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ENERGY TRANSFORMATION AND INNOVATIVE LOW-CARBON ENERGY POLICIES IN SWEDEN

Introduction

The aim of the article is to demonstrate how the strategy of renewable energy development and low-carbon energy sources influences improving the Sweden energy security, and to which extent it stimulates the country's economy while reducing GHG emissions. The intention of the research is to show how environmental objectives are linked with economic objectives and how energy ecological transformation policy pursues economic objectives. Adaptation of the energy sector to climate changes becomes a catalyst for the Sweden economy modernization. Energy transition based on renewable sources, energy saving and efficiency, brings socio-economic benefits and increases energy independence and flexibility of the energy system. The analysis results show that the Swedish energy sector can be a model for countries that want to transform energy sector and diversify the national energy mix. The structure of the article includes the presentation of the achievements of the Nordic countries in the development of carbon-free energy sources, conditions of modernization of the energy sector of Sweden and the Swedish assumptions for energy system "eco-transformation".

Norden countries accomplishments in the development of carbon-free energy sources

The Scandinavian countries are strongly involved in activities aimed at protection of the natural environment and their energy safety relies on renewable energy sources (RES) to a great extent². Such approach has created an internationally

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² Scandinavian countries are Denmark, Sweden and Norway and some of Nordic countries - Finland and Iceland, therefore term Norden / nordisk is considered a more appropriate as it covers these five countries and their autonomous territories, compare with: Ryszard, M. Czarny, *Razem jesteśmy silniejsi. Świat Norden w trzynastu odsłonach*, (Kielce: Scandinavium, 2014) 10-11.

recognized image of environmentally friendly countries, involved in climate protection. This refers to the use of forces of nature to produce energy (hydro, solar and wind power), as well as recycling and broadly-understood investments in low-emission energy sources. These countries developed business activity which may be called an “environmentally friendly industry”, which entails a restricted role of fossil fuels and other non-renewable resources in the *energy mix* and their replacement by low-emission energy sources. Energy transformation is a great challenge, but it also creates great opportunities. Popularising low-emission energy sources is conducive to improvement of energy safety. An increase in the share of renewable energy sources in the general energy balance, decreases the country’s dependence on the import of fossil fuels and also offers economic benefits that result from export of energy-saving devices and systems.

The Scandinavian countries are an excellent example of using low-emission energy sources. The country that has the highest level of renewable energy sources in the energy balance is Norway, where two-thirds of consumed energy derive from RES and make this country a world leader with respect to the share of renewable sources in the country’s *energy mix*³. Moreover, 99% of all power production in Norway comes from hydropower. The remaining slight portion is generated from fossil fuels and other renewable sources, including wind and biomass⁴. Norway also implemented a trading system in carbon dioxide emission allowances. On 1 January 2012, a common Norwegian-Swedish certificate market for renewable electricity production was established.

A country well-known for a significant share of wind energy in the production of electric energy is Denmark⁵. Denmark is the first country in the world with respect to the power of wind turbines per capita: 863 W per capita⁶. In July 2015, wind farms produced the amount of energy corresponding to 116% of energy demand of the Danish economy during the daytime, whereas at night-time, energy production reached 140% of the demand. Energy surplus was sent via interconnectors to Norway, Sweden, and Germany. In 2014, wind power in Denmark covered 39% of the demand in the Danish energy mix (whereas in 2005, this was 19% only)⁷. Approximately a half of electric energy consumed in this country derives from offshore wind turbines. In Iceland, hydropower and geothermal sources are used to heat houses (geothermal waters heat over 90% of buildings in Iceland). Solutions

³ Tomasz Młynarski, Marcin Tarnawski, *Źródła energii i ich znaczenie dla bezpieczeństwa energetycznego w XXI wieku*, (Warszawa: Difin, 2016), 142-143.

⁴ “Norway”, Country Analysis Briefs, Energy Information Agency, 30.09.2015, retrieved 16.08.2016 <https://www.eia.gov/beta/international/analysis.cfm?iso=NOR>.

