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Energy Policy Transition

The Perspective of Different States

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Contents

Abbreviations

ACEEE – American Council for an Energy–Efficient Economy
AEC – Adverse Effect on Competition
ATES* – Aquifer Thermal Energy Storage
BAT – Best Available Techniques
BBC – Bâtiments basse consommation
bcm – Billion cubic metres
BEIS – Department for Business, Energy & Industrial Strategy
BEPOS – Bâtiments à énergiepositive
BETTA – British Electricity Transmission and Trading Arrangements
BTES* – Borehole Thermal Energy Storage
CAES – Compressed Air Energy Storage
CCAs – Climate Change Agreements
ccm – catalyst coated membrane
CCS – Carbon Capture and Storage
CCT – Clean Coal Technologies
CERT – Carbon Emissions Reduction Target
CESP – Community Energy Saving Programme
CM – Capacity market
CMA – Competition and Markets Authority
DAM – Day–Ahead Market
DNTE – Débat national sur la transition énergétique
DOE – United States Department of Energy
EC – European Commission
ECCC – Energy and Climate Change Committee
ECO – Energy Company Obligation
EDF – Électricité de France
EEOSs – Energy efficiency obligation schemes
EFET – European Federation of Energy Traders
EIA – Energy Information Agency
EJ – Exajoule
EMR – Electricity Market Reform
ENR – Bureau for Energy Resources
EEA – European Economic Area
ERO – Energy Regulatory Office
ESCO – Energy Service Company
ETS – European Union Emission Trading Scheme
EU – European Union
FES – Future Energy Scenarios
FTI – Strategie der Bundesregierung für Forschung, Technologie und Innovation
GB – Great Britain
GDP – Gross Domestic Product

GHG – Green House Gases
GSE – Gestore dei Servizi Energetici
GW – Gigawatt
GWh – Gigawatt hour
HTS – High–TC Superconductors
ICT – Information and Communication Technology
IDM – Intra Day Market
IEA – International Energy Agency
INDC – Intended Nationally Determined Contributions
IRENA – International Renewable Energy Agency
J – Joule
kW – Kilowatt
kWh – Kilowatt–hour
LNG – Liquefied Natural Gas
Mtoe – Million Tonnes of Oil Equivalent
NAO – National Audit Office
NBP – National Balancing Point
NEEAP – National Energy Efficiency Action Plan
NEP – Neue Energiepolitik
NYMEX – New York Mercantile Exchange
OECD – Organization for Economic Co–operation and Development
Ofgem – Office of Gas and Electricity Markets
OPEC – Organization of the Petroleum Exporting Countries
OTC – Over–the–counter
RES – Renewable energy sources
P2G – Power to Gas
PCM – Phase change materials
PJ – Petajoule
POM – Politische Massnahmen
PV – Photovoltaics
PwC – PricewaterhouseCoopers
QER – Quadrennial Energy Review
R&D – Research and Development
REMIT – Regulation of 25 October 2011 on Wholesale Energy Market Integrity and Transparency
SMR – Small Modular Reactors
TGC – Tradable Green Certificate
TPA – Third–Party Access
TSO – Transmission system operator
TWh – Terawatt hour
UAE – United Arab Emirates
UNFCCC – United Nations Framework Convention on Climate Change
UNO – United Nations Organization
UTES* – Underground Thermal Energy Storage
UPS – Uninterruptible power supply
V2G – Vehicle to Grid
WWB – Weiter wie bisher
**Underground storage technologies*

Part I

Energy policy transition

Chapter 1

Introduction

Michał KURTYKA[1]

The concept of "transition" is already deeply rooted in the vocabulary of energy management, and the aim of this book is to present it in all its many facets. The book is not an attempt to assess or compare the ways chosen by the world's largest economies to achieve their visions of energy transition. Without passing unnecessary judgments, this volume covers the different roles energy sources play in the process, showing the diversity and multiplicity of various "transitions". It describes what is happening in countries such as Germany or Denmark, which have made energy transition a priority, but we also look at the likes of Great Britain, France and Italy who are combining traditional and renewable energy production methods, while also making reference to Central European countries such as Austria, Slovakia, and the Czech Republic.

I think as you explore the abundance of data and detailed descriptions contained in this volume, you will find yourselves pondering questions about the nature of the process that we have decided to call "energy transition". Is it a mere result of "dispassionate" technical progress? Is it more the effect or the cause of the changing ways of thinking about energy? We are used to approaching national energy strategies as determined mostly by technical (i.e., apparently objective) conditions. And for obvious reasons they may not ignore objective laws of

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Opinions expressed in the book by Michał Kurtyka, PhD are his personal views and not the official stance of the Ministry of Energy.
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physics. However, they are also a powerful tool for communicating values which have great importance to our communities. Energy systems are also dependent on the political and cultural environments in which they are embedded. Moreover, they are inspired by industrial strategies and they develop platforms for these strategies: friendly for some, deadly for others. Assuming a broader perspective, while reading this book it is worth asking ourselves whether we are "merely" experiencing the erosion of the previous energy paradigm, embodied in energy transition, or whether we should also question the traditional framework of reference through which we analyse energy strategies. Actually, there is more and more evidence to suggest that the classic energy trio (competitiveness, security of supply and environmental protection) is not enough to understand all that is going on in the world of energy. A new trio is emerging: social expectations, technological changes and industrial policy. This new set in some ways enhances the old, but in others it might actually be coming to replace it.

The sources of energy transition involve a breakthrough in each element of the "new trio". Firstly, it is a question of the ultimate goal of economic development, asked by the citizens of developed economies, providing the background for much debate. There is growing public disapproval of the influence civilization has on our surroundings, our natural environment and our climate. Developed societies are becoming more and more sensitive to environmental matters. Secondly, we are witnessing the emergence of new technologies which involve sourcing energy from water, wind or sunlight. They no longer require fossil fuels, using natural forces instead. Thirdly, being less visible to external observers yet equally fundamental are countries' industrial strategies surfing on the wave of these new technologies and trends. With the help of pioneers in technological breakthroughs, modern countries are creating markets for their solutions using the regulatory instruments of the state, hoping that the increased scale and accumulation of competencies on a national level will help them secure a globally competitive advantage.

Mass individualization and robotisation are about to became the driving forces of the post-industrial era. In wealthy economies, human work and labor-intensive "tailoring" are being displaced by uniform products using common basic features, where production is becoming more and more automated. Individualization can and is becoming the object of industrialization. Fads come and go; modifying and fixing products is unprofitable, so they are becoming increasingly disposable, matching instead consumers' rapidly changing tastes. The life cycle of most products is becoming increasingly shorter.

When applied to the energy industry, a new dynamic is emerging in which all elements of the new trio work to reinforce each other. The compact character of renewable home installations means that dispersed energy corresponds perfectly well to the idea of energy democratization. Up till now, the technologically advanced, conventional methods of energy production required the knowledge and competence of many people. And then economies of scale ensured the supply of relatively cheap energy. More capital-intensive renewable technologies provide opportunities for research and development. This is occuring today at the expense of a rise in the per-unit cost of energy production, financed by subsidies. But wealthy communities are agreeing to incur these higher costs in return for a move away from fossil fuels, believing that future energy production methods will have less impact on our climate than the two previous centuries of industrial development. In the future, robotization, the drive towards standardization and shorter life cycles of industrial products may reduce the cost of producing and then installing standardized renewable energy technologies in millions of homes. Are they going to become the object of mass consumption? Who knows, perhaps now that the age of great industrial undertakings and associated wide-scale energy production facilities is coming to an end, the future might involve a new form of "disposable energy production installations"? If so, then the triple cycle will conclude. After lengthy investment efforts, wealthy communities may become even wealthier, feeling they have done well for the planet, and energy production technologies may become more standardized (and maybe ultimately also cheaper). In any way, the energy industry will become thoroughly renewable and renewed at the same time.

As a result of the three above-mentioned factors, the most common understanding of energy transition (supported by communities' expectations) is the political will to move away from centralized use of fossil fuels towards diversified energy generation using renewable resources. This process is accompanied by the growth of new branches within the industry.[2] The community-technology-industry trio thereby aims to became a self-propelled spiral of growth. Nowadays, it is rising at the expense of an increase in the unit price of energy, so in order to limit the inevitable rise of costs of energy consumption in the economy, energy transition thus is accompanied by policies aimed at increasing energy efficiency.[3] Modernity, dating back to the Renaissance, should no longer be tantamount to incessant growth (growth in terms of the wealth, consumption, production, life expectancy etc.) but also encompass self-limitation. We would now like our future growth to be compatible with a reduction in energy usage.

The European Union has set itself one of the most ambitious goals in terms of energy transition. The objective is to ensure its position as world leader in renewable energy production and to fight global warming by reducing greenhouse gas emission by between 80% and 95%.[4] The project is widely supported, both by the governments of EU member states and (predominantly) by Western European societies and industries.[5] At a time when Europe no longer claims a position of global dominance, energy transition is becoming one way to maintain European leadership, not in political or military, but in moral terms. The EU is the most active advocate of the setting of planetary goals and ambitions through climate protection, believing this to be the best way to find new sources of economic and industrial growth. France's newly elected president Emmanuel Macron responded to Donald Trump's decision to pull the USA out of the Paris Agreement with the words "*Make our planet great again*", thereby not only paraphrasing the American President's electoral slogan, but also echoing what many Europeans believe is a shared responsibility to protect the future of our

[2] Relationships between energy strategy and industrial strategy are illustrated by the example of the situation in Austria and the United States.

[3] The concept of energy transition is defined in detail in another chapter. Its description presented above is supplemented with the component of social expectations and the resultant political will of departure from fossil fuels towards renewable ones.

[4] See e.g., *2050 Energy Strategy,* http://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy (accessed: 20.08.2017).

[5] I. Jakuszko-Dudka, *Energiewende - konsensus społeczny, a nie fanaberie [Energiewende: a social consensus, not a whim],* http://cse.ibngr.pl/wp-content/uploads/cse-iwona_jakuszko-dudka-energiewende-konsensus_spoleczny_a_nie_fanaberia.pdf (accessed: 19.08.2017).

world. Energy transition serving climate ambition has given Europe a new direction, not only in terms of a local but also global narrative. Its central motif is the move aware from fossil fuels: the symbol of caring for the environment, the expression of responsibility wealthy communities have to care for those with fewer resources, especially where climatic and economic, or even existential, challenges collide. This is the case in places such as the Pacific Islands, whose gradual erosion due to rising sea levels is the most common example of climate warming and its dire results.

As already mentioned, climate concern involves the belief, popular with European consumers, that economic growth of the industrial age was not always in line with due care for the environment and contemporary capitalism, being focused solely on satisfying consumer needs, disregards the natural resources that it exploits. The common goal of energy transition originates from generations of experience, making common activity meaningful, and serving as a factor which strengthens communities both politically and morally. This global ambition has been symbolically reflected in the language of our western neighbours. *Energiewende*, the German term for energy transition, is based around the word "*Wende*" which literally means a dramatic 180 degree turn, and was used with reference to the collapse of the Berlin Wall and the comprehensive evolution of Germany following its reunification. This linking of energy transition with German reunification carries a profound historical and civic message.

However, despite the relatively broad historical and philosophical ambitions communicated in this way, for many European countries the fight against climate change – both at civil and governmental level – is at heart about replacing fossil fuel based energy production with new technologies which use wind, sunlight, waste, biomass and water. Coal, which for many symbolises a bygone age of industrialisation, is publicly condemned in narratives connected with energy transition in Europe. Hence, decarbonization has become the central pillar of the Energy Union (the equivalent of a European energy strategy). Coal is the only one of all the fossil fuels to have become labelled as "dirty", thus becoming the symbol of "bad" industrialization in the eyes of the public. Even the seemingly positive search for "clean coal" technology implies a problem: the cleaner the coal of the future, the dirtier the coal of today. The gas industry has succeeded (although we might ask whether this success is only down to them, and what role has been played by national interests) in making us believe that gas, whose combustion emits half as much carbon dioxide as coal, deserves the popular label of "clean": after all, gas is colloquially referred to as "blue fuel". As a result, the ambition of energy transition has narrowed to attempts at eliminating coal, and any discussion about gas has been quietly disregarded, attributing this form of fuel a "transitional" character. Crude oil, responsible for the third remainder of carbon dioxide emissions due to its use by the transport sector, has been practically ignored, even though combustion engines have ten times the power of that installed in the production of electric energy.[6]

Challenges to European energy transition

The European concept of energy transition understood and developed in this way still leaves questions to be asked. The new "trio" comes up against barriers which originate in the preceding trio. Social expectations, renewable technologies and new industrial strategies must try hard to maintain competitiveness, ensure security of supply and a global environmental balance.

First of all, given the knowledge we have now, unifying the system of energy provision in all European countries using renewable resources is an unprecedented challenge in terms of expenses and materials. Effective delivery of such a transition is a very complex undertaking. It involves a number of factors, such as the country's unique features, its geographical location, size and potential for the development of renewable energy sources, its previous way of developing its energy mix, its willingness to incur extra costs, and so on. Not all countries can develop hydropower like Sweden, Norway or Austria, because not all have the necessary environmental conditions. Few are lucky enough to have an abundance of sunlight, like Spain or Portugal. The size of the country is not unimportant if its ability to produce energy from renewable energy sources (such as wind or sunlight) per 1 m^2 of surface area (so-called power density) is several orders of magnitude lower

[6] In the EU, crude oil has already been eliminated as a fuel from which electricity is produced (see chapter on the role of fossil fuels in energy transition).

than that of conventional sources. This means that in order to ensure sufficient energy for more and more urbanized mankind, centralized wind and photovoltaic farms require huge areas for their development.[7] In other countries, such as Poland, the historical energy path has been dominated by a single fuel. Poland has not witnessed even a symbolic development of nuclear energy, such as in neighbouring countries with a similar history (e.g., the Czech Republic, Slovakia or Ukraine). The Polish mix is dominated by that much-maligned fuel – coal. From the point of view of the above-mentioned European energy ambition, this is a huge challenge, especially as its historical experience means Poland attaches great importance to issues of energy and geopolitical security connected with autonomous energy supplies, not only in terms of resources but also of technology. As a result, it is one of the most energy-independent states in the EU.[8]

If *Energiewende* has allowed Germany to install more than 50 GW wind power and 40 GW photovoltaic power, it has come at an extremely high price. A German consumer adds as much money to production from renewable sources as an American pays for their whole energy bill. Calculated using averaged wholesale prices, the aggregate annual value of the German market of electricity production is less than €20 billion, while subsidies for renewable sources are €25 billion. German decision makers are concerned about how much it costs to run a system fully based on renewable sources[9], in spite of its many positive aspects. In the case of Germany, we should remember that despite very robust economic growth, the demand for electricity is not going to increase as spectacularly. There are considerable surpluses of production capacities, while 80% of Germans are willing to continue paying extra money for energy transition. They also approve of the idea of cross-subsidizing industries: an average German worker pays twice as much for their electricity at home as the company they work for. In

[7] R. Wilson, *The Future of Energy: Why Power Density Matters,* http://www.theenergycollective.com/robertwilson190/257481/why-power-density-matters (accessed: 20.08.2017).

[8] *Polish power sector getting the facts straight,* http://www.pkee.pl/upload/files/Unpopular_facts_about_polish_power_sector[10].pdf (accessed: 20.08.2017).

[9] *Renewables versus fossil fuels - comparing the costs of electricity systems,* https://www.agora-energiewende.de/fileadmin/Projekte/2016/Stromwelten_2050/Agora_Gesamtkosten-Stromwelten-EN_WEB.pdf (accessed: 20.08.2017).

comparison, Poland's demand for energy is quickly growing (especially at peak summer levels), while energy production facilities built in the 60s, 70s and 80s are slowly coming to the end of their lives, and it is necessary to either create new installations of energy production or thoroughly modernize the old. Besides, costs for the industry, especially energy-intensive branches, are already quite high, and in the case of households, the share of energy costs in family budgets is one of the highest in Europe.

Thus, while shaping European energy policy, we should not assume that the technical conditions of its implementation will be the same everywhere, nor that all the communities are ready to shoulder similar costs in energy transition. For some, the share of energy expenses in family budgets has reached its limit. Poland, with its 10% share, is currently in a much more difficult situation than Germany with 5%, so there is serious objection to transferring the costs of energy transition to the end customer here.

Secondly, the way in which renewable installations are working means that in the foreseeable future they will not be able to function independently. Even though the sun stops shining each day, and the winds don't always continue blowing, the energy needs consumers have are there to be matched, and the need to balance demand and supply makes it necessary to maintain a parallel system, in which conventional energy sources and storage facilities serve a back-up role. The German system of energy production delivers one third of its total energy demand from renewable sources at the expense of not only double, but 250% of its generating capacity. Despite this dual and expensive system, it is impossible to achieve a share of production higher than that. There are periods when wind do not blow in large areas, and the nights remain long.

In this context, a further increase in how much energy is meant to be produced using renewable sources may not be the only solution. It is necessary to search for other options. Many people believe these can be found through effective use of flexibilities, called the "new paradigm of energy transition".[10] It includes transitional use of traditional

[10] *Zrozumieć Energiewende. Najczęściej zadawane pytania dotyczące transformacji energetycznej w Niemczech [Understanding the Energiewende. FAQ on the ongoing transition of German power system],* Agora Energiewende, https://

production capacities as complementary sources, but focuses mainly on maximising the potential for collaboration between countries (i.e., because of the complementary character of weather conditions), energy storage, as well as educating consumers about the benefits of reduced usage (in other words demand management[11]).

There is a belief that complementary weather conditions in different parts of Europe may offer a solution to the problem.[12] If there is no wind in Poland, perhaps it is blowing instead in Portugal or Scotland? True, in Europe the distribution of wind and sunlight is varied, but due to the size of the system and the need to simultaneously extend industrial lines it is unrealistic to think that such a system would be able to satisfy Europe's energy demand. Also projects such as combining a Scandinavian hydroelectric power station battery with the European system, or producing solar energy for Europe in the Sahara desert, are too complex to consider as solutions which satisfy total European demand. Carrying out such projects would require favourable political conditions and the extension of transmission and distribution networks in Europe beyond what is conceivable today. The same social dynamic which resists traditional methods of producing electricity underlies the heated opposition to the extension of networks used to transport it. It is one of the greatest dilemmas of European energy transition, which is focused on ways of producing energy, not the means of its delivery. The problem is that the extension of renewable energy sources in Europe does not involve expanding transmission and distribution lines. For instance, the high wind capacities in northern Germany are not connected with customers (most of whom are commercial) traditionally located in the south of Germany. The construction of such lines was strongly opposed by activists and local communities. Consequently, when there is a lot of wind activity, in accordance with Kirchhoff's laws, a large part of the generated energy flows out via Poland, the Czech Republic and Austria to then loop back and reach users in Bavaria. These loop flows (known also as transit, carousel or unplanned flows)

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www.agora-energiewende.de/fileadmin/Projekte/2015/Understanding_the_EW/Agora_Understanding_the_Energiewende_PL_WEB.pdf (accessed: 20.08.2017).

[11] *Ibidem.*

[12] *Ibidem.*

destabilize European energy systems, especially the Polish system, burdening it with extra costs and limitations.[13] We had to confront this problem when on the 10th of August 2015 the Polish Transmission System Operator was forced to announce restrictions for thousands of industrial customers. One factor of power insufficiency in the system was the fact that due to wind conditions, only 100MW out of a possible 4000MW of generating power in wind sources in the National Energy System was being produced. Simultaneously, renewable sources in the north of Germany produced electricity, sending it via Poland, the Czech Republic and Austria to the south of Germany. Transmission lines in Poland were blocked with the transmission of idle energy, at least from the point of view of Polish customers. Loop flows made intervention import impossible and added to the burden of the Polish production system. This situation is going to worsen unless a dynamic extension of both transmission and distribution networks occurs along with the appearance of millions of individuals simultaneously consuming and producing energy at home. We are facilitating the emergence of a hybrid producer and consumer - a new entity we call "prosumers".

Many hope that consumers will turn out to be flexible enough to allow a shift towards energy production from RES. There is certainly much left for us to do in this respect. Customers, or users – as they tended to be called by energy enterprises until quite recently – used to be severely neglected. The power sector was too focused on itself and its technological perfection to be inclined to provide space for active customers. Along with liberalization and digitalization, this is changing very quickly. There is great potential on the part of consumers to optimize their consumption of energy and reduce its costs.

Doubts, however, persist: are we not expecting too much of these future recipients? Is the vision of millions of active customers, or even prosumers, participating in the energy market *en masse*, instantly adjusting their consumer behaviours to the dynamically changing conditions in the system (including prices), not too ambitious? Is it

[13] The problem of inability to channel all the wind power from north Germany has its very concrete cost as well. For example, in 2015, one billion euros was spent on subsidies for wind capacities which could not be accepted by the system. As a result, the produced energy was wasted.

not utopian to think that they will actively secure their production profile with storage capacities or balance it with traditional entities?

Offering consumers the opportunity to engage in market activity does not mean – taking into account the way the market works, requiring constant attention, involvement as well as reasonable knowledge and competence – that consumers will really be that active. Many experiences with differentiated day, night and weekend tariffs, including tests in Poland, show that some users never become actively involved; instead, they simply expect a stable power supply and reasonable prices. Although today it is not difficult (from a technological point of view) to achieve energy savings, and there are many interesting support schemes, these are not as popular as one could expect. It seems we need to look for answers not in the very opportunities related to energy, but in comparisons with alternative choices ordinary people face every day. If a monthly electricity bill is as much as several hundred zlotys, more than 10% of savings (which, relatively speaking, is a lot) must compete with the opportunity to save – or even earn – a similar amount another way. In attracting people's attention, energy must compete with housing, food, transport, children and so on, especially considering that in a country like Poland for most households the electricity bill is separate from that for heating (or gas). Any attempt to convert everyone into active players is complicated, and it remains unclear whether raising the price of energy and thus helping focus public attention on this problem would be the best way of solving it.

In turn, the vision of millions of self-sufficient customers is not compatible with maintaining current electricity networks. Although a self-sufficient prosumer is the dream and ultimate goal of energy transition for many, for network operators this is the one surefire way towards extinction. The more prosumers leave the network, the more others will have to pay to sustain it. The higher the charge for the network, the higher the motivation others will have to leave too. It will not be in anyone's interest to maintain networks connecting millions of prosumers. As a result, either the network costs will be partially covered by the consumers who have left, or they will be financed centrally, through taxes. Or else the network will just collapse. If it does disappear, the question arises whether a mosaic of unconnected individual installations is compatible with energy security. Do we really want a jigsaw puzzle of energy autarchies, in which each user takes care of their own electricity and is unconnected with others?

It seems we are not ready for such extremes. In an age when our civilization is totally dependent on electricity, the privatization of energy security is very risky. For many years, the state will feel the need to be its guarantor, for example due to the growing importance of electricity in maintaining critical infrastructure, securing cyber security and data bases, not to mention hospitals, schools, nurseries and so forth. Thus, if the costs of maintaining networks are transferred to the state, we return to the question of the total social cost of energy transition, because ultimately the bill will be footed by the community.

Therefore, looking for independence through individual installations will be in opposition to maintaining the common system of security, especially regarding electricity networks.[14] As far as we are able to foresee, networks will have to continue functioning and even evolving, hence their cost will grow. Freeing users by equipping them with the instruments to produce their own energy should not prevent us from looking for ways to develop, as well as for new roles for the established energy industry, both in terms of production and transmission networks. European energy transition, as the outcome of social expectations regarding new renewable technologies and industrial strategies, is already challenging two of the three vertices of the traditional energy triangle: the costs of energy and the security of supply.

With respect to the last vertex of the traditional energy triangle, i.e., environmental protection, the overall picture is mixed, also many very positive things happened. Certainly, after decades of investing in better (and increasingly expensive) environmental standards, Europe can boast much better quality of air, water and soil than newly industrialized countries such as China or India. However, it goes on ignoring some of the environmental consequences of its activity and evading inconvenient questions. Most importantly, the notion of decarbonization in Europe has carefully ignored the second most important source of carbon dioxide emissions: the transport sector. In some cases, activities were undertaken which were – as we have recently found out – counter-productive from the point of view of air quality

[14] This difficulty may be illustrated by the decision made by Belgian regulators to considerably raise networking fees for prosumers who use photovoltaics.

protection, such as promoting diesel engines. Turning a blind eye to real vehicle emissions was an encouragement to fraudsters and cartels. Instead of reducing nitrogen compound emissions which cause smog, automotive concerns focused on manipulating emissions measurements. But without accepting the challenge connected with this sector, it will be impossible to combine political aspiration with its technical implementation in Europe, or to combine the global challenge of climate protection with the local challenge of protecting air quality.

The issue of eliminating crude oil from energy production in European countries has only gained in importance recently. It may be argued that this has mostly happened for reasons beyond our grasp. After more than 100 years of stagnation, electric cars are regaining popularity. This was first of all caused by rapid development in battery technologies, largely thanks to more and more miniaturized individual electronic devices (telephones, computers etc.), leading to a spectacular fall in lithium-ion cell prices. But we also need to remember that it is persistent dependence on hydrocarbons importations that motivated the United States to make systemic efforts aimed at reducing it. The combination of Americans' financial capabilities and entrepreneurship has already resulted in a revolution of shale gas and oil, which is transforming the USA from a structural importer to the largest producer or even exporter of these resources. We are now witnessing another revolution, that of electric cars. For California, the leader in this field, the electric car is something more than a new business; it is a manifestation of the views about the climate and our planet. When President Donald Trump withdrew from the Paris Agreement, Elon Musk did not hesitate to instantly withdraw himself from the president's advisory team, posting on Twitter: "*You quit Paris, I quit you*". This gesture will surely be very well received by his investors and clients, many of whom are from California.

Following the pioneering success of Tesla, America's e-mobility revolution is coming to Europe. It is driven by both the spectacular development of electric battery technologies and the dramatic crisis among leading European car producers (its extent still not fully known). Nothing can justify the organized fraud perpetrated by some of Europe's biggest automotive manufacturers. Europe, with a century-old tradition of intellectual capital relating to combustion engines and the ability to defend its flagship industries, has no reasons to further delay the energy transition of its transportation systems. In understanding correctly the growing role of electro-mobility in energy transition, we are devoting an entire chapter of our book to the topic.

Additionally, the ambition to eliminate carbon dioxide from the European economy has had some unintended side effects. The European industry is facing not only higher and higher costs of energy supply but also higher uncertainty. We are seeing the appearance of a phenomenon called "carbon leakage", which in practice causes the inhibition of investment processes in many European energy-intensive industries. Regulatory solutions, such as subsidies for energy-intensive industries, question the principles of honest competition in the European Union. They also face cost barriers. When no other solutions are available, governments resort to chaotically patching up gaps. For example, at the beginning of 2016 the British government declared it was ready to buy as much as 25% of shares in the manufacturing facilities owned by the metallurgic concern Tata (located in Great Britain), so as to encourage potential buyers of its steelworks, put up for sale by their Indian owner.

As a result of carbon leakage, the discrepancy between CO_2 emission and CO_2 consumption per capita in wealthy countries is deepening.[15] In many cases, estimates show that the reduction in greenhouse gases emission per capita is not really caused by the efficiency of local energy management systems, but rather by the transfer of emissions.[16] Statistically, the share of Europe in global GHG emission is decreasing. Soon, it is even going to drop below 10%, but this is accompanied by

[15] D. Clark, *New data on imports and exports turns map of carbon emission on its head,* https://www.theguardian.com/environment/datablog/2011/apr/28/carbon-emissions-imports-exports-trade (accessed: 21.08.2017); *CO2 emissions are being 'outsourced' by rich countries to rising economies,* https://www.theguardian.com/environment/2014/jan/19/co2-emissions-outsourced-rich-nations-rising-economies (accessed: 21.08.2017).

[16] Taking an example from North America, the city of Vancouver: the difference between communicated numbers of CO_2 reduction and estimated consumption is considerable: 4.5 vs 19 tons of CO_2 equivalent a year. See: J. Petrie, *Our post-truth culture and greenwash,* https://pl.scribd.com/document/147478414/Our-Post-Truth-Culture-and-Greenwash (accessed: 21.08.2017).

the growth and increasing industrialization of non-European economies: instead of domestic emissions, Europe imports them as a ready product. The import is often from countries where lower environmental standards apply, which leads to a global increase in harmful emissions. The share of high-emission industries in European economies is reduced, which is especially negative for a country such as Poland, where industrialization is a considerable carrier of growth and affluence.

Also, taking into consideration total carbon dioxide emissions, gas may prove to cause more emissions than coal. In direct combustion, the ratio of CO_2 emission is 1:2, gas being the fuel with lower emission. But if we take into account the whole cycle, from extraction, processing and transport via gas pipelines and by LNG carriers, through to delivery to the end customer, the losses are so huge that they exceed the benefits.[17] If gas is a more emission-intensive fuel than coal, it may shatter the hopes connected with its "transitional" role.

Energy transition in Poland – "Energy Available For All"

In turning to the specific topic of Polish energy transition, we must begin by setting boundary conditions involving the Polish structure of energy production, the technical condition of the national transmission system, geographical and geopolitical conditions, as well as the maturity of technological development and technological limitations. As mentioned before, it is hard today to talk about a universal path to meeting climate objectives as part of national commitments, common to all member states of the European Union. Despite the active policy of many countries, it is impossible to implement unified solutions in all EU countries. If the economy of Germany has the financial capability to accept this challenge, and the vast majority of residents accept its consequences in spite of growing electricity bills, it does not mean the same will occur in other countries. So what should be the response of Poland, a country which is flat, more northern than

[17] G. Vaidyanathan, *Leaky Methane Makes Natural Gas Bad for Global Warming*, https://www.scientificamerican.com/article/leaky-methane-makes-natural-gas-bad-for-global-warming/ (accessed: 19.08.2017).

southern, rich in coal, but developing rapidly while aiming to further increase the share of manufacturing in its GDP?

Since the beginning of systemic and economic transformations in the early 1990s, Poland has been on a path of very intensive transformation and modernization. This has resulted in a 33% reduction in the emission of greenhouse gases, so emissions per capita are lower than in Germany, the Czech Republic, the Netherlands or Finland. The energy-intensity of the economy has dropped by half. The 1990s was a period of very intensive reductions in harmful emissions: approximately 50% less sulphur and nitrogen oxides, and over 90% reduction in dusts.[18] This dynamic is still true: in the period 2005-2014, the Polish energy sector was further reducing oxides emissions: 53% less sulphur and 27% less nitrogen.[19] Wind energy was developing very quickly, and generating capacities exceeded Denmark (6,000 MW). In the coming years, new, highly efficient coal installations are going to be incorporated into the National Electricity System, built using supercritical technology, ensuring efficiency of approximately 46% in places such as Kozienice, Opole, Jaworzno and Ostrołęka. New gas blocks have been or are going to be launched soon in Gorzów, Włocławek, Płock and Stalowa Wola. All these are elements of Polish energy transition which clearly reduce environmental impact and increase flexibility within the system.

Further evolution of the Polish energy industry is inevitable, given EU and international obligations, as well as the ambition of sustainable and innovative development of the economy. The choice of tools and measures should strengthen the competitiveness of the economy and foster the creation of new opportunities and sectors.

Therefore, Polish energy transition is about evolution, not revolution. What matters is that it occurs in a proactive way, following a specific order of priorities which may change over time. After a period of very intensive investments in a huge environmental programme, it is now of key importance that we ensure the lowest cost of energy,

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[18] M. Kurtyka, *Od restrukturyzacji do modernizacji. Opóźniona transformacja polskich przedsiębiorstw energetycznych w latach 1990-2009 [From restructuring to modernization. Late transition of Polish energy enterprises in the 1990-2009 period],* CeDeWu, Warsaw 2013.

[19] *Polish power sector ... op. cit.*

continue activities aimed at securing uninterrupted supply and further limit both environmental and climatic impacts – in this very order of importance.[20]

Security will be ensured by production capacities, which will not only cover the increase in the future demand for energy, but will be adjustable in terms of production profile to the peaks of load, also whenever weather-dependent wind and photovoltaic energy fail to produce. In the choice of technology, it is necessary to combine high performance, flexibility and environmental parameters. The challenge is how to reduce so-called "low emissions" (due mostly to individual heating devices and transport), especially in medium and small towns, where the quality of air is still substandard. Hence the pressure for the development of heat distribution networks, especially cogeneration, allowing the use of a single unit of primary energy in two ways: to produce electricity and to produce heat. Thanks to lower night tariffs, electrical heating should also gain in popularity. All this must be done with the intention of ensuring the lowest cost of energy for the system. Energy must be affordable, both for domestic and commercial buyers.

Energy available for all is also energy that brings people together and animates local communities. We can now see a change in business models. The original model of a centralized energy system where power plants, built for the needs of heavy industry in rapid development, were located near mines and factories is being supplemented by a more decentralized model with multiple dispersed energy sources. Therefore, it is worth assisting the formation of local energy clusters where combining different technologies producing synergy and opening the space for lower scale innovations will be the asset. This is a way to fully use the spectacular drop in prices of renewable technologies we are witnessing nowadays (the lowest price in the first half of 2017 in Germany was €42/MWh), whereas centrally controlled systems of support dedicated to single technologies have replaced the idea of the local dimension of the energy industry and its optimization.[21]

[20] L. Jesień., M. Kurtyka, *New Electricity and New Cars, The Future of European Energy Doctrine*, CeDeWu, Warsaw 2016.

[21] *Nordex: niemiecki rynek wiatrowy na mieliźnie [Nordex: the weakness of German wind energy market]*, http://www.cire.pl/item,149670,1,0,0,0,0,0,nordex-niemiecki-rynek-wiatrowy-na-mieliznie.html (accessed: 21.08.2017).

Actually, full use of opportunities resulting from varied technologies requires bottom-up initiative and creativity. Ample opportunities are to be found in the optimization and harmonious synergy between different technologies.

Regarding new business models, we need to focus on demand management. Creating demand for energy supplies is desirable, both for economic efficiency and system security. Implementing solutions which make it possible to regulate the intake in real time is encouragement for customers to change their behaviours. The overall effect will be proportional to the maturity of the customer, whose usefulness for the optimum functioning of the system will be higher if they have better access to information and know how to use it. Its energy-saving and economically rational use of energy will have beneficial effects for the whole energy system. Summarising, Poland has ambitions to become a country which knows where its opportunities lie and pursues them in a pioneering way. In this context, the development of e-mobility appears particularly attractive as a practical way of following global trends and surfing new needs and sectors. There is much evidence to prove that the impact of Tesla on the automotive industry will be comparable to that the iPhone had on the cell phone market. It will redefine the automotive sector, and previous players will have to radically transform their strategies if they want to maintain their advantage. Ensuring full technical readiness and economic availability of electric cars is one of the current Polish government's flagship projects. Its goal is to have a million electric cars on Polish roads by the year 2025.[22] Batteries which are becoming cheaper and more powerful may be the key tool in this transition. If lithium-ion batteries reach the price of 100 dollars per 1 kWh and energy density of 300-400 Wh per kilogram in the years 2020-2022, as the Department of Innovation and Technology Development in the Ministry of Energy predicts[23], it will make electric vehicles more and more popular. Electric cars backed up by a widespread energy production

[22] *Elektromobilność [Electromobility]*, Ministerstwo Energii, http://www.me.gov.pl/Innowacyjnosc/Elektromobilnosc (accessed: 21.08.2017).

[23] Quoted in the article *Electrifying everything. After electric cars, what more will it take for batteries to change the face of energy?*, The Economist, https://www.economist.com/news/briefing/21726069-no-need-subsidies-higher-volumes-and-better-chemistry-are-causing-costs-plummet-after (accessed: 18.08.2017).

infrastructure is the way to satisfy active consumers. If we can find a way to make this combined system cooperate with the public electricity network, Poland's energy transition will ensure both dynamic mobility and energy distribution.

Energy available to all is at the heart of Poland's energy transition process. By 'available' we mean affordable, easy to understand and access in ways which are essential to optimum usage, as well as being widely accessible across the whole country (including the needs of transport and mobility). Finally, it must be available in any weather conditions, and in the case of technical emergencies, affecting either individual installations or even the technology itself. Today, availability also means that regulatory activities must not burden the energy industry with costs incurred by households' and companies' budgets even more than they do now. This is an ambitious, but highly worthwhile task.

Chapter 2

The concept of energy transition

Tomasz MŁYNARSKI[24], Adam SZURLEJ[25], Mariusz RUSZEL[26]

The concept of transition is naturally associated with innovation and new technologies. For millennia, mankind was developing relatively slowly, until the 17th century satisfying their energy demands mostly with the use of wood (biomass) combustion energy, wind energy, or water energy (water wheel). The 21st century is a time of energy transition defined as a transition from fossil fuels to zero emission or low emission energy sources. Sustainable development, which results in the formation of sustainable economies, will in the long run lead to considerable, and in some cases even complete, replacement of coal, oil, and natural gas with renewable energy sources (RES) in the energy mix, both in terms of individual countries and the global structure of energy consumption. Energy production from renewable energy sources is one of the most prospective foundations of ecology and energy modernization.[27] It is especially evident in the European Union. According to data from EWEA, in 2015 the greatest power increase

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[27] T. Młynarski, M. Tarnawski, *Źródła energii i ich znaczenie dla bezpieczeństwa energetycznego w XXI wieku [Energy sources and their importance for energy security in the 21st century],* Difin, 2016, pp. 223-226.

occurred in wind power plants (12,800 MW, which was 44.2% of the total increase of new power in the EU) and power plants using solar energy (8,500 MW, accounting for 29.4%). These two energy technologies are also going to dominate in the near future. Analyzing the scale of increase of generating capacities of wind power plants in 2015, the highest increase was traditionally observed in Germany: 6,013 MW. Germany is the country with the highest generating capacity of wind power plants in the EU and it is followed by Poland with 1,266 MW.[28]

Definitions of energy transition

A narrow definition of energy transition is: change from the current energy system using non-renewable energy sources (fossil fuels) to an energy system mostly based on renewable sources. Therefore, it is an important element of the ecological approach in the energy industry, involving gradual replacement of exhaustible hydrocarbons and uranium fuel with RES in almost all areas of human activity (transport, industry, energy sector, heating, etc.). Factors that promote the development of renewable energy are technological advancement, growing competition, and an appropriate policy of support, especially in countries such as the USA, India or China. Besides, more and more countries intend to develop renewable energy so as to reduce the impact of the traditional energy sector on the environment, diversify energy supplies, and enhance their own energy independence.[29]

In a broader sense, energy transition is identified as the popularization of low-emission energy sources on the basis of low-emission and effective (energy saving) technologies of energy production. One element of energy transition is the development of the idea of energy saving, which means an improvement in energy efficiency in different sectors of industry and services (i.e., insulation and thermomodernization, energy-saving lighting, cogeneration – generating heat and energy at the same time and energy recovery in industrial processes).

Research carried out by Ludger Gailing and Timothy Moss shows that energy transition applies to four aspects: institutional change,

[28] *Wind in Power: 2015 European statistics,* EWEA, 2016; www.ewea.org

[29] *The Medium-Term Renewables Market Report, Market Analysis and Forecasts to 2021,* International Energy Agency, Paris 2016.

material aspect, power and space.[30] In the first aspect, energy transition means the need of institutional collaboration leading to better understanding of the social context of energy transition and the development of a relevant strategy.[31] The second, material aspect leads to the conclusions that energy may not only be generated from fossil fuels or RES, but also e.g. from waste processing (waste to energy) or improving energy efficiency.[32] The third plane, referring to power, shows that different actors clash at the local and regional level, often representing different interests connected with energy projects that follow the concept of energy transition.[33] The fourth aspect, related to space, highlights that local, regional and national spatial planning plays a significant role in the process of energy transition, as it is directly related to the location of new investments.[34]

Energy transition vs sustainable development

The concept of energy transition is also connected with sustainable development, which can be defined in two ways: as a process of development (e.g. of countries) that unconditionally combines the needs of today's generation with the ability to satisfy the needs of future generations.[35] The other definition of sustainable development is: a chain of changes in which the use of resources, the structure of investments, as

[30] L. Gailing, T. Moss, *Conceptualizing Germany's Energy Transition*, Palgrave Macmillian, London 2016, pp. 4-7.

[31] S. Becker, R. Beveridge, A. Röhring, *Energy Transition and Institutional Change: Between Structure and Agency* [in:] L. Gailing, T. Moss, *Conceptualizing Germany's Energy Transition*, Palgrave Macmillian, London 2016.

[32] T. Moss, S. Becker, L. Gailing, *Energy Transitions and Materiality: Between Dispositives, Assemblages and Metabolisms* [in:] L. Gailing, T. Moss, L. Gailing, T. Moss, *Conceptualizing Germany's Energy Transition*, Palgrave Macmillian, London 2016.

[33] A. Bues, L. Gailing, *Energy Transitions and Power: Between Governmentality and Depoliticization* [in:] L. Gailing, T. Moss, *Conceptualizing Germany's Energy Transition*, Palgrave Macmillian, London 2016.

[34] S. Becker, T. Moss, M. Naumann, *The Importance of Space: Towards a Social-Material and Political Geography of Energy Transition* [in:] L. Gailing, T. Moss, *Conceptualizing Germany's Energy Transition*, Palgrave Macmillian, London 2016.

[35] W. Sztumski, *Idea zrównoważonego rozwoju a możliwości jej urzeczywistnienia [The idea of sustainable development vs the possibility of its implementation],* Problemy Ekorozwoju, vol.1, 2006, p. 73.

well as the direction of technological advancement and institutional structures must prevent discrepancies between present and future needs.[36] The idea of sustainable development is mentioned in several national and international legal or political documents. In Poland, it is referred to in Article 5 of the Constitution of the Republic of Poland.[37]

Energy efficiency and renewable energy are regarded as twin pillars of sustainable energy policy. Ecological modernization of the economy through technological innovations is to ensure progress in the achievement of environmental goals and industrial progress (sustainable development).[38] Energy transition – not only the transition of the energy sector – is centralized, proportional to the development of an international regime of counteracting climate change, and is based on radical changes in energy policy, i.e. transformation from centralized to decentralized and prosumer production (dispersed production installation). It is worth emphasising that low and very low capacity units (so-called mini and micro cogeneration) have recently appeared on the market. They are characterized i.a. by simple installation and short time of investment performance. These characteristics, as well as the module character of the devices, make them an attractive alternative to large energy producers.[39] Thus, it is ecology-energy transition, which allows the separation of economic growth from pollution emission. In social sciences related to energy, scientific debate is going on concerning energy transition.[40] It is emphasized that thinking in the categories of "transition" leads to understanding how new and inno-

[36] Report from the UN World Commission on Environment and Development (WCED), 1987.

[37] A. Pultowicz, *Przesłanki rozwoju rynku odnawialnych źródeł energii w Polsce w świetle idei zrównoważonego rozwoju [Reasons for the development of renewable energy sources market in Poland in the light of the ides of sustainable development],* Problemy Ekorozwoju – Problems Of Sustainable Development, vol. 4, No 1, 2009, pp. 109-115.

[38] Cf.: L. van Schaik, S. Schunz, *Explaining EU Activism and Impact in Global Climate Politics: Is the Union a Norm- or Interest-Driven Actor?*, JCMS, Journal of Common Market Studies , 2012, Vol. 50. No. 1, p. 178.

[39] E. Mokrzycki (ed.), *Rozproszone zasoby energii w systemie elektroenergetycznym [Dispersed energy resources in electricity system],* Wyd. Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk, Kraków 2011, pp. 7-8.

[40] S. Strunz, *The German Energy Transition as a Regime Shift*, "Ecological Economics" no. 100, pp. 150-158.

vative technologies can develop a more sustainable society. According to Robert B. Laughlin, in the future, people will prefer to live with clean air, water and natural environment.[41] This means that energy transition should take into account the needs of civil society in terms of reducing the negative influence of the energy sector on the natural environment. This is especially important given that the energy sector is the main source of greenhouse gases emission. In Poland, energy transition is associated with the hope for lower emissions of different air pollutants, because according to the report of the European Environment Agency of 2016, the level of air pollution in Poland is very high (Poland is second in terms of the concentration of particulate matter PM_{10} in the air, and first in terms of benzo[a]pyrene).[42] The report of the Supreme Chamber of Control of 2014 also confirms that Poland has the most polluted air out of all EU countries.[43]

Energy transition as a lever for economic development

Energy transition understood as conversion towards a sustainable development economy does not only promote environmental protection, but also – in the long run – will enhance the competitiveness of the economy, providing thousands of jobs and improving people's quality of life. Modernization of energy industry gives an advantage to regional and global regimes of CO_2 emissions reduction based on modern, low-emission energy technologies. Energy transition will support the development of industry and employment, attract investments for sustainable, innovative and low emission technologies, which improves the competitiveness of industry. Adapting the energy sector to climate change is becoming a catalyst for the modernization of economies (new branches of the economy are emerging, which stimulate employment). Energy transition is a great opportunity to promote economic

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[41] R. B. Laughlin, *Powering the Future*, Basic Books, New York 2011, p. 5.

[42] *Air quality in Europe — 2016 report,* European Environment Agency, Copenhagen, Denmark, 2016, pp. 29-48.

[43] *Informacja o wynikach kontroli: ochrona powietrza przed zanieczyszczeniami [Information on the outcome of control of air pollution protection],* Najwyższa Izba Kontroli, Warsaw 2014.

interests based on stimulating economies through the establishment of new eco-jobs and the export of low carbon emission technologies. Increasing the share of alternative energy sources in the total energy balance of a country and improving energy efficiency does not only help improve energy security, but also gives some economic benefits through ensuring competitive advantage connected with the use and export of modern energy technologies reducing GHG emission. In the future, the potentially significant rise in the price of the right to emit greenhouse gases will enforce even greater profitability of preferred technologies supporting low emission economies. Energy transition thus means the formation of a more competitive low emission economy; environmental protection including the reduction of greenhouse gases and the prevention of biodiversity loss; the implementation of new, climate-friendly technologies of energy production and intelligent networks for its transmission (*Smart Grid*); and educating consumers The effect is economic stimulation, creating new jobs, and promotion of the development of local communities. Therefore, energy transition links economic growth and respect for the natural environment by reducing the growth of energy demand, by developing competitive renewable energy sources and other low emission energy carriers, in particular alternative fuels used in transport, and by improving competitiveness connected with the production of clean energy and rational energy use (efficiency based on innovative technologies). Thus, it integrates three goals: improvement of energy security (stability of supply from domestic energy sources), development of new branches of a "green economy" (increase in competitiveness and GDP), and eco-technological modernization of energy production processes (eco-jobs). This way, environmental goals are connected with economic goals, and the policy of ecological energy transition achieves economic goals.[44]

It is commonly assumed that new technologies lead to reducing energy dependence on fossil energy resources through more effective use of or departure from such resources in favor of the development of renewable energy based on natural use of sunlight, wind energy, river course and geothermal energy. We also need to remember energy

[44] T. Młynarski, M. Tarnawski, *Źródła energii i ich znaczenie [Energy sources and their importance]... op. cit.*, p. 203.

technologies that allow the combustion of fossil fuels in an environmentally clean way. Whereas the dynamic growth of importance in RES in the energy balances of different countries, regions, or the world, is certainly true, we need to remember that about 77% of electricity globally is produced from fossil fuels. In the case of Poland, because of its having substantial (with regard to Europe) resources of hard coal and lignite, the share of those fuels in electricity production in 2015 was 86% and was one of the highest in the world. Therefore, *CCT (Clean Coal Technologies)* are expected to be the main direction of development towards clean energy technologies in Poland. We should remember that clean energy technologies using fossil fuels are related to high investment expenditure and higher operating costs than technologies used currently. Among other things, this is due to the costs of installation of *CCS (Carbon Capture and Storage)*. With the current assumptions of EU energy policy, it seems that apart from economic factors, ecological aspects will also play an important role in making decisions on the choice of technology of electricity production.[45] The significance of ecological aspects is proved, not only by EU regulations, but also by the provisions of the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change, which took place in December 2015 in Paris. The Paris Agreement was signed by Poland on April 27, 2016, in the UN headquarters in New York. Accepting the agreement will be connected with efforts to reduce CO_2 emissions. But it should be stressed that the way of achieving this goal is determined by each country independently.[46]

However, the crucial issue in achieving the goals of the agreement is probably the change in the energy sector, which is the main source (at least 2/3) of greenhouse gases emission.[47] It is important to see the variety of locations of fossil energy resources, as well as geographical potential enabling their use in renewable energy industry. Taking

[45] D. Kryzia, L. Gawlik, M. Pepłowska, *Uwarunkowania rozwoju czystych technologii wytwarzania energii z paliw kopalnych [Determinants of the development of clean technologies of energy production from fossil fuels]*, Polityka Energetyczna – Energy Policy Journal, vol. 19, part 4, 2016, pp. 63-74.

[46] B. Zaporowski, *Zrównoważony rozwój źródeł wytwórczych energii elektryczne [Sustainable development of electricity production sources]*, Polityka Energetyczna – Energy Policy Journal, vol. 19, part 3, 2016, pp. 35-48.

[47] World Energy Outlook 2016, International Energy Agency, Paris 2016, p. 35.

into account the fact that the energy balance structure is different in each country, the process of energy transition in the countries will also differ. This results from the fact that globally the governments of each country have retained the greatest rights to shape national energy policies. The situation is the same at the EU level, because Article 4 section 2 of the Treaty on the Functioning of the European Union (TFEU) provides that competencies in the area of energy are shared between member states and EU institutions.[48] The diversity of energy transition in different countries not only refers to the potential connected with geographical conditions and resource potential, but also to the diversity of R&D specialization in each economy. Doubtless, climate policy, which has become the catalyst for implementing new technologies in the energy sector, will have a significant impact on energy transition processes, but global energy infrastructure should be strengthened in parallel with this process. Currently, it is evident that in many countries considerable investments in new capacities of renewable energy do not correspond to the speed of development of investments in electricity infrastructure. Broad application of renewable energy requires the stabilization of electricity networks ensured currently by conventional energy. This means that appropriate spatial planning is necessary, even more so because the process of energy transition increasingly applies to the transport sector, which is one of the most high emission sectors of economy. The process of modernization of the energy sector should strengthen sustainable transport through the development of global electromobility. Energy transition and the increase in importance of RES in the energy balances of each country are closely connected with the problem of energy storage. Recently, energy storage technologies (e.g., power-to-gas) have been developing, which enables the conversion of energy surplus to a form of energy that is easier to store and transport (e.g., hydrogen). The consequence of these activities will be a gradual reduction in countries' oil import dependency and greater use of electricity in the automotive industry. Globally, this will allow many economies to save some

[48] *Treaty on the Functioning of the European Union* (consolidated text, OJ EU C 326/47.
G. Moens, J. Trone*, The political institutions of the European Union,* "Commercial Law of the European Union", Springer, Netherlands, 2010, pp. 26–27.

financial resources, which – if they are used properly – may become a source of financing new investments, improving energy efficiency and optimum use of energy resources even more.[49] A similar process can occur in the area of construction, where modern materials are now used which allow the construction of energy-saving passive houses. We need to stress that innovation resulting from energy transition also involves a change of tendencies and a departure from old business models in favor of decentralized ones, and the formation of local energy clusters combining different technologies and aiming at synergy between them.[50] For this reason, energy transition is not only technological innovation, but also regulatory innovation of the energy sector on the global scale.[51] The process of energy transition will not only lead to protecting the natural environment, but first of all, to creating new jobs and enhancing energy security.[52]

Analyzing data of the International Energy Agency of 2015, we may conclude that energy transition is already a fact. The upward tendency of CO_2 emissions related to the energy sector came to a halt in 2015, mostly as a result of lowering the energy intensity of the global economy by 1.8%, connected with accomplishments in energy efficiency and higher use of low emission energy sources all over the world, especially renewable energy sources. Maintaining the decrease of GHG emissions in the following years will enable countries to meet their climate obligations as part of the Paris Agreement. Recently, the drop in oil and natural gas extraction investments (the highest within nearly seventy years) has been accompanied by growth in investments in the sector of clean energy technologies by approximately 1.8 trillion USD

[49] "In 2012 Poland imported almost 25 million tonnes of oil, of which 95 percent came from Russia, for over 15 billion euro". See L. Jesień, M. Kurtyka, *New Electricity and New Cars. The Future of the European Energy Doctrine*, CeDeWu, Warsaw 2016, p. 118.

[50] M. Kurtyka, presentation at the National Scientific Conference "Polityka energetyczna UE - filary i perspektywa rozwoju" *[EU energy policy: foundations and prospects of development]*, Rzeszów 25-26.04.2016.

[51] K. Steinbacher, M. Pahle, *Leadership by Diffusion and the German Energiewende.*, "SSRN Electronic Journal", 2015, http://doi.org/10.2139/ssrn.2565313

[52] D. Tänzler, S. Wolters, S., *Energiewende und Außenpolitik: Gestaltungsmacht auf dem Prüfstand*, "Zeitschrift für Außen- und Sicherheitspolitik", no. 7(2), 2014, pp. 133–143.

a year. On the other hand, the value of subsidies for the consumption of fossil fuels fell to 325 billion USD in 2015 from almost 500 billion in 2014. This significant reduction is the result of lower prices of fossil fuels and reforms of fuel subsidizing in many countries.[53]

Data from the market of renewable energy also proves energy transition. Globally, in 2015, RES installations accounted for more than half of new generating capacities (153 GW, i.e., 15% more than in 2014, including 63 GW more in wind energy and 49 more in solar energy). The IEA estimates that within five years, RES will be the quickest developing source of electricity, and their share will grow up to 28% in 2021. In 2015, the share of RES was 23%. The IEA forecasts that in 2021 the costs of technology will be reduced by 25% in photovoltaics and by 15% in land wind energy.[54]

Energy transition is also a comprehensive change in the way of thinking about and perception of the energy sector. The perception of the process with reference to the energy sector should be interpreted much more broadly than merely the replacement of fossil fuels with renewable energy.

[53] World Energy Outlook 2016, International Energy Agency, Paris 2016.

[54] *The Medium-Term Renewables Market Report, Market Analysis and Forecasts to 2021,* International Energy Agency, Paris 2016.

Chapter 3

Electromobility as a new segment of the economy

Mariusz RUSZEL[55], Adam SZURLEJ[56]

The transport sector has one of the highest shares in the total consumption of energy in different countries and is mostly based on the use of fuels produced from oil: different kinds of gasoline and diesel oil. Due to its very uneven distribution, the majority of countries need to import oil. It is worth emphasizing that in EU countries the dependence on oil and oil derivatives import is the highest out of all fuels, and is growing: 2005 – 82.1%, 2014 – 87.4%.[57] That is why the popularization of electric cars, i.e., the development of electromobility, is regarded to be a new segment of the low emission economy, which will contribute to a revolution in the automotive industry. However, the subject of electromobility is not new: as early as 1881, Gustav Trouvé presented the first battery for an electric vehicle.[58] That was more than 100 years ago, and nowadays there is still global discussion on the development of different forms of electric vehicles (e.g., battery electric vehicle – BEV, range-extended electric vehicle – REEV,

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[57] Eurostat: *Energy, transport and environment indicators – 2016 edition*. Luxembourg, p. 48.

[58] M. Bertram, S. Bongard, *Electromobilität im motorisierten Individualverkehr. Grundlagen, Einflussfaktoren und Wirtschaftlichkeitsvergleich*, Springer Vieweg, Wiesbaden 2014, p. 1.

hybrid electric vehicle – HEV, plug-in hybrid electric vehicle – PHEV, fuel cell hybrid electric vehicle – FCHEV).[59]

Barriers to the development of electromobility

Analyzing how this sector of economy develops in time, we can see that the speed of the development is connected with the need to overcome certain barriers, which lead to the inhibition of developmental processes. The barriers can be classified as political, economic, technical and social.

It seems that the main political barrier causing poor development of electric cars so far has been, on the one hand, the lack of will to make political decisions in different countries, and on the other hand, the lack of appropriate instruments, including strategic documents at the national level of the world's biggest economies, as well as at the level of international organizations. Moreover, the largest international oil industry corporations that have invested considerable financial resources in deposits of energy carriers, as well as countries rich in oil, have been lobbying to use fossil fuels in transportation. This means that so far there have been no coordinated global political processes to allow the implementing of electromobility globally. Obtaining the relevant political will and making certain decisions would help create appropriate instruments of support for electric vehicles. Especially important will be the political activity of the United States of America (USA) and People's Republic of China (PRC), because these countries have a huge influence on the world's economy and are the biggest consumers of energy carriers. In addition, trends set by these countries will contribute to adopting certain strategic documents at the level of international organizations, i.e., the International Energy Agency (IEA), United Nations Organization (UNO) and the European Union, which is a potential and affluent market for electric cars with its 500 million citizens.[60]

[59] *Electromobility in Germany: Vision 2020 and Beyond*, Germany Trade & Invest, Berlin 2015, p. 5.

[60] *Member State compliance with EU law improving, but more work ahead to unleash full potential of Single Market*, European Commission, http://europa.eu/rapid/press-release_IP-16-2245_en.htm (accessed: 02.01.2017).

Environmental regulations may be of special importance, since they may contribute to the development of electromobility.

From November 30 to December 12, 2015, the 21st Conference of the Parties to UNFCCC (United Nations Framework Convention on Climate Change) and the 11th session of Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP 21 and CMP 11) took place in Paris, during which a new global climate agreement was adopted.[61] The *Paris Declaration on Electro-Mobility and Climate Change & Call of Action*, which is to be based on concrete actions leading to the electrification of transport, is very important.[62] The declaration assumes the accomplishment of at least a 20% share of electric vehicles among all vehicles in the world by the year 2030[63], and the support from a growing number of institutional partners indicates an increase in political will concerning the development of electromobility all over the world.[64] Especially important is the support from an inter-governmental forum EVI, which was established in 2009 and is made up of 16 countries. It is led by the USA and the PRC jointly, and EVI's secretariat

[61] *Paris UN climate change conference, 30/11-12/12/2015,* http://www.consilium.europa.eu/en/meetings/international-summit/2015/11/30/ (accessed: 02.01.2017).

[62] *Opinion of the European Economic and Social Committee on 'The impact of the conclusions of COP21 on European transport policy'*, OJ EU C303/10 of 19.08.2016, p. 5.

[63] *Paris Declaration on Electro-Mobility and Climate Change & Call of Action*, http://newsroom.unfccc.int/media/521376/paris-electro-mobility-declaration.pdf (accessed: 02.01.2017).

[64] List of partners [as of 02.01.2017]: Avere-Europe, Avere-France, ChargePoint Electric Vehicle Charging, Clean Air Asia (Clean Air Initiative for Asian Cities Center, Inc.), E-poste, Electric Vehicle Initiative (EVI), EV4SCC (Electric Vehicle for Smart Cities and Communities), FIA Foundation, Global Fuel Economy Initiative, Industry Pledge COP21 to Achieve Electro-mobility Goals, International Energy Agency, International Zero-Emission Vehicle Alliance (ZEV Alliance), Michelin Worldwide, Move Climate Challenge, Partnership on Sustainable - Low Carbon Transport (SLoCaT), Polis – European Cities and Regions Networking for Innovative Transport Solutions, Renault-Nissan Alliance, SOLUTIONS – Global, Taxis4SmartCities, Tesla Motors, United Nations Environment Programme (UNEP), Urban Electric Mobility Initiative (UEMI), Wuppertal Institute for Climate - Environment and Energy, Zero Emissions Urban Bus System (ZeEUS) by International Association of Public Transport (UITP). See: *Paris Declaration on Electro-Mobility and Climate Change and Call to Action. Electrifying Sustainable Transport*, http://newsroom.unfccc.int/lpaa/transport/the-paris-declaration-on-electro-mobility-and-climate-change-and-call-to-action/#downloads (accessed: 02.01.2017).

is run by the IEA.[65] It is clear that political decisions connected with the development of electromobility are going to contribute to achieving the set goals of energy/climate policy since, currently, transport accounts for the emission of 23% of carbon dioxide globally.[66]

Another important group is economic barriers, which are fundamental from the consumers' perspective. For this reason, the costs of production and operation of an electric vehicle, which translate into its market availability, are of key importance. Therefore, it is essential to reduce the economic costs of launching the product to the market.[67] One of the main components of the cost of an electric car is the price of the battery. It seemed that when the Frenchman Georges-Lionel Leclanche presented the patent of theoriginal battery in 1866[68], the work on creating a cheap battery would accelerate. In addition, in 1900, Ferdinand Porsche presented a prototype of electric vehicle at the world exhibition in Paris.[69] But the work is still going on to create relatively cheap batteries that would be able to store sufficient electricity, recharge quickly, and have an appropriate life cycle. In the 2008-2015 period, there was a dynamic reduction in the costs of battery production and the growing potential of energy content (Figure 1). Yet, the costs of batteries and energy storage facilities are still one of the main barriers to the development of electromobility.[70]

The third group of barriers is technical, which mostly refer to the need to extend and modernize energy infrastructure so that it

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[65] Canada, China, France, Germany, India, Italy, Japan, Korea, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, the United Kingdom and the United States.

[66] *Paris Declaration on Electro-Mobility and Climate Change and Call to Action. Electrifying Sustainable Transport*, http://newsroom.unfccc.int/lpaa/transport/the-paris-declaration-on-electro-mobility-and-climate-change-and-call-to-action/#downloads (accessed: 02.01.2017).

[67] L. Fazel, *Akzeptanz von Elektromobilität. Entwiklung und Validierung eines Modells unter Berücksichtigung der Nutzungsform des Carsharing*, Springer Gabler, Chemnitz 2013, p. 54.

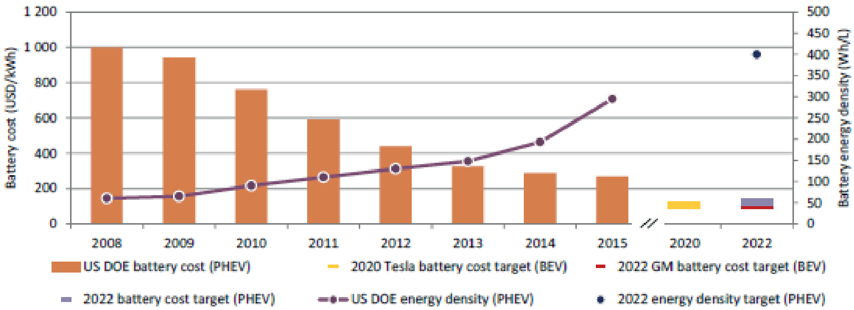
[68] A. Kampker, *Elektromobil-produktion*, Springer Vieweg, Berlin Heidelberg 2014, p. 43.

[69] *Electromobility in Germany: Vision 2020 and Beyond*, Germany Trade & Invest, Berlin 2015, p. 3.

[70] *Global EV Outlook 2016. Beyond one million electric cars*, International Energy Agency, France 2016, p. 4.

would be able to satisfy the growing electricity demand at its peak. This means the need to ensure appropriate capacities in the electricity system, including its stability, and to create a relevant number of charging stations. In November 2016, the biggest car manufacturers signed an agreement concerning investments in charging stations in order to stimulate interest in electromobility.[71]

Figure 1. Evolution of battery energy density and cost.



Notes: USD/kWh = United States dollars per kilowatt-hour; Wh/L = watt-hours per litre. PHEV battery cost and energy density data shown here are based on an observed industry-wide trend, include useful energy only, refer to battery packs and suppose an annual battery production of 100 000 units for each manufacturer.

Source: *Global EV Outlook 2016. Beyond one million electric cars*, International Energy Agency, France 2016, p. 4 [for:] US DOE (2015 and 2016) for PHEV battery cost and energy density estimates; EV Obsession (2015); and HybridCARS (2015).

