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THE MODERNIZATION OF THE ENERGY SECTOR IN DENMARK

MODERNIZACJA SEKTORA ENERGII W DANII

Denmark is among the leaders who change their energy policy to guarantee its stable and sustainable character. The consistent pursuit of an energy policy enabled the country to lower both the level of its energy consumption and greenhouse gas emissions, while providing grounds for economic development. The study demonstrates that the main factors which led to the transition of Danish energy policy were the oil crisis of the 1970s as well as public expectations regarding their energy policy which was to be based on the concept of stability and sustainability.

Keywords: modernization, energy market, energy efficiency, liberalization

Dania jest jednym z liderów zmian w polityce energetycznej, zmierzających do stosowania koncepcji rozwoju zrównoważonego i trwałego. W wyniku konsekwentnie realizowanej polityki energetycznej w Danii udało się ograniczyć poziom zużycia energii i emisji gazów cieplarnianych, jednocześnie zapewniając warunki do rozwoju gospodarczego.

W opracowaniu wskazano, że głównym czynnikiem, który doprowadził do zmian w polityce energetycznej Danii, był kryzys naftowy lat 70. XX wieku. Przed jego wybuchem dominujący udział w strukturze źródeł energii pierwotnej Danii miała importowana ropa naftowa, która w 1972 r. zaspokajała ponad 90% zapotrzebowania na energię pierwotną w tym kraju. Cechą duńskiego sektora energii była także jego niewielka efektywność oraz wysoki poziom zanieczyszczeń atmosfery związany ze spalaniem paliw kopalnych. Kryzys naftowy wymusił podjęcie działań modernizacyjnych, których celami było m.in. zmniejszenie zużycia energii pierwotnej, zdywersyfikowanie struktury jej źródeł oraz poprawa efektywności sektora energii.

Istotnym czynnikiem wymuszającym modernizację duńskiego sektora energii była także kwestia zmiany nastawienia społecznego do prowadzonej polityki energetycznej w Danii. Obecnie w społeczeństwie dominuje pogląd, że podstawą polityki energetycznej powinna być koncepcja rozwoju zrównoważonego i trwałego. Kierunek ten jest szczególnie mocno obserwowany w Danii od końca lat 80. XX wieku po publikacji raportu Światowej Komisji ds. Środowiska i Rozwoju (tzw. raportu Brundtlanda).

W tym okresie w Danii występowała znacząca emisja zanieczyszczeń atmosfery związana ze zwiększeniem znaczenia węgla kamiennego. Za sprawą rosnącej świadomości społecznej co do konsekwencji środowiskowych gospodarowania energią w latach 90. XX wieku podjęto działania na rzecz ograniczenia zużycia energii. Dla osiągnięcia tego celu istotne było przyjęcie w 1988 r. przepisów zabraniających sto-

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sowania ogrzewania elektrycznego w nowych budynkach, które mają dostęp do sieci ciepłowniczej lub do sieci gazowniczej (Jacobsen, (<http>)). Przyjęcie tych przepisów przyczyniło się do ograniczenia zużycia węgla będącego w tym okresie głównym źródłem energii elektrycznej i jednocześnie źródłem emisji zanieczyszczeń atmosfery. Wpłynęło to także na zmniejszenie zapotrzebowania na import tego paliwa. Promowanie w tych przepisach rozwoju sieci ciepłowniczych wiązało się ze spalaniem w instalacjach kogeneracyjnych gazu ziemnego, którego zasoby gwarantowały niezależność od importu surowców. Dodatkową korzyścią z wprowadzenia tych przepisów była poprawa bilansu płatniczego kraju oraz zwiększenie zużycia gazu ziemnego.

Uświadomienie społeczeństwu konsekwencji ekologicznych realizowanej polityki energetycznej wpłynęło na zwiększenie poparcia dla rozwoju proekologicznych źródeł energii. Społeczeństwo duńskie jest gotowe ponosić większe koszty energii w zamian za gwarancję, że przyczynia się to do ochrony środowiska. Zwiększeniu roli OZE w bilansie energetycznym służy m.in. zrealizowana w 1992 r. reforma podatków dotyczących gospodarowania energią. Reforma ta wprowadziła podatek od paliw konwencjonalnych, przy jednoczesnym zwolnieniu z opodatkowania OZE, co przyczyniło się do ograniczenia zużycia paliw konwencjonalnych. Istotą reformy było zobowiązanie wszystkich grup odbiorców, w tym odbiorców domowych, do płacenia podatku, którego wysokość została uzależniona od wielkości emisji CO₂ wywołanej spalaniem paliw. Podatek ten jest formą przeniesienia na odbiorcę finalnego kosztów efektów zewnętrznych wywołanych przez zużycie nośników energii pierwotnej.

Współcześnie sektor energii w Danii charakteryzuje się zróżnicowaną strukturą źródeł energii pierwotnej. Mimo ograniczenia znaczenia ropy naftowej w dalszym ciągu ma ona największy udział (44% w 2011 r.) w bilansie energetycznym Danii (BP, 2012). Oprócz tego paliwa po ponad 15% udziału mają węgiel, gaz ziemny i OZE. Należy podkreślić, że udział OZE w produkcji energii elektrycznej w Danii jest jednym z najwyższych na świecie, co wiąże się z poparciem społecznym dla stosowania tego rodzaju źródeł. Istotnym elementem polityki energetycznej Danii jest silna pozycja OZE oraz duża efektywność zużycia nośników energii.