⁵ In 1990, Norway, Sweden, Finland and Denmark integrated their electricity markets into the Nordic region single market.

⁶ “Renewables 2014 Global Status Report” (Renewable Energy Policy Network for the 21st Century, 2014), 33; “Renewables 2015 Global Status Report” (Renewable Energy Policy Network for the 21st Century, 2015), 20.

⁷ “EU energy in figures” (Statistical Pocketbook 2015) 182-183.

applied in Iceland are not only environmentally-friendly but also economically beneficial.

Norden countries possess significant experience in the technological application of biomass, obtaining biomass from timber industry waste, reduction in energy consumption and looking for innovative solutions in this respect. Biomass plays a significant role in the final consumption of energy, making up over 25% of Finland's and Sweden's *energy mix*.

Particularly favourable conditions in terms of forestation has Finland- the most forested country in Europe. The country also aims at a replacement of mineral fuels in road transport with biofuels and plan that by 2030 their usage in the road transport sector will be 40%. These are so called 2nd generation biofuels based on the conversion of domestic wood as a raw material⁸. The long-term goal for the Finish government is a carbon-neutral society to be achieved in the next few decades, and specifically an 80-95% reduction in greenhouse gas emissions by 2050. In practice, it means the elimination of almost all emissions from the energy consumption. Detailed governmental program to meet this goal is under preparation but the main strategy is already known. It involves an increase in energy-efficiency and the use of renewable energy⁹. Finland has an ambitious renewable energy program and aims to meet 38% of its final energy consumption from renewable sources by 2020¹⁰.

The Nordic region also largely benefits from the emission-free nuclear power. Sweden and Finland are among countries, which based its energy mix on nuclear energy in electricity production with its participation of 34.6% and 41.5% respectively.

Replacing hydrocarbons with RES is one thing, and the reduction of emissions is the second hallmark policy of Scandinavian countries. Scandinavia has managed to reduce its carbon emissions and achieve considerable economic growth. Societies of countries like Denmark and Sweden have chosen a way a sustainable economics and significant reliance on limitless natural resources, gradually moving towards reducing its CO₂ emissions. For example, Denmark's economy grew by 45% from 1990 to 2007 and its CO₂ emissions were reduced by more than 13%¹¹. Similar in Finland and Sweden where GHG emissions were decoupled from the gross national

⁸ "2nd Generation - the biofuel carbon is derived from cellulose, hemicellulose, lignin or pectin. For example this may include agricultural, forestry wastes or residues, or purpose-grown non-food feedstocks", in: "Advanced Biofuels in Europe", European Biofuels Technology Platform, retrieved 30.08.2016, <http://www.biofuelstp.eu/advancedbiofuels.htm>.

⁹ Lea Gynther, Saara Elväs, *Energy efficiency trends and policies in Finland*, (ODYSSEE-MURE, 30.09.2015), 12-13.

¹⁰ Tina Koljonen, "Impacts of the 2030 targets on Finnish energy systems and national economy", EERA JP e3s expert workshop, 15.01.2015, Brussels, Research Team Leader VTT Technical Research Centre of Finland, retrieved 16.08.2016, http://www.eera-set.eu/wp-content/uploads/1As_Finland_Koljonen_15-1-2015.pdf.

¹¹ "We can learn a lot about clean energy from Scandinavian nations", Blue & Green Tomorrow, 26.02.2013, retrieved 22.08.2016, <http://blueandgreentomorrow.com/features/clean-energy-scandinavian-nations>.

product growth¹². Between 1990 and 2013 Swedish the economy grew 58% while emission reduction reached 22%¹³. Sweden has also reduced its fossil fuels imports since 1973 and is planning to become oil-free in the not-too-distant future. The Swedish government has launched a multi-billion dollar program to promote renewable energy, whose output in the country has risen from 33.9% in 1990 to 43.3% in 2009¹⁴. Overall the Nordic countries seem to have embraced the concept of a clean energy more than others in Europe.

