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Expert Estimation of the Ways for Creating Energy Security Potential in Latvia

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Object of the research is the condition of energy supply in Latvia. Goal of the research – analysis of data on electric energy production in Latvia and expert estimate of the ways for creating energy security potential of the country. Methods of the research are analysis of statistical data, and methods of expert evaluation. Novelty of the paper is conditioned by the fact that expert estimation of the possible ways for creation of energy security potential of Latvia has been performed for the first time, and the consolidated opinion of a group of independent experts has been obtained on the most prospective ways. One of the main aims is diversification of ways of energy resources supply to Latvia. By the year 2030, the Ministry of Economic Affairs of the Republic of Latvia has been planning to decrease the volume of imported energy resources by 2 times and produce half of the energy by using its own renewable energy sources. Currently there are the ongoing negotiations in Latvia about the construction of another large hydropower plant (HPP) with the output of about 200 MW on the Daugava River. In the discussions the new HPP is considered to be a more ecological and economic alternative than the construction of Visaginas Nuclear PP. The estimates obtained from the expert query show large differences in their opinions. Altogether four methods are used for the processing of results of expert estimation, all the results of alternative ranking are compared and analysed by four methods. The conducted analysis makes it possible to conclude the following: the most promising directions for electric energy industry development in Latvia and, on this basis, for the creation of energy security potential of the country is the construction of HPP and heat power plants using its own energy resources. The direction of wind power industry development is recognised as important.

Keywords: *energy resources, electric energy production, method of expert estimation, fuzzy set theory*.

Introduction

The world energy consumption has doubled within the period from 1970 until the beginning of the 21st century. According to the forecasts, it will be increased by more than 60 % by the year 2030 (EU. Doc. SEC, 2006). According to the forecasts, by the year 2050 there are no acceptable technical solutions anticipated, which would allow substituting the existing hydrocarbon base of power industry with something else (EU. Energy Scenarios, 2006). At the beginning of the 21st century, the explored reserves of oil comprised 180 BT, whereas 56 % were located in the Middle East (Oil & Gas, 2006). At that time, the world reserves of natural gas comprised about 175 TCM. Almost 60% of the explored natural gas reserves are located in three countries – Russia, Iran and Qatar. The level of reserve availability is higher for gas than for oil.

Building of nuclear power plants (NPPs) becomes more expensive due to problems with safety. At the beginning of the 21st century, NPPs functioned in more than 30 countries in the world and the largest number of them was in the USA, France and Japan. Natural uranium contains about 0,7 % of uranium-235, which is used in modern thermal reactors (types LWR, PWR and others). The remaining part is uranium-238, which can be used only in fast neutron reactors. In case of using only thermal reactors, the reserves of natural uranium will end soon (within 100 years). Reactors of the second type allow using more than 80 % of natural uranium energy, thus providing energy supplies for several centuries. For this purpose it is necessary to provide a closed nuclear fuel cycle (NFC). Such reactors are more expensive than thermal ones. Prototype models of fast reactors are built in several countries: the USA, France, Russia and others. The product cost for electric energy generated by NPP is relatively low (40–45 €/MWh), and the greenhouse gas emission level is also low (about 15 кgCO_2/MW). A number of countries (France, Great Britain, Finland, the Czech Republic) do not plan to withdraw from nuclear power.

In many countries all over the world, it is possible to observe the increasing dependence on external energy supplies in proportion to economic growth, while keeping the restricted use of inner energy resources. Thus, in the period from 2000 until 2010 the amount of imported fuel was increased for Germany (from 65 % to 66 %), China (from 3 % to 6 %) and India (from 26 % to 36 %). Quite high dependence on the import of fossil energy resources (about 80 – 90 %) is also observed in such countries as Japan, the Republic of Korea, Taiwan and Italy (BP Stat. Rev., 2011). France focuses on nuclear power and, thus, is less dependent on external energy supplies (55 %).

In the past few years, natural and industrial disasters have occurred in the field of power production. Following the major breakdown of Sayano-Shushenskaya hydroelectric power plant (HPP) in Russia, which is one of the largest hydroelectric power plants in the world, there was a catastrophe on the platform "Deepwater Horizon" in April 2010 in the Gulf of Mexico, which resulted not only in the loss of life and injuries, but also in a continuous oil spill. The economy of the region experienced a record loss (BP Annual Report.., 2010). In March 2011, there was the strongest in history earthquake in Japan with the magnitude of 9 points that caused 14 m high tsunami; more than 14 thousand people died. According to the preliminary estimate, the losses exceeded $200 billion. More than 30 % of oil refinery plants stopped working. The breakdowns and accidents in Japan and the USA will definitely be the reason for making technological and ecological requirements more severe in respect to the projects in all sectors of the power industry (Mitrova & Kulagin, 2011).

Aggravation of energy problems stimulates the world community to actively develop the field of renewable energy sources (RESs). Apart from the main RES – water (HPP), at the present stage of scientifically-technical and economic development there are biomass and wind energy, which are becoming more and more popular. The main advantage of biomass is its flexibility, that is, a possibility to use this resource for production of any type of energy (thermal, electric) as well as liquid (ethanol, biodiesel) or gas fuel (biogas). Over the last ten years, the total amount of power generated by wind-driven power plants has increased approximately by 10 times. The countries possessing the most developed wind power plants are the USA, Federal Republic of Germany, People's Republic of China and Spain (Bulletin of the for.., 2011). According to the statistical data, in the period from 2000 to 2010 the energy production by RESs increased almost by three times – from 51 MT of oil equivalent up to 159 MT, and its part in the world power balance increased from 0,5 % to 1,3 %. Thus, taking into account a hydroelectric power plant, the total part of RESs reached 7,8 % of primary energy consumption in the world.

The power industry is one of the most important spheres of mankind's life activities, which becomes more and more sensitive due to the growing problems in technologies, economics, society and nature. And to resist such rather unpredictable challenges, it is necessary to develop broad international cooperation and mutual understanding at various levels.