The fourth group of barriers are social ones connected with consumers' habits and distrust in new technologies. Icek Ajzen highlights in his theory of planned behavior (TPB) that the main factor affecting consumers' behaviors is their attitude formed by knowledge and experience, as well as subjective norms accepted by the society.[72] This means that drivers' habits combined with strong marketing by oil companies may consolidate the positive image of a combustion vehicle. Interestingly, electric cars do not occur in movies and series watched by the society. Instead, well-known combustion cars are

[71] eMobility - nowy dział Innogy *[eMobility: a new segment of Innogy]*, http://www.cire.pl/item,138723,1,0,0,0,0,0,emobility---nowy-dzial-innogy.html (accessed: 28.12.2016).

[72] I. Ajzen, *The theory of planned behavior*, "Organizational Behavior and Human Decision Processes" 1991/50, pp. 179–211.

often shown. And there is research to confirm that the media affect consumers' decisions.[73]

Public opinion studies show that when we buy a car, the following criteria are significant for us: costs, reliability, safety, and comfort.[74] Research carried out in several EU countries in 2012 showed that citizens emphasize the excessive costs of electric cars and the need to create conditions for recharging them in their private garages as the main barriers to the development of electromobility.[75] Similar problems connected with the development of electric vehicles use were mentioned by Poles. In a study performed by *ARC Rynek i Opinia*, the main factors discouraging people from using electric cars were: the high costs of purchase (81%) and an insufficient number of charging stations, including problems with charging on the way.[76] In February 2016, a study was carried out in Great Britain, confirming that only 5% were thinking of buying an electric car.[77]

A study by Suzanna M. Long shows that social approval for electric cars will be the basis for commercial success, and hence, consumers' expectations need to be treated seriously. It proved that citizens are afraid of the insecurity connected with electric cars, which translates into low trust in electromobility, and tax incentives are not going to help much. More important will be the implementation of appropriate educational programmes and instruments supporting the lowering of costs of operation of the vehicles. Political decision makers of different countries will respond to arguments connected with energy security and climate policy through the media.[78]

[73] B. Lane, S. Potter, *The adoption of cleaner vehicles in the UK: exploring the consumer attitude–action gap.* "Journal of Cleaner Production", 2007/15 (11–12), p. 1085–1092; E. M. Rogers, *Diffusion of Innovations*, fifth ed Free Press, New York 2003.

[74] *Public attitudes towards electric vehicles: 2016 (Revised),* Department of Transport 2016, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/551446/electric-vehicles-survey-2016.pdf (accessed: 09.01.2017).

[75] *Attitude of European car drivers towards electric vehicles: a survey,* JRC Scientific and Policy Reports, European Commission, 2012, p. 19.

[76] ARC Rynek i Opinia: http://www.arc.com.pl/polacy_o_samochodach_elektrycznych-41999612-pl.html (accessed: 10.01.2017).

[77] *Public attitudes towards electric vehicles: 2016 (Revised),* Department of Transport 2016, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/551446/electric-vehicles-survey-2016.pdf (accessed: 09.01.2017).

[78] S. M. Long, *Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions*, "Energy Policy", September 2012, p. 724.

Strategic resources of electromobility

It should be stressed that global development of the electromobility sector will cause, on the one hand, a systematic decrease in demand for oil in the automotive industry, and on the other hand, an increase in demand for certain resources, such as lithium, cobalt, or nickel. According to data from USGS (United States Geological Survey), global resources of nickel are estimated at 34 million tons; including 9 million tons in Bolivia and Chile; 6.5 million tons in Argentina; 5.1 million tons in People's Republic of China; 1.7 million tons in Australia; Canada, Congo and the Russian Federation have 1 million tons each; Brazil and Mexico, 180 thousand tons each; and Austria, 130 thousand tons.[79] In 2015, the largest amounts of nickel were produced in Australia, Chile, Argentina, and People's Republic of China. The second significant resource affecting the development of electromobility is cobalt, whose identified global deposits (according to USGS) are 25 million tons; on the bottom of the Atlantic Ocean, Indian Ocean, and Pacific Ocean there may be more than 120 million tons. In 2015, the largest amount of cobalt was extracted in Kinshasa in the Democratic Republic of Congo (almost 50% of the world's production). The greatest business partner of the Democratic Republic of Congo is People's Republic of China, which imports the highest amounts of cobalt produced in that country. Apart from the Democratic Republic of the Congo, cobalt is produced in China, Canada, the Russian Federation, Australia, Zambia, the Philippines and Cuba.[80] When manufacturing batteries, synthetic graphite is also used, and graphite mostly comes from Poland and Japan.[81] As modern technologies using new materials and resources for their production develop, the importance of certain resources may change over time, corresponding to the most energy- and cost-effective batteries for electric vehicles.

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[79] *Lithium*, United States Geological Survey, http://minerals.usgs.gov/minerals/pubs/commodity/lithium/mcs-2016-lithi.pdf (accessed: 12.12.2016).

[80] *Cobalt*, United States Geological Survey, http://minerals.usgs.gov/minerals/pubs/commodity/cobalt/mcs-2016-cobal.pdf (accessed: 12.12.2016).

[81] S. Kane, *These 5 arguments slowed the electric car revolution — and they're all bogus*, http://www.businessinsider.com/electric-car-myths-inaccuracies-2016-2?IR=T (accessed: 8.01.2017).

Electromobility: a new branch of industry

Electromobility is regarded as a new branch of industry which will contribute to the development of low emission technologies to be applied in transport and electricity storage. Together with the development of electromobility, the demand for oil from the automotive industry, especially cars, will begin decreasing.[82] Given the uneven global distribution of oil, most countries are dependent on importing this energy resource, as well as ready fuels and other energy products.[83] Oil is mostly used in the transport sector to produce fuels. According to the IEA, in 2014, 64.5% of the world's oil consumption was in transport. In 1973, the share was 45.4%.[84] This energy resource has become the object of competition and collaboration between countries in the context of geopolitical competition. It seems electromobility is going to be a new factor changing the rules of competition and collaboration (a game changer).[85] The automotive revolution that will lead to popularizing electric cars will allow countries that spend considerable amounts on imported oil (only in Poland import expenses connected with the purchase of oil increased from 5.23 to 15.22 billion euros between 2005 and 2012)[86] to spend it on electricity instead. In most cases, electricity is produced in the countries that actually use it.[87] In other words, financial resources that are spent on imported fuels now could be spent within the country, contributing to the development of some areas of industry. Obviously, this will work assuming that electricity is produced domestically, not imported. This process will correspond to the growing number of installations based on renewable energy sources, which are connected to electricity networks, and to the

[82] International Energy Agency, *World Energy Outlook 2016*, Paris 2016.

[83] M. Gałczyński, M. Ruszel, P. Turowski, R. Zajdler, A. Zawisza, *Globalny rynek LNG [Global LNG Market]*, Wydawnictwo Rambler, Warsaw 2015, pp. 22-23.

[84] International Energy Agency, *Key world energy statistics 2016*, Paris 2016, p. 33.

[85] J. A. Bolanos, *The future of oil: Between cooperation & competition*, Department of War Studies, EUCERS, King's College London, Strategy Paper Thirteen, p. 37.

[86] *Raport o stanie handlu zagranicznego [Report on international trade]*, Ministerstwo Gospodarki, Warsaw 2015, p. 90.

[87] P. Turowski, *Bezpieczeństwo energetyczne na szczycie NATO w Warszawie: priorytetem dywersyfikacja ropy i gazu [Energy security at the NATO summit in Warsaw: oil and gas diversification as the priority]*, "Bezpieczeństwo Narodowe" 2016/I-IV, pp. 154-160.

process of formation of energy clusters. It will be necessary to extend energy infrastructure to recharge electric vehicles, and the digitalization of electromobility will develop along with those processes. This means that cyber security will be another challenge. These processes will also affect the development of technologies connected with electricity storage. At the same time, the development of electromobility will surely also occur in the segments of utility cars, buses, taxis, bicycles, and even electric scooters. Thus, electromobility will contribute to the development of GDP and creating new jobs.

The process of introducing new electric vehicles also translates into an innovative approach to cars, since car sharing is becoming more and more popular. It seems the interest in this form of using a car will go on increasing proportionally to the growing costs of operating one's own vehicle.[88] In 2015, 1.26 million electric vehicles began their journey all over the world. More than half of them appeared in the USA and People's Republic of China (Figure 2).[89] Notably, in Norway the share of electric cars in relation to the total number of registered vehicles is almost 20% (this country is the leader in terms of the number of electric cars per 1 thousand residents). In the Netherlands, it is 10%, while in China, e-scooters are extremely popular.[90] The IEA estimates that by 2030, about 100 million electric cars will appear on the roads globally.[91] Electromobility will stimulate the R&D sector in the context of using alternative and low-emission fuels, different technologies of battery production, and energy storage. More and more projects are connected with the use of hydrogen in transport and power-to-gas technology. In some countries, hydrogen is perceived as a potential fuel to propel trucks.[92] It should be emphasized that the popularization of electric cars will influence the development of research connected with the use of IT technologies in the electromobility sector.

[88] *Rzędowska: 2016 był rokiem elektromobilności? [Was 2016 a year of electromobility?],* http://biznesalert.pl/rzedowska-2016-rokiem-elektromobilnosci/ (accessed: 30.12.2016).

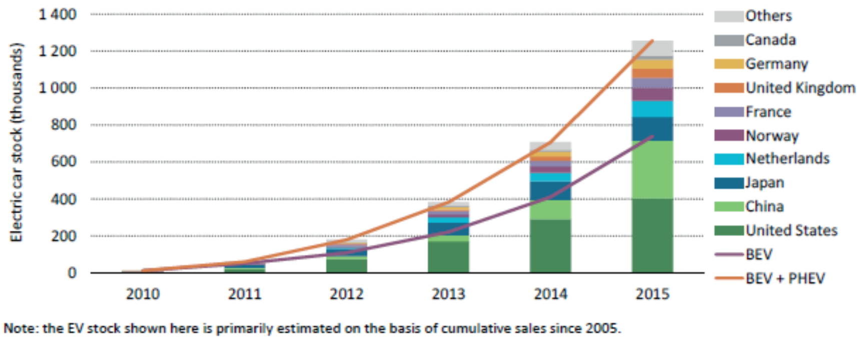
[89] *Global EV Outlook 2016. Beyond one million electric cars ... op. cit.*

[90] *Ibidem.*

[91] *Ibidem*, pp. 5-6.

[92] L. Jesień, M. Kurtyka, *New Electricity and New Cars. The Future of the European Energy Doctrine,* CeDeWu, Warsaw 2016, p. 95.

Figure 2. Evolution of the global electric car stock, 2010-15.



Source: *Global EV Outlook 2016. Beyond one million electric cars*, International Energy Agency, France 2016, p. 4.

Conclusion

Remembering international agreements referring to climate and the reduction of atmosphere pollution, countries' declarations concerning support for the purchase of electric vehicles (e.g. through appropriate tax policy and changes in the regulatory environment), the high dynamics of sales of those vehicles, technological advancement in electricity storage and the parameters of batteries for electric cars, and the announcements of automotive companies regarding higher expenditure on investments connected with electromobility, we cannot but agree with the assessment of German minister of transport Alexander Dobrindt, who said that the world is facing "the greatest mobility revolution since the invention of the car".[93] Especially that in the years 2014-2015, the number of electric vehicles nearly doubled, and at the end of 2016, it exceeded 2 million.[94] In 2016, People's Republic of China was the most dynamic market for electric vehicles (40% of global sales). The IEA forecasts that the number of electric cars will reach 30 million by 2025, and exceed 150 million by 2040. According to T. Szeba, some factors, such as the reduction in prices of electric

[93] N. Doll, *Multimillionen-Förderprogramm für Wasserstoffautos,* https://www.welt.de/wirtschaft/article160261283/Multimillionen-Foerderprogramm-fuer-Wasserstoffautos.html (accessed: 10.01.2017).

[94] *Global EV Outlook 2017. Two million and counting*, International Energy Agency, France 2017, p. 5.

cars, lower costs of operation and higher durability than in the case of combustion cars, will ultimately lead to the popularization of electric cars and the collapse of the oil industry.[95] He also forecasts a further reduction in the price of oil, which will cause lower profitability of drilling, and as a result affect the financial condition of oil exporters and some automotive concerns. In Europe, the sale of electric cars is also increasing, and some cities have banned traditional vehicles from entering their centers (Paris, Madrid, Athens) or are planning to do so (London, Brussels). Apart from electric vehicles, European cities are developing public transport and bicycle transport (Copenhagen, Helsinki, Amsterdam). It seems that this "mobility revolution" will be inevitable to considerably reduce the emission of CO_2 in the transport sector of EU countries. This sector was the only one to increase GHG emissions by 27% in the 1990-2010 period. In Poland, CO_2 emissions from road transport grew from 26.52 million tons to 42.33 million tons between 2000 and 2014. In that period, the number of cars doubled and reached 20 million in 2014.[96] Analyzing emissions in different areas of the transport sector in the EU, it is worth emphasizing that road transport had the greatest share: 72.1% of total GHG emissions from transport (data as of 2010)[97]. Thus, the development of electric cars may help reduce CO_2 emissions, of course on the condition that electric cars will be powered with electricity produced in low or zero emission energy technologies. In the case of Poland, due to the high share of solid fuels in the structure of electricity production, assuming electricity consumption of 15 kWh/100km per electric car, we need to expect the growth of CO_2 emission by approx. 13 kg.[98] Practically the same CO_2 emission level occurs in the case of a combustion car

[95] J. Arbib, T. Seba, *Rethink X. Disruption, Implications and Choices. Rethinking Transportation 2020-2030*, 2017.

[96] Central Statistical Office, Environment 2016. Warsaw; www.stat.gov.pl (accessed: 1.06.2017).

[97] U. Motowidlak, *Polityka Unii Europejskiej na rzecz zwiększenia efektywności ekonomicznej i środowiskowej transportu [European Union's policy of enhancing energy efficiency and environmental efficiency of transport]. Part 2. Dekarbonizacja transportu [Decarbonization of transport].* Logistyka 3/2014 (accessed: 1.06.2017), pp. 4515-4523.

[98] http://samochodyelektryczne.org/porownanie_zuzycia_energii_samochodow_elektrycznych_z_2013r.htm (accessed: 1.06.2017).

(with an engine consuming 5.6 l/100 km of gasoline or 4.9 l/100 km of diesel oil)[99]. Obviously, in the case of older combustion cars with higher fuel consumption, which dominate in Poland, the levels of CO_2 emission are higher.

In accordance with an EU document, it is forecast that the share of CO2 emission from European transport in the total emission of the gas in the EU will go on growing and will reach 38% in the year[100] 2030 and almost 50% in 2050. This will be caused by a relatively small reduction of CO_2 emission from transport in comparison to other sectors, and especially the energy sector. It is anticipated that air and sea transport will be the branches responsible for the greatest dynamics of growth of CO_2 emission, by 150% and 110% respectively in the years 1990 – 2050.

Overcoming barriers connected with the development of electromobility and creating appropriate instruments of support will help develop electric vehicles. Research shows that fiscal measures, such as subsidizing the purchase of electric cars (e.g. in Germany), tax or fee exemptions, as well as benefits in the form of scrapping the old combustion vehicle (e.g. in the Netherlands or France) are one of the elements leading to electric vehicles becoming more popular. But enhancing social trust in electric vehicles will be of key importance. Electromobility will have an influence on the development of research connected with the use of new materials and contribute to creating new jobs, as well as affect geopolitics through changing oil demand. The development of electromobility will also require transformation in the regulatory environment of the electricity market. On the one hand, the need to extend electricity networks is emphasized, but on the other hand, there is a challenge connected with building an interactive market, where digitalization will play a significant role.

In the case of some EU countries it seems that a well developed market of fuels alternative to the traditional ones may be an extra barrier to the dynamic development of electromobility. For example, Poland with 2.914 million LPG vehicles is the European leader

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[99] http://www.kaizenfleet.pl/nowe_normy_emisji_spalin/ (accessed: 1.06.2017).

[100] Accompanying the White Paper - *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*, SEC(2011) 391 final, Brussels 2011.

in this regard and is the fifth country in the world in terms of LPG consumption in cars.[101] In Italy, in turn, the market of CNG (Compressed Natural Gas) is very well developed, with approximately 900 thousand vehicles powered with CNG. In the near future, apart from electric vehicles, we may also expect increased use of natural gas (CNG/LNG) as an alternative fuel in transport. But the direction and speed of development will surely mostly depend on price relations between natural gas, traditional fuels and electricity.[102]

[101] *Raport roczny 2015 [Annual report 2015],* Polska Organizacja Gazu Płynnego (POGP), Warsaw 2016, p. 11.

[102] Szurlej A., Ruszel M., Olkuski T., *Czy gaz ziemny będzie paliwem konkurencyjnym? [Will natural gas become a competitive fuel?]* Rynek Energii, 2015 no. 5, pp. 3–10.

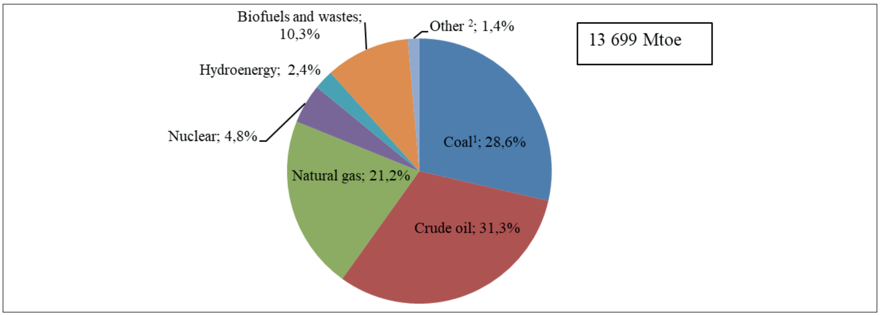
Chapter 4

The role of fossil fuels in energy transition

Lidia GAWLIK[103]

Technological development in the last century contributed to the improvement of mankind's living conditions. This development is indispensably connected with energy demand. The world was first fascinated by oil, then by nuclear energy, gas, and nowadays, by renewable energy sources. Coal has always been in the background, serving an important role in ensuring the security of supply and stability of prices.[104]

Chart 1. Global consumption of primary energy carriers in 2014



Source: author's study based on: IEA[105].
[1] *including the production of peat and oil shale;*
[2] *geothermal, solar, wind energy etc.*

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[104] L. Gawlik., E. Mokrzycki , R. Ney, *Acceptability of Coal – A Way to Energetic Safety,* Prace naukowe GIG. Górnictwo i Środowisko, special issue No. IV. 2008, Wyd. GIG, pp. 79–90.

[105] *Key World Energy Statistics 2016*, International Energy Agency, Paris 2016.

Fossil fuels' (coal, oil, and gas) share in global consumption of primary energy carriers is 81.2%. The structure of consumption of primary energy carriers in 2014 is presented in Chart 1.

Global primary energy consumption in 1973 was 6,115 Mtoe, which means that 41 years later the world is consuming more than twice (2.25 times) as much energy. At that time, the share of fossil fuels was 86.6%, including: coal 24.5%, oil 46.2%, natural gas 16.0%.

Between 1973 and 2014, the share of oil decreased by 14.9 percentage points, while the share of coal and natural gas grew.

Resources and production of primary energy carriers

In recent years (Table 1), there has been a constant growth in production of all fossil fuels: natural gas by 9.4% in 2015 as compared to 2010, oil by 9.0%, and coal by 6.0%. Coal and oil production slightly decreased in 2013. The data for 2015 are only preliminary, but on their basis we may conclude that the increase in fossil fuels production has slowed down (it was only +0.5% more than in 2014), which was the result of lowering coal production by 2.8%, accompanied by slightly greater increases in oil and gas production (+3.1% and 1.9%, respectively). Coal production decreased both in OECD countries and in China.[106]

Table 1. Global production of fossil energy carriers in the years 2010-2015

Fuel	Unit	2010	2011	2012	2013	2014	2015
Coal	Mt	7,229	7,783	7,831	7,823	7,925	7,709
Oil	Mt	3,973	4,011	4,142	4,117	4,200	4,331
Natural gas	bcm	3,282	3,388	3,435	3,479	3,524	3,590

Source: author's study based on: *Key World Energy Statistics,* International Energy Agency, Paris, issues of 2011-2016.

The use of fossil fuels is dependent on their availability. Regional preferences for their use result from the location of deposits of the resources.

Proved recoverable reserves of fossil fuels as of the end of 2015 are presented in Table 2.

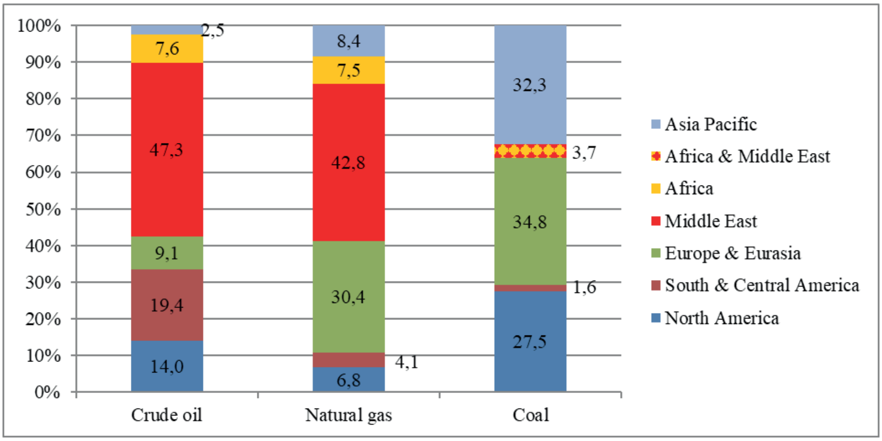
[106] *Key World Energy Trends, Excerpt from World Energy Balances,* International Energy Agency, Paris 2016.

Table 2. Proved recoverable reserves of fossil fuel deposits in the world

Fuel		Oil billion tons	Natural gas trillion m^3	Coal billion tons
Global resources		239.4	186.9	893.531
including:	North America	35.9	12.8	245.088
	Central and South America	51.0	7.6	16.641
	Europe and Eurasia	21.0	56.8	310.538
	Middle East	108.7	80.0	32.936
	Africa	17.1	14.1	
	Asia-Pacific	5.7	15.6	245.088

Source: author's study based on: *Statistical Review of World Energy*, British Petroleum, 2016.

Chart 2. Percentage share of each region in terms of oil, natural gas and coal



Source: author's study based on: *Statistical Review of World Energy*, British Petroleum, 2016.

47.3% of all global deposits of oil has been documented in the Middle East. In that region there is also 42.8% of the world's resources of natural gas, but no deposits of coal. In Europe and Eurasia the greatest resources of oil are in Russia (14 billion tons) and Kazakhstan (3.9 billion tons). Russia also has the largest resources of natural gas in the region (32.3 trillion m^3), followed by Turkmenistan (17.5 trillion m^3). The largest deposits of coal (hard coal and lignite) can be found in Europe and Eurasia, where Russian resources dominate as well (157 billion tons). In Asia and Pacific region there are 32.3% of global deposits of coal: mostly in China (114.5 billion tons), Australia (76.4 billion tons) and India (60.6 billion tons).

North America is a region rich in fossil fuels. It has 14.0% of the global resources of oil, 9.7% resources of natural gas, and 27.5% resources of coal (Chart 2). The USA is noteworthy in the region, with its 10.4 trillion m³ of natural gas and over 237 billion tons of coal. The biggest deposits of oil belong to Venezuela (47 billion tons) and Canada (27.8 billion tons).

Fossil fuels production (Table 3) is connected with the available resources, but also with their management and the level of development of the mining industry.

Table 3. Largest producers of oil, natural gas and coal in 2015 and their share in the global production of those energy sources

Oil			Natural gas			Hard coal and lignite		
Country	Production Mt	Share %	Country	Production Mt	Share %	Country	Production Mt	Share %
Saudi Arabia	572	13.2	USA	769	21.4	China	3,527	45.8
USA	567	13.1	Russia	638	17.8	USA	813	10.5
Russia	533	12.3	Iran	184	5.1	India	691	9.0
Canada	221	5.1	Canada	164	4.6	Australia	509	6.6
China	215	5.0	Qatar	164	4.6	Indonesia	469	6.1
Iraq	175	4.0	China	134	3.7	Russia	349	4.5
Iran	168	3.9	Norway	122	3.4	South Africa	252	3.3
UAE	160	3.7	Saudi Arabia	87	2.4	Germany	185	2.4
Kuwait	160	3.7	Turkmenistan	83	2.3	Poland	136	1.8
Venezuela	144	3.3	Algeria	82	2.3	Kazakhstan	107	1.4
Others	1416	32.7	Others	1163	32.4	Others	671	8.7
Total	4331	100.0	Total	3590	100.0	Total	7,709	100.0

Source: author's study based on: *Key World Energy Statistics 2016*, International Energy Agency, Paris 2016.

Ten countries produce more than two thirds of the world's oil; only three countries, Saudi Arabia with the production of 572 Mt in 2015, the USA (567 Mt) and Russia (533 Mt) account for 38.5% global production. The other OPEC countries (Iran, Iraq, UAE and Kuwait) combined produce another 663 Mt of oil.

Two countries are leaders in natural gas extraction: the USA (769 bcm) and Russia (638 bcm), and the group of ten largest producers provide 67.6% of the world's production of the fuel.

Coal production is dominated by China, which in 2015 extracted over 3.5 billion tons. Although that was a decrease in comparison with 2014 (3.65 billion tons), still it is almost half (48.5%) of global extraction. The ten biggest producers provide 91.3% of coal to world markets.

The reserves-to-production ratio (R/P), i.e., the amount of proved recoverable reserves divided by the amount of production in a year, shows that there is enough oil for 50.7 years (if it is extracted as intensively as in 2015), natural gas, for 52.8 years, and coal, for 114 years.[107]

The use of primary energy carriers

Primary energy carriers are mostly used to generate electricity (Table 4).

Table 4. Electricity production by energy carriers in selected years, TWh

Energy carrier	1973	2004	2013	2014
Coal[1]	2,348	6,944	9,633	9,707
Oil	1,520	1,170	1,028	1,023
Natural gas	742	3,419	5,066	5,155
Nuclear energy	203	2,748	2,478	2,535
Hydro energy[2]	1,281	2,808	3,801	3,906
Others[3]	36	361	1,316	1,490
Total	6,131	17,450	23,322	23,816

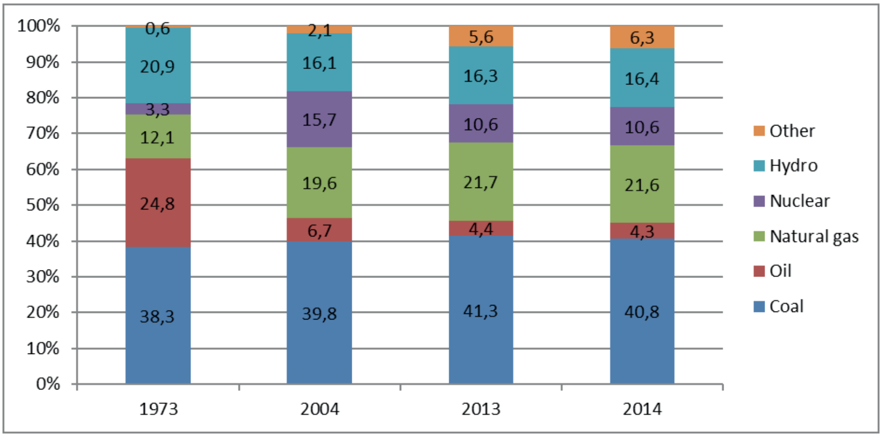
Source: author's study based on: IEA.[108]
[1] including all solid fossil fuels, also peat and oil shale,
[2] without energy from pumped storage power plants,
[3] renewable (geothermal, solar, wind etc.) and non-renewable (waste etc.).

[107] *Statistical Review of World Energy,* British Petroleum, 2016.

[108] *Key World Energy Statistics*, International Energy Agency, Paris, issues of 2006, 2015, 2016.

The increasing importance of coal and natural gas in electricity production is a constant phenomenon, and the use of oil is decreasing (Table 4). Within the last 40 years, there has been a 3.88-fold growth in global electricity production. The last decade (2004-2014) saw a 36% rise, and the highest increases in electricity production occurred in production from natural gas (51% increase in 2014 in comparison to 2004), with decreasing use of oil (-12.6%) and nuclear energy (-7.8%). In that period, electricity production from coal rose by approx. 40%, which means that coal is still the basic fuel to produce electricity globally, despite the small reduction of the share in fuel structure of electricity production in 2014 in favor of dynamically developing other (renewable) energy sources, especially wind energy (Chart 3).

Chart 3. Structure of energy carriers used in electricity production in selected years



Source: author's study based on: *Key World Energy Statistics 2016*, International Energy Agency, Paris 2016.

Global production of nuclear energy in 2014 was 2,535 TWh, accounting for 10.6% of the energy supply. It was the second year of slight rise in production after the extremely low production level in 2012 (2,461 TWh). The drop in nuclear energy production from approx. 2,760 TWh in 2010 was the result of a change in many countries' approach to nuclear energy after the tragic accident in Fukushima

(Japan) in 2011 caused by the enormous tsunami[109], which resulted in the greatest nuclear power plant disaster since Chernobyl).

As of the end of 2015, 390 GW of nuclear energy was functioning. In spite of some countries' declarations to discontinue nuclear energy production, at the end of 2015, 65 reactors with the total capacity of 64 GW were under construction[110]. New nuclear power plants are being built in China, India and Russia. The analysis of planned development shows that nuclear energy is going to develop in the Far East, whereas in North America and Western Europe the use of nuclear energy to produce electricity is going to gradually decrease. For rapidly developing countries such as China or India, nuclear energy is considered to be a good alternative to traditional energy based on fossil fuels due to its reduced emissions, and problems connected with the flexibility of the source, water consumption, and a supply of cheap energy will gradually be solved through technological development (small modular reactors, generation IV reactors, etc.).

Hydro energy is the traditional way of generating renewable electricity. Its share in global electricity production in 2014 was 16.4%, accounting for 72% of renewable electricity. The generating capacity of hydropower plants in 2015 reached 1,209 GW, including 145 GW of pumped storage power plants, which means an increase by more than 30% than in 2007. China has the highest number of hydropower plants (26% of global production capacity); the USA (8.4%), Brazil (7.6%) and Canada (6.5%) have much fewer. The unused global technical potential of water energy is estimated to be approximately 10,000 TWh, 72% of which is in Asia.[111] New investments are concentrated in China, Latin America, and Africa. We can expect that because of the growing use of RES, characterized by high changeability of operation, the potential of water energy will develop wherever there are appropriate conditions for it, being a flexible source stabilizing the work of electricity networks.

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[109] *The Fukushima Daiichi Accident. Report by the Director General,* International Atomic Energy Agency, Vienna 2015, http://www-pub.iaea.org/mtcd/publications/pdf/pub1710-reportbythedg-web.pdf

[110] *World Energy Resources/Nuclear* [in:] *World Energy Resources 2016*, World Energy Council, London 2016.

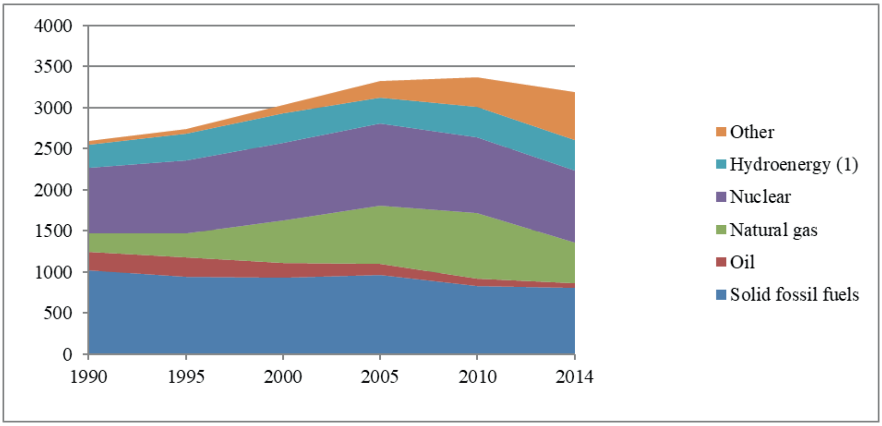
[111] *World Energy Resources/Hydro* [in:] *World Energy Resources 2016*, World Energy Council, London 2016.

A characteristic feature in recent years is the development of RES because of growing fears connected with climate changes resulting from the higher and higher emission of greenhouse gases to the atmosphere.

The latest 15 years have seen an unprecedented development of technologies connected with RES, especially wind energy. The huge market growth has caused the increase of new investments. Many new RES-based production capacities have been established. Lowering investment expenditure and operating costs has become a fact, and as a result, economic growth and GHG emissions, formerly linked, have been partially separated.[112]

In 2015, generating capacity in wind energy reached 432 GW (420 GW onshore and 12 GW offshore), which accounted for around 7% of global generating capacity. In 2015 alone, there was 63 GW of new wind installations, and the value of the wind energy market was US$ 109 trillion (2015).

Chart 4. Gross electricity production by fuels in the European Union (EU-28) in the 1990-2014 period, TWh



Source: author's own study based on data from: *Energy, transport and environment indicators*, Eurostat, Luxembourg 2016.
(1) without energy from pumped storage power plants.

Solar energy has had exponential growth over the last 10 years. In 2015, generating capacity reached 227 GW, producing about 1% of

[112] *World Energy Resources 2016, Summary*, World Energy Council, London 2016, http://www.worldenergy.org/publications/2016/world-energy-resources-2016/

the world's electricity. In solar heating and cooling systems, generating capacity reached 406 GW.[113]

The fuel structure of electricity production depends on the region and is the product of many factors, the most important of which is access to energy carriers, current and historical economic determinants, and the adopted direction of development. Chart 4 presents the fuel structure of electricity production in the European Union in the 1990-2014 period.

Two characteristic features make the fuel structure of electricity production in the European Union (Chart 4) different from the global structure (Table 4, Chart 3). First, in the European Union the growth in production of electricity has slowed down, or has even decreased. The reasons for the phenomenon are related to growing energy efficiency in the use of energy. Furthermore, in 2014:

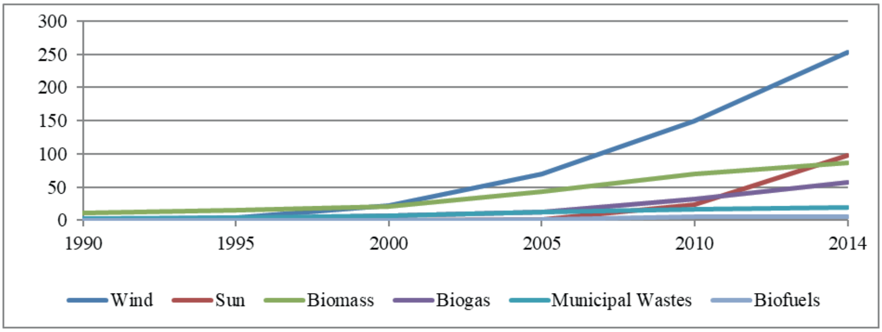
1) the share of solid fuels was 25.3%, whereas the global average was 40.8%, and coal consumption lowered by 15.8% as compared to the year 2005;
2) oil, with the share of 1.8%, became unpopular (just like in the global scale), but in the European Union the process of resigning from its use was much quicker;
3) the share of natural gas was 15.4%, far below the global average (21.6%), and its consumption fell by 44% as compared to the year 2010;
4) nuclear energy accounted for 27.5%, which means a decrease of its share by 4.6 percentage points as compared to 1995. The share of nuclear energy in Europe was significantly higher than the global average (10.6%);
5) the use of renewable water resources in hydropower was lower in the EU (11.8%) than globally (16.4%), although there was a little growth of electricity production in hydropower plants in comparison to the year 2005, when it had been very low (9.8%);
6) the share of other energy sources in electricity production was 18.3% – almost three times higher than the global average (6.3%), which points to the preferred direction of the Union's energy transition.

The European Union is the leading force in the development of electricity production from renewable energy sources (Chart 5), due to the

[113] *Ibidem.*

implemented and consistently applied climate package, and especially newer plans concerning climate protection to be implemented until 2030[114] and in the long-term perspective (Energy Roadmap 2050).[115] The wind energy industry is particularly dynamic. Within just four years (2010-2014), wind energy production grew by 70%. In 2015, in Denmark the share of production using wind turbines was 42% of total electricity production.[116] In Germany, after another year of growing production, wind energy accounted for a 13% share in electricity demand, and generating capacity reached 45.2 GW, giving the country third place among the biggest wind energy powers, after China (148 GW) and the USA (74.3 GW). The fourth place in terms of generating capacity of wind energy was India (24.8 GW), followed by EU countries: Spain (23 GW) and Great Britain (13.6 GW).[117]

Chart 5. Development of the use of renewable energy sources in electricity production in the European Union in the 1990-2014 period, TWh



Source: author's own study based on data from: *Energy, transport and environment indicators*, Eurostat, Luxembourg 2016.

[114] *Framework 2030: A 2030 framework for climate and energy policies. Green paper,* European Commission (EC). COM(2013) 169 final, http://cor.europa.eu/en/activities/stakeholders/Documents/comm169-2013final.pdf.

[115] *Roadmap 2030: Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions. Energy Roadmap 2050*, COM(2011) 885 final, European Commission (EC), http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0885&from=EN.

[116] *World Energy Resources/Wind* [in:] *World Energy Resources*, World Energy Council, London 2016.

[117] *Ibidem.*

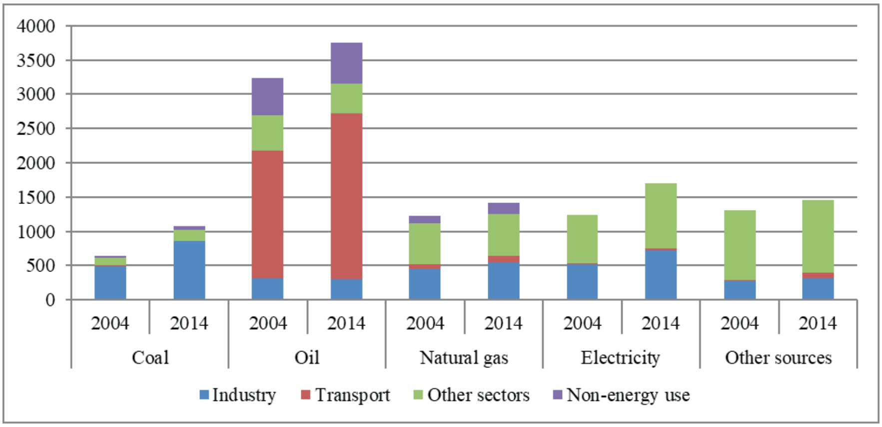
The final global energy consumption in 2014 was 9,425 Mtoe. The shares of final energy carriers in this amount were:

— coal and other solid fossil fuels – 11.4%,
— oil – 39.9%,
— natural gas – 15.1%,
— biofuels and waste – 12.2%,
— electricity – 18.1%,
— other final energy carriers (including geothermal, wind, solar and other kinds of energy) – 3.3%.

Thus, the share of fossil fuels (coal, oil, and gas) in final consumption is 66.4%, and an additional 18.1% is the consumption of electricity, 66.7% of which, globally, is a transformation product of fossil fuels.

Final consumption of primary energy carriers is presented in Chart 6.

Chart 6. Directions of final consumption of the main energy carriers globally in the years 2004 and 2014, Mtoe



Source: author's study based on: IEA.[118]

In the chart, 'other sectors' include all sectors of the economy except industry and transport, i.e., agriculture, commerce, public administration and households.

The final consumption of all energy carriers has grown within the last 10 years. The greatest increase occurred in the case of coal con-

[118] *Key World Energy...*, 2006, 2016, *op. cit.*

sumption (by 67.2%). The second quickest developing final energy carrier is electricity (37.7% increase). The final consumption of natural gas and oil has risen by 16.4 and 16.2%, respectively. The least increases were in other final energy carriers (11.6%). In this item, final energy from geothermal power, biofuels, biomass, sun, wind and waste (renewable and non-renewable) was aggregated.

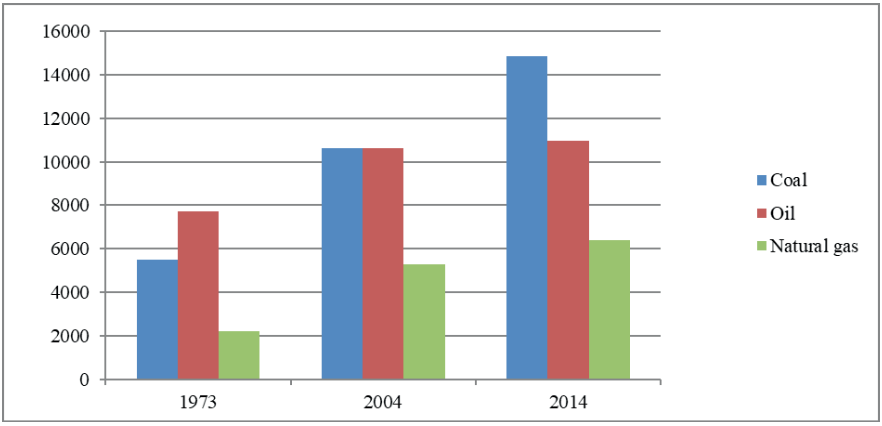
Within the analyzed 10 years, there was a clear tendency to change final energy consumption in transport. Although the share of oil and oil derivatives is still dominant (92% in 2014), it is lower than in 2004 (94%), because the increase in oil consumption (30%) is slower than the increase in natural gas (43%) and other carriers (five-fold increase).

Climate change vs fossil fuels

A problem that is inseparable from the use of fossil fuels is the fact that their extraction and use involves greenhouse gases emission to the atmosphere.

The global amount of emitted greenhouse gases is growing at a high rate. The main reason is the combustion of fossil fuels (Chart 7).

Chart 7. World emissions of carbon dioxide from fossil fuels combustion in selected years, millions of tons of CO_2



Source: author's study based on: *Key World Energy Statistics 2016*, International Energy Agency, Paris 2016.

If humankind do not take any new steps to reduce emissions, we should expect warming by 4.5°C before the end of the century, and the rise would be hard to stop in the next centuries, leading to disastrous consequences.

Target global warming by 2°C is regarded as the safety threshold. The scenario of reducing temperature growth by 2°C involves quick reduction of emissions, by 80-90% before the middle of the century and to zero in the second half of the century. This means the use of only approximately half of the fossil fuels used so far. The European Union has accepted the challenge, and in its plans described in Roadmap 2050[119] and finalized in agreements concerning activities taken before 2030[120] it declared the decarbonization of the Union economy, especially the energy industry. It also announced a binding objective of the Union, assuming the reduction of GHG emissions before 2030 by at least 40% in comparison to the level of 1990.[121]

The response of the rest of the world was not unambiguous, and negotiations continued at the next UN conferences on climate change. The agreement made in 2015 in Paris during COP21 is regarded as a breakthrough in international climate policy. The Paris agreement assumes that the parties will strive to stop the increase in warming and to maintain the temperature at about 1.5°C above the temperature from before the industrial age; the ways of conduct were agreed upon which took into consideration specific conditions of all the parties, and funds will be made available to allow low-emission development and counteract the effects of climatic changes.

Before the conference, 187 countries voluntarily commissioned themselves to reduce emissions, signing INDC (Intended Nationally Determined Contributions). These include the goals to be achieved in the 2020-2030 period. Achieving them would allow reduction of warming to 2.7-3.5°C before the end of the century, which is not enough. Hence, in the text of the agreement there were provisions on periodical reviews of performance of obligations every 5 years, begin-

[119] *Roadmap 2030..., op. cit.*

[120] *Framework 2030..., op. cit.*

[121] *Conclusions – October 23–24, 2014 . 2030 climate and energy policy framework,* European Council, EUCO 169/14, CO EUR 13, CONCL 5, 24.10.2014.

ning in 2023, so as to deepen them and make them enough to achieve the global goal of preventing warming below the agreed limit.

Another COP conference in November 2016 in Marrakesh did not give any significant progress, but it confirmed the wish of collaboration between countries to enable the performance of the Paris Agreement. It must be emphasized that among the signatories of the Paris Agreement there were countries that in their previous climate policy had not accepted self-limitation in terms of reducing greenhouse gases, e.g., China and the USA, but later on president Trump has withdrawn this promise.

Conclusion

Global intentions concerning energy transition and reduction of greenhouse gases emission will require changes in energy systems and the structures of consumption of primary energy carriers, which will be connected with the reduction of fossil fuels. The desired directions of development include particularly: increase in energy efficiency, energy saving, and the development of low emission technologies, with particular consideration of renewable energy sources. Technological development oriented at technologies that meet the conditions of emission reduction will require concentrating power and expenditure on research and development and will refer not only to the energy industry, but also to all other sectors of the economy, especially the transport sector. The growing market of electric cars is one example.

The requirement of emission reduction first eliminates coal as the highest emission fuel. There are even short-term plans to replace coal with gas (regarded as a fuel the combustion of which causes less emission of greenhouse gases) before energy production becomes fully no-emission.

Energy transition, understood as the application of innovative technologies to achieve sustainable social development thanks to ensuring energy availability while limiting negative effects to the environment, is a process that requires a comprehensive approach to production processes and the use of primary energy sources with consideration of conditions and interests of regional communities. Conditions differ from region to region and from country to country, so the ways to achieve low or zero emission economy are bound to differ, too.

Lowering the share of fossil fuels in the structure of primary energy carriers from the current 80% globally is inevitable, but it is not clear what level of reduction is really achievable. Some countries that traditionally use those fuels will rather invest in clean technologies of using fossil fuels than change all their economies to renewable energy sources.

Chapter 5

Prospects for RES and nuclear energy in the process of energy transition

Tomasz MŁYNARSKI[122]

In 2014, fossil fuels accounted for 82% of total primary energy production. Popularizing renewable energy sources (RES) and nuclear energy (together accounting for one third of global electricity production) as zero emission energy sources improves the transition processes towards a low emission economy based on energy sources without GHG emission. Energy transition brings certain economic benefits, not only connected with the improvement of air quality and limitation of the negative effects of coal production to the environment (the greenhouse effect) but also with the development of production of low emission devices and technologies as well as services that are the object of business and export strategies. In the 21st century, the main criterion for evaluating the usefulness of individual energy sources will not only be the ability to ensure long-term energy supplies but also their ecological properties. In 2015, more than 140 countries submitted their *Intended Nationally Determined Contributions* to the United Nations Framework Convention on Climate Change (UNFCCC), which altogether is expected to reduce the global CO_2 emission by 8% per capita by 2025 and 9% by 2030.[123] Many countries intend to reduce the role of fossil fuels and other non-renew-

[122] Tomasz Młynarski, PhD, Associate Professor in Jagiellonian University, Faculty of International and Political Studies, Institute of Political Studies and International Relations, Jagiellonian University, Kraków, e-mail: tomasz.mlynarski@uj.edu.pl

[123] *Renewable Energy and Electricity*, WNA, *November 2016*, http://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/renewable-energy-and-electricity.aspx (accessed: 12.15.2016).

able resources in their energy mix by means of replacing them with low emission energy sources such as RES and nuclear energy.

The role of RES in energy transition

As anticipated by the International Energy Agency (IEA), the development of renewable energy in many countries will raise its share in global electricity production from 23.7% in 2015 up to 1/3 in 2040.[124] International Renewable Energy Agency prognoses that as early as 2030, RES will achieve approx. 36-40% share in total electricity production of the world. Renewable energy sources are one of the fastest-developing methods of generating energy.[125] The year 2015 saw bothan increase in generation capacity (147 GW from RES added in 2015, which is the greatest increase in the history), and in the amount of energy generated using those technologies.[126]

The increase of RES share, especially in the sector of electricity, is promoted e.g., by improving the cost competitiveness of renewable technologies, better access to financing, expansion to new markets, i.e., the growing demand for renewable energy in developing countries, as well as the capacity for dispersed energy generation (energy production by small units connected directly to distribution networks or being part of the recipient's electricity network), usually producing electricity from renewable energy sources.[127] In 2015, worldwide electricity production was dominated by large sources of electricity

[124] World Energy Outlook 2014, IEA, p. 5; *Renewables 2016. Global Status Report*, Renewable Energy Policy Network for the 21st Century, p. 18; T. Młynarski, M. Tarnawski, *Źródła energii i ich znaczenie dla bezpieczeństwa energetycznego w XXI wieku [Energy sources and their importance for energy security in the 21st century]*, Kraków 2016, p. 128; *World Development Indicators: Electricity production, sources, and access*, The World Bank, http://wdi.worldbank.org/table/3.7 (accessed: 15.12.2016); *Renewables 2016. Global Status…*, p. 32.

[125] In 2014, RES provided about 19.2% of the final energy consumption (hydroelectric power plants provided 3.9%, and biomass, 8.9%), data from: Renewable Energy Policy Network, *Renewables 2016. Global Status …*, p. 28.

[126] *Ibidem,* p. 17.

[127] Dispersed energy generation is a dynamically developing sector of electrical engineering, which is characterized by lower power than professional generation units, private ownership, independence from central administration and integration with medium and low voltage grid.

(exceeding 1 MW) belonging to municipal companies or big investors. At the same time, markets of low capacity energy sources developed. Among them, Bangladesh is the leader (house solar systems) and other developing countries (Kenya, Uganda, Tanzania, China, India, Nepal, Brazil and Guiana), where small-scale RES are developing which provide electricity for residents living far from energy networks.[128] Global technical, economic, and market transformation of the energy sector is accelerating. In the second half of the second decade of the 21st century, more power in the electricity sector is generated annually from RES than from all fossil fuels. In favorable conditions (good environmental availability and legal regulations), electricity from water, geothermal energy, and some biomass sources was cost competitive to fossil fuels, even without encumbering the latter with externalities.

The growing share of RES in the global fuel and energy balance helps save the resources of fossil fuels, improve countries' energy security, and reduce greenhouse gases (GHG). According to the IEA, global production of electricity from renewable sources will grow by almost 45% before 2020.[129] The costs of generating energy from renewable energy sources are gradually decreasing. Between 2010 and 2015, average costs of onshore wind energy production dropped by approx. 30%, and of solar energy, by two-thirds.[130] The high level of subsidy is no longer necessary for the development of PV and wind energy, but the economic attractiveness of those energy sources is still dependent on a market regulatory framework.

In the third decade of the 21st century, the construction of new RES capacity will expand geographically (especially in countries beyond the OECD), and renewable technologies will become more cost competitive. This is confirmed by global investments in the years 2000-2013, 57% of which was power plants supplied with renewable energy sources, whereas fossil fuel plants 40%, and nuclear energy plants only 3%.[131]

This dynamic is especially visible in Asian countries (China, India, Japan, South Korea), where the development of new zero emission

[128] *Renewables 2016. Global Status…, op.cit.,* p. 18.

[129] *Renewable Energy. Medium-Term Market Report 2014*, Market Analysis and Forecasts to 2020, OECD/IEA, 2014, p. 4.

[130] *Renewable Energy. Medium-Term Market Report 2015*, Market Analysis and Forecasts to 2020 (Executive Summary), OECD/IEA, 2015, p. 5.

[131] M. Schneider, A. Froggatt, et al., *The World Nuclear Industry Status Report 2014*, Paris, London, Washington, D.C. 2014, p. 10.

capacities determines economic development, lowering the dependence on fuel importation. Whereas in the first decade of the 21st century Europe accounted for 40% of global RES investments, in the second one the main actor in the development of new RES capacities is China, responsible for nearly 40% of the global increase and over 60% of the increase in countries out of the OECD.[132] In 2014, China alone was responsible for 40% of the global increase of the potential of renewable energy sources (three times more than the aggregate value of RES capacity in Great Britain).[133] The region of the Middle East is also in an early, though also very dynamic, phase of development of renewable energy technologies (Saudi Arabia, UAE). In OECD countries the stable increase of RES will mainly be supported by the need to diversify energy sources and decarbonization policy, as well as decapitalization of conventional power plants' infrastructure.

In the EU, the increase of RES capacities in electricity production is dynamically growing, though solar systems have also been integrated with several urban heating systems (mainly in Western Europe). RES, however, especially fluid biofuels with a 4% share in the global fuel structure of the transport sector, do not play a crucial role. Although the popularity of electric cars is growing (the technology is even used in trucks), policy support for RES in the transport sector is much lower than policy support for RES in the sector of electricity production.

Decarbonization policy and the fight against global warming makes renewable energy one of the most dynamically developing areas of energy industry. RES are more and more widely used in four basic sectors: electricity production, heating and cooling, in transport, and as a source of energy in areas without a permanent energy infrastructure. The increase of RES is also dependent on the behavior of individual and industrial consumers, who more and more often buy electricity from renewable sources.

The development strategy of renewable energy is not only designed to improve energy security, but also to stimulate economies, including the creation of new eco jobs.[134] In 2015, employment in the RES sector

[132] *Renewable Energy. Medium-Term Market Report 2014, op.cit.,* p. 5., p. 8.

[133] *Renewable Energy. Medium-Term Market Report 2015, op.cit.,* p. 4.

[134] A. Jordan, D. Huitema, T. Rayner, H. van Asselt, *Governing the European Union: policy choices and governance dilemmas*, [in:] *Climate Change Policy in the European Union Confronting the Dilemmas of Mitigation and Adaptation?*, A. Jordan,

grew to approx. 8.1 million workplaces (direct and indirect), mainly in the segment of PV and biofuels (except big hydropower plants): mostly in China (3.52 million), Brazil (0.91 million), the USA (0.76 million), India (0.41 million), Japan (0.38 million) and Germany (0.35), and in the whole EU, 0.64 million).[135] In terms of all RES technologies, China, Brazil, the USA and India were the leading employers. The segment with the highest share of jobs in renewable energy sector all over the world is photovoltaics (2.8 million), the second, liquid biofuel production (1.67 million), and the third, wind energy (1.08 million). Approximately 1.3 million people were employed in the hydrological energy sector (mainly in China, 34%).[136]

Thus, the policy of energy transition is oriented toward economic goals, and in this context the policy of developing renewable energy sources is a relatively new but very dynamically developing field of economy in many countries, which intend to make use of their technological advantage on the global market. This way the policy of adjusting the energy sector to climate changes is becoming a catalyst to modernize economies, and leading to the emergence of a new sector of the "green" economy.[137]

In the following decades of the 21st century, RES are bound to gradually replace fossil fuels as a result of energy transition. The main advantages of renewable energy sources are their availability, the lack of costs of obtaining the resources/fuels, low costs of processing, as well as being non-exhaustible and natural environment-friendly (no emission when producing electricity) and the possibility to use wasteland such as coastlines or rocks. An important advantage of solar systems is that they are dispersed and can be launched close to the places of demand, reducing costs and losses of electrical current transfer from traditional power plants often located far away from the end customers.[138] The main drawback is the instability of energy generation (too

D. Huitema, T. Rayner, H. van Asselt, F. Berkhout (eds.), Cambridge University Press 2010, pp. 29-50.

[135] *Renewable Energy and Jobs Annual Review 2016*, IRENA, p. 5, p. 11.

[136] *Ibidem, p.* 9.

[137] The opportunity to use hydrogen on the large scale as a transport fuel in the future increases the potential both of renewable energy sources and of electricity supplies.

[138] In Germany, 1.5 million solar PV installations with the capacity of 40 GW supplies 940 equivalent hours of full electricity load annually. On working days in the summer, it covers 35% of German grid demand, and at weekends, almost 50%.

low or too high wind speed, clouds). Clouds for example can reduce energy production by 70% in a minute, which is a serious problem in integrating solar systems with the standard grid. Innovative battery systems have reduced the loss to 10% per minute. Therefore, batteries or other energy storage technologies are necessary in order to use solar and wind energy in individual systems. Over the last two decades, wind turbines have developed considerably, and photovoltaic technologies are more and more effective and efficient. Significant progress in the storage of energy generated from renewable sources is also visible. Along with governmental encouragement to use these energy sources, their costs have dropped and are currently comparable to the costs of fossil fuels if we take into account the charges for CO_2 emission. But there is a problem with periodic production of large amounts of electricity, which causes difficulties with maintaining the economic reliability and profitability of the whole system. Therefore, large-scale use electricity from solar and wind energy in main grids is difficult. So in order to use RES in standard grids it is necessary (due to quickly changing weather conditions, especially in the case of solar and wind energy) to ensure an extra source (back-up) with high availability. This means that it should be able to start operations quickly so as to make up for changes in energy production. So the basic condition of popularizing RES in the process of electricity production is to use them in such a way that they will meet the demand (especially at peak moments), taking into consideration its changeable character and dispersed nature.[139]

The role of nuclear energy in energy transition

Nuclear energy supplies a significant part (11% in 2015) of global electricity production in a way that is neutral to the problem of greenhouse effect.[140] It is a reliable zero emission high power source of energy

[139] Hydroelectric power plants are able to respond to seasonal and daily changes in energy demand by regulating the amount of water flow. Another source may be gas power plants, quick to use. *Renewable Energy and Electricity*, WNA, November 2016, http://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/renewable-energy-and-electricity.aspx.

[140] Nuclear energy is treated as separate from renewable sources, because reactors use mineral fuel (uranium ores) and clearly exhaust the available uranium resources,

(the lowest emission of greenhouse gases in the whole life cycle out of all the energy production sources), so it can play an important role in mitigating the effects of climate change. The Director General of *World Nuclear Association XXX* put it this way: *"We must meet the world's growing energy needs and protect the planet. We will need all low carbon energy options to work together to achieve this, and nuclear will make a major contribution, because it is scalable, reliable and competitive."*[141]

According to World Energy Outlook 2016, in order to reduce the growth of temperature all over the world below 2°C it is necessary to ensure the increase of nuclear production capacity by nearly two and a half times by 2040 (so as to obtain electricity production growth in nuclear power plants from 2535 TWh to 6101 TWh).[142] This means that approximately 80% of electricity generated all over the world should be low-emission. It is a global challenge, which requires the use of all the available low-emission technologies.[143] Therefore, the nuclear industry has set itself the goal of tripling its production capacity up to over 1,000 GW on the basis of new facilities by 2050, so that nuclear energy would meet 25% of the global demand for electricity.[144] France, Switzerland, and the Ontario province in Canada have created a model of low-emission *energy mix* in the electricity sector, achieving more than 80% of the produced electricity from nuclear energy, developed in harmony with renewable sources.[145]

According to IEA, by the middle of this century, the number of countries that use reactors will grow from 31 to 36. As the number of

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but in the future they will use again the combusted fuel, so they will achieve the "renewability" effect. Moreover, common elements such as thorium are more and more often used as a fuel.

[141] *Nuclear key to a clean energy future: IEA World Energy Outlook*, WNA, 16 November 2016, http://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/nuclear-key-to-a-clean-energy-future-iea-world-ene.aspx (accessed: 12.10.2016).

[142] Ibidem.

[143] Nuclear for Climate, http://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/nuclear-forclimate.aspx (accessed: 10.11.2016).

[144] *Nuclear must be part of the international response to climate change*, 17 November 2016, http://www.world-nuclear.org/focus/climate-change-and-nuclear-energy/nuclear-must-be-part-of-the-international-response.aspx

[145] *Ibidem*.

countries introducing nuclear energy exceeds the number of countries that discontinue its use[146], nuclear reactors may contribute to the reliability of the energy system – especially where they increase the level of technological diversification. For energy-importing countries this may reduce their dependence on supplies from abroad and their sensitivity to changes in fuel prices on the international market. Energy transition also gives real socio-economic benefits, such as the mitigation of effects of climate change or the improvement of health conditions. For these reasons, the environmental benefits of developing nuclear energy involve the reduction of harmful emissions, as nuclear power plants do not emit any greenhouse gases or pollutants (ashes, dust) into the atmosphere. Within the last 45 years (since 1971), the equivalent of two years of total global emission of carbon dioxide (almost 80 tons of CO_2) has been avoided thanks to NE.[147] If conventional power plants were to be replaced by nuclear ones to produce the same amount of energy, 2,581 tons of CO_2/GWh would be saved in comparison to lignite, 1,773 tons of CO_2/GWh in comparison to oil, and 1,183 tons of CO_2/GWh in comparison to natural gas combustion.[148] Just like in the case of RES, common application of nuclear energy in the global scale allows a substantial reduction of dependence on the three main fossil fuels (coal, oil, and natural gas) in total consumed energy, and as a result, the reduction of greenhouse gas emissions. Replacing fossil fuel energy with renewable energy sources or nuclear energy is going to result in similar reductions of greenhouse gases.[149] IEA forecasts that in 2014, the annual reduction of emissions will be almost 50% in South Korea, 12% in Japan, 10% in the USA, 9% in the European Union, and 8% in China.[150] The mean cost of emissions avoided thanks to new nuclear capacities depends on the mix and fuel prices (and it may be from very low up to over 80 dollars per ton).

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[146] *World Energy Outlook 2014*, IEA, p. 7.

[147] *Ibidem,* p. 6.

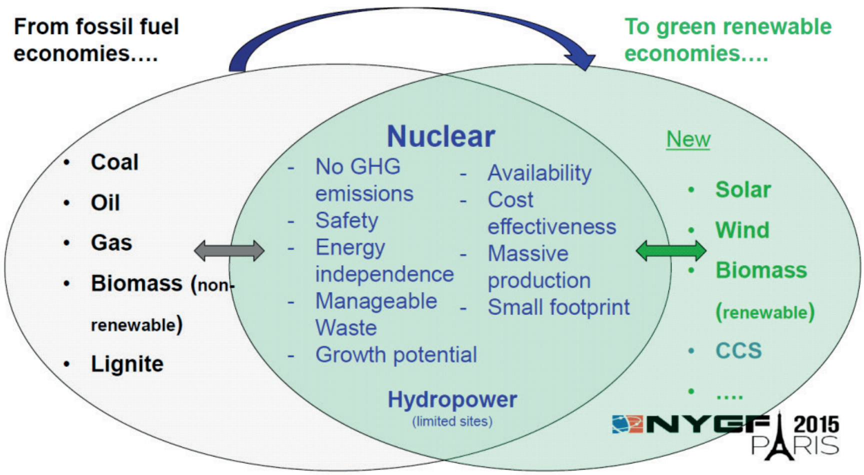
[148] *Greenhouse gas emissions avoided through use of nuclear energy*, http://www.world-nuclear.org/nuclear-basics/greenhouse-gas-emissions-avoided.aspx (accessed: 10.11.2016).

[149] According to the *World Nuclear Association*, comparing emissions from the life cycle of nuclear energy and renewable energy (all the main kinds of renewable energy sources: solar, wind, biomass, hydropower plants), we can see they are all on a comparable level.

[150] *World Energy Outlook 2014*, *op. cit.,* p. 6.

More than 52% of the world's fleet of nuclear reactors are over 30 years old, so by the year 2040, about 200 out of 450 reactors all over the world (2016) will be removed (most of them in Europe, the USA, Russia, and Japan). For these reasons, nuclear energy will rather play an intermediate role in the process of energy transition before the share of renewable sources in the global energy mix grows considerably (Fig. 3)[151] Nuclear energy will be a very dynamically developing sector of industry in the nearest 20-40 years, mainly in Asia (China, India, Japan, South Korea), which is especially important, as the region accounts for 40% of global CO_2 emissions (2014).[152] In 2016, in China and India 40% of the world's reactors were under construction.[153]

Figure 3. Energy sources in energy transition



Source: M. Tripathi, *COP21, challenges and opportunities*, European Nuclear Young Generation Forum 2015.