The oil crisis and modernization of the energy sector in Sweden

Sweden is a country without own hard coal, natural gas, and petroleum resources. Apart from hydropower, it does not possess any other significant energy sources, thence it depends on their import. The world petroleum crisis in the 1970's shook the energy policy in Sweden. At that time, it was one of the few industrialized countries so greatly dependent on petroleum usage¹⁵. Sweden gradually started to undertake activities aimed at withdrawal from the use of petroleum. In 1974, the Swedish parliament decided to decrease energy dependency on petroleum, opting for the nuclear power¹⁶. In the 1970's, Sweden launched six nuclear reactors¹⁷. A great amount of electric energy is produced by hydro plants which were built between 1940 and 1980. In consequence, the *electricity mix* is dominated by these two sources of energy.

In the modern times, nuclear energy and RES make up 73% of the energy consumed in Sweden.¹⁸ The country has ten operating nuclear blocks at its disposal, which provide 35% of the electric energy produced (2015)¹⁹. In Sweden, consumption of electric energy per capita is one of the highest in the world, primarily on account of its common use for heating houses²⁰. Soon after the failure of American power plant *Three Mile Island* in 1979, Swedes decided (via

¹² "Finnish climate policy – towards a low-carbon and energy-efficient future", Ministry of the Environment, Ministry of Agriculture and Forestry and Ministry of Employment and the Economy 2015, 15, retrieved 30.08.2016, https://ilmasto-opas.fi/ilocms-portlet/article/8a54c390-fed4-42da-a2c2-4bab74993ebd/r/b844a8fb-f69d-4c20-a506-cf17ac9f5a9e/suomen_ilmastopolitiikka_rgb_en.pdf.

¹³ "Climate is key for Sweden, Facts about Sweden, Environment", The Swedish Institute, June 2015, 3, retrieved 22.08.2016, www.Sweden.se.

¹⁴ "We can learn a lot about clean energy from Scandinavian nations", Blue & Green Tomorrow, February 26th, 2013, retrieved 22.08.2016, <http://blueandgreentomorrow.com/features/clean-energy-scandinavian-nations>.

¹⁵ In the 70s of the twentieth century, 75% of energy usage was based on imported oil. In 2013 the share of crude oil in domestic energy consumption was only 24%, ref. to: "EU energy in figures", 228.

¹⁶ Tomasz, Młynarski, *Energetyka jądrowa wobec globalnych wyzwań bezpieczeństwa energetycznego i reżimu nieprolifacji w erze zmian klimatu*, Kraków 2016, 169.

¹⁷ Ibidem, 169-170.

¹⁸ "EU energy", 228-229.

¹⁹ Sweden, IAEA, retrieved 20.08.2016, <https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=SE>.

²⁰ Sweden is among the countries with the highest consumption of energy, including electricity per capita in the world.

a referendum) on a gradual withdrawal from nuclear energy by 2010²¹. The decision was revoked at the beginning of the 1990's, and in 2010 the ban on construction of new nuclear reactors was abolished²². The Swedish parliament voted on maintaining the nuclear program, yet new nuclear power plants may be built only when one of the existing plants is closed down (the maximum number of power plants is not to exceed 10). The Swedish government explained the suspension of the moratorium for constructing nuclear reactors by the necessity of limiting the emission of greenhouse gasses and decreasing energy dependence from Russia²³.

Since the 1970's, Sweden has been intensely developing renewable energy. In consequence, it is a leader in the production of electric energy from renewable sources: 53% in 2013 (and only 5% of electricity is generated with the use of fossil fuels); in combination with the production of power in nuclear power plants (43%), this means that as much as 96% of the electric energy produced in Sweden derives from sources that do not emit CO₂²⁴. In 2015 the country's wind power electricity production reached a new record strongly supporting electricity exports. As a result, net exports from Sweden accounted for 22.6 TWh which was the largest number ever²⁵. Additionally, Sweden had the highest rate of renewable energy consumption in EU (35% in 2013)²⁶.

