World Journal of Nuclear Science and Technology, 2013, 3, 123-130
http://dx.doi.org/10.4236/wjnst.2013.34021 Published Online October 2013 (http://www.scirp.org/journal/wjnst)

Nuclear Power for Poland

Andrzej G. Chmielewski
Institute of Nuclear Chemistry and Technology, Warsaw, Poland
Email: A.G.Chmielewski@ichtj.waw.pl

Received July 16, 2013; revised August 14, 2013; accepted August 22, 2013

ABSTRACT

The present situation in Poland and Europe, regarding electric power generation by source, is discussed in the paper. The results of the implementation of EU competitive-low-carbon economy policy in some most developed countries in the continent, have given already good experimental data for evaluation of this strategy. Analysis of the reports provided by official sources for Germany, Denmark and Finland is a base for EU energy policy evaluation. The combustion technologies will be a main energy sources for many years from now. Therefore effects of fossil fuels and biomass combustion on the environment are presented briefly. Finally, the developments regarding Polish Nuclear Energy Programme are overviewed.

Keywords: Energy Policy; Europe; Poland; Nuclear Power

1. Introduction

The energy policy is one of the most important issues for all nations and political structures such as the European Union. The EU is committed to reducing greenhouse gas emissions to 80% - 95% below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group. The Commission analysed the implications of this in its "Roadmap for moving to a competitive low-carbon economy in 2050". The scenarios in this Energy Roadmap 2050 explore routes towards decarbonisation of the energy system. Forecasting the long-term future is not possible. However the experiment regarding this policy implementation has already started in some most economically and technologically developed countries in Europe, like Germany and Denmark. Result of this experiment should be adopted to the roadmap as quick as possible, otherwise Europe may lose its pathway to the bright future. The power sector which provides electricity is a backbone of the contemporary economy. More precisely, the big blocks with capacity bigger than 500 MW_e are the crucial for the development of a civilization whose members will live and work in the big metropolises by the year 2050. At least 80% of the world population will be there. Unfortunately, the energy policy is run by politics and the quick-return economy. Looking at some energy programmes one may consider that thermodynamics is not any longer thought in the schools or that sustainable development is just a slogan which helps to buy an election.

2. Polish Power Sector

Poland is a growing European economy. However, energy consumption per capita is much lower than in "Old" EU countries. The same concerns electricity, which is well illustrated in **Figure 1** [1]. This is one of the limitations as the country's economic and social prosperity grows. Therefore, the growing demand for energy is expected (see **Table 1**) [2]. Production of primary energy in Poland is based mainly on fossil fuels. The first place belongs, and will most likely belong for a long time, to hard coal and lignite, which cover 56% of demand.

It is important to mention that even Poland is a big producer of hard coal, and imports of this fuel are growing year by year, from 1.05 Mtoe in 1995, up to 8.16 Mtoe in 2010. In 2008, for the first time in history, import exceeded export, and amounted to 10.1 million tones [3]. Crude oil also has a significant share of 25%. The worst situation concerns electricity generation, where almost 90% is based on the combustion of fossil fuels or biomass (see **Table 2** [4]).

Due to the fact that electricity production is based mostly on solid fuels combustion, the emission of pollutants is tremendous, the numbers are given in **Table 3** [5].

Control of pollutants emission makes coal combustion technology very expensive. The new regulations affecting even smaller boilers have to be observed in the EU by the year 2016. In addition, SO_2, NO_x, total fly ash, new pollutants such as non-methane hydrocarbons, mercury and