Zmiany polityki energetycznej przyczyniły się do zwiększenia niezależności energetycznej Danii, co wiązało się głównie z wprowadzeniem do eksploatacji w początku lat 80. XX wieku złóż ropy naftowej i gazu ziemnego. W wyniku prowadzonych prac poszukiwawczych w 1997 r. Dania po raz pierwszy stała się w pełni wystarczająca energetycznie.

Do zwiększenia bezpieczeństwa energetycznego Danii przyczynia się także obserwowany począwszy od ostatniej dekady XX wieku, rosnący udział OZE. W kolejnych latach, zgodnie z priorytetami duńskiej polityki w tym zakresie, znaczenie tych paliw w zapewnieniu bezpieczeństwa energetycznego kraju wzrosło. Podejście to jest związane z oczekiwaniami społecznymi, aby polityka energetyczna Danii pozwalała na wdrażanie koncepcji rozwoju zrównoważonego i trwałego.

Prowadzona polityka energetyczna przyczynia się także do poprawy konkurencyjności duńskiej gospodarki przez rozwój technologii energetycznych oraz eksport wyrobów przemysłu pracującego dla „zielonej gospodarki”. W wyniku rozwoju technologii energetycznych obecnie około 1/3 zainstalowanych na świecie turbin wiatrowych pochodzi z Danii (EREC, 2009). Sprzedaż zaawansowanych technologicznie produktów duńskiego przemysłu energetycznego jest źródłem 11% przychodów z eksportu (*The Danish...*, 2012). Silna pozycja przedsiębiorstw produkujących zaawansowane technologicznie wyroby dla „zielonej gospodarki” sprzyja zwiększeniu zatrudnienia w duńskich przedsiębiorstwach, przyczynia się do zwiększenia dochodu społeczeństwa oraz wpływają na poparcie społeczeństwa dla rozwiązań proekologicznych w prowadzonej gospodarce energetycznej.

Duże znaczenie dla zmian modernizacyjnych miała liberalizacja duńskiego rynku energii elektrycznej i gazu ziemnego. Reformy liberalizacyjne rynku były związane głównie z dążeniem duńskich firm do udziału w wymianie na liberalizującym się rynku pozostałych krajów nordyckich (OECD/IEA, 2005). Oprócz korzyści z wymiany z innymi krajami nordyckimi liberalizacja wpłynęła także na poprawę bezpieczeństwa energetycznego Danii (Hellmar i Warell, 2009).

Liberalizacja wiązała się z wymuszeniem konkurencji między uczestnikami rynku, co wpłynęło na poprawę efektywności tych przedsiębiorstw. Działania liberalizacyjne przyczyniły się do poprawy jakości obsługi klientów finalnych oraz do ograniczenia poziomu cen dla tych odbiorców. Duży wpływ na poprawę efektywności przedsiębiorstw energetycznych miała działalność regulatorów rynku, którzy przez prowadzenie analiz porównawczych wymuszali poprawę efektywności duńskich przedsiębiorstw sektora (Jamash i Pollitt, 2001; NEP, 2009; DARE, 2011). Poprawa efektywności wpływa na wzrost konkurencyjności duńskiej gospodarki.

Słowa kluczowe: modernizacja, rynek energii, efektywność energetyczna, liberalizacja

1. Introduction

Currently, energy management is one of the most crucial requirements for the world's economic development. Therefore, various countries take actions to secure their access to supplies of energy resources, to attain a competitive level of prices of these resources, as well as to protect climate, the ultimate being connected with the implementation of an idea of a balanced and sustainable development. The competitiveness of these countries' endeavors and the quality of living of their societies depend on the efficiency of these actions.

The aim of this study is to discuss the conditions for a transition in the energy policy in Denmark - one of the leaders of changes in this sector, leading to the implementation of an idea of a balanced and sustainable development. As a result of a consistently employed energy policy, Denmark managed to limit the consumption level of energy and emissions of greenhouse gases, thus providing conditions for economic development. The key element of Denmark's energy policy is a strong position of renewables and high consumption efficiency of its energy supplies. The study focuses on the description of factors which led to the transition of energy policy in Denmark as well as on the assessment of today's energy policy in this country. The role of renewables in the energy balance of the country has also been discussed.

2. The change of the structure of primary energy sources in Denmark

During the past four decades, Denmark fundamentally changed the structure of primary energy sources. Initially, the change was related mainly to the oil crisis of the 1970s. Before its outbreak, the imported oil had a dominant position in Denmark's structure of primary energy sources, satisfying the needs for primary energy in 90% in 1972. It needs to be stressed that the transport industry, house heating and production of electricity were then based on oil. The Danish energy sector was also characterized by its low efficiency and a high level of air pollution due to the combustion of fossil fuels.

As a result of this strong economy's reliance on oil supplies, Denmark was severely affected by a radical increase in oil prices, which was caused by the aforementioned oil crisis. The increase led to a slump in oil consumption, which was more dramatic than a drop in the consumption of primary energy¹.