Approx. 60% of the demand for heat in households and the commercial sector is satisfied by RES, mainly bio-energy produced by individual installations and network heat (predominantly timber mass, waste from the paper industry)²⁷. The excess heat generated in the technological process is used in the heating system, which results in complete energy efficiency on the level of 90%²⁸. Sweden is a model for integrating waste management with energy policy, as bio-energy constitutes approx. 20% of the total energy consumption in the country²⁹. Timber industry and paper industry waste, as well as municipal, industrial and organic agricultural waste are used by biogas plants, which greatly reduces the carbon dioxide emission. An example of modern technology development is a plant in Goeteborg (Goeteborg Energi) which gasifies forest waste for the purpose of converting synthetic gasses,

²¹ Tomasz Młynarski, *Energetyka jądrowa...*, 169-170. Daniel Nohrstedt, "External shocks and policy change: Three Mile Island and Swedish nuclear energy policy", *Journal of European Public Policy*, 2005, 12(6), 1041-1059.

²² Staffan Jacobsson, Anna Bergek, Transforming the energy sector: the evolution of technological systems in renewable energy technology, *Industrial & Corporate Change*, October 2004, Vol. 13 No. 5: 827.

²³ Swedish nuclear power is facing major investment needs to meet future safety requirements to be implemented by 2020.

²⁴ 45% is produced from hydropower, and 11.7% from other RES, ref. to: "EU energy.." 228-229.

²⁵ "Large electricity production and record exports in Sweden, News from Vattenfall", retrieved 20.08.2016, <http://news.vattenfall.com/en/article/large-electricity-production-and-record-exports-sweden>.

²⁶ "EU energy", 228-229.

²⁷ "Renewables 2014 Global..", 33. In 2013, 10% of the electricity in the country was generated from biomass only.

²⁸ Ibidem, 37.

²⁹ "EU energy", 228. The Swedes are buying waste even from their neighbors, e.g. Norway.

hydrogen and carbon oxide, into biomethane, which is transferred to the network. At the beginning of the 1990's, Sweden invested in the so-called energy farming, i.e. cultivation of plants that are subsequently transformed into various types of fuels or incinerated offering thermal power.

The sector that strongly depends on the imported petroleum is the road transport. Swedes are aiming for a fleet of vehicles powered by non-fossil fuels (mainly bio-fuel and electric vehicles). This objective is an element of the Swedish vision of the zero-emission energy system by 2050³⁰. An important element of Sweden's energy policy is energy-efficiency, which decreases the costs of operation of the entire economy. It is worth noting that consumption of energy in Sweden has remained on a more or less similar level for the last 25 years, yet with a systematic growth of GDP.

Sweden tries to use such energy sources that do not contribute to the degradation of the natural environment and do not cause high emission of pollution to the atmosphere. The government has been systematically eliminating barriers thwarting the development of RES; for example, procedures for procuring permits were simplified, coordinated planning was implemented and biomass certification procedures were limited. The Swedish government also adopted the premise of the so-called "technological neutrality" – everything that was not fossil fuel was "renewable" fuel, i.e. everything that could be burnt. Products that were earlier considered waste and often posed a problem by generating utilization costs, became an important source of energy and income for companies selling, next to their traditional activity, waste and leftovers used as fuel or directly as energy. Local government also provided support via plans for managing own energy resources and appropriate tax policy, encompassing taxation of what was energetically inefficient and ecologically inappropriate (e.g. tax on energy, tax on consumed energy, green energy certificates)³¹. In 1991, a tax reform was conducted in relation to energy consumption, its effects included:

- the introduction of taxes that limited the use of fuels emitting carbon dioxide to the atmosphere;
- the introduction of a tax on carbon dioxide emission;
- tax reliefs regarding the use of energy carriers by industrial recipients and electric energy producers;
- no taxation on bio-fuels.