Energy transition improves energy independence and the flexibility of the energy system. Diversification of energy sources helps improve energy security of the country that applies it. In this sense

[151] IAEA 2015, www.iaea.org.

[152] *CO_2 emissions from fuel combustion*, OECD/IEA, 2016, p. 12.

[153] *The Database on Nuclear Power Reactors*, IAEA Power Reactor Information System, https://www.iaea.org/pris (accessed: 10.11.2016).

nuclear energy can be treated as a domestic source of energy, which was emphasized in May 2008 by the contemporary president of the European Commission, José Manuel Barroso, at the European Nuclear Energy Forum in Prague: *"But in addition, nuclear energy, as one of the cheapest low carbon energy sources and with less vulnerability to fuel price changes than some other energy sources, can help protect our economies against price volatility"*.[154] The nuclear energy industry also ensures measurable short-term and long-term economic benefits connected with the creation of new jobs and economic growth. Obviously, nuclear energy does not generate as many jobs as traditional energy production, but it promotes development of highly qualified specialists, whose resources can be used in other areas of the economy. Nuclear power plants are usually constructed in poorly populated and economically developed places. Therefore, they generate an increase in employment in the region, an influx of new residents and financial profits from taxes, as well as the development of local service infrastructure. Nuclear industry fosters research, supporting the modernization of many areas of industry (construction, machinery, electrical or chemical), and highly qualified researchers can support the national economic system in other areas (medicine, nuclear chemistry, environmental engineering, automatic control, electronics or IT).

Conclusions

— The future of the world energy industry lies in the use of varied low emission technologies ensuring the security of supply with a minimum impact on the environment. An important role in the process will be played by renewable energy and nuclear energy as zero emission sources of electricity. Nuclear energy may also significantly support the efforts connected with ensuring energy supplies while reducting greenhouse gases emissions and supporting sustainable development. For these reasons, many countries are considering the development of nuclear energy in the process of energy transition.

[154] J. M. Barroso, *Address to the European Nuclear Energy Forum*, SPEECH/08/259, Nuclear Energy Forum, Prague, 22 May 2008, http://europa.eu/rapid/press-release_SPEECH-08-259_en.htm (accessed: 10.12.2016).

— The need to change an economy into a low emission one is connected with gradual reduction of the role of the fossil-fuel-based energy industry. Despite benefits offered by conventional energy industry (high energy value of conventional fuels, familiar technology, or advanced system of extraction – transfer – storage system), high emission of greenhouse gases is its basic disadvantage. Therefore, countries should be given the opportunity to choose from the whole spectrum of energy technologies reducing CO_2 emission. This provides an opportunity for nuclear energy, which is characterized by low emission, availability, and competitiveness.
— IEA assumes that the basic source of low emission electricity production in the 21st century will still be renewable energy sources and nuclear energy, which contribute greatly to the process of transition of the energy system in the face of the need to counteract climate change. The transition in the energy sector, which is the source of two-thirds of greenhouse gases emissions, is necessary to achieve the goal of inhibiting the increase of CO_2 emissions globally. It requires the acceleration of implementing renewable energy sources, and wherever it is politically and socially acceptable, also nuclear energy, as the two basic sources of energy without GHG emission.
— Preventing climate chang through promoting a low-emission economy means adjusting economic policy through technological innovations which will ensure progress in achieving environmental goals and economic benefits, including the formation of new eco jobs. The development of RES and nuclear energy may contribute to eliminating the relationship between economic growth and emission growth. In addition, the prospect of growing costs connected with CO_2 emissions in developed countries in the future will considerably change the economic perspective of no-emission energy sources.

Chapter 6

Energy efficiency

Tomasz MIROWSKI[155]

Energy transition is identified with a change from fossil fuels to low emission energy sources. It means replacing previously used energy carriers and saving fuels and energy as well as improvement of energy efficiency through certain activities. Lowering the concentration of greenhouse gases and other harmful pollutants in the air requires a fundamental transformation of the energy supply system, including the replacement of fossil fuels with alternative energy sources and technologies such as renewable energy sources, nuclear energy, or clean coal technologies – CCT.[156] At the same time, technologies capturing CO2 emission from exhaust fumes through CCS cause a number of application problems, have operation faults, and involve different risks. But first of all, they are very expensive in relation to other ways of lowering CO_2 emissions, such as e.g., improvement of energy efficiency, substitution of input fuel, or some kinds of RES.[157] This part of the chapter presents the approach to energy efficiency as one of the instruments for reducing the consumption of energy resources and the emission of greenhouse gases.

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[156] T. Młynarski, *Energetyka jądrowa wobec globalnych problemów bezpieczeństwa energetycznego i zmian klimatu w XXI wieku [Nuclear energy vs global challenges of energy security and the non-proliferation regime in the age of climate changes]*, Bezpieczeństwo. Teoria i praktyka, Kwartalnik Krakowskiej Akademii im. A.F. Modrzewskiego, Kraków 2016, no. 1 (XXII), pp. 17-28.

[157] L. Gawlik, D. Kryzia, M. Pepłowska, *Uwarunkowania rozwoju czystych technologii wytwarzania energii z paliw kopalnych [Determinants of the development of clean technologies of energy production from fossil fuels]*, Polityka Energetyczna, 2016, Vol. 19, part 4, pp. 63-74.

The concept of energy efficiency and the ways of its improvement are sometimes erroneously identified only with the performance of energy equipment and activities aimed to improve it. An extended definition of energy efficiency proposed in the work explains the concept fully[158]: *Energy efficiency is lowering primary energy consumption at the stage of voltage change (energy transformation), transfer, distribution, or final energy consumption, caused by technological changes, changes in behavior, or economic changes, ensuring the same or a higher level of comfort or services. Solutions increasing the effectiveness of final energy consumption reduce both the consumption of energy consumed by end users and of primary energy.*

The definition of energy efficiency in Polish law (Act of 2016) is formulated for the needs of trade mechanisms with energy efficiency certificates (so-called white certificates) discussed further in the chapter. The definition is as follows: *energy efficiency is the ratio of the obtained operational effect of the facility, technological device, or installation in typical conditions of operation or use, and the amount of energy consumed by the facility, technological device, or installation, or as a result of the provided service necessary to achieve that effect.*

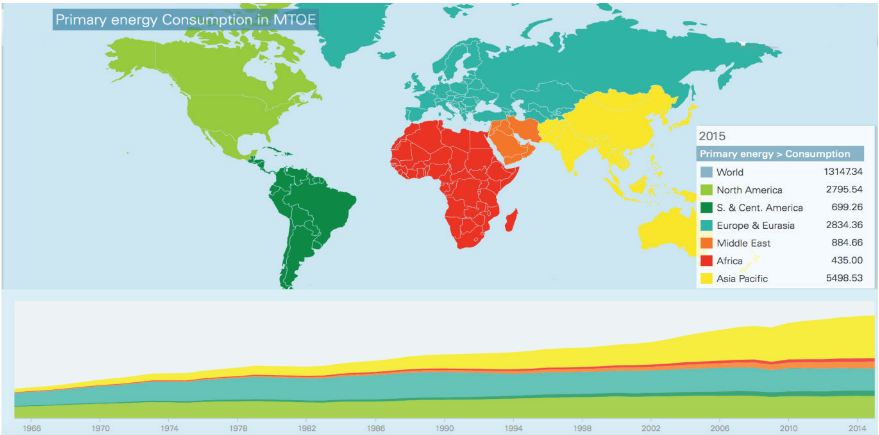
Global primary energy consumption

Global primary energy consumption grew from 3,730 Mtoe in 1965 to 13,147 Mtoe in 2015, more than a three-and-a-half-fold increase within half a century (Fig. 3).

The accumulated rates of increase of primary energy consumption per capita also display high dynamics, especially in Asian and Middle East countries. Chart 8 presents the percentage increment of the consumed primary energy represented on the left axis by world regions (bars). The lines (curves) represent energy consumption per capita in the regions expressed as accumulated increase toe/person in percentage. Comparing data concerning the demand for energy and demographic changes within the latest 50 years, we can see a kind of relationship. In places where population is dynamically growing, energy consumption

[158] T. Skoczkowski, *Wprowadzenie do efektywności energetycznej. Inteligentna energia. Efektywne zarządzanie energią w małej i średniej firmie [Introduction to energy efficiency. Intelligent energy. Effective energy management in a small or medium-sized enterprise]*, KAPE, Warsaw 2009.

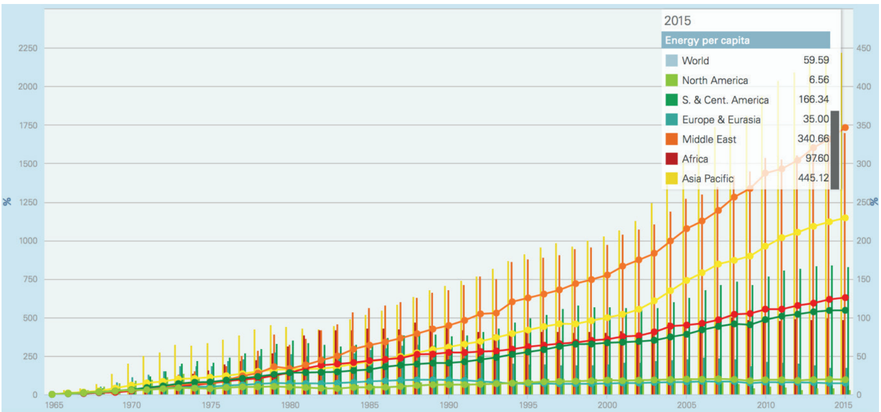
Figure 4. Global and regional primary energy consumption in the years 1965-2015 in Mtoe



Source: *Statistical Review of World Energy*, British Petroleum, 2016, www.bp.com (accessed: 09.12.2016).

per capita is also increasing.[159] Economically developed regions, such as North America or Europe and Eurasia, have maintained a similar stable level over the last five years, with a downward tendency.

Chart 8. Accumulated increase in primary energy consumption (left axis) and energy per capita (right axis) for world regions in the years 1965-2015



Source: *Statistical Review of World Energy*, British Petroleum, 2016, www.bp.com (accessed: 09.12.2016).

[159] *Population growth database*, World Bank, http://data.worldbank.org (accessed: 14.12.2016).

Governments intend to reduce primary energy consumption through saving, and to reduce final energy at the user through modern energy technologies and energy management techniques.

EU energy efficiency policy

The future of energy is more and more often discussed due to the prospect of exhaustion of fossil fuels and climate changes connected with the emission of gases during their combustion with growing energy consumption per capita. After the European Union announced the so-called climate package, governments of member states intensified their work on setting the direction of development of the national energy industry. Documents included in the package (colloquially called “3x20”) set the activities to take in order to meet the three basic assumptions by 2020. The main aim is to increase energy efficiency by 20% in comparison to a scenario which does not involve any activities in this regard. It is so important because all the goals are interrelated, and the improvement of effectiveness is of key importance for meeting the other obligations. The other assumptions of the package are to increase the share of renewable energy sources and to decrease the emission of greenhouse gases. After negotiations at the national level, quantity targets were decided for each member state, which will allow the whole EU to meet the goal. The base year was negotiated individually by selected (developing) countries to which the reduction of greenhouse gases emission applied. Developing countries have a higher share of the industry sector in the national economy, so they emit more greenhouse gases into the atmosphere. Imposing on them the same requirements as on developed countries could lead to inhibiting national economies, and thus, development. The assumptions of the climate and energy package are also the main goals of the “Europe 2020” strategy aimed at intelligent, lasting and social inclusion-promoting economic growth (Komorowska A., 2016). For that purpose, activities have been taken to limit greenhouse gas emission through the introduction of the Emissions Trading System (ETS) which is the European Union’s priority system for limiting greenhouse gases emission from industrial installations, transport, and big power plants. New investments in low emission technologies promoted by the ETS are also an example of activity aimed at improving energy efficiency in the main sectors of the economy of every country. ETS refers to 45% greenhouse gases emitted in the European Union. According to the strategy "Europe 2020", those emissions should be reduced by 21% before the year 2020. The year 2005 was adopted as the base year. The remaining 55% of greenhouse gases are emitted in the sectors of housing, agriculture, and waste management. National emission reduction targets were established in order to reduce them. The scope of intervention differs depending on the level of economic development and affluence of the country. The most developed countries are obliged to reduce GHG emissions by 20% before 2020, and less developed ones may increase the emissions by 20% at the maximum. Another activity of the European Union is the support for renewable energy. The objectives in this regard have also been divided depending on the capacity for renewable energy production and the initial position of member states. The last but not least area supported by the European Union is energy efficiency.[160]

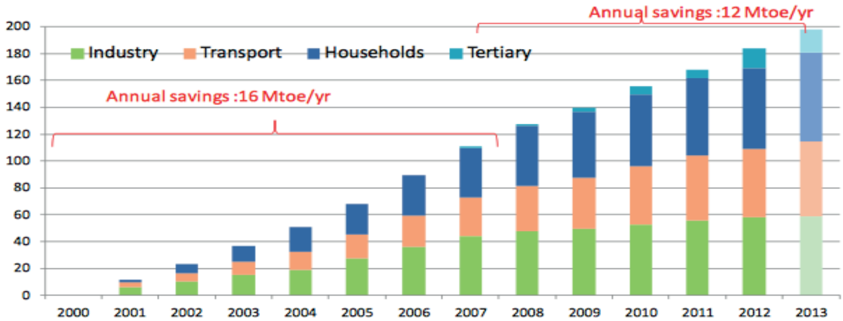
Two indices are used to evaluate the improvement of energy efficiency in member states' economies. These are GDP energy intensity, i.e., the ratio of GDP to energy consumption, and the ODEX index. ODEX is an aggregated energy efficiency index of the end consumer. It has been introduced to monitor the energy efficiency of EU countries. It has a simple methodology behind an understandable, simple and comparable index to illustrate progress in the energy efficiency of member states. ODEX indices are useful in monitoring the achievement of the indicative objective of energy efficiency determined in Directive 2006/32/EC. There are two alternative methods of computing ODEX. The first of them is aggregation based on the effect of unit consumption, combining the progress in energy efficiency achieved in all the subsectors based on the amount of saved energy in Mtoe: it is based on "the effect of unit consumption". The other method ("weighted average method") weighs a separate index of unit consumption of each subsector on the basis of its share in the energy consumption of

[160] A. Komorowska, T. Mirowski, *Mechanisms to improve Energy efficiency in the context of the objectives of climate and Energy package*. Humanistas and Social Sciences, 2017, HSS-24-(x-2017) (in printing).

the whole sector.[161] The disadvantage of this index is that it does not show the current level of energy intensity but progress as compared to the base year.

Energy savings in the EU in 2013 are estimated to be approx. 200 Mtoe. In other words, without energy saving, the consumption of final energy would be 200 Mtoe (or 19%) higher in 2013 than in 2000. If we compare the amount of energy saved this way with the energy of natural gas consumed in Germany, we can see it is the equivalent of 3 years' gas consumption (2013-2015). For Poland, the saved energy is equivalent to almost 15 years of natural gas consumption (2001-2015). As a result of the economic crisis, the annual rate of energy consumption in the EU has dropped to 12 Mtoe/year, as compared to 16 Mtoe/year before the crisis. In 2013, approximately 33% of the savings was in the sector of households, 30% in industry, 28% in transport, and 9% in services. In 2012, the amount of saved energy was 180 Mtoe for the whole EU as compared to the year 2000, which is equivalent to 17% of the energy consumed by the end customers. Chart 9 presents the accumulated values of energy saved in EU countries divided into two periods: before the economic crisis (2000-2007) and after the economic crisis (2007-2013).

Chart 9. Energy savings in the EU by sector



Source: Odyssee-Mure, *Synthesis: Energy Efficiency Trends and Policies in the EU. An Analysis Based on the ODYSSEE and MURE Databases*, Fraunhofer ISI Germany and ENERDATA France, September 2015.

[161] *System Monitorowania Rozwoju [Development monitoring system]*, Strateg 2017, www.strateg.gov.pl (accessed: 07.12.2017).

Improvement of energy efficiency illustrated with the example of selected EU countries

In order to increase energy efficiency, some mechanisms of activity have been established and included in Directive 2012/27/EU.[162] Each member state should establish its own system of energy efficiency obligations. It obligates both the distribution sector and the energy sales sector to meet the combined energy saving target by the end of 2020. An alternative to this system is to implement other ways of improving energy efficiency, allowing countries to meet the end customer targets of energy saving. The following energy efficiency policy instruments can be applied[163]:

— taxation of energy or CO_2, leading to end customers reducing energy consumption,
— financial plans and instruments or tax incentives, which result in the introduction of new, energy effective technologies and lead to the reduction of energy consumption by end customers,
— regulations or voluntary agreements that lead to the application of energy effective technologies or techniques and result in lower energy consumption by end customers,
— norms and standards aimed at the improvement of energy efficiency of products and services, including buildings and vehicles,
— energy marking systems,
— training and education, including energy advisory programmes, which lead to the application of energy effective technologies and result in lower energy consumption by end customers.

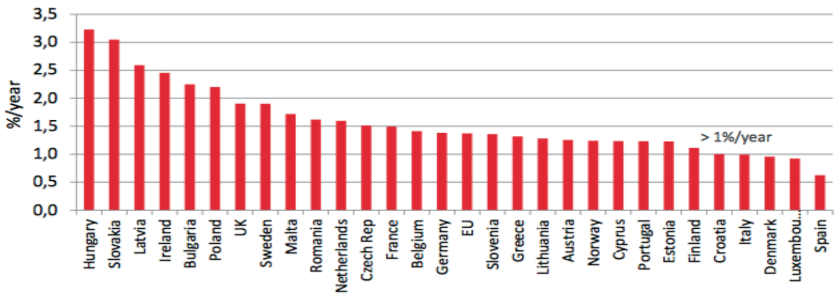
The improvement of energy efficiency since 2000 is the highest in 6 EU countries (Hungary, Slovakia, Latvia, Poland, Bulgaria and Poland), exceeding 2%/year (Figure 4). In the other 20 countries, the improvement has been between 1% and 2%/year. This does not mean that countries such as Germany, Luxembourg, Denmark or Italy do not have energy policies promoting the improvement of energy efficiency. In those countries the living standard is much higher, thanks

[162] Directive of the European Parliament and of the Council 2012/27/EU of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

[163] A. Komorowska, T. Mirowski, *Mechanisms to improve Energy..., op.cit.*

to which in the households and services sectors and partially, the transport sector, a high level of savings was achieved in the 1990s. Decarbonization in EU-15 countries through the replacement of coal-based energy technologies with nuclear power plants and RES led to the situation in which savings at the level of the countries of the "new Union", e.g., Poland, are impossible.

Chart 10. Progress in energy efficiency in different countries (without the services sector)



Source: Odyssee-Mure, *Synthesis: Energy Efficiency Trends and Policies in the EU. An Analysis Based on the ODYSSEE and MURE Databases*, Fraunhofer ISI Germany and ENERDATA France, September 2015.

Poland

In Poland, energy saving was included in the assumptions of Polish Energy Policy until 2030. Since 2005, most of the planned activities concerning energy efficiency have been carried out or at least commenced:

— support for cogeneration on the basis of utility heat demand on the internal market (implementation of Directive 2004/8/EC) through the introduction of a system of certificates of origin from cogeneration, also applying to natural gas energy (so-called red and yellow certificates),
— review of energy intensity of selected branches of economy and the possibility to reduce energy losses in the national electricity system; the results of these analyses were used when developing system solutions concerning the reduction of energy intensity of economy,

- launching an information campaign by the Ministry of Economy promoting rational energy use,
- implementing Directive 2002/91/EC on the energy performance of buildings, promoting pro-efficiency activities, in particular thermomodernization,
- implementing Directive 2006/32/EC on energy end-use efficiency and energy services,
- adopting the Act of 15.04.2011 on energy efficiency (Journal of Laws No. 94, item 551 as amended), which set the national objective of economical energy management, tasks of public sector entities in this regard, the rules of obtaining and redemption of energy efficiency certificates and rules for performing an energy efficiency audit.

The currently applicable Act on energy efficiency of 20 May 2016 (Journal of Laws of 2016, item 831) points to three basic areas in which measurable effects of energy efficiency improvement can be obtained with the use of appropriate instruments. These are the white certificates system, energy efficiency audits in enterprises, and energy management systems. Energy efficiency certificates, (so-called white certificates) are a mechanism that stimulates and enforces pro-saving behaviors. The Act on energy efficiency imposed the obligation to obtain and submit for the President of the ERO a certain number of energy efficiency certificates for redemption or to pay a substitution fee. The obligation lies with:

- energy enterprises that sell electricity, heat or natural gas to end customers connected to the grid within the Republic of Poland (RP),
- end customers connected to the grid within the Republic of Poland that are members of the mercantile exchange, as regards transactions made individually on the mercantile exchange,
- commodity brokerage houses or brokerage houses, as regards transactions made on the mercantile exchange at the order of end customers connected to the grid within the Republic of Poland.

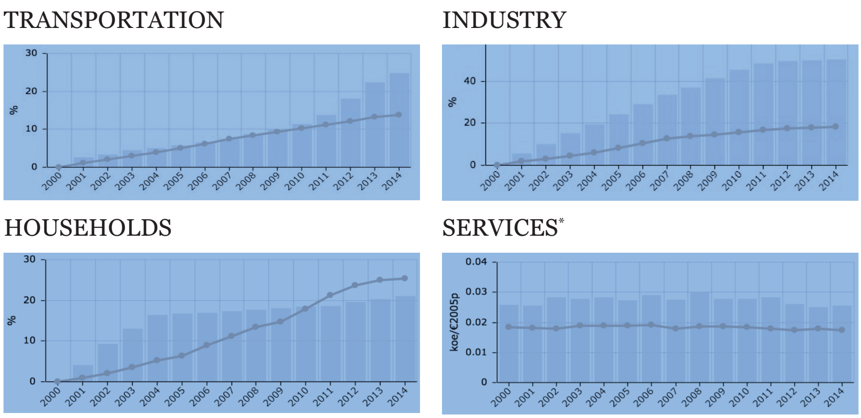
Energy efficiency certificates and their redemption are administered by the President of the Energy Regulatory Office, and the property rights resulting from them are transferable, being an exchange commodity tradable on power exchange. This market mechanism makes it possible to obtain energy saving in three areas:

— end customers,
— own equipment of energy producers and suppliers,
— reduction of losses of electricity, heat or natural gas in transfer or distribution.

For the three above-mentioned project categories aimed at improving energy efficiency, the President of the ERO organizes at least three times a year tenders for projects used to improve energy efficiency for which energy efficiency certificates (white certificates) can be granted. They can be received for already carried out pro-efficiency activity (completed after 01/01/2011) or for an activity that is planned. An energy efficiency certificate can be received for an activity as a result of which annual primary energy saving is at least 10 toe, or for a group of activities of the same kind, whose combined effect exceeds 10 toe.[164]

Table 5 presents the latest ODEX indices for Poland in the 2000-2014 period as compared to the mean of EU countries.

Table 5. Increase of energy efficiency in the main sectors since 2000 in Poland and EU countries



Source: Odyssee-Mure, on-line database: http://www.indicators.odyssee-mure.eu/online-indicators.html (accessed: 27.01.2017).

Although the efficiency of energy use in Poland has improved a lot in recent years, further measures are needed to reduce the distance from the mean value obtained by EU countries. Industry has had the

[164] Website devoted to energy efficiency, Energopomiar, 2016, www.bialecertyfikaty.com.pl (accessed: 11.11.2016).

greatest share in reducing energy intensity. However, changes in the sector require high costs and are introduced slowly, usually if there are financial benefits to be achieved. The most important sectors in which energy efficiency needs to be improved in Poland are residential construction and transport. Anywhere that the consumption of energy from fossil fuels is lowered or replaced with renewable sources, energy efficiency is improved. In construction energy consumption can be cheaply reduced. Thermomodernization and conversion of heating technologies powered by fossil fuels into RES systems (solar collectors, biomass boilers, heat pumps, photovoltaic panels) contribute to the improvement of energy balance in the municipal and residential sector. It is worth remembering that the changes are largely dependent on the participation of individual customers, so any changes reducing primary energy consumption are beneficial. That is why so much attention has been given to rational energy use recently. Information programmes, device marking, subsidies to RES systems, and stimulating energy consumption by price diversification (dedicated tariffs) are designed to develop the habit of saving energy in citizens.

The situation in transport regarding energy efficiency is slightly different. In this case, apart from increasing the use of final energy through technological changes (e.g., energy-saving engines), economic changes and changes in users' behaviors are necessary. Many towns all over the world have changed or are changing the organization of town transportation, promoting public transport and cycling at the same time. This involves e.g., banning passenger car traffic in town centers, combined with the creating of parking lots at the borders of closed areas and offering public transport from there, assigning bus passes on roads with more than one lane, regulating public transport ticket prices, incentives for environment-friendly vehicles (hybrid and electric cars) and the extension of tramway, subway and electric urban railroad infrastructure.

Conclusion

Energy policy is a significant element of economic development of every country. High energy consumption and dependence on external supplies of energy resources and ready fuels are reasons to look for new solutions to ensure energy security. The first oil crisis of 1973 contributed to the inclusion of energy security among the priorities of energy policy. Rational use of fuels became an important element of the European strategy of reducing the dependence of the whole European Union on oil importation. An example of response to this can be changes introduced in the automotive sector in Germany. Volkswagen AG introduced new models with small gasoline engines (from 1,100 ccm) and at the end of the 1970s, diesel engines for compact cars of 1,500 ccm, consuming on average 5.5 liter/100km, and after 1980, 1,600 ccm consuming on average 5.0 liter/100 km.[165] In the energy sector, the oil crisis changed the fuel mix of many countries. In France, the use of oil converted into primary energy decreased from 64% in 1970 to 31% in 2012[166] (IEA 2014). Power plants using heavy fuel oil were liquidated and replaced with nuclear blocks. Seeing the positive effects of this approach, in the following years, activities connected with the optimization of consumption were extended to other energy sectors as part of the broad objective of improving energy efficiency.

So the aim is to diversify the supply of energy and to look for new deposits of energy resources, but departure from the basic fuel involves much investment and transformation of the industrial infrastructure. By introducing the idea of sustainable energy development into their policies in order to ensure a clean, ecological, and secure energy future, countries concentrate on improving efficiency and diversifying energy sources. This is to be promoted, not only by increasing the share of renewable energy sources (RES) and decreasing energy intensity of sectors, but also by the introduction of nuclear (not necessarily large scale) energy, and energy management as part of intelligent networks.

[165] Fuel consumption reports for Volkswagen Golf I 1.5 D 50KM 1976-1980 and 1.6 D 54KM 1980-1983, www.autocentrum.pl, (accessed: 07.12.2016).

[166] *Energy mix source: 2009 and 2014*, International Energy Agency Statistics, International Energy Agency, www.iea.org.

Chapter 7

Storage of electrical and thermal energy

Tomasz MIROWSKI[167], Mariusz FILIPOWICZ[168]

Storing energy is indispensable to the search for solutions to improve effective use of energy in energy systems. This applies both to large-scale electricity, heating, gas or oil systems, and to medium (up to 5 MW) and small or micro scale (up to several kW) ones. In gas and oil systems, storage technologies have been thoroughly studied in terms of technological and economic issues, so they are no challenge for researchers nowadays. But electricity and heat storage facilities are still the object of research and development work.

As energy is generated, the problem of its effective use arises, because the supply does not always equal the demand. This especially applies to electricity. Energy demand is not always the same or easy to predict. Daily and seasonal volatility of some renewable energy sources makes the balancing of energy in energy systems even more difficult. Usually, whenever a large amount of energy is needed, only a small amount or no energy can be generated. So as to eliminate the effects of this inappropriate though natural supply of energy, when there is always a surplus when the demand for energy is low, it is necessary to store it. The means of storage must be adjusted to its method of generation and the needs of the recipient.

Energy can be stored in different forms. Storing thermal, electrical, and mechanical energy arouses the highest interest. The growing number

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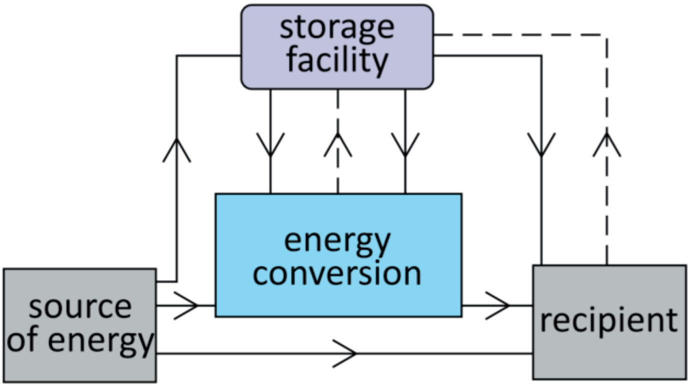
of unstable renewable energy sources and the surpluses of unused heat from big conventional coal or nuclear power plants make energy storage a necessary element of such systems of energy generation. The objective is to find solutions that are highly effective and environment-friendly.

The basic role of energy storage is presented in the diagram in Figure 5.

Figure 5. The role of storage



Source: author's study

We can see that energy storage occurs between the source of energy and the supplier, and meets several important goals:

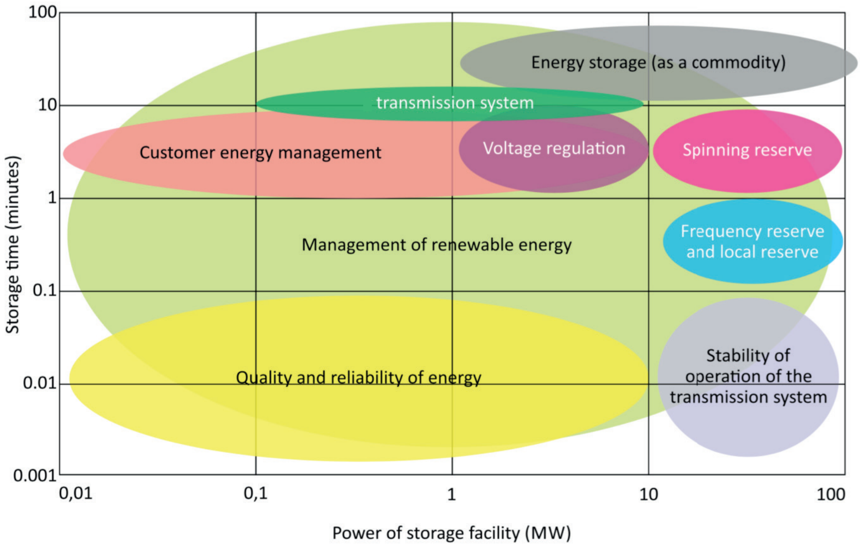
— it allows the source of energy to work at nominal power, when it is more efficient,
— it supplies energy when the source is not working or is working with lower power: this has fundamental importance when unstable renewable sources are used,
— it compensates the lower quality of electricity.

For practical reasons, we can identify storage of heat and storage of electricity. They involve completely different technologies and construction of storage facilities, as well as kinds of sources and customers.

Storage of electricity

The growing demand for electricity is strongly related to its quality and the security of supply. Storing electricity contributes to the reduction of transmission limitations and – through monitoring the

Figure 6. Application of electricity storage facilities



Source: author's study based on: S. Kalaiselvam, R. Parameshwaran, 2014[169]

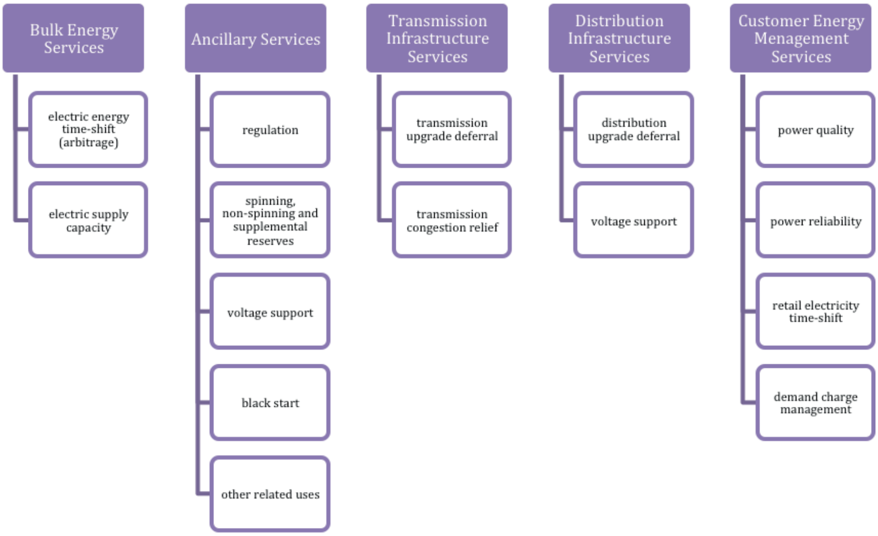
grid load – to higher reliability and quality of energy supplies. Locally stored electricity can be used in emergency situations (e.g., when the grid is covered with ice) in order to continue the supply at least for some customers. The problem is especially important in production sectors, where the quality of supply is one of the main elements of the technological process. UPS systems can secure the supply to the most vulnerable devices or technological chains, but more and more demands in this regard are being transferred to network operators. It is time to expand the scope of activities beyond the local market. This is possible thanks to intelligent networks, in which electricity is transferred in two directions, and the collection and processing of source-grid-customer information is the basis for the functioning of the Smart Grid. During the work of an electricity system, the energy stored in tanks can used to balance the supply and demand, to supply system services (regulation and reserve), to eliminate transmission limitations, to manage the demand from end customers, to increase

[169] S. Kalaiselvam, R. Parameshwaran, *Thermal Energy Storage Technologies for Sustainability. Systems Design, Assessment and Applications*. Academic Press, 2014, Elsevier Web Library: https://doi.org/10.1016/B978-0-12-417291-3.09983-7.

the reliability and controllability of renewable sources, and to reduce the costs of connecting sources to the system.[170] Figure 6 presents the role of energy storage facilities.

Figure 7 shows the services on the electricity market which thanks to the storage of energy would doubtless facilitate the work of transmission and distribution networks operators, allowing quicker development of energy, based on local balancing of energy from big generation sources and from dispersed sources, including RES.

Figure 7. Services in electricity engineering which can be ensured thanks to energy storage



Source: *DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA*, Sandia National Laboratories Albuquerque, New Mexico and Livermore, California 2015.

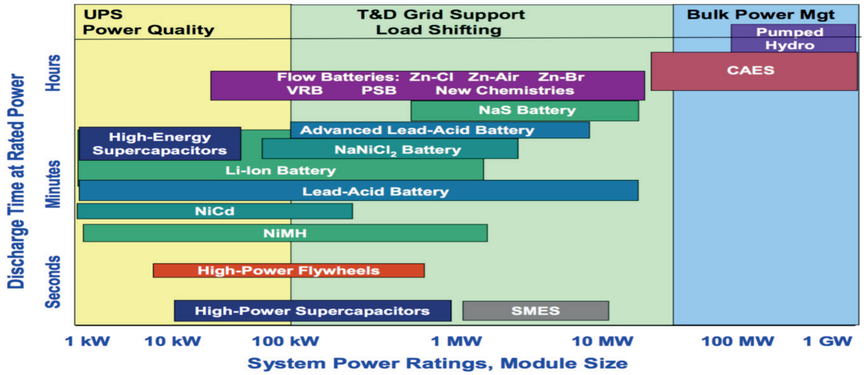
The following methods are used to store electricity:
— high temperature superconducting – HTS (magnetic field),
— supercapacitors (electric field),
— spinning wheels (mechanical),

[170] T. Siewierski, M. Szypowski, *Zasobniki energii elektrycznej i bilansowanie odnawialnych źródeł energii [Energy storage facilities and balancing renewable energy sources]*, Elektroenergetyka – Współczesność i Rozwój, 2012, nos. 3–4 (13–14), pp. 65–75.

— compressed air energy storage – CAES (compressed air),
— chargeable and non-chargeable batteries (electrochemical),
— pumped storage power plants.

The possibilities to apply selected technologies in three areas of services in electric energy engineering is presented in Figure 8.

Figure 8. Diagram of selected energy storage technologies: discharge time – power



Source: *DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA*, Sandia National Laboratories Albuquerque, New Mexico and Livermore, California 2015.

Storage with the use of magnetic field requires superconductors. Accomplishments in the field of making high temperature superconductors which can be cooled with liquid nitrogen allow the production of many energy transmission and storage systems. The use of brittle ceramic material may be a problem, but the technology of superconductive tapes has been developed, and the tapes are used to make superconductive cables. Examples of application of such storage facilities are so-called D-SMES, i.e., Dispersed Superconducting Magnetic Energy Storage (in this case, low temperature superconductors are used). They are installed wherever there are problems with the quality of electricity, e.g., voltage dips, deformed course, etc. Power parameters can be improved through temporary "injection" of stored energy.

Using the phenomenon of levitation between the magnet and the superconductor allows the building of no-friction bearings, which are used in the construction of low-loss flywheels used to store mechanical energy, which is converted into electricity and back in a special engine/generator system (High-Power Flywheels technology). Example structures of such storage facilities have been developed, e.g., flywheels storing between several and more than ten kWh energy and the peak power of several hundred kW.

They are able to perform over 100 thousand loading/unloading cycles, but a failure may occur due to fatigue of the rotor. Since these are rather short-term storage systems, they are not attractive for large-scale network support. Currently, these units are being launched to the market. Examples are the 23 MW unit installed by Okinawa Power, or the 20 MW unit working since 2011 in Stephentown, USA, used to regulate frequency.[171]

Another technology is supercapacitors (electric double-layer capacitors), whose capacities are thousands of times higher than in the case of classic capacitors thanks to unfolded electrodes and a special electrolyte. In practice they still store relatively little electricity, but they already have more and more applications, such as assisting vehicle batteries, regenerative brakes, or bus propulsion. Supercapacitor bus in Shanghai is an example of that. The network involves network stabilizers based on storage systems made up of lithium-ion batteries and supercapacitors.

Storage facilities based on compressed air are also becoming more and more important. They use underground containers with the proper parameters (e.g., unused salt or limestone mines), into which air is pumped so as to achieve the proper pressure. When there is an excess of energy, the reversible engine/generator system uses the system of compressors to pump air. In the case of energy intake, compressed air is used to power the gas turbine. No compressor integrated with a gas turbine is needed then to supply compressed air to the combustion chamber. This way, the efficiency of gas turbine improves greatly. It is also possible to construct a system with a turbine working on compressed air without the need to use fuel (second-generation CAES systems).

Currently, apart from pumped storage power plants, only CAES systems are used commercially to collect large amounts of energy.

[171] *Energy storage. Technology Brief,* IEA-ETSAP and IRENA Technology Policy Brief E18, IRENA, 2012, www.etsap.org/www.irena.org (accessed: 10.11.2016).

The first installation was the Huntorf system with a 300 thousand m^3 container, a 60 MW compressor consuming energy to pump air for 8 hours a day, and a 290 MW gas turbine releasing energy during the 2-hour demand peak. Another example is the storage facility in Macintosh, USA, with the following parameters: 110 MW capacity, cave of approx. 70x300 m, 100 thousand m^3, pressure approx. 75-45 bar, unloading time 26h, 100 MW gas turbine.

Units are also possible which do not involve underground storage facilities. Overground facilities are used in that case. However, those units have lower capacity (3-50 MW) and unloading time of 2-6 hours. They are also easier to construct but more expensive (in relation to a unit of power). This is connected with requirements regarding aboveground facilities.

Other ways of storing energy are chemical and electrochemical facilities. Chemical storage facilities are: hydrogen, biofuels, synthetic fuels, substitute natural gas, and methanol. Electrochemical ones are: batteries, flow batteries, and fuel cells. The use of chemical energy storage facilities is connected with the possibility to generate hydrogen from electrolysis with electricity, obtained e.g., from renewable energy sources. Chemical fuels can be produced from biomass (or other carboniferous materials).

Electrochemical batteries have the following advantages: good voltage characteristics, convenient size, and a long history of manufacture. The disadvantages are: a limited number of charge cycles and limitations to working voltages and currents, often detrimental to the environment.

The oldest solution of electrochemical batteries is lead-acid batteries, invented in the mid-19th century and still widely used, especially in transport. The positive electrode is lead oxide, and the negative one, metallic lead. Sulfuric acid is the electrolyte.

One variation of it is the use of carbon in one of both electrodes, improving battery parameters. Other advanced technologies, substantially improving the parameters of lead-acid batteries, are also being applied. One example is the 1MW/1.5MWh unit in Metlakatla (USA). A number of units with the capacity of 1-20 MW are operating. Another example is the Tappi Wind Park in Japan, where advanced lead-acid batteries with the capacity of 10.4MWh are used to stabilize the 15

MW wind power plant. Flow batteries have two liquid electrolytes containing metal ions, which flow through porous, graphite-coated electrodes separated with a membrane through which protons can be transferred. During the exchange of charge, current flows through the electrodes, which can be used by a battery-powered device.

This reaction can be reversed, allowing for a full charge cycle of the battery. The cost of storage is approx. USD 500 per 1 kWh. If the battery charge level is low, the discharged electrolyte "powering" the battery can be simply replaced with a charged one. After the electrolyte is pumped out, it can be refilled at a gas station. Storage systems with flow batteries require large amounts of electrolyte in case of storage needs of megawatt hours. The systems are designed to survive 10 thousand charge cycles, although Sumitomo Electric Industries Ltd., manufactures 20 kW batteries with 13 thousand cycles. Examples are the 600 kW unit with a capacity of 3.6 MWh installed in Gills Onions, Oxnard, the USA, or the 1MW/5MWh system installed in Japan.[172]

Sodium–sulfur batteries are still another solution. In a cylindrical chamber of sodium sulfide there is a negative electrode, which is surrounded by liquid sodium at the service temperature. Another active component of this battery is liquid sulfur surrounded by graphite felt. It is not only used to transport electrons, but it also absorbs polysulfides formed when discharging the battery, which ensures the supply of sulfur to the zone of electrochemical reaction. Sodium-sulfur batteries have better parameters than ordinary batteries (high performance, temperature-independence, and the lack of self-discharge). The only problem is that they work at high temperatures (approx. 300^{o}C). Currently, it is a commercial technology used in units supporting network operation or in integration with a network of wind turbines. What is important in this is the possibility of long discharge (approximately 6 hours). Possible energy density is 170 kWh/m^3 and 117 kWh/ton. The number of charge cycles is 4,500, and the designed life cycle is 15 years.

Sample uses are: the biggest single installation with a capacity of 34 MW located in Rokkasho (Japan), stabilizing the power from wind turbines; in Tokyo there are smaller units which, combined, produce 160 MW.

[172] *DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA*, Sandia National Laboratories Albuquerque, New Mexico and Livermore, California 2015.

At the moment, 221 units operate with the power of 316 MW and a storage capacity of 1,896 MWh.

Sodium-nickel chloride batteries, just like sodium-sulfur ones, are high temperature devices. They are based on a reversible reaction of sodium chloride with nickel (metal dust). Units with the power of 50 kW – 1 MW are currently produced. A sample application is the 222 kWh unit installed in the Duke Energy Rankin Substation in New York. Wider application in units integrating renewable energy systems and the grid is planned.

Other examples of electrochemical devices are iron-chromium batteries or zinc-bromine batteries, but in comparison to previously mentioned electrochemical units they have a much narrower range of applications.

One significant electrochemical energy container are lithium-ion batteries. Currently, this technology is commercialized and mostly used in electronic devices or various electric vehicles. The capacities of those batteries may reach 50 kWh.

Small scale (5-10 kW/20 kWh) and large scale (1 MW) demonstration systems with a discharge time of 15 minutes until frequency regulation are presently being implemented.

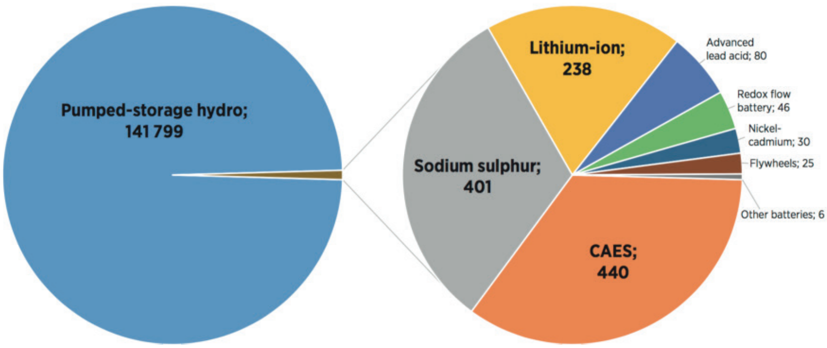
They are also used in off-grid systems, where they ensure the users power supply for 1-3 hours after the failure of grid power supply. They may also serve as energy banks in PV systems.

Currently, pumped storage power plants have the greatest storage capacities, which are quite commonly used to store energy in electricity systems. The idea involves a reversible turbine/pump placed between two containers, an upper and lower one. When there is a surplus of energy, water is pumped from the lower to the upper container, and when there is a demand for energy, water released from the upper container propels the turbines. Certainly, the system has both advantages and disadvantages. Its advantages are high capacity, efficiency about 80%, and the possibility to start quickly in the case of emergency. The disadvantages are limited possibilities for localization and interference with the natural environment.

The system has the greatest storage capacity, because the only limitation is the size of the upper and lower water tank.

In Poland, the pumped storage power plant in Żarnowiec is the biggest. Its capacity is 716 MW for turbine work and 800 MW for pump work. Globally, their storage ability is over 99% of the total capacity of all storage facilities (Chart 11), providing 127 GW storage capacity and 740 TWh of energy.[173] The world's biggest installation (USA) has a capacity of approx. 3 GW. By the year 2020, more units are planned in Europe, with total capacity of up to 15 GW.

Chart 11. Share of pumped-storage hydroelectricity in the global electricity storage system (in MW)



Source: *Renewables and electricity storage. A technology roadmap for REmap 2030*, IRENA, 2015, www.irena.org (12.11.2016).

Thermal energy storage

In the case of storing thermal energy, we can identify the following methods (Fig. 9). The basic parameters of thermal energy storage facilities are the density of the stored energy, capacity, the time of loading and unloading the tank (or charging and discharging the battery), working temperature and total efficiency.

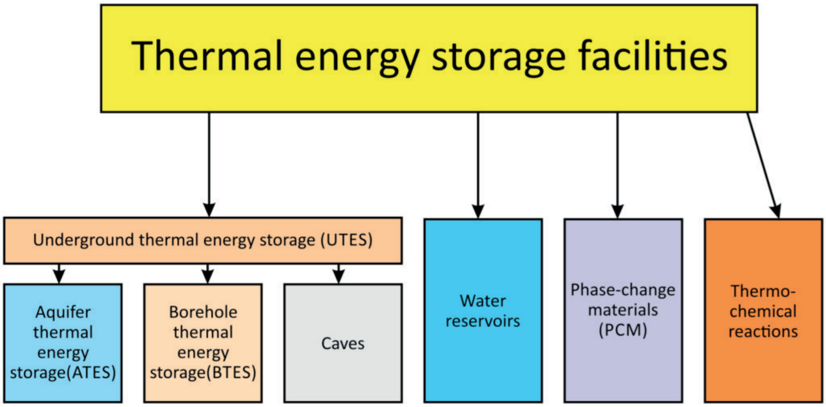
Each currently used energy storage facility has the capacity of $200 \div 2 \cdot 10^{16}$J, and power of $6 \cdot 10^{-4} \div 10^{15}$W. The time of thermal energy storage is between several seconds and several decades.

The most frequently used methods are:
— methods of underground thermal energy storage,
— the use of the specific heat of the water,
— phase change materials,
— other, less often used methods.

[173] *Ibidem*.

Underground thermal energy storage may be achieved thanks to the following technologies:
— BTES (Borehole Thermal Energy Storage),
— ATES (Aquifer Thermal Energy Storage),
— UTES (Underground Thermal Energy Storage).

Figure 9. Methods of thermal energy storage



Source: author's study.

Systems based on BTES are already in use on a small and large scale. The small scale is e.g., a detached house with a solar thermal collector, a BTES unit, and a system of heating including a heat pump. The excess heat from the summer season is stored in a borehole, and in winter the heat is regained by the heat pump for the purpose of a low temperature heating system in the building. This way, because of the higher temperature of the bottom heat source, the efficiency of the heat pump considerably increases.

The large scale is much bigger projects for residential areas etc. One example is a residential area near Calgary with 52 houses, where 144 boreholes have been made. They are integrated with 800 solar thermal collectors with a surface area of 2,300 m^2.

The use of ATES involves similar depositing of energy in underground water layers; it may also be cold energy. One example is the Arlanda airport in Stockholm, where two groups of "cold" and "hot" wells have been used, providing thermal power up to 10 MW and annual heat savings of up to 10 GWh.

The use of specific heat of water involves using different water tanks of different sizes, coupled with thermal systems. These may be both renewable systems (e.g., storing heat absorbed by the surface of a parking lot in underground tanks and using it later to melt snow). Another example is the application of two water tanks with a total capacity of 580 m^3 in Crailsheim for a system of 7,300 m^2 of solar collectors and borehole energy storage. The storage of ice water for the needs of large cooling installations is also possible.

Quick technological and application development can be observed in phase change materials. Their important advantage is that their temperature does not change during the facility loading/unloading. The basic materials are paraffins, hydrated salts, and liquid salts.

The criteria for selecting the appropriate PCM are their physical properties (phase change temperature, latent heat of synthesis, thermal conductivity, phase separation, steam pressure, volume change, density, and crystal growth), chemical properties (chemical stability, security) and economic ones (availability, profitability).

They can be used e.g., as a support for passive cooling/heating systems in passive or low-energy buildings (improvement of thermal properties or reduction of temperature oscillation), which allows e.g., reducing the power of classic heating/cooling systems. Building walls constructed for this purpose contain a PCM layer e.g. in the form of micro capsules placed in gypsum board or insulation material. Active solar walls which store heat can also be constructed.

Systems that make use of chemical reaction heat or the release of water from hydrates or zeolites are much more rarely used.

The development of energy storage may occur as a result of popularizing so-called virtual power plants based on dispersed energy systems. In order to connect a number of different energy producers and customers with different characteristics of production and reception, it is necessary to monitor and predict in advance both the production and consumption of energy. In the case of a high share of power plants based on renewable sources, it is necessary to use energy storage facilities which can be set up remotely using an appropriate control and management system.

Nowadays, technological development means new possibilities of energy storage. A number of solutions need to be better studied and implemented; at the moment they are treated as so-called emerging technologies. These are:

- storage based on the use of condensed air; currently, small-scale demonstration systems are being constructed,
- no fuel (or low consumption) CAES and isothermal systems,
- underground pump power plants (in the research phase),
- nano-supercapacitors (in the phase of laboratory tests),
- advanced flywheels (in the phase of research and development),
- a number of advanced battery systems (H_2/Br flow batteries, advanced lead-acid batteries, advanced lithium-io).

Chapter 8

The role of exchanges and hubs on contemporary gas markets

Marcin SIENKIEWICZ[174]

Many contemporary natural gas markets are undergoing intensive transition from a closed and monopolistic model towards an open and liberal one. Clear progress in the process is visible first of all in the European Union and North America. One goal of the Third Energy Package adopted by EU countries in 2009 is to build an intra-European, liberalized market of natural gas. Competition is to be the basic principle of the functioning of the European natural gas market. In the case of natural monopolies, usually occurring in transmission and storage areas, market participants make use of applicable regulations protecting them from excess prices (tariffs) and discriminatory practices (the Third Party Access principle). Market mechanisms are implemented e.g., through the abolishment of price tariffs in extraction and trade segments.[175] In the case of the United States, the market transition is referred to as the "shale revolution", which means the rapid increase of extraction of natural gas from unconventional resources in the USA. Thanks to the popularization of extraction methods using hydraulic fracturing of deposits, natural gas production in the USA grew by 42% between 2005 and 2013.[176] As a result, the United States became the world's greatest

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[175] K. Nowak, *Rynek gazu ziemnego – zasady funkcjonowania [The rules of functioning of natural gas market]*, [in:] *Vademecum gazownika*, Tom IV, ed. A. Matkowski, Kraków, 2012, p. 23.

[176] R. F. Aguilera, M. Radetzki, *Rewolucja łupkowa: Światowe rynki gazu i ropy naftowej w warunkach transformacji [Shale revolution: Global gas and oil markets*

gas producer, whose extraction level reached 767.3 m³ in 2015.[177] The global significance of natural gas as a fuel in the energy sector and as a resource in the chemical industry is growing. This is proved by the 86.4% increase in turnover at international gas markets between 2001 and 2012.[178] The development of the LNG sector is becoming a factor that creates good integration conditions even for gas markets that are geographically distant. An example of this process in action is the first supplies of American liquefied gas to European ports in Portugal and Spain in 2016. The increase in natural gas supply combined with its increased mobility (thanks to LNG technology and the development of sea transport) is conducive to more and more evident price emancipation of natural gas as a commodity in relation to oil. In the transformation process described above, leading to open and liberal markets, commercial infrastructure is becoming increasingly significant. Commercial infrastructure is formal institutions allowing market participants to carry out sale transactions. It includes gas exchange markets and electronic trade platforms dedicated to OTC (over-the-counter) market. More complex institutions, such as gas hubs combining commercial and logistic functions, have also been formed on gas markets.

Gas exchanges

Gas exchanges are mercantile exchanges. They are institutions that allow and organize trade in natural gas, usually with brokerage houses as intermediaries in the trade. Exchanges are a transparent source of information on terms and conditions of transactions and give more entities access to the market. In practice, gas exchanges operate as part of bigger entities such as mercantile or specialized energy exchanges. In the USA, organized wholesale trade with natural gas takes place at the New York Mercantile Exchange (NYMEX), which

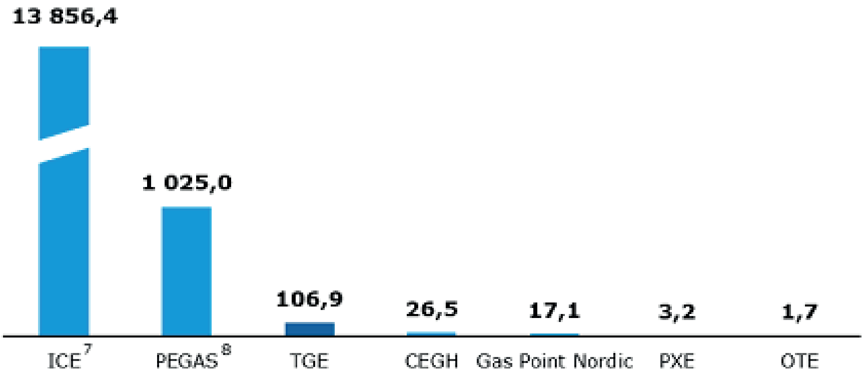
under transition], “Gospodarka Surowcami Mineralnymi”, 2015, Volume 31, Part 1.

[177] The Statistics Portal, *Natural gas production in the United States from 1998 to 2015* https://www.statista.com/statistics/265331/natural-gas-production-in-the-us/, (accessed: 13.11.2016).

[178] A. Szurlej, P. Janusz, *Natural Gas Economy in the United States and European Markets*, “Gospodarka Surowcami Mineralnymi”, 2015, Vol. 29, Part 4, p. 78.

belongs to the CME Group from Chicago. In Europe, gas exchanges in the form of separate markets function within the framework of mercantile energy exchanges, e.g.:
- APX Group – established in 1999 in Amsterdam, currently operating on energy markets in Great Britain, the Netherlands, and Belgium. The exchange gas market was launched in 2003.
- EEX – European energy exchange operating in Germany. The gas market was opened in July 2007.
- Nord Pol – Scandinavian energy exchange. The exchange gas trade began in March 2008.
- Powernext – a pan-European energy exchange operating on the markets of France, Belgium and the Netherlands. In November 2008, PEGAS was set up, which runs two natural gas markets: Powernext Gas Spot and Powernext Gas Futures.
- CEGH Gas Exchange – run since December 2009 by Vienna Stock Exchange as part of the Baumgarten Central European Gas Hub AG.
- ICE group – operating globally. In Europe it engages in exchange gas trade in the Netherlands and Great Britain.
- Towarowa Giełda Energii S.A. – Polish Power Exchange, with gas exchange launched in December 2012.

Chart 12. Trading volume on natural gas exchanges in Europe in 2015 (TWh)



Source: *Raport Roczny 2015 [Annual Report 2015]*, GPW, http://raportrocznygpw.pl/pl/grupa/otoczenie-rynkowe/rynek-towarowy#start (accessed: 13.11.2016).
[7] *Data for British and Dutch markets, not including data from the USA.*
[8] *Data for all PEGAS markets.*

Gas exchanges play a special role on the market, offering the possibility to change gas prices in a transparent process which enables the publishing of price indices. Exchanges are also a transparent source of information on terms and conditions of transactions and give more entities access to the market. However, in order to participate in exchange trade, market participants need to meet certain formal requirements, after which they become exchange members. This is so because trade on exchange is organized and based on two basic documents: exchange statute and rules. The first of them describes e.g., the conditions of membership, the object of activity, the internal structure, as well as the bodies of the exchange and the mode of appointing them. As already mentioned, exchange members are usually brokerage houses and direct participants in the exchange market. The rules include information concerning e.g., the obligations of exchange members, categories of traded commodities, as well as units, place of delivery, or collateral. Exchange transactions concluded on gas markets are cleared through clearing houses, thanks to which the parties to the transactions may remain anonymous and the transaction risk is minimal.

Energy exchanges that run the natural gas market also need to meet reporting obligations established in the Regulation of the European Parliament and of the Council (EU) no. 1227/2011 of 25 October 2011 *on Wholesale Energy Market Integrity and Transparency* – REMIT.

The basic function of the exchange on a gas market is to establish an objective market price, i.e., a share price, thanks to concentrating and organizing supply and demand in one place. The transparent mechanism of the functioning of exchanges is a guarantee that the established commodity price will only reflect the balance of power between the supply and demand at the moment. This way of gas pricing is alternative to the model based on indexing to the prices of oil and oil derivatives adopted in long term contracts, now functioning for several dozen years.[179]

In Europe, PEGAS has the broadest product offer. It offers spot products and futures contracts, as well as spread transactions using price differences between hubs. In the first case, sale transactions are cleared at the currently applicable price with the clearance deadline

[179] Institute of Energy for South-East Europe, *The Outlook for a natural gas trading hub in Europe*, An IENE Study Project (M19), Athens, July 2014, p. 111.

usually up to 2 days of its conclusion. Futures contracts are contracts made between two parties, one of which commits itself to buy, and the other, to sell so-called underlying, at a specific date, at a specific price, and in a specific amount, under the conditions determined by the exchange in the standard of derivatives. The performance of the contract follows the principles set out in the contract standard (delivery of the commodity or financial clearance). In the case of exchange gas future contracts, the performance of the contract involves gas delivery to the relevant gas hub. Contracts cleared in money, e.g., on the basis of the estimated index of gas prices, are rare.

In Poland, since December 20, 2012, intraday market (IDM) and day-ahead market (DAM) natural gas trade has been carried out on the Polish Power Exchange. Gas trade occurs every day in the fixed quotation system.[180] The establishment of the exchange was connected with the implementation of the policy of liberalizing the natural gas market. Its development was the result of the coming into force of amendments to *Energy Law Act* on September 11, 2013, which introduced the obligation of exchange trade for energy enterprises trading in gas fuels in the form of high methane gas pumped into the transmission network in the given year.[181] The obligation was introduced gradually:

— from September 12, 2013, to December 31, 2013: 30% of natural gas;
— from January 1, 2014, to December 31, 2014: 40% of natural gas;
— from January 1, 2015: 55% of natural gas.

In 2015, 97 entities were members of the Polish gas exchange, including 25 companies directly trading in gas. The total trading volume on gas markets run by TGE in 2015 was 106.9 TWh. The development of an exchange market in Poland should be fostered by the abolishment of the obligation of tariffing wholesale gas prices in 2017 and carrying out diversification projects involving transmission connecting with the Norwegian shelf, as well as the extension of regasification capacities of the Świnoujście LNG terminal.

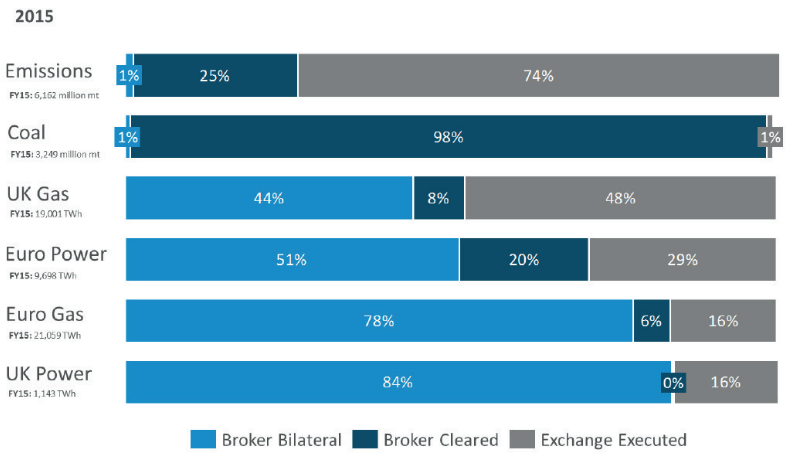
Wholesale trade carried out on gas exchanges has not yet become dominant on EU markets, although in recent years it has been dynami-

[180] *O giełdzie [On the exchange]*, Polish Power Exchange, https://www.tge.pl/pl/2/o-gieldzie (accessed: 13.11.2016).

[181] Energy Law Act of 10 April 1997, Article 49b, Journal of Laws 1997 No. 54 item 348.

cally growing. In the years 2013-2015, the share of exchange trade in gas in the EU nearly tripled, from 6% in 2013 to 16% in 2015 – Chart 13.[182]

Chart 13. Trading volume and structure in selected European energy markets in 2015



Source: *Trayport Euro Commodities Report*, Trayport, December 2015, p. 4, *http://www.trayport.com/cms/uploads/december-2015-trayport-euro-commodities-report-media-version_001.pdf*, (13.11.2016).

Legend:

Broker bilateral	Transactions concluded by brokers (entities functioning as intermediaries) on the OTC market, not cleared by clearing houses.
Broker Cleared	Transactions concluded by brokers and cleared by clearing houses.
Exchange Executed	Transactions concluded at exchanges and cleared by clearing houses.

Electronic trading platforms

On the wholesale market of natural gas, electronic trading platforms, also referred to as brokers' platforms, are an alternative to gas

[182] *Trayport Euro Commodities Report*, Trayport, December 2015, p. 5. http://www.trayport.com/cms/uploads/december-2015-trayport-euro-commodities-report-media-version_001.pdf (accessed: 13.11.2016).

exchanges.[183] The platforms are properly organized virtual places run by specialized entities, where natural gas supply and demand concentrate. Sale transactions are concluded through a relevant transaction programme, to which market participants receive access if they meet some formal requirements. In this case, the requirements are not as strict as in the case of mercantile exchange. Participation in the platform is based on a framework agreement including rules. No broker's license is needed to trade on the platform. The business partners lose their anonymity after concluding a transaction on the platform and signing a bilateral sales contract (partnership contracts), usually based on the model developed by the European Federation of Energy Traders (EFET).[184] Besides, trading platforms give an opportunity to make commercial offers 24/7. Trade on wholesale OTC platform market is not controlled by institutions supervising the financial market. Unlike on exchanges, the transactions are not cleared by clearing houses, which substantially reduces the costs of participation on the trading platform. The functioning of electronic trading platforms dedicated to the OTC market is based on the following principles:

— non-discrimination of access and equal principles of participation for all entities that have concluded a relevant accession agreement;
— uniform conditions of concluding transactions;
— uniform access at the same time to market information, ensuring the transparency of product quotations, volumes and prices.[185]

Gas hubs

Gas hubs were established independently in different places all over the world when national natural gas markets were developing and diversifying. Originally, they were created in places with high concentration of transport and storage infrastructure. One example is Henry Hub located in Louisiana by the Gulf of Mexico. It is the oldest

[183] It also applies to electricity market, where this form of organized trade has emerged before.