Subject and relevance. The EU is the largest importer of energy in the world. Population of the EU exceeds 500 million people and more than 20 million plants operate on its territory. The EU is the largest energy market in the world. Population of the EU makes only 7 % of the total population on the Earth, whereas it produces a quarter of the world GDP and provides 20 % of world trade volume. The area of the EU contains only 2 % of world oil reserves and 4% of gas reserves, which will end in 25–30 years (Intern. Energy Ag.., 2006). By the year 2030, the demand for energy in the EU will again increase by 15 %, while the dependence on energy import will increase up to 70 % (at present, it is about 50 %). For reliable provision of energy at reasonable prices in the EU, it is planned to maximally use non-borrowed reserves, fully acquire local fields, elaborate effective measures for energy conservation and widely use renewable energy sources (Table 1) (EU. Energy Scenarios, 2006).

Table 1

Forecast for Energy Sources in the EU

Energy sources	Year 2010		Year 2030		Change in the demand	
	a	b	a	B	A	b
Solid fuel	287	16	293	15	6	2
Oil	669	37	640	33	-29	-4,3
Gas	462	25	578	29	116	25
Nuclear energy	249	14	211	11	-38	-15,3
Renewable sources	144	8	231	12	87	60
Total	1811	100	1953	100	142	8

***a** – Mt of oil equivalent (o.e.),*
***b** – %%.*

The main sources of renewable energy in the EU are supposed to be wind generators and biomass. The production cost for renewable energy sources, excluding HPP, is still considerably higher than for traditional sources of energy. Therefore, state governments assign considerable grants, subsidies and benefits for the development of renewable energy sources in the EU. Until the year 2025, it is planned to invest more than €115 billion into wind energy and €70 billion into biomass. It is planned that by the year 2020 the wind energy field will provide 7,6 % of the total energy in the EU, biomass – 6,2 %, and by the year 2030 – 10,1 % and 8,1 %, respectively (EU. Energy Scenarios, 2006). The disadvantage of wind-driven power plants, in comparison to traditional energy sources, is variability of output. If the part of such plants in the energy system exceeds 20–30 %, unacceptable voltage and frequency fluctuations can appear. To avoid such negative effects, it is necessary to use additional power converters that lead to rise in the price of wind power. Nevertheless, it is anticipated that by the year 2020 there will be 130 thousand wind-driven power plants in the EU (Europe can enlarge.., 2011). By the end of the year 2010, there were 7 sites for 24 wind generators in Latvia with the total power exceeding 30 MW. In Lithuania, there are 3 times as many wind generators, and in Estonia – 4,7 times as many as in Latvia.

A typical example is Germany that made the decision to gradually stop using nuclear energy and to accelerate the transition to the application of renewable energy sources after the breakdown of "Fukushima" NPP in Japan in spring 2011 (The Bundestag approved.., 2011). A large-scale reform has been started in Germany in the power industry (Energiewende), a plan for transition to renewable energy sources has been accepted for the period until the year 2050, and a legislative package has been accepted in respect to acceleration of elaboration and construction of new power plants. The plans include the final refusal to use nuclear energy by the year 2022 and acquisition of 80 % of energy from renewable energy sources by the year 2050 (Germany is plann. rev.., 2011). The remaining 20 % of energy is planned to be obtained by using traditional sources, mainly gas. Building of gas power plants is 1,5 times cheaper than building coal power plants, the atmosphere pollution level is lower (about 400 kg CO_2/MW). For this purpose, the government will need a new power -producing infrastructure, which, apart from power plants, includes new power lines and energy depositories. Gas will be delivered mainly from Russia. Before making such an important decision, the German government summoned the Expert Council, which approved the feasibility of plans.

The EU countries, following the same coordinated energy policy, have almost the same amount of total fuel consumption (in 2010 – 670 MT o.e.) as the leaders of consumption (the USA, China, Japan) (in 2010 – 970 MT o.e.) (Ivanov & Matveev, 2011). However, the situation is not homogeneous in the EU. Thus, Norway is a traditional net exporter of energy resources (180 – 190 MT o.e.), but the Federal Republic of Germany, France, Italy and Spain suffer from the shortage of energy resources in the amount of 140 – 210 MT o.e. annually. It is typical that in 2000 – 2010 the efforts to raise the energy efficiency of the EU member state economies maintained the total deficiency of the EU in about close to 600 MT o.e. To soften the shortage of energy resources, the EU member states actively develop the field of renewable energy and production of alternative energy resources (slate gas and other types of gas).

Reducing natural energy base all over the world raises interest to saving of energy that has good opportunities. In the EU, special attention is devoted to this issue (EU. Energy Scenarios, 2006; An Energy Pol.., 2007). Thus, in 2000 the specific consumption of energy in the field of industry in respect to a unit of GDP was equal to 0,8. In 2006, the EU Council accepted a special plan of actions in respect to energy efficiency, which anticipated saving of up to 20 % of energy by the year 2020. This corresponds to saving of 390 MT of fuel in oil equivalent, €100 billion for importing energy resources and decrease of CO_2 emission into the atmosphere by 780 MT. Certain directions of economy are planned as well as ways of implementation (obligatory indicators, energy capacity standards, certification of goods etc.). It is anticipated to change the fuel of TPP from coal to gas and use cogeneration technologies – simultaneous acquisition of electric energy and heat that increases the efficiency of fuel combustion up to 60 %. It is also necessary to improve energy conversion processes, where almost one third of energy can be lost.

Novelty of the paper is conditioned by the fact that expert estimation of the possible ways for creation of energy security potential of Latvia has been performed for the first time, and the consolidated opinion of a group of independent experts has been obtained on the most prospective ways.

Object of the research is the condition of energy supply in Latvia.

Goal of the research – analysis of data on electric energy production in Latvia and expert estimate of the ways for creating energy security potential of the country. Such kinds of studies have not been carried out before.

Methods of the research are the analysis of statistical data, methods of expert estimation based on traditional ways of computation as well as on the application of fuzzy set theory.

The Condition of Electric Energy Production in Latvia and Lithuania

The leading producer and supplier of electric energy and heat in Latvia is JSC "Latvenergo", which produces more than a half of the whole electric energy in the country. About 70 % of electric energy provided by "Latvenergo" is produced from renewable energy sources, including hydroelectric power plants. Latvia takes the second place in the EU after Sweden in respect to renewable energy resources. HPPs on the Daugava River produce more than a half of the total amount of electric energy, Riga TPPs – about 20 %. Average import of electric energy in Latvia is 30 % of the total volume of consumed energy and is done from Estonia, Russia and the Scandinavian countries (by using Nord Pool trade market). Riga TPPs produce about 70 % of the total heat required by Riga. Various independent producers provide about 5 % of electric energy in Latvia.