All these factors led to the limitation of pollution emitted to the atmosphere. In effect, the country's mitigation of its impact on the environment continues to rank among the best in the world, with comparatively low emission intensity and air and water pollution levels. As a result of energy transformation, Sweden has reduced the CO₂ emission by more than a half since 1971³². Modernization of the electric energy sector in Sweden limited the share of conventional fuels for the benefit of renewable

³⁰ Ibidem, 29.

³¹ Energy, carbon dioxide and sulphur taxes are regulated in the *Energy Tax Act* (1994:1776).

³² "CO₂ emissions from fuel combustion", International Energy Agency 2016 Edition, 48.

energy sources (biomass, hydropower) and nuclear power. Nowadays, Sweden is almost independent from foreign supplies of fossil fuel for production of electric energy and heat, with the exception of transport. In effect of long-term energy modernisation, where key issues included diversification of energy directions and sources, making environmental protection standards more rigorous and restrictions aimed at energy saving, as well as programmes intended to increase energy efficiency, dependency on energy import was decreased (to 31,6% in 2013) and CO₂ emission was reduced (between 1990 and 2013 by -28%)³³.

Assumptions of the Swedish "green transformation" toward a zero-emission

Sweden's aim is to ensure the reliability of electricity supplies and other energy carriers with a minimum impact on health, environment, and climate. The principles and priorities of Sweden's energy policy rely on such objectives as maintaining environmental balance, competitiveness, and safety of supplies. The hitherto premises of Swedish energy and climate policy were based on the following objectives³⁴:

- the share of RES on the level of 50% in total energy consumption by 2020; by 2040, the goal is 100% renewable electricity production,
- a 20% increase in energy consumption efficiency in comparison to 2008,
- reduction of greenhouse gas emission by 40% by 2020 in comparison to 1990.

Sweden's long-term ambition is to have a vehicle fleet that is independent of fossil fuels by 2030.

The aim of the transformation of the energy sector in Sweden is to ensure a sustainable system of energy supply in the long term from renewable sources. At the latest by 2045, Sweden shall not have net emissions of greenhouse gasses to the atmosphere and in the long term fully rely on renewable energy. Such approach would benefit not only future generations, but also support economy development allowing Sweden to become one of the world's first fossil-free welfare countries³⁵.

A broad political agreement supports changes to the country's energy policy. In June 2016 the Swedish government coalition together with a couple of the opposition parties presented a basic concepts for reaching ambition climate policy goals

³³ *EU energy in figures...*, 229; *CO₂ emissions...*, 48.

³⁴ "Energy in Sweden 2015", Swedish Energy Agency, December 2015, 74-75, available 25.08.2016, <https://www.energimyndigheten.se/globalassets/statistik/overgripande-rapporter/energy-in-sweden-till-webben.pdf>; *Agreement on Swedish energy policy*, Government Offices of Sweden, 16.06.2016, retrieved 25.08.2016, <http://www.government.se/articles/2016/06/agreement-on-swedish-energy-policy>

³⁵ "A climate policy framework and a climate and clean air strategy for Sweden", Government Offices of Sweden, 5.07.2016, available 28.08.2016, www.government.se/articles/2016/07/a-climate-policy-framework-and-a-climate-and-clean-air-strategy-for-sweden.

together with a road map for a gradual transition to an entirely renewable electricity system. According to it, Sweden aims to³⁶:

- reach 100% energy production from renewable energy sources by 2040,
- saving nuclear power in the long term and short term,
- allow for 10 new nuclear facilities to be built in place of the existing ones³⁷.