[184] *EFET*, European Federation of Energy Traders, http://www.toe.pl/pl/standardy-umow/efet, (accessed: 17.11.2016).

[185] *Information on Polish and Internet Trade Platforms,* Towarzystwo Obrotu Energią *[The Association of Energy Trading],* http://www.toe.pl/pl/ (accessed: 22.11.2016).

and the biggest gas hub in the USA (functioning since 1990). It was established at the junction of 13 gas pipelines transporting gas from different sources, and near 3 gas storage facilities. Connecting them all allowed physical trade with natural gas. Henry Hub is an example of a physical hub, defined as a natural gas market center, which allows clients (suppliers, customers) access to a higher number of gas pipeline systems, ensures transport between the pipelines, and offers administrative services that facilitate the transmission of gas and transfer of ownership rights. Sales transactions involve the need to reserve capacity and a route through which the commodity can reach from the point of entry to infrastructure to the point of exit (end customer).

Besides physical hubs, there are also virtual hubs. The largest one is the National Balancing Point (NBP) located in Great Britain. It covers the whole system of gas transport in Great Britain. It is a virtual point where natural gas sales and exchange transactions take place. In this case, the object of transaction is natural gas occurring within the defined infrastructure area with specified points of entry and exit. In a virtual hub, the place of "meeting" the routes of gas transmission is not a point but a whole gas system managed by the network operator. A virtual hub can be established in a gas system where the fees for transmission are collected at the entry and exit points, not linearly for a section of transmission. This allows gas trade in the network (at a virtual point) without the need to reserve capacity. Thus, virtual hubs do not have a physical location, but their operation covers the whole national gas system. The virtual model of gas hub can be described as organizing the wholesale gas market defined as the sum of systemic activities in the areas of the gas trade, gas supplies, changes of ownership of the commodity, transaction clearance, and balancing the system. Virtual hubs develop much more quickly and are the future of the European gas system.

To sum up, gas hubs are first of all the points of trade in gas, affecting market prices of natural gas regardless of changes in oil pricing. They are based on a well-developed, diversified, and varied transport infrastructure (gas pipelines, LNG terminals), allowing a range of services. Gas hubs are a comprehensive commercial and infrastructure solution, considerably improving the functioning of the natural gas market by improving its transparency, liquidity, and infrastructure passability. Hence, gas hubs can be treated as a systemic solution serving the following market functions:

a) Commercial function

Gas hubs make it possible to conclude sales transactions on electronic trading platforms and on gas exchanges cooperating with the hub. Trade on gas hubs is an alternative to the traditional model based on long-term 20- or 30-year contracts in which the price was based on indexation to oil and oil derivatives. It contributes to greater transparency of the pricing mechanism and the prices' relevance to the market situation. Thus, trade on hubs allows the establishing of a market price for natural gas and achieves a balance between the supply and demand. Trade on a hub also helps meet one of the conditions for maintaining energy security, i.e., buying gas fuel at a price acceptable for both parties to the transaction. Gas hubs give access to short-, medium- and long-term contracts, increasing the flexibility of gas trade.

b) Service function

The natural gas market is an infrastructure market. Gas hubs also offer participants a whole spectrum of infrastructure services. In this field, they closely cooperate with operators of storage and transmission systems, together developing formal/procedural and technical solutions improving access to the gas infrastructure. The essence of functioning of a gas hub is to simplify the process of trade in natural gas. Hence, clear principles of market access must apply to a gas hub, and all the participants of an organized market need to be treated equally. Infrastructure services should be available for different market participants at equal prices. In order to observe the principle of non-discrimination, a separate legal person serving as an operator may be appointed.[186] Gas hubs may also do the obligatory reporting (REMIT) to ACER on behalf of the clients.

c) Information function

The institution of a gas hub ensures all market participants transparent knowledge on the concluded transactions, volumes and prices.

[186] European Regulators' Group for Electricity and Gas, *Gas Regional Initiative – Region: South-South East. The hub used as a balancing point*, Brussels, p. 4., http://www.ceer.eu/portal/page/portal/EER_HOME/EER_ACTIVITIES/EER_INITIATIVES/GRI/South_South_East/Final%20docs/GRI-SSE-SG-02-05_HUB.pdf, (accessed: 26.11.2016), p. 4.

A gas hub will collect knowledge on the development of the gas market situation. It will be a specific center of market information for gas market participants. A gas hub will first of all become the source of knowledge on gas prices, formed by the market mechanism. It will also show dynamically the relations between supply and demand. Access to historical and current data archived by the hub will facilitate business decisions made by gas market participants.

d) Balancing function

Gas hubs allow physical and commercial balancing of the system of natural gas transmission. This function involves balancing the demand for natural gas with its supplies.

On contemporary gas markets, the commercial function of gas hubs is becoming more and more important. Gradually, they are assuming the role of centers determining the reference price, not only for national but also for regional markets. The Henry Hub in the USA, as well as NBP and TTF in Europe, already have this market status. In this respect, there is competition between gas hubs on European markets to take over the greatest gas volumes and the highest numbers of trade participants. The "churn" rate is an indicator to assess the competitiveness of the organized wholesale market (an exchange or an electronic trading platform operating as part of the hub). The rate *"… is the ratio of the total volume of gas traded on a hub and the amount of gas physically supplied for consumption through the hub. The value shows to what extent the price of natural gas on the hub can be regarded as reliable market price. It is based on the fact that multiple trade with a unit of natural gas by many market participants is treated as a mechanism that confirms that the price determined this way is a market price."*[187]

Conditions for the establishment of a gas hub

In terms of geographic distribution of gas hubs, we can see they are especially numerous is two regions: North-Western Europe and the USA. As already mentioned, gas hubs were established and developed in places with a well developed and diversified transport infrastruc-

[187] R. Zajdler, *Polski rynek gazu ziemnego na tle rynków Unii Europejskiej [Polish natural gas market against the background of European Union markets]*, Warsaw 2014, p. 31.

ture and sufficient demand for natural gas. In Europe, the formation of a hub was not always the result of natural consolidation processes; instead, it was often a governmental decision. In 2005, the government of the Netherlands announced that the objective of their policy was to establish a gas hub that would play the role of a transport, storage, and distribution center for domestic and foreign customers. Launching the project was mainly justified with the intention to ensure gas supplies to the Netherlands and to promote the continuity of gas supplies to the European Union.[188] Dutch authorities saw the project as an opportunity to improve the competitiveness of the Dutch economy through the reduction of natural gas prices.[189] The activities involved i.a., strengthen the diversification of natural gas supplies by obtaining direct access to the global LNG market. The first Dutch LNG terminal was established for that purpose in the Europort of Rotterdam. The reloading capacity of the gas port launched in September 2009 was 12 bcm a year, with a possible extension up to 16 bcm.[190]

The history of the Iberian Gas Hub also began upon a decision made by the Spanish government. The project was officially launched in March 2011 together with the establishment of a dedicated company, which currently operates as Sociedad Bilbao Gas Hub, AF. The aim of the project was to strengthen the competitiveness and integration of the Iberian market (integration of the Spanish and Portuguese markets), and to enhance the fluency of trade by improving its infrastructure and commercial functionality. Unlike the Netherlands, Spain's problem was not insufficient diversification of external markets. Thanks to its LNG terminals and transmission connection with Africa, Spain was fully secure in terms of diversification of external supplies. After

[188] Working Group on Audit of Extractive Industries, *The Netherlands as a European gas transmission hub A gas hub: benefits, need and risks*, 2012, p. 2, http://www.wgei.org/wp-content/uploads/2015/06/A-gas-hub-benefits-need-and-risks.pdf (accessed: 25.11.2016).

[189] Eerste Kamer der Staten-Generaal, *Voorzienings- en leveringszekerheid energie (29.023); brief regering; Voortgangsrapportage Gasrotonde 2011 (TK, 112),* https://www.eerstekamer.nl/behandeling/20111107/brief_regering/info (accessed: 26.11.2016).

[190] *Pierwszy holenderski morski terminal LNG [First offshore Dutch LNG terminal]*, "Portalmorski.pl",
http://www.portalmorski.pl/zegluga/inne/19667-pierwszy-holenderski-morski-terminal-lng-8211-otwarty, (accessed: 18.11.2016).

2008, a considerable decrease in consumption, which resulted in growing costs of the functioning of the storage infrastructure developed before, became a serious challenge to Spanish gas sector. The gas hub was to stimulate the Iberian wholesale market integrated within it. The authorities of Spain are also trying to attribute European importance to the project, presenting it as the western pillar of security of gas supplies and trade for the European Union.[191]

Practice resulting from the history of establishing and developing gas hubs in North America and Europe proves that the success of such projects depends upon meeting at least the following conditions:

a) access to at least three different independent gas sources (through the diversification of supply directions and sources obtained thanks to properly extended transport infrastructure, e.g., 7 gas pipelines crossing at the Zeebrugge hub);
b) free access of market participants to transport and storage infrastructure (implementation and observance of the principle of third party access to the infrastructure – TPA);
c) a high number and diversification of market participants (differing in terms of profile and scale of activity);
d) contracts worked out by the operators of gas infrastructure (standardized offer of infrastructure services for market participants);
e) infrastructure operators' support for the development of organized wholesale trade (trade instructions facilitating the development of an exchange market and facilitating new entities' entering the gas market and simplification of the rules of use of the transmission system;[192]
f) annual demand for gas in the future market area of the hub should be approx. 20 bcm;[193] the existence of an aftermarket for unused transmission capacity.

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[191] M. Sienkiewicz, G. Małecki, *Rynek gazu ziemnego w Królestwie Hiszpanii [Natural gas market in the Kingdom of Spain]*, "Wiadomości Naftowe i Gazownicze", no. 12, 2015, pp. 18-23.

[192] M. Fantini, *Conditions for a Gas Hub to Appear in CEE Countries*, GasReg21-Regional Market Places & Infrastructure panel, Poznań, 11.05.2016.

[193] Working Group on Audit of Extractive Industry, *The Netherlands as a European gas transmission hub.*

A gas hub: benefits, need and risks, 2012, http://www.wgei.org/wp-content/uploads/2015/06/A-gas-hub-benefits-need-and-risks.pdf, (accessed: 20.11.2016).

Conclusion

The trade infrastructure described above is currently the crucial element of natural gas markets in the European Union and the USA. For many participants of the markets, trade on the gas exchange or a gas hub has become an attractive and competitive option beside long-term contracts concluded in a single supplier. Considered from the perspective of an economic entity, it allows the creationof procurement strategies and risk management in this respect on the basis of flexible pricing models. Liberalized trade in gas has also become a solution alternative to the traditional model of external supplies, based on long-term contracts including clauses that limit customers' freedom in terms of using the purchased commodity (the territorial clause). Doubtless, the development of gas trade carried out by gas exchanges and hubs was supported by the implementation of Regulation no. 994/2010 of the European Parliament and of the Council of 20 October 2010 concerning measures to safeguard security of the gas supply. The list of market measures promoting supply security introduced with this legal act included "enhancing gas flexibility" and "diversification of gas sources and routes of supply".[194] Thus, the regulation made a formal basis which could be used to question the provisions concerning a ban on re-export included in contracts for gas supplies concluded with Russian Gazprom. Appropriate regulations ensuring the freedom of gas trade, as well as transport infrastructure diversifying the directions and sources of gas supplies, make a foundation for the development of trade infrastructure on contemporary gas markets.

[194] Regulation (EU) no. 994/2010 of the European Parliament and of the Council of 20 October 2010 concerning measures to safeguard security of gas supply and repealing Council Directive 2004/67/EC, Annex no. II, Official Journal of the European Union, 12.10.2010, L295/1.

Part II

Energy transition in selected states

Chapter 9

Energy Policy Transition – the German perspective

Nicole KAIM-ALBERS[194], Mariusz RUSZEL[195]

Introduction: Energiewende – energy transition as a label

The definition of "Energiewende" (German Energy Transition) is vague and gives room for various interpretations. Literature shows that the term 'energy transition' (in German *Energiewende*) was first used in 1980 by a German think-thank Öko-Institute to refer to the model of energy modernization from a system based on fossil fuels to a system based on renewable energy.[196] The Federal Ministry of Economics and Energy refers to it as "... our way to a secure, environmentally friendly and economically successful future".[197] Two major pillars appeared in the centre of Germany's energy policy in the last decade: The expansion of renewable resources and the phase-out of nuclear power. The political targets and measures are, however, much broader and increasingly complex. Moreover, the national energy visions and policy framework

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[196] F. Krause, H. Bossel, K. F. Müller-Reissmann, *Energie-Wende Wachstum und Wohlstand ohne Erdöl and Uran*, S. Fischer, Frankfurt 1981, p. 13.

[197] http://www.bmwi.de/DE/Themen/Energie/Energiewende/gesamtstrategie.html, "*Die Energiewende ist unser Weg in eine sichere, umweltverträgliche und wirtschaftlich erfolgreiche Zukunft"*.(accessed: 4.11.2016)

are complemented with an international perspective: On the bilateral level, Germany's energy policy has an impact on the market structures and physical conditions of the energy systems of its neighbor countries. On the European level, national energy policies have to be in accordance with the European regulatory framework. At the same time, Germany is takeing an active part in shaping European internal and external energy policy, which leads to the international dimension: Is Germany able to sell its "Energiewende" – its standards, products, and vision – in Europe and beyond? It is obvious that parts of this vague and highly complex concept will be or have been adopted by others.[198] Some countries might adopt equivalently ambitious goals, however, while implementing more innovative measures.

Energy policy of the Federal Republic of Germany is affected by internal and external factors.[199] It is often highlighted that the Federal Republic of Germany is an example of a country with *geo-economic power*.[200] Scientific literature demonstrates that the foreign policy model of the German geo-economy is characterized e.g., by defining national interest from an economic perspective, the dominant role of export-oriented business affecting foreign policy, and the use of economic power to impose the country's national preferences on others.[201]

The implementation of the above model is connected with German energy policy, oriented at improving the competitiveness and innovativeness of the economy. It can also lead to strengthening the "geo-economic power", which is based on different scale instruments such as export initiatives, communication of *Energiewende* through the German Ministry of Foreign Affairs, the German Accelerator, as well as regulations and standards. The aim of this article is to determine how the process of energy transition affects the improvement of energy efficiency, energy security, and how it might strengthen Germany's economic competitiveness.

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[198] *German energy policy – a blueprint for the world? Survey by the Weltenergierat – Deutschland* (2015). http://www.weltenergierat.de/wp-content/uploads/2014/02/Energiewende-Survey-English-final.pdf (accessed: 9.11.2016).

[199] J. Schild, S. Harnisch, *Deutsche Außenpolitik und internationale Führung: Erwartungen, Ressourcen, Partner, Praktiken,* [in:] *Deutsche Außenpolitik und internationale Führung*, Nomos Verlagsgesellschaft mbH & Co. KG, 2014.

[200] H. Kundnani, *Germany as a Geo-economic Power*, "The Washington Quarterly", vol. 34, no. 3, 2011, pp. 31-45.

[201] H. Kundnani, *Germany as a Geo-Economic Power … op. cit.,* pp. 31-45.

Energiewende – the long history of the energy debate in Germany

The idea of an environmentally friendly energy system has a long history in Germany. The anti-nuclear movement has been particularly strong in Germany, finding its roots in the late 1970s, among others with the establishment of the Öko-Institut in 1977. This Öko-Institut claims to be "the attorney of the environmentalist movement".[202] Simultaneously, political discussions on energy transition were intensified due to oil crises (1973, 1979), which showed the effects of excessive dependence on imported oil. To a high degree, decisions on the modernization of the German energy sector were the result of a statement by the Saudi Minister of Oil, Scheich Yamani, published in "Le Monde" on October 19, 1979: *"Ich glaube, wir verlieren jede Kontrole über die Erdölpreise …"*.[203] Like the Öko-Institut, the Green Party, founded in the late 1970s as an anti-nuclear movement, has lasted until today and even increased its influence.[204] Interestingly, even if the Green party's programme is located on the left side of the political spectrum, links and coalitions with the conservative CDU were not excluded. This relationship reached its peak so far in the government of Baden-Württemberg, with over 10 million people the third biggest state within Germany. In May 2016 the first coalition between the Green Party and the CDU started – with the CDU as junior partner and with Winfried Kretschmann as first green prime minister.[205] One could say that this government is the heritage of a much longer cooperation: The founders of the famous Electricity Feed-in Law, the predecessor of today's Renewable-Energy-Act (EEG), were equally a conservative-green couple.[206]

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[202] Öko-Institut e.V., "*Unser Leitbild*" (2005) https://www.oeko.de/uploads/oeko/download/leitbild_oei.pdf (accessed: 9.11.2016).

[203] F. Krause, H. Bossel, K. F. Müller-Reissmann, *Energie-Wende Wachstum …, op. cit.,* p. 13.

[204] Über uns: 1977-1979 http://www.gruene.de/ueber-uns/1977-1979.html (accessed: 06.01.2017).

[205] *Die Landesregierung*, https://www.baden-wuerttemberg.de/de/regierung/ (accessed: 09.11.2016).

[206] "*Das unterschätzte Gesetz*", Article, Die Zeit http://www.zeit.de/online/2006/39/EEG/komplettansicht (accessed: 9.11.2016).

This law allowed the feed in of electricity generated by renewable resources and introduced a remuneration mechanism in 1991. Its successor, the German-Renewable-Act increased incentives for renewables in the year 2000 (with amendments in 2004, 2009, 2012, 2014, 2016). The installed guaranteed feed-in-tariff for the various renewable technologies was slowly replaced by more market-orientated remuneration mechanisms. While PV for example received a remuneration of around 50 Euro Cents per KWh in the year 2000, ten years later it was reduced to around 18 Euro Cents per KWh. A corridor for the expansion of renewable energies was established to control and limit the growth of renewable energies in order to cope with demand and the development of the electricity grid. Recent revisions to the EEG have removed administratively determined feed-in-tariffs or feed-in-premiums for most renewables. Instead, investors must now take part in competitive tenders.[207]

From the institutional side, competences in energy policy-making were traditionally divided by the ministry of economy and the ministry of environment. After the election in 2013, the new government tried to establish a more holistic approach, which resulted in the complete movement of energy competences to the ministry of economy. However, the competences in climate and nuclear safety have been left in the ministry for the environment, which has caused political struggle sometimes, especially after the COP21 Paris agreement.[208]

The most important milestone in the recent history of the Energiewende is the energy concept of 2010 where major goals of energy policy have been defined until 2050.[209] The Concept aimed at accelerating the shift towards an energy system which broadly relies on renewable energy sources. The change in Germany's energy policy was further intensified by the Fukushima disaster in Japan in 2011. As a result, Germany decided to completely exit from nuclear energy by 2022.

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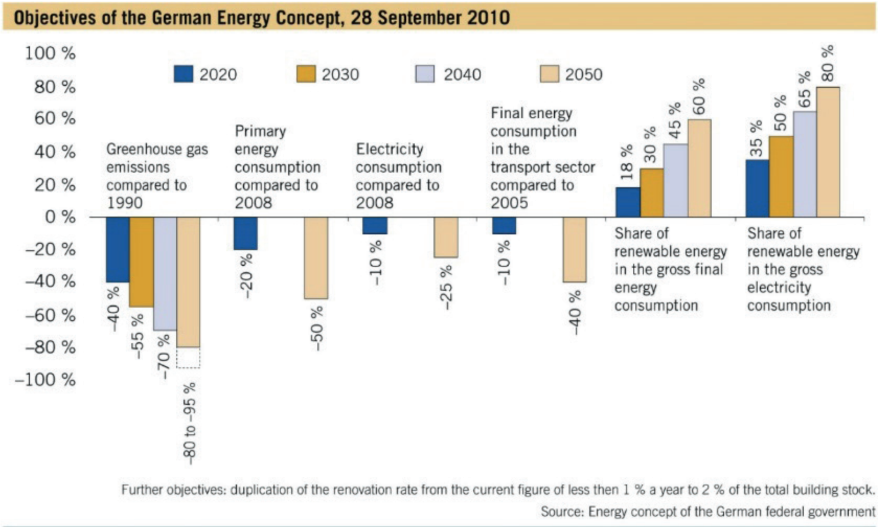
[207] *Erneuerbare-Energien-Gesetzt*, https://www.erneuerbare-energien.de/EE/Redaktion/DE/Dossier/eeg.html?cms_docId=132292 (accessed: 9.11.2016).

[208] Handelsblatt.de http://www.handelsblatt.com/politik/international/bundesumweltministerin-hendricks-klimaschutzplan-ist-eine-klare-ansage/14842734.html (accessed: 9.11.2016).

[209] *Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung*, https://www.bundesregierung.de/ContentArchiv/DE/Archiv17/_Anlagen/2012/02/energiekonzept-final.pdf?__blob=publicationFile&v=5 (accessed: 8.11.2016).

Chart 14. Objectives of the German Energy Concept



Sources: *Energy concept of the German federal government.*

The defined targets of 2010 will only be partially accomplished in 2020. A tremendous expansion dynamic has been achieved in Germany's renewable electricity production, which has tripled to about 33% of electricity production in 2015 compared to 11 % in 2010. Moreover, energy consumption has decreased to the lowest level since 1990. However, other targets like the reduction of Green House Gas emissions, the reduction of final energy consumption in the transport sector, reductions in the use of electricity, and the increase of energy efficiency by 2.1 % annually, are not on track, on the contrary. The use of lignite in Germany has increased due to low coal and CO_2-prices under the European emission trading system, and also over the course of the nuclear phase-out. Germany will most likely not reach its climate goals for 2020. Furthermore, the German government wants renewable electricity to become the most important source of energy, used also for heating, transport and industrial production.[210] Due to this larger area of application for electricity, the goal for a reduction of electricity use is contested.

[210] *Strom 2030. Langfristige Trends – Aufgaben für die kommenden Jahre,* BMWI, Berlin 2016.

Another key feature of the German Energiewende is that a growing number of consumers are starting to produce their own electricity (for example with a photovoltaic system on the roof top) and become "prosumers". Energy production is thus no longer in the hands of a few major electricity companies, but with a variety of players – about 50% of renewable electricity is generated by citizens.[211] New business models and start-ups in the energy sector are emerging. Starting in 2017, Germany will begin a rollout of smart meters, to be completed in 2032. This should help to better integrate renewable energies, enhance flexibility in the energy system, and generate new business models.

The spirit of the energy transition has been a trigger for ideas and innovation in the whole value chain of the energy sector and the growing start-up business in Germany. Fortunately, this transition is more and more linked to another transition: the digitalization of processes. The collection of "big data" brings in new efficiencies in the energy market, especially in the sphere of control systems, sales, and analysis. In German cities and universities the network of start-up companies is growing. So is the engagement by major utility companies who themselves hold shares in start-up companies and offer support for innovative businesses.[212] Bootcamps and accelerators both public and private are growing. The Ministry of Economy has, for example, installed "German Accelerators" in the United States. in Silicon Valley, to support German start-ups entering the market.[213] Public programmes like the "export initiatives of energy efficiency" and the "export initiative on renewable energies" have even a longer history in selling solutions and technologies on the international market (since 2002).

Generally, Germany is not particularly known as the best place for venture capital. In a ranking of the OECD countries it is only represented in the 17th position.[214] Also, research policy and research funds

[211] *Trend:Research 2013*, https://www.unendlich-viel-energie.de/media/file/284.AEE_RenewsKompakt_Buergerenergie.pdf (accessed: 19.03.2017).

[212] U. Franke, N. Paladini, *Intelligente Vernetzung – Notwendigkeit und Chance in der Energiewende*, in: "Schriftenreihe des Kuratoriums", Forum für Zukunftsenergien, p. 118.

[213] German Accelerator, http://germanaccelerator.com/ (accessed: 11.04.2017).

[214] U. Franke, N. Paladini, *Intelligente Vernetzung – Notwendigkeit ... op. cit.*, p. 119.

are not of particular volume compared to other OECD countries, even if the public budget on research has doubled since 2006, with renewables and efficiency in the centre of support.[215]

Structure of the electricity balance

In 2016, German economy consumed 592.7 TWh of electricity; in comparison to 2015, this means a decrease by approx. 0.4% (2.4 TWh).[216] The main source of electricity production is coal (hard coal and lignite) with a 41.3% share in the electricity balance (including 23.1% lignite and 18.2% hard coal), followed by renewable economy sources (29.5%), nuclear energy (14.2%), natural gas (9.2%) and crude oil (5.1%).[217] The security of supply is still very high. According to the SAIDI Index, the minutes of electricity interruption in Germany even decreased in the last years (12.70 minutes in the year 2015).[218] However, the interference of the transmission system operators has dramatically increased with the expansion of fluctuating renewables. While TSO spent around 1500 hours for re-dispatch activities, in 2015 they were already at 15800 hours.[219] Of special relevance on the topic of security of supply is, on the one hand, the lack of investments in new capacities in power plants and, on the other hand, the delay of the expansion of high-voltage transmission grids. As a consequence the expansion of wind-onshore has been limited for some areas in the North of Germany. The background to this is that all off- and most on-shore wind projects are located in the North of Germany, whereas major consumers are located in the South of Germany.

[215] P. Nießen, C. Rolle, Forschungsprioritäten für die Energiewende(n), "Energiewirtschaftliche Tagesfragen" No. 66/2016.

[216] P. Graichen, M. M. Kleiner, Ch. Podewils, *The energy transition in the power sector: State of affairs 2016. A review of the major developments in Germany and an outlook for 2017*, AgoraEnergiewende, Berlin 2017, p. 4.

[217] *Ibidem*, p. 4.

[218] http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Stromnetze/Versorgungsqualitaet/Versorgungsqualitaet-node.html (accessed: 10.04.2017).

[219] http://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Versorgungssicherheit/Stromnetze/Engpassmanagement/Redispatch/redispatch-node.html (accessed: 10.04.2017).

The dimension of competitiveness is particularly discussed in Germany, as the costs for the transformation of the system have increased more than expected. The Renewable-Energy-levy ("EEG-Umlage") that was implemented to finance the RES-subsidies also rose significantly from 2.05 cent/KWh in 2010 to 6.35 cent/KWh in 2016. To ensure that German industry does not suffer a competitive disadvantage as a result, around 2000 energy-intensive companies (e.g., steel production) were freed from this levy. However, 48 % of the total "EEG-Umlage" is still paid by industry, commerce, and service companies. Germany's household electricity prices rose in average from 23.7 cent/KWh in 2010 to 28.7 cent/KWh today. Over 50 % of the electricity price are taxes and levies in Germany. In 2010 the total cost for electricity for an average household was 69.1 € per month, which rose to 83.7 € per month in 2016. Further costs have to be added to the overall electricity bill: the costs for re-dispatch as well as the costs of grid expansion on various levels. The decision to favor underground cables instead of high-voltage lines above the ground to foster acceptance, will increase the delay and the costs likewise.[220]

The German "Energiewende" is constantly under debate. It represents the unique transition of an industrialized country, with a 23% share of industry in the GDP, towards a decarbonized future. The long-term targets in energy policy have been set; however, the milestones in between will not all be reached, and not all of the market assumptions made are still valid. This sometimes leads to questions about the effectiveness of measures and to discussion about short term reactions. One example is the early shutdown of 2.7 GW of old lignite power plants to reduce up to 12.5 million t CO_2. The utilities receive around 1- 3.6 billion euros as compensation, also to function as back-up capacity in case of electricity shortage until 2020.[221] It is necessary that the monitoring process and discussion about this unique transition continues to ensure regular assessment about the past and the future. Sometimes measures and targets have been confused, for example the target of the share of renewables which could represent more of an instrument for the reduction of fossil fuels in the electricity mix. Feed-in tariffs gave opportunities for new businesses and for economies of scale, not exclu-

[220] *Energie für Deutschland 2016,* Weltenergierat – Deutschland, p. 117.

[221] https://www.tagesschau.de/inland/klimareserve-fragen-und-antworten-101.html

sively in the German market. It led to an important rise of renewable electricity into the system, however, not without any conflict for market, technological, and even ecological questions, as the expansion of renewables has not led to greenhouse emission reduction so far.

The "Energiewende" are leading to a change in the market with more and more new actors emerging, offering new ideas in the sphere of demand-side-management and storage, prosumers and small scale systems of production and consumption (the "blockchain"), as well as new investment structures.[222] The success of most innovations are nevertheless highly dependent on the extremely regulated energy market. Moreover, "Energiewende" is not a guarantee itself for an innovative economy: in a globalized market, ideas, standards, and products could be also well developed in other parts of the world and then imported to the German market.

Energy efficiency

According to the American Council for an Energy-Efficient Economy, Germany is already the world champion in energy efficiency, and scores the most points in the categories of national efforts, buildings, and industry.[223] Since the 1990s energy consumption in Germany has been stagnating despite economic growth. Between 2008 and 2014 energy productivity rose annually by 1.6% on average. However, this efficiency rate is still beyond the proclaimed target of 2.1% annually until 2020. Also not on track is primary energy consumption reduction with its target of minus 20% in comparison to 2008, as in 2014 a reduction of only 8.7% was achieved. The same is true for electricity consumption: in 2014 a 4.6% reduction was achieved in comparison with 2008. It is likely that electricity consumption will rather rise than decrease with the ongoing electrification of the society. Final energy consumption in the transportation sector has increased about 1.7% in comparison with 2005 and will fail to reach the 10% reduction target in 2020.[224]

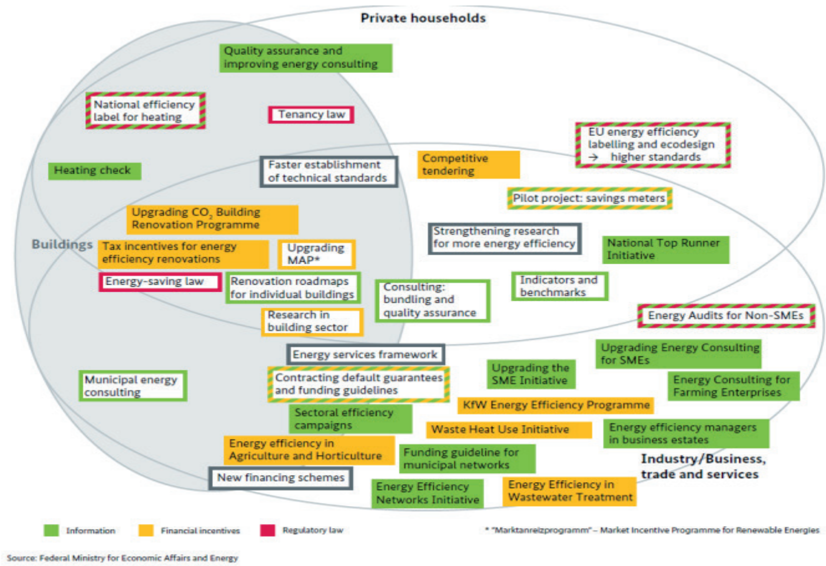
[222] *Energie für Deutschland 2015*, ... op. cit., p. 19 ff.

[223] P. Kiker, *Germany, Italy, and Japan Top World Energy Efficiency Rankings*, http://aceee.org/press/2016/07/germany-italy-and-japan-top-world (accessed: 01.02.2017).

[224] Federal Ministry for Economic Affairs and Energy, Monitoring Report , p. 23 ff.

To enhance the efforts for energy efficiency and comply with European Union legislation, the German Government introduced in 2014 the so called "National Action Plan for Energy Efficiency" (NAPE) with several programmes and instruments such as legislation, financial incentives, and information. At the centre of the short-term measures of NAPE were the introduction of new competitive tendering for energy efficiency; funding for building renovation and introduction of tax incentives, and the setting up of energy efficiency networks together with business and industry. The aim of NAPE is to achieve a reduction of 390 to 460 PJ by 2020.[225] To what extent the various measures have been successful has to be evaluated in the future.

Figure 10. Short-term measures and long-term work processes of NAPE for the 18th legislative term



Sources: Federal Ministry for Economic Affairs and Energy.

The "efficiency potential" has various dimensions: it has to be distinguished between technological potential, economic potential, feasibility

[225] https://www.bmwi.de/BMWi/Redaktion/PDF/M-O/nationaler-aktionsplan-energieeffizienz-nape,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf (accessed: 12.04.2017).

potential, and the realistic potential.[226] Keeping the extreme complexity of industrial processes and value chains in mind, the definition of an absolute target is very difficult to achieve: various components of the system have completely different dimensions of potential, including technical and economic limitations on different levels. Moreover, with a growing demand for flexibility in the electricity system due to the fluctuation in renewable power production, efficiency is not always the overall objective. In each branch, company, or production site, the limitations of efficiency have to be considered. On the other hand, the potential of demand-side-management in the industry is as difficult to calculate as it is for efficiency: in the industry the potential is estimated between 3 and 15 GW.[227] In an electricity system, where demand-side-management is crucial for stability, the controlling of decrease or increase of demand for electricity represents a service which has to be incentivized adequately (and compensate e.g., the loss of production, the inefficient use of various components, extra time for storage etc.). In Germany, this is partially the case in the industry sector.[228] Small consumers, however, are not yet part of the compensation system. Neither do consumers benefit from price differences on the wholesale market as their price per kilowatt hour is fixed. With the rollout of the smart meter from 2017 on and the further increase of smart systems, demand-side-management might gain importance in the future.[229] Especially, energy productivity is relevant in the concept of energy efficiency. It can be assumed, however, that even if efficiency is further enhanced, Germany is still increasing its energy consumption. This is related to the so called "rebound effect", which argues that the energy which is saved due to efficiency measures is spent elsewhere. It is estimated that up to 70% of the efficiency is lost in the "rebound effect".[230]

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[226] *Energie für Deutschland 2015*, ... op. cit., p. 85.

[227] F. Holtrup, *Potenzial für Demand Side Management der energieintensiven Industrie in Deutschland*, http://www.weltenergierat.de/wp-content/uploads/2016/01/2016-01-DSM-Papier-v8.pdf (accessed: 10.04.2017).

[228] *Ibidem.*

[229] U. Franke, N. Paladini, *Intelligente Vernetzung – Notwendigkeit ... op. cit.,* p. 116.

[230] Energie für Deutschland 2016, Weltenergierat – Deutschland, p. 110.

Drivers for efficient efficiency policy

While the success of various policies and initiatives to enhance efficiency has to be analyzed in the future, there are more relevant drivers of energy efficiency: On one hand is the international promotion of German technological solutions in energy efficiency, enabled among others through the “Export Initiative“ of the Ministry of Economy[231]; non the other , funding for research and development is another driver for efficiency. Around one third of the total sum of 863 million Euros allocated by the federal government for energy research projects in 2015 went to energy efficiency projects.[232] Efficiency is key in German energy policy to reach the political targets in 2020 and beyond. On the other hand, the development of efficient technologies as well as efficient policies are needed to keep costs for the transition on a competitive level.

Energy security

In Germany, energy security (in German: *Energiesicherheit*) is understood as the certainty of energy supplies at a reasonable price.[233] Therefore, continuous, uninterrupted, and stable supply of energy resources significant for the development of “Energiewende”[234] and energy is an important goal of energy policy. The analysis of Germany’s energy balance structure confirms that the country does not have enough energy resources of its own and needs to import them, mostly from the Russian Federation, Norway, and the Netherlands. The Russian Federation is the most important of those suppliers, supplying to the Federal Republic of Germany hard coal, crude oil, and natural

[231] http://www.efficiency-from-germany.info/ENEFF/Navigation/DE/Ueber_uns/ueber_uns.html;jsessionid=4F081EF984712B7858229B3CBA7D877F (accessed: 10.04.2017).

[232] http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/bundesbericht-energieforschung-2016,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf (accessed: 10.04.2017).

[233] *Streitkräfte. Fähigkeiten und Technologien im 21. Jahrhundert - Umweltdimensionen von Sicherheit - Teilstudie 1: Peak Oil. Sicherheitspolitische Implikationen knapper Ressourcen*, Zentrum für Transformation der Bundeswehr, Strausberg, 2010, p. 9.

[234] *Mineralische Rohstoffe für die Energiewende*, Energie für Deutschland 2016, p. 112.

gas, i.e., all of the three energy resources imported by Germany. We must point out that German energy policy reflects the interests of the main entities within the country which determine its form. Stephen F. Szabo emphasizes the roles of the German government, political parties, and business.[235] Florian Baumann notes that "a solely economic understanding of securing the energy supply by means of trade and business is not enough"[236]. Furthermore, Frank Umbach stresses that in case of energy market mechanisms functioning improperly, the state is expected to take responsibility for ensuring energy security to its citizens.[237] Nevertheless, German business is strongly oriented at exporting products to the Eastern market. The analysis of strategic documents shows that the strategic character of German-Russian relations may result in the need to make concessions in foreign policy with regard to the Russian Federation in order to maintain the stability of supplies of Russian natural gas.[238] The strategic character of German-Russian relations in the energy sector dates back to the agreement for natural gas supplies of February 1, 1970 concluded between Ruhrgas AG and Sojuzgazexport, under which Germany provided loans for the purchase of 1.2 million tons of pipe from Mannesmann AG for the construction of a gas pipeline in the USSR.[239] Taking into consideration the completed and planned joint investment projects between Russia and Germany, the relations are bound to remain strategic in the near future. In 2015, the Russian Federation supplied almost 45 bcm to the Federal Republic of Germany.

The process of energy transition contributes to reduced dependence on imported energy resources and a higher amount of energy produced from renewable sources. This results in improved energy self-reliance, especially in the context of the growing proportion of

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[235] F. Szabo, *Germany, Russia, and the Rise of Geo-Economics,* Bloomsbury 2015, p. 35.

[236] F. Baumann, *Energy Security as multidimensional concept*, Research Group on European Affairs, CAP Policy Analysis, no. 1, March 2008, p. 4.

[237] F. Umbach, German Debates on Energy Security and Impacts on Germany's 2007 EU Presidency, in *A. Marquina* (ed.), Energy Security. Visions from Asia and Europe, New York 2008, pp. 1-21.

[238] *Streitkräfte. Fähigkeiten und Technologien im 21. Jahrhundert - Umweltdimensionen von Sicherheit - Teilstudie 1: Peak Oil. Sicherheitspolitische ... op. cit.*

[239] B. Molo, *Polityka bezpieczeństwa energetycznego w XXI wieku*, Oficyjna Wydawnicza AFM, Kraków 2013, p. 224.

renewable energy in the structure of electricity balance and electrification of the heating industry and transport. In time, this will cause reduced demand for crude oil and natural gas and a growing demand for electricity, mostly produced from renewable sources in the German model of energy transition. Soon, the surplus of electricity may be stored using the power-to-gas technology. This technology also enables the production of hydrogen to be mixed with natural gas in the appropriate proportion.

Strengthening Germany's competitive position

Provided that one of the goals of EU energy policy is to develop a common energy market through the extension of natural gas and electricity interconnectors between states, Germany clearly has the best developed energy infrastructure of all EU countries. The central geographical location and numerous interconnectors enable it to serve as the center of distribution of natural gas and electricity in Europe. Price differences are going to intensify this process. In the case of natural gas, the pricing policy of the Russian Federation is crucial, since Germany buys gas from Russia at a lower price than other countries of Central and Eastern Europe and thus can resell its surplus gas. As for electricity, in Germany it is cheaper on the wholesale market than in Central and Eastern European countries. After the extension of electricity interconnections, this will contribute to the improvement of Germany's position as an energy distribution center. The planned energy cooperation with Denmark involving the construction of a 1500 MW electricity connection AC Network, and a 1400 MW connection with Norway, Nord-Link, will improve the competitiveness of the German energy sector.[240] In addition, a 1000 MW connection between Germany and Belgium, Alegro, is currently being built by Amprion company.[241]

The Federal Republic of Germany has a strong industrial potential and it seems that in the context of developing low-emission transport

[240] M. Ruszel, *The political importance of energy cooperation between Germany and Denmark on the European Union energy market*, E3S Web of Conferences 10, 00135 (2016), p. 2.

[241] Alegro, http://www.elia.be/en/projects/grid-projects/alegro/alegro-content (accessed: 11.03.2017).

and electric vehicle networks it will play an important role. On the one hand, German automotive concerns will try to create new models of electric, hydrogen, or hybrid vehicles, which can be sold in Europe and beyond.[242] On the other hand, it is a challenge to create relevant solutions for the creation of an infrastructure of electric- or hydrogen- vehicle charging and batteries able to accumulate high amounts of energy. The R&D and technological potential makes the German economy play an important role in the process. Taking into account the assumptions of the German federal government, which predicts that by 2020 almost a million electric vehicles will be used, this process will definitely progress.[243] The Federal Republic of Germany also carries out innovative research concerning the use of power to gas (P2G) technology, which could be applied in using surplus electricity produced from renewable energy sources.[244] The use of this technology enables the storage of hydrogen or methane produced from hydrogen, and then their retransformation into electricity. This way, P2G technology will have a significant application in the heating, automotive, and chemical industries and may contribute to gradual replacement of crude oil and natural gas by renewable energy. Carrying out pilot projects in this regard and drawing up pioneer regulatory solutions may contribute to the development of this technology in other EU countries that have similar gas infrastructure.[245]

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[242] http://www.manager-magazin.de/unternehmen/autoindustrie/bmw-und-daimler-wollen-das-wasserstoffauto-voranbringen-a-1130491.html (accessed: 10.04.2017)

[243] As of January 1, 2017, there are 34,022 electric cars in Germany. See: *Anzahl der Elektroautos in Deutschland von 2006 bis 2017*, https://de.statista.com/statistik/daten/studie/265995/umfrage/anzahl-der-elektroautos-in-deutschland/ (accessed: 10.04.2017).

[244] *Potenzialatlas Power to Gas*, DENA, Berlin 2016.

[245] In Germany, 20 pilot power to gas projects are currently carried out: Windgas Haßfurt, GrInHy, Leuchtturmprojekt Power-to-Gas Baden-Württemberg, Wasserstofftankstelle Stuttgart Talstraße, "Smart Grid Solar" - ZAE Bayern und Bayerisches Speichertestzentrum Arzberg betreiben Plattform für Erneuerbare Energien, Hochschule Ostwestfalen-Lippe forscht im Projekt bioCONNECT, Rieselbettreaktor GICON-Großtechnikum, Extyron Zero-Emission-Wohnpark, WindGas Hamburg, Exytron Demonstrationsanlage, WindGas Falkenhagen, Windpark RH2-WKA, Hybridkraftwerk Prenzlau, Audi e-gas Projekt, Wasserstofftankstelle Hafen City, H2Herten, RWE-Demonstrationsanlage Ibbenbüren, Multi-Energie-Tankstelle, H2-Forschungszentrum der BTU Cottbus, HYPOS, sunfire, CO2RRECT, Pilotanlage Allendorf, Power to Gas Biogasbooster, Power-2-Hydrogen-Tankstelle Hamburg,

Strengthening Germany's competitive position will also be supported through promoting the solutions of German energy transition. According to Karoline Steinbacher, Germany may become an international leader of energy transition processes and then aim to diffuse them. These activities comply with the concept of "leadership by diffusion".[246] The success of the Energiewende is on the one hand defined by the accomplishment of its targets, and on the other is the balance between environment, security of supply, and competitiveness. The situation of the Energiewende and its impact on the three dimensions of the "triangle of energy policy" is regularly measured by an official monitoring report of the Ministry of Economy.[247] The international success of the "Energiewende" highly depends on its domestic success. At the same time, Germany has developed a number of instruments to promote climate policy, which is the catalyst of energy transition. Jörn Richert points out that in 2003, BMWi established an export initiative of renewable energy sources, and one year later, at the conference "Renewables 2004", the REN21 network was formed with German financial support. Organizations such as IRENA (International Renewable Energy Agency) and REN21 were also established on German initiatives and greatly contributed to supporting national interests.[248] The policy of imitation implemented by the Federal Republic of Germany provides a channel supporting the export of German products, standards, management system, regulatory environment, and services connected with renewable energy and energy efficiency. Germany wants to export high quality surplus products.[249] To achieve

BioPower2Gas, Methanisierung am Eichhof, Energiepark Mainz, Thüga, ZSW, Viessmann Power-to-Gas im Eucolino. See *Pilotprojekte*, http://www.powertogas.info/power-to-gas/pilotprojekte-im-ueberblick/?no_cache=1 (accessed: 7.03.2017).].

[246] K. Steinbacher, M. Pahle, *Leadership by diffiusion and the German Energiewende,* PIK, Discussion Paper, February 2015.

[247] Federal Ministry for Economic Affairs and Energy: Vierter Monitoring-Bericht zur Energiewende, https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/vierter-monitoring-bericht-energie-der-zukunft.pdf?__blob=publicationFile&v=24 (accessed: 11.04.2017).

[248] J. Richert, *Global, gemeinsam, vernetzt. Wie eine deutsche Energiewende-Außenpolitik aussehen müsste,* https://zeitschrift-ip.dgap.org/de/ip-die-zeitschrift/archiv/jahrgang-2016/juli-august/global-gemeinsam-vernetzt
(accessed: 03.03.2017)

[249] K. Solberg Soilen, *Geoeconomics*, Ventus Publishing ApS 2012, p. 84.

competitive advantage, it needs to create functional mechanisms for creating sources of technological advantage.

Conclusion

Energy transition, which originated in the 1980s, accelerated in the years 2000-2010, with the peak dynamic of EEG reform in 2005 and the energy concept in 2010. The goals of the process are climate protection, improvement of energy security, and enhancing economic competitiveness. After some time, this activity additionally led to achieving the ability to influence the political preferences of other countries and international institutions. The process of energy transition also contributes to improving energy security by enhancing energy self-reliance and reducing import dependency on energy resources and electricity. This means that all the goals of Germany's energy transition are external. Since climate protection is supported by German foreign policy (e.g., during COP climate summits), energy security may be manifested in lowering the import of energy resources, and thus, change Germany's position at the geo-political level.

Improving competitiveness is of fundamental importance. Therefore, Germany wants to disseminate the German model of energy transition so as to make it an export product and a way of integrating renewable energy with the electric system. Politicians may support visions of extending renewable energy or standards at the regional level, and give the country's business access to foreign markets. This is true, yet policies do not always have a positive economic effect. For example, billions of Euros are spent every year to support renewable energy, especially on solar panels and windmills, but the key producers of such technologies are mostly Chinese companies. This means that business in other countries can make use of Energiewende. At the same time, political conditions in Germany such as technological preferences and high energy levies encourage companies to develop their production in other countries.

Therefore, activities as part of energy policy should be intelligent and flexible. It is increasingly obvious that innovation is a way to improve competitiveness. This mostly refers to combining the world of energy with digital technology, and in time, thanks to new technologies (power-to-x), even with the gas system. Different instruments at different levels are being used for this purpose.

The effectiveness of German energy policy is based on strong energy partnerships, the most important of which is political relation with the Russian Federation. The diversified structure of directions and sources of energy resources, diversified contract structures, and complex energy infrastructure provide the basis for building a distribution center of natural gas and electricity (a gas hub and an electricity hub). Therefore, Germany has a strong position in the new global race connected with the manufacture of electric, hydrogen, and hybrid vehicles. The process of developing low emission transport means that there will be a global race in the production chain of different goods and services to increase export. The catalyst for this process, as well as the process of energy transition, is climate policy.

Chapter 10

Energy transition in France: towards green development

Tomasz MŁYNARSKI[250]

Energy transition in France involves different directions of reform, such as improving energy efficiency, reducing the emission of greenhouse gases and fossil fuels consumption, and the growth of renewable energy sources in the energy basket. The goal of energy transition is to gradually change from energy generated from hydrocarbons (oil, natural gas, coal) and centralized energy sources (nuclear energy) to low emission, dispersed energy sources (RES). The scope of the works included three main areas of reform: to decentralize the energy system (gradual reduction of the share of nuclear energy), to enhance energy saving and reduce energy consumption (energy efficiency and performance), and to ensure environmental protection and development of "green" and energy-saving economy sectors.

Energy balance structure of France

The programme of nuclear energy introduced over political divisions has led to a significant lowering of energy dependency of the country, compensated for the lack of its own fossil resources, and allowed a departure from coal. Thanks to nuclear energy, France has developed a unique model of energy security. In 2014, nuclear energy covered 42% of total energy consumption. France's energy independ-

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ence is relative and mainly refers to the electricity sector, where almost 75% of energy production comes from nuclear power. Nuclear energy has priority economic and strategic importance for France: it balances over 1/3 of the costs of fossil fuels import. Nuclear energy meets three fundamental goals: it enhances the energy self-sufficiency and security of supply in the country, ensures low and stable prices of electricity (which increases the competitiveness of the French economy, especially in sectors with high demand for electricity), and is an instrument in the fight against global warming. The nuclear power industry is an important asset and link in the country's economy, and export of electricity is an important source of extra income. Additional economic benefits come from low emissions in the French sector of electricity in the face of tightening the European system of quoting the emission of greenhouse gases (*EU Emissions Trading System*). Thanks to nuclear energy, France has not only reduced the import of fossil fuels, but has even become the main supplier of products and services for the nuclear industry.

The share of fossil fuels (oil: – 30%, natural gas – 14%, and coal – 4%) in the total amount of primary energy consumed in France does not exceed 50%; it is the lowest rate in all EU member states.[251] Thanks to the common use of nuclear energy, France's import dependency rate is 48%.[252] However, the dominance of nuclear energy has caused significant backwardness and the lack of a consistent political and economic strategy concerning the development of RES.[253] France has a rich potential of renewable energy sources, but apart from water energy, they are rather poorly used. Renewable energy with a share of 9.5% is developing, in 2015 employing about 170 thousand people (in Germany, 355 thousand).[254]

New directions for France's energy policy were determined by the process "*Grenelle de l'environnement*" initiated in 2007 (with the partici-

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[251] Commissariat Général Au Développement Durable, *Chiffres clés de l'énergie*, Édition 2015, Commissariat Général Au Développement Durable, Février 2016, http://www.developpement-durable.gouv.fr/IMG/pdf/reperes-chiffres-cles-energie-2015.pdf (accessed: 15.12.2016).

[252] *EU Energy in Figures*, European Commission, Statistical Pocket Book, 2015, p. 194.

[253] The basic drawback is the low diversification of new renewable energy sources, because the share of wind and solar energy in energy production is still very low.

[254] *Renewable Energy and Jobs Annual Review 2016*, IRENA, p. 5, p. 11.

pation of representatives of regional authorities, trade unions, employers, and non-governmental organizations) in order to establish plans of action concerning sustainable development. It was a special form of consultation and inclusion of the community in the process of political debate on the future of the energy sector in France. Public consultations involved five parties (trade unions, entrepreneurs, NGOs, members of parliament, and the administration). The programme "*Grenelle de l'environnement*", created a future framework for policies and measures, setting ambitious goals for individual sectors and sources of energy and guidelines to improve research and development for clean energy technologies. Priority areas were the reduction of emissions in the construction and transport sectors, as well as the production industry. Grenelle also introduced support for heating based on RES.

After the presidential election in spring 2012, public consultations continued as a form of national debate on energy transition. The debate started on November 29, 2012, under the auspices of the Ministry of Ecology, included extensive regional consultations focused on reducing dependence on fossil fuels and nuclear energy.[255] As part of the national energy debate there were hundreds of meetings with the participation of local communities, non-governmental organizations, companies, and universities. Recommendations for the future energy law pertained, to the following issues: simplification of administrative procedures necessary for the development of wind, solar, and geothermal energy, and increased support for renewable energy. The National Debate on Energy Transition (DNTE) provided the basis for a governmental draft of the law concerning changes in the energy sector. France adopted the assumptions of deep energy transition in order to reduce emissions and promote energy efficiency. The French act on energy transition (*Act on energy transition for green growth*/ *Transition énergétique pour la croissance verte* after Senate amendments of July 15, 2015[256]) finally adopted on July 22, 2015, includes

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[255] *Ouverture du débat sur la transition énergétique*, http://www.lepoint.fr/societe/ouverture-du-debat-sur-la-transition-energetique-29-11-2012-1535085_23.php (accessed: 15.12.2016).

[256] *Loi n° 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte* (1), JORF n°0189 du 18 août 2015, https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000031044385&categorieLien=id (accessed: 15.05.2016).

a change of the energy model based on fossil fuels through promoting "green growth" and energy efficiency with gradual lowering of nuclear energy. The key goals of French energy transition assume the reduction of CO_2 emission, in part through the development and integration of renewable energy sources with the energy system, with a gradual reduction of nuclear energy. GHG emissions are to be reduced by 40% before 2030, and by 75% before 2050 (as compared to 1990). The French act on energy transition introduced a high tax on CO_2 emission ("climate-energy tax" / "contribution climat énergie", CCE) from fossil fuels, depending on the generated emission.[257] France has also chosen to tax high emission sectors (heavy industry, energy sector, aluminum, etc.), and even to introduce an international carbon tax. Its goal is to effectively encourage industry to reduce emissions and invest in low emission energy sources.

Competitiveness on global and European energy markets in light of the assumptions of energy reform in France

France is one of the most industrialized countries, and at the same time emits one of the lowest amounts of greenhouse gases. Its ratio of CO_2 emission/GDP is one of the lowest in the world. As a result, contemporary France is trying to build its leadership capacities, not only in traditional spheres of international relations (e.g., opposition to the attack on Iraq in 2002 or its active role in the military intervention in Libya in 2011), but also in new areas, such as counteracting climate change. Just like the EU, France displays strong ambitions to be a leader in counteracting climate change, which is confirmed by its role as a key player in international negotiations (see the role of France in the negotiations before the COP21 summit). This is so because France has ambitions to be a climate leader, which in practice means support for tightening the objectives of GHG emission reductions, both regionally (EU ETS) and globally. The nuclear programme developed on a scale unique in Europe has not only ensured the competitiveness of the French economy, but also enabled its exceptional

[257] The CCE mechanism also occurs independently of the fuel tax (TICPE, *la taxe intérieure de consommation sur les produits énergétiques*).

success in activities aimed at preventing climate change, i.e., separating economic growth from pollution emissions. Therefore, France is attempting to achieve global climate leadership by influencing international institutions, which suits the Gaullist ambitions of building a multipolar world where it would play the role of a leader. Thanks to the significant role of nuclear energy, France is one of the few highly industrialized economies with the lowest ratio of CO_2 emissions per capita and in the sector of energy production, so it is pursuing the role of leader in the fight against climate change, promoting the development of nuclear technology as a zero emission source of energy. As a nuclear world power, France strives to popularize civil nuclear technologies at the regional and global level. This provides an opportunity to develop the industry sector, where it has had the know-how advantage for several decades. In this way, climate policy may be an instrument for improving the competitiveness of the French economy on the global market. In this sense climate policy is becoming first of all an instrument of economic strategy.

Energy efficiency.

French law supports investments in the sustainable development of energy sources e.g.., by interest-free loans for those who buy a house for the first time (if the building meets standards higher than those set in construction law, i.e., is characterized by energy saving or low energy consumption, the so-called BBC – *bâtiments basse consommation*) and BEPOS – *bâtiments à énergiepositive*).[258] The act also supports the conversion of already existing houses, including a system of tax deductions. In January 2011, a new system of tariffs was introduced for electricity produced from biomass, and in March the same year, for electricity produced using solar panels.[259] EDF is obliged to purchase all the power produced from solar and wind energy. France is

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[258] T. Młynarski, *Uwarunkowania transformacji polityki energetycznej Francji. Między ekologiczną modernizacją a ekonomiczną kalkulacją [Determinants of French energy transition policy: Between ecological modernization and economic calculation]*, Rocznik Integracji Europejskiej, no. 9/2015, Wydział Nauk Politycznych i Dziennikarstwa Uniwersytetu im. Adama Mickiewicza, p. 372.

[259] T. Młynarski,*Francja w procesie uwspólnotowienia bezpieczeństwa energetycznego i polityki klimatycznej Unii Europejskiej [France in the process of communitizing energy security and climate policy of the European Union]*, Kraków 2013, pp. 70-71.

making up for delays in the development of renewable energy sources and supports investment in RES or energy saving technologies.

Energy saving and the growth of the eco-work sector One of the main ways of reducing energy consumption by 20% in 2030 and by 50% in 2050 in comparison to 2012 is to be energy efficient in the sectors of construction and transport. In the housing sector (which accounts for almost half of energy consumption in the country), activities will include e.g., mandatory thermomodernization of public and private buildings, so that they can achieve the standard of "low emission" buildings by 2050. For this purpose, subsidizing loans is assumed to support the energy efficiency of buildings (interest-free loans, lower VAT), especially in the case of households with low incomes.[260] A 30% tax deduction for labor costs connected with improving efficiency is also planned. The development of the energy saving sector is expected to create tens of thousands of extra jobs (in construction, biosectors, or projects of reducing energy consumption, e.g., the installation of smart meters.

Another issue is the support for innovative energy-saving projects and the policy of reducing waste by 50% (e.g., banning the use of disposable plastic bags or dishes). In that country, the age of disposable plastic items has finished upon the decree of 31 March 2016: as of July 1, 2016, all disposable plastic bags were banned and replaced by reusable bags. One anticipated effect of energy transition is the creation of 100 thousand jobs.

The development of "green energy".

Ségolène Royal, Minister of Ecology, Sustainable Development and Energy, discussing the draft of the act on energy transition in April 2016 said: *"The development of renewable energy is at the heart of the transition to our energy model of the 21st century, more efficient and more sober, more diversified…"*[261]. The transition assumes

[260] Establishment of a National Guarantee Fund, offering subsidies for less affluent families or people who buy a house for the first time (if the building meets the standards higher than those set in construction law, i.e., is characterized by energy saving or low energy consumption, so-called BBC – *bâtiments basse consommation*) and BEPOS – *bâtiments à énergiepositive*). Other instruments of support are e.g., tax deductions for the conversion of already existing houses.

[261] *Les objectifs pour le développement des énergies renouvelables. Programmations pluriannuelles des*

dynamic development and integration of renewable sources with the energy system: their role is to fill the gap in reducing the share of nuclear energy in electricity production. Dynamic development of renewable installations is to be stimulated by administrative incentives for local governments, which will receive preferential state loans for the achievement of the goals of energy transition. Instruments stimulating the development of RES include financial support for small-scale energy generation for communes and local communities, as well as facilitation of laws and simplification of issuing permits for innovative local government projects, such as wind energy, water energy, and biogas (1,500 new installations are planned), as well as special tariffs for electricity produced from RES. As a result, the government assumes an increase in the share of renewable energy in gross final energy consumption from 14% in 2012 to 23% in 2020 and 32% by 2030. 40% of the consumed electricity is to come from RES.[262] Besides, roofs of all new commercial buildings with a surface area over 1,000 m^2 will have to equipped with renewable energy sources or vegetation that will ensure thermal insulation and will help maintain biodiversity.

France has set ambitious operational goals to meet by 2023[263]:

— growth of generating capacity in electricity production from renewable sources by more than 50% as compared to 2015 (from 43 GW to 71-78 GW),
— double the power from land wind power plants,
— triple the power from new photovoltaic parks,
— double the generating capacity to produce electricity from timber,
— developing France's potential in sea renewable energy (including 3,000 MW from offshore wind installations, 100 MW from sea liquid energy, and then expanding the capacities to 6,000 MW and 2,000 MW respectively).
— increase by more than 50% of heat production from renewable sources in comparison to 2014 (including more than 20% of heat

investissements de production – PPI, Ministère de l'Environnement, de l'Energie et de la Mer, 25 avril 2016, http://www.developpement-durable.gouv.fr/IMG/pdf/2016-04-25_Obj-_Dvp-_Energies_Renouvelables.pdf.

[262] Others: 38% of heat consumption, 10% of gas consumption, and 15% of engine fuel consumption.

[263] *Les objectifs pour le développement des énergies renouvelables…, op.cit.*

production from biomass, seven-fold increase of heat production from biogas (methanization), four-fold increase of heat production from geothermal energy, increase by over 75% of heat production from heat pumps, and increase by over 80% of heat production from solar collectors),
- improvement of effectiveness and energy recovery from the grid,
- introducing to the gas network 8 TWh of biogas from anaerobic fermentation and support for the development of the sector of powering cars with natural gas (bioNGV) up to 20% in transport consumption in 2023.

Reducing the share of nuclear energy and conventional fuels.

The act provides for lowering the share of nuclear energy in electricity production from 75% to 50% by 2050 as compared to the year 2012 (unlike Germany, France is not going to give up on it completely) under the condition of maintaining a competitive price for electricity and a guarantee of no increase in GHG emissions. Electricity production will remain at the previous stable level. For this purpose, extending the life cycle of reactors is planned, and the reactors will be shut down gradually as new renewable sources are launched.[264] Thanks to retaining a stable share of nuclear energy, an uninterrupted and evolutionary transition in French energy balance will be possible. Simultaneously, the government assumes a reduction in fossil fuels (oil, gas, coal) consumption by 30% (as compared to 2012), so as to achieve 40% of electricity in France coming from renewable sources by 2030 (besides 50% from nuclear energy).

The transport sector.

The sector in which a considerable reduction of CO_2 emission is possible is the sector of transport, being the main source of GHG emissions apart from the heating sector. This goal is to be achieved by popularizing electric cars and extending the infrastructure of electric car charging stations.[265] Another instrument is financial incentives for the purchase of an electric car or tax deductions for the construc-

[264] It must be emphasized that the French nuclear fleet is obsolete, because as many as 22 out of 58 reactors will have operated for 40 years in 2022, so EDF intends to extend the life cycle of reactors from 40 to 50 or 60 years.

[265] By 2020, 2-3 million electric cars are planned to be going on French roads, powered at home or from public grids.

tion of an electric power station (approximately 7 million of them are planned, compared to 10 thousand now functioning).[266] Extension of battery technologies is planned in order to store energy. The act on energy transition introduced subsidies for the replacement of an old car with a new, ecologically powered one. The development of the electric car sector is intended to support the system of "electric bonuses" applying when replacing an old Diesel car (older than 13 years) with a new, electric one (emissions up to 20 g CO_2/km) or purchase or lease of a new hybrid vehicle (emissions from 21 to 60 g CO_2/km).[267] Both individuals and public entities (enterprises, local governments, offices etc.) may use the assistance. The reform of the sector is to be supported by promoting bicycles and public transport or car sharing.

Intensive development of clean public transport is a separate branch of energy modernization. In addition, public institutions (in 50%) and local governments (in 20%) were obliged to renew their transport fleets based on low emission technologies (for vehicles up to 3.5 tons) before 2025. The replacement will apply to public transportation (buses) – 50% from 2020 and 100% after 2025. Energy transition has also introduced the requirement of ecologically clean vehicles for car rental companies and taxis (at least 10% of the fleet will have to have low emission engines by 2020).[268]

Plans for competitive advantage / new branches of economy.

In February 2014, France and Germany announced the development and adoption of a common industrial and technological strategy, and in the future, the establishment of a common consortium producing components for renewable energy devices (photovoltaic panels, wind turbines, etc.), oriented toward the export of low emission technolo-

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[266] T. Młynarski, *Uwarunkowania transformacji… [Determinants of energy transition …], op. cit.,* p. 372.