The Ministry of Economic Affairs in Latvia elaborates a strategy of energy policy of the country for the period until the year 2030. One of the main aims is diversification of ways of energy resource supply to Latvia (Comm. for regul.., 2011). Such a policy should be implemented according to action plans for reliable provision of energy supply approved at the summit of the EU in Brussels at the beginning of 2011 (The EU is going.., 2011). "Provision of reliable uninterrupted supply with energy resources at a reasonable price is one of the priority tasks", was underlined at the final communiqué of the summit. To increase the safety of energy supply, a series of measures is proposed: stimulation of non-borrowed resource development, expansion of renewable energy sources, energy saving etc. The aim of these measures is to decrease the excessive dependence of the EU on gas supplies from Russia. Even in July 2010 the European Parliament accepted a resolution on the strategy of the Baltic Sea region, where it was proposed to decrease the dependence on energy sources from Russia by diversification of energy resource supplies (The Eur. Parl.., 2010). According to forecasts, building of a sea terminal for taking liquefied gas in the Baltic States will decrease the dependence of these countries on gas import from Russia by 25 %. Construction of the liquefied gas terminal should be co-financed by the EU. At the present moment, the Baltic States are 100 % dependent on the gas from Russia and, therefore, pay more for it in comparison, for instance, with Germany.

As the Chancellor of Germany Angela Merkel pointed during her visit in Lithuania in 2010, the situation with energy in Latvia and Lithuania could not be considered good. The Baltic States are still not connected to the inner energy market of the EU and it is necessary for them to be integrated into it as well as create a base for reliable electric energy supplies (Merkel, 2010). In this case, Poland is a good example. In 2011, Poland started acquisition of slate gas, the amount of which was estimated to be equal to 5–6 TCM. If such estimation is true, the energy resources of the EU will increase by 47 % and Poland will be self-sufficient in respect to gas. As the Prime Minister of Poland said, in 24 years Poland would become an independent state in respect to energy (Poland took.., 2011). Search for slate gas in Poland is provided by companies *Conoco Phillips* and *Chevron.*

Latvia is one of the leaders in respect to growth of energy dependence in the EU. According to *Eurostat* data, in 2009, for instance, the energy dependence of Latvia or part of the imported energy, in respect to the general volume of energy resource consumption, increased by 5,2 % (Latvia-the leader.., 2011). The indicator of energy dependence for Lithuania decreased by 6,2 % in the same year, while for Estonia it decreased only by 2,1 %. On the other side, according to the research of the audit and consulting company KPMG Baltics, out of the three Baltic States Latvia is the most dependent on the increase in prices for energy resources with the highest specific indicator of the total energy consumption in the economy (KPMG Balt.., 2012). In the long term, in can lead to the decrease in economic efficiency.

By the year 2030, the Ministry of Economic Affairs of the Republic of Latvia has been planning to decrease the volume of imported energy resources by 2 times and produce half of the energy by using its own renewable resources (Latv. energy ind.., 2012). Construction of a large power plant that uses coal or biomass is considered unpromising; therefore, it is proposed using peat as a raw material in the power industry due to peat reserves that are estimated to be equal to 1,5 BT in Latvia (Latv. can.., 2011). Latvia takes the eighth place in the world in respect to peat reserves per capita. At present, peat is little used in Latvia, more than 90 % of the acquired peat is exported to Japan, South America and other countries. Peat is a kind of resource requiring strict quality control. Each year the amount of peat in nature grows only by 1 mm, but it gives 1 MT increase of peat to the country. Experts think that when appropriately used, the amount of peat in Latvia will be sufficient for 300 years. Use of peat will increase the number of work places in the country. At present, peat bogs take 11% of the area of Latvia, but only 1 % is used.

There are plans to build hybrid power plants in the main cities of Latvia, which produce electric energy and heat and use wood chips and pellets as fuel (Latvia is going.., 2011). Such domestic fuel, together with peat, can significantly decrease consumption of imported gas. In 2012, the largest solar power plant in the Baltic States was commissioned in Latvia (Latvia builds.., 2012). It consists of solar cell panels with total area of 700 m^2 and output of 120 KW. The level of solar radiation on the earth surface in our country is rather small, namely 800 – 1000 KWh/m^2 per year depending on weather conditions. The efficiency coefficient of solar cells is low ~ 20 % and the life cycle is only 20 years. Therefore, having today's level of technical development of solar energy industry cannot compete with traditional sources of electric energy in the Baltic region.

Use of wind energy is more promising. In Kurzeme region, it is planned to create another park of wind-powered generators. In Riga, the construction of a factory for producing wing generator towers has been started; cost of the project is €243 million (A 243 million €.., 2011). The produced towers will be exported not only to the Baltic States but also to Germany, Sweden, Finland and other countries. Owing to hydroelectric power plants, Latvia takes leading positions in the EU in respect to the use of renewable energy sources. In Latvia, there are three large HPPs on the Daugava River: Riga HPP, Plavinas HPP and Keguma HPP. Currently there are negotiations in Latvia about the construction of another large HPP with the output of about 200 MW on the Daugava River in Daugavpils region (The President.., 2012). In the discussions the new HPP is considered to be a more ecological and economic alternative than the construction of Visaginas nuclear power plant (NPP) in Lithuania. However, the construction of such HPP would be a reason for flooding of large areas not only in Latvia but also in Belarus.

In whole, the energy policy of Latvia is still at the stage of discussions and formation. The application of NPPs is widely discussed in respect to participation of Latvia in the construction of Visaginas NPP in Lithuania. Implementation of such a large high technology power project in the Baltic region with participation of Lithuania, Latvia and Estonia would implement the idea of regional Baltic integration, development of society oriented to knowledge-based economy (Melnikas, 2008; Melnikas & Reichelt, 2004). After the stop of the second block of Ignalina NPP in December 2009, Lithuania became almost 100 % dependent on energy resource supplies from Russia. Lithuania imports 100 % of the consumed gas, the significant part of oil and electric energy (Lithuanian gov.., 2012). In the report of the Cabinet of Ministers of Lithuania for the year 2011, it is stated that such almost complete energy dependence of the country on energy supplies from Russia is the main threat to national security. Lithuania pays 18,2 % higher price for gas from Russia than Latvia. Lithuanian experts offered a "ruler of energy independence". At the moment, it shows 45 points out of 100. If there is an NPP constructed in Lithuania as well as liquefied gas terminal, power bridges with Poland and Sweden, gas pipeline to Poland, then energy security will increase up to 75 points. Thus, among the Baltic States Lithuania is the most dependent on the import of energy resources. Estonia uses its own slate gas and is the least dependent.

