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-

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[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

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[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

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[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.

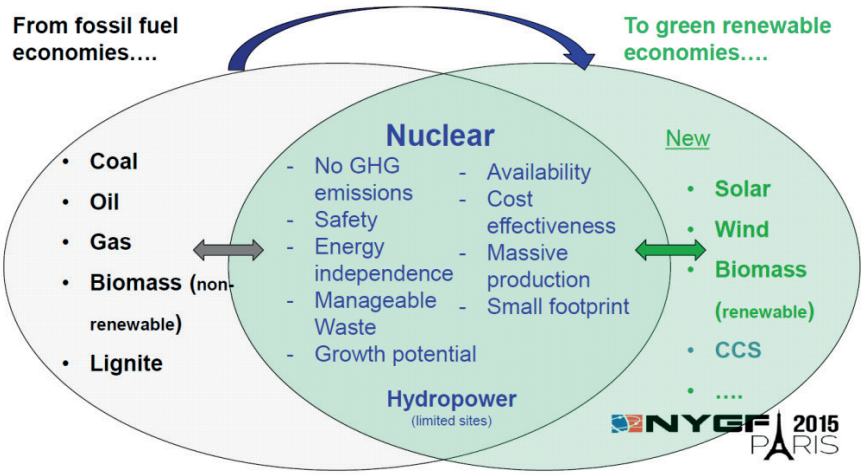
[148] *Greenhouse gas emissions avoided through use of nuclear energy*, http://www.world-nuclear.org/nuclear-basics/greenhouse-gas-emissions-avoided.aspx (accessed: 10.11.2016).

[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.