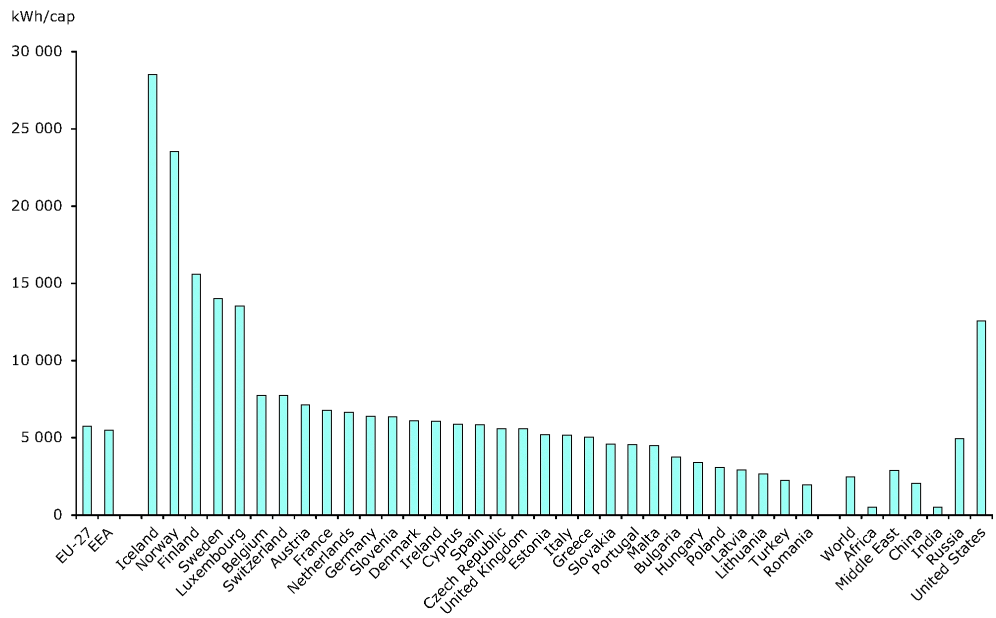

Figure 1. Electricity consumption per capita in different countries of the world [1].

Table 1. Forecast of demand for final energy by sector [Mtoe] [2].

Sector	**2015**	**2020**	**2025**	**2030**
Industry	19.0	20.9	23.0	24.0
Transport	16.5	18.7	21.2	23.3
Agriculture	4.9	5.0	4.5	4.2
Services	7.7	8.8	10.7	12.8
Households	19.1	19.4	19.9	20.1
Total	**67.3**	**72.7**	**79.3**	**84.4**

Table 2. Structure of power installed in electricity production sector, November 2011 [4].

EPS + EHPS (Hard coal fuel)	56%
EPS (Lignite fuel)	26%
EPS (Gas fuel)	2%
EPS (Hydro)	6%
Renewable (biomass combustion + wind)	7%
Others	3%

Table 3. Emission of pollutants from power sector in 2010 [5].

Pollutant	SO_2	NO_x	$PM_{2.5}$	VOC
[Mg]	509,847	287,324	14,337	18,257
PAH & PCB [kg]	Hg [kg]	Dioxins & Furans [mg i-TEQ]		
578	8,771	11,446		

PM 2.5 will have to be treated in the future. The effects of pollutant emissions are harmful to the environment and human beings. Loss of statistical life expectancy, attributed to anthropogenic contributions to PM 2.5, in some regions is equal to several months [6]. The emission of mercury from coal combustion in Europe is equal to 20 tons per year. The metalorganic compounds formed find their way into the human food chain [7]. Finally, non-methane cancerogenic volatile organic compounds (VOCs), including polyaromatic hydrocarbons (PAH), are emitted as well [8]. In 2020, the country will probably be forced to buy 100% CO_2 certificates, as sequestration will not solve the problem [9].

3. Europe: Lessons Learned

Europe has a dream: carbon-free electricity generation which, unfortunately, is and will remain a dream for this century. The tragedy is that the dreams cost too much. The share of installed electricity capacity by source is given in **Table 4** [10].

Analysis of this table shows that the share of installed capacity, based on combustion processes, is equal to 57.1%. Wood, municipal and industrial waste, biofuels and biogas combustion are counted as “renewable”, which is a joke, since a combustion process that is friendly to the environment does not exist. Cherubini and co-authors propose that CO_2 emissions from biomass combustion for bioenergy should no longer be excluded from Life Cycle Assessment studies, or be assumed to have the same global warming potential as anthropogenic CO_2 emission [11].

Therefore, the installed capacity of real clean renewables (hydro, wind, solar and geothermal) is equal to 27.4%, but the real input to the total share gives hydro (16.7%) and wind (8.7%). It is interesting that these

Table 4. Installed electricity capacity (*) and generation (**) in EU-27 by source [%].