Lithuania quite successfully implements modern technologies of producing electric energy from rubbish (A new power plant.., 2010). Construction of a power plant on the landfill area near Vilnius, which uses methane emitted by waste, was done by a British company. The output of this power plant is 1 MW. Similar objects are also in Klaipeda and Alytus. According to the technology offered by a Swiss company *Matrix*, the mixed household waste is sprinkled with microbiologic organisms, which stop the process of decay and stimulate waste drying-out. Then waste is disintegrated and 4–8 cm long granules are formed, which are burned with the release of energy. Such processing of household waste is called the method of *pyrolysis* and it does not emit smoke, ash or other harmful stuff into the atmosphere (Electricity will be prod.., 2012). Construction of a power plant according to such a technology will be financially worth if the output is 33,6 MW when processing 80 KT of unsorted waste annually.

Life cycle of pyrolytic power plant is 25 years. The company "Naftos grupe" anticipates the construction of such a power plant in Siauliai, where the annual amount of waste reaches 100 Kt.

According to the plans, the liquefied natural gas terminal in Lithuania should be launched in 2014, electric bridges with Poland and Sweden – in 2015. The main energy project – Visaginas nuclear power plant – should be launched in 2022. The NPP will contain a nuclear reactor with the output exceeding 1300 MW. Lithuania intends to build a new NPP in cooperation with Latvia and Estonia. The strategic partner-developer of the reactor and constructor of NPP will be the company *Hitachi-GE Nuclear Energy* based in Japan. According to the preliminary calculations, the building of NPP can cost about €5 billion. Latvia's part in this project will be represented by the company Latvenergo (Zarins, 2012). In the project, the part of Latvenergo will correspond to €1 billion or 20 % that will guarantee supply of not more than 275 MW of energy to Latvia. As a reason for concern in Latvia, there is a series of aspects of the NPP project, first of all, concerning the issues of safety and reliability of the plant. The planned nuclear reactor is planned to be of the same type as the one at Fukushima and, therefore, requires an active security system. Such a security system at Fukushima did not work in an appropriate way and it became one of the reasons of the breakdown. It is not clear how the safety of storing the used nuclear fuel will be provided and what the decommissioning mechanism will be for the NPP at the end of its lifecycle when it is necessary to liquidate the plant. In the plans of the new NPP, the so-called "responsibility of stock holders for the possible nuclear damage" is not mentioned for the case of emergency.

The EC has already accepted the project of construction of NPP in Visaginas, Lithuania (The Europ. Comm. accept.., 2012). According to the President's Chief Advisor of Lithuania N. Udrenas, the NPP will provide LTL 30 billion of dividends within the period of 60 years. On 19th June 2012 during the first reading the Lithuanian Parliament approved the draft law of the NPP in Visaginas (Lithuanian Parl. accept.., 2012). According to the concession agreement on the Visaginas NPP, approved by the Lithuanian government, Lithuania will own 38% of shares, Estonia – 22%, and both the strategic investor (the concern *Hitachi-GE*) and Latvia – 20 % of shares. According to the Lithuanian Minister of Energy A. Sekmokas, the cost of electric energy produced by the proposed Lithuanian NPP will not exceed 7,25 €-cents/KWh. In this case, the price for electric energy in Lithuania should be twice as low as it is now. These numbers are negotiated with the strategic investor (In 2022 the cost.., 2012). Some Lithuanian experts, for example, the professor of Vilnius Technical University Vidmantas Jankauskas, believe that after Lithuania joins the common electric energy market of the EU prices will not decrease but become equal in various countries (Lithuanian NPP, 2011). One of the main strategic aims of the EU is to create a single competitive electric energy market. The key element is the effective elimination of monopoly in the field of electric energy supply from competitive producers to consumers (Milciuviene & Tikniute, 2009; Milciuviene, Milcius & Praneviciene, 2006). Formation of national investor in Lithuania – LEO LT AB – created a problem of vertical integration in the operation of electric energy sector: generation of electric energy, its transfer, distribution and proposal. Creation of LEO LT AB was reasoned by the necessity to have a financially strong company, which could coordinate the project of the new NPP and other important energy projects. At the same time, the aim to create a competitive market of electric energy was outcompeted.

Problems of electric energy market regulation in Lithuania are considered in a series of works (Andreikenas, Bui.., 2004; Vilemas & Miskinis, 2003; Ciegis.., 2002; Jankauskas, 2002). It is possible to conclude that creation of the national investor LEO LT AB is in violation of the model of "unbundling nodes of ownership rights", to which the attitude of the EC is most favourable as it is considered to be the prospective legislative policy of the European electric energy market and the best way of improving competitiveness in this market (Milciuviene & Tikniute, 2009). In 2010, a process of large changes in the sector of electric energy supply was launched in Lithuania – gradual liberalization of electricity market (Jasiukevicius & Christauskas, 2011). Likewise in other countries, this should lead to a higher level of competition and diversification in the market (Ginevicius, 2009; Ginevicius & Podvezko, 2009). In this regard, an important role is given to the research of modern performance measurement systems in the sector of electric energy in Lithuania for the elaboration of competitive strategies of development for companies dealing with generation of electric energy, transfer and distribution (Jasiukevicius & Christauskas, 2011; Gimzauskiene & Valanciene, 2009; Strumickas & Valanciene, 2009; Valanciene & Gimzauskiene, 2009).