In addition by end of 2017, a specific goal for energy efficiency for the time period 2020-2030 will be worked out and be approved. The main focus of changes in the energy system will be on the introduction of a variety of large-scale and small-scale renewable installations adapted to local and industrial needs. Sweden will also apply a specific energy efficiency program for the electricity intensive industry. In order to speed up the energy system transition the Government proposes a significant increase in solar investment and support it with spending SEK 390 million per year during 2017–2019 on the expansion of solar cell plants (the program total budget SEK 1.4 billion)³⁸. Sweden also aims to development of a bio-based economy, in which new bio-based products from forests, agriculture or aquaculture can replace fossil-based products. Various instruments will be directed at improvement of a public transport system and the upgrade of the existing railways. The conceptual works taken by the Cross-Party Committee on Environmental Objectives involves also aggressive targets for the reduction of emissions outside the EU Emissions Trading System: by 2030, they should be at least 63% lower than emissions in 1990 and by 2040 the reduction should reach at least 75% lower than emissions in 1990³⁹. Reductions in emissions from domestic transport (excluding domestic air travel) of at least 70% by 2030 compared with 2010. Achieving the goals in the transport sector requires a combination of rapid electrification of passenger transport, a major expansion in usage biofuels, an increase of efficiency of goods transport and implementation of measures in urban areas benefitting public transport and bicycle and pedestrian traffic.

Sweden has the ambition of being a global role model on climate and air quality and a leading country in work to realize the ambitious goals of the Paris Agreement (taken during the COP21). The long-term climate goal for the country is to not have GHG net emissions by 2045 and after negative emissions will be attained (absorption). Consequently, emissions from activities on Swedish territory will be cut by at least 85% compared to 1990 levels, achieving just about one ton per capita in 2045⁴⁰.

³⁶ “Framework agreement between the Swedish Social Democratic Party, the Moderate Party, the Swedish Green Party, the Centre Party and the Christian Democrats”, the Swedish energy policy agreement of 10 June 2016, Government Offices of Sweden, retrieved 25.08.2016 <http://www.government.se/contentassets/8239ed8e9517442580aac9bcb00197cc/ek-ok-eng.pdf>.

³⁷ It is possible to grant permits for successively replacing current reactors as they reach the end of their economic life.

³⁸ “Investments in climate change adaptation and energy”, Government Offices of Sweden, retrieved 25.08.2016, <http://www.government.se/articles/2015/09/investments-in-climate-change-adaptation-and-energy>.

³⁹ Ibidem.

⁴⁰ *A climate policy framework and a climate...*

However, principles of the Swedish energy transformation policies encounter some criticism. Given the country's harsh climate demand for the electricity power significantly varies during the year from 10 GW in the summer to 27 GW in winter. Although already installed and planned capacities of renewable energy sources are large (about 30 GW), there is a risk that in the winter period these are insufficient to cover peak demand (the gap is estimated at 5-7 GW) due to the instability of the electricity generation from RES⁴¹.

Therefore additional actions are needed in order to avoid shortages, mainly through expansion of the import capacity, reserve power, possible demand control in some hours during a year, and extension of intrastate transmission capacity. The latter is critical for making maximum use of hydropower, as if it is fully utilized, the transmission grid from northern Sweden must be strengthened. Similar steps need to be taken to enlarge import capacities from countries outside of the Nordic region⁴².

Sweden will need to continue on growing usage of biopower as an energy source. Its importance will increase together with the more significant contribution of other renewables, as it is an energy source independent of the weather conditions. Therefore comes its crucial role to stabilize energy system.

Conclusions

Sweden since the 70s of the twentieth century has made a significant progress in the energy sector modernization based on the use of various renewable energy sources, widely supported by the society. As a result, the country strengthened national energy security, among others, by reducing the significance of imported fossil fuels and consistent application of waste management and making their efficient use as an energy source.

Sweden, similar to other Scandinavian countries is fully committed to building an energy system that in minimum extent interfere with the ecological system. Reliance on the energy mix from renewable sources and nuclear power allowed to avoid the burden of air pollution and contributed to the fact that the country is relatively safe in terms energy supplies.

From an economic viewpoint, the most efficient manner of supporting energy system transformation would be to keep using nuclear power until the end of its technical lifetime (approx. till around 2045). With a rapidly growing share of hydro, the wind and solar technologies in the country energy mix, stable and independent of weather conditions energy sources are of growing importance.