The oil crisis forced the world to take modernizing actions, aimed, amongst others, at the reduction of primary energy consumption, diversification of the structure of its sources, as well as the improvement of the efficiency of the energy sector. Particularly extreme modernizing changes occurred in 1970s and 1980s, which were connected to the implementation of the aims of the country's subsequent energy policy plans (Fig. 1).

In short, the changes in the structure of primary energy sources in the past four decades were mainly related to:

- a decrease in oil significance (as a consequence of the oil crisis followed by a price hike),
- an increase in coal consumption, which took over nearly half of the oil share from the energy balance,

¹ In 1973-1983 the consumption of primary energy in Denmark decreased by 19.9%, and oil consumption by 42.1% (BP, 2011).

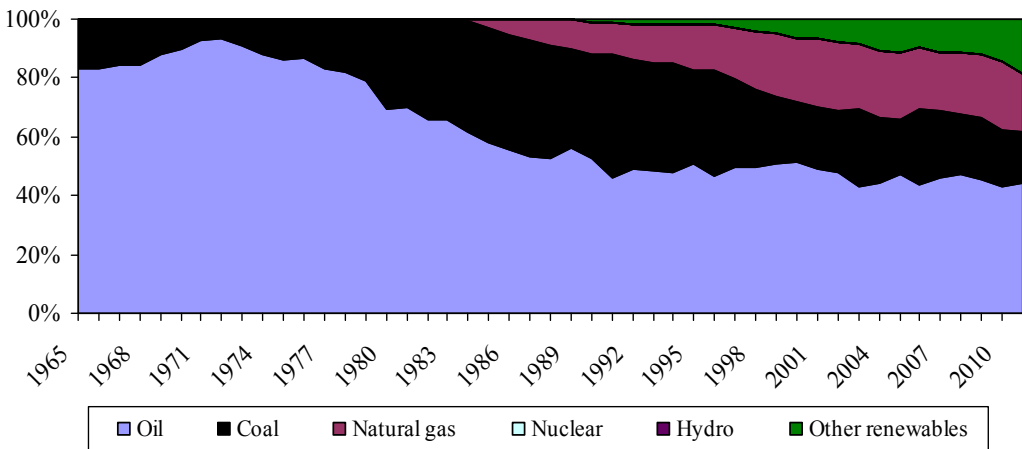


Fig. 1. The structure of primary energy sources in Denmark in 1965-2011 (BP, 2012)

- an introduction in the 1980s of natural gas which gradually took over a significant part of the coal and oil share,
- promotion of renewable energy sources which – particularly in the last decade – replaced coal significantly.

Today, Denmark's energy sector features a diversified structure of primary energy sources. Despite the decrease in oil importance, it continues to have the largest share (44% in 2011) in Denmark's energy balance (BP, 2012). Next to this fuel, over 15% of the share belongs to coal, gas and renewables together. It needs to be emphasized that the share of renewables in the production of electricity in Denmark is one of the largest in the world, which is related to a high social support for this kind of energy.

The production of electrical energy from renewables and coal as key sources is less diversified. Apart from those fuels, gas had a significant share (16.5%) in the production of electricity in 2011. In the past decade, rapid changes in the structure of electrical energy sources were observed which were connected with a constant increase in the share of renewables. The fact that in 2000-2011 the consumption of renewables in the production of electrical energy increased by 154.2%, and the consumption of oil, gas and coal decreased respectively by 89.9%, 33.8% and 16.2%, shows the scale of those changes. As a result of those changes in 2000-2011, the share of renewables (mainly biomass and wind energy) in the production of electrical energy increased from 15.4 to 40.3% (Fig. 2).

The dynamics demonstrates a strong determination of the Danish energy sector to modernize. This was possible thanks to a change of the public attitude and economic decision makers towards the subject of energy policy. The oil crisis made all the entities aware of the importance of energy management and the necessity to actively shape the energy policy.

In order to update the energy policy aims, every few years subsequent versions of the policy guidelines are published, which point at the current needs and tools for the implementation of objectives (Lipp, 2007). Apart from the plans for Denmark's energy policy devised by government departments, the plans prepared by teams of independent scientists were of critical importance.

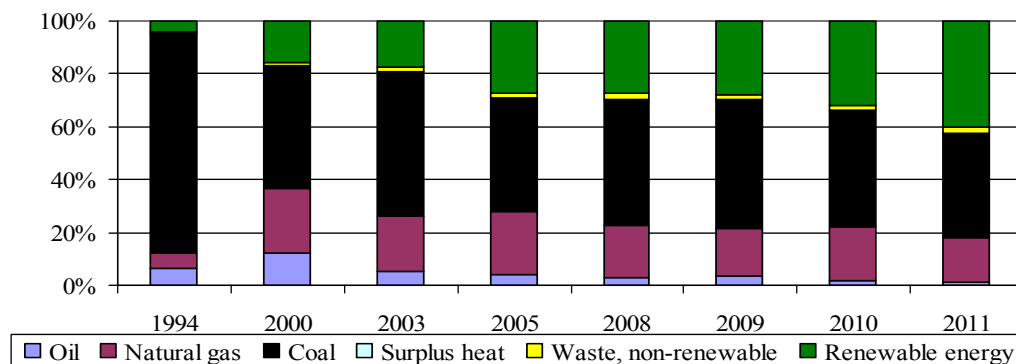


Fig. 2. The structure of energy supplies consumption in the production of electrical energy
 Source: DEA, 2012b

Their studies made the society aware of a choice of options for the energy sector (Lund, 2000, 2010), as well as a need for a real discussion between supporters of different variants (Table 1).