According to the opinion of some experts in the power industry in Latvia, they feel the shortage of reliable information on the project of Visaginas NPP. In Latvia, most experts incline to an opinion that the construction of Visaginas NPP is profitable, first of all, to Lithuania, which has the largest part – 38 % (Zarins, 2012; Lithuanian Parl. accept.., 2012). Besides, there will be new work places provided, new branches of science as well as new infrastructure will be developed, tax revenue will increase etc. At the moment, Lithuania is forced to buy about two thirds of the required energy from Russia. In Latvia, concerns are expressed in respect to the fact that in 10 years the technologies of Visaginas NPP will go out of date, but still will have to be used for a rather long period of time. As to commercial benefit for Latvia in respect to this project, there are doubts about a possibility for Latvia to purchase electric energy from Lithuania at the price, which is close to the production cost. Most probably, Latvia will have to purchase electric energy from Visaginas NPP according to the established model of the electric energy market in the EU at the current market price.

At the Energy Forum in Tallinn in 2013, the necessity of development and improvement of energy market of the Baltic States (Latvia, Lithuania, and Estonia) was underlined. It was mentioned that the total volume of electric energy consumption in the Baltic States is about 25TWh, and only less than half thereof goes through the general Nord Pool market. One of the important problems of electric energy market is the fact that distribution of the transmission power does not work according to the EU requirements, and large producers of electric energy in Latvia and Lithuania do not transmit the produced electricity fully to the market. An important problem accepted at the forum was the necessity of creation of gas market for the Baltic States. Opening of a gas market will create more opportunities for saving energy. At the moment, the Baltic States pay the highest price for gas in the EU. Development of energy markets for electricity and gas in the Baltic States will increase the competition, and consumers will benefit from it. Gas sellers should open the access to the wholesale market and gasholders. Now only gas monopolists have such opportunities. It was also noticed that the most successful steps towards opening of the gas market are made in Lithuania.

Expert Estimation of Promising Directions of Development of Power Sector in Latvia

To estimate the possible ways of development of electric energy production in Latvia and to elaborate recommendations for acceptance of managerial solutions, it is possible to apply optimisation methods as well as probability and statistical models. However, for the construction of such models it is necessary to have unbiased data or information on all possible directions of energy generation, scientifically based forecasts of state and development of the current and prospective energy sources for our region for several decades in advance. Acquisition of the necessary data for such modelling in an experimental way is almost impossible due to a very large number of factors, which have to be taken into account, and also due to high expenses. At the same time, intelligence of modern energy sources, for example, shale gas and oil, has not been performed on the widest scale in our region. The intelligence of traditional oil deposits is only planned on a large scale, though in Lithuania oil extraction is performed in small amounts. It is also impossible in our region to make a forecast on climate changes for a long period, which influences production, scope and consumption of energy. Therefore, when making forecasts for longer periods it is possible to anticipate only qualitative estimations, not the substantiated numerical data. To make optimal solutions in such situations, it is necessary to rely on knowledge, experience and intuition of experts. In the second part of the 20th century, a new discipline – theory together with a practice of expert estimations – was developed, which was used in the paper.

In Latvia, there is a wide range of opinions about possible ways of development in future production of electric energy in the country. But practically all of them are common when it concerns the necessity to decrease the dependence of Latvia on import of energy resources and to form a certain energy security potential of the country. There is not enough empirical data about the production of electric energy from any possible source in the conditions Latvia can provide, so it is impossible to make scientifically grounded recommendations and conclusions about the ways of developing the electric energy industry. Taking into account the absence of representation of situation development tendencies and fuzziness of the information field, for the analysis and elaboration of recommendations concerning the ways of forming the energy security potential in Latvia a method of expert estimation was used in the same way as the decisions were made about the directions of development of electric energy industry in Germany (Germany is plann. rev.., 2011).

The method of expert estimation reduces the risk of making incorrect decisions. The method of expert estimation means measuring some parameters of the studied phenomena by the corresponding group of experts for the preparation of optimal recommendations. The group of experts includes competent persons representing scientific and academic environments as well as experienced engineers in the field of production and implementation of electric energy. Among them are professors and research scientists of the Faculty of Power and Electrical Engineering of Riga Technical University, Latvian Academy of Sciences, experts of the companies Latvenergo, JSC “Liepājas Metalurgs”, Resursu Kontroles Grupa (Resource Control Group), Latvian Energy Efficiency Association, Atjaunojamo Enerģiju Konfederācija (Renewable Energy Confederation), Vēja Enerģijas Asociācija (Wind Energy Association), having 12 experts altogether. Each expert was offered to estimate the directions of development of electric energy production in Latvia taking into account the maximum number of possible factors: use of own and renewable energy sources, influence on the environment, social significance of each direction of development, economic efficiency etc. Experts’ estimations were done in points by using a universal quantitative scale [1, 10]: 1 – the lowest mark, 10 – the best and highest mark. The results of expert survey are given in Table 2.

Table 2

Results of Expert Survey

Denotation	Directions of development of electric energy production	Expert estimations											
		1	2	3	4	5	6	7	8	9	10	11	12
A	Building of nuclear power plant (with Lithuania)	6,5	9,5	9	5,5	5	3	6	1	1	1	9	8
B	Construction of hydroelectric power plant	9,5	8,5	4	9,5	9	8,5	7	2	7	10	4	7
C	Solar energy power plant	2,5	2	6	9,5	7	4	1	10	4	1	3	4
D	Use of wind energy	3,5	3	8	8	8	9	5	4	4	1	8	4
E	Use of TPP working on the imported fuel	7,5	8,5	2	7,5	6	6	1	1	4	7	1	6
F	Use of TPP working on domestic fuel	5,5	4,5	9	9,5	10	8	5	10	5	8	5,5	5

The estimates obtained from the expert survey show a large difference in their opinions. The information field is fuzzy and ill-defined. In this situation, the problem of elaboration of consolidated conclusions and recommendations is mostly connected with uncertainty. For solution of such problems it is impossible to apply the theory of probability because it does not conform to the subjective categories of human thinking.

There are quite many theories of decision making, starting from the popular theory of Neumann J. and Morgenstem O., which is based on the construction and use of a utility function (Neumann & Morgenstern, 2004). However, this theory is often not approved in real life (McCardle & Winkler, 1992; Bunge, 1985). That is why it was not used in the paper. Since the 1970s, another theory has started its development based on the Analytic Hierarchy Process (AHP) method (Saaty, 1980; Saaty, 2001; Saaty, 2008). The basis of this method implies the application of mathematics and psychology. The AHP method represents a theory of decision making, which is based on expert estimation and opinions of certain experts or groups. Its aim is to reach a compromise and balance in the opinions. The AHP methodology includes the decomposition of a problem and further construction of a multi-level hierarchic structure, where it is possible to estimate the importance and influence of certain elements. Then, measurement of element preference is carried out by using a ratio scale, obtained from paired comparisons of the hierarchy elements. The final stage is the synthesis of generalized (global) priorities of alternatives from the matrices of paired comparisons. As a result of the synthesis, a global ratio scale is formed, which allows obtaining a generalized result and choosing the best alternative. The advantage of AHP is the opportunity to keep the rank order of the set of alternatives in accordance with the principle of invariance, but there is also a procedure, when the order can and has to change.