[267] *Voitures électriques et hybrides : Comment obtenir le nouveau bonus de 10 000 € ?*, http://www.developpement-durable.gouv.fr/Voitures-electriques-et-hybrides.html?var_mode=calcul (accessed: 15.12.2016).

[268] *Loi no 2015-992 du 17 août 2015 relative à la transition énergétique pour la croissance verte* (1), Chapitre II Efficacité énergétique et énergies renouvelables dans les transports, article 37, http://www.developpement-durable.gouv.fr/IMG/pdf/joe_20150818_0189_0001_1_-2.pdf (accessed: 15.12.2016).

gies and the extension of smart grids.[269] France hopes that as a result of the agreement it will become (together with Germany) the center of the world's industry of advanced technologies in the "green energy" and energy saving sectors.

Planes of competitive advantage and new branches of economy

Energy transition fosters the creation of new jobs and may become a stimulus to technological innovation. Energy eco-modernization is an opportunity for re-industrialization in the industry sector. It is connected with the need to patent and implement technological ideas on a large scale, and at the same time, develop new, advanced, energy saving technologies, not only for the internal market but also for export.

Socio-economic benefits of energy transition that may occur in France are:

- domestic energy and improvement of energy security due to reducing the importation of energy sources,
- economic development and industrialization in the modern industry sector,
- new eco jobs,
- energy saving,
- socio-ecological benefits connected with the improvement of environment and air condition,
- technological leadership and the opportunity to profit from low-emission and energy consumption-reducing technologies.

Thus, France counts on the development of the biomass and biogas sectors, sea renewable energy, small hydropower plants, the development of electromobility, projects for heat production from renewable sources, and the development of innovation and research support. As a result, 40 thousand jobs are to be created in the sector of onshore wind energy and photovoltaics (plus 8 thousand in the thermomodernization industry) by 2023. Besides, the construction of 250 PV stations, doubling the number of electric cars, and building 59 start-ups for green energy are assumed.

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[269] *Conseil des Ministres Franco-Allemand du 19 Fevrier 2014*, 16ème Conseil des ministres franco-allemand à Paris, https://de.ambafrance.org/16eme-Conseil-des-ministres-franco (accessed: 15.12.2016).

The impact of energy transition on the energy security of France and recommendations for other countries

The French transformation of the energy sector involves the development of RES, improvement of energy efficiency and energy saving, the transition from hydrocarbons to electric cars in the transport sector, and ecologization of the public domain. All these initiatives are to enhance the competitiveness of the country's economy, to create new jobs, and to improve the security of energy supply in the country. So energy transition is an expression of France's pragmatism, and if stable energy supplies can be ensured, it will be a strong stimulus for technological modernization and the country's economic growth.

French action on energy transition may be a source of inspiration for innovative solutions in designing the "ecological and economic modernization" of the energy industry in other countries that want to achieve: 1) intensive development of renewable energy sources supplemented with governmental support, 2) creating a national programme supporting energy efficiency growth, especially connected with the construction industry (low-energy construction), 3) development of modern forms of light eco industry which offers new jobs, 4) innovation in public transport (systems of municipal electric vehicles and charging stations) supported by the creation of special no-traffic eco zones in town centers, combined with popularization of *park & ride mobility*, 5) promoting cogeneration and modernization of waste management, including the use of post-industrial (mining) areas.

Chapter 11

Energy Transition in Great Britain

Marta KRAJEWSKA[270]

The British electricity market is in the middle of a rapid transition. In the wholesale electricity market a system which has developed to allow, almost exclusively, large scale thermal power stations to supply customers who didn't change their level of consumption, is moving into something characterized by large levels of renewable generation, huge volumes of distribution connections, extensive interconnection, and an active demand side.

Meanwhile the retail market, long characterized by little switching, large numbers of disengaged customers, and concerns about competition, is seeing a significant new entry. This market will continue to face significant change as the findings of the Competition and Markets Authority (CMA), which recently investigated the market due to concerns about insufficient competition, are implemented. And on the energy efficiency side there have been recent changes in Government policy, prompted by concerns about their effectiveness which may put the ability to meet objectives in doubt.

In addition, it seems clear that the decision of the British people to leave the European Union could also have a significant, though currently unknown, impact on all aspects of the energy market.

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This report seeks to provide an overview of the British electricity market and to provide an explanation of recent changes and current issues, and to consider what might be some of the challenges ahead.

The structure of the energy mix

The first important point is that it is a British Market (rather than a market covering the entire United Kingdom). The market covers England, Wales, and Scotland (following the merger of the two markets in 2005 as part of the British Electricity Transmission and Trading Arrangements (BETTA) project). The market does not cover Northern Ireland, which is part of a single "All Island' market with the Republic of Ireland and has a separate TSO[271]; separate regulatory authority[272]; and a separate governance framework covering the entire Irish market.[273]

<u>The generation market</u>

Britain has a competitive generation market in which parties compete to supply customers at the lowest price. The table below shows the electricity generation mix over the past decade. It can be seen that nuclear has played a relatively constant role in the energy mix (and will continue to do so over the next decade following the recent Government approval of a new nuclear reactor at Hinkley Point C[274]). Coal has played an important, but increasingly declining, role in the energy mix; providing a much needed source of flexibility. Interestingly summer 2016 was the first time for a century that there were days when no electricity was generated from coal.[275] Gas is currently the fuel with the greatest share of the fuel mix. It can also be seen that imports via interconnectors are playing an increasing role and that wind and solar generation have seen a marked increase in the past five years or so.

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[271] System Operator Northern Ireland (SONI) which is wholly owned by Eirgrid, the Irish SO.

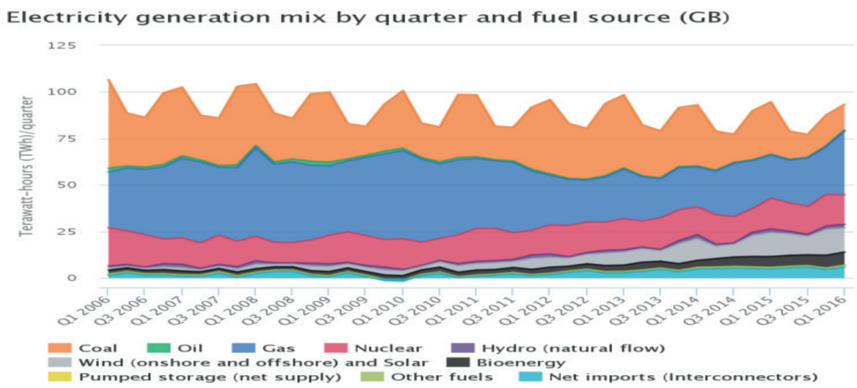
[272] The Utility Regulator for Northern Ireland (UREGNI).

[273] A Single Electricity Market Committee containing both regulators and a number of independent experts oversee the operation of the SEM.

[274] See the coverage at: https://www.edfenergy.com/energy/nuclear-new-build-projects/hinkley-point-c (accessed: 13.10.2016).

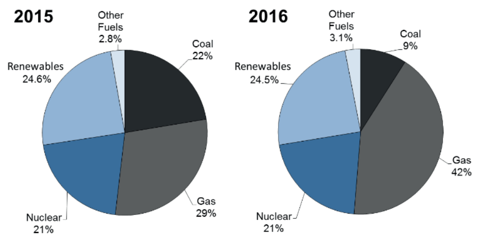
[275] See coverage at: http://www.telegraph.co.uk/business/2016/05/10/britain-gets-no-power-from-coal-for-first-time-on-record/ (accessed: 13.10.2016).

Chart 15. Generation mix by quarter and fuel source 2006-2016



Source: Ofgem[276].

Chart 16. Shares of electricity generation by fuel for 2015 and 2016



Source: Digest of UK Energy Statistics (DUKES)[277]

The generation market is relatively competitive, as shown in chart 15 below. EDF (28% of the market share) owns the nuclear fleet, Scottish Power (owned by Iberdrola of Spain) own wind and thermal assets, as do SSE[278] (with respectively 7% of the market share for each of them). German utilities RWE (13% of the market share) and E.ON (which recently split the business to form E.ON and Uniper, with Uniper holding 6% of the market share) have generation interest, and the

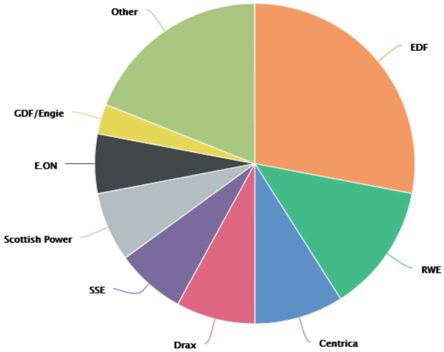
[276] See: https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators (accessed: 13.11.2016).

[277] See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/633779/Chapter_5.pdf (accessed: 13.11.2016).

[278] SSE stands for Scottish and Southern Energy.

largest supplier, British Gas, has generation interests via Centrica (9% of the market share). Other companies such as Drax or GDF/Engie have shares of 8% and 3% respectively. An increasing share of small scale and independent generation (19%) has recently entered the market.

Chart 17. Generation ownership by company, 2015



Source: Ofgem[279].

Embedded generation

A significant feature of the market in the last few years has been the connection of very large volumes of generation at distribution voltages. This is typically wind and solar generation with variable running patterns. The growth is shown in the diagram below. These connections have tended to be concentrated in particular areas of the country – particularly the South West of England and Scotland. This new trend also means that there are times when distribution systems export onto the transmission network, as opposed to taking power from it as would have traditionally been the case.

The retail market

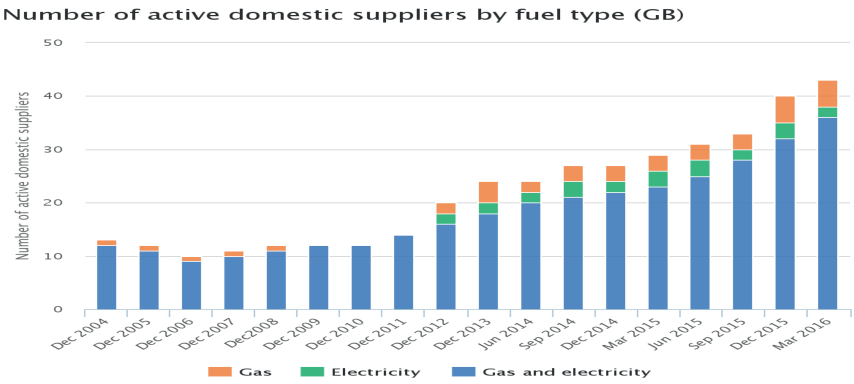
The British retail market has seen rapid changes in the past few years as a situation in which a relatively small number of suppliers, termed "the Big Six"[280], who also own generation has been challenged

[279] See: https://www.ofgem.gov.uk/data-portal/wholesale-market-indicators (accessed: 13.11.2016).

[280] The "Big Six" is a term used to describe the six largest British energy suppliers (being at the same time the oldest British electricity companies). They are made up of British Gas, EDF Energy, E.ON UK, npower, Scottish Power and SSE.

by significant new entry. This is probably the most dramatic change ever seen in a market which was opened up to competition in the late 1990s. The table below shows the growth in the number of suppliers in both the gas and electricity markets over the past decade.

Chart 18. Number of active supply market participants



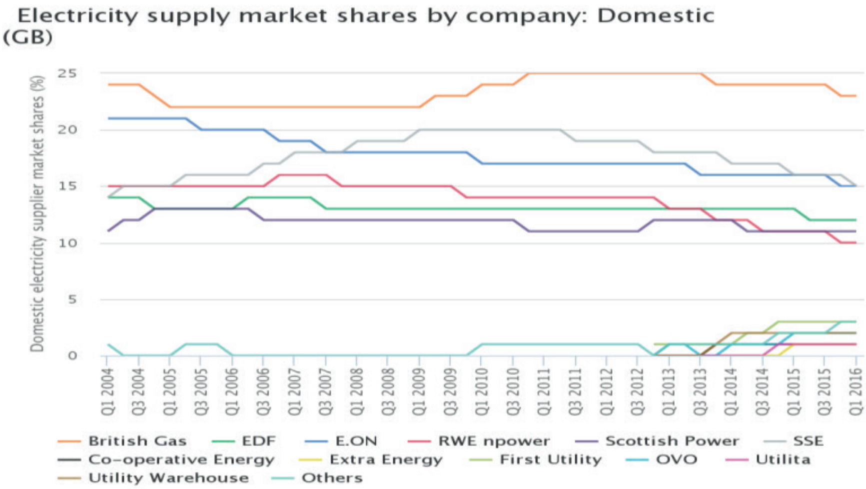
Source*:* Ofgem[281].

The table below illustrates this phenomenon in more detail and shows the market shares per company. The most striking thing is perhaps the increase in the market share of smaller suppliers from 2013 and the relative decline in the market share of each of the "Big Six". While appearing as relatively small in the diagram, this is the first significant time that independent suppliers have gained any market share and that there's been a sustained decline in the "Big Six" companies' market shares.

As of March 2016 there are 38 suppliers active in the British electricity market. Of those, 36 provide both gas and electricity. 86.6% of the market is held by large suppliers and 13.4% by small and medium sized suppliers. As discussed in the competition chapter, the CMA's recent investigation has scrutinized the level of competition within both the wholesale and the retail market and proposed a set of remedies with the aim of further enhancing retail competition.

[281] See: https://www.ofgem.gov.uk/chart/number-active-domestic-suppliers-fuel-type-gb. (accessed: 13.11.2016).

Chart 19. Market share of electricity supply market participants (2004 – 2016)



Source: Ofgem[282].

<u>Networks and Interconnection</u>

Britain's electricity networks are owned by a variety of companies. There are 12 separate distribution companies (with more than one owned by the same party). The transmission network[283] onshore is owned by 3 companies – National Grid Electricity Transmission plc, Scottish Hydro Electric Transmission plc and Scottish Power Transmission plc.

In addition, various companies own parts of the offshore network which have been awarded by competitive tender.[284] The entirety of the transmission network is operated by the National Grid – in its role as System Operator.[285] As renewable volumes increase, the pros-

[282] See https://www.ofgem.gov.uk/chart/electricity-supply-market-shares-company-domestic-gb (accessed: 20.04.2017).

[283] Comprising the 275kv and 400kv networks in England and Wales and also the 132kv network in Scotland.

[284] For details of the competitive OFTO regime see: https://www.ofgem.gov.uk/electricity/transmission-networks/offshore-transmission. There are also plans to expand the use of competition to the construction of onshore transmission assets.

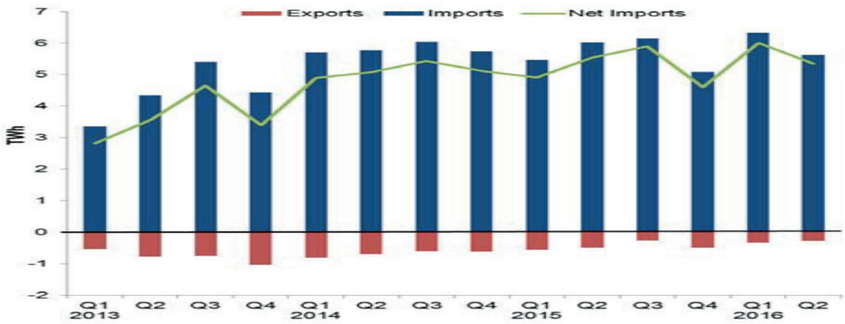
[285] While not discussed in this report there are suggestions that greater separation of the system operation would be desirable.

pect of distribution networks needing to be more actively managed is becoming a reality.

Interconnection with neighboring countries has been a feature of the British market since the Interconnexion France Angleterre was commissioned in 1986. Britain is also connected to the Netherlands (via the Britned interconnector), Northern Ireland (via Moyle) and the Republic of Ireland (via the East West Interconnector). Plans are in place for at least 6 GW of interconnection capacity with connections to Denmark (the Viking Link), Belgium (the NEMO link), Norway, and further French interconnectors, IFA2, ElecLink, and FAB link projects, planned.[286]

The decision on whether interconnection should be built is market led and driven by the presence of price differences between GB and other countries. Historically, the GB price has been above that in surrounding markets hence creating a case for interconnection and, in general, meaning that interconnectors which do exist have tended to import from the continent (though an interconnector can change direction several times a day). Interconnector imports and exports are shown in the figure below.

Chart 20. Interconnector gross and net imports and exports (2013 – 2016)



Source: Ofgem[287].

[286] The list of existing and future interconnectors projects can be found here: https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors (accessed: 13.11.2016).

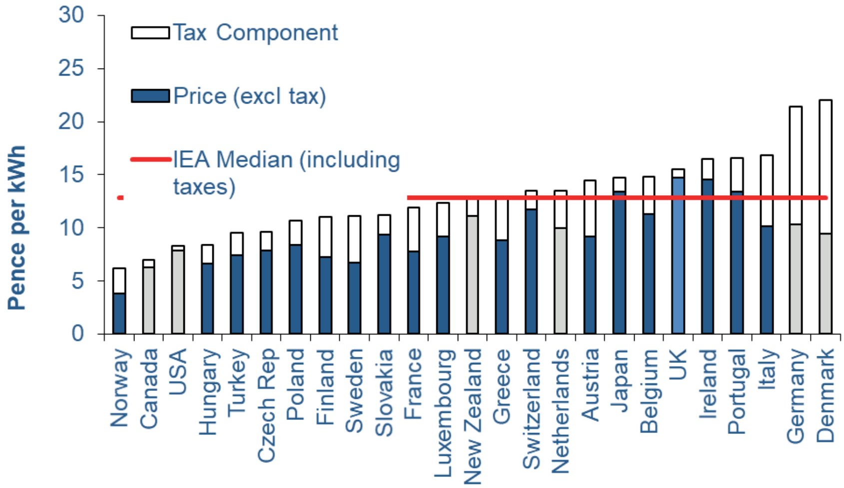
[287] See: https://www.ofgem.gov.uk/data-portal/all-charts (accessed: 13.11.2016).

<u>Government Policy and Regulation</u>

British Government policy is focused on resolving the so called energy trilemma – of secure supplies, affordable energy for customers, and decarbonization.

The Department for Energy and Climate Change (recently changed to the Department for Business, Enterprise and Industrial Strategy[288]) is responsible for making policy decisions – including decisions about supporting particular technologies and how to encourage low carbon generation. The most significant piece of energy specific government policy has been the Electricity Market Reform (EMR) which introduced a Capacity Market, designed to ensure sufficient investment in Generation, and which replaced the previous regime for supporting renewables with a new regime based on Contracts for Difference. This is covered in more detail in Chapter 4 on security of supply.

Chart 21. Electricity price comparison for domestic usage in world



Source: BEIS, See https://www.gov.uk/government/statistical-data-sets/international-domestic-energy-prices (accessed: 13.11.2016).

The British market is regulated by the Office of Gas and Electricity Markets (Ofgem) responsible for monitoring, enforcing, and improving

[288] As from July 2016.

wholesale and retail market rules and setting price controls to determine the revenues which network companies can recover.[289]

Energy use

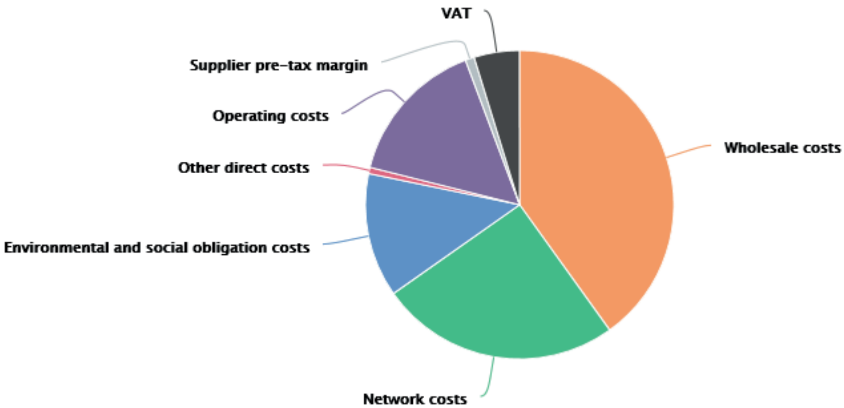
The transport sector is currently the biggest final energy user in the UK, accounting for 38% of the total in 2012. Households account for 30% of final energy use, industry 18%, tertiary 14% and agriculture approximately 1%. In general, a rule of thumb of 1/3 transport, 1/3 domestic and 1/3 industrial use tends to be used.[290]

Prices and the make-up of a domestic bill

The figure below shows where GB compares in a Europe-wide electricity price comparison for domestic usage.

The structure of an average domestic energy bill is shown in the figure and the explanatory table below.

Chart 22. Structure of an average domestic energy bill



Source: Ofgem[291]

[289] This is done via a model called RIIO, standing for Revenue = Incentives + Innovation + Outputs.

[290] Source: Ofgem- see https://www.ofgem.gov.uk/data-portal/all-charts (accessed:13.11.2016).

[291] Source: Ofgem- see https://www.ofgem.gov.uk/data-portal/all-charts (accessed: 13.11.2016).

Table 6. Explication of the structure of an average domestic energy bill

Annual cost	Percentage
Wholesale costs	40.09%
Network costs	25.16%
Environmental and social obligation costs	12.99%
Other direct costs	0.65%
Operating costs	15.40%
Supplier pre-tax margin	0.94%
VAT	4.76%

Source: Ofgem[292].

Projections for the future

As noted in the introduction, GB is going through a significant period of change. There are many projections about how the system will develop in the future and considerable uncertainty – including the impact of smart meters, the impact of batteries and electricity storage, future interconnection development, fuel costs, Brexit; and many other factors. The National Grid produces - on a yearly basis - a series of Future Energy Scenarios (FES) which tend to form the basis for consideration in the future.[293]

Energy efficiency

Energy efficiency is frequently described as the most cost effective way of reducing carbon emissions. However, Britain's energy efficiency is still lagging behind, partly because of a relatively old housing stock which is one of the least energy efficient in Europe. This section looks at the context within which energy efficiency policies are set, their content, the evaluation of those policies (including those which have recently been removed) and the future.

Energy efficiency is essential to help consumers reduce their energy consumption and improve the comfort of their homes. It is also central to achieving the UK's commitment to reducing its greenhouse gas emissions by at least 80% by 2050, relative to 1990 levels. It is

[292] *Ibidem*. (Source: Ofgem- see https://www.ofgem.gov.uk/data-portal/all-charts (accessed: 13.11.2016)).

[293] See: http://fes.nationalgrid.com/ (accessed: 13.11.2016).

a key part of the Government's strategy and is considered central to reducing greenhouse gas emissions, improving energy security, and mitigating fuel poverty.

There is no doubt that further policy action is required. In June, the Fifth Carbon Budget[294] was adopted by the Government, setting firm carbon targets for the period from 2028 to 2032. Parliament approved them in July. Reaching those targets will require bold and ambitious policy action across all sectors.

A number of important directives set EU-wide standards and targets for energy efficiency. First of those is the Ecodesign Directive[295] that requires manufacturers of electrical appliances to increase the energy efficiency of their products over time with increasing standards.

New buildings need to meet energy efficiency standards set by the Energy Performance of Buildings Directive.[296] Recent policy changes in the UK such as scrapping the zero carbon homes target show that buildings' energy efficiency is not quite on top of the political agenda right now.

Finally, it's worth mentioning the Energy Efficiency Directive[297] which requires all Member States to set firm energy saving targets covering all sectors to reach the EU's 20% energy efficiency target by 2020 (and subsequent targets thereafter). Article 7 of the Energy Efficiency Directive is central and requires Member States to introduce energy efficiency obligation schemes (EEOSs).

Domestic households

Energy efficiency policy targeted at households in the UK has worked through energy supplier obligations, where energy suppliers are required to offer consumers opportunities to be more energy efficient. The government has obligated suppliers to improve homes' energy efficiency in this way for more than 20 years.

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[294] See: https://www.gov.uk/guidance/carbon-budgets (accessed: 13.11.2016).

[295] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related product.

[296] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.

[297] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

In 2013, the Government implemented two schemes with the primary aim of improving household energy efficiency to reduce CO2 emissions – the Green Deal[298] and the Energy Company Obligation (ECO).[299] These replaced two previous energy efficiency programmes, the Carbon Emissions Reduction Target (CERT) and the Community Energy Saving Programme (CESP). The replacement was mainly driven by concerns about the impact of the previous policies on customer bills. ECO reduced suppliers' obligatory CO2 savings and decreased the requirement for them to improve harder-to-treat homes.

- Through ECO, the Government required energy suppliers with more than 250,000 customers to install measures in homes, such as loft or wall insulation, that would cumulatively reduce CO2 emissions by a certain amount. Suppliers are given targets based on their share of the domestic gas and electricity market. Suppliers work with a range of suppliers to deliver the measures (such as installers for instance), and face penalties if they do not meet the targets set by Government. The suppliers pass on the costs of delivering the ECO to their customers through energy bills.
- The Green Deal is primarily a finance mechanism which enables householders to borrow money so they can improve the energy efficiency of their homes. They repay this money through their energy bills ("Green Deal finance"). This is complemented by a framework of advice, accreditation, and assurance intended to increase homeowners' trust in the supply chain for home improvements.

Government is now designing a policy that will supercede ECO in April 2017 and has committed to an annual funding of £640 million for the policy, which will focus increasingly on the fuel poor. Under the current consultation proposal, a one year transition to the four-year long scheme would see social housing included under ECO, as well as a greater role for Local Authorities to identify customers eligible for ECO.

[298] See: https://www.gov.uk/green-deal-energy-saving-measures/overview (accessed: 13.11.2016).

[299] See: https://www.ofgem.gov.uk/environmental-programmes/eco (accessed: 13.11.2016).

Industrial energy efficiency

The EU Emissions Trading Scheme (EU ETS), which covers 40% of UK emissions, is a key EU measure driving energy efficiency improvements in the industry sector. In addition, the UK introduced the Climate Change Levy[300] – a tax on the business use of fossil fuel energy – in 2001. Companies that are part of Climate Change Agreements (CCAs) and which successfully meet the conditions of their agreement are eligible for a discount on the levy.

The Government has also implemented the CRC Energy Efficiency Scheme[301] which targets large, non-energy intensive businesses and public sector organizations and emissions not already covered by the EU ETS or Climate Change Agreements.

In July 2015, the Government announced that it would not provide any further funding for Green Deal loans, effectively bringing the scheme to an end. ECO will end on 31 March 2017, and will be replaced with a smaller scheme that focuses on mitigating the main causes of fuel poverty.

This decision was, in part, motivated by an assessment by Britain's National Audit Office (NAO) – which seeks to ensure that Government funds are used effectively. Sir Amyas Morse, Head of the NAO said on 14 April 2016: *"Improving household energy efficiency is central to government achieving its aims of providing taxpayers with secure, affordable and sustainable energy. The Department of Energy and Climate Change's ambitious aim to encourage households to pay for measures looked good on paper, as it would have reduced the financial burden of improvements on all energy consumers. But in practice, its Green Deal design not only failed to deliver any meaningful benefit, it increased suppliers' costs – and therefore energy bills – in meeting their obligations through the ECO scheme. The Department now needs to be more realistic about consumers' and suppliers' motivations when designing schemes in future to ensure it achieves its aims"*[302].

[300] See: https://www.gov.uk/green-taxes-and-reliefs/climate-change-levy (accessed: 13.11.2016).

[301] See: https://www.gov.uk/guidance/crc-energy-efficiency-scheme-qualification-and-registration (accessed: 13.11.2016).

[302] Full report can be found here: https://www.nao.org.uk/report/green-deal-and-en-

The report goes on to state: "*The Green Deal has not achieved value for money. The scheme, which cost taxpayers £240 million including grants to stimulate demand, has not generated additional energy savings. This is because DECC's design and implementation did not persuade householders that energy efficiency measures are worth paying for*".

Also, following the decision to bring ECO to an end, the Energy and Climate Change Committee (ECCC) in the House of Commons has made its own investigation into reducing home energy efficiency and demand. The Committee examined what lessons could be learnt from these and previous energy efficiency schemes. The results of this parliamentary inquiry were published in a report in March 2016.[303]

In particular the ECCC expressed serious concerns regarding the Government's proposed approach to tackling fuel poverty through commercial energy suppliers, arguing that they might not be the best placed to reach those households who need it most. In addition, the Committee has underlined that the Government should be doing much more to reduce consumer energy bills by improving the energy efficiency of new and existing homes. Finally, the MPs have also stressed the need for the Government to promptly demonstrate a renewed commitment to tackling energy efficiency by establishing adequate policies with long-term, ambitious objectives, which restore confidence to the industry.

Government is now designing a policy that will succeed ECO in April 2017, and has committed to an annual funding of £640 million for the policy, which will focus increasingly on the fuel poor. Under the current consultation proposal[304], a one year transition to a four-year long scheme would see social housing included under ECO, along with a greater role for Local Authorities to identify customers eligible for ECO.

However, with those recent changes many are asking the question how feasible the current targets set in the Fifth Carbon Budget are. In its recent statement, the Association for the Conservation of Energy has underlined: *"The last 18 months have been a major set-*

ergy-company-obligation/ (accessed: 13.11.2016).

[303] Full report can be found here: https://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/inquiries/parliament-2015/home-energy-efficiency/ (accessed: 13.11.2016).

[304]For more information see: https://www.gov.uk/government/consultations/energy-company-obligation-eco-help-to-heat (accessed: 13.11.2016).

back in the British policy landscape affecting carbon emissions from buildings: the trajectory to zero carbon new build has been paused; Government support for Green Deal finance was withdrawn with no alternative mechanisms in place to encourage and enable investment by able-to-pay households; the government announced that funding from the Energy Company Obligation will be reduced again; and a review of business energy taxes has led to proposals for a new tax structure but, as yet, no coherent supporting framework to encourage energy efficiency action".

It goes on to state: *"(...) the Government's own projections for abatement show that the UK will not meet the 5th Carbon Budget in buildings. Taken together, policies as they currently stand are the Department of Business, Energy & Industrial Strategy (BEIS) to achieve a 21% cut in direct emissions from buildings by 2030 compared to 1990, just 12% below the 'business as usual' emissions for 2030. This means that the UK's emissions from buildings will exceed those recommended by the Committee on Climate Change for the Fifth Carbon Budget, in 2030, by 18%".*[305]

In addition, while BEIS' work focuses on policies that will succeed ECO, there are no measures in place to incentivize the able-to-pay market in the UK. Several groups are also calling for energy efficiency to become a national infrastructure policy.

Competitiveness

Building on the data on historic and current market shares presented in Chapter 1, this section focuses on the CMA's investigation into competition in the energy market and the 'remedies' which it brought forward.

Following significant pressure, Ofgem referred the market to the Competition and Markets Authority (CMA) in June 2014.[306]

[305] Full statement can be found at: http://www.ukace.org/2016/10/the-uk-will-miss-its-climate-targets-without-a-step-change-in-buildings-energy-efficiency/ (accessed: 13.11.2016).

[306] Decision to make a market investigation reference in respect of the supply and acquisition of energy in Great Britain from 26th June 2014, see https://www.ofgem.gov.uk/publications-and-updates/decision-make-market-investigation-reference-respect-supply-and-acquisition-energy-great-britain (accessed: 13.11.2016).

The CMA, which is the UK's competition authority and has broader powers than a regulator, then undertook an investigation into competition in the market. This investigation took 2 years and concluded in June 2016.[307]

It identified a number of features in the wholesale and retail markets which might constitute an Adverse Effect on Competition (AEC) and, where it did so, it proposed remedies, which the regulator will need to implement, to address these problems. Perhaps equally interestingly, it also reached some conclusions about the competitiveness of wholesale markets and about vertical integration – however without prescribing remedies.

a) Factors that led to the CMA referral

Concerns about the competitiveness of the British energy market have existed for some time. They have included:

- the presence of vertical integration – i.e. the ownership of supply and generation interests by the same companies and the suspicion that this could create a barrier to entry in both the wholesale and retail markets;
- the low levels of switching by customers and microbusinesses and a lack of trust in the market – in particular a concern that up to 80% of consumers were not willing or able to engage with the energy market and that levels of generation were low;
- insufficient generation market competition including a worry that excessive profits were being made in one or both of the wholesale and retail markets, as well as the idea of prices going up quickly and coming down slowly[308];
- a lack of transparency – about trades being undertaken within the market as well as about profits.

Prior to the referral, Ofgem itself undertook several investigations into these issues. However, it was felt that the CMA investigation could *"offer an important opportunity to clear the air (...) helping rebuilding consumer trust and confidence in the energy market as well as provide the certainty investors have called for"*[309].

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[307] See: https://www.gov.uk/government/news/cma-publishes-final-energy-market-reforms (accessed: 13.11.2016).

[308] Being now collectively referred to as "rockets and feathers".

[309] Extract from Dermot Nolan's, Ofgem Chief Executive's statement made on 24th June 2014 to be found at: https://www.ofgem.gov.uk/publications-and-updates/

b) The CMA's diagnosis of competition in the British wholesale power market

The CMA's conclusions suggest that competition is working well in the wholesale gas and electricity market, despite the presence of vertically integrated firms.

Excessive profits

CMA concluded that there is no evidence to suggest that the main energy firms earned excessive profits from their generation business or that wholesale market prices were above competitive levels. The CMA conclusions states: *"We have considered a range of aspects of electricity wholesale market design and operation. Generally we have found that the wholesale electricity market appears to be working well. In particular: (...) our view is that our analysis of profitability does not provide evidence that, overall, the Six Large Energy Firms earned excessive profits from their generation business over the period or that wholesale market prices were above competitive levels"*[310].

Vertically integrated electricity companies

With respect to vertical integration, the CMA found that vertical integration of energy generators and suppliers is not problematic for competition. In particular it found[311]:

— no evidence that independent generators were unable to compete effectively because of the prevalence of vertically integrated suppliers;
— that a lack of unilateral market power made it implausible that vertically integrated generators would be able to discriminate by refusing to supply independent suppliers, or by supplying them on worse terms. In concluding this, CMA pointed to the recent increase in the number of suppliers discussed in Chapter 1; and
— that vertically integrated firms carried out extensive external trading, and that the liquidity in the product that vertically integrated firms used to hedge their exposure to wholesale market risk was

decision-make-market-investigation-reference-respect-supply-and-acquisition-energy-great-britain (accessed: 13.11.2016).

[310] CMA, *Energy market investigation - final report*, 24th June 2016, point 6.2 (b) pp. 262-263, https://assets.publishing.service.gov.uk/media/5773de34e5274a0da3000113/final-report-energy-market-investigation.pdf (accessed: 13.11.2016).

[311] CMA, *Energy market investigation- final report, op. cit.* pp. 312-340.

sufficient for independent firms to hedge in a similar way. Therefore, vertical integration didn't seem to raise barriers to entry and growth by new suppliers due to difficulties in securing sufficient wholesale supply.

<u>Other features creating AECs</u>

The CMA didn't give electricity wholesale markets a totally clean bill of health and suggested that the absence of locational charging for transmission losses (where charges vary to reflect the distance power needs to travel to reach customers and vice versa) constitutes an AEC. This is because it sees a cross subsidy which distorts short term energy dispatch decisions.

It is also interesting that the CMA was critical of the method the Government had used to allocate Contracts for Difference (long term contracts intended to provide stable revenues to low carbon generators) and argued that it was insufficiently competitive.[312]

c) The CMA's diagnosis of competition in the British retail power market

However, the CMA did find a number of features of the retail market that did distort or prevent competition.[313] Most of these were focused on the concern that a significant proportion of customers were not aware of opportunities to switch. The CMA's work in this area was also critical of previous regulatory interventions by Ofgem.

The CMA concluded that:

- there was a weak customer response and lack of engagement with domestic retail energy markets;
- the "Big Six" companies enjoyed unilateral market power over their inactive customer base (i.e. those who do not switch), which they had been able to exploit through their pricing policies; and
- the regulatory framework governing domestic retail market competition had contributed to the issues – particularly through restrictions on regional price discrimination and by limiting the number of available tariffs.

Overall the CMA found that customers who were on a tariff with the cheapest of the "Big Six" energy firms were paying around £95 less than a customer on a tariff with the most expensive of the "Big Six"

[312] CMA, *Energy market investigation- final report, op. cit.* pp. 263-311.

[313] *Ibidem*, p. 342.

energy firms.[314] The CMA also found that possible savings are often ignored by customers. These customers tend to have certain characteristics, such as low incomes, lack of internet access, relatively old meters, and find it hard to engage with the market, tending to stick with the same supplier.

However, CMA found no evidence of tacit co-ordination between retail suppliers in relation to price announcements.

d) Proposed retail remedies

The CMA came up with a series of remedies to try and deal with these issues[315]:

— disengagement by domestic and microbusiness customers – a number of remedies are proposed to tackle the CMA's central finding – lack of customer engagement – including the roll-out of smart meters; a penalty for firms that fail to switch customers within the mandated period; the introduction of specific measures to facilitate switching for customers living in rented accommodation; Ofgem to provide an independent price comparison service. A key proposal is the introduction of a "default" regulated tariff for those disengaged customers who do not switch
— the "simpler choice" component of the so-called Retail Market Review (RMR[316]) rules –remove from domestic energy suppliers' licenses the "simpler choices" component of the RMR rules, which would seek to enhance competition amongst domestic retail energy suppliers by allowing them to offer customers as many tariffs and/or tariff structures as they wished. This would give domestic retail energy suppliers an incentive to tailor tariffs to the needs and/or preferences of different customers, allowing them to compete vigorously for these customers.
— regulatory framework - the CMA proposes giving Ofgem more enforcement powers by measures including: revising its statutory objectives and duties to increase its ability to promote effective

[314] *Ibidem,* p. 1026.

[315] *Ibidem,* pp. 634-675.

[316] The Retail Market Review (RMR) was launched by Ofgem in late 2010 due to concerns that the energy market was not working effectively for consumers. One of the components of the RMR was based around "simpler choices", which included in particular: four core tariffs for gas and electricity from each supplier, a single standing charge, advanced notice of when the customer's deal ends etc.

competition; introducing a formal mechanism to address disagreements with the Government over policy decisions; improving the accounting framework so that Ofgem has a better, more consistent set of data from suppliers to work with; and giving Ofgem more powers to develop and implement industry code changes.

e) Conclusions

The CMA investigation has been an important driver for reviewing the functioning of the GB energy market and enhancing its competitiveness.

Government, Ofgem, and industry have expressed their strong commitment to give full effect to the remedies suggested by the CMA.

This will be an important yet challenging task. In particular, implementing the remedies related to the disengagement by domestic and microbusiness customers (e.g. the database of all the "sticky" customers) will require a significant effort from all the parties involved. Also, the future will show how the full success of the measures proposed by CMA will be measured.

As once again demonstrated by the CMA investigation, the UK has tended to follow a market based approach to energy policy. This willingness to foster the development of competitive markets for both gas and power has been a key factor for the UK to strengthen its position on the European (if not global) energy market. This has been a relatively successful approach with new investment, for example in LNG facilities, being developed in GB. It is the combination of prices determined by supply and demand and a stable regulatory regime which the UK relies on to ensure competitiveness. That said, political discussion is currently focussed on creating an industrial strategy which may see particular technologies supported.

Security of Supply

This section considers the circumstances which saw Britain, traditionally seen as a good example for energy only market design, implement a capacity market and other policies driven by security of supply concerns. It also considers the potential impact of future technologies and of Brexit on electricity security of supply.

Since the introduction of competition in the England and Wales market in 1990 Britain has had an energy only market. That is, it was expected that prices would rise when generation capacity was scarce until a point when new investment would be encouraged. This market design, some have argued, was particularly well suited to a market with, at least initially, excess capacity and which was broadly perceived as stable. Hence, when the GB Pool was changed to the New Electricity Trading Arrangements in 2001 (a bilaterally traded market replacing a pool design) no explicit means of rewarding capacity outside the market was introduced.

a) The advent of the capacity market

In the early 2010s there started to be concerns about security of supply and a worry about a "missing money" problem. That is, that prices would never rise high enough (or perhaps be allowed to rise high enough) to allow new investment to be financed. Some have also argued that this problem was compounded by a more interventionist approach from policy makers and a greater political prominence for energy within the mainstream media.

As such, the Government launched its "Electricity Market Reform (EMR)"[317] program. The key components of EMR were the introduction of a capacity mechanism, with the aim of bringing forward sufficient new generation capacity, and a change in renewable subsidies from a certificate based scheme (Renewable Obligation Certificates) to a system of Contracts for Difference, with the aim of providing more stable returns to investors in low carbon technologies.

Explanation

The EMR capacity market (CM) works by offering the opportunity to all capacity providers (new and existing power stations, electricity storage, capacity provided by demand side response and the interconnectors[318]) of a steady, predictable revenue stream termed capacity payments. The cost of the CM will be met by consumers via the supplier levy on electricity suppliers. Those costs should be minimized due to the competitive nature of the auction process which aims at ensuring the lowest cost provision of capacity to meet the level of secu-

[317] See: http://webarchive.nationalarchives.gov.uk/20140405112802/https:/www.gov.uk/government/policies/maintaining-uk-energy-security--2/supporting-pages/electricity-market-reform (accessed: 13.11.2016).

[318] Although the interconnectors were allowed to participate in the capacity market auction as from 2015.

rity of supply determined by the Secretary of State. In return for this revenue, providers must deliver energy when needed or face penalties. The auction is organized on a yearly basis.

Results of the first auction

The first CM auction took place in December 2014 (the 2014 T-4 auction), for delivery in 2018/19. 49.3 GW of capacity was procured in the 2014 T-4 auction at a clearing price of £19.40/kW/year.

These results were interesting in many ways.[319] First, the price was far lower than predicted. Second, and linked, a much larger volume of small, diesel generation participated – raising significant concerns within the government about carbon emissions. Third, no new generation plant received a contract.

Results of the second auction and the third capacity market

The second CM auction took place a year later (i.e. in December 2015), for delivery in 2019/20. This was also the first auction where the interconnectors – both existing and prospective – were allowed to participate.

A total of 46.4 GW of capacity was awarded in the T-4 Auction at a clearing price of £18.00/kW/year. This resulted in 1.689 GW of extra capacity being awarded over the target level. The majority of cleared capacity was existing generating capacity (42.0 GW). New build generating capacity accounted for around 1.94 GW of total acquired capacity, whilst the interconnector capacity accounted for another 1.86 GW.[320]

The auction cleared at slightly lower than in 2014. While low prices are good for consumers, some experts are raising concerns that plants failing to clear in the 2019/20 auction may choose to close, putting pressure on security of supply between now and 2018/19. Some also highlight that due to closures and possible delays in the commissioning of a new plant, a larger than expected amount of capacity will now need to be procured in the T-1 auction for 2018/19 raising concerns about a lack of supply in that auction.[321]

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[319] See: https://www.ofgem.gov.uk/sites/default/files/docs/2015/06/annual_report_on_the_operation_of_the_cm_final_0.pdf (accessed: 13.11.2016).

[320] See: https://www.ofgem.gov.uk/system/files/docs/2016/06/annual_report_on_the_operation_of_the_capacity_market_6_june_2016_final.pdf (accessed: 13.11.2016).

[321] See: https://www.frontier-economics.com/de/documents/2015/12/lcp-briefing-review-of-the-second-capacity-auction_dec-2015.pdf (accessed: 13.11.2016).

Once again we can see a large amount of newconstruction small-scale diesel and gas generation clear in the auction. However, no new gas power stations have been contracted. The third capacity market auction will take place on 6th December 2016.[322]

The most front-page security of supply related news of 2016 was the new Prime Minister, Theresa May's, decision to re-examine the decision of the former coalition[323] to grant financial support to a nuclear project at Hinkley Point C. The project, a joint venture by EDF of France and General Nuclear Power Corporation of China, will see a new nuclear plant commissioned in 2025. The plant will receive financial support of £92.50/MW guaranteed for 35 years.

Whether the project was examined for reasons of the countries of ownership, its value for the money, or due to concerns about the need for nuclear generation in 2025, is unclear. However, following deliberations the project was granted approval on the original terms.

As shown in figure 5 above, Britain has historically been a net importer of electricity from continental Europe, and interconnectors can make a substantial contribution to security of supply. However there has been a reluctance to treat them on an equivalent footing to domestic generation in the capacity mechanism, where they're only eligible for one year contracts, and there has been a tendency to apply relatively conservative de-rating factors. With a number of projects currently in the pipeline, one can predict they are likely to play a much greater role in future.

In Britain security of supply has tended to be seen as an issue of capacity – are there enough MWs to meet demand at winter peak? However, as the energy transition gathers pace many are questioning whether it is flexibility that is important. Britain is already seeing prolonged periods of low prices, principally when the wind blows and the sun is shining, and has seen negative prices on wholesale markets. It has also seen very high prices (up to £800/MWh in the balancing market in recent months[324]) on summer days where wind and solar

[322] See: https://www.emrdeliverybody.com/Lists/Latest%20News/Attachments/69/Capacity%20Market%20Auction%20Guidelines%204th%20Nov%202016.pdf (accessed: 13.11.2016).

[323] Coalition between the Conservatives and Liberal Democrats with Ed Davey (a liberal democrat) as energy minister.

[324] See: https://www.elexon.co.uk/wp-content/uploads/2014/10/22_Panel246_02_BSC_Ops_Headline_Report.pdf- pp. 2 (accessed: 13.11.2016).

haven't been available. In these circumstances it is generation technologies or customers who can alter their consumption very quickly which are of the greatest value to the system.

The capacity mechanism, as designed, does not take a plant's capabilities into account and, as such, could struggle to incentivize the construction of this sort of plant, particularly if environmentally motivated measures are introduced to reduce the advantages of diesel generators. This seems to suggest that ancillary service markets[325] are going to need to be a greater source of value for these generators. Indeed, recently the National Grid signed contracts for Black Start totaling £113m[326] which may be the start of this trend.

The decision of the British people to leave the European Union may well raise questions for security of supply. Britain requires considerable investment in new generation, in network infrastructure, and in new technology in the coming decades. The regulatory and policy regimes in Britain are heavily influenced by European Regulation (which Britain has heavily influenced). At present it is unclear on what basis, if any, Britain will interact with the European Energy Market; whether barriers to trade could be introduced; and whether companies, many of which operate across Europe, will be able to access the skills and workforces they need. As such, there is the danger of an investment hiatus – which may lead to higher prices due to the increased return investors will demand.

While not the key issue of this report, it is also interesting to consider how Brexit could impact on the single market in Ireland. The Irish market has recently been redesigned to comply with European rules and to be ready to "market couple" with the rest of Europe. In the event that the United Kingdom does not apply the same rules as the rest of Europe, it is difficult to see how the single market in Ireland could continue. In this case, the Republic of Ireland would lose access to the wider European market and costs in Northern Ireland might be expected to increase and the security of supply could potentially deteriorate.

Security of supply is by far the most important of the three trilemma outcomes for Britain and Britain's policy makers. Concerns about it have driven the vast majority of recent energy sector policy changes and have seen a capacity mechanism introduced and the Government

[325] Markets for system services.

[326] See: https://www.ofgem.gov.uk/system/files/docs/2016/08/decision_letter_iae_notice_17_08_2016final.pdf (accessed: 13.11.2016).

taking a much more active role in energy mix decisions. While it is possible that the capacity mechanism, energy market, and ancillary service markets may interact to bring forward a fuel mix (including the demand side) with sufficient capacity and flexibility, there appears to be a risk, aggravated by Brexit, of future market interventions. It will be interesting to see what the Government's Industrial Strategy will involve in energy.

Final remarks

This report has provided a very brief snapshot of the very significant energy transition taking place in the British market. We examined the important changes in market structure and shares in the last few years. We also reflected on the recent changes in energy efficiency policy, highlighting that it remains to be seen whether it would become a national infrastructure policy. In the context of competitiveness, we talked in detail about the CMA's energy market investigation and the relatively clean bill of health that has been given to the wholesale market and vertical integration, as well as the suite of changes proposed to promote further switching and greater trust in retail markets. Finally, to address the recent security of supply concerns we provided an in-depth description of the capacity market and discussed how new concerns about having sufficient flexible capacity to operate the system are emerging. In this context, our analysis also briefly speculated on what the impact of Brexit on the British energy sector might be.

As an island system with relatively low current levels of interconnection and high volumes of intermittent and distributed generation, Britain may experience issues before countries in the continental European synchronous area. If so, then it is possible that there are lessons to learn, both in terms of how and how not to do it. What is clear is that the last decade has seen an unprecedented amount of change in the GB energy sector and that the change does not show signs of slowing.[327]

[327] As a closing thought, I will mention what has not been included in the report. On the technology side - the impact of batteries and storage; a new smaller nuclear plant, or the role of aggregation. On the market design and regulation side - market splitting; North Sea Grids; or the creation of a more independent system operator.

Chapter 12

Energy transition in Poland

Lidia GAWLIK[328]

The aim of the energy and climate policy being promoted and gradually implemented in the European Union is to thoroughly change the economies of EU countries so as to dramatically reduce emissions in accordance with the principles of sustainable development. In some EU countries (e.g., Denmark, Germany or France) energy transition is being carried out through the elimination of fossil fuels in favor of renewable energy sources. In practice, for a number of countries, it simply means the replacement of conventional energy with RES, promotion of energy saving, and improvement of energy efficiency.

Transforming the economy so as to reduce emissions is one of the most serious economic and environmental challenges faced by Poland as a member state. Within the past 25 years, despite difficulties and substantial social costs, Poland has shortened its developmental distance from Western Europe, going from an ineffective centrally planned economy to the market model, European integration, and competition on the globalized market of goods, services, and capital. Modernization of industry has played an important role in the process. The modernization involved: liquidation of ineffective heavy industry plants, investment in mechanization of other enterprises, development of new areas of industrial processing, and producing for both the developing internal market and for export.[329] However,

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[329] M. Bukowski, A. Kassenberg, A. Śniegocki, Perspektywy niskoemisyjnej transformacji w Polsce *[Prospects of low-emission transition in Poland]*, Redakcja Pol-int, https://www.pol-int.org/pl/salon/perspektywy-niskoemisyjnej-transformacji-w-polsce-pl (accessed: 27.07.2016).

there is still a lot to do, especially in the broadly understood power system, characterized by high dependence on fossil fuels. Emissions and high concentrations of harmful pollutants are becoming a developmental problem. The emissions come from different sources, but the dominant role is played by emissions connected with fossil fuels consumption in the economy. 78% of all emission in Poland is emission from fossil fuels combustion.[330] Broadly understood the system of energy use is one significant area in which Poland still needs serious modernization. The most important sectors that need to be modernized are the energy sector, transport, and the use of fuels in buildings.

Due to extensive use of coal, the energy sector is associated with high emissions. Besides, despite partial modernization performed so far, most functioning production capacities are obsolete and have low efficiency.

For several decades, the model of development of road transport was based (in many cases, for financial reasons) on the import of old cars from Western European countries, in poor technical condition and causing high emissions. As in Poland the consumption of fuels per capita is lower than the EU average, we need to face further growth of fuel consumption in transport, which will mean higher emissions, even if the number of new means of transport grows.

Against the background of the European Union, Poland has quite a high share of coal in the final use of energy in residential buildings (30%) and non-residential buildings (10%).[331] Heating and hot water in households is coal-based to a much greater extent than other EU countries, as it is more price-competitive than gas or electricity. Often, low quality coal is combusted in old, low efficiency furnaces, and rooms have low thermal insulation. New houses have better thermal parameters, but the number of houses is growing all the time, and although the rate of energy use for heating purposes per surface area unit is improving, it is still much lower than the EU average. All this makes the problem of low emission more and more serious.

Therefore, the country's challenges do not only result from the directions of the EU climate policy. Actually, they need to be met to

[330] National Programme of Low-Emission Economy, draft, version of August 4, 2015, Ministry of Economy, Warsaw, 2015.

[331] *Ibidem.*

ensure the long-term welfare of the state and its citizens. The specificity of the country (the only one in the EU to have considerable deposits of hard coal and lignite and a well developed system for using them) combined with economic and geopolitical determinants means that Poland has to find its individual way of further development. Although the governmental document directing Poland's energy policy until 2050 is not ready yet, we can see more and more clearly that the emphasis is put on issues connected with energy and geopolitical security. It means that Poland is going to keep its coal-based energy sector, at the same time looking for competitive advantages and new possibilities for the industry. The costs of transition, which will ultimately need to be covered by the citizens, also play a role.

The structure of electricity production in Poland is considerably determined by historical decisions concerning the sources of energy production, mostly based on the available resources. The Polish sector of commercial heat and power plants is mainly based on production capacities using hard coal or lignite as the fuel.

Table 7. Electricity production in Poland in selected years by energy carriers, TWh

Energy carrier	Year					
	2004	2006	2008	2010	2014	2015
Hard coal	90.5	93.4	85.7	87.8	76.2	77.7
Lignite	52.2	53.4	53.2	48.7	53.4	52.8
Natural gas	4.9	4.6	4.7	4.8	5.3	6.4
Other non-renewable carriers	3.5	6.0	5.3	5.6	4.4	5.3
Renewable energy sources	3.1	4.3	6.6	10.9	19.8	22.7

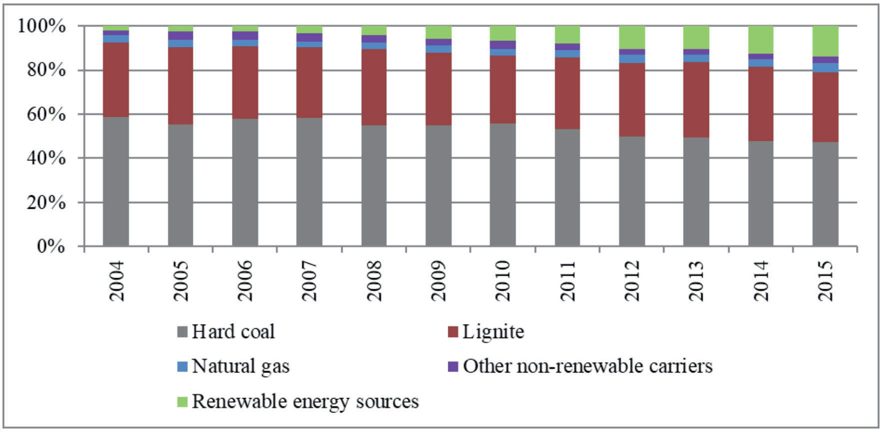
Source: *Statystyka Elektroenergetyki Polskiej [Polish electricity statistics]*, Agencja Rynku Energii SA, Warsaw (2005-2016), *Energia ze źródeł odnawialnych [Renewable energy]*, Central Statistical Office, Warsaw (2005-2016)

In 2004, when Poland accessed the European Community, even 92.5% of electricity was produced from solid fuels (Table 7). This unique situation of the country and the level of economy, differing from other EU countries (e.g., high energy intensity and low energy efficiency), has contributed to introducing activities aimed at energy transition. Polish energy policy formulated in successive governmental documents[332],[333] has declared for the diversification of production structure, at the same time stressing an increase in the energy efficiency of the economy.

The direction of changes necessary in the Polish economy corresponds to the directions set by the energy and climate policy of the European Union, and potential nuisances connected with the early stages of ETS have been eliminated thanks to derogations. Poland adopted the conditions of the 3 x 20 package, which in the energy system translates into the development of renewable energy. At the same time, the share of solid fuels has dropped (Chart 23).

In the years 2004-2015, the share of hard coal decreased from 58.7% to 47.1%. The reduction of lignite use was slightly lower (from 33.9 to 32%), and in some years, due to the competitive price of the fuel and available production capacities, generation of electricity from lignite even grew: in 2013, up to 56.2 TWh, which was 34.1% of the share of the fuel in electricity production in that year.

Chart 23. Fuel structure of electricity production in Poland in the years 2004-2015, [%]



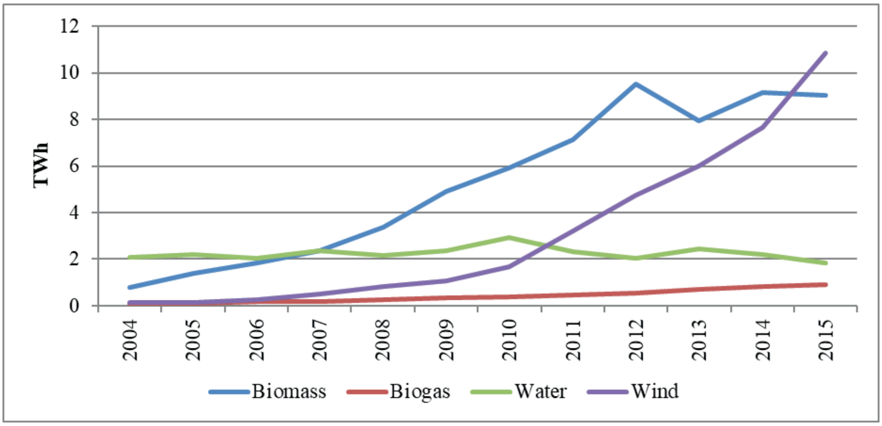
Source: *Statystyka Elektroenergetyki Polskiej [Polish electricity statistics]*, Agencja Rynku Energii SA, Warsaw (2005-2016), *Energia ze źródeł odnawialnych [Renewable energy]*, Central Statistical Office, Warsaw (2005-2016)

[332] *Polityka Energetyczna Polski do 2025 r. [Polish Energy Policy until 2025]* Document adopted by the Council of Ministers on 4.08.2005.

[333] *Polityka Energetyczna Polski do 2030 r. [Polish Energy Policy until 2030]* Document adopted by the Council of Ministers on 10.11.2009.

In the 2004-2015 period, electricity production from RES was regularly growing. The share of energy carriers in that production was changing. Chart 24 shows the amount of electricity generated using the dominant energy carriers, such as solid biofuels, wind, water and biogas.

Chart 24. Electricity produced from renewable energy carriers

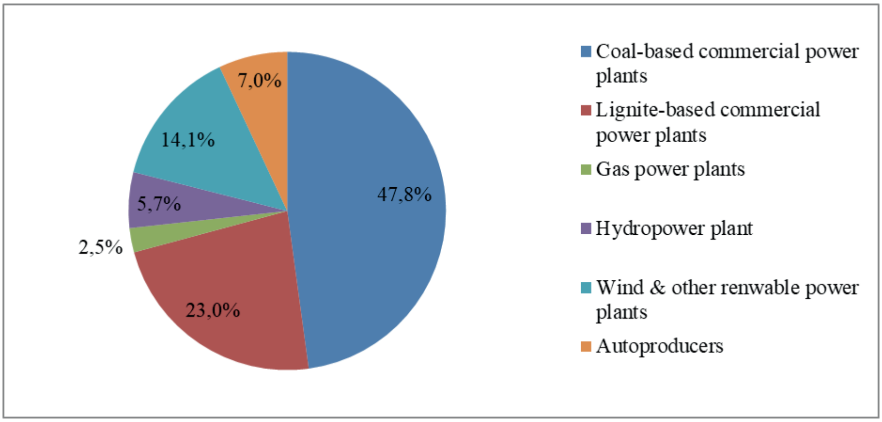


Source: *Energia ze źródeł odnawialnych [Renewable energy]*, Central Statistical Office, Warsaw (2005-2016)

Generation of electricity in wind power plants was dynamically growing then. In 2004, approximately 140 GWh came from wind energy, while in 2015, it was 10.9 TWh, which means a 77-fold increase. Wind has become the dominant renewable energy carrier in the energy sector, and with a 47.9% share in energy production from renewable sources in 2015 it outstripped solid biofuels (39.5%). In 2004, production of electricity from renewable sources was only 2% of the produced electricity (nearly 3.1 TWh), more than 2 TWh of which (almost (68%) came from hydropower plants. Production in hydropower plants remains at a stable level. But we can see dynamic growth of electricity production in power plants and heat and power plants using solid biofuels, although recently the co-combustion has slowed down, and the use of biomass in energy industry has become dominant (in 2012, over three fourths of biomass used to produce electricity was combusted together with coal). In terms of installations using biogas, there has also been an increase in electricity production, with small but regular increments. In 2015, twice as much such energy was produced as in 2011. Apart from these four dominant renewable energy carriers, in recent years electricity has also been produced from photovoltaic cells.

At the end of 2015, the generating capacity of the national electricity system was 40.4 GW. The generating capacity of commercial heat and power plants was 79% of the whole system capacity, 19.3 GW of which was based on hard coal, and 9.3 GW, on lignite (Chart 25).

Chart 25. Percentage structure of generating capacity in the national electricity system in 2015



Source: *Struktura mocy zainstalowanej w KSE [Structure of generating capacity in National Electricity System]*, [in:] *Raport 2015 KSE [2015 report of the National Electricity System]*, Polskie Sieci Elektroenergetyczne SA. http://www.pse.pl/index.php?did=2870 (accessed: 27.07.2016).

The current condition of Poland's energy system needs to be seriously modernized. This results, first of all, from the considerable degree of decapitalization of the majority of the existing production capacities in the sector. Over thirty-year-old units account for more than 53% of all power plants and more than 66% of the total capacities.

Because of the advanced age structure and high wear level of production infrastructure, medium- and long-term maintaining of the existing capacities will be very difficult. Expenditure on renovation and modernization of existing units and on investment in new capacities will be necessary. The shutting off of units may additionally be because of environmental standards imposed on the sector by implementing the directive on industrial emissions (IED)[334] in national law, and further limitations resulting from the detailed conclusions of BAT (*Best Available Techniques)*.[335]

Currently, more than a dozen projects for constructing new production capacity units are being carried out in Poland. The initiated investments in hard coal power plants in Kozienice, Opole, and Jaworzno will ultimately (by 2019) increase the generating capacity by 3.785 GW. More distant developmental plans include the construction of a power plant in Ostrołęka based on hard coal. Launching a 450 MW lignite block is planned for 2020 in the Turów power plant. In several heat and power stations there are also new investments, with hard coal (sometimes including the possibility of burning biomass or RDF) or gas as the basic fuel.

Governmental plans include the development of the energy industry towards hard coal use to ensure the continued functioning of Polish mines. It is also emphasized that new capacities will be highly efficient (even 46% performance). Revitalization and restoration of power on the basis of 200 MW blocks[336] is a change in the previous approach to the issue of ensuring the required volume of production capacities in Poland. In the next decades, the existing 200 MW blocks may be used thanks to lengthening their exploitation periods by thorough modernization. This solution is cheaper than the construction of new blocks. The proposed scope of work includes:

— identifying blocks where modernization is most profitable (the other blocks should be assigned to strategic reserve),
— reconsidering support for co-combustion as the means of lowering blocks' emissions,
— analyzing which solution will give the most measurable technological benefits, such as enhancing the system's efficiency. The following solutions can be chosen for this purpose:

[334] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (Official Journal L 334/17, 17.12.2010).

[335] *Best Available Techniques (BAT) Reference Document for Large Combustion Plants*, Institute for Prospective Technological Studies and Sustainable Production and Consumption Unit European IPPC. Bureau. Final Draft 2016.

[336] *Program ramowy Energetyka 200+ rewitalizacja i odbudowa mocy na bazie bloków 200 MW [Framework Programme 200+ revitalization and power restoration using 200 MW blocks]*, Ministry of Energy, 2016.

- building duoblocks – by combining two modernized boilers with one turbine set it is possible to make a 500 MW block with higher efficiency and lower technical minimum (about 20 % of the rated power),
- hybrid systems, allowing the use of substandard fuels, e.g., coal slurry or industrial and municipal waste. In the coal mining industry the annual production of slurry is estimated at approximately 2 million tons. There is high potential to use these resources. The technology would be based on pre-combustion of slurries or municipal waste, which would give extra environmental benefits as otherwise they should be disposed,

— transformation of some of the blocks into exclusively biomass blocks,

— the use of oxy-combustion technology with CO_2 capture e.g., to support the extraction of oil and gas. This would allow reduction of emissions by as much as 80%.