What is also crucial is continuity of the Danish energy policy, related to a consensus that was reached between the industry representatives, the government departments and the society, with regard to directions of Denmark's future energy policy. It contributed to a consistent implementation of changes to the energy policy in accordance with the adopted course.

One of the key factors enforcing modernization of the Danish energy sector was also the change in the attitude of the society towards the pursued energy policy in Denmark. The opinion that dominates in today's society is that their energy policy should be based on the idea of a balanced and sustainable development. This direction has been particularly strongly visible in Denmark since the end of 1980s, after the publication of a report of the World Commission on Environment and Development (the so-called Brundtland Report).

In that period, Denmark was suffering from significant emissions of air pollution, which resulted from the implementation of the Energy Plan 81 goals, whereby the role of coal increased. As a result of the society's increasing awareness concerning the environmental consequences of energy management, in the 1990s efforts were made to decrease energy consumption. What was crucial to this objective was the acceptance of regulations in 1988, which forbade electrical heating installations in new buildings that had access to a heating grid or gas network (Jacobsen, (http)). The regulations caused lower consumption of coal, which was the main source of electrical energy at that time, and at the same time the source of air pollution.

Furthermore, the new regulations also had an influence on the decrease in the fuel's imports. They promoted the development of heating networks through the combustion of natural gas in cogeneration installations, with gas deposits guaranteeing independence from imports of raw energy supplies. Another benefit from the implementation of the regulations was the improvement of the country's balance of payments and the increase in natural gas consumption.

The fundamentals of selected plans for changing Denmark's energy policy

	Characteristics of plans
<i>Danish Energy Policy, 1976</i>	<ul style="list-style-type: none"> – taking actions to enhance the country's energy security, reducing the country's reliance on oil supplies through diversification of the structure of energy sources – decreasing the demand for energy through an increase in its efficiency – construction of nuclear installations and popularization of natural gas
<i>Alternative Energy Plan for Denmark 1976</i>	<ul style="list-style-type: none"> – an alternative energy plan designed by independent researchers in response to the guidelines of the Danish Energy Policy – initiatives for reducing energy consumption, cogeneration development and popularization of renewable energy sources instead of nuclear energy – the plan allowed for a real discussion between supporters of alternative ideas for changes in the energy sector
<i>Energy Plan 81, 1981</i>	<ul style="list-style-type: none"> – the issue of the country's energy security was sustained and attention turned to the matter of interrelationship between economic development and the increase in demand for energy – four alternative options were proposed, which included: increasing the significance of nuclear energy, focusing on the development of renewables, taking actions to reduce the consumption of energy, as well as increasing the share of natural gas in the sector – it was concluded that a possible decision concerning the construction of nuclear power plants would be made following a positive result of a referendum – in 1985 the Danish parliament, responding to the public expectations, decided to ban any construction of nuclear installations in Denmark
<i>Energy Action Plan, 1990</i>	<ul style="list-style-type: none"> – it was devised by three independent researchers involved in the range of issues in the energy sector – initiatives in this sector should be focused on reducing energy consumption and popularization of cogeneration and renewables
<i>Energy 2000, 1990</i>	<ul style="list-style-type: none"> – the priority of Denmark's energy policy was to decrease the emission of CO₂ by 20% by 2005 in comparison with the emission levels from 1988. – actions to achieve a set objective should be aimed at reducing primary energy consumption by 15% by 2005, in comparison with the consumption level from 1988, as well as at increasing the significance of natural gas and renewables in the country's energy balance – the introduction of a ban to build new fully or partly coal-fired power plants
<i>Energy 21, 1996</i>	<ul style="list-style-type: none"> – simultaneous reduction of primary energy consumption and the emission of air pollution – the increase of the share of renewables in the energy balance to 12-14% by 2005, – taking into consideration the unused potential of wind power plants as sources of electricity – making a decision about building coal-fired power plants dependent on the development of the CCS technology (<i>Carbon Capture and Storage</i>).
<i>A Visionary Danish Energy Policy 2025, 2007</i>	<ul style="list-style-type: none"> – reducing non-renewable fuels consumption by a minimum of 15% by 2025 with respect to the current level – counteracting an increase in energy consumption and a simultaneous creation of conditions for the economic development – increasing renewables consumption in the energy-mix by 30% by 2025 – doubling the expenses for research on the development of energy technologies by 2010

Source: a study based on Lund (2000); Maegaard (<http://>); Krenz, 2011.