However, the AHP methodology has also weaknesses. It is quite bulky and often requires experts to work jointly as one group. During such team work, opinions of some experts can change due to the pressure of the most authoritative team members and this can influence the final result. In the present paper, the method of individual expert survey was used, where experts expressed their opinions independently and did not change them thereafter. This allows obtaining more objective and reliable final results of expert estimation. When using the AHP method at the most important stages for modelling of hierarchy and then for choosing the way and ranking alternatives, the majority depends on individual preferences of the experts performing the modelling. Here a possibility of lobbying someone's interests is not excluded, though it is undesirable. At the final stage of AHP, when the synthesis of local priorities is done at hierarchies in order to obtain the global rating scale, which is necessary for acquisition of the generalized result, additive weighting of local ratio scales is used. The result here is non-linear and quite complicated, when the number of levels and elements of hierarchy is large (Saaty, 2001).

Another possible way of synthesis of priorities in the AHP is the multiplicative weighting, and it also has several drawbacks: it is not allowed to introduce additional arguments of experts because the matrix of paired comparisons should be ideally correlated. The multiplicative synthesis cannot be used for interdependent structures having feedbacks. Taking into account the abovementioned situation in Latvia in respect to energy supply and priorities, the AHP has not been used in the paper. Several elements of AHP (method of paired comparisons and group decision making) (Saaty, 2001) were used in computations for construction of membership functions of fuzzy sets and correspondingly for generalized ranking of alternatives.

Here it is possible to quite successfully apply a mathematical fuzzy set theory, which allows estimating fuzzy concepts and information, making the corresponding calculations and grounded conclusions (Kaufmann, 1977). The efficiency of application of the fuzzy set theory is based on the Fuzzy Approximation Theorem (FAT), which was proved in 1993 and states that any mathematical system can be approximated by a system, having fuzzy logic in its basis. A fuzzy logic is much closer to human thinking than traditional logical schemes. This allows for its successful application in the field of managing and decision making.

In this paper, a multi-criterion estimation and analysis of alternatives were performed for the case when criterion scores were defined as a degree of conformity of alternatives to concepts determined by criteria. A convolution of the basis of fuzzy set intersection was used (Bellman & Zadeh, 1976). Having a set of m alternatives ($a_1, a_2, \ldots, a_m$), for the criterion C it is possible to consider a fuzzy set (Borisov.., 1990):

$$\tilde{C} = \sum_{i=1}^{m} \frac{\mu_c(a_i)}{a_i} \quad (1)$$

where $\mu_c(a_i) \in [0,1]$ – the estimation of an alternative a_i by the criterion C, which describes the degree of conformity of an alternative to the concept defined by the criterion; $i = \overline{1,12}$; Σ means the collective of pairs $\mu_c(a_i)$ and a_i.

From n criteria, the best alterative will be the one satisfying all the criteria C_1, C_2, …, C_n. The rule for choosing the best alternative is written in a form of intersection of the corresponding fuzzy sets (Borisov.., 1990):

$$D = C_1 \cap C_2 \cap \ldots \cap C_n. \quad (2)$$

Fuzzy set intersection corresponds to the minimization operation, which can be applied to their membership functions:

$$\mu_{\mathcal{D}}(a_j) = min\, \mu_{c\,i}(a_j), \; i = \overline{1,n};\; j = \overline{1,m} \quad (3)$$

As the best alternative a^* is chosen, which has the maximum value of the membership function:

$$\mu_{\mathcal{D}}(a^*) = max\, \mu_{\mathcal{D}}(a_j), \quad j = \overline{1,m} \quad (4)$$

Construction of fuzzy set membership functions was done by a method of paired comparisons based on the processing of estimator matrix, reflecting expert opinion about the degree of expressiveness of a set element property, which was formalized by this set (Saaty, 1974;

Saaty, 1979). A special scale was used for determining the matrix of estimations with qualitative evaluations of importance from "1" (equal importance) to "9" (absolute supremacy). Denote a set of n elements as X = {x}. Evaluation of an element x_i in comparison to an element x_j from the viewpoint of some property of a fuzzy set S is denoted by a_{ij}. For concordance it is assumed that $a_{ij} = 1/a_{ji}$. Evaluations a_{ij} form a matrix **A** = $\|a_{ij}\|$. The solution of an equation **Aw** = λ**w**, where λ – eigenvalues of the matrix **A**, is determined as an eigenvector of the matrix **A: w** = (ω_1, ω_2, … ω_n). The found values of ω_i, forming the eigenvector **w,** are taken to be the degree of conformity of elements x to the set S:

$$\mu_S(x_i) = \omega_i, \quad i = \overline{1,n} \tag{5}$$

As an example of calculations, processing of expert No. 1 estimations is given (Table 2). A matrix of paired comparisons of expert answers constructed according to the scale of evaluations of importance (Borisov.., 1990; Saaty, 1974) takes the form:

$$\mathbf{A} = \begin{pmatrix} 1 & 2 & 3 & 5 & 7 & 9 \\ \frac{1}{2} & 1 & 4 & 5 & 6 & 7 \\ \frac{1}{3} & \frac{1}{4} & 1 & 4 & 5 & 7 \\ \frac{1}{5} & \frac{1}{5} & \frac{1}{4} & 1 & 4 & 5 \\ \frac{1}{7} & \frac{1}{6} & \frac{1}{5} & \frac{1}{4} & 1 & 4 \\ \frac{1}{9} & \frac{1}{7} & \frac{1}{7} & \frac{1}{5} & \frac{1}{4} & 1 \end{pmatrix} \tag{6}$$