Another important area is cogeneration. Here, the emphasis is put on restoration of cogeneration capacities on hard coal, including a partial shift of capacity to commercial power plants from commercial and local (municipal) heating plants. This solution will allow using coal very efficiently, which will translate into reducing emissions. At the same time, providing district heat to a higher number of users will allow partial elimination of low-stack emissions in the area of households. This is important since 73% of the heat produced in 2015 by licensed heating enterprises came from hard coal, and in the case of cogeneration, the share of heat produced from hard coal was 81%. The use of coal to produce heat on the licensed market was 13,491.29 thousand tons.[337]

The act on RES amended in 2016[338] changed the auction system towards greater support for the production of energy from biomass and co-combustion. As a result, together with the act on wind investments[339], conditions were created to promote, mainly, stable generation from renewable energy sources. The reduction of support for unstable

[337] Energetyka cieplna w liczbach – 2015 *[Heat power sector in numbers – 2015]*, Energy Regulatory Office (ERO), Warsaw 2016.

[338] Act of 22 June 2016 amending the act on renewable energy sources and certain other acts (Journal of Laws 925.2016).

[339] Act of 20 May 2016 on wind power plants investments. (Journal of Laws 961.2016).

production capacities in the energy sector will definitely slow further development of wind energy, but despite that, and despite the reduction of support for some prosumers, it seems that the indicated targets concerning RES for 2020 will be achieved. Later, Poland will face more strict targets set by the European Union[340], which means the need to further reduce CO_2 emissions and increase the share of energy from renewable sources.

The Polish Nuclear Power Programme adopted in 2014[341], assuming the construction of 6 GW capacity of nuclear energy, has had a number of technical, social, and first of all financial barriers, and its future is unknown.

For these reasons, anticipating the future energy mix in Poland is not easy. We may only be sure that coal will remain the dominant fuel in the energy sector of Poland for more than ten years. It should be supported by already developed capacities based on renewable energy, and new capacities that will display economic efficiency and be financed in the changed conditions of support. Among them, gas sources have a chance to do so, especially if used for cogeneration.

It is also crucial for natural gas supplies to be more diversified, which has been partially achieved by opening the LNG terminal in Świnoujście. The purpose of building the *Baltic Pipe*, with the aim to supply natural gas from Norwegian deposits, also involves reducing the dependency on its supplies from the East, and thus, improving the security of gas supply.

Poland's priority goals are: to improve energy security, reduce the dependence on imported energy raw materials, increase energy self-sufficiency, and achieve sustainable development based on innovative technologies.

Basing development of the energy industry on coal with the support of stable renewable energy and diversification of the direction of gas import enhances the country's energy security. Sustainable development of the energy system, apart from the security of fuels and energy

340 *A 2030 framework for climate and energy policies. Green paper.* European Commission (EC). COM(2013) 169 final. http://cor.europa.eu/en/activities/stakeholders/Documents/comm169-2013final.pdf (accessed: 27.07.2016).

341 Resolution No. 15/2014 of the Council of Ministers of 28 January 2014 on the multi-year project "Polish Nuclear Power Program" (Official Gazette of 2014, item 502).

supply, should ensure electricity at prices acceptable for the community and the industry. The adopted direction of the energy transition means that electricity production will be relatively cheap. This is an important aspect of competition on the European market, but first of all, it may ensure cheaper economic development and introduce the element of competitiveness in international trade.

Having considerable resources of hard coal and lignite, it is important to develop new economic areas based on this potential. The desirable direction is development of energy technologies that are highly efficient in energy processing and environment-friendly. Another vital aspect is to ensure the stability of operation of the energy system, thus, such properties as high operational flexibility or fuel flexibility.[342] Technologies based on supercritical parameters and Integrated Gasification Combined Cycle (IGCC) power plants potentially meet these criteria to a higher or lesser degree and can be applied on an industrial scale.

Innovative solutions in the area of clean coal technologies are the key to sustainable development. The economic priorities in R&D and innovations include national smart specializations concerning sustainable energy, the development of which is supported and subsidized (from national and Union funds), in order for new solutions to accelerate the transformation of the national economy through its modernization and structural transformation. The emphasis is on:

- highly-efficient, low-emission, and integrated systems of production, storage, transmission, and distribution of energy,
- smart and energy-saving construction,
- environmentally friendly transport solutions.

These three areas of activity are determining the direction of Polish energy transition. In order to make the country's economic development follow sustainable development, the stress is on transforming the economy towards low emissions. The basic assumption is energy saving and improved energy efficiency, which can be achieved thanks to innovations and adapting them to the existing system, leading to

[342] D. Kryzia, L. Gawlik, M. Pepłowska, *Uwarunkowania rozwoju czystych technologii wytwarzania energii z paliw kopalnych [Determinants of the development of clean technologies of energy production from fossil fuels]*, "Polityka Energetyczna - Energy Policy Journal", 19, 4/2016, pp. 63-74.

economic growth with a relatively low increase in demand for energy and to minimal costs of energy production. The aim of such transition is to develop the competitiveness of industry, to strengthen gross domestic product, to create new jobs, and to improve energy security.

This way of thinking is reflected in launching the national electromobility programme, which is expected to popularize electric, hybrid, and hydrogen cars. Research and development connected with this and the final implementation of the results may contribute to reducing emissions from transport and increasing demand for electricity, which may be based on coal coming from Polish mines. As a result, many new jobs will be created, and the country may achieve competitive advantage on the international market.

The essence of sustainable development is to ensure economic, social, and environmental benefits from activities that reduce emissions. Energy transition should make electricity available for citizens and develop enterprises now and in the future, i.e., to make it sufficient and not too expensive.

Unfortunately, it is not clear whether such changes will be sufficient in the long run due to the expected growth in electricity consumption, despite activities taken to improve energy efficiency and support for them in the form of new regulations.[343] System changes concerning energy efficiency management and improvement should contribute to concretization and intensification of pro-efficiency activities in Poland, but long-term economic growth will be impossible without higher energy consumption.

The need for development of prosumer energy, energy storage technologies, and production of fuels from energy surpluses (e.g. P2G) is emphasized; further investment will also be necessary in the energy industry, preferably in low-emission technologies. So perhaps nuclear energy will finally find its place in the Polish energy mix, though later than anticipated. The construction of a nuclear power plant in Poland is associated with huge financial expenditure, and big nuclear power plants are inflexible and cannot be regulated. On the other hand, they do not cause emissions, and technological development in this area is evident. Currently, pilot works are being carried out under the name SMR (Small Modular Reactors), which involve low power units from

[343] Act of 20 May 2016 on energy efficiency (Journal of Laws 851.2016).

35 to 350 MW, with a simplified and reproducible structure, which might be used in the future.

Assuming that the use of Polish coal in the Polish energy sector remains one of the priorities, we need to realize that even after successful restructuring of the coal mining sector, the possibilities for using coal will be limited by the competitiveness of other energy carriers, which must be taken into consideration when planning long-term development of the electricity sector.

The situation is made even more complicated by the EU proposal for further changes on the energy market, presented by the European Commission in the so-called Winter package of 30.11.2016.[344] The proposal includes changes in the functioning of the capacity market and modifications in directives concerning renewable energy and energy efficiency. Apart from the targets for 2030, i.e., a 40% reduction of CO_2 and 27% share of RES in the energy mix, it proposes the introduction of an emissions limit below 550 g/kWh for power plants which will be allowed to be a part of the capacity market, which in practice excludes the coal energy industry.

In its future transformation activities, Poland must stick to coal, at least for the time being, at the same time improving the performance of energy blocks, investing in the technological process of coal combustion, and in this way reducing emissions. There is also a need to develop new sources of low-emission energy, green industry, and dispersed energy. Poland must move towards a low-emission economy, because the development of advanced technologies reducing emissions and raising energy efficiency potentially means new jobs, and innovative solutions may be an export product.

Poland needs to build its long-term energy policy and strategy of energy transition going beyond the energy sector, taking into consideration the internal and external determinants and priorities, and then negotiate its own path of development within the Union, consistent with the direction of proposed changes but also with its capabilities.

[344] *Czysta energia dla wszystkich Europejczyków, czyli jak wyzwolić potencjał wzrostu Europy [Clean Energy for All Europeans – unlocking Europe's growth potential]*, European Commission – press release, Brussels, November 30, 2016.

Chapter 13

Energy transition in Austria

Anna KUCHARSKA[345]

Energy balance structure

The character of Austria's energy sector is significantly influenced by its location. It lies inside the continent, has no deposits of energy resources, and is relatively small. For these reasons, it obviously needs to import conventional fuels, which account for approx. 64% of the Austrian energy mix.[346] Imported energy carriers are predominantly natural gas (29.5%), coal (10.8%) and oil (48.1%).[347] In Austria, import of energy from fossil sources costs approx. 12 billion euros a year, which equals about 42% of GDP of the country.[348]

Despite the high import level, Austria has a quite well balanced energy mix, in which about 37% of the primary energy demand (as of 2014) is covered by domestic production.[349] Renewable energy sources have a share of 77.2% in national primary energy production, including 38.2% of water energy and 29.7% of wood fuel.[350]

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[346] C. Morris, M. Pehnt, *Niemiecka transformacja energetyczna. Przyszłość oparta na odnawialnych źródłach energii [German energy transition. Future based on renewable energy sources],* Heinrich Böll Foundation, 28.11.2012, pp. 80-81.

[347] Data as of 2014: *Energiestatus 2016. Abteilung III/2 – Energiebilanz und Energieeffizienz*, Bundesministerium für Wissenschaft, Forschung und Wirtschaft, Vienna, May 2016, p. 9.

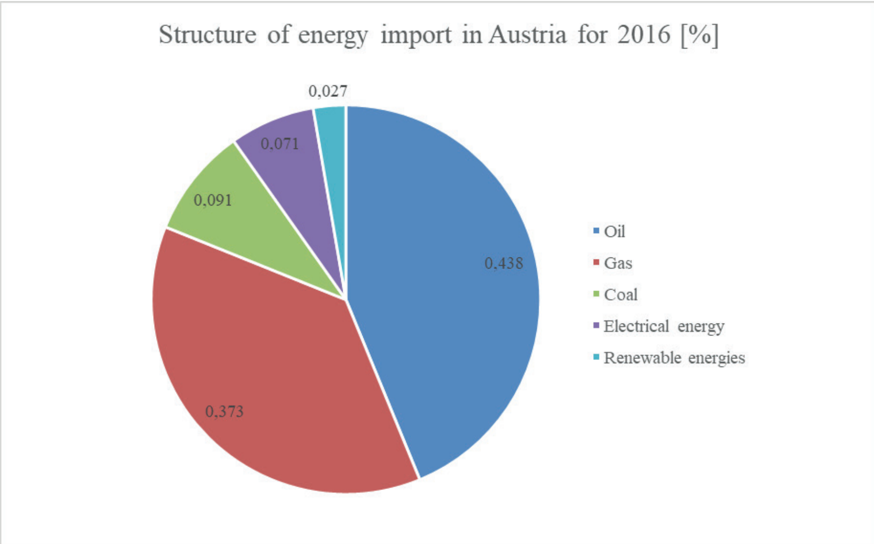
[348] C. Morris, M. Pehnt., *Niemiecka transformacja... [German energy transition...] op. cit.*, pp. 80-81.

[349] *Fossil Fuel Support Country Note*, OECD, September 2016, http://www.oecd.org/site/tadffss/data/ (12.11.2016).

[350] Data as of 2014: *Erneuerbare Energie in Zahlen. Die Entwicklung Erneuerbarer Energie in Österreich Datenbasis 2014*, BMLFUW, Vienna, December 2015, pp. 15-17.

Large-scale use of hydropower stations was mostly possible thanks to the mountainous landform features. Hydroelectric power plants have been operated and developed in Austria since the 1950s. Until the 1990s, Austrian electricity supply had been almost exclusively based on the combination of hydropower plants and heat supply industry.

Chart 26. Structure of energy import in Austria for 2016 [%]



Source: *Energie in Österreich. Zahlen, Daten, Fakten*, BMWFW, Vienna 2017, p. 6.

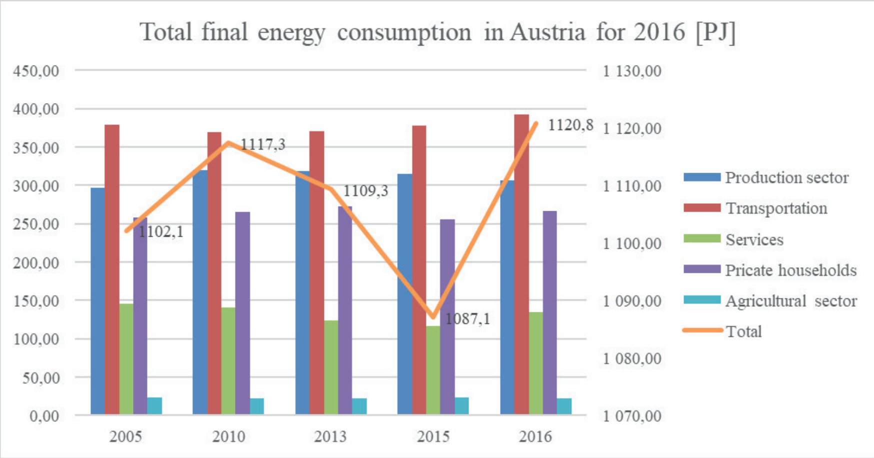
Gross national energy consumption is 1,381 PJ (about 383 TWh), including only 513 PJ (ok. 142.5 TWh) from domestic production.[351] Transport had the highest share in Austria's final energy consumption in 2015: 33.9%, followed by industry: 29.3%, and households: 23.4%; services: 11.2%, and agriculture: 2.1% consumed less.[352] Currently,

[351] Data as of 2014: *Energiestatistik. Energiebilanzen Österreich 1970 bis 2014*, Statistik Austria, 29.02.2016, http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/energie_und_umwelt/energie/energiebilanzen/index.html (accessed: 12.11.2016).

[352] *Energieverbrauch in Österreich 2015 zugelegt*, DiePresse.com 04.05.2016, http://diepresse.com/home/wirtschaft/energie/4981825/Energieverbrauch-in-Osterreich-2015-zugelegt (accessed: 12.11.2016).

the existing studies and scenarios for Austria allow us to expect that national consumption of electricity by 2030, even with moderate economic growth, may rise by approx. 50 PJ (14 TWh).[353]

Chart 27. Total final energy consumption in Austria for 2016



Source: *Energie in Österreich. Zahlen, Daten, Fakten*, BMWFW, Vienna 2017, p. 6.

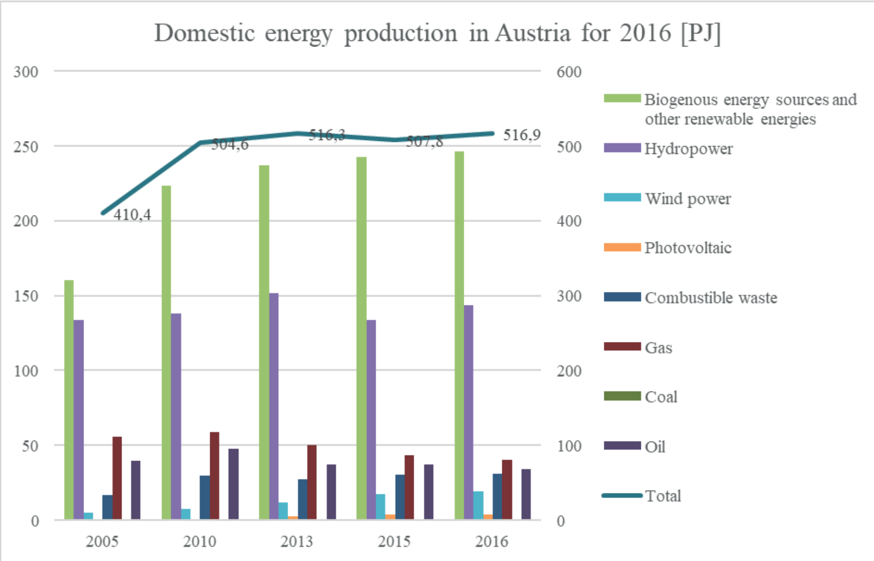
Since 2000, there has been intensive integration of electricity production from wind, photovoltaics, biomass, gas from waste and sewage treatment plants, and geothermal energy. In Austria the use of wind energy and photovoltaics is relatively low. The share of wind energy is 3.7% (3,827 GWh), and photovoltaics, 0.7% (785 GWh) in the total final energy consumption.[354] This results directly from unfavorable weather conditions in the country and the small and mountainous territory, leaving little area to be used to construct such installations. Still, the use of wind energy and photovoltaics has risen considerably within the last ten years, under the influence of the policy of support introduced along with the Act on electricity production from renewable energy sources (*Ökostromgesetz*). In general, it was an increase

[353] *Land am Strom. Jahresbericht Oesterreichs Energie 2016*, Oesterreichs Energie, July 2016, http://oesterreichsenergie.at/medien/publikationen-452/land-am-strom.html?file=files/oesterreichsenergie.at/Downloads%20Publikationen/Land%20am%20Storm/Jahresbericht%20OE%202016.pdf (accessed: 12.11.2016), p. 15.

[354] *Erneuerbare Energie in Zahlen..., op. cit.*, pp. 15-18.

by 242%, i.e., almost 15% a year. In the case of wind, the growth was approximately 189%, and photovoltaics, 3,600%. In comparison to the year 2013, in 2014 the growth was 22% and 34,9% for wind and photovoltaics, respectively.[355] In 2015, the production of those renewable sources was almost 12 TWh.[356]

Chart 28. Domestic energy production in Austria for 2016 [PJ]



Source: *Energie in Österreich. Zahlen, Daten, Fakten*, BMWFW, Vienna 2017, p. 6.

The Austrian Energy Strategy adopted in 2009 (*EnergieStrategie Österreich*) describes the dominant challenges to the state's energy sector and economic sectors related to it, as well as the main assumptions of the national energy policy. The Strategy stresses the extension of renewable energy sources, especially water energy, wind power plants, biomass, and photovoltaics. The increase of renewable energy carriers in gross final energy consumption is expected to reach 34% by the year 2020.[357] In accordance with the plan from the Strategy,

[355] *Energiestatus 2016. Abteilung III/2 – Energiebilanz und Energieeffizienz*, BMWFW, Vienna, May 2016, p. 48.

[356] *Land am Strom... op. cit.*, p. 15.

[357] *EnergieStrategie Österreich*, BMWFW, BMLFUW, Vienna 2010, pp. 7-8.

the use of RES is anticipated to reach 395.6 PJ, and the total gross final energy consumption is to be 1,114.9 PJ. The Austrian Strategy also assumes that by 2020, the use of oil and oil derivatives will drop to 362.3 PJ, and natural gas, to 191.2 PJ. Hence, growth in the share of biofuels up to 34 PJ is anticipated.[358]

Strategy of energy efficiency growth

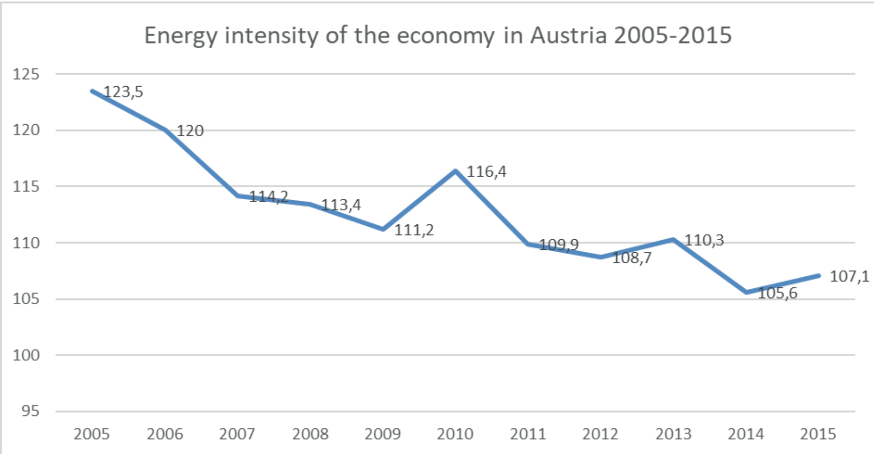
The three pillars of energy policy being implemented by the Austrian Energy Strategy are, apart from the development of RES, consistent growth of energy efficiency in all the main sectors. In December 2013, a governmental programme was established for another 5 years, describing the goals, challenges, and a wide range of means to carry out Austria's energy policy. Ensuring long-term supplies of energy and the related costs, as well as the environmental impact, largely affect the economic efficiency and performance of the country. Thus, it is necessary to keep energy consumption at the lowest possible level, to conservatively use the country's resources of natural resources, to develop RES, diversify the necessary import, and in this way ensure and protect the energy transport infrastructure and sufficient storage capacity.[359]

By raising its energy efficiency, Austria is striving to overcome the tendency of ever-growing energy demand. Stabilizing final energy consumption by 2020 at the level of consumption in 2005 (1,118 PJ) is the target of this priority set in the Austrian Energy Strategy. Reducing final energy consumption is to occur through certain measures to enhance energy efficiency which refer to many areas. Effective implementation of these measures is to be a guarantee that the goals set in the Strategy will really be achieved by 2020. Activities in this regard involve the consideration of energy and climate objectives in the spatial development policy, reform of the ecological tax, a wide review of instruments of support, and subsidies for the development of research, technology, and innovation.[360] The effects of previous activities in Austria are already visible: in the area of heat engineer-

358 *Ibidem*, p. 11.
359 *Ibidem*, pp. 7-8.
360 *Ibidem*, p. 9.

ing, emissions have been reduced by 34% in comparison to the level of 1990.[361] The newest data shows that in 2014, Austria reduced its final energy consumption by 4.3% in relation to the year 2013.[362] The increasing growth of energy efficiency in the country is also visible in the example of natural gas. In 2015, the demand for this resource grew by 6% up t almost 7.9 bcm (89 TWh). At the same time, national production dropped by 5%, reaching 1.2 bcm, and net import of gas was reduced by 1.6 bcm (-22%).[363]

Chart 29. Energy intensity of the economy in Austria 2005-2015 – Gross inland consumption of energy divided by GDP (kg of oil equivalent per 1 000 EUR)



Source: Eurostat, *Energy intensity of the economy*, http://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=tsdec360 (accessed: 25.08.2017).

In the Austrian Energy Strategy it is anticipated that in 2020, the area of heat engineering and transport will play the biggest role in final energy consumption in Austria, so significant attention is being concentrated on these sectors. The share of the construction sector

361 C. Morris, M. Pehnt, *Niemiecka transformacja energetyczna... [German energy transition ...] op. cit.*, pp. 80-81.

362 *Erneuerbare Energie in Zahlen..., op. cit.*, p. 10.

363 *OMV Geschäftsbericht 2015*, OMV AG, Vienna, https://www.omv.com/SecurityServlet/secure?cid=1255769898259&lang=de&swa_id=1117068374618.7583&swa_site= (accessed: 12.11.2016), p. 6.

currently accounts for approx. 1/3 of Austrian final energy demand.[364] Plans for enhancing energy efficiency in this area assume the improvement of building standards to the level of minimum energy demand. The package of activities to be implemented in raising energy efficiency in construction includes e.g., a 3% rate of building renovation by 2020, aimed at gradual optimization of heating in buildings, conforming to regional concepts of spatial development. This means the choice of the source of energy should be appropriate to the potential existing in the region and in conformity with it; should assume central heating with the use of waste, cogeneration, or biomass; and individual heating with the use of solar energy, biomass, or heat obtained from the environment (e.g., heat pumps).[365] It must be noted that Austria is already the European pioneer in terms of the proportion of passive houses. The main stimulus for development in this field is state subsidies, being an incentive to renovate buildings.[366]

Equally important is electricity and heat consumption in households, smaller production facilities, and enterprises, especially energy-intensive ones. Here, special attention is given to energy counselling and educating the community in energy awareness, i.e., more effective consumption of primary energy and heat.[367]

Transport is also significant in the energy sector. In this field, Austria is planning to develop alternative drives, especially electric, but also hydrogen. Furthermore, public transport and car sharing, as well as mobility management services, are being extended and promoted. The package of activities for mobility also includes lowering emissions by greater use of RES, understood primarily as a higher share of biofuels (10% in accordance with the EU Directive).[368] The total share of energy consumption in road transport is expected to drop from 87.7% (in 2010) to 74.3% in 2050.[369]

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[364] C. Morris, M. Pehnt., *Niemiecka transformacja... [German energy transition...]* op. cit., pp. 80-81.

[365] *EnergieStrategie Österreich..., op. cit.*, pp. 7-10.

[366] C. Morris, M. Pehnt., *Niemiecka transformacja... [German energy transition...]* op. cit., pp. 80-81.

[367] *EnergieStrategie Österreich..., op. cit.*, p. 7.

[368] *Ibidem*, p. 7.

[369] S. Schleicher, A. Köppl, *Energieperspektiven für Österreich. Zielorientierte Strukturen und Strategien für 2020 und 2030*, published by WIFO, October 2013, p. 37.

Apart from activities in the above-mentioned areas, it is also necessary to develop transmission and distribution networks and energy storage facilities. The existing network infrastructure must be adapted in the future to strong, decentralized energy production and higher levels of energy flow combined with the lowest loss of energy during transmission.[370]

Development of competition on international markets

Austria, as a small and rather poorly populated country, mostly bases its economic model on quality categories and thus predominantly counts on improving research, technological development, and innovations. In this way, it wants to create highly specialized jobs and support long-term economic growth and its labor market. Austria's objective is to leave the group of countries importing innovative technological solutions and to join the leaders of innovation and exporters of new knowledge.[371] The energy sector is especially attractive for Austria in this regard, as it is driven by stimuli from environmental and climate policy. Therefore, Austria wants to create new technologies marked *Made in Austria*, recognizable abroad. Austria intends to become the most innovative region in Europe in terms of energy. This is to be achieved through support for enterprises and research institutions so as to strengthen their competitive position.[372] The scope of priorities in this area is presented in the Austrian Strategy for Research, Technology and Innovation (*Strategie der Bundesregierung für Forschung, Technologie und Innovation* – hereinafter: FTI Strategy) of 2011.

RES technologies have a long tradition in some regions of Austria, originating from the high level of national economy and a well developed community with high expectations referring to the quality of life, but also awareness concerning protection of the natural environment. Many patents and research competences guarantee Austria

[370] *EnergieStrategie Österreich..., op. cit.*, p. 8.

[371] *Der Weg zum Innovation Leader. Strategie der Bundesregierung für Forschung, Technologie und Innovation*, Vienna, March 2011, p. 4.

[372] *EnergieStrategie Österreich..., op. cit.*, p. 14.

a good economic position in Europe, which in turn gives domestic companies great opportunities to join export markets, and later ensure substantial profits for the national economy.[373] Within the latest 20 years, the number of RES patent applications has grown six-fold in Austria, and 42% of patents before 2010 were connected with thermal energy[374]. For the last 4 years in a row, Austrian economy has seen steady growth, 0.8% annually (2015).[375]

In Austria, energy-saving construction, geothermal energy, smart electric grids, and electromobility development are all areas of special potential. Austria has ambitions to become a technological pioneer in the global trend of departure from fossil fuels in energy production and CCS – Carbon Dioxide Capture & Storage.[376] Elements such as new products on the market and innovation, an increase in export of advanced technologies, high tech products, and knowledge-based services are expected to make Austrian enterprises recognizable world leaders in high tech industry. Public procurement and political infrastructure oriented toward innovation is to contribute to the increase of demand for high technology products and knowledge-based services.[377]

Austria has the potential to develop the use of biomass energy, especially connected with wood and wooden products. Nowadays, two out of three biomass boilers installed in Germany come from Austria.[378] Apart from Germany, the main export countries are France, Italy, and Spain. Great Britain may become a potential market in the future because of ongoing work on an act concerning subsidies for heating from renewable sources.[379] The upward trend is also visible in the

[373] *Erneuerbare Energie in Zahlen…, op. cit.*, p. 26.

[374] R. Bointner, P. Biermayr, et al., *Wirtschaftskraft Erneuerbarer Energie in Österreich und Erneuerbare Energie in Zahlen*, "Blue Globe Report. Erneuerbare Energien", no. 1/2013, Vienna, p. 57.

[375] *OMV Geschäftsbericht…, op. cit.*, p. 16.

[376] *Energietechnologie*, BMWFW, Abteilung Energie/Technik und Sicherheit, http://www.bmwfw.gv.at/EnergieUndBergbau/Energieeffizienz/Seiten/Energietechnologie.aspx (accessed: 12.11.2016).

[377] *Der Weg zum Innovation…, op. cit.*, pp. 12-13.

[378] *Umwelt und Energie im Überblick*, Österreichische Forschungsförderungsgesellschaft,
https://www.ffg.at/content/umwelt-und-energie-im-berblick (accessed: 12.11.2016).

[379] *Erneuerbare Energie in Zahlen…, op. cit.*, pp. 30-31.

sector of liquid biofuels, in the case of which Austria is one of the EU pioneers. Bioethanol is produced on a large scale, and the produced 191,000 tons exceeds more than twice the country's demand.[380] A lot of potential also lies in Austrian experience acquired in biogas production. Wide competencies in this area are visible in the purification of raw gas and processing it to biomethane with quality corresponding to natural gas, then allowing it to enter into the network. In the construction of bio gasworks and cogeneration installations, the knowledge and experience of Austrian enterprises is at a particularly high level in the EU.[381] Austria's experience in water energy is also considerable. For this country, the technology of building hydropower plants and their necessary components has become an export service. Austria produces photovoltaic modules, too, 47% of which are exported, mostly to other EU countries. As regards photovoltaic components, Austria manufactures inverters, in which case global export accounts for approx. 89%. The total sale of Austrian heat pumps to foreign markets was 9,858 in 2014, which accounts for 33.7% of the export quota.[382] The share of Austrian export of solar collectors is 82%. As for components for wind power plants, the level of export is 96%.[383]

Planes of competitive advantages in the economy

The goals set in Austrian plans for economic development from the perspective of energy transition are based on three basic priorities: decarbonization, decentralization, and digitalization. One of the elements decisive for the future of the Austrian energy system is the development of technology and solutions for optimum system integration of the high share of RES combined with an increase in the efficiency of distribution (transmission) and consumption of energy. Thanks to improved technologies, a comprehensive approach to system integration, and innovative ICT technologies, system efficiency can be considerably enhanced and the quality of energy services can be improved. Because of difficulties with electricity storage and the specific

[380] *Erneuerbare Energie in Zahlen…, op. cit.*, pp. 32-33.

[381] R. Bointner , P. Biermayr, et al., *Wirtschaftskraft Erneuerbarer…, op. cit.*, p. 30.

[382] *Erneuerbare Energie in Zahlen…, op. cit.*, pp. 35-37.

[383] *Umwelt und Energie…, op. cit.*

character of electricity networks with the need to ensure appropriate stabilization of frequency and voltage, but also because (in accordance with present tendencies) the significance of energy carriers is going to increase considerably in the future, the need for research in this area is particularly high.[384] Thanks to the use of innovative technologies, more than 50 TWh energy was produced from RES in 2014, reducing emissions harmful to the climate by 10.8 million tons of CO_2 equivalent.[385] On the basis of previous achievements and taking into account the government's specific support for improving the innovativeness of domestic enterprises, Austrian industry has the chance to achieve great success in energy and environmental technologies.

The newly developed field of electric transport provides great potential for Austria. First of all, this is because the country is already a pioneer in the sector of liquid biofuels in the EU, although it still needs to import a lot. It is a relatively new economic area in Austria, developed intensively since 2004, and especially attractive for its environmental benefits. Biofuels may contribute to a considerable reduction in greenhouse gases in the transport sector. For the same reasons, biogas produced from waste is attractive for the industry. In 2014, the combined capacity of 384 bio gasworks was 113.9 MW.[386] Moreover, Austria is working on the development of power-to-gas technology, which will ultimately also be applied in transport. It is carrying out a pilot project *wind2hydrogen* to develop the technology of obtaining hydrogen from surpluses of electricity produced by RES installations. The *wind2hydrogen* project is being implemented mainly by the energy concern OMV as part of a programme including broader research on electricity.[387]

Climate changes combined with insufficient energy resources and the need to ensure a proper quality of life in the face of demographic transformations are definitely global challenges of our times which

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[384] *Intelligente Energiesysteme der Zukunft. Smart Grids Pioniere in Österreich. Strategien – Projekte – Pionierregionen*, BMVIT, Vienna 2010, https://nachhaltigwirtschaften.at/resources/edz_pdf/broschuere_smart_grids_pioniere.pdf (accessed: 12.11.2016), p. 5.

[385] *Umwelt und Energie…, op. cit.*

[386] *Erneuerbare Energie in Zahlen…, op. cit.*, pp. 32-34.

[387] *Factsheet: Research project wind2hydrogen*, OMV Aktiengesellschaft, August 2015.

need appropriate solutions. The Austrian FTI Strategy includes "Climate change and limited resources" as one of the country's priority challenges. In this regard, the Strategy points to the need to develop new technologies as a means to fighting those threats.[388] Another activity in the field was reform of the Austrian Act on renewable energy (*Ökostromgesetz*) in 2011, allowing introduction to the network of more wind and solar energy. The work on the act may be considered as an attempt to make Austrian energy transition more dynamic. According to estimates connected with the reform of the act, by 2020, Austria will probably reach an 80% share of electricity from RES, which could give it the position of EU leader.[389]

The FTI strategy also implements an interesting concept of so-called *Smart Cities* (*Stadt der Zukunft*), which are to be model urban centers with a modern energy system. One central aspect of such cities is the role of modern technological solutions in smart urban infrastructure involving ICT. Another priority is to maintain and try to improve the quality of the environment and life in cities. The primary element is still the use of RES, including integration of photovoltaics and solar panels into construction, and an increase in energy efficiency, not only of buildings, but also energy industry and mobility.[390]

Energy security

Energy transition in Austria faces important challenges connected with future social, economic, and climate aspects and threats to which solutions need to be found. What is important is that national energy production is not sufficient for consumers' needs, hence the necessary import of energy and resources plays an important role in the country's energy balance. It is necessary to fight the problem of diminishing energy and environmental resources, which includes the transition

[388] *Österreichischer Forschungs- und Technologiebericht 2016. Lagebericht gem. § 8 (1) FOG über die aus Bundesmitteln geförderte Forschung, Technologie und Innovation in Österreich*, BMWFW, BMVIT, Vienna 2016, p. 3, p. 81.

[389] C. Morris, M. Pehnt, *Niemiecka transformacja energetyczna... [German energy transition ...] op. cit.*, pp. 80-81.

[390] *Österreichischer Forschungs- und..., op. cit.*, p. 83.

to new and renewable energy sources.[391] Intensification of activities aimed at developing RES is very important for securing national energy supplies and thus, strengthening national energy security. Additionally, this means the creation of highly specialized jobs, strengthening the competitiveness of the Austrian economy, and the achievement of EU climate objectives.

The Austrian governmental programme concerning the future of the energy industry in the country emphasizes that an efficient, affordable and socially acceptable energy system should guarantee the security of supplies, affluence of the society, competitiveness of the economy, and environmental protection.[392] Thus, the energy and political goals of Austrian Energy Strategy assume the following elements: security of supply, the environment-friendly character of the system, social acceptability, economic competitiveness, and financial efficiency.[393]

The task of energy policy is to ensure the security of energy supplies in two ways. On one hand, by guaranteeing sufficient infrastructure for energy transmission and distribution, both in domestic production and in imported energy. The requirements for ensuring supply security must be formulated especially in the area of network transmission and distribution. In the future, network infrastructure must meet the needs of stronger, decentralized production, higher volumes of energy flow, and higher requirements in supply security. An appropriate set of measures includes the extension and modernization of Austrian transmission and distribution networks, development of systems of central heating and cooling, extension of the energy storage system, as well as smart grids and counters. On the other hand, the state should strive to lower its energy demand. Attempts to ensure secure and long-term supply of energy are a necessary factor due to Austria's location and society. The level of diversification of energy resources and sources, whose import is still unavoidable, should be enhanced all the time. Therefore, European and global energy markets are of strategic importance for Austria.[394]

[391] *Der Weg zum Innovation…, op. cit.*, p. 9.

[392] *Energiestatus 2016. Abteilung III/2…, op. cit.*, p. 74.

[393] *EnergieStrategie Österreich…, op. cit.*, p. 14.

[394] *Ibidem*, p. 25.

Activities connected with the liberalization of the energy market, which are expected to strengthen the national economy, are also important. Consumers should benefit from it too, as by assumption they can expect a higher quality of the services provided by competitive energy providers. Generally, energy users are becoming more and more important because, thanks to new market rules and products, they receive the possibility of active participation in the energy market and can optimize their own energy demand. This way, they also make an important contribution to the security of the whole energy system.[395]

The progressive liberalization of European energy markets has also made the Austrian energy system more and more connected with the systems of neighboring countries. So in addition, there is international energy trade, and it has become necessary to balance the supply and demand, not only internally, but also supranationally.[396] In the case of Austria, good conditions for the development of importation are ensured by its central location in Europe, which is conducive to crossing trans-border networks within it, and to exchanging energy with the neighboring countries. This leads to the country's responsibility for European energy transmission and supplies, as well as a chance for the development of the Austrian economy.[397] But it also means that, regarding the transit of energy resources, Austria is still dependent on other countries.

[395] *Empowering Austria. Die Strategie von Oesterreichs Energie bis zum Jahr 2030*, Österreichs E-Wirtschaft, Vienna 2015, p. 5.

[396] *Erneuerbare Energie in Zahlen…, op. cit.*, p. 18.

[397] *EnergieStrategie Österreich…, op. cit.*, p. 8.

Chapter 14

Energy transition in Switzerland

Anna KUCHARSKA[398]

Energy balance structure

As a result of a combination of several factors, Switzerland is unique among European countries. First, it is located in the middle of Europe, so it has naturally become a trans-border corridor of energy transmission. Second, it is not a member of the EU or EEA, which gives it a unique legal status in the face of advancing physical integration with neighboring countries belonging to the EU. Besides, Switzerland is 100% dependent on the import of oil, natural gas, and uranium. Because of the high level of civil development, the country has a great demand for energy despite its small surface area and population. And finally, the decentralized character of the political system and the tradition of citizens' direct participation in political life through referenda make changes in the country occur slowly and gradually, and they cannot affect citizens too much, since otherwise they simply do not agree to the reforms.

In Switzerland their full dependence on fossil fuels is connected with the high demand for energy. In 2014, the total final energy consumption in Switzerland was 825,770 TJ, in which 21.4% was energy from RES. In 2014, the share of RES in final energy consumption was 176,902 TJ, which means a decrease by 6.4% in comparison to 2013 (189,001 TJ). The share of so-called new RES (i.e., without water energy) was 9,415 TJ in 2014 (in 2013: 7,913 TJ; i.e., growth by 19%), which in 2014 made it possible to produce 3.9% of electricity. Total

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production of electricity from RES was 142,446 TJ (2012: 142,697 TJ, i.e., a decrease by 0.2%). In 2014, 47,768 TJ of heat from RES was consumed (2013: 52,447 TJ; a reduction of 8.9%).[399]

The share of non-renewable energy carriers in total consumption is 78.58%. Oil is mostly imported from Africa. In Switzerland, there are huge refineries, so it is a significant importer of oil derivatives for Europe (e.g., gasoline). Most natural gas imported to Switzerland comes from EU countries and Norway, and 1/4 from Russia. Switzerland has no direct agreements with Russia. For the import of natural gas, Switzerland is totally dependent on the transmission network of EU countries. Switzerland's problem is the lack of its own gas storage facilities. For geological and technical reasons, Switzerland was unable to develop great gas storage facilities, so it only has transmission networks and small containers to balance daily gas demand.

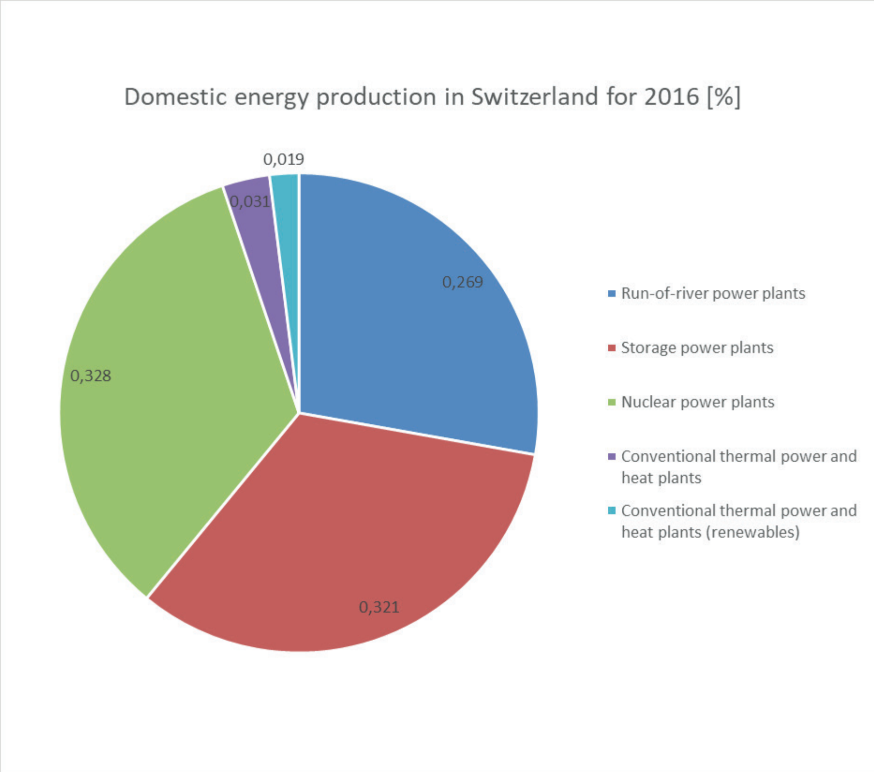
Currently, 5 nuclear power plants in Switzerland ensure 40-45% of its electricity. A higher share in energy production occurs in winter due to the lower use of RES. Uranium is supplied from politically stable regions such as e.g., the USA, Canada, or Australia, so dependence on this resource is not considered in terms of any threat to the country's security. It is also emphasized that Switzerland has learnt to store radioactive waste in a safe way, and the amount of needed nuclear fuel is many times lower than other fossil fuels. Besides, it is a zero emission source of energy with a stable volume of production, which is important for the mostly obsolete Swiss transmission networks.[400] Despite substantial social support for nuclear energy, after the Fukushima disaster Switzerland began work on Energy Strategy until 2050 (*Energiestrategie 2050*) assuming a gradual resignation from nuclear energy, which was to begin by not building new blocks or extending the use of existing ones unless necessary for safety reasons.[401]

[399] *Schweizerische Statistik der Erneuerbaren Energien. Ausgabe 2014*, UVEK, BFE, Bern, September 2015, pp. 40-41.

[400] J. Lundsgaard-Hansen, *Energiestrategie 2050 – das Eis ist dünn. Die Schweiz und Deutschland auf neuen Wegen*, published by NZZ, Zürich 2013, p. 82.

[401] *Energiespeicher in der Schweiz. Bedarf, Wirtschaftlichkeit und Rahmenbedingungen im Kontext der Energiestrategie 2050*, Schlussbericht 12. December 2013, UVEK, BFE, Bern 2013, p. 30.

Chart 30. Domestic energy production in Switzerland for 2016 [%]

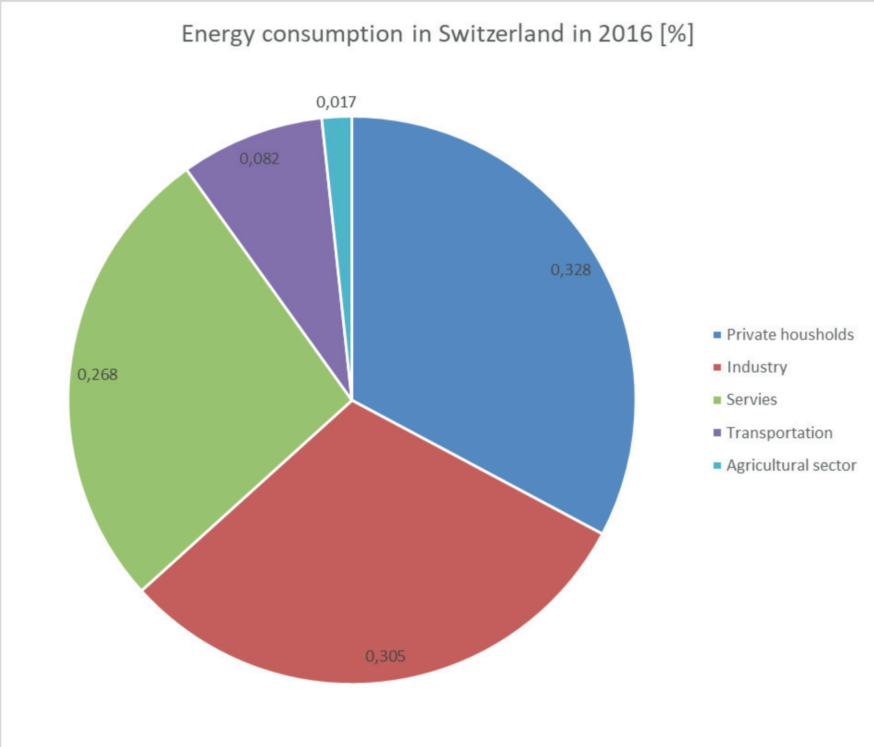


Source: *Schweizerische Elektrizitätsstatistik 2016*, BFE, Bern, p. 3.

Swiss model of energy strategy

Energy Strategy Until 2050 is an extension of the document of 2007, which applies to the period until 2035: Energy perspectives (*Energieperspektiven 2035*). The document that refers to Switzerland's energy strategy until 2050 updates socio-economic data, technical requirements and energy policy, and presents goals assuming gradual transformation of the Swiss energy system until 2050. The Strategy includes 3 scenarios for the development of energy supply and demand in Switzerland and 7 priorities for Swiss energy policy. The key ones raise the share of RES in electricity production, strengthen research on the energy industry, and extend and transform energy networks and storage facilities.[402] The increase in electricity production from RES assumed until 2050 involves, according to different sources, an annual increase in the share of water energy by 3.2 TWh up to 38.6 TWh; wind energy should reach the production capacity of 4.3 TWh; photovoltaics, 11.2 TWh. It is also necessary to guarantee enough available capacity through appropriate storage capacities and sufficient network capacity, already emphasized by the Ministry of Energy in the Strategy Until 2035.[403]

Chart 31. Energy consumption in Switzerland in 2016 [%]



Source: *Schweizerische Elektrizitätsstatistik 2016*, BFE, Bern, p. 4.

The Swiss Energy Strategy presents 3 possible scenarios of development for Swiss energy policy before 2050. Thus, Switzerland not

[402] *Die Energieperspektiven für die Schweiz…, op. cit.*, p. 1.

[403] *Energiespeicher in der Schweiz.., op. cit.*, p. 34.

only has aplan, but it is flexibly developing its energy policy to allow the adoption of whatever variation is the most beneficial socially and economically. The introduction of scenarios depends i.a., on technological advancement allowing the application of specific system activities.[404] The general priorities of energy policy set in the Strategy refer to all three scenarios, but differ in the ways and degree of their achievement. All scenarios assume a decrease in importation of fossil energy carriers, reduction of CO_2 emissions, an increase in the use of RES, and rising energy efficiency.[405]

All the scenarios assume a decrease in the import of fossil energy carriers from the current 80% of total energy consumption to 29-62% depending on the scenario.[406] The increase in the share of RES in electricity production assumed for 2050 is by 11 TWh for photovoltaics, 4 TWh for wind power plants, 4 TWh for geothermal energy, and 16 TWh for run-of-river hydroelectricity. The Swiss energy networks adopting the anticipated volumes of electricity from wind, solar, and geothermal power plants will be possible for all three scenarios thanks to the high flexibility of pumped storage power plants and power plants at water reservoirs.[407] They are of key importance in securing Swiss electricity supply. With their huge energy potential, they are currently able to cover in critical situations the majority of Swiss electricity demand.

The least demanding scenario in terms of achievement of general energy priorities is the *Weiter wie bisher* – WWB scenario *(The same as before)*, whose name clearly shows the policy direction. WWB is oriented to the existing situation and the possibilities of developing energy policy on the basis of currently available instruments and tools.[408] This variant is most often referred to when planning current activities and the near future.

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[404] *Ist das geplante Stromsystem der Schweiz für die Umsetzung der Energiestrategie 2050 aus technischer Sicht geeignet? Swiss Energy Strategy 2050 and the Consequences for Electricity Grid Operation – Full Report* , SATW, Zürich, Mai/Juli 2014, http://www.satw.ch/publikationen/SATW_Energiestudie_def.pdf (accessed: 6.11.2016), p. 82.

[405] *Die Energieperspektiven für die Schweiz…, op. cit.*, p. 617.

[406] *Ibidem.*

[407] *Ist das geplante Stromsystem…, op. cit.*, p. 11.

[408] *Die Energieperspektiven für die Schweiz…, op. cit.*, p. 3.

a) Development of renewable energy sources

The scenario titled *Neue Energiepolitik* – NEP (New energy policy) is the scenario of the federal government of May 2011. It presents a probable path for changing electricity consumption and production in Switzerland until 2050, providing the basis for the assumption of reducing CO2 by 1.0-1.5 tons per capita. This would mean that the goal of reducing CO2 emissions before 2020 by 20% in comparison to 2000 is met. An important aspect of this scenario assumes that constantly available biomass resources are limited, both within the country and globally. Therefore, the NEP scenario excludes the possibility of basing itself on the unlimited import of biogenous energy carriers. It points to the need for international cooperation, especially in terms of research and development, in order to have a uniform policy of CO_2 reduction and energy efficiency improvement. In particular, it emphasizes the need to develop and implement new technologies on the basis of division of tasks on the international scale.[409]

The Swiss Ministry of Energy anticipates extending the power of pumped storage power plants from 1.8 GW to approx. 6 GW before 2025. At the same time, the storage capacity of the water tanks is to be increased up to 200 GWh.[410] In 2015, 37 hydropower plants operated. 15 of them were newly built, 12 were restructured, and 10, adjusted. The Russein power plant has the highest energy production: 66.8 GWh. At the end of 2015, more hydropower plants that were being built will ensure the level of electricity production of 321 GWh. As much as 18% of that will be provided by the extension of the Krafthaus Prutz/Ried hydropower plant.[411] Despite their high potential and importance for the Swiss energy industry, hydropower plants have losses. The classic economic model in which water is released at the maximum load has lost its profitability since the differences in wholesale electricity prices (so-called spreads) began decreasing during the day. This is the result of factors such as low prices of fossil fuels and rights to CO_2 emissions in previous years. An important factor was also the extension of installations using

[409] *Ibidem*, p. 4.

[410] *Ist das geplante Stromsystem…, op. cit.*, p. 7.

[411] *Schweizerische Elektrizitätsstatistik 2015*, BFE, Bern, p. 39.

solar radiation, which have priority for entering higher amounts of energy into the network in the afternoon.[412]

Achieving 11.2 TWh electricity from photovoltaics a year, which is the Ministry's target, means the necessity to extend solar installations by 9 GW a year. With the technology available now, 17% of the surface area (about 80 km_2) allocated for development (industry, residential areas) will be used for this purpose, which conforms to Swiss spatial requirements. The problem is, however, that the assumptions of the Swiss Ministry of Energy are based on optimum solar exposure, i.e., 1,250 full hours of load a year. However, data reported by companies applying for subsidies from the instrument of support for RES shows that actual solar exposure is approx. 900 full hours a year. Taking this data into consideration, the value of necessary capacity of 12 GW should be used instead of 9 GW, so that the target of annual electricity production could be 11.2 TWh. In this case, the above-mentioned data concerning spatial demand must be raised by 1/3.[413] Forecasts of growth in the use of photovoltaics in Switzerland connected with the development of the expected potential of this source of energy are estimated at between 0.1 and 2.7 TWh by 2035, and by 2050, the values will be 0.2-9.7 TWh.[414] This increase means the multiplication of current electricity production, i.e., 0.02 TWh, 6- or even 100-fold by 2035. Before 2050, growth by 10 to even 500 times is expected in comparison to contemporary production. In terms of production costs, photovoltaics is currently the most expensive technology of electricity production in Switzerland; the price of produced energy is 40-100 Rp./kWh.[415]

A wind power plant already functions as a mature and economically competitive technology with high developmental potential. The costs of production are lower than in the case of a small hydro power plant, but largely depend on location. This kind of energy source, however, is not usually approved by the local community. In Switzerland, the development of wind energy is very limited by territorial conditions,

[412] *Energiespeicher in der Schweiz.., op. cit.*, p. 34.

[413] *Ist das geplante Stromsystem..., op. cit.*, p. 51.

[414] Span depending on the adopted scenario from the Energy Strategy Until 2050.

[415] *Energie-Strategie 2050. Impulse für die schweizerische Energiepolitik. Grundlagenbericht*, Energie Trialog Schweiz, Zürich 2010, pp. 50-59.

because there are few available locations appropriate for the development of such installations. Currently, in Switzerland there are 13 wind installations, which produce 0.02 TWh annually. Approximately 90 more installations are planned. To achieve the target of producing 2 TWh, set in the Energy Strategy, it would be necessary to install approximately 1,200 wind turbines. According to many studies carried out by research centers at the request of the Ministry of Energy, the increase in the use of such an energy source could reach 0.6 to 2.2 TWh a year by 2035. This way, today's production would be increased by 40 or even 100 times. It is estimated that the level of wind energy use will grow considerably by 2035, but before 2050, this progress will no longer take place. However, the development of wind energy is strongly dependent on the demand and location possibilities.[416]

b) Increase in energy efficiency and international competitiveness

The "Political Measures" scenario (*Politische Massnahmen* – POM) assumes a politically coordinated set of instruments used to achieve the goals of energy transition. The priority in this scenario lies in raising energy efficiency and results from the intention to secure in the future sufficient electricity supplies because of giving up on nuclear energy. For these reasons, different variants of covering electricity demand are taken into consideration. For example, a number of in-depth analyses were prepared, concerning the effects of the growing share of fluctuating energy production from RES in the energy mix, cogeneration, electromobility, and biomass potential.[417]

The emphasis on raising energy efficiency is considered to be much more beneficial than extending energy production. What is important in this aspect is such energy sources as photovoltaics, wind energy, and biomass, which are not a valuable and freely available resource because of the established density of energy and power per surface area unit.[418] In other words, due to spatial limitations, in Switzerland there are not many opportunities to extend wind or solar farms. Therefore, the goal is to maximize energy efficiency in energy production using the available locations.

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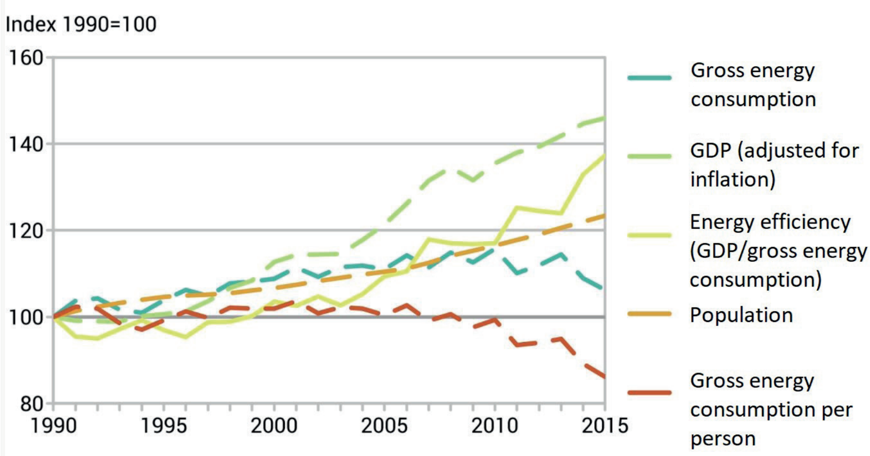
[416] *Ibidem.*

[417] *Die Energieperspektiven für die Schweiz..., op. cit.*, p. 1.

[418] *Ibidem*, pp. 4-5.

Chart 32. Energy efficiency in Switzerland (1990-2015)



Source: Bundesamt für Statistik, *Umweltindikator – Energieeffizienz*, Bern 2016 [Internet:] https://www.bfs.admin.ch/bfs/de/home/statistiken/raum-umwelt/ressourcen/umweltindikatorensystem/nutzung-natuerliche-ressourcen/energieeffizienz.html (accessed: 27.08.2017).

The aspect of raising energy efficiency is connected with the issue of capturing and storing energy surpluses. Further, energy storage facilities are connected with the area of industrial networks, because they have to be integrated with them. It is necessary to raise efficiency, not only in the sphere of production, but also the whole energy infrastructure. The classic tasks of energy storage facilities involve compensating annual changes in consumption and fluctuations of daily peaks, so the significance of RES grows along with their development. The strong need to store energy occurs when energy production from RES dependent on external conditions is periodically insufficient to meet the demand. On the one hand, the development of research concerning new technologies plays a big role in the development of storage facilities. On the other hand, changes in the system of remunerations for controlled RES, i.e., hydro power plants, are also important.[419]

The goal of the implementing political instruments proposed by the POM scenario is to activate the potential of energy efficiency. As a result of the activities, the final consumption of energy may drop by 33% before 2050 in relation to present consumption. It is anticipated

[419] *Energiespeicher in der Schweiz.., op. cit.*, pp. 35-37.

that this may stabilize the consumption of electricity, and growth will begin again after 2035 because of stronger electrification of traffic by approx. 3.4%.[420]

Unlike in the NEP scenario, the assumptions of POM include pursuing the nation's autonomy and independence in satisfying the demand for energy at the cost of lowering the degree of achievement of energy policy priorities. Activities proposed in POM may be implemented in Switzerland independently of international energy policy, except the boundary values of emissions in traffic. Dependence on measures implemented internationally occurs in industries which are not very well developed in Switzerland, e.g., the automotive industry, because Switzerland does not produce vehicles. Hence, the growth of vehicle efficiency in this country is closely connected with the activities of countries that are producers of cars.[421]

The increase of energy efficiency in all kinds of fuel, including alternative (biogenous) fuels, is still significant. In the end, electromobility is expected to be competitive to conventional combustion engines in terms of efficiency. A technological leap in solutions for batteries may make the market share of electric vehicles grow, but increasing the performance of combustion engines may temporarily inhibit the expansion of electric cars. Hybrid vehicles make use of the development of technology in both areas and may be regarded as an element of the transition phase to electric mobility together with so-called range extenders. Electromobility must develop as part of a collaboration of world actors and responsible regional development, and be properly carried out in this sense.[422] In the case of Switzerland, the automotive parts industry, with a turnover of approx. CHF 14 billion, is an important branch of industry. Thanks to investments in R&D and the production of highly specialized parts it has good recognition all over the world.[423] Hence, the potential existing in this area can be used in the field of electromobility along with technologies developed in Switzerland, such as power-to-gas.

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[420] *Die Energieperspektiven für die Schweiz…, op. cit.*, p. 615.

[421] *Ibidem*, pp. 4-5.

[422] *Elektromobilität 2012. Bericht des Bundesamts für Strassen ASTRA,*UVEK, ASTRA, October 2012, p. 3.

[423] *Ibidem*, p. 5.

c) New technological solutions

The increase of fluctuating production of energy combined with the increase of national share of RES in electricity production is associated with some challenges. What is necessary is both higher shares of regulatory production (pumped storage and reservoir power stations, gas-steam systems, or cogeneration installations), but also the extension of extra seasonal storage capacities. It is still not stated clearly in Swiss documents what the combination of changeable energy production with the needed storage capacities or control through market stimuli will look like. Yet, the need for change in the present market structure is forecast. This also involves the improvement of distribution networks and the distribution system.[424] So far, the emphasis is on the development of technology for storing energy surpluses.

Hydrogen produced in the process of electrolysis from electricity generated from wind or solar energy, but also from a temporary energy surplus from conventional power plants, can be used for storage of energy surpluses produced by RES. Hydrogen obtained this way can then be reused to charge vehicles or in power plants. Hydrogen can also be used like current hydropower plants in emergency situations. The potential of this technology is attractive because it enables both short-term (e.g., a week) and seasonal energy storage.[425] For these reasons, research is being carried out in Switzerland to work out concepts appropriate for small photovoltaic power plants combined with hydrogen production and the use of fuel cells.[426] In 2015, Switzerland launched a pilot programme of a power plant generating electricity from RES, where installations using power-to-gas were installed. As planned, gas produced this way is to be used as eco fuel for vehicles. The companies involved in the project assume that the concept will be used on a large scale in the future in the area of environment-friendly mobility.[427]

Making up for the lack of possibilities of gas storage, Switzerland decided to develop modern technologies and supplement the energy reserves system with storage facilities in the form of batteries, com-

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[424] *Die Energieperspektiven für die Schweiz…, op. cit.*, p. 617.

[425] *Energiespeicher in der Schweiz.., op. cit.*, p. 42.

[426] *Elektromobilität 2012…, op. cit.*, p. 3.

[427] *ETOGAS constructs the First Power-to-Gas plant in Switzerland*, Press Information, 22.01.2015, , http://etogas.com/fileadmin/documents/news/Pressemitteilung_EN/2015-01-22_EtG_PI_final_EN_first_PtG_plant_Switzerland.pdf (accessed: 6.11.2016).

pressed air containers, or electrothermal tanks. These, however, are technologies that are still being tested and only have the potential to be used short-term. The *Vehicle to Grid* (V2G) programme is one such concept. It assumes vehicles can be used as buffers for irregular, unplanned surpluses of energy from RES. At the moment, the life cycle of batteries is too low for a vehicle, and additionally shortens after each charging. Therefore, the aim of this concept is also to develop a technology that would solve problems typical of batteries, such as an insufficient life cycle for the vehicle, additionally decreasing at each charging.[428]

The problem is, however, that at present, the process of electrolysis in order to obtain hydrogen and its re-conversion to electricity is still not very effective and involves substantial loss of energy. Despite intensive research in this regard, the approach of the government to this solution and to batteries is rather conservative, because we cannot be fully sure yet that it will be possible to really apply the solutions to store electricity.[429]

Energy security

Geopolitical location and relationships with the European Union are very important for the energy security of Switzerland. The location of Switzerland in the center of Europe gives the country a strategic character in terms of international energy trade, as more than 40 cross-border connections cross there[430], ensuring it a considerable share in the international exchange of energy: 10% of all European transmission of electricity. Switzerland is practically an integral part of the European energy system, which causes mutual dependence of Switzerland and the European Union. Access to the internal European energy market is attractive to Switzerland due to its economic attractiveness and the security of supply guaranteed by the Union.[431]

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[428] *Elektromobilität 2012…, op. cit.*, p. 3.

[429] *Ibidem.*

[430] W. Kwinta, *Rynek energii: Szwajcaria [Energy Market: Switzerland]* [in:] *Polska Energia*, no. 6/2011.

[431] *Europäischer Markt für die Schweiz wichtig*, Schweizerische Bundeskanzlei, Bern, https://www.news.admin.ch/message/index.html?lang=de&print_style=yes&msgid=55212 (accessed: 6.11.2016).