Making the public aware of ecological consequences of the implemented energy policy helped increase the support for the development of environmentally friendly sources of energy. The Danish society is ready to bear higher costs of energy provided that it would contribute to the protection of the environment. Amongst others, the implemented tax reform of 1992 – concerning the energy management – helps to increase the importance of renewables in the energy balance. The reform introduced a tax on conventional fuels, with a simultaneous exemption of renewables, causing a reduction in the consumption of conventional fuels. The essence of the reform was to oblige all groups of consumers, including home consumers, to pay a tax whose rate had been made dependent on the level of CO₂ emissions caused by fuel combustion. This tax is a way of transferring the cost of external effects (externalities), i.e. caused by the consumption of primary energy supplies, on the final consumer.

Despite the access to its own oil resources, which seems to guarantee the country's energy security, Denmark nowadays does not attempt to give this fuel such importance it had prior to the oil crisis. It is a result of a conscious choice to reduce the utilization of conventional fuels.

3. The modernization of the energy sector vs. Denmark's energy security

The transition of the energy policy led to Denmark's higher energy independence, which was related mainly to the use of oil and gas deposits at the beginning of 1980s. At first, these resources were prospected for by the Danish company A. P. Moller, which had obtained exclusive rights to do so. Starting from 1981, the company was obliged to release their rights in areas not explored by them or in areas not planned for exploration. This fact enabled other enterprises to prospect for resources. As a result, several new deposits of oil and natural gas were discovered (Czarny, 2008).

As a result of the undertaken exploratory operations, in 1997, Denmark's energy sector became fully self-sustainable for the first time² (Fig. 3).

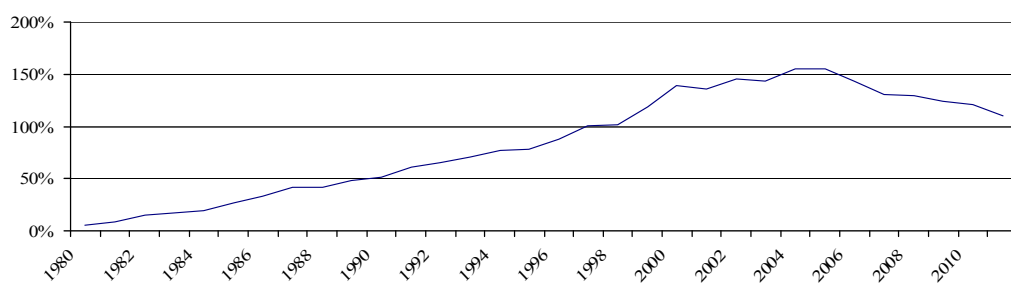


Fig. 3. Denmark's reliance on the import of energy supplies [%]

Source: DEA, 2012b

The deposits also enabled the country to export energy resources, thanks to which Denmark is currently the second largest oil exporter and the sixth natural gas exporter among the EU countries (BP, 2012). In subsequent years, due to depletion of the resources, Denmark's position

² Already in 1993, oil production exceeded its consumption in Denmark, which allowed for exporting this fuel.

as a major exporter of energy resources on the EU energy market may weaken. Because of the mentioned depletion of Denmark's own gas resources, projects aimed at enabling the import of gas from Germany are being prepared, which necessitates preparation of the necessary infrastructure. These projects will eliminate the isolation of the Danish gas market.

Denmark, being a major EU oil and gas exporter, is a significant coal importer as well. To secure uninterrupted supplies of coal, it is imported from several countries (Russia, Poland, South Africa and Colombia), which helps avoid the dominant position of one supplier. Denmark also has loading ports at its disposal, adapted to large-scale coal imports.

It needs to be emphasized that the increase in the role of coal noted since the 1970s was connected with its combustion in high-efficiency energy installations, as well as with the development of appropriate energy technologies. Thanks to these initiatives, Danish coal power plants were among the highest in efficiency power plants in the world at the end of the 20th century. The infrastructure was also adjusted to capture a large part of air pollution (Czarny, 2008). Despite the development of coal technologies, beginning from the last decade of the 20th century, the importance of coal was rapidly decreasing, which was caused by the efforts to limit the emission of air pollutants. This transition is particularly strongly illustrated by the fact that in 1990-2011 the consumption of coal decreased by 46%, which is related to the pursued policy leading to the removal of fossil fuels from the energy-mix.

Starting from the last decade of the 20th century, a growing share of renewables is being observed, which contributes to Denmark's energy security. In subsequent years, according to the priorities of the Danish policy in this matter, the significance of these fuels in ensuring the country's energy security will grow. This attitude is connected with social expectations, according to which Denmark's energy policy shall facilitate the implementation of an idea of a balanced and sustainable development.

The pursued energy policy not only contributes to better standards of living, but also improves the competitiveness of Denmark's economy through the development of energy technologies and increased exports of products from the industry working for a "green economy". As a result of the development of energy technologies, about a third of wind turbines installed in the world currently come from Denmark (EREC, 2009). The sale of technologically advanced products of the Danish energy industry is a source of 11% of income coming from the exports (*The Danish...*, 2012). The development of technologies concerning wind turbines, biomass and the production of the second generation bioethanol is of particularly great importance. It is estimated that the industry, geared for the production of wind turbines in Denmark, employed 28 400 people in 2008 (CEPOS, 2009), which significantly influenced the Danish labor market and helped obtain public support for renewables. The strong position of companies producing technologically advanced products for the "green economy" facilitates an increase in employment in Danish businesses and ultimately leads to the growth of the society's income.