Eigenvalues of the matrix **A** obtained by calculations: λ_1 = 6,627; λ_2 = 0,163 + 1,93i; λ_3 = 0,163 - 1,93i; λ_4 = -0,268; λ_5 = -0,343 + 0,643i; λ_6 = -0,343 – 0,643 i, here λ_{max} = $\lambda_1 \cong 6.63$. Then it is necessary to find the eigenvalue of the matrix **A** on the basis of the equation:

$$\begin{pmatrix} 1-6{,}63 & 2 & 3 & 5 & 7 & 9 \\ \frac{1}{2} & 1-6{,}63 & 4 & 5 & 6 & 7 \\ \frac{1}{3} & \frac{1}{4} & 1-6{,}63 & 4 & 5 & 7 \\ \frac{1}{5} & \frac{1}{5} & \frac{1}{4} & 1-6{,}63 & 4 & 5 \\ \frac{1}{7} & \frac{1}{6} & \frac{1}{5} & \frac{1}{4} & 1-6{,}63 & 4 \\ \frac{1}{9} & \frac{1}{7} & \frac{1}{7} & \frac{1}{5} & \frac{1}{4} & 1-6{,}63 \end{pmatrix} * \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \\ \omega_5 \\ \omega_6 \end{pmatrix} = 0 \tag{7}$$

Consider introduction of the normalization requirement: $\omega_1 + \omega_2 + \omega_3 + \omega_4) + \omega_5 + \omega_6 = 1$. Further, a system of equations is considered (8):

$$\begin{cases} -5{,}63\ \omega 1 + 2\ \omega 2 + 3\ \omega 3 + 5\ \omega 4 + 7\ \omega 5 + 9\ \omega 6 = 0 \\ 0{,}5\ \omega 1 - 5{,}63\ \omega 2 + 4\ \omega 3 + 5\ \omega 4 + 6\ \omega 5 + 7\ \omega 6 = 0 \\ 0{,}33\ \omega 1 + 0{,}25\ \omega 2 - 5{,}63\ \omega 3 + 4\ \omega 4 + 5\ \omega 5 + 7\ \omega 6 = 0 \\ 0{,}2\ \omega 1 + 0{,}2\ \omega 2 + 0{,}25\ \omega 3 - 5{,}63\ \omega 4 + 4\ \omega 5 + 5\ \omega 6 = 0 \\ 0{,}14\ \omega 1 + 0{,}17\ \omega 2 + 0{,}2\ \omega 3 + 0{,}25\ \omega 4 - 5{,}63\ \omega 5 + 4\ \omega 6 = 0 \\ 0{,}11\ \omega 1 + 0{,}14\ \omega 2 + 0{,}14\ \omega 3 + 0{,}2\ \omega 4 + 0{,}25\ \omega 5 - 5{,}63\ \omega 6 = 0 \end{cases} \tag{8}$$

System (8) has only trivial or zero solution. To find the eigenvector **w,** one equation of system (8) is substituted by the normalization requirement. As a result of solution of the new system of equations, an eigenvector **w** of the matrix **A** is obtained**:**

ω_1=0,37; ω_2 = 0,3; ω_3 = 0,17; ω_4 = 0,09; ω_5 =0,05; ω_6 = 0,02, (λ_{max} = 6,63). $\sum_{i=1}^{6} \omega_i = 1$.

The values ω_i (i = 1, … 6), forming the eigenvector **w**, are taken to be the degrees of conformity of the E_1 expert answers to the fuzzy set.

Having determined how each of the alternatives corresponds to the considered criteria, the following sets are obtained:

C_1 ={0,17/*A*; 0,37/*B*; 0,02/*C*; 0,05/*D*; 0,30/*E*; 0,09/*F*};

C_2 = {0,37/*A*; 0,23/*B*; 0,03/*C*; 0,06/*D*; 0,23/*E*; 0,23/*F*};

C_3 = {0,32/*A*; 0,05/*B*; 0,09/*C*; 0,18/*D*; 0,02/*E*; 0,34/*F*};

C_4 = {0,04/*A*; 0,25/*B*; 0,25/*C*; 0,14/*D*; 0,07/*E*; 0,25/*F*};

C_5 = {0,03/*A*; 0,25/*B*; 0,09/*C*; 0,17/*D*; 0,05/*E*; 0,41/*F*};

C_6 = {0,03/*A*; 0,25/*B*; 0,04/*C*; 0,38/*D*; 0,10/*E*; 0,20/*F*}; (9)

C_7 = {0,26/*A*; 0,45/*B*; 0,03/*C*; 0,13/*D*; 0,03/*E*; 0,10/*F*};

C_8 = {0,02/*A*; 0,08/*B*; 0,37/*C*; 0,14/*D*; 0,02/*E*; 0,37/*F*};

C_9 = {0,03/*A*; 0,46/*B*; 0,09/*C*; 0,09/*D*; 0,09/*E*; 0,25/*F*};

C_{10} = {0,03/*A*; 0,47/*B*; 0,03/*C*; 0,03/*D*; 0,16/*E*; 0,27/*F*};

C_{11} = {0,48/*A*; 0,09/*B*; 0,04/*C*; 0,22/*D*; 0,02/*E*; 0,15/*F*};

C_{12} = {0,43/*A*; 0,25/*B*; 0,04/*C*; 0,04/*D*; 0,16/*E*; 0,09/*F*}.

The choice rule takes the form:

D = {min (0,17; 0,37; 0,32; 0,04; 0,03; 0,03; 0,26; **0,02**; 0,03; 0,03; 0,48; 0,43)/*A*;

min (0,37; 0,23; **0,05**; 0,25; 0,25; 0,25; 0,45; 0,08; 0,46; 0,47; 0,09; 0,25)/*B*;

min (**0,02**; 0,03; 0,09; 0,25; 0,09; 0,04; 0,03; 0,37; 0,09; 0,03; 0,04; 0,04)/*C*;

min (0,05; 0,06; 0,18; 0,14; 017; 0,38; 013; 0,14; 0,09; **0,03**; 0,22; 0.04)/*D*;

min (0,30; 0,23; **0,02**; 0,07; 0,05; 0,10; 0,03; 0,02; 0,09; 0,16; 0,02; 0,16)/*E*;

min (**0,09**; 0,23; 0,34; 0,25; 0,41; 0,20; 0,10; 0,37; 0,25; 0,27; 0,15; 0,09)/*F*}= {**0,02**/*A*; **0,05** /*B*; **0,02**/*C*; **0,03**/*D*; **0,02**/*E*; **0,09**/*F*}.