For the EU, Switzerland is a corridor of electricity transmission. The country is located on the north-south axis of energy transmission, especially useful for Italy, which imports its electricity this way. Import of natural gas from a gas pipeline running through the Swiss Alps is equally important for Italy, accounting for 20% of the Italian demand for gas. Switzerland has more than a dozen interconnections with gas pipelines running from Germany and France. Besides, Swiss storage capacities of hydropower stations in the Alps, which are available much quicker than those of traditional fossil fuel power stations, play an important role.[432] Thus, Switzerland is a hub of cross-border connections of European energy trade.

Switzerland is a member of the European Network of electricity transmission system operators (ENTSO-E) and shares with neighboring EU countries numerous points of entry to and exit from the transmission network. From that system of high voltage transmission networks, electricity is distributed to supra-regional, regional, and local end customers.[433] For decades, Swiss energy enterprises have been participants of the European energy market as sellers, distributors, shareholders, and network or power plant operators. With the environment-friendly production of electricity dominant in its energy mix, and because of being the center of European energy exchange due to its location, Switzerland is very important for the EU.[434]

The basic energy-related goals of the EU are the security of energy supplies in three categories: reliable and sufficient, competitive and economically profitable, and environment- and climate-friendly. This understanding of energy supply security results in certain tasks and obligations. The development of the energy market in the EU also has an influence on Swiss energy legislation, supply security, electricity flows, and thus, requirements of the transmission network. It is essential for Switzerland to become part of the future European system of high voltage transmission networks (the Super grid).[435]

[432] *Analyse der Schweizer Energieversorgungssicherheit. Eine Abschätzung der Verwundbarkeit des Energiesystems*, ETH-UNS Projekt-Schlussbericht, Zürich 2013, p. 12.

[433] *Ibidem.*

[434] *Stromabkommen mit der EU*, UVEK, https://www.uvek.admin.ch/uvek/de/home/energie/stromabkommen-mit-eu.html (accessed: 6.11.2016).

[435] *Zukunft Stromversorgung Schweiz*, Akademien der Wissenschaften Schweiz, Bern, July 2012, p. 34.

But Switzerland is neither a member of the EU or of the EEA. Individual agreements and contracts necessary for fluent collaboration or facilitating it, including bilateral electricity agreements, have been negotiated with the EU. The electricity agreement, which is an element of the third package of regulations concerning internal energy market, allows Switzerland free exchange of electricity with other countries and thus, equal chances on the European energy market. The goal of this agreement between Switzerland and the EU is a common, competitive, and consumer-friendly electricity market with high security of supplies for Europe.[436]

Using its negotiating position, during negotiations on the electricity agreement, Switzerland rejected the issue of extending renewable energy sources and improving energy efficiency. It was regarded as unnecessary because of considerable financial encumbrances for the society that cannot be fully forecast, especially in the area of heat engineering and transport.[437]

Both entities, Switzerland and the EU, have some interest in cooperation. The bilateral agreement should allow the Swiss energy industry and offices to further develop as part of the European connections system. But individual bilateral agreements are not enough to ensure Switzerland energy security, especially since adopting the Lisbon Treaty. In this document, the EU established its own and its member states' competence regarding energy policy and made a division between them; moreover, it was set out that third party states, such as Switzerland, would be treated as secondary in the case of emergencies or import needs.

The delayed liberalization of the Swiss energy market is also a problematic issue. Its goal is to strengthen competition on the energy market and to reduce the role of previously dominant energy producers and energy system operators, and thus, to allow consumers free choice of energy providers. As expected by the EU, liberalization will be one element of guaranteeing energy supply security and sustaina-

[436] *Stromabkommen EU – CH. Hintergrundnotiz*, swisselectric, UVEK, Bern, http://www.stromversorgungsrecht.ch/Internationales.html?file=tl_files/media/Themen/Internationales/20100519_swisselectric_Hintergrundnotiz_Stromabkommen.pdf (accessed: 6.11.2016).

[437] *Stromabkommen EU – CH.., op. cit.*

ble prices of energy for end customers. Liberalization will involve the ensuring of stable general conditions for the functioning of the energy market on the basis of transparent legal regulations; it will also help achieve climate and environmental goals.

Cooperation between Switzerland and the EU definitely gives benefits for both entities in the area of energy security. Mutual dependence, which results from the geographical location, is also a fact. However, the tradition of isolationism and substantial direct influence of citizens on Swiss policy means that the legal and institutional integration of the energy system with the EU is rather slow.

Chapter 15

Energy transition in the USA

Rafał JAROSZ[438]

Since 1943, when the USA was first affected by a lack of access to energy resources, ensuring the energy security of the country and influencing the direction of American energy transition have been the priority of each cabinet of the federal government and state authorities. The main reason is the fact that for many years, the economic development of the US has been closely connected with access to energy sources. As a result, the direction of changes in the energy sector are discussed in the US both in terms of internal policy and as part of the debate on the character and goals of international involvement of the United States.[439]

Currently, energy security is closely connected with the country's national security, hence ensuring the security is part of the competence of many entities of the administration responsible for foreign, defense, and internal policy. The direction of the transition in the energy sector is established both by the President himself and by a number of governmental institutions, such as: the Department of State, Department of Defense, Department of the Interior, National Security Council, and the Congress (especially the Senate Foreign Relations Committee and House Committee on International Relations).

Since the 1970s, in order to alleviate public moods, all American Presidents have pointed to the need to reduce the consumption of energy resources, mainly oil, and the need to make the United States

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[439] This was manifested by the establishment of a separate Bureau for Energy Resources in the Department of State in 2011. The goals of activity of the new bureau were to solve global energy conflicts, to fight "energy poverty" and to promote energy transition in the USA and on the global market.

independent from its importation. During his Presidential campaign in 2012, when the price of a barrel of oil reached or exceeded a record USD 140 and the high cost of military involvement in the Gulf region evoked growing opposition of the American community, B. Obama called to increase the extraction of American energy resources. He presented the solution to this problem as a national challenge and one of the key goals of his presidency.[440] At the same time, he was the first US president to try to combine the issue of reduction in fuel consumption with the need to implement renewable and energy-efficient technologies that would not only lower American dependence on the import of oil and gas, but also have a beneficial effect on the environment and reduce the negative effects of climate changes.

The future presidency of Donald Trump seriously questions the maintenance of the direction of the "green" energy transition in the USA initiated by his predecessor.[441] But on the other hand, it is hard to imagine that the transition carried out now by both the American and global private sectors, based on the development and implementation of clean technologies reducing the emission of greenhouse gases, could be easily and quickly reversed. Still, the core of the present energy transition is the so-called shale revolution. It may be assumed that the newly elected Republican Congress led by a Republican President will continue the implementation of the national energy strategy "all of the above", which assumes the use and promotion of different sources of energy in the USA. In the near future, unlike during the rule of the Democratic Party and President Obama, we may expect greater support by the federal government for the American sector of fossil fuels, especially oil and gas, at the expense of reducing previous governmental subsidies and grants for the development of renewable energy sources. However, the future structure and speed of changes

[440] Barack Obama and Joe Biden: New Energy for America, http://energy.gov/sites/prod/files/edg/media/Obama_New_Energy_0804.pdf (accessed: 20.04.2017).

[441] Some candidates for the function of administrator of the Environmental Protection Agency (EPA) are strongly sceptical about the issues of climate change, such as Myron Ebell from the Competitive Enterprise Institute, Robert Grady, or Joe Aielllo. The function of the Secretary of Energy will probably be served by a current advisor to Donald Trump, billionaire Harold Hamm, being the president of an oil and natural gas exploration and production company Continental Resources.

in the US energy balance will not only depend on the energy policy of the federal government, but largely on the competitive power of different sources of energy. Access to cheap sources of energy will ensure America the possibility to reindustrialize its national economy using the advantages of technical advancement. The newly formed state administration of the USA is planning to shape both the improvement of American affluence and the competitive position of the American economy on that basis.

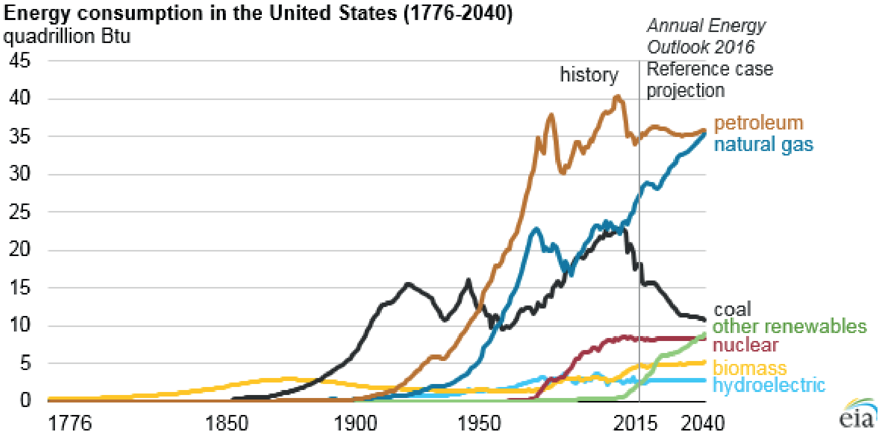
Energy balance structure

Analyzing the changes in the historical and future structure of the USA's energy basket, it is worth stressing that for more than 100 years, three sources of fossil fuels – oil, natural gas, and coal – have accounted for more than 80% of the energy consumed in the USA. In 2015, the share of fossil fuels in energy consumption exceeded 81.5%, and according to the statistics of the U.S. Energy Information Agency[442], their share is going to drop to 76.6% by 2040 (Chart 32). Consumption of energy produced from renewable sources oscillates around 10-15%, and the highest increases occur in solar and wind energy. Considerable decreases can be observed in the coal sector, where production is falling year by year: in 2015, coal extraction dropped by 13%, which was the greatest decrease in production of the resource in the US within the last 50 years.

Changes in the American energy market are mostly connected with technological advancement in each of the analyzed sources of energy. It is technological progress that has become the main factor determining the competitive position of different energy sources in the US. Commercial use of the technologies for hydraulic fracturing and horizontal drilling in the extraction of natural gas and oil has dominated the American energy market, lowering the competitive position and the development of other technologies like small, modular reactors in the sector of nuclear energy, clean coal technologies, or the cost competitiveness of producing solar panels or wind turbines.

[442] But it is worth remembering that EIA forecasts do not take into account either future changes in the directions of the country's governmental policy, or technological progress.

Chart 33. Energy consumption in the USA in the years 1776-2040 (in quadrillions of Btu)



Source: *Annual Energy Outlook 2016*, Monthly Energy Review, U.S. Energy Information Administration, https://www.eia.gov/todayinenergy/detail.php?id=26912 (accessed: 19.03.2017).

The United States is still one of the world's biggest producers of oil and natural gas. In 2015, oil production exceeded the record level of 9.4 million barrels a day, and more than 90% of the extra production came from the exploitation of shale rocks. It source was the enormous deposits of unconventional gas from formations in the north-eastern (Marcellus), north (Bakken), middle (Woodford, Fayetteville) and southern (Barnett, Eagle Ford) part of the country. Now, more than 65% of the oil consumed in the US comes from domestic production.

As for natural gas, the data of EIA suggests that the United States, by continuing its current consumption of 650-700 bcm, may ensure the supply of natural gas from domestic sources for 25 to 80 years. EIA forecasts that the extraction of natural gas from conventional and unconventional sources will grow from approx. 700 bcm in 2011 to over 900 bcm in 2040. Nearly all the forecast growth in national gas production is connected with the development of the shale gas sector (increasing from 220 bcm in 2011 to 470 bcm, respectively). The year 2015 proved to be record-breaking in terms of natural gas production, as its extraction amounted to 767 bcm (by comparison Russia produced 635 bcm). As a result, within less than a decade, the United States did not only solve the serious problem of its growing demand for imported natural gas, but also faced an opportunity to export the resource to foreign markets.

Thus, the shale revolution and relatively high growth of production of renewable energy sources, connected with the unprecedented scale and speed of technological advancement, show that the direction of energy transition of the American economy based on the development of technologically guaranteeing the competitiveness of the country's resources will ensure a varied structure of the USA's energy basket in the nearest decades. A big question is the real potential for developing technology in the American nuclear energy and coal sectors, ensuring competitiveness on the domestic market. It seems certain that a long-term effect of gas production from unconventional sources in the USA is the gradual departure from the use of coal in energy production (this phenomenon is mostly observed in the south-eastern part of the USA). It also has an indirect impact on American energy and climate policy and the potential possibilities for reducing CO_2 emission.

Energy efficiency[443]

Doubtless, recently, activities in the area of climate policy have become a new element of the USA's energy policy, including economic issues, defense, and the very energy security. The risk of climate change is nowadays one of the biggest threats to the security of the US as defined in the National Security Strategy.[444] In the case of the US, the

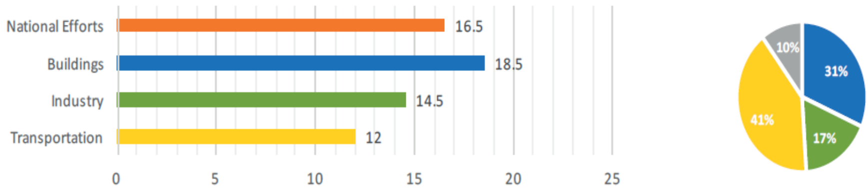
[443] The DOE emphasizes that the American energy sector (2.6 million miles of pipelines, 414 natural gas storage facilities, 330 ports and oil refineries, and over 140 thousand miles of railroad transporting oil, gas and coal) is still one of "the most developed and effective" energy sectors in the world. It also points out, using the example of gas infrastructure, that most investments were in the 1950s and 1960s (23% and 24%, respectively; only about 9% new gas pipelines were built in the latest decade). Currently the United States supplies approximately 3.875 terawatt hours of electricity to more than 159 million customers, with the use of 7 thousand power plants and 19 thousand individual generators of electricity.

[444] The US Department of Defense has appointed within its organizational structure a special climate change working group. In October 2013, Pentagon published the first report analyzing the impact of climate change on the security of the USA. The Department of Defense has also announced a new strategy concerning the Arctic, in which climate change is defined as one of the main threats to the area. An example of activities of the American army is the roadmap for US marines concerning

improvement of energy efficiency aimed at reducing the level of GHG emissions is one of the key elements of the country's energy transition.

This year in June, the American Council for an Energy-Efficient Economy (ACEE) analyzed the energy efficiency of the world's 16 biggest economies, which account for more than 70% of global energy consumption.[445]

Chart 34. Energy efficiency of the US economy (on a scale from 0 to 25 points)



Source: *The 2016 International Energy Efficiency Scorecard*, The American Council for an Energy-Efficient Economy (ACEE), http://aceee.org/portal/national-policy/international-scorecard.

The analysis included a number of different factors, such as programmes for reducing energy consumption, standards of fuel consumption, or standards of energy efficiency for devices. Although the USA improved its ranking position from 13 in 2014 to 8 in 2016 (Chart 34), energy efficiency in the American economy is still relatively low. It primarily refers to areas such as construction law, the level of efficiency of devices, or standards of fuel consumption and fume emissions for cars and trucks.

This year in April, the White House published at the request of the Presidenta Quadrennial Energy Review (QER) prepared by the experts of the American Department of Energy (DOE). The aim of QER was to identify areas in the American energy sector that needed extra investment, and to work out specific activities and recommendations to streamline its functioning by 2030. The DOE[446] pointed out in the

climate change, which points to climate change as a potential factor that may cause armed conflicts in the world.

[445] http://aceee.org/portal/national-policy/international-scorecard (accessed: 19.03.2017).

[446] The US Department of Energy is going to allocate 70 million dollars to improving the energy efficiency of production processes alone.

report that by 2030, in order to improve the energy efficiency of the American economy, the United States would have to invest more than USD 1.5 trillion in modernizing and developing the American energy sector, including over 900 billion in distribution. One key element of building a new energy system in the US will be the modernization and extension of the natural gas transmission infrastructure. The costs of investment estimated for the years 2015-2030 will be approx. USD 2.6-3.5 billion a year (depending on future demand). Thus, the US on the one hand intends to increase the extraction and share of natural gas at the expense of hard coal, and on the other hand to maintain the dynamic growth of energy production from renewable sources. But is this strategy a guarantee for improving the energy efficiency of the country?

According to the International Energy Agency (IEA), the higher extraction of shale gas, which is increasingly replacing coal as an energy resource in the US, has led to the greatest decrease in CO_2 emission. The Agency's data shows that annual emissions of CO_2 in the US have fallen within the last five years by 450 million tons; this is the greatest drop in emissions observed in all countries surveyed by the IEA. Fatih Birol, IEA chief economist, attributed this fall to improvements in fuel efficiency in the transport sector and a "major shift" from coal to gas in the power sector. "This is a success story based on a combination of policy and technology – policy driving greater efficiency and technology making shale gas production viable," Mr Birol told the Financial Times.

Economists Travor Houser and Shashank Mohan from the Rhodium Group, however, are of a different opinion. Promoting the book *Fueling Up: The Economic Implications of America's Oil and Gas Boom* published in January 2016, they explain that the benefits of transition to a cheap energy resource will eventually increase the demand from households, the transport sector, and industry. This, in turn, will mean that by 2035, the effects of reducing GHG emissions as a result of the transition to natural gas will not be very significant, i.e., from 5.5 billion tons a year in 2013 to 5.4 billion in 2035. In their opinion, if there had been no "shale revolution", and thus the price of natural gas remained relatively high, in 2035 coal, natural gas, nuclear energy, and renewable energy sources would maintain a similar, approx. 25%, share in the energy mix. The authors calculate that the shale revolution will cause a 60% share of natural gas in the American energy basket in 2035 (in addition, the share of coal will dwindle from 44% to 7%).

Competition on the global energy market

The growing domestic production of energy resources improves the security of access to energy, but on the other hand, it dramatically changes the global balance of power in the oil and natural gas trade. In terms of analyzing the direction and further speed of energy transition in the US, changes on the global energy market are currently the greatest challenge to the United States.

It seems, then, that the technological revolution in American energy irreversibly changes the global energy market. Technological advancement has not only occured in the area of extracting energy resources and producing energy from renewable sources, but also on the markets of energy sellers and customers. It is a chain of changes whose aim is to totally modernize the way of using energy. Hence, it is a whole process of technological changes, where energy security will not only require access to energy resources but also their effective use, at the same time meeting the challenges of reducing CO_2 emissions. In this context, fossil fuels will maintain priority importance in the US. It is on the global market of natural gas and oil the greatest changes are occurring at the moment, involving the fight for a share in the global energy market.

Even 10 years ago, the United States faced the challenge of the lack of a sufficient amount of natural gas and a growing dependence on the import of oil, as well as a considerable decrease in domestic production of those resources. In 1999, the EIA forecast some growth in the import of natural gas to the US by 12.9% before 2020. The situation appeared so serious that the American government took decisive action to ensure the appropriate supply of gas. One of them was support for the private sector in the construction of terminals importing LNG. In the years 2000-2005, American energy companies built 5 regasification terminals, greatly increasing the capacity of the units.[447]

[447] At the moment, there are 12 terminals in the USA with total import capacity of 396 million m^3 a day (i.e., about 141 bcm a year).

In 2005, the situation changed dramatically. Thanks to the use of hydraulic fracturing technology on an industrial scale, the American natural gas sector experienced a historical revolution. Its source was the enormous deposits of unconventional gas from formations in the north-eastern (Marcellus), north (Bakken), middle (Woodford, Fayetteville) and southern (Barnett, Eagle Ford) part of the country. As a result, within less than a decade, the United States not only solved the serious problem of growing demand for imported natural gas, but also faced an opportunity to export the resource to foreign markets.

So far, the export of gas from the US has not been significant and has been limited to transmission through gas pipelines to Canada and Mexico (95% of the export in 2011; between 1999 and 2011, the level of export grew 11-fold). In 1969, with the construction of the export terminal Kenai LNG in Nikiski in Alaska, the United States transmitted a small amount of LNG to Japan. Not so long ago, there was a public debate in the US concerning the effects of launching natural gas export from the country. It involved representatives of the private sector and government administration and research and development circles. On one side, the existing strong lobby of energy companies demanded that the Department of Energy issue more permits for the export of LNG from the US. Their main argument was the fear that low prices of natural gas on the American market would block further research and extraction of shale gas in the US. Another argument was that the export of LNG would accelerate development of the American gas sector, improve the country's position on the global energy market, and ensure extra revenue in the budget. Opponents of launching LNG exports pointed out that the relatively low prices of natural gas on the American market ensured the US economy a global competitive advantage, and thus its stable development and new jobs.

Now we know that the United States is simplifying the process of issuing government licenses for gas export, and the federal government strongly supports American companies in their attempts to conclude commercial agreements. It must be emphasized, yet, that the scale of future economic benefits for the US will be the product of: (1) the possibility of maintaining high production of shale gas at a relatively low price; (2) dynamic growth of global demand for natural gas, and (3) limited production capacity of gas exporters from other regions. The first American LNG load for a foreign recipient left the Sabine Pass terminal on February 24, this year. Next year, the Cove Point terminal in Maryland is going to be launched. In the years 2018-2019, another four installations should be launched. All of them will be located in the Gulf of Mexico (Table 8).

Table 8. List of selected applications submitted to the Department of Energy concerning LNG export

Company	Quantity (bcf/day)
Sabine Pass Liquefaction	2.2
Freeport LNG Expansion	1.4
Lake Charles Exports	2.0
Carib Energy	0.04
Dominion Cove Point LNG	1.0
Jordan Cove Energy Project	2.0
Cameron LNG	1.7
Freeport LNG Expansion	1.4
Gulf Coast LNG Export	2.8
Cambridge Energy	0.27
Gulf LNG Liquefaction	1.5
LNG Development Company	1.25
SB Power Solutions Inc.	0.07
Southern LNG Company	0.5
Excelerate Liquefaction Solutions I	1.38
Golden Pass Products	2.6
Cheniere Marketing	2.1
Main Pass Energy Hub	3.22
Total:	45.3

Source: U.S. Department of Energy

The rapid growth of the supply of gas on the global market combined with decreasing demand in Asia has led to increasing competition between LNG suppliers. The growing supply of LNG may, however, become a serious challenge to traditional suppliers such as Russia. Gazprom is becoming more and more flexible nowadays: it is increasing its engagement in European markets, and adapting to the rules of price competition. The conditions for commercial agreements being signed for the purchase of LNG are also changing with the growing role of spot transactions and short-term agreements.

In the case of oil, the years 2014-2015 brought the unique phenomenon of a three-fold drop in the price of oil within just 17 months. The main factor leading to that was the decrease in demand for the resource resulting from the economic crisis. Another was the doubled extraction of oil in the US. In 2008, the US produced 4.5 million barrels of oil a day, and in 2016 the extraction amounted to 8.84 million barrels of oil a day. The overproduction was mostly caused by extracting oil from the deposits of shale rocks. It aroused national debate on the potential effects of abolishing the ban on export of the resource from the USA, applicable for more than 40 years. Finally, on December 18, 2015, the Congress decided, by virtue of an act setting out budgetary expenses for 2016, to abolish the ban, thus releasing the possibility of export of the resource and enlivening the competition in areas so far monopolized by the group of resource producers. The reluctance to reduce the production of oil, especially by OPEC member states, combined with the US reducing its import, have caused the instability and low prices of oil recently.

Within a short period of time, due to the currently persistent low prices of oil and thus the decreasing price difference between Brent and WTI oil, the possibility of the US quickly entering the market as an exporter seems to be limited. Equalizing the benchmarks of American and European oil means that a large group of American refineries will return to importing heavy oil from the markets of Nigeria or Algeria, maintaining an advantage in the costs of transport of the resource.[448] It seems, however, that in the long run, starting to export American oil will strengthen the USA's global position and improve its competitiveness on the global energy market. As a result, export of American oil may in the future reduce the susceptibility to disturbances in supplies of countries importing from American producers, strengthening the negotiating position of the USA in political relationships with the main actors on the energy market (i.e., Russia, and the Middle East). With the present fight of exporters for maintain-

[448] In order to compensate for the losses of American refineries that were against abolishing the ban on oil export because of benefiting from the low price of the resource, Congress has granted them tax deductions, thanks to which they will be able to deduct more costs of transport of the resource, which will cost the budget approx. USD 1.8 billion within the next 10 years.

ing their market shares, the potential of extra supply of the resource from the USA on the global market may be the factor preventing the increase in oil prices in the following years. The winners in this scenario will be great importers such as India, China, Japan, or many developing countries. Low prices of oil will foster economic growth and lead to a reduction in the prices of basic products. On the other hand, there will be the fear that the lack of market reasons for the growth of oil prices in the near future may initiate even seismic changes in the global balance of power, especially including the growth of crime and fear of insolvency of many former export powers such as Russia, Venezuela, Algeria, or Nigeria.

So natural gas and oil, which even 10 years ago contributed the most to the growing commercial deficit of the USA, weakening its position on the global market, now are the source of the greatest potential in the USA's geopolitical fight on the international arena. One expression of the growing importance of the energy sector in US foreign policy was appointing in 2011 as part of the Department of State a separate Bureau for Energy Resources, today made up of over 70 specialists. The goals of activity of the new bureau are to solve global energy conflicts, to fight "energy poverty", and to promote energy transition on the global market. Another task of the bureau is to lobby American diplomacy to include domestic companies in energy investments all over the world.

Planes of competitive advantages / new branches of the economy

Energy transition in the US caused by the release of cheap resources of natural gas and oil has significantly improved the attractiveness of the American economy, especially industrial producers. In combination with the power of creating innovations, protecting intellectual property, and developing the "made in America" brand, the American economy is experiencing an unexpected increase of interest from foreign companies and domestic business in investment in the US. According to IEA data, the US currently has the lowest cost for a megawatt of all the countries that provide data on energy production. Besides, the prices of natural gas and diesel oil will remain relatively low. As a result, companies from industrial sectors (e.g., German BASF, Canadian Methanex Corp, Austrian Voestalpine, or Dutch Royal Dutch Shell) are choosing to move their production to the United States. As estimated by the American Chemistry Council, until 2020, over USD 70 billion of new investment will take place in the USA in the chemical sector alone. In its report of 2012, PwC points out that employment in this sector will grow from the current 2.1 million to 3.9 million jobs by 2025. Energy transition involves dynamic growth of employment and production also in other energy-intensive sectors, such as the production of fertilizers, synthetic resins, iron, or steel. The energy sector itself is becoming an important source of economic development and new jobs. The U.S. National Association of Manufacturers estimates that the extraction of natural gas and oil from shale rocks will cause an increase in employment from current 900 thousand to 2 million new jobs in 2035.[449]

Energy security

Energy security of the United States has continuously affected the general security of the country for many years. Although the US has the world's largest stocks of energy resources (total documented resources of coal, oil, and natural gas are 973 billion barrels of oil equivalent)[450], at the same time it imports nearly 10 million barrels of oil daily, thus ensuring the functioning of a global oil market financed with American dollars and controlled by the USA. Therefore, despite its "energy independence" caused by the "shale revolution", it still has some obligations towards its previous suppliers, mainly those from the Persian Gulf. For the strategic role of the US, it is the crucial area of control of global fossil fuels resources, currently being sent to the economically developing region of Asia. Thus, reduced dependence of the US on oil from Arab countries is causing new opportunities to "manage" the balance of power in the region.

A practical aspect of the US becoming independent from import of

[449] *IHS released America's New Energy Future: The Unconventional Oil and Gas Revolution and the US Economy*, October 2012.

[450] The others are: Russia – 955 billion barrels, China – 480 billion barrels, Iran – 291 barrels.

energy resources is the reduction in oil prices on global markets, whose effects are geopolitical. Actually, considerable reduction of income from trade in oil in Arab countries may cause a further expansion of Muslim fundamentalism. The other energy power, Russia, must face the challenge of budgetary imbalance and changes on the demand side. China is quickly increasing its presence on the energy market, at the moment being the biggest oil importer in the world. China is currently most dependent on oil supplies from the Middle East: almost 15 million barrels a day (the USA imports around 2 million of barrels, and Europe, almost 3 million barrels).

In addition, the security of the US is largely dependent on the American military stationed both in the country's territory and more than 63 bases located in countries all over the world. The American military is the world's biggest single consumer of energy. In 2015, it spent nearly USD 20 billion, consuming more than 90 million barrels of oil, 60% of which was imported.

A new element of US security policy, applying to economic, defense, and energy security issues, is climate policy. One of the most measurable successes of American diplomacy in recent times, certainly, is the climate agreement with China, setting GHG emission limits, and the global climate agreement in Paris. Future engagement of the USA in global activities aimed at climate change lies in the hands of the developing new administration of president Trump, who has so far expressed scepticism concerning the need for further US leadership in this matter. This is manifested in his appointment of former Texas governor Rick Perry – a heated denier of climate change – as Secretary of Energy.

Conclusion

Energy transition in the US, moving towards growing extraction of natural gas and oil, has dramatically changed the position of the American energy sector recently, making the country one of the key actors in the global energy sector, competing with such powers as Russia or Saudi Arabia.

Thus, the United States is changing its status on the global energy market completely, from the role of the biggest importer of energy resources to the role of energy exporter. The achieved independence in the energy sector will translate into the direction of US international policy.

The success of energy transition has also become the source of hundreds of thousands of new jobs, not only necessary for the construction of pipelines, railroad systems, drilling machines, and equipment, but also in other energy-intensive sectors such as the chemical, metal, machinery, metallurgic, glass, or even textile industries. Access to cheap shale gas and the low price of energy also fosters export and is attract more and more foreign investors to the USA.

The important role of the federal government in setting the direction of US energy transition means that the change of power and the election of D. Trump as President will cause an adjustment in the assumptions of the vision of US energy transition. However, it is not only deregulation in the fossil fuels sectors, but predominantly the future role of the United States in the fight against the negative effects of climate change. The current administration has taken the US out of the Paris climate agreement. The President has signed numerous directives eliminating environmental standards and requirements.[451] The budgets of government agencies that carry out climate policy are being slashed (e.g., the President's proposal to reduce the budget of EPA for 2018 by 1/3, to USD 5.6 billion). The key environmental reform by B. Obama, the so-called *Clean Power Plan*, limiting GHG emissions in different states, has been reviewed.[452] And the positions in key environmental institutions are now manned by heated sceptics of climate change.

[451] On August 15, 2017, the President signed the directive *Executive Order on Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure*, which cancelled the environmental standards introduced in 2015 by President Barack Obama (*Executive Order 13690*), which imposed restrictive environmental requirements on infrastructure projects. President Trump's directive establishes the limit of 90 days as the maximum period for issuing decisions for the implementation of infrastructure projects.

[452] President Trump's directive *The Energy Independence Executive Order* of March 28, 2017.

Chapter 16

Energy transition in Denmark

Yingkui YANG[453], Jingzheng REN[454]

Introduction

Denmark is one of the world pioneers in wind energy technology. Wind supplies about 40% of the electricity in Denmark today. Denmark is also a pioneer in the green energy system transition (in Danish *grøn omstilling*) such as widespread use of district heating and encouraging energy efficiency codes in buildings, etc. Over the past decades, the proportion of fossil fuel energy production has declined dramatically, but the share of renewable energy has increased considerably, as seen in Chart 35. Wind power was given the highest priority in promoting renewable energy sources. From the mid-70s to the mid-90s, Denmark was endowed with a number of strategic efforts for promoting wind power.[455] The rationales for focusing on wind power are: (1) Denmark's long tradition of exploiting wind power, and (2) its limited energy resource base. The national energy policy for supporting wind energy is a basket of a number of policies that are concerned with securing energy supply and protecting the environment. This basket is based on three key pillars: (1) research and technologically oriented support, (2) market oriented support, and (3) regulation

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[455] For detail, please refer to Meyer, N. (2004). Renewable energy policy in Denmark. *Energy for Sustainable Development, 8* (1), pp. 25-35.

oriented support.[456] Each support pillar contains a number of instruments. For instance, the market oriented support consists of subsidies to renewable energy technology producers and also to investors; green certificates, and fees for other alternative technologies, etc. The regulation oriented support pillar consists of requirements for physical plants and conditions for connecting to the grid. Indeed, the basket embraces all six types of energy policy approaches.[457] The advantage of such a basket of policy is that every single policy can complement each other and generate a synergic effect in terms of effectiveness to achieve environmental targets, economic efficiency, administrative feasibility, and political acceptability. The key disadvantage is the heavy financial cost. In fact, approximately two-thirds of electric bills paid by Danish consumers are different forms of taxes such as a CO_2 tax, value added taxes, etc. Nonetheless, Danish energy policymakers have established a successful feed-in model for stimulating the expansion of wind power. Under this model, Danish utilities were required to buy wind power at 85% (at 1992 levels) of the electricity retail price. Meanwhile, a tax reimbursement was paid to the producers to stimulate environmentally friendly production.[458] Table 9 presents the historical feed-in tariff. The high level of feed-in tariff makes it highly profitable to set up new wind turbines, reflecting a rapid increase in wind power share. Combining with the increasing cost effectiveness of wind power, the wind industry has become more and more competitive.[459] Today, Denmark is the most wind intensive country in the world, meaning that Denmark has the highest rate per capita of wind installations. The share of wind power production in 2014 was over 20 times that of 1990, see Chart 35.

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[456] K. Skytte, S.G. Jensen, p/ E. Morthorts, & O. J. Olsen, *Støtte til vedvarende energi? (Support for renewable energy?).* København/Copenhagen, Denmark: Jurist- og Økonomforundets Forlag/The Danish Association of Lawyers and Economists Press 2014.

[457] M. Jaccard, *Sustainable Fossil Fuel: the unusual suspect in the quest for clean and enduring energy.* Cambridge, U.K.: Cambridge University Press 2005.

[458] N. Meyer, *Renewable energy policy in Denmark*, "Energy for Sustainable Development" 2004, 8 (1), 25-35.

[459] R. Redlinger, & P. M. Andersen, *Report on New and Renewable Sources of Energy, Wind Energy, for the UN Committee on New and Renewable Sources of Energy and On Energy for Development.* United Nations, Report of the secretary General 1998.

Table 9. The feed-in tariff for wind turbines in Denmark

Time of installation	*Feed-in Tariff*
Before the end of 1999	about DKK0.60/kWh for specific full-load hours or until the turbine is 10 years old.
After 2001 and before 2003	about DKK 0.43/kWh for specific full-load hours or until the turbine is 10 years old; green certificate income failed to reach the date for liberalization.
After 2003	all new renewable installation will be through a free green certificate market; the market has a minimum price of DKK0.10/kWh and a maximum price of DKK 0.27/kWh.

Source: Meyer& Koefoed, 2003.[460]

However, wind is the most variable energy source, thus it is difficult to predict its output. Moreover, the grid has almost zero tolerance of outages and significant voltage or frequency fluctuations.[461] Due to the industrial structure in Denmark, domestic demand is rather limited. The large volume of wind power feed-in is problematic. To solve this issue, therefore, interconnection with its neighboring countries is needed.

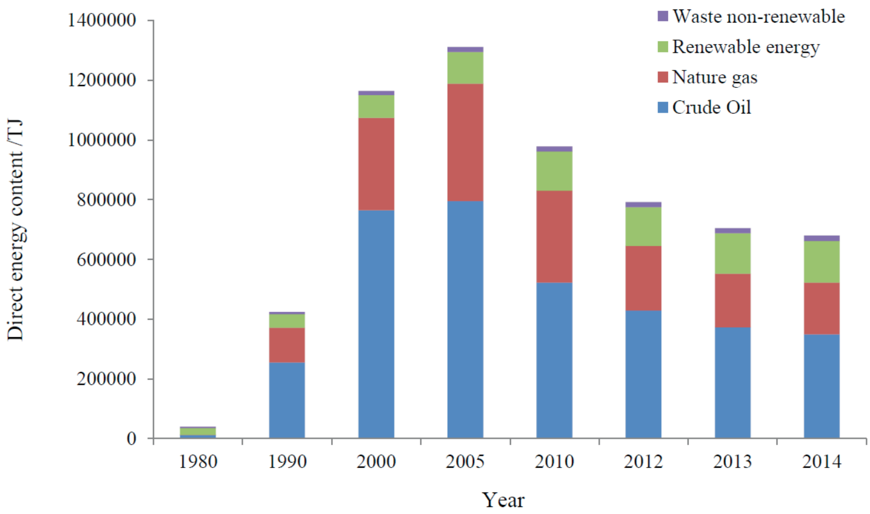
In addition to wind power, bio-mass also plays a significant role in renewable energy power production, shown in Chart 35. Indeed, biomass energy accounts for about half of the total renewable energy output. Renewable energy waste, wood waste, and firewood are the top three contributors of biomass energy generation, see Chart 36. The major pitfall of biomass energy generation is greenhouse gas emission. Although biomass can function as an alternative for coal- and gas-fueled power plants in order to achieve the goal of fossil fuel independence, the effect of greenhouse gas reduction, especially the emission of carbon dioxidize, is limited. Chart 37 presents CO_2 emissions from energy consumption across four sectors. The transport sector is the largest contributor of CO_2 emissions, accounting for approximately 60% of total CO_2 emissions from energy consumption. CO_2 emissions reached a peak in 2005 and afterwards began to fall slightly. CO_2 emissions have remained almost constant from 2012.

[460] N. I. Meyer, A. L. Koefoed, *Danish energy reform: policy implications for renewables*. "Energy Policy", 2003, 31(7), 597-607.

[461] B. Hively, J. Ferrare, *Understanding today's electricity business*. San Francisco, CA: Enerdynamics LLC, 2005.

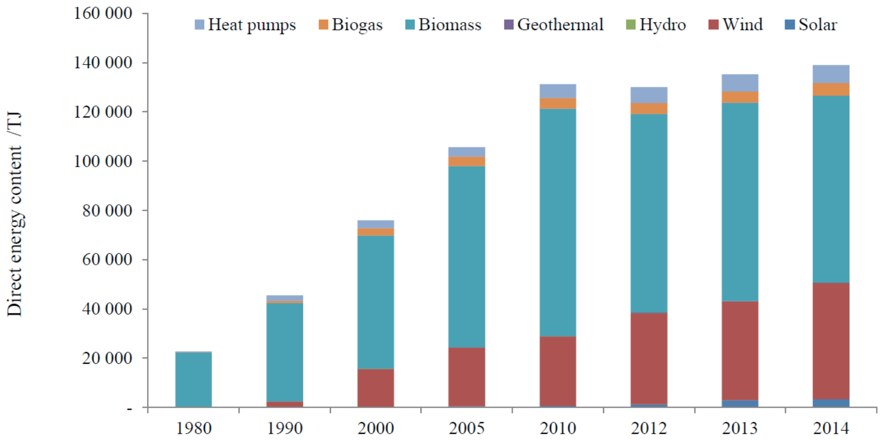
Commercial and industrial services and the household sectors are the two next largest contributors in terms of CO_2 emissions. Unlike the transport sector, CO_2 emissions in these sectors has fallen considerably over the past decades.

Chart 35. Development of energy production in Denmark



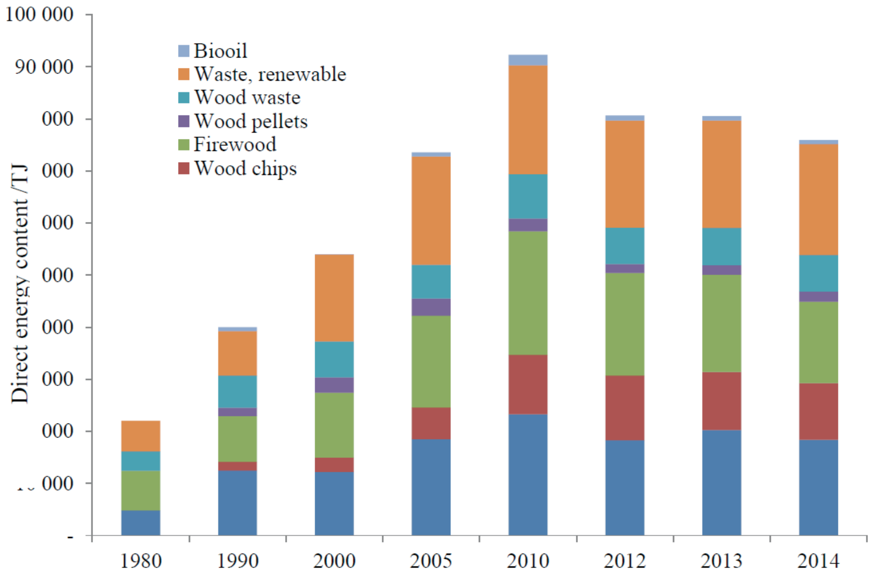
Source: Danish Energy Agency

Chart 36. Development of renewable production in Denmark



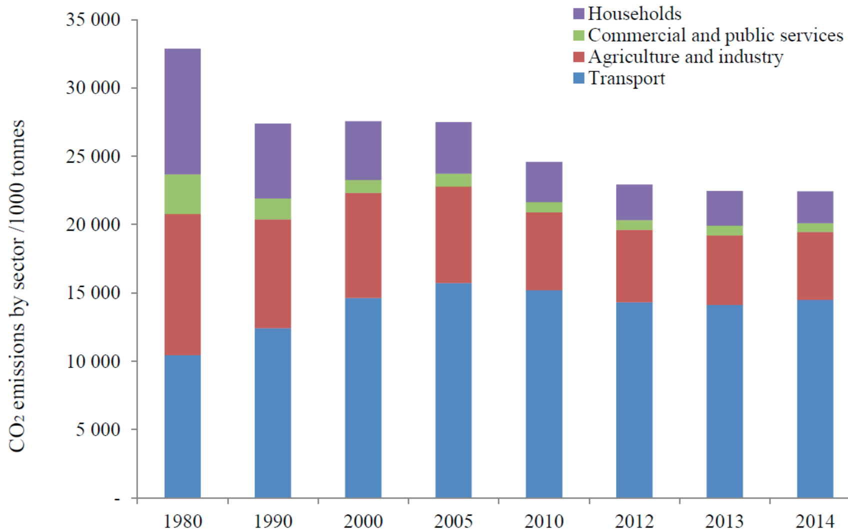
Source: Danish Energy Agency

Chart 37. Development of biomass energy in Denmark



Source: Danish Energy Agency

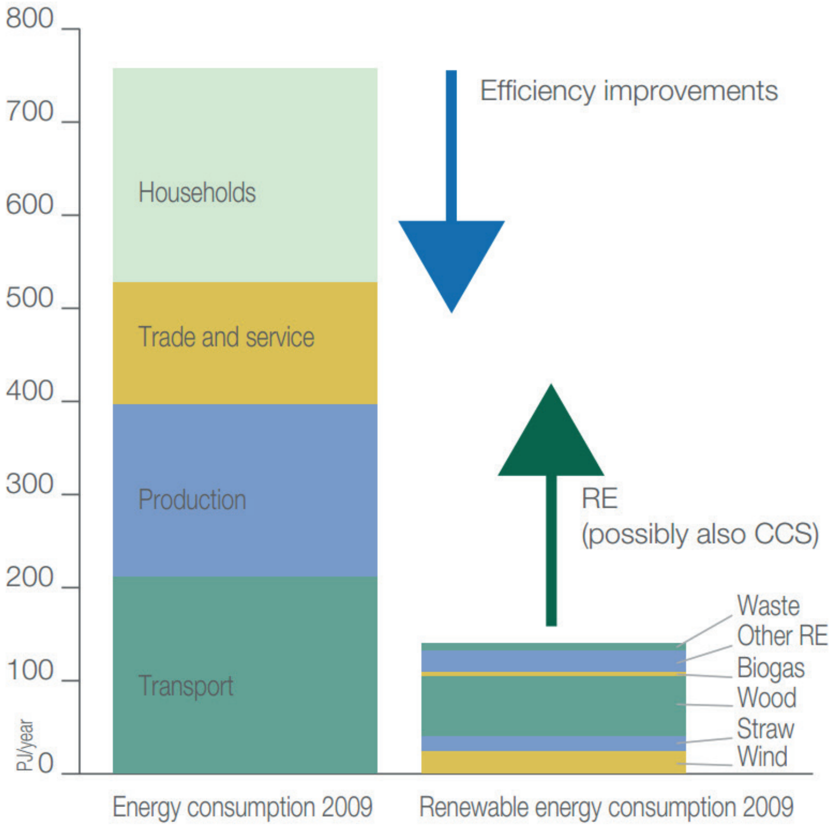
Chart 38. CO_2 emission of energy consumption by sector



Source: Danish Energy Agency

The long term goal is to become a fossil fuel independent nation by 2050.[462] Increasing the share of renewable energy supply plus possible carbon capture storage (CCS) and taking energy efficiency measures so as to minimize energy consumption across all sectors are the two primary tools for achieving the goal of being a fossil fuel independent nation, as shown in Figure 11.

Figure 11. The two pillars of the Danish energy transition: energy efficiency and increasing renewable energy (RE) according to Energy Strategy 2050.



Source: *Energy Strategy 2050 - from coal, oil and gas to green energy*, Danish Government, 2011.

[462] *Energy Strategy 2050 - from coal, oil and gas to green energy*, Danish Government, 2011.

According to Energy Strategy 2050, gross energy consumption in 2020 should be reduced by 4% as compared to the 2006 level[463], and net energy consumption in 2020 should be decreased by 12% as compare to the 2006 level.[464] The penetration of renewable energy differs across sectors.[465] For the electricity sector, half of the electricity consumption should come from wind energy in 2020. All coal-fired power plants should be phased out by 2030, and all electricity should come from renewable energy by 2035. For the heat sector, all oil boilers should be phased out by 2030. The entire heat sector should be powered by 100% renewable energy by 2035. For the transport sector, biofuels should be used in the transport sector by 10% by 2020 and 100% by 2050. Meanwhile, several milestones have been set by the government in order to achieve the goal of a fossil fuel independent nation by 2050, see Table 9. Furthermore, it is also expected that greenhouse gases should be reduced by 40% by 2020 in relation to 1990.

Table 10. Milestones for a fossil independent nation

Year	*Energy Policy Milestones*
2020.	50% of electricity consumption should come from wind energy by 50%
2030.	100% renewables in electricity and heat supply
2035.	all coal fired power plants and oil burners should be phased out by renewables
2050.	100% renewable energy supply across all sectors, including transport sector

Source: *Energy Strategy 2050 - from coal, oil and gas to green energy*, Danish Government, 2011.

This chapter provides an overview of the energy transition in Denmark. It describes how Denmark is going to modernize its structure

[463] *Aftale mellem regeringen (Socialdemokraterne, Det Radikale Venstre, Socialistisk Folkeparti) og Venstre, Dansk Folkeparti, Enhedslisten og Det Konservative Folkeparti om den danske energipolitik 2012-2020,* den. 22 marts 2012 (The Energy Agreement of 2012). Copenhagen: The Government of Denmark.

[464] *Aftale mellem regeringen (Socialdemokraterne, Det Radikale Venstre, Socialistisk Folkeparti) og Venstre, Dansk Folkeparti, Enhedslisten og Det Konservative Folkeparti om om strategi for solcelleanlæg og øvrige små vedvarende energi (VE)-anlæg*, den 15 november 2012 (Agreement on the Strategy for Solar PV of 2012). Copenhagen: The Government of Denmark.

[465] *Energy Strategy 2050..., op.cit.*

of energy balance and strengthen its energy efficiency using instruments resulting from energy transition. Moreover, it also discusses how Denmark is going to strengthen its competitiveness on the integrated European energy market through its energy transition. Finally, this chapter will also discuss how energy transition contributes to its energy security. The chapter is organized as follows. Section 8.3 provides the current status and future trend of energy balance structure in Denmark. Section 8.4 presents how Denmark used the energy efficiency instrument for energy transition. Section 8.5 presents how Denmark is going to strengthen its market competitiveness on the market through its energy transition. Section 8.6 describes its competitiveness in the power market. Finally, energy security issues are discussed.

Energy balance structure: current state and future scenarios

Cross-border interconnection

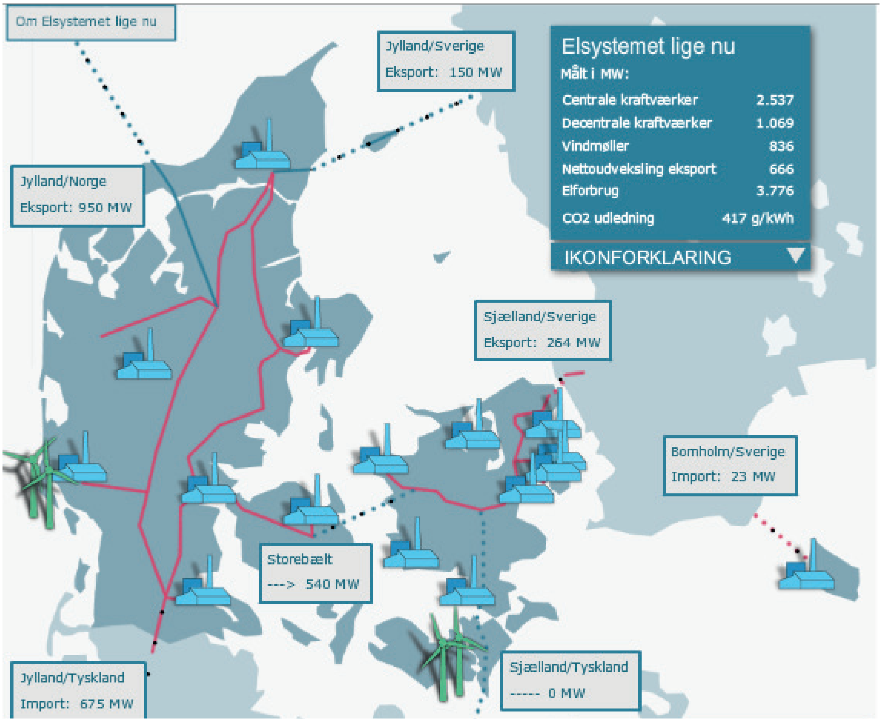
Denmark has one of the highest degrees of regional interconnection in the world. The Danish electricity market is part of the integrated Nordic electricity market. The wholesale market is the common Nordic market. On a voluntary basis, all electricity generators and traders are trading freely on the Nordic electricity exchange, Nord Pool. Nord Pool is Europe's leading electricity market and provides services across nine European countries. To become a wholesaler one does not need to own either generators or end-users/consumers. In the physical market at Nord Pool, electricity can either be traded on a spot market for the next 24 hours, namely Elspot, or on the forthcoming day after the day-ahead market, namely the Elbas.[466] Power grids from Norway, Sweden, Finland, and Demark are the major owners in the Nordpool spot market. The wholesale price is determined on the basis of the marginal production cost. The wholesale prices in Denmark fluctuate with market conditions both domestically and internationally (primarily its neighboring countries)[467], e.g., in case of a rainy season,

[466] *Nordic market report 2014 - Development in the Nordic electricity market*, NordREG, Helsinki 2014.

[467] *Lessons from Liberalised Electricity Markets, OECD/IEA, Paris, France(2005).*

electricity from the hydroelectric stations in Norway and Sweden is likely to be cheap, and in case of a windy season, electricity from wind farms in Denmark is likely to be cheap. Figure 11 illustrates real time cross-border electricity transmission in Denmark from Energinet.dk. As shown in Figure 12, western Denmark is synchronized with the power system in Norway, Sweden, and Germany while Eastern Denmark is synchronized with the Swedish power system. Thus, Denmark functions as a bridge for interconnection between the Scandinavian power systems and the German power system and, thereby, the continental European power system.

Figure 12. Cross-border Electricity Transmission in Denmark



Source: Energinet.dk

The total interconnection capacity from Denmark to its neighboring countries is about 6.4 GW, of which the interaction capacity from Demark to Sweden and Norway is 4072 MW and to Germany is 2380 MW. The total cross-border interconnection capacity is slightly higher than the peak demand of 6 GW in Denmark. Thus, the cross-border interconnection countries are important for power balancing because they allow Denmark to send power abroad on windy days and to import power in times of low wind.

Promoting flexible consumption

As the share of renewable energy, especially wind power, increases in energy production, the current energy system will face important challenges. Energy production will fluctuate more than currently. To achieve a balanced and yet sustainable energy supply will require significant changes in the structure of both the supply and the demand of energy. On the one hand energy producers will need to coordinate the interaction between different ways of producing electricity, such as wind power, natural gas, and thermal power, so as to minimize the emission of CO_2 and production costs. On the other hand, energy end-users will have to change their current energy behavior in order to synchronize their demand with the inherent fluctuations in the sustainable energy supply.

During the energy transition stage, rather than supply being expected to meet the growth and variation of energy demand over time, demand will need to be actively managed to fit the energy supply over time. Whereas renewable energy technology innovation is certainly important, technology alone will probably not be able to manage the demand side and change consumption habits to synchronize demand with the inherent variations in supply from a 100% renewable energy system in which wind and solar energy are important factors.[468] Thus, the transition to a sustainable society will have to involve consumers, as well as insight into their consumption behavior and lifestyle and also into how changes in consumption behavior and habits such as daily routines with respect to energy can be triggered.[469]

By motivating flexible energy consumption, consumers can contribute to optimizing the operations of a 100% renewable energy system, particularly when the 100% renewable energy system contains a dominant share of wind power. This can eventually bring

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[468] S. G. Hauser, K. Crandall, *Chapter 1 - Smart Grid is a Lot More than Just "Technology",* P. S. Fereidoon (Ed.), Smart Grid, Boston: Academic Press, 2012, pp. 3-28.

[469] J. Axsen, J. TyreeHageman, A. Lentz, *Lifestyle practices and pro-environmental technology*, Ecological Economics, 2012, 82(0), pp. 64-74, C. P. Stern, *Individual and household interactions with energy systems: Toward integrated understanding*, Energy Research & Social Science, 2014, 1(0), pp. 41-48.

important economic and environmental benefits to the society. In line with current environmental and energy research we will focus on the theories of consumer behavior that place emphasis on 'interpersonal influence', and draw from multiple perspectives (i.e., diffusion, conformity, dissemination, translation, and reflexivity) on consumer behavior to develop a model of energy consumption habits.

To build a 100% renewable energy system, significant changes in the structure of both supply and demand of energy will be needed.[470] Rather than supply being expected to meet the growth and variation of energy demand over time, demand will need to be actively managed to fit the energy supply over time. Whereas renewable energy technology innovation is certainly important, technology alone will probably not be able to manage the demand side and change consumption habits to synchronize the demand with the inherent variations in supply from a 100% renewable energy system in which wind and solar energy will be important factors.[471] Although there is a paucity of energy research incorporating social science methodology and insights compared to energy research rooted in the technological sciences and economics[472], several studies clearly indicate the need for understanding consumer energy consumption habits, especially their daily routines of energy usage and lifestyle, what drives or triggers their consumption behavior, and the necessity for engaging consumers in energy technology innovations in order to be able to realize the potential of such projects.[473] Thus, research has shown that human behavior/responses to new energy improving technologies often offset the beneficial effects of the new technology, which is also known as the "rebound effect"[474].

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[470] P. F. Sioshansi, *Smart grid : integrating renewable, distributed & efficient energy*, Boston: Elsevier/Academic Press, Amsterdam 2012.

[471] S. G. Hauser, K. Crandall, *Chapter 1 - Smart Grid, op.cit.*

[472] J. Axsen, J. TyreeHageman, A. Lentz, *Lifestyle practices..., op.cit.,* pp. 64-74, B. K. Sovacool, *What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda*, Energy Research & Social Science, 2012, 1(0), pp. 1-29.

[473] F. Gangale, A. Mengolini, I. Onyeji, *Consumer engagement: An insight from smart grid projects in Europe,* Energy Policy, 2013, 60(0), pp. 621-628, P. C. Honebein, F. R. Cammarano, C. Boice, *Building a Social Roadmap for the Smart Grid,* The electricity journal, 2011, 24(4), pp. 78-85.

[474] G. H. P. Berkhout, C. J. Muskens, J. W. Velthuijsen, *Defining the rebound effect*, Energy Policy, 2000, 28(6–7), 425-432, M. Binswanger, *Technological progress*

Besides, even with detailed feedback information about an individual's energy consumption, actual energy savings can be very different from the expected savings.[475] Moreover, although most people seem to accept that climate change fundamentally will alter living conditions on earth unless the amount of CO_2 emissions is reduced drastically[476], most individuals also fail to react to this problem by switching to green energy, and/or by changing usage habits so as to reduce their energy consumption.[477] Since energy is a necessity and a low involvement good, it may be a great challenge to change energy behavior, which may become a non-technical barrier for achieving the national goal of being a fossil fuel independent nation.

The future energy structure: grid expansion

The current grid in Denmark has sufficient capability to accommodate the increasing share of wind power flow into the system.[478] Depending on the level of voltage of the transmission line, the grid network consists of three levels: 400-kilovolt transmission lines for connections between central power stations and interconnection with neighboring countries, 150-kilovolt regional transmission lines for west of the Big Belt, 132-kilovolt regional transmission lines for east of the Big Belt, and a 60-100 kilovolt line for distributing electricity from

and sustainable development: what about the rebound effect? Ecological Economics, 2001, 36(1), pp. 119-132, R. Brännlund, T. Ghalwash, J. Nordström, *Increased energy efficiency and the rebound effect: Effects on consumption and emissions*, Energy Economics, 2007, 29(1), pp. 1-17, H. Herring, R. Roy, *Technological innovation, energy efficient design and the rebound effect*, Technovation, 2007, 27(4), pp. 194-203.

[475] W. Abrahamse, L. Steg, C. Vlek, T. Rothengatter, *The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents*, Journal of Environmental Psychology, 2007, 27(4), pp. 265-276, K. Buchanan, R. Russo, B. Anderson, *Feeding back about eco-feedback: How do consumers use and respond to energy monitors?,* Energy Policy, 2014, 73(0), pp. 138-146.

[476] *Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, IPCC, 2014, *Privat engagement skal drive klimakampen videre*, Mandag Morgen, 2014, 36, pp. 4-5.

[477] *Ibidem.*

[478] S. Ropenus, H. Jacobsen, *A Snapshot of the Danish Energy Transition: Objectives, Markets, Grid, Support Schemes and Acceptance*, Agora Energiewende & DTU, 2015.

high voltage electricity to end-users.[479] Energinet.dk owns the transmission lines over 100 kilovolts. The planning of the grid in Denmark includes biannual grid development plan, the Kabelhadlingsplan, and the cross-sectoral system plan.[480] Energinet.dk publishes a plan for grid development every second year. Following the Energy Agreement from 2008, the entire grid lines of 132-150 kilovolts should be laid as underground cables completely by 2030, and the new 400 kilovolt lines should also be laid as underground cables.[481]

Energy efficiency

Improving energy efficiency is an important part of Danish energy policy. It is also a crucial element in the transition towards a fossil-fuel-independent society. According to its energy plan in 2050, final energy consumption (excluding consumption for non-energy purposes) should be reduced by 7.2% in 2020 compared with 2006.[482] Primary energy consumption should be reduced by 12.6% in 2020 compared with 2006. To ensure accomplishment of the goal of being a fossil-fuel-independent nation, the gird and distribution companies in Denmark (which includes about 70 electricity operators, 3 natural gas distributors, about 400 district heating companies, and 6 oil companies) have set a target of annual energy savings of 3% in energy end use excluding transport between 2015 and 2020.[483] Energy savings are supposed to be achieved through improved energy efficiency. Examples could be improved insulation of buildings, and replacing oil boiler heating systems with district heating or a heat pump.

Energy efficiency measures in Denmark

Energy efficiency is an important measurement for achieving the 2050 goal, see Figure 13. Denmark has a relatively high share of

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[479] *Ibidem.*

[480] *Ibidem.*

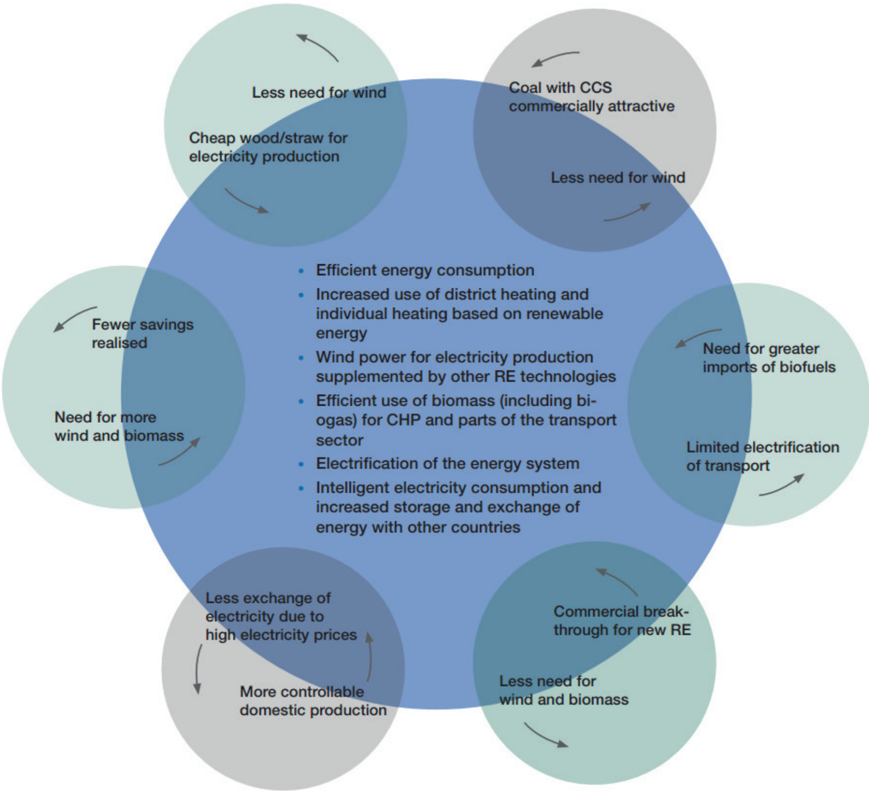
[481] *Ibidem.*

[482] *Aftale mellem regeringen (Socialdemokraterne, Det Radikale Venstre, Socialistisk Folkeparti) og Venstre, Dansk Folkeparti, Enhedslisten og Det Konservative Folkeparti om den danske energipolitik 2012-2020*, den. 22 marts 2012 (The Energy Agreement of 2012). Copenhagen: The Government of Denmark.

[483] *Ibidem.*

combined heat and power plants (CHPs), which brings on challenges for maintaining a high level of energy efficiency.[484] Energy efficiency measures consist of two major parts: energy efficiency obligations are assigned to energy companies, and requirements to the commercial and building sectors. In 2020, a decrease in net energy consumption of 12% as compared to 2006[485] is expected.

Figure 13. Measurements for achieving the goal of fossil fuel independent by 2050



Source: *Energy Strategy 2050 - from coal, oil and gas to green energy*, Danish Government, 2011.

[484] H. Lund, A. P. Østergaard, I. Stadler, *Towards 100% renewable energy systems*, Applied Energy, 2011, 88(2), pp. 419-421.

[485] *Energy Strategy 2050 - from coal, oil and gas to green energy*, Danish Government, 2011.

Competitiveness in the power market

The Danish electricity market is structured around generators, retailers (also known as "electricity suppliers"), wholesalers, distribution system operators, and system operators.[486] Energinet.dk has the primary task of regulating and controlling the electricity market. After the market liberalization, the supply function on both the generation and the retail sales side was removed from the earlier monopolies. Wholesalers and retailers acquire electricity from the generators and sell to each other and to the end-users. Electricity is delivered from generators to end-users and money flows from end-users back to generators. In the entire transaction process, electricity suppliers function as intermediaries who buy and sell electricity in the market. An important role for the electricity suppliers is to sell more green electricity in the energy transition, thereby pushing generators to build more renewable plants to increase the renewable capacity. The end-users can be divided into three segments: residential customers, commercial customers, and industrial customers.