The main objective of the Sweden energy policy is to ensure sustainable energy supply system with a long-term vision of obtaining of all energy from renewable sources. The Swedes conducted a modernization of an energy sector in a comprehensive manner, and each investment is accompanied with alternative

⁴¹ Lars-Magnus Kihlström, "Can Sweden become fully renewable?", News from Vattenfall, 3.03.2016, retrieved 28.08.2016 <http://news.vattenfall.com/en/article/can-sweden-become-fully-renewable>.

⁴² Ibidem.

possibilities for generating energy, such as in the case of wind turbines associated with waste incineration plants to prevent interruptions in the supply of electricity. Due to the high public awareness and support for social changes carried out the Swedish energy sector can be a model for countries that want to transform their energy sectors.

Bibliography

1. "A climate policy framework and a climate and clean air strategy for Sweden", Government Offices of Sweden, 5.07.2016. Retrieved 28.08.2016, www.government.se/articles/2016/07/a-climate-policy-framework-and-a-climate-and-clean-air-strategy-for-sweden.
2. "Advanced Biofuels in Europe", European Biofuels Technology Platform. Retrieved 30.08.2016, <http://www.biofuelstp.eu/advancedbiofuels.htm>.
3. "Climate is key for Sweden, Facts about Sweden, Environment", The Swedish Institute, June 2015. Retrieved 22.08.2016, www.Sweden.se.
4. "Energy in Sweden 2015", Swedish Energy Agency, December 2015. Retrieved 25.08.2016, <https://www.energimyndigheten.se/globalassets/statistik/overgrip-ande-rapporter/energy-in-sweden-till-webben.pdf>.
5. "EU energy in figures" (Statistical Pocketbook 2015).
6. "Finnish climate policy – towards a low-carbon and energy-efficient future", Ministry of the Environment, Ministry of Agriculture and Forestry and Ministry of Employment and the Economy 2015. Retrieved 30.08.2016, https://ilmasto-opas.fi/ilocms-portlet/article/8a54c390-fed4-42da-a2c2-4bab74993ebd/r/b844a8fb-f69d-4c20-a506-cf17ac9f5a9e/suomen_ilmastopolitiikka_rgb_en.pdf.
7. "Framework agreement between the Swedish Social Democratic Party, the Moderate Party, the Swedish Green Party, the Centre Party and the Christian Democrats", the Swedish energy policy agreement of 10 June 2016, Government Offices of Sweden. Retrieved 25.08.2016 <http://www.government.se/contentassets/8239ed8e9517442580aac9bcb00197cc/ek-ok-eng.pdf>.
8. "Investments in climate change adaptation and energy", Government Offices of Sweden. Retrieved 25.08.2016, <http://www.government.se/articles/2015/09/investments-in-climate-change-adaptation-and-energy>.
9. "Large electricity production and record exports in Sweden, News from Vattenfall". Retrieved 20.08.2016, <http://news.vattenfall.com/en/article/large-electricity-production-and-record-exports-sweden>.
10. "Norway", Country Analysis Briefs, Energy Information Agency 30.09.2015. Retrieved 16.08.2016 <https://www.eia.gov/beta/international/analysis.cfm?iso=NOR>.
11. "Renewables 2014 Global Status Report" (Renewable Energy Policy Network for the 21st Century, 2014).
12. "Renewables 2015 Global Status Report" (Renewable Energy Policy Network for the 21st Century, 2015).