Fossil fuels	Nuclear	Wood, waste	Liquid biofuels, -gas	Hydro	Wind	Solar	Geotherm.	Other
1	2	3	4	5	6	7	8	9
(*)54.0	15.4	2.4	0.7	16.7	8.7	1.9	0.1	0.1
(**)50.9	27.7	20.6 (so called renewables)						0.8

tragi-comic data seem to be well understood by the authors of the document, since the generation input for "renewables" is given as a total number only. 78.3% of electricity produced in EU-27, in 2010, came from fossil fuel combustion and nuclear power. Unfortunately, 23.6% of electricity production was based on gas combustion which does not agree with sustainable development philosophy. Gas is a raw material for chemical/other industries and household applications, and gas combustion in big power blocks should be considered as a crime against future generations.

Two countries in Europe pointed out as the leaders in the renewable energy utilization are Denmark and Germany. In Denmark in 2011, 39.7% of total electricity production was generated by coal. Natural gas accounted for 16.5% of electricity production. Oil and non-renewable waste accounted for 1.3% and 2.2% of the electricity production, respectively. In addition, wind accounted for 28.1%, combustion of straw 2.2%, wood 6.6%, waste 2.7% and biogas 1.0%; solar and hydro 0.0% [12].

In Germany, the production of electricity was based on hard coal, 19%; lignite, 25%; natural gas, 14%; nuclear energy, 18%; heating oil and pumped storage, 5%; wind, 8%; biomass, 5%; water, 3%. photovoltaics, 3%; and biogenic household waste 1%. The annual full-load hours of German power stations in 2010 were; photovoltaics 900 h; pumped storage installations 1100 h; petroleum 1210 h; wind 1380 h; natural gas 3180 h; storage and run-off-river hydroelectric installations 3820 h; hard coal 3870 h, biomass 6400 h; lignite 6600 h; and nuclear energy 7330 h [13]. The German Federal Government plans that renewable energy will provide the main source of electricity by 2030, and projects that 58% of total electricity will be sourced from renewable energy, with wind being the dominant source in 2030, at 30.6%. Electricity from wind is expected to triple over the next years, while electricity from solar will double. Hydro will grow by 35.8% to account for 5.2% of generation, as will the use of biofuels, growing by 39.1% to reach 13.3% of the total. The use of natural gas in electricity generation will also increase over the period to 2030, growing to 22.6% of the total. Coal-fired generation is expected to contract to less than 20% of the total, with nuclear power being completely phased out by 2022 [14].

The numbers from 2010 show that a programme should consider good import-export relations of Germany with neighbours, since the main source of renewable energy will be wind, for which the full load hours equal to 1400 hours annually will not assure continuous electricity supply throughout the year. Imports from a newly constructed nuclear power plant in Kaliningrad, via the Baltic Sea route, may be a solution. The combustion technologies will still cover 56 % (coal 20% + gas 23% + biofuels 13%) of electricity production, which proves that the country will be not able to follow sustainable development policy. One may expect that biomass combustion will be excluded from the list of renewable energy sources and natural gas combustion in the big power blocks has been always considered as a robbery of raw material used by many sectors of economy and household appliances. The example of Denmark, and especially Germany, is proof that Trianer is right; renewables will not solve the greenhouse problem, and will not provide a sufficient electricity supply for the future [15].

The other example of electricity production mix is illustrated, now and in the future, by Finland; one of the most innovative countries in the world. Its economy is highly industrialized, with sizeable high-tech manufacturing, electronics and chemical sectors operating alongside a significant forestry and paper industry. Finland's energy consumption per capita is the highest in the International Energy Agency—Organisation for Economic Co-operation and Development (IEA-OECD) countries. Finland's electricity supply mix is very diversified, with nuclear, hydro and bioenergy accounting for around 31.6%, 16.9% and 15.6% of electricity supply respectively, and gas, coal and peat also contributing to the energy mix. Furthermore, as part of the Nordic electricity system, Finland is one of the most advanced electricity markets in the world. Yet security of electricity supply remains a high priority concern. Supply concerns are exacerbated by the fact that Finland currently imports up to 2000 MW of electricity from its neighbours during peak hours, as domestic electricity supply is limited. In 2010, the Parliament adopted decisions-in-principle for two new nuclear power stations, in addition to Olkiluoto 3, which is currently under construction. Finland hopes to achieve relative self-sufficiency, being able to cover peak load situations and possible disturbances of imports, through the development of biomass-fired power, and particularly the construction of additional nuclear power capacity [16].