Retail competition and product offerings

As of 2011, there are around 60 electricity retailers in the Danish market competing against one another, among which 33 are default suppliers and 10 in the electricity retailing market.[487] The retailers' terms of retail sales and prices are publicly available on www.elpristavlen.dk, a website for comparing all available electricity products and prices in Denmark. The wholesale price is the underlying price for retail market products.[488] Although the retail market is fully open to households, the majority of the electricity suppliers are actually regionalized or local monopolies with market shares of 94% in their region.[489] Because of this, these 33 default suppliers take up approximately 90-95% of the total market share.[490]

Price is the primary competitive factor in the retail market. The electricity price is a sum of (1) the electricity price paid to the electricity suppliers, (2) transportation related costs, (3) electricity taxes,

[486] www.energinet.dk

[487] *Nordic market report 2012*, NordREG, Helsinki 2012.

[488] *Ibidem.*

[489] *Konkurrencen på detailmarkedet for el (The competition in the electricity retail market)*, Konkurrencestyrelsen, Copenhagen 2009.

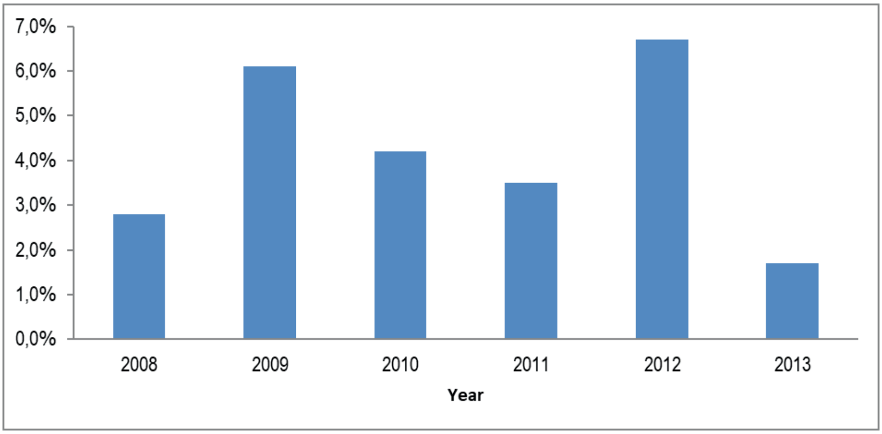
[490] *Ibidem.*

and (4) VAT (i.e., value-added tax, *moms* in Danish). About half of the total price is derived from fixed taxes, and the electricity price is only about one-fourth of the total price.

In addition to price, the environmental quality of the electricity is another important competitive factor. Products known as green electricity (or grøn strøm in Danish) have a variety of forms. Currently, only a few electricity suppliers are offering green electricity. Due to the nature of environmental-friendless nature, green electricity has a price premium.

Although the retail market is well-established, the supplier switching rate in Denmark remains surprisingly low, see Chart 39. Factors for the low switching rate can be explained by the small economic benefit from switching, psychological lock-in with the current supplier, and good relationship management from the supplier.[491]

Chart 39. Supplier switching in the deregulated electricity market in Denmark



Source: *Nordic market report 2012*, NordREG, Helsinki 2012, *Nordic market report 2014 - Development in the Nordic electricity market,* NordREG, Helsinki 2014.

Conclusion

Denmark is one of the first movers in implementing a renewable energy transition. The long-term national goal is to become a fossil-fu-

[491] Y. Yang, *Understanding household switching behavior in the retail electricity market*, Energy Policy, 2014, 69, pp. 406-414.

el-independent nation by 2050. This chapter presented an overview of the energy transition in Denmark from three main aspects: the energy balance structure, energy efficiency, and competitiveness in the power market. Due to its geographic location and historical energy experience, wind power is a very important role in the future energy mix. The intermittent wind power output will bring challenges on balancing the grid. Cross-border interconnection, increasing the share of renewable energy consumption, and promoting flexible energy competition are three important tools for utilizing the increasing share of wind power in the future. The Danish power market is quite competitive and well-established, but the switching rate for consumer remains at a very low level. There is a need for establishing a new pricing structure and market mechanism to encourage consumer involvement in their energy consumption.

Chapter 17

Energy transition in Italy

Andrea PRONTERA[492]

Italian transition and the National Energy Strategy

Italian energy transition began in the 1990s hand in hand with the parallel development of EU energy, environmental, and climate policy. During the 2000s several new policy instruments have been deployed in order to promote energy efficiency and renewable energy. Since 2009, according to the 20-20-20 EU targets, Italy is also committed to achieve 15.5 Mtoe of energy savings in annual final energy consumption between 2011 and 2020, a 17% share of renewable energy in final gross consumption, and reduced greenhouse gas emissions (GHG) by 18% compared with 2005. However, only in 2013 did the Italian government issue a new, comprehensive and forward-looking policy document approving a National Energy Strategy (the last national energy plan dated back to 1988).

The National Energy Strategy (NES) confirmed the Italian commitment to the progressive decarbonization of the economy and proposed different actions for achieving and exceeding all the EU targets for 2020.[493] In particular, with regard to the reduction of GHG emissions, a 21% lower level than in 2005 is provided, thus exceeding the previous EU objective of 18%. With regard to the development of renewable energy, according to the NES it is expected that Italy will reach, by 2020, 19-20% of gross final consumption, exceeding the 17% target set

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[493] *Italy's National Energy Strategy: For a more competitive and sustainable energy*, NES, Ministry of Economic Development, Rome 2013.

in the 2010 National Action Plan. Finally, with regard to energy efficiency – an area where the 20-20-20 targets are not binding – Italy intends to outdo the European targets of 20% compared to inertial consumption, with expected savings of up to 24% (equivalent to a reduction of about 20 Mtoe of primary energy compared to 2011).

Energy efficiency, in particular, is considered crucial by the NES to achieve decarbonization of the Italian economy. New targets for energy efficiency are put forward not only in the NES but also in the 2014 Italian Energy Efficiency Action Plan (NEEAP 2014). This document has updated the precedent plan issued in 2011 and better clarified the measure-by-measure and sector-by-sector contribution to achieve the global targets for 2020 set in the NES (table 11). It is worth noting, however, that mainly as a result of the economic crisis between 2005 and 2012, Italy has already exceeded by 58% the target for 2016 set in the Energy Efficiency Action Plan of 2011.[494]

Table 11. Energy efficiency targets and measures for 2020 (final and primary energy, Mtoe/year)

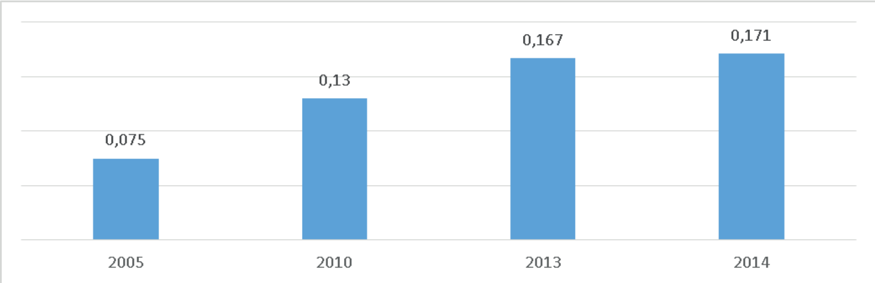
Sectors	Planned measures for 2011-2020					Final energy consumption	Primary
	Regulatory standard	Measures and investments for mobility	Thermal account	Tax deductions	White certificate	Expected savings by 2020	Expected savings by 2020
Residential	1.60		0.54	1.38	0.15	3.67	5.14
Services	0.20		0.93		0.10	1.23	1.72
Public authorities	0.10		0.43		0.04	0.57	0.80
Private	0.10		0.50		0.06	0.66	0.92
Industry					5.10	5.10	7.14
Transport	3.43	1.97			0.10	5.50	6.05
TOTAL	5.23	1.97	1.47	1.38	5.45	15.50	20.05

Source: *Italian Energy Efficiency Action Plan*, NEEAP, July 2014, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_italy.pdf (accessed: 7.10.2016).

[494] *Italian Energy Efficiency Action Plan*, NEEAP, July 2011, *European energy market reform. Country profile: Italy*, Deloitte, available at https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Energy-and-Resources/gx-er-market-reform-italy.pdf (accessed: 3.10 2016).

With regard to renewable energy, according to the NES, about 21.4 Mtoe of final energy consumption should come from renewables in 2020, compared to 17 Mtoe in 2012, 11 Mtoe in 2008 and 8 Mtoe in 2004: this means that an additional 5.3 Mtoe will still be needed by 2020.[495] However, looking at recent trends this target seems to be reachable: in 2014 Italy had already surpassed the 17% EU target (Chart 39).

Chart 40. Percentage of renewables in Italian final energy consumption



Source: *Italian Energy Efficiency Action Plan*, NEEAP, July 2014, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_italy.pdf (accessed: 7.10.2016).

This important result has been possible especially thanks to the significant progress made in the electricity sector, where Italian governments have enacted several policy instruments and granted very generous financial support (above the EU average for Renewable energy sources for electricity support schemes, or RES-E support schemes).

Finally, with regard to the CO2 emissions targets – according to the 2020 EU requirements – Italy is committed to an 18% reduction in global GHG emissions compared to 2005 (a 21% reduction in the sectors covered by the Emission Trading System, ETS, and a 13% reductions in non-ETS sectors). However, also in this case, Italy has achieved and surpassed its targets before the 2020 schedule. By 2012 Italy had achieved 130% of its target for non-ETS sectors and 109% of its target for global GHG emissions.[496] This important achievement is the result both of the measures to promote energy efficiency and

[495] *European energy market reform..., op.cit.*

[496] *Ibidem.*

renewables and the effects of the economic crisis. As we saw, against this background, the 2013 NES set more ambitious targets with a 21% decrease in global GHG emissions (for ETS and non-ETS sectors) by 2020 compared to 2005.

As a result of the above-mentioned measures (and of other measures included in the NES) an important transformation of the Italian energy mix by 2020 (table 12.) is expected, with a prominent role, especially in the electricity sector, for renewables and natural gas, which is expected to be a crucial source in the Italian energy transition (also by virtue of its relative lower environmental impact in respect to oil and coal) (table 13.). This trend, on the other hand, confirms the special role that natural gas has traditionally played in Italy since the 1980s, when this source became the 'Italian way' to partially replace oil.[497] Italy, in this regard, is a peculiar case in Europe because in comparison to the other major European consumers it has no nuclear energy (two referendum held in 1986 and 2011 twice halted the development of a nuclear programme in the country) and a very low contribution of coal in its energy mix.

Table 12. Italian total gross primary energy consumption (Tot, in Mtoe) and source mix (%): 2010 and 2020

	2010	2020
Electricity imports	2%	1%
Coal	9%	8-9%
Renewables	11%	23%
Oil	37%	30-32%
Gas	41%	35-37%
Tot (Mtoe)	165	155-160

Source: *Italy's National Energy Strategy: For a more competitive and sustainable energy*, Ministry of Economic Development, NES, March 2013, Rome.

In what follows, the main policy instruments and achievements in the area of energy efficiency and renewables are illustrated. In particular, with regard to renewables the focus will be mainly on the

[497] L. De Paoli, *Italian Energy Policy: From Planning to an (Imperfect) Market*, in F. McGowan, (ed.), *European Energy Policies in a Changing Environment*, Heidelberg: Physica-Verlag, 1996, pp. 88-129.

measures adopted in the electricity sector, where dramatic changes have recently occurred. Finally, in the last section, the chapter illustrates the main implications of the energy transition for Italian competitiveness, growth, and energy security.

Table 13. Source mix of gross electricity consumption: a shift to a gas-renewable mix

	2010	2020
Oil	3%	2%
Imports	13%	7-10%
Coal	16%	15-16%
Renewables	22%	35-38%
Gas	44%	35-40%
Other	1%	1%

Source: *Italy's National Energy Strategy: For a more competitive and sustainable energy*, Ministry of Economic Development, NES, March 2013, Rome.

Promoting energy efficiency: main instruments and achievements

In line with EU policy, Italy has enacted several policy instruments to meet its energy efficiency targets. The main horizontal measures implemented in recent years are[498]:

— Transposition of Directive 2002/91/EC and implementation of Legislative Decree No 192/05 with regard to the requirement of minimum energy performance standards for buildings.
— Granting of tax deductions ('fiscal deduction 55%') for improvements in the energy efficiency of existing buildings.
— Energy efficiency certificates ('White Certificate' scheme).
— Measures to encourage an environmentally sustainable renewal of the fleet of cars and commercial vehicles up to 3.5 tons and implementation of the EC Regulation No 443/2009.

Table 14 below highlights the contribution expected by each instrument in different sectors and the first important results already

[498] *Italian Energy Efficiency Action Plan*, NEEAP, July 2011, *Italian Energy Efficiency Action Plan*, NEEAP, July 2014, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_italy.pdf (accessed: 7.10.2016).

achieved. In particular, by 2011, Italy had already reached more than 20% of the final 2020 targets in the residential and industrial sectors, while minor results have been achieved in transport and services (Table 14.).

Table 14. Annual energy savings achieved in the period 2011-12 and expected by 2020 under the NES (final energy, Mtoe/y)

Sectors	Leg. Decree 192/05	White Certificates	Fiscal deductions (55%)	Incentives (pursuant to 443/2009)	Saving achieved 2011-12	Expected savings by 2020	Targets met (%)
Residential	0.62	0.14	0.21	-	0.96	3.67	26.2%
Services	0.02	0.03	0.01	-	0.05	1.23	4.1%
Industry	0.05	1.04	0.01	-	1.09	5.10	21.4%
Transport	-	-	-	0.22	0.22	5.50	4.0%
TOTAL	0.68	1.20	0.23	0.22	2.33	15.50	15.0%

Source: *Italian Energy Efficiency Action Plan*, NEEAP, July 2014, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_italy.pdf (accessed: 7.10.2016).

Another important energy efficiency policy instrument, not included in table 14, is the so-called 'Conto termico' (Thermal Account), introduced in 2012. This measure represented the first nationwide direct incentive scheme for the generation of renewable thermal energy, but also the first scheme encouraging public authorities to implement energy efficiency actions in buildings and technical installations.[499] The scheme is addressed both to public authorities and to private parties i.e. individuals, condominiums, businesses, and farms. All these beneficiaries can implement the energy saving actions via an Energy Service Company (ESCO), by means of a third-party financing contract, an energy service contract, or an energy performance contract. As for the 'White Certificates', this scheme is also managed by the GSE (Energy Service Operator), a public company established by the Italian state. Examples of energy efficiency actions supported by this policy instrument include: thermal insulation of walls; replacement of windows; installation of screening and shading systems; replacement of heating systems with condensing boilers; etc.

[499] *Italian Energy Efficiency Action Plan*...2014, *op.cit.*

Measures have also been enacted for supporting energy audits and energy management systems, including the metering and billing systems for which Italy is at the forefront in Europe. Additional set of measures include many information and communication campaigns, professional training and support for the ESCO, measures for the simplification and harmonization of the legislative framework, and other financial instruments to support energy efficiency in buildings' construction and maintenance.[500] Finally, it is worth noting that other actions have been taken by regional and local governments in the context of the EU structural funds for the periods 2007-2013 and 2014-2020. Italian local governments are also widely involved in the 'Covenant of Mayors' programme launched in 2008 by the European Commission after the adoption of the Climate and Energy Package. In particular, Italy is first in the covenant as to its number of signatories, coordinators, and supporters: 2,081 signatories for a total of 2,185 municipalities involved, including the largest Italian cities (Rome, Milan, Naples, Turin, Palermo, Bologna, Florence, Bari, Venice, and many more).[501] In line with this program, local governments have formulated and enacted Sustainable Energy Action Plans which are considered key instruments for improving energy efficiency at local level.

Promoting renewable energy: main instruments, issues, and achievements

In the last two decades Italian governments have implemented various policy instruments (RES-E support schemes) to promote renewables in the electricity sector (table 15.). A briefly review of the history, achievements, and problems of these schemes is offered below (based on Prontera 2014).

The first important decision of the Italian government in the area of renewables traces back to 1992, when the support scheme known as CIP 6/92 was established. This scheme was based on a feed-in tar-

[500] P. Sospiro, *Le Politiche europee e nazionali energetiche e di efficienza energetica*, in P. Sospiro (ed.), Case PRO.P.RI.E proposta di un piano di ristrutturazione energetica del patrimonio immobiliare, pp. 27-43. Rome: Aracne 2015.

[501] *Italian Energy Efficiency Action Plan*...2014, *op.cit.*

Table 15. The main policy instruments (RES-E support schemes) of Italian renewable electricity policy

Instrument denomination	Start/End	Type of Instrument	Main elements of design/amendments (*)
CIP 6/92	1992-1999	Feed-in tariffs	No distinction among RES-E technologies; open to «assimilated» sources; 8 years of duration of the incentives
Certificati Verdi	1999-2012	Tradable Green Certificates	Quota system for net generation; no distinctions among RES-E technologies; TGC's duration 12 years. TGC's minimum size 100MWh. (*) = Amended in 2008: increase of quota obligation for suppliers; extension of TGC's duration from 12 to 15 years; differentiation of TGC for RES-E technologies. TGC's minimum size 1MWh.
Conto Energia	2005-2012	Feed-in premium	For PV only, duration of incentives: 20 years (*) = Amended in: 2007 ('Secondo Conto Energia'), 2010 ('Terzo Conto Energia'), 2011 ('Quarto Conto Energia'). 'Quarto Conto Energia': incentives gradually decreasing over time plus annual cap.
Tariffa Onnicomprensiva	2008-2012	Feed-in tariffs	For power plants under 1 MW (or under 200 KW for wind), duration of incentives 15 years, differentiation for RES-E technologies.
Nuovo Sistema	2012-	Feed-in tariffs/premium Tendering system	PV ('Quinto Conto Energia'): FIT on generation feeding the grid coupled with a premium on generation used onsite, spending cap set at 6.7 billion euro. RES-E except PV: FIT for power plants up to 1 MW and Feed-in Premium for RES power plants above this threshold; Tendering system above 5 MW (10 MW for hydroelectricity and 20 MW for geothermal power); total spending cap set at 5.8 billion euro per year.

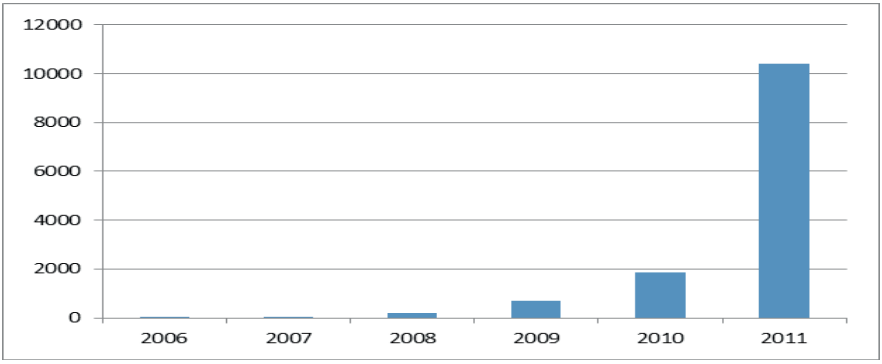
Source: A. Prontera, *Process Sequencing and Policy Change. The Evolution of Italian Renewable Electricity Policy Over Two Decades*, in 'Rivista Italiana di Politiche Pubbliche', 2014, 9(2), pp. 287-320.

iff (FIT) for all renewable energy technologies and was also open to so-called 'assimilated' sources (e.g. co-generation plants, heat recovery, waste fumes, and other types of recoverable energy from processes and equipment, equipment which uses waste materials/energy and/or processes, and those which use sources of fossil fuels produced exclusively by minor isolated deposit). However, the implementation of the CIP 6/92 was very problematic both in terms of costs and due to the fact that the system was more favorable to 'assimilated' than renewables. As a result, the instrument was first suspended, in 1997, and then abandoned with the policy reform of 1999 (known as the Bersani Decree), which introduced a new scheme based on a quota system and Tradable Green Certificate, TGC ('Certificati Verdi') to be managed by the GSE. The implementation of the quota system, however, was very problematic. But this measure, along with generous financial support, resulted in a rapid increase of renewables' electricity production, that almost tripled in four years: from about 11 TWh in 2008 to about 28 TWh in 2011. Despite this result, the government was concerned about the limited rate of development of solar energy and of smaller installations, which found difficulties under the TGC regime. In 2005, a 20-year feed-in tariff designed for photovoltaic solar panels (PV), the 'Primo Conto Energia', was introduced. Thanks to the generosity of the tariff the instrument was a success: it allowed for a maximum of 100 MW of solar power to be admitted to incentives, but this target was reached in nine days, and in the following two months a further request arrived for 300 MW more; thus the cap was increased to 500 MW per year.[502] In 2007 a 'Secondo Conto Energia' was introduced. The scheme was very similar to 'Primo Conto Energia', however its impact was impressive. PV electricity production grew dramatically: from 2.1 GWh in 2006 to 700 GWh in 2009 (Chart 41). However, also the total cost of the incentives – which are covered, with the exception of the TGC, through a component (A3) of the electricity bills – began to become considerable, reaching 110 million euros in 2008 and 303 million in 2009.[503]

[502] C. Stagnaro, *How Solar Subsidies Can Distort the Power Market: The Case of Italy*, in: 'European Energy Review', 5 July 2012.

[503] *Incentivazione degli impianti fotovoltaici. Relazione delle attività*, GSE, Rome 2013.

Chart 41. Italian PV electricity production (in GWh) under 'Conto Energia' (2006-2011)



Source: *Incentivazione degli impianti fotovoltaici. Relazione delle attività*, GSE, Rome 2013.

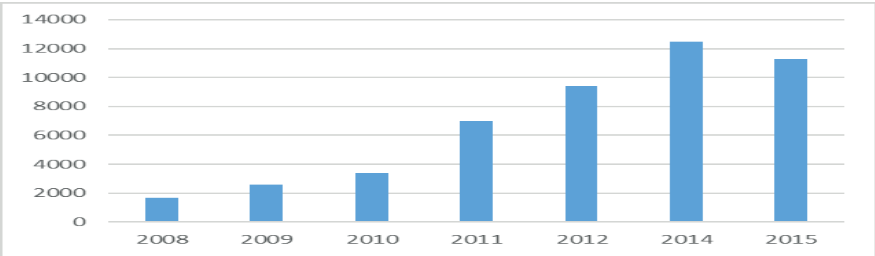
Nevertheless, the success of the scheme was highly appreciated by the renewables producers' organizations, and established an important precedent for the advocates of green technologies and decision-makers. With Budget Law 2008 (Law n. 244 of 24 December 2007) a feed-in scheme ('Tariffa Onnicomprensiva') was introduced for non PV small generations up to 1 MW (with the exception of wind plants, whose limit is 200 KW), that until then had the choice between selling their green certificates on the market or receiving a feed-in tariff. In 2010 a 'Terzo Conto Energia', with only a limited revision of the incentives, was introduced. The partial revision of the incentives did not slow down the investment boom in PV (in 2010 PV electricity production reached 1,850 GWh), and the government decided to adopt a new decision to slow down the cost of the system. In 2011, a 'Quarto Conto Energia' was established, designed with lower financial incentives gradually decreasing over time and an annual cap. However, using a special law passed in 2010 (the so called 'Decreto Salva Alcoa') many PV producers were able to access the generous scheme provided by the 'Secondo Conto Energia' until June 2011.[504] The incentives became more than 3.9 billion euros in one year, forcing the government to adopt a 'Quinto Conto Energia', with the explicit aim of putting the system under control. The 'Quinto

[504] C. Stagnaro, *How Solar Subsidies…, op.cit.*

Conto Energia' also introduced a new cap: when total spending for the support scheme reaches an approximate cost of 6.7 billion euros, it will no longer be possible to access the incentives.

A more important policy change occurred for the TGC system, which in 2012 was abandoned in favor of a new system ('Nuovo Sistema') which combines feed-in tariffs/premium measures, a tendering system and a spending cap (table 15). As a result, in 2014-15, the total costs of the RES-E schemes were more effectively put under control (chart 42). However, renewable electricity production has continued to grow surpassing the 60 TWh in the same period (chart 43).

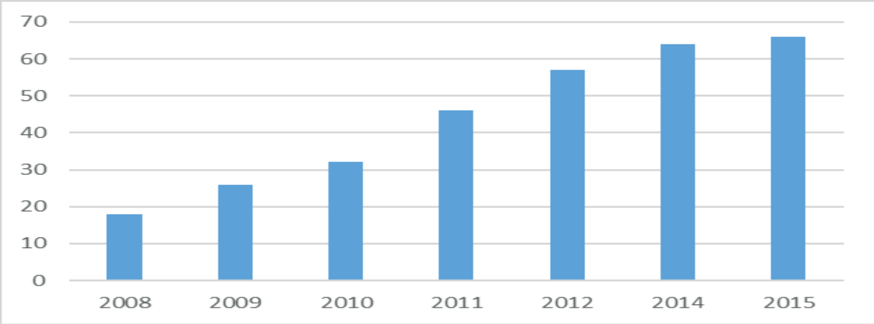
Chart 42. Total costs (in billions euros) of RES-E supporting schemes: Certificati Verdi, Conto Energia, Tariffa Onnicomprensiva, and Cip 6/92 (only renewables)



Source: *Relazione annuale sullo stato dei servizi e l'attività svolta*, Autorità per l'energia elettrica, il gas e il sistema idrico, AEEG, Rome 2016, available at: http://www.autorita.energia.it/allegati/relaz_ann/16/RAVolumeI_2016.pdf (accessed: 26.09.2016).

Along with electricity generation, important contributions for meeting the renewable energy target are also expected by other sectors: the residential and tertiary sectors, heating and cooling and transport. In the first case, the use of biomass and other renewables is to be promoted mainly through a 'Thermal Account'. For heating and cooling the main promotional measures are energy efficiency credits and tax deductions that cover different technologies, including solar thermal installation, biomass boilers, heat pumps, and geothermal cogeneration systems. For transport as well, different measures are provided to promote the use of biofuel through binding minimum quotas (especially in public transport fleets). The energy efficiency credits scheme might also be extended to support the use of electric vehicles.

Chart 43. Total of renewables electricity production (in TWh) under RES-E supporting schemes: Certificati Verdi, Conto Energia, Tariffa Onnicomprensiva, and Cip 6/92



Source: *Relazione annuale sullo stato dei servizi e l'attività svolta*, Autorità per l'energia elettrica, il gas e il sistema idrico, AEEG, Rome 2016, available at: http://www.autorita.energia.it/allegati/relaz_ann/16/RAVolumeI_2016.pdf (accessed: 26.09.2016).

Finally, it is worth noting that along with these important policy instruments managed by the central government and the GSE other instruments to promote renewables are in the hands of regional governments. In 2012, the central government established methods to divide the national targets set for renewables between the Italian regions, including possible sanctions for non-compliance (with the so-called Decree 'Burden sharing', Decree 15 March 2012 of the Ministry of Economic Development). Accordingly, all the Italian regional governments have implemented Regional Energy and Environmental Plans in order to facilitate the diffusion of renewables and support national decarbonization objectives. The Regional plans provide additional financial and regulatory measures and are usually coordinated with the cycles of EU structural funds.

Competitiveness, green economy and energy security

With its energy transition strategy, the Italian government not only aims at the decarbonization of the national economy but also at achieving other important goals: strengthening national competitiveness by reducing energy prices; supporting growth, employment, and technological innovation (a 'green economy'); and improving the country's energy security. With regard to the first goal, the government aims to align Italian energy prices with those of other EU countries, and possibly with other competitors outside Europe (like the United States). Both the instruments in the areas of energy efficiency and renewables are considered important to this end. As we can see, incentives for renewables have been traditionally very high in Italy and this situation has favored a dramatic increase in renewables production in recent years. However, with the last reform the government has managed to get the system under control while continuing to support these new technologies. According to the NES, with the measures envisaged by the government it will be possible, by 2020, to reduce the overall costs of energy bills by 13,5 billion euros (in respect to 2012) and improve the competitiveness of Italian firms. Another important contribution to lowering the overall energy bill for the country is expected by decreasing the import of energy. Energy dependency is expected to decrease from about 85% to about 67% by 2020. As a result, it is expected that Italy will save about 14 billion euros each year after 2020. The savings expected on energy imports will represent about 1% of national GDP and will have important positive effects on the Italian commercial balance.

On the other hand, natural gas will play an important role also in the future Italian energy mix (35-37% by 2020 according to the NES). The Italian government has continued to focus on diversification of its gas supply, especially after the 2006 and 2009 Russian-Ukraine gas crisis and the recent deterioration of EU-Russia relations in the wake of the war in Eastern Ukraine and the annexation of Crimea. Italy is the second EU consumer of Russian gas (after Germany) and Russian gas accounts for about 35% of Italian gas imports. Moreover, Russian gas is supplied to Italy mainly through the Ukrainian route. Up to 2014, Italy and the Italian gas company ENI supported the South Stream project to diversify Russian export route from Ukraine, but this project was halted by the European Commission. Italy is also involved in the development of the Southern Gas Corridor. Thanks to the Trans-Adriatic Pipeline Azerbaijani gas is expected to arrive in Italy (and other EU markets) in the following years (about 8 bcm/y). To improve its diversification of gas supply, the Italian government has also supported the construction of new LNG terminals. The first, with a capacity of 8 bcm/y, was opened in 2009 in the North of Italy (near Ravenna) and the second (a FSRU with a capacity of about 4 bcm/y) in 2013 near Livorno in Tuscany. Through these projects the government aims at supporting energy transition and energy security but also at gaining additional economic benefits by transforming the country into an 'energy hub' for the wider European gas market.

Finally, as anticipated, investments in energy transition are intended also to create growth and jobs. According to the NES, by 2020 a cumulative investment of 60-70 billion euros in the area of renewables (40% of which comes from the private sector) and about 50-60 billion euros in the area of energy efficiency (60% of which is from the private sector) is expected. These investments, paralleled by the regaining of competitiveness in sectors with high energy consumption, are eventually expected to create wider benefits on economic development. Although the overall impact of these measures is difficult to quantify, some indications from the existing data are significant in this regard. In the area of energy efficiency, the estimated total volume of investments which benefited from tax deductions in 2012 alone was about 14 billion euros. These investments accounted for an estimated 207,000 direct jobs and 311,000 total jobs (this figure is particular significant considering that in the same period the building sector, where many energy efficiency actions are concentrated, lost about 200,000 jobs due to the economic crisis).[505] Another important figure regards the progressive shift of the Italian expenditure for research and development in the energy sector: in 2007 most of the expenditures were still concentrated on traditional fossil fuels, while in 2014 energy efficiency and renewables surpassed fossil fuels and became the first (31%) and second (19%) areas of expenditures.[506]

More broadly, the impact of a 'green economy' on overall Italian growth is more and more evident, and sustainability is now a key for innovation in all sectors of the national economy. In 2015, the green economy in Italy was worth about 102 billion euro and guaranteed 3

[505] *Italian Energy Efficiency Action Plan*, NEEAP, July 2014, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_neeap_en_italy.pdf (accessed: 8.10.2016).

[506] *La situazione energetica nazionale nel 2015*, MISE, Italian Ministry for Economic Development, Rome 2016.

million job opportunities.[507] Recent data shows that there are 372,000 Italian enterprises (about 25% of all businesses) that since the 2008 economic crisis have invested in green technology in order to reduce their environmental impact, conserve energy, and limit CO2 emissions. This trend involves all sectors – from the most traditional to the high-tech, from agribusiness to construction, from manufacturing to chemistry – and is very high (32%) in manufacturing, where it has proved to be a strategic factor for 'Made in Italy'[508]. An additional 294,200 new jobs connected to the green economy ('green skills') are expected also in 2016, accounting for about half of the total demand for labor. To support this trend, at the end of 2015, the Italian government also enacted new comprehensive legislation on the 'green economy' (Law No. 221 of December 28, 2015, 'Provisions on the Environment to Promote a Green Economy and Restrict the Excessive Use of Natural Resources'). This law covers a very broad range of policy sectors, including environmental impact assessment, waste management, environmental liability, green public procurement, water, energy and soil protection, the so-called circular economy, and measures to promote sustainable mobility (e.g., the improvement of public transport, car-pooling, bike-sharing and the creation of cycle lanes).

[507] G. Latour, *Italy's green economy is bigger than people think*, in Il Sole 24 Ore, 5 November 2015, available at: http://www.italy24.ilsole24ore.com/art/business-and-economy/2015-11-04/anti-crisis-green-economy-italy-the-sector-accounts-for-372-thousand-enterprises-for-turnover-of-102-billion-143736.php?uuid=ACQZONTB (accessed: 5.10 2016), *Relazione sullo stato della green economy in Italia 2015*, Sustainable Development Foundation-Green Italy, Rome 2015, available at: http://www.statigenerali.org/cms/wp-content/uploads/2015/11/relazione_lo_stato_della_green_economy_in_Italia.pdf (accessed: 18.09.2016).

[508] *Italy's green economy...op.cit., Relazione sullo stato...op.cit.*

Chapter 18

Energy transition in Slovakia and the Czech Republic[509]

Matúš MIŠÍK[510]

Energy sectors of the Czech Republic and Slovakia are very closely connected as they were for the most part developed as a single system during the period when they formed Czechoslovakia. Although the country broke up in 1993, many energy related legacies are visible also nowadays (for example, excellent electricity grid interconnection). The energy sectors of both republics underwent a significant change after the fall of Communism during which high energy demand sectors (especially heavy industry) dominated their economies. Change in their economic systems meant a significant decrease in heavy industry characterised by high energy consumption and very low energy efficiency, and gave way to less energy demanding sectors of industry and an increase in the share of services. These changes (together with other measures) meant also a very significant decrease of greenhouse gases emission – in the case of Slovakia the change from 1990 levels was 41 % in 2013[511]; it was 27.9 % in the Czech case for the period 1990 to 2011.[512]

Energy transition started very rapidly at the beginning of the 1990s with the dramatic change of economy, however, it slowed down sig-

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[511] *Energy Policy of the Slovak Republic*, Ministry of Economy of the Slovak Republic (MoE), 2014, http://www.economy.gov.sk/energy-policy-of-the-slovak-republic_october-2014-qci/145533s (accessed: 2.05.2017).

[512] *GHG trends and projections in the Czech Republic*, European Environment Agency, 2013, http://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-5/assessment-1 (accessed: 3.05.2017).

nificantly later on. Energy transition has been significantly connected to the development of renewable sources of energy (RES) that have been sensitive especially towards the feed-in tariffs introduced in both countries at the end of 2000s. At the same time, however, both countries utilise thermal power plants for electricity generation that support the status quo within the energy sector. Nuclear power is considered by both countries to be an emission-free source of electricity contributing to the development of a carbon-free economy.

Moreover, nuclear energy and thermal power plants are considered by the Czech Republic and Slovakia to be cornerstones of their energy security, which is one of the main issues of interest for these countries.[513] Thanks to domestic sources of coal the Czech Republic is "fully self-sufficient in electricity production".[514] On the other hand, RES – crucial for the energy transition and development of a carbon-free economy – have been subject to unstable development caused by challenges connected to the implementation of feed-in tariffs and technical issues connected to grid stability. Therefore, for example the Slovak strategic document on RES claims that these energy sources can improve energy security only to "some extent and to partially diversify the energy supply".[515] The Czech strategic document[516] questions especially the economic feasibility of the RES – their competitiveness vis-à-vis other sources of energy and the subsequent competitiveness of the whole EU in a global market with many players using cheaper sources of energy.

Energy balance structure

The energy mixes of the Czech Republic and Slovakia are characterised by a few common traits (utilisation of nuclear energy, level of RES) while they differ in others (especially a higher share of solid fuels

[513] M. Mišík, *On the way towards the Energy Union: Position of Austria, the Czech Republic and Slovakia towards External Energy Security Integration*, Energy, 2016, vol. 111, pp. 68-81.

[514] Státní energetická koncepce České republiky, Ministerstvo průmyslu a obchodu, 2014, http://www.mpo.cz/assets/dokumenty/52841/60959/636207/priloha006.pdf (accessed: 20.05.2017).

[515] *National Renewable Action Plan*, Ministry of Economy and Construction of the Slovak Republic (MoEC), 2010.

[516] *Státní energetická koncepce České republiky, op.cit.*

but also a lower share of natural gas in the Czech case). The energy mix of the Czech Republic is characterised by the dominant position of solid fuels and the use of nuclear power (Figure 36). Thermal power plants cover 60 % of electricity demand and therefore in spite of environmental concerns this energy source is "irreplaceable ... from a security as well as an economic point of view"[517]. Nuclear energy covers more than 30% of electricity consumption and thus also has a prominent role within the Czech energy mix. Renewables contributed to the energy mix with 8% in 2013, while the binding national target set within the 2020 Climate and Energy Package is 13% by the end of 2020. Contrary to Slovakia, hydropower in the Czech Republic has only a very small share of total electricity consumption – only about 3%, which is also the whole potential of hydropower in the country. However, a common factor is their rather small utilisation of biomass, which in both countries has significant potential.

The Slovak energy mix is characterised by almost equal distribution among different energy sources, which is considered to be an advantage from the energy security point of view. Renewable sources of energy are, however, used less (8.2%) and nuclear energy is used more (23.8%) compared to the EU average.[518] Renewables thus covered very similar portions of gross domestic consumption of primary energy sources in both countries in 2013 (chart 44).

The main contributors to the share of RES in Slovakia are big hydroelectric power plants, especially the Gabčíkovo hydropower plant (which produces up to 19% of domestic electricity consumption). Overall, more than 90% of all RES came from hydropower before 2010.[519] However, with the introduction of feed-in tariffs and other supporting measures (preferential grid access) at the end of the 2000s, other types of RES also started to play a prominent role in the Slovak energy mix. Act No 309/2009 on the promotion of RES approved in 2009 brought a long-term guarantee of feed-in tariffs for 15 years as well as preferential access for these types of sources to the grid. Thanks to this support the installed capacity of photovoltaic power plants had

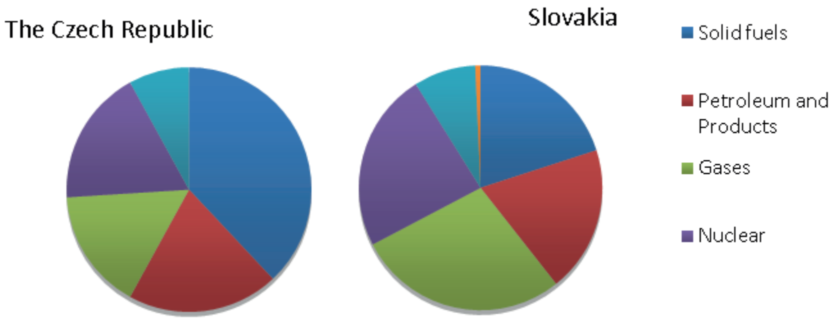
[517] *Státní energetická koncepce České republiky, op.cit.,* p.13.

[518] *Country Factsheet Slovakia. State of the Energy Union*, European Commission, 2015, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015SC0237&-from=EN (accessed: 21.05.2017)

[519] *National Renewable Action Plan, op.cit.*

reached 537 MW by the end of 2013. The support scheme introduced by the Act 309/2009 was cancelled in 2011 as "legislative support for installations above 10 kW is no longer needed given the current installed capacity of solar power plants and the price development of technologies at grid parity".[520]

Chart 44. Energy mixes of Slovakia and the Czech Republic (2013)



Source: *Country Factsheet Slovakia. State of the Energy Union*, European Commission, 2015, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015SC0237&from=EN, *Country Factsheet Czech Republic. State of the Energy Union*, European Commission, 2015, http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1449825446922&uri=CELEX: 52015SC0220. (accessed: 20.05.2017).

The Slovak target within the Climate and Energy package 2020 is 14 % of renewable sources of energy in the energy mix until 2020. This goal was set in the National Renewable Action Plan that forecasts a 15.3 % share of RES in the energy mix by 2020.[521] The biggest potential is in biomass that can produce up to 120 PJ of energy in Slovakia. In order to reach the 14% target only 80 PJ are needed – which means that Slovakia has enormous biomass potential that can significantly contribute to the increase of RES in its energy mix in the future. This potential is currently not utilised to a high degree; however, thanks to its potential it has seen a significant increase in the recent past, and further increase of its utilisation is expected by the Ministry of Economy.[522] Biomass can compete in terms of price with fossil fuels and therefore has been prioritised by the strategic documents of the

[520] *Energy Policy of the Slovak Republic, op.cit.*

[521] *National Renewable Action Plan*, *op.cit.*

[522] *Ibidem.*

Slovak government. Moreover, it can, together with energy savings and other types of RES (for example geothermal energy), be used to decrease the amount of natural gas used for heating purposes (and thus also decrease its import and thus increase Slovak energy security).

Neither Slovakia nor the Czech Republic have binding targets in the area of renewables utilisation in the case of the Energy 2030 proposal. However, Slovak strategic documents expect that the country will reach 20% of RES by that date.

From the energy transition point of view, both countries can be characterised by high level of utilisation of solid fuels for electricity generation and also the use of nuclear power for this purpose. Both countries are supporters of nuclear energy and are currently building or planning to build new nuclear reactors. Slovak nuclear power plants Mochovce 3 and 4 are supposed to be commenced in 2017/2018 while the Czech Temelín 3 and 4 was stopped for now in 2014 in its preparation phase due to problems during the procurement procedure. The Czech Republic uses much more coal for production of electricity (almost 60%[523]) compared to Slovakia (thermal power plants produced 22 % of generated electricity in 2013[524]). However, the share of solid fuels in the energy mix of the Czech Republic has decreased rather substantially since 1995 (by 18%) while the share of RES and nuclear energy has increased (from 3 to almost 8 % and from 8 to 18% respectively).[525] A high share of domestic coal in energy production is considered, especially by the Czech authorities, to be a guarantee of energy security and the strategic documents consider coal to be an irreplaceable source of electricity in spite of acknowledging its environmentally challenging nature.[526]

Energy efficiency

Energy efficiency is a rather challenging issue for both countries. Although the trend is very positive with energy efficiency steadily improving, the Czech Republic as well as Slovakia are currently lag-

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[523] *Státní energetická koncepce České republiky, op.cit.*

[524] *Energy Policy of the Slovak Republic, op.cit.*

[525] *Country Factsheet Czech Republic. State of the Energy Union*, European Commission, 2015, http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1449825446922&uri=CELEX: 52015SC0220 (accessed: 4.04.2017)

[526] *Státní energetická koncepce České republiky, op.cit.*

ging behind the EU average in this area. Slovak energy efficiency issues are currently governed by the Third Energy Efficiency Action Plan prepared in line with Act No 476/2008 on efficiency in energy use.[527] The document sets goal of energy saving amounting to 11% of the average final consumption for the period from 2001-2005 until the year 2020. General energy efficiency target for the country is thus 16.4 Mtoe (tons of oil equivalent) of primary energy. Although consumption decreased during 2005-2013, later this trend was reversed and Slovakia is facing a challenge to increase its energy efficiency during a period of continuous economic growth.[528] Energy intensity is, however, still a problem as it remains in absolute terms almost twice the EU average.[529]

The Czech energy efficiency target for 2020 is 39.6 Mtoe of primary energy. The Commission assumes that the Czech Republic will meet this goal if the current trend of energy efficiency improvement is kept. Similarly to Slovakia, energy intensity has stayed almost double the EU average, in spite of a fast decrease in the last period. The biggest decrease was recorded in the industry sector where energy intensity decreased by 35% in the period between 2005 and 2013.[530]

Energy transition and the resulting increase in energy savings and higher rate of RES utilisation will positively contribute to the increase of energy efficiency. The on-going effort to decrease energy consumption in all sectors of the economy combined with the increase of RES production in both countries paves the way for a gradual decrease of fossil fuels utilisation for electricity generation. However, the recent low price of electricity complicates these efforts, as old coal-fired power plants can provide currently more economically feasible solutions. For example, the gas-fired power plant in Slovak Malženice was shut down just after a couple of months of production in 2013 due to low utilisation rate. The potential of the power plant as an electricity

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[527] Energy Efficiency Action Plan 2014-2016 with an Outlook up to 2020, Ministry of Economy of the Slovak Republic (MoE), 2014, https://ec.europa.eu/energy/sites/ener/ files/documents/NEEAP_EN_ENER-2014-01001-00-00-EN-TRA-00.pdf (accessed: 7.04.2017).

[528] *Country Factsheet Slovakia. State of the Energy Union*, European Commission, 2015, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015SC0237&-from=EN (accessed: 7.04.2017).

[529] *Ibidem*.

[530] *Country Factsheet Slovakia..., op.cit.*

source using a “bridging” source (i.e. gas – creating a bridge between fossil fuels and renewables thank to its low emissions) and a back-up source for RES was thus not utilised.

Planes of competitive advantages / new branches of economy

Neither Slovakia, nor the Czech Republic are leaders in developing new technologies connected to energy transition in general or RES in particular. Their main agenda when it comes to transition to a zero-emission economy is support of nuclear energy, which is considered to contribute to the reduction of greenhouse gas emissions as the production of electricity in nuclear power plants is basically emission-free. The Czech Republic and Slovakia are therefore also trying to support further utilisation and development of nuclear energy within the EU. In cooperation with the European Commission, the Czech Republic and Slovakia established the European Nuclear Energy Forum in 2007.[531] Its main current aim is to support discussion of nuclear-energy-related issues especially in the post-Fukushima nuclear accident world. The Forum meets annually in Bratislava or Prague; participants include EU member states, EU institutions, regulators, energy companies, and other stakeholders.

Both the Czech Republic and Slovakia are keen supporters of nuclear energy being two of the very few countries within the EU that are preparing or actually building new nuclear reactors (although expansion of the Czech nuclear power plant Temelín was cancelled in its preparation phase when the tender was cancelled, Mochovce 3 and 4 have been being built since 2008). Nuclear energy is considered to be a “low-carbon” technology that will help reduce fossil fuel consumption and thus also greenhouse gas emissions. Slovakia does not directly includes nuclear among RES and is not part of its strategic documents about this type of energy source; however, Slovak energy policy claims that “the preservation of nuclear energy in the energy mix has also played an important role…[in:] continuous reductions

[531] *Nuclear energy forum launched in Bratislava*, Euractive, 2007, http://www.euractiv.com/section/energy/news/nuclear-energy-forum-launched-in-bratislava/ (accessed: 11.04.2017)

in the carbon intensity of GDP".[532] Later it is even more direct when the document claims that "Nuclear energy is the driving force of low carbon growth in Slovakia".[533]

Energy security

Energy security is an issue that is very important for both countries. The Czech Republic is much more active in this area and many of its energy sectors underwent changes in order to improve energy security. Slovakia had been a rather passive observer until the 2009 gas crisis which meant a crucial change in the country's perspective on energy security and diversification. However, from the energy transition point of view, energy security is an issue that supports the status quo (especially in the Czech case) as "traditional" energy sources are considered to be the most secure ones. Moreover, RES have been connected in the region especially with high prices caused by feed-in tariffs and problems with grid stability.

The state energy conception of the Czech Republic states that the significant share of thermal power plants burning domestic brown and hard coal is a crucial contribution to energy security of the country.[534] Contrary to the Czech Republic coal does not play such an important role in Slovak energy security as the main part of coal consumed in this country is imported (in 2012 Slovakia imported 4861 kilotons of coal out of 7153 kiloton of total coal consumption what represented almost 68%).

Also nuclear energy is considered to be a very "secure" source of energy by the Czech strategic documents as it enables, contrary to other energy sources, creation of a strategic reserve for a longer period given the high concentration of the fuel.[535] Therefore Czechs, but also Slovaks, sometimes go so far as to consider nuclear to be a "domestic" source of energy.[536]

Renewables (especially biomass) are considered by the Slovak

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[532] *Energy Policy of the Slovak Republic, op.cit.,* p. 40.

[533] *Ibidem,* p. 41.

[534] *Státní energetická koncepce České republiky..., op.cit.*

[535] *Ibidem.*

[536] M. Mišík, The *Influence of Perception on the Preferences of the New Member States of the European Union: The Case of Energy Policy*, Comparative European Politics, 2015, Vol. 13, No. 2, pp. 198-221.

authorities to have an important position in decreasing dependency on natural gas supplies from abroad.[537] This is based on the idea that renewables are domestic energy sources. Moreover, according to the Ministry of Economy, these sources of energy will help to reduce greenhouse gasses and pollution. However, as noted above, the Slovak position is cautious in this area and strategic documents mention also the challenges connected with the utilisation of RES. The National Renewable Action Plan states that RES carries several risks including fluctuations that have "an adverse effect on the safety and reliability of grid operations"[538] and significant price hikes caused by feed-in tariffs. Therefore, other documents, for example, the Energy Policy of the Slovak Republic, states that the country support "particular those [RES] with predictable generation" that are able to deliver energy at a price that is "close to market prices"[539].

Renewables and their consequences for the electricity grid thus present a challenge for the analyzed countries. Although there are the above mentioned issues at the domestic level, there are also challenges connected to the stability of the grid at the regional level. Especially, German RES cause problems for the Czech and Slovak electricity grids. *Energiewende* significantly supported development of RES capacities in northern Germany, where there are much better conditions for wind as well as photovoltaic power plants than in other parts of the country. However, after the Fukushima nuclear accident, Germany revisited its decision to shut down its nuclear program and decided to close all nuclear power plants by the end of 2022 and fully concentrate on RES. Moreover Germany immediately shut down several of its oldest reactors located mostly in the southern part of the country. This has created a regional unbalance between electricity supply and demand – while the northern part of the country produced a significant surplus of electricity from RES, there was a shortage in the southern part of Germany. Electricity produced in the north started to be consumed in the south.

However, the internal German grid was insufficient to support such a huge volume of electricity and therefore it started to flow to southern Germany through neighboring countries – especially Poland

[537] *National Renewable Action Plan, op.cit.*

[538] *National Renewable Action Plan, op.cit.* p 5.

[539] *Energy Policy of the Slovak Republic, op.cit.*, p. 60.

and the Czech Republic (so called loop flows). Moreover, the bidding zone between Austria and Germany enabled the export of electricity from German RES to Austria without the necessary infrastructural support thus adding to the problem (transit flows). These unscheduled flows emerged shortly after the German decision to shut down nuclear power plants and already by August 2011 were causing severe problems for electricity grids in Central Europe including Czech and Slovak ones.[540] For example, overall transit through Slovakia increased by 79 % in 2011 compared to 2010.[541] These flows were unscheduled due to the partly unpredictable nature of RES, thus putting extra pressure on the grids and its operators, threatening the grids' stability and enabling possible blackouts.

Many levels of cooperation have been used to deal with this issue. First, it was addressed at the ENTSO-E (Network of electricity transmission system operators) level; however, neither this nor at the bilateral or regional (Visegrad four) levels brought the desired outcomes. The problem became less urgent after 2012 as Germany started to limit the amount of unscheduled flows, and better coordination between grid operators enabled the prevention of blackouts. However, Poland decided to solve this problem by building a phase shifting transformer that received financial support from the European Union through the Project of Common Interest scheme.[542] The Czech Republic approaches this issue through improved cooperation at the regional level – collaboration with Germany and Austria on this issue was one of the priorities of its 2015-2016 presidency of Visegrad group.[543]

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[540] *Position of ČEPS, MAVIR, PSE Operator and SEPS regarding the issue of Bidding Zones Definition*, 2012, http://www.mavir.hu/c/document_library/get_file?uuid=-513b0eee-8eb1-405b-85f1-3df85c47237d&groupId=10262 (accessed: 13.04.2017)

[541] *Ibidem.*

[542] Commission Delegated Regulation (EU) 2016/89 of 18 November 2015 amending Regulation (EU) No 347/2013 of the European Parliament and of the Council as regards the Union list of projects of common interest. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:JOL_2016_019_R_0001&from=EN (accessed: 13.04.2017).

[543] *V4 Trust – Program for the Czech presidency of the Visegrad Group*, Visegradgroup, July 2015–June 2016, http://www.visegradgroup.eu/documents/presidency-programs/20152016-czech (accessed: 14.04.2017).

Conclusion

Energy transition in the Czech Republic and Slovakia can be characterised by several traits. Nuclear energy is an important part of the transition for both countries as it is considered to be a low-emission source of energy and at the same time an important part of energy security as it is considered to be a "domestic" source of energy. In the Czech case also coal-fired power plants using domestic coal stocks contribute significantly to energy security which is considered by both countries to be one of the most important energy-related issues. On the other hand, renewable sources of energy are being approached cautiously after very fast development at the end of the 2000s and the beginning of the 2010s that brought concerns about the ability of these energy sources to be implemented in the existing electricity grid as well as issues connected to the feed-in tariffs and their influence on the price of electricity for end consumers (households as well as businesses). Neither of the two countries are leaders in developing new technologies or policies connected to energy transition. Their position when it comes to energy transformation is rather passive with a dominant interest in energy security issues.

Conclusion

Energy transition is an inevitable process, currently going on in many countries. At the national level, it requires a coordinated policy involving cooperation between different institutions, and especially the world of science and industry. With the diversity of energy balance structure of different countries in mind, we can also see different approaches to the issue of energy transition. Energy transition based on low-emission energy sources is connected with real social and economic benefits such as alleviating the effects of climate change, its influence on human health, and enhancing energy independence or energy system flexibility. Transition-focused thinking means the ability to see many different forms of energy production beyond the commonly used fossil fuels.

Transforming the economy into a low emission economy (energy transition) is one of the biggest economic-environmental challenges of the 21st century. The longer the emitting countries wait to start the transition, the higher will be its costs and the more difficult its implementation, because present investment in the traditional technologies producing energy from conventional fuels will form the energy mix for many years[544]. Properly designed energy and climate policy has a stimulating influence on all areas of socio-economic life and fosters the building of a modern and highly developed economy, and modernization of the energy sector seems the only solution allowing the maintaining of energy security and competitiveness of energy production in the age of climate change[545]. Associating environmental policy with energy policy results from the fact that energy is the sector with the greatest impact on the quality of air and is the source of the concentration of greenhouse gases in the atmosphere responsible for global warming. The sector of energy production is one of the greatest

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[544] T. Młynarski, *Bezpieczeństwo energetyczne i ochrona klimatu w drugiej dekadzie XXI wieku. Energia - Środowisko – Klimat [Energy security and climate protection in the second decade of the 21st century. Energy – Environment – Climate]*, Kraków 2017, p. 189.

[545] *Ibidem.*

CO_2 emitters and must play a fundamental role in the decarbonization of the world's economy. Energy transition forces the modernization of the energy infrastructure and reduction of energy intensity of the economy through investment in innovative green energy technologies. Growing awareness in the international community of the need to counteract GHG emissions has increased the importance of the ecological aspect of energy security, which includes the reduction of negative effects on the natural environment at each stage of energy management (extraction, processing, transport, storage, and consumption). The threat resulting from climate change, in turn, requires revaluation of the traditional concept of energy security, including the still present preference for cheap energy sources that actually prevent the effective reduction of CO_2 emissions.

The process of energy transition is seeding up globally as a result of the growing role of electricity in new branches of the economy, including transport. It will contribute to the replacement of previous fossil fuels (oil) with electricity perceived as "fuel" for vehicles. The global fleet of electric vehicles nearly doubled in the years 2014-2015, reaching the level of 1.3 million. In the first quarter of 2017 alone, the number of registered electric vehicles in three countries which are the leaders in this regard, i.e., China, the USA, and Japan, exceeded 1.3 million. The IEA estimates that the number will grow up to 30 million cars by 2025 and exceed 150 million in 2040. Such development of electric cars will reduce the demand for oil by approximately 1.3 mb/d in 2040[546]. T. Seba assumes a much more dynamic development of electromobility. He anticipates within 8 years that all land transport will be powered with electricity, which will lead to a slump in oil prices and the collapse of the petroleum industry.[547] Surely, the dynamics of electromobility development will depend on the speed of overcoming different barriers to it, such as the development of an energy infrastructure for charging electric vehicles, production of efficient batteries, the growth of public acceptance, and first of all, lower prices for electric cars. This will help countries that spend considerable financial resources on the import of oil and fuels to rather spend

[546] *World Energy Outlook 2016*, IEA.

[547] J. Arbib, T. Seba, *Rethink X. Disruption, Implications and Choices. Rethinking Transportation 2020-2030.*

it on electricity, which is mostly generated on domestic markets, and so the flow of funds may become a lever for economic development in each country. The crucial question is how different countries will decide to invest in it and whether they will achieve in this way certain sources of economic advantage.

It is clear that despite technological development, fossil resources are still dominant in the structure of primary energy (nearly 80%). However, in the coming decades, the situation will likely change, given the dynamics of development within the last 15 years of energy technologies based on RES, which do reduce emissions. The process will additionally stimulate a dynamic growth in demand for electricity, whose production has increased 4-fold in the last 40 years. The development of ICT systems, digitalization, and robotization are bound to make the demand for electricity grow in the future. The development of renewable energy also leads to changing the model of relations between the producer and consumer of electricity, as the previous consumer may now also produce energy, becoming a prosumer. Restrictive environmental standards also favor nuclear energy, which is regarded as one of the low-emission forms of final energy production. But it seems that nuclear energy will play only an intermediary role in the process of energy transition, because by 2040 nearly 200 out of 450 nuclear reactors may be discontinued. Within the nearest several decades, nuclear energy will mostly develop in Asia. Natural gas may also prove to be an intermediary fuel in the transition process. As a result of developing LNG technology, the natural gas market is becoming more and more integrated and globalized. Transition processes also involve new forms of contracting energy resources and electricity as a result of the development of energy exchanges and electronic platforms for energy trade. The formation of physical and virtual gas hubs provides conditions for a new architecture of energy contracts, which are alternative to long-term contracts.

It must be emphasized that one way of reducing GHG is to improve energy efficiency by optimum use of energy resources. Energy transition processes mean that optimum energy management in smart grids will soon become a challenge. It seems that the improvement of energy efficiency is the most economically optimal way of reducing GHG emissions. The growing demand for electricity causes the need to ensure stable and secure supplies to end customers. It also contributes to maintaining the proper quality of electricity, and this increases the demand for electricity storage facilities, which may help improve the flexibility of the electricity system and balance energy supply and demand. Nowadays, different methods of storing electricity are available, and ongoing work in new technologies mean there will soon be more.

Analyzing the model of energy transition in selected countries, we can see that the process not only leads to the modernization of the energy balance structure, but also to changes in thinking about the energy sector. Even a decade or two ago, nobody would have expected the US, which used to import over 100 bcm/year, to become an exporter of natural gas. The process of technological change that has taken place in the last few decades in the US refers to the area of extraction and production of energy resources, which will soon make the country change from being an importer of natural gas to being its net exporter. The so-called shale revolution, which began with natural gas and then also applied to oil, has affected the global market of energy resources and become one of the factors of transition. Considerable amounts of oil and natural gas entering the American market have led to lowering energy prices, and together with the intellectual potential has become a factor that attracts investments to the American market. In the case of the US, the process of transition has caused the creation of a huge number of jobs in areas of the economy connected with the energy sector.[548]

In the EU, one of the first countries to begin the transition involving extensive implementation of renewable energy is Denmark. Similar activities are being taken in the Federal Republic of Germany, which is pursuing the regular growth of renewable energy in its energy balance structure. These activities are also a response to the oil crisis of the 1970s, when Western European countries felt the effects of excessively high dependence on imported oil. It is important, however, that Germany, having a substantial share in renewable energy technologies,

[548] M. Paszkowski, *Analiza implikacji zniesionego przez Stany Zjednoczone Ameryki zakazu eksportu ropy naftowe [Analysis of implications of the ban on oil exporting abolished by the USA]. POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL,* 2017, vol. 20, part 1, p. 37.

has made it one of their export goods, which have become a source of their competitive advantage. Denmark has noticed a similar opportunity and is the leader in wind energy technologies. At certain times of the day, surpluses of electricity may be sent (exported) to other countries. Therefore, well developed energy structure and electricity interconnections are a significant element affecting the position of Germany (the second greatest exporter of electricity in the EU, just next to France) and Denmark on the integrating energy market in the EU. Among EU countries, Italy has also found the potential for developing its competitive energy sources as part of a "green economy". This way, Italy has created many new jobs. Recent significant investments by Italian companies in the development of renewable energy technology is giving the economy some benefits. France has been building its position in another way. Initially, it based the modernization of its energy sector on nuclear energy, which not only enabled it to lessen its dependence on fossil fuels import, but also made the country one of the main suppliers of products and services for the nuclear industry. The Act on energy transition adopted in 2015 showed priorities such as the development of renewable energy and energy efficiency, combined with the reduction of nuclear energy.

Whereas France is planning to reduce nuclear energy, the Czech Republic and Slovakia perceive this form of electricity production as the solution ensuring a low-emission energy sector. Apart from the existing nuclear power plants, they are also planning to construct new installations, which will facilitate the process of energy transition, also supported with the development of renewable energy. Nuclear energy is also an important element of the energy balance structure in Great Britain, which is planning to build another installation as well. Recently, that country has developed its energy infrastructure and liberalized its energy market, in some elements becoming the point of reference for many emerging energy exchanges. One of the British priorities is currently to improve energy efficiency, both in households and in industry.

Within the last several decades, Poland has had significant successes. Previously, it based its energy balance on hard coal and lignite deposits, which are used to produce the majority of its electricity. Evidently, on the one hand, Poland's future energy transition is going to involve the improvement of coal blocks, which may contribute to the reduction of greenhouse gases emission. On the other hand, the country is looking for its sources of competitive advantage, trying to determine its way of energy transition by considering the specificity of the previous energy balance structure. Austria and Switzerland skilfully use their central location in Europe. In the case of the former, its location enables it to serve the transit function for the import of energy resources to other European countries. On one hand, it provides an opportunity for developing the Austrian economy, but on the other hand, it makes the country dependent on others. Regarding the national priorities of the energy sector, further improvement of energy efficiency is important, and the sources of competitive advantage are based on technological development resulting from the extensive research sector, and technological ideas then become the export product. Similar assumptions were adopted in Switzerland, which mainly pursues technological development. The factor that makes Switzerland different from many other European countries is pumped storage power plants, which ensure the possibility to store electricity. Switzerland can also see the potential in developing the technologies of energy storage and the use of hydrogen in the energy sector and transport.

To sum up, we can see that energy transition in different countries is not the same. This mainly results from the variety of the previous energy balance structure. However, in each country, energy transition is an opportunity for re-industrialization of industry and building new branches of the economy, as well as creating competitive advantage. It is in the interest of each country to strengthen its energy security and to create new jobs as part of the economy. Social expectations and renewable technologies correspond more and more to the countries' industrial strategies. In many countries, energy transition occurs by evolution, not revolution. Daniel Yergin emphasizes that technological speed is not the only factor to affect the pace of transition.[549] Apart from this factor, there are others. Therefore, it is even more difficult to reduce the phenomenon of energy transition to one common denominator.

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[549] D. Yergin, Quest, Penguin Books, New York, p. 722.

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In my opinion, the strongest point of the publication is that it is so comprehensive, showing the main elements of energy transition against the background of their practical applications in ten selected countries. I would recommend the book to anyone who wants to understand the comprehensive approach to the analysis of energy transition as well as the practical forms of its implementation.

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It is a book for all those who are interested in an active participation in the process of energy sector transition at any level of political, economic, or technological structures. It provides, first of all, the "food" for matter-of-fact discussion and debate on the trends connected with energy policy transitions, the reasons for them, and the ways of implementing different models of energy transition in different countries. The authors of the volume have put considerable effort into preparing a list of valuable references, which should be helpful in further studies of the discussed issues.

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