Undoubtedly, these factors influence the support, coming from the public and economic decision makers, for the environmentally friendly solutions in the pursued energy management. The export of energy technologies and the creation of workplaces in the energy sector is a source of additional benefits from the environmentally friendly energy policy.

The key importance for Denmark's energy security and its competitiveness lies in the expansion of power transmission grids and connections of the Nordic countries to energy networks. These investments contribute to increased reliability of supplies and facilitate the transmission of energy between the Nordic countries allowing them to obtain income from the transition of electricity from the Nordic countries to the countries of Central Europe.

4. The energy intensity of Denmark's economy

The transition of the energy policy also involved a radical decrease in the energy intensity of the economy, due to a much higher efficiency rate of processing energy supplies than the average of the EU countries (Table 2).

The high efficiency is related to the energy policy aimed to protect the environment from the consequences of the adopted energy management and to enhance energy security by reducing the demand for energy supplies. As a result of consistent actions in the energy sector, Denmark managed to separate the increase in demand for energy from the economic growth, which is a rare phenomenon among the economically developed countries. The changes in the implemented energy policy allowed the country to maintain the primary energy consumption at the level from before the oil crisis alongside a considerable economic development³.

TABLE 2

Selected data concerning energy sectors of EU and Nordic countries in 2007

	EU-27	Sweden	Finland	Denmark	Norway
Energy consumption per unit of GDP [toe/M€ '00]	169	156	230	106	129
The reliance on imports of energy supplies [%]	53.1	36.1	53.8	-25.4	-664.9
Energy consumption per capita [kgoe/cap]	3 641	5 527	7 115	3 757	5 884
CO ₂ emission per capita [kg/cap]	9 066	6 694	13 095	10 895	10 249

Source: EU, 2010.

The importance of the matter of energy intensity is shown by the fact that beginning from 1980s, the transport industry, whose share in the structure of final energy sources is higher than the average of the EU countries, was the only area of economy where energy intensity has increased (Fig. 4).

The investments increasing the extent of building insulation, which helped reduce the demand for heating energy, were of particular importance in the initiatives aimed at lowering the energy intensity. Apart from these actions, it was greatly important to increase the significance of cogeneration, which, due to its high efficiency, is a source of relatively cheap electrical and heating energy. The popularization of this solution influences an increase in the consumption efficiency of energy resources, thus limiting the demand for primary energy. It is also crucial to reduce greenhouse gases emission levels related to the decrease in consumption of fuels.

Concerning the development of cogeneration, it was necessary to create a market for district heating, which meant that Denmark needed to expand its heating network. Thanks to the investments in the sector in 2010, 61% of households were connected to district heating (DEA, 2011). Increasing the significance of centralized energy sources was connected with a tariff policy directed at the promotion of district heating as a price-competitive source of energy, and a long-standing practice of gradual development of heating companies (Lund, 2000). These factors caused a rapid increase in cogeneration, indicated by the growth of district heating share from 39% in 1980 to 80% today, as well as an increase in the share of electrical energy produced in cogeneration from 18% to 53%, which was registered at the same time (DEA, 2011).

³ In 1980-2011, Denmark's GDP increased by 69.2%, whereas primary energy consumption decreased by 0.8% (EREC, 2012).

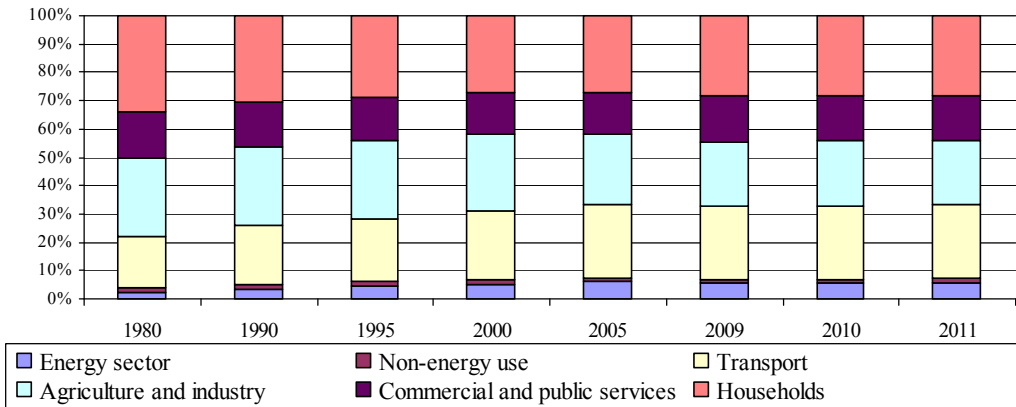


Fig. 4. The structure of final energy consumption in 1980-2011 in Denmark.
 Source: DEA, 2012

Despite the high economic efficiency of Denmark, its level of greenhouse gases emission is considerably higher than the average of the EU countries. Such a high level results from maintaining a significant share of conventional fuels in the energy balance of the country. The speed of modernization in the sector and its direction indicates that a rapid reduction of the scale of harmful emissions is going to take place in the following years.