According to the rule *max(min)*, it is found that the best alternative from those considered by experts, in compliance with the fuzzy set theory, is the alternative *F* (construction of TPP working on domestic fuel). The second place in respect to preference is taken by the alternative *B* (construction of a hydroelectric power plant) and the third place – the alternative *D* (use of wind energy). The other three alternatives (*A* – a nuclear power plant in Visaginas, *C* – a solar energy power station and *E* – a TPP working on the imported fuel) are equal in respect to preference and take the next places after the third.

To reach conclusions, which reflect the consolidated opinion of the expert commission more precisely, it is necessary to rely upon the concept of stability (Varian, 1993). The concept of stability recommends using various methods for processing of expert opinions in order to select similar recommendations obtained when using such methods. Change of recommendation depending on the chosen method will indicate the high degree of dependence on the expert subjectivism. Therefore, apart from the fuzzy set theory, for acquisition of a consolidated expert opinion, two traditional methods were used: arithmetic average rank method and median rank method. In the given paper, a quantitative rather than the order scale was used for expressing expert preferences. Therefore, for aggregating individual preferences a method of group decision making was used, which was based on computation of geometric average values (Aczel & Saaty, 1983; Guzzo & Salas, 1995). Geometric average values of ranks are at equal distances from the minimum and maximum expert estimations. Table 3 demonstrates the results of processing the expert opinions by using these methods.

Table 3

Results of Calculations for Ranking Alternatives According to the Four Different Methods

Alternatives	***A***	***B***	***C***	***D***	***E***	***F***
Sum of ranks	44	27,5	53,5	44	51,5	31,5
Arithmetic average rank	3,67	2,29	4,46	3,67	4,29	2,63
The final rank by the arithmetic average	**3,5**	**1**	**6**	**3,5**	**5**	**2**
Medians of ranks	4	2	5	3,75	4,5	2,5
The final rank by medians	**4**	**1**	**6**	**3**	**5**	**2**
The final rank by the geometric average	**4**	**2**	**6**	**3**	**5**	**1**
The final rank by the fuzzy set theory	**4–6**	**2**	**4–6**	**3**	**4–6**	**1**

Final ranks by the median method as well as by the arithmetic average method are assigned by using the same rule. As a result, it is obtained that rankings of alternatives calculated by the both methods of expert opinion elicitation are almost the same. The best is the alternative *B*, the second place in respect to preference is taken by the alternative *F* and the third place – by the alternative *D*. The nuclear power plant in Visaginas city is ranked fourth by the experts, and the last place is taken by the solar cell power plants.

The final ranks of alternatives, obtained by two other ways of computation, according to the theory of fuzzy sets and according to the group decision making, are very similar in values. The best alternative accepted by the both ways is *F* (TPP using the local fuel). The second place is taken by the alternative *B* (HPP), the third place is taken by the alternative *D* (wind powered generators). Alternatives *A*, *E* and *C* according to the theory of fuzzy sets are equal and take positions from 4 to 6. According to the method of group decision making, alternatives *A*, *E* and *C* take the 4th, 5th and 6th places, and this coincides with the two traditional methods of computation (the method of arithmetic average ranks and the method of median ranks).

Thus, it is found that the consolidated opinion of independent experts representing various organisations, according to the computations, is quite unanimous. It is possible to say that the final ranks from the 3rd to the 6th in all the four ways of computation are practically equal. Some deviations are noticed in the average arithmetic rank method (the final 3rd and 4th ranks are equal – 3,5) and in the fuzzy set method (the 4th, 5th and 6th final ranks are equivalent). The traditional arithmetic average rank method and median rank method put alternative *B* in the first place, the second place is given to alternative *F*. On the contrary, the up-to-date methods of processing of the results of expert estimation (a method using fuzzy sets and a method using group decision making) put alternative *F* in the first place and alternative *B* in the second place. This shows that according to all four methods of computation, which are used in the paper, the first and final ranks are taken by alternatives *B* and *F*. Altogether, the final results of ranking alternatives adequately correspond to the requirements of result stability conception for scientific research and can be used in real life (Varian, 1993). This allows making conclusions.

Conclusions

The conducted analysis and the obtained results of mathematical processing by various methods of expert opinion elicitation make it possible to conclude the following:

1. The most promising directions for electric energy industry development in Latvia and, on this basis, for the creation of energy security potential of the country, according to the consolidated expert opinion, is the construction of HPP and heat power plants using its own energy resources.
2. The direction of wind power industry development is recognised as important, taking into account the geographic location of Latvia on the coast of the Baltic Sea without any obstacles for air mass transfer. This is the third place in the top list of the most promising sources of energy.
3. As to participation of Latvia in the construction of Visaginas nuclear power plant in Lithuania, it is probably the insufficient amount or absence of reliable information on a series of aspects of this project that has become the reason for experts to put this direction only in the fourth place of the top list.
4. All the directives and resolutions of the managing boards of the EU, relating to the energy policy, in the recent years contain requirements to reduce the dependence of the EU countries on external energy supplies. Therefore, it is natural that development of a direction based on the construction of TPP working on gas imported from outside the EU, is considered unpromising. It has the fifth place in the top list.
5. And the last place in the top list of energy industry development directions is taken by solar power plants. This is related to their relative expensiveness at present as well as to the geographic location of Latvia, which is situated in the temperate climate area with not so many clear days in a year like, for example, in Italy or Greece.

6. It is necessary to improve and streamline the operation of electric energy market of the Baltic States according to the EU requirements. On the agenda, there is the opening of the gas market that will increase the competition in the field of energy and will be beneficial for consumers. Taking into account the proximity and similarity of geographic and climate conditions of the Baltic States (Lithuania, Latvia and Estonia), it is necessary to develop collaboration in the field of creation of new generating capacities, and also in the field of transmission and implementation of electric energy. Good results could be achieved by cooperation in scientific research and by introducing new renewable energy resources because such studies could be quite expensive for one country.

7. It is necessary to pay more attention to the level of awareness of population and society of the Baltic States when discussing and implementing large-scale projects in the field of energy production (power industry), as they can influence the ecological security of vast territories and affect the interests of all the counties in the region.

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