4. Nuclear Power for Poland

The Ministry of Economy has issued a programme regarding power sector development, "Energy Policy for Poland until 2030" [17], and considers nuclear power as an important component of the electricity supply mix. The Council of Ministers of the Republic of Poland adopted resolution 4/2009, related to the Polish Nuclear Power Program (PNPP) development on 13 January, 2009. The Ordinance of the Council of Ministers of 12 May, 2009, on establishing the Government's Commissioner for Nuclear Energy and Undersecretary of State, Ministry of Economics was the next step in this process. The Resolution of the Council of Ministers of 11 August, 2009, was adopted; "Framework time schedule for nuclear power activities". The 13 May, 2011, amendment to the Atomic Law and other laws entered into force on 1 July, 2011. The additional law of 29 June, 2011, on the preparation and realization of investments in nuclear facilities and accompanying investments entered into force on 1 July, 2011.

An IAEA-led team of international experts that reviewed Poland's programme for introducing nuclear power found that significant progress has been made in the development of the country's nuclear infrastructure. They also noted good practices and made recommendations for further actions. The experts, assembled at Poland's request by the IAEA, conducted an Integrated Nuclear Infrastructure Review (INIR) mission in Poland from 18-22 March, 2013.

PGE (Polska Grupa Energetyczna; Polish Power Group) plans to install around 3000 MW_e of nuclear capacity, with its first unit expected to be online by 2025. In November 2011, the short list of three potential sites was announced to the public: Choczewo (Choczewo commune, poviat of Wejherowo, Pomeranian voivoidship); Gąski (Mielno commune, poviat of Koszalin, West Pomeranian voivoidship), and Żarnowiec (Krokowa commune, poviat of Puck, Pomeranian voivoidship) (**Figure 2**).

PGE signed MOUs regarding collaboration with big companies involved in engineering, construction and operations of NPPs: French EDF (2009), GE Hitachi (2010), and Westinghouse Electric Company LLC (2010). On 7 February, 2013 Polish company PGE EJ 1 sp. z o.o. concluded the contract with a consortium composed of Worley Parsons Nuclear Services JSC, Worley Parsons International Inc. and Worley Parsons Group Inc. The contract pertains to the performance of site characterization works and licensing support required, in order to complete the first Polish NPP building project led by PGE EJ1. The first Polish NPP is to generate approx. 3000 MW_e, as mentioned earlier.