13. "We can learn a lot about clean energy from Scandinavian nations", Blue & Green Tomorrow, February 26th, 2013. Retrieved 22.08.2016, <http://blueandgreentomorrow.com/features/clean-energy-scandinavian-nations>.
14. "We can learn a lot about clean energy from Scandinavian nations", Blue & Green Tomorrow, 26.02.2013. Retrieved 22.08.2016, <http://blueandgreentomorrow.com/features/clean-energy-scandinavian-nations>.
15. *Agreement on Swedish energy policy*, Government Offices of Sweden, 16.06.2016. Retrieved 25.08.2016, <http://www.government.se/articles/2016/06/agreement-on-swedish-energy-policy>.
16. Czarny, Ryszard M. *Razem jesteśmy silniejsi. Świat Norden w trzynastu odsłonach*. Kielce: Scandinavium, 2014.
17. Energy, carbon dioxide and sulphur taxes are regulated in the *Energy Tax Act* (1994:1776).
18. Gynther, Lea, Elväs Saara. *Energy efficiency trends and policies in Finland*, (ODYSSEE-MURE, 30.09.2015).
19. Jacobsson, Staffan, Bergek, Anna. "Transforming the energy sector: the evolution of technological systems in renewable energy technology", *Industrial & Corporate Change*, Vol. 13 No. 5, (2004): 827
20. Kihlström, Lars-Magnus. "Can Sweden become fully renewable?", News from Vattenfall, 3.03.2016. Retrieved 28.08.2016 <http://news.vattenfall.com/en/article/can-sweden-become-fully-renewable>.
21. Koljonen, Tina. "Impacts of the 2030 targets on Finnish energy systems and national economy", 15.01.2015, Brussels, Research Team Leader VTT Technical Research Centre of Finland. Retrieved 16.08.2016, http://www.eera-set.eu/wp-content/uploads/IAs_Finland_Koljonen_15-1-2015.pdf.
22. Nohrstedt, Daniel. "External shocks and policy change: Three Mile Island and Swedish nuclear energy policy", *Journal of European Public Policy*, 12(6), (2005): 1041-1059.
23. Młynarski, Tomasz, *Energetyka jądrowa wobec globalnych wyzwań bezpieczeństwa energetycznego i reżimu nieprolifracji w erze zmian klimatu*, Kraków: WUJ, 2016.
24. Młynarski, Tomasz, Tarnawski, Marcin. *Źródła energii i ich znaczenie dla bezpieczeństwa energetycznego w XXI wieku*, Warszawa: Difin, 2016.
25. Sweden, IAEA. Retrieved 20.08.2016, <https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=SE>.

Abstract

Sweden, similar to other Scandinavian countries made a significant modernization of the energy sector since the 70s of the twentieth century has based on the use of various forms of renewable energy. As a result, national energy security was increased, among others, by reducing the share of imported fossil fuels. Sweden seeks to ensure reliability of electricity supplies and other energy sources together with limiting to a minimum their impact on health, environment and climate. The country is trying to use such energy sources that do not contribute to environmental degradation or cause high emissions of pollutants to the

atmosphere. The objective of energy security policy of Sweden is to provide a sustainable system of energy supply from renewable sources. Due to the high public awareness and support for social changes carried out the Swedish energy sector can be a model for countries that want to transform energy management and diversify the national *energy mix*.

Transformacja energetyczna i innowacyjne polityki niskoemisyjne w Szwecji

Szwecja podobnie jak inne skandynawskie państwa od lat 70. XX wieku dokonała znaczącej modernizacji sektora energetycznego w oparciu o wykorzystanie różnych form energii odnawialnej. W efekcie zwiększono bezpieczeństwo energetyczne kraju m.in. poprzez ograniczenie znaczenia importowanych paliw kopalnych. Szwecja dąży do zapewnienia niezawodności dostaw elektryczności i innych nośników energii z ograniczonym do minimum wpływem na zdrowie, środowisko i klimat. Kraj ten stara się korzystać z takich źródeł energii, które nie przyczyniają się do degradacji środowiska naturalnego ani nie powodują wysokiej emisji zanieczyszczeń atmosfery. Celem polityki bezpieczeństwa energetycznego Szwecji jest zapewnienie trwałego systemu zaopatrzenia w energię ze źródeł odnawialnych. Dzięki dużej świadomości społecznej i poparciu społecznemu dla przeprowadzonych zmian szwedzki sektor energii może być wzorem dla krajów, które chcą dokonać transformacji gospodarki energetycznej i dywersyfikacji krajowego *energy mix*.

Keywords:

Sweden, energy sector, transformation, low-carbon

Słowa kluczowe:

Szwecja, sektor energetyczny, transformacja

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