5. The liberalization of the energy sector

The Danish electricity market, similarly to the markets in the other Nordic countries, is fully liberalized and constitutes a part of the integrated Nordic energy market. Liberalization undertaken in Denmark was a response to the changes which had been taking place in the rest of the Nordic countries. That is why the liberalization reforms of the Danish energy sector were introduced relatively late. This market liberalization was connected mainly with the Danish companies striving to participate in the trade exchange on the more liberal markets of the remaining Nordic countries (OECD/IEA, 2005).

The Energy Act, accepted in 1999, served as a basis for deregulation causing the Danish energy market to open faster than the UE directives required. Since January 2001, the market has been liberalized for consumers using over 1GW of energy per year, and since January 2003, the energy market has been freed for all consumers. Nowadays Denmark is a full member of the completely liberalized Nordic energy market.

Beside the benefits of trade exchange with the rest of the Nordic countries, the liberalization enhanced Denmark’s energy security, because of its support, amongst others, for the creation of the Nord Pool energy market, the elimination of payments for cross-border electrical energy transactions, the appointment of operators of transmission systems, managing electrical energy networks, as well as a close cooperation between these operators (Hellmar & Warell, 2009).

The liberalization of the energy sector was connected with changes in the way its companies functioned. For this reason Denmark used the experience of other countries, which already in

the 1990s carried out liberalization reforms based on the deregulation of parts of the sector with a simultaneous strict control of such areas which cannot be liberalized completely (Frączek & Kaliski, 2009). Prior to liberalization, the functioning of the Danish energy sector was based on a strict control of all companies involved in the production of energy, its transmission and distribution. The essence of this control was that companies had to relinquish profits from the pursued business activity (the non-profit principle) (Hauch, 2001). This attitude did not encourage energy companies to increase their efficiency, and consequently it was not reflected in any reduction of energy prices for final consumers. The liberalization process involved some competition between market participants, which had an impact on the improvement of the efficiency of the enterprises. The actions improved the quality of service for final consumers and reduced prices for them.

The activities of market regulatory authorities had a great influence on the improvement of the efficiency of energy companies. By performing comparative analyses, they forced the Danish energy sector companies to improve their performance (Jamasp & Pollitt, 2001; NEP, 2009; DERA, 2011). The increase in efficiency in turn influences the enhancement of competitiveness of the Danish economy.

Deregulation processes also affect the natural gas market in Denmark. The introduction of Gas Directive (98/30/EC) served as a basis for these actions. Its implementation was related to the introduction of the Natural Gas Supply Act in 2000, which regulated the way of functioning of the Danish gas market. The implementation of this act led to market. Since 1.01.2004 all consumers have obtained the right to choose their supplier.

To ensure competition on the gas market, since 2005 the market regulatory entity (DERA – Danish Energy Regulation Authority) has introduced an obligation to sell some share of gas (20% in 2010) through the largest mining consortium (DUC – Dansk Underground Consortium). Another important element of the liberalization of the gas industry in Denmark was the creation of gas exchange (Nord Pool Gas) in 2008. Since 2012, the sole owner of this exchange has been the national gas and electrical energy system operator (Energinet.dk). The creation of the gas exchange caused the development of competition and enhanced the transparency of the market (Pedersen, 2012).

6. Perspectives of Denmark's energy policy

Today Denmark undertakes activities related to the Energy Strategy 2050, which aims at the complete elimination of conventional fuels. This approach stems from the findings of the Danish Commission on Climate Change (called *Danish Commission on Climate Change Policy*), which in 2010 concluded that it is possible to gear towards such an energy policy that will allow for complete independence from solid fuels (*The Danish...*, 2011). In addition to eliminating dependence on conventional fuels, the other aims of the Danish energy policy until 2050 will be the following (*The Danish...*, 2011):

- increased security of energy supplies – a tough task since increasingly raw energy supplies tend to accumulate in countries with low political stability,
- reducing adverse climate changes being the result of human energy activity; it is assumed that by 2050 greenhouse gas emissions will have declined by 80-95% as compared to 1990 levels.

The increase in importance of renewable energy sources is also possible thanks to an agreement concluded in March 2012 between the Danish government, political parties and energy companies, assuming the achievement of ambitious energy policy objectives by 2020 including (Danish. ..., (http)):

- 12% reduction in energy consumption compared with the level in 2006,
- an increase to 35% of RES share in the final energy consumption,
- a gain of 50% of wind energy in the electrical energy consumption,
- reduction of greenhouse gas emissions by 34% compared to the 1990 levels.

The implementation of the agreement contributes to the enhancement of RES in the energy balance of the country and to the elimination of fossil fuels from the energy balance of Denmark. The long-term, until 2050, goal of the agreement is to meet total energy demand (electricity, heating, industry and transport) by means of renewable energy sources.

In order to achieve these objectives, the energy management must be based on the use of low-carbon energy sources, which is expected to contribute to the competitiveness of the Danish economy. This will, in particular, be associated with improved competitiveness of Danish companies operating in the field of energy technologies which will use environmentally-friendly technologies and will further increase the role of renewables in the heating of buildings.