The public attitude to nuclear power plants construc-

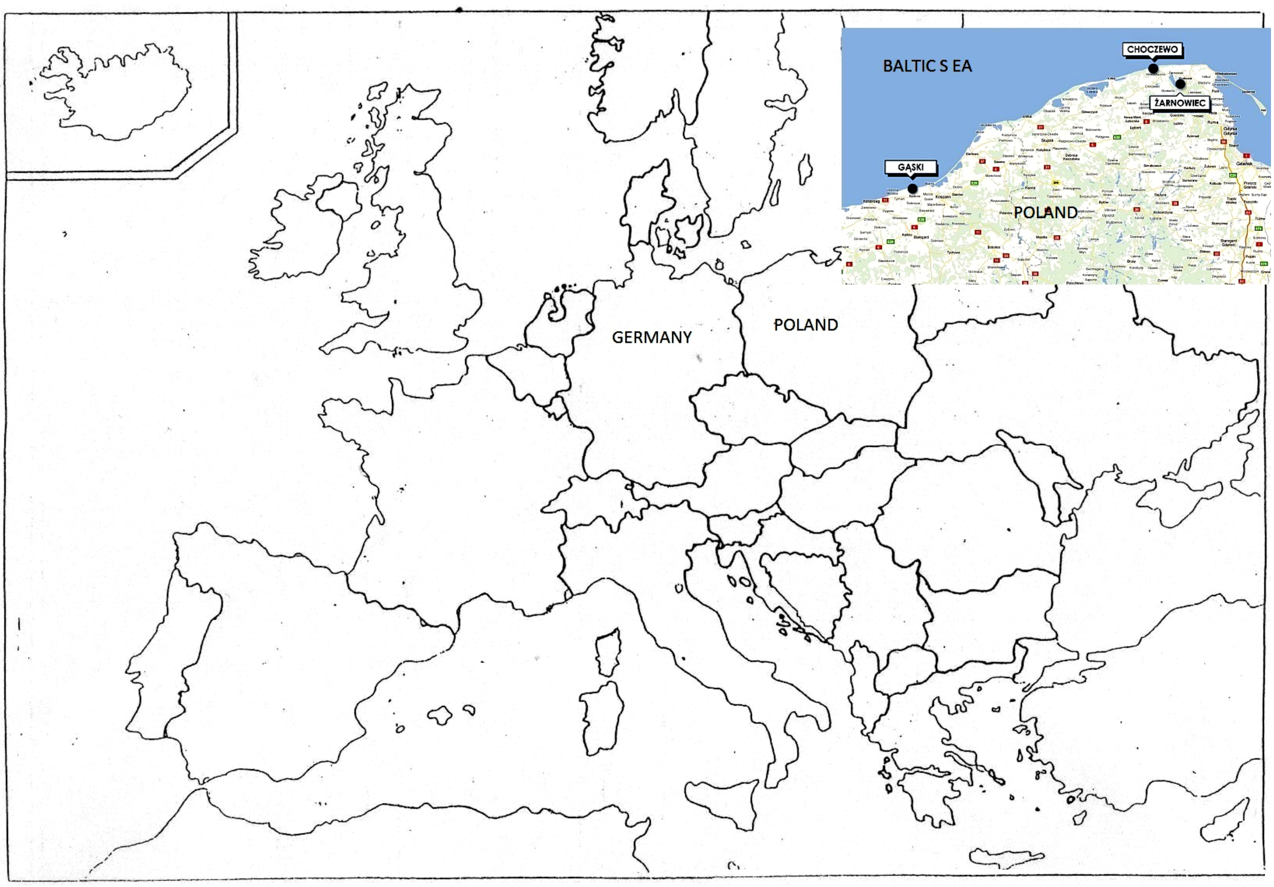

Figure 2. Possible localization for first Polish NPP.

tion in Poland changed over the years 1987-2011. Just after the Chernobyl accident, only 30% of responding citizens declared support for nuclear energy. This has changed in the past few years. The radical breakthrough was observed in 2009, when 50% of population tested said "yes" to the nuclear option, with only 40% against. The situation changed after the crisis in Japan, reducing public confidence and support for nuclear energy. According to the last polls, only 40% of responders supported nuclear power, and 53% were against. In comparison with previous years, the amount of indecisive answers was small (7%). As in other countries, the operation of radioactive waste disposal facilities arouses even more fear and distrust [18].

5. R & D and Industrial Programs Supporting PNPP

Polish Universities and R & D institutes are involved in the implementation of the activities supporting the Polish Nuclear Power Programme. The most active among the academic centres are Warsaw University of Technology, Warsaw University, and the Mining Academy in Cracow, Gdansk University of Technology, and Silesian University of Technology. With regard to R & D institutions, these are the National Centre for Nuclear Research, Swierk; the Institute of Nuclear Chemistry and Technology (INCT), Warsaw; the Central Laboratory for Radiological Protection (CLRP), Warsaw; and the Institute of Nuclear Physics PAS, Cracow. INCT and CLRP have signed agreements with the National Atomic Energy Agency (NAEA), to support this regulatory body in the fields related to Technical Support Organization (TSO).

The activities of the President of the National Atomic Energy Agency (NAEA), as a central organ of governmental administration, for the issues of nuclear safety and radiological protection, is regulated by the Act of Parliament of 29 November, 2000, Atomic Law (O.J. 2007, No 42, Item 276) and relevant regulations. Further tasks of the NAEA President result from many other legal acts. Since 1 January, 2002, the NAEA President is supervised by the minister competent in environmental issues. The NAEA President executes their tasks through the National Atomic Energy Agency, whose internal organization is established by the statute conferred by the Environment Minister.

The Institutes have signed agreements in collaboration with CEA, France. In 2009, twenty Polish scientists participated in a nuclear "tour de France", visiting for six weeks the most significant manufacturing sites and laboratories in Poland. Specialists in training, research and industry—from mining to waste management, from design to decommissioning—discussed with them technical issues, as well as public relations. During the second phase, at the end of 2010, the Polish scientists received intensive twelve-week training at the Institute of Nuclear Science and Technology in Saclay. The most fundamental aspects of nuclear science were addressed, as well as radiation protection, safety and security, operation and waste management. The trainees had access to central driving simulators. Thirteen educators were hosted by French companies and laboratories for twelve weeks at the end of 2011. They stayed at the CEA in Cadarache, Saclay and Marcoule, at Andra in Chatenay-Malabry, at EDF in Lyon, at Areva in La Défense, and at the CNRS in Orsay [19].

