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Regional energy strategy for selected region in Poland as a result of foresight project

作为预见项目结果的波兰选定区域之区域能源战略

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Abstract - **The paper describes the foresight methodology, especially the Delphi survey, which was conducted in 2010 in Lower Silesia. The Delphi survey was based on experts' opinions about technological theses. The research contains the analysis of the influence of particular theses on the implementation of the strategy's main aim. The mission of the strategy is to ensure energy security in the conditions of innovative and ecological regional energy sector, which uses local energy sources and, additionally, is open to competition. We used the foresight methodology for the following things: to identify main barriers as well as positive and negative factors for implementing Delphi theses; and to formulate the regional energy strategy, its mission, aims and activities for regional authorities.**

We propose to compare the Delphi's results to the results of quantitative methods, mainly growth curves, in order to control the results obtained by semi-quantitative methods, based on experts' opinions. The comparison could be made only for separate results because the main barrier is the access to relevant and representative data. There will be presented a short analysis for a separate thesis.

Keywords - **foresight, Delphi methods, growth curves, logistic substitution model, regional strategy**

I. INTRODUCTION

On the background of directions and current problems (e.g. innovativeness in the energy sector and economies; energy security in the European, domestic and regional scope; an ecological trend connected with climate changