of resources, oil- and gas-intensive industries should be located close to the countries exporting these fuels. Finally, the profits from exports of oil resources should be distributed more equally among a larger percentage of people in oil-producing countries and around them.

Electric Power. The deployment of CO_2 capture and storage and clean coal technologies should be promoted in all countries relying on coal-based power generation. The investments in combined cycle power plants, biomass cogeneration, solar (PV and thermal), wind energy and other renewable energy options should be increased radically, along with the investments in research and development of advanced and inherently safe nuclear fission, thermonuclear fusion and fuel cells technologies.

Transportation. The vision for a sustainable energy use in transport includes the following issues: The better mastery of human mobility and cargo traffic through the design of more sustainable urban agglomerations; promotion of plug-in hybrid electric vehicles in the near term and pure electric vehicles, FCVs and hydrogen in the longer term; development of sustainable biofuels, first mainly as a substitute to gasoline and diesel in light duty vehicles and, in the longer term, mainly for heavy duty vehicles.

A new relation between economic development and energy. According to the old paradigm, economic development relies on unconstrained access to inexpensive energy resources that resulted in numerous examples of "power games", energy supply disruptions due to geo-political reasons and a generally insecure world. In the new paradigm, economic development will have to cope with more expensive energy that needs joint efforts by producers and consumers to reduce the volatility of energy prices, to ensure more secure energy supply as well as to safeguard a more peaceful and fair world. Industrialised countries should anticipate this situation by boosting investments in innovation and promoting more energy-efficient technologies and products.

It is technically possible to make this vision become a reality. Its realisation mainly depends on the decisions of policymakers in industrialised countries and emerging economies who should strive for larger international cooperation for equitable governance of finite natural resources.