The National Centre for Research and Development established a so-called strategic project, entitled "Technologies Supporting Development of Safe Nuclear Power Engineering" [20]. The Project comprises the following research tasks:

- Development of high temperature reactors for industrial purposes (consortium leader: Academy of Mining and Metallurgy, Cracow);
- Research and development of technology for controlled thermonuclear fusion (consortium leader: Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences);
- Meeting the Polish nuclear power engineering's demand for fuel: fundamental aspects (research network leader: University of Warsaw);
- Development of spent nuclear fuel and radioactive waste management techniques and technologies (contractor: Institute of Nuclear Chemistry and Technology);
- Study of possibilities and criteria for participation of the Polish industry in the worldwide expansion of nuclear power engineering (research network leader: Warsaw University of Technology);
- Development of nuclear safety and radiological protection methods for nuclear power engineering's current and future needs (research network leader: Central Laboratory for Radiological Protection);
- Study of hydrogen generation processes in nuclear reactors under regular operation conditions and in emergency cases, with suggested actions aimed at upgrading nuclear safety (research network leader: Institute of Nuclear Chemistry and Technology);
- Study of processes occurring under regular operation of water circulation systems in nuclear power plants, with suggested actions aimed at upgrading nuclear safety (research network leader: Institute of Nuclear Chemistry and Technology);
- Development of methods and performance of safety analyses in nuclear reactors with heat reception disturbances under critical failure conditions (contractor; Warsaw University of Technology);
- Development of a method and performance of an

exemplary systemic analysis of the operation of a nuclear plant, with a water reactor under partial association conditions (contractor: Gdansk University of Technology).

The Polish Institutes represent Poland in different international organizations, such as Euratom Supply Agency (ESA), Nuclear Energy Agency (NEA-OECD), International Framework for Nuclear Energy Cooperation (IFNEC) etc. The universities and institutes participate in several FP 7 and EURATOM projects, such as TALISMAN, ASGARD, IPPA, ADVANCE, MULTI-BIODOSE etc.

The role of EU and its programs on Polish program implementation is very important. In June 2013 the Commission has proposed to amend the 2009 nuclear safety directive. The proposal:

- Introduces new EU-wide safety objectives;
- Sets up a European system of peer reviews of nuclear installations;
- Establishes a mechanism for developing EU-wide harmonised nuclear safety guidelines;
- Strengthens the role and independence of national regulators;
- Increases transparency on nuclear safety matters;
- Includes new provisions for on-site emergency preparedness and response.

The EU needs its own verification mechanism to ensure that common safety objectives are achieved. At least every 6 years nuclear installations would have to undergo specific assessments on one or more nuclear safety issues. The assessments would be submitted for EU-wide peer reviews. Such strategy forms solid foundation for construction and operation of NPPs in Europe, and in Poland.

The abounded former project regarding construction of NPP in Żarnowiec was realized in 70% - 80% by Polish industry. Nowadays, Polish companies are involved in the construction of nuclear power plants in Finland and France. The foreign companies seek similar cooperation with Poland located enterprises. For example, General Electric Hitachi has announced a number of other preliminary project development agreements with various companies and organizations, to support future projects in Poland, including the following [21]:

- Fluor Corp., to serve as GEH's engineering, procurement and construction (EPC) partner (2011),
- Energoprojekt Warszawa, S.A. (EW), a Warsaw-based engineering firm (2011),
- The Institute of Atomic Energy in Poland (POLATOM); a research institute located in Świerk that advises the government on nuclear energy issues (2011),
- Stocznia Gdansk, a leading Polish shipyard, for the potential manufacturing of nuclear components for GEH (2011),
- RAFAKO S.A., Europe's leading boiler equipment manufacturer, for the potential manufacturing of nuclear components for GEH (2011),
- Gdansk University of Technology, West Pomeranian University of Technology, Szczecin University and Koszalin University of Technology (2011),
- SNC-Lavalin Polska, a global engineering services firm (2010),
- Warsaw University of Technology (2012).

Similar actions have been taken by the AREVA/EDF team. Besides a large scientific collaboration with Polish universities (mainly Warsaw University of Technology (WUT), with AREVA specialists' lectures at WUT in Warsaw and master's degrees in AREVA research facilities), AREVA has been active in the field of the industrial localization in Poland:

- March 2010: a study on "Polish Industry Participation" in the nuclear project,
- Since July 2010, sourcing and pre-qualification investigations of the Polish industry landscape, with about 60 days of visits in Polish enterprises, and 29 prequalifications. This action is still running.
- September 2010: first AREVA Suppliers' Day in Warsaw.
- October 2011: second ARVA Suppliers' Day in Warsaw.
- April 2012: first AREVA/EDF Suppliers' day in Gdańsk.
- Starting from December 2012: AFCEN codes seminars (continuing).
- April 2013: specific contacts with Polish heavy industry in Pomerania (shipyards) and major civil work companies.
- Continuation of collaboration with leading Polish companies working on AREVA nuclear power plant construction site in Olkiluoto (Finland).

The role of the technical organizations, such as Polish Nuclear Society (PTN) [22] and Environmentalists for Nuclear Energy (SEREN) [23] in NE promotion and education, cannot be overestimated.

Technology foresight for a vision of the energy sector development in Poland till 2030, was performed at the request of the Ministry of Economy [24]. The aim of the project was to indicate energy and fuel sector development directions in the time horizon up to 2030, and identify key energy technologies of strategic importance. Impact assessments ranks for the 20 Delphi statements published as a result of this study placed on the position number 3 statement: "Without nuclear energy, it will be impossible to assure national energy security and the production of electricity covering total demand". The number of experts who participated in the survey was 750. They represented R & D institutes, academy, industry and other organizations, including NGOs [24].

6. Conclusion

The lessons learned in Europe, especially in Germany, have proved that renewable energy sources have limited potential regarding environmentally friendly energy (electricity) production. This thesis needs more studies, however more scientific, thermodynamics based evaluation should be adopted as an approach in its evaluation. Any combustion process, including biomass combustion, cannot be considered as pollution-free technology, ensuring sustainability of resources. Gas combustion, leading to lower pollutant emissions, cannot be considered as a sustainable energy source, since this is a raw material for industry, and an energy carrier for municipal applications. In the case of Poland, as in other countries in Europe, coal will be a main energy source for the next few decades. However, the construction of the nuclear blocks of the size 2 × 1500 MW_e by year 2025 will reduce the expected stress on the environment. The next power plant (3000 MW_e) constructed by the year 2035 together with renewable (wind, biogas) energy sector development will ensure that Poland may meet carbon free EU energy policy strategy till 2050.

7. Acknowledgements

The studies presented in this paper received funding from The National Centre for Research and Development under the strategic project entitled "Technologies Supporting the Development of Safe Nuclear Power Engineering" research tasks 7 & 8. The author appreciates discussions with: Mr Ziemowit Iwanski, GE Energy, Country Executive, Central and Eastern Europe; Mr Adam Rozwadowski, Director, Areva Poland; and Nathalie Beauzemont, EDF, Senior Nuclear Project Manager. Finally thanks go to the reviewers whose valuable remarks helped to improve this paper.

REFERENCES

[1] European Environment Agency, 2008. http://www.eea.europa.eu/data-and-maps/figures/electricity-consumption-per-capita-in-

[2] Ministry of Economy, "Forecast of Demand for Fuels and Energy by 2030," 2009. http://www.mg.gov.pl/files/upload/8134/Appendix2.pdf

[3] T. Olkuski, "New Trend in Polish Coal Trade (in Polish)," *Polityka Energetyczna*, Vol. 13, No. 2, 2010, pp. 365-375. http://www.meeri.pl/zaklady/zrynek/zasoby/10_14to_pe_z.pdf

[4] H. L. Gabryś, "Electric Power Industry of the Year 2012 in Poland in the Light of Energy Balance for 2011 and Not Only (in Polish)," Energetyka, 2012, pp. 139-141. http://elektroenergetyka.pl/upload/file/2012/3-4/Gabrys.pdf

[5] KOBiZE, "Poland's National Inventory Report," Warsaw, 2013. http://www.kobize.pl/materialy/Inwentaryzacje_krajowe/2013/NIR-2013-PL-en.pdf

[6] "Loss of Statistical Life Expectancy Attributed to Anthropogenic Contributions to PM2.5, 2000 and 2020," 2000. http://www.eea.europa.eu/data-and-maps/figures/loss-of-statistical-life-expectancy-attributed-to-anthropogenic-contributions-to-pm2-5-2000-and-2020

[7] A. P. Weem, "Reduction of Mercury Emissions from Coal Fired Power Plants," Working Group of Strategies and Review, Geneva Informal Document No. 3 2011. www.unece.org/.../Info.doc.3_Reduction_of_mercury_emissions_from_coal_fired_power_plants.pdf http://www.fossil.energy.gov/programs/powersystems/pollutioncontrols/overview_mercurycontrols.html

[8] S. H. Safe, "Hazard and Risk Assessment of Chemical Mixtures Using the Toxic Equivalency, Environ," *Health Perspect*, Vol. 106, No. S4, 1998, pp. 1051-1058. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1533329/pdf/envhper00539-0123.pdf

[9] European Environment Agency, "CO_2 Emission Trends," 2012. http://www.eea.europa.eu/pressroom/publications/ghg-trends-and-projections-2012/

[10] EU Energy in Figures, "Luxembourg: Publications Office of the European Union," 2012. http://ec.europa.eu/energy/publications/doc/2012_energy_figures.pdf

[11] F. Cherubini, G. Guest and A. H. Strømman, "Application of Probability Distributions to the Modeling of Biogenic CO_2 Fluxes in Life Cycle Assessment," *Bioenergy*, Vol. 4, No. 6, 2012, pp. 784-798.

[12] Danish Energy Agency, "Energy Statistics, 2011," Copenhagen, Denmark, 2012. http://www.ens.dk/enUS/Info/FactsAndFigures/Energy_statitstics_and_indicators/Annual%20Statistics/Documents/Energy%20Statistics%202011.pdf

[13] Federal Ministry of Economics and Technology (BMWi), "Germany's New Energy Policy—Heading towards 2050 with Secure, Affordable and Environmentally Sound Energy," Berlin, 2012. http://www.bmwi.de/English/Redaktion/Pdf/germanys-new-energy-policy

[14] OECD/IEA, "Energy Policies of IEA Countries: Germany (2013 Review)," OECD/IEA, Paris, 2013.

[15] T. Trainer, "Can Renewables etc. Solve the Greenhouse Problem? The Negative Case," *Energy Policy*, Vol. 38, No. 8, 2010, pp. 4107-4114. http://www.dieoff.com/_Energy/TrainerRenewables.pdf http://dx.doi.org/10.1016/j.enpol.2010.03.037

[16] OECD/IEA, "Energy Policies of IEA Countries: Finland (2013 Review)," OECD/IEA, Paris, 2013.

[17] Ministry of Economy, "Energy Policy for Poland until 2030," Warsaw, 2009. http://www.mg.gov.pl/files/upload/8134/Polityka%20energetyczna%20ost_en.pdf

[18] G. Zakrzewska and T. K. Anderson, "Transparency and Public Participation in Radioactive Waste Management,"

Materials Research Society Symposium Proceedings, Vol. 1475, 2012, pp. 51-56.

[19] http://www.i2en.fr/en/news/47-poland-uk.html

[20] http://www.ncbir.pl/en/strategic-programmes/technologies-supporting-development-of-safe-nuclear-power-engineering/

[21] http://www.genewscentre.com/Press-Releases/GE-Hitachi-Nuclear-Energy-Continues-to-Build-Nuclear-Infrastructure-in-Poland-3b8d.aspx

[22] http://www.ptn.nuclear.pl/

[23] http://www.seren.org.pl/

[24] K. Czaplicka-Kolarz, K. Stańczyk and K. Kapusta, "Technology Foresight for a Vision of Energy Sector Development in Poland till 2030. Delphi Survey as an Element of Technology Foresighting," *Technological Forecasting & Social Change*, Vol. 76, No. 3, 2009, pp. 327-338. http://dx.doi.org/10.1016/j.techfore.2008.05.007