Achievement of the objectives of the agreement provides for the introduction of taxes on all fuels used for heating, including renewable energy sources, which have so far been exempt from tax. The revenue from this tax will increase renewable energy subsidies. In addition, to reduce the consumption of oil and natural gas for heating purposes, from 2013 onwards these fuels will not be used for heating of new buildings (DEA, 2012).

It is also worth mentioning that the promotion of renewable energy must be linked to the issue of development of an electrical energy system and centralized sources of energy based on cogeneration. The cooperation of these sources will ensure continuous energy supply in the event of interruptions in the production of energy from renewable sources e.g. in windless weather.

7. Danish experience and modernization of the energy sector in Poland

In the following years, the Polish energy sector will have to undergo significant changes associated with the implementation of the energy and climate package provisions. This means that the dominant position of coal in the energy mix of the country will need to be gradually replaced by environmentally friendly energy sources. In subsequent years, this structure will change. This will result from both the recovered productive capacity of satisfying the requirements of the climate and energy package, and with the construction of new generating capacity needed to meet the projected increase in demand for electricity⁴.

In this regard, the country's main emphasis is placed on increasing the role of natural gas sourced from both conventional and shale deposits and on building the first nuclear power plant. These solutions are not associated with adverse environmental effects. Due to their favorable ecological characteristics, such options are supported in the developed economies.

⁴ Predictions show that by 2020 it will be necessary to build and overhaul installations of 12.7 GW capacity (c.a. 39.7% of the capacity installed in the country in 2006) (*Polityka...*, 2009; *EU Energy...*, 2009).

Currently in Poland, the role of natural gas is significantly lower compared with the EU average. Its growing importance in this country will depend, amongst others, on continued efforts to increase its production from domestic conventional deposits and on the new extraction of shale deposits as well as on the further liberalization of the industry (Rychlicki & Siemek, 2011; Nagy & Siemek, 2011).

An alternative option to modernization is the construction of the first nuclear power plant in the country. It should be noted that, taking into account the cost of gas emissions, and the cost of decommissioning of the reactors at their retirement, electricity produced from nuclear reactors is price-competitive to other energy sources (DECC, 2011; Vattenfall, 2003; IEA, 2010). Consequently, the competitiveness of the Polish economy will to a large degree depend on the progress of construction of the first nuclear power plant in the country.

The Danish experience in many aspects can be used in the modernization of the energy sector in Poland. Particular attention needs to be paid to reaching a consensus of all political forces in the country as to the directions of its energy policy. In the current, highly polarized political system, it seems an uphill task. The purpose of a long-term national energy policy must be clearly defined so it can contribute to a faster and more consistent implementation of the modernization works.

The Danish modernization experience of the energy sector can be a model for change in the gas sector in Poland. In particular, the experience of liberalizing the Danish gas industry is worth mentioning here, including the act of gas release program (Kaliski et al., 2012; Siemek et al., 2012). A further development of gas infrastructure and improvement of gas companies efficiency will matter too.

It is also necessary to make efforts for developing an extraction technology of natural gas from shale deposits, which in the future may:

- help obtain benefits from the sale of these technologies
- help reduce the import of energy technologies in the country thanks to access to their own solutions in these areas, which will improve the country's balance of payments and employment.

The Danish experience may also contribute to an increased importance of renewable energy in the national energy mix. So far the slow pace of growth in the use of RES in Poland shows that it is very difficult to ensure implementation of the assumed targets. This is mainly hindered by insufficient development of energy infrastructure, administrative barriers and lack of funds for investment in this area. An important obstacle is the low wealth of the society, which leads to relying on the cheapest possible energy sources with little regard for environmental consequences of their use.

The Danish experience may prove that the basis for increasing the role of renewable energy in the national energy mix should be through the use of tax instruments, and raising public awareness about the consequences of burning conventional fuels in the country.

It should be noted, however, that the high cost of energy from renewable energy sources may ultimately reduce the competitiveness of the national economy.

8. Conclusion

The reform of the Danish energy sector was spurred by the need to counteract the consequences of the oil crisis in the 1970s and by the change in public attitudes to their energy policy

and the related expectations that the new energy policy should contribute to the concept of sustainable development. These actions led to the overall change in the energy policy.

The policy change was associated with the growing public awareness of the environmental consequences of pursuing the existing energy policy and the realization of a choice of options. This high public awareness led to support for modernization and acceptance of the costs of those activities resulting in higher prices of final energy. A consensus of political forces, industry and broad sections of society as to the direction of energy policy changes in the country was also important.

Of key importance in the carried out modernization was a consistent and active role of state institutions working towards a change in the energy mix, reduced dependence on oil and lower energy consumption. In so doing, the state institutions cooperated with different actors involved in the implementation of the energy policy.

What facilitated the change was the long-standing tradition of developing heating plants. Modernization works increased the availability of district heating, which allowed for the creation of a market for heat produced in cogeneration. The development of high-energy technologies, including technologies for cogeneration also played a part.

The technological changes were accompanied by liberalization reforms of the Danish energy sector. Their conduct has contributed to improving the country's energy security and increased the efficiency of the energy sector enterprises, consequently reducing energy prices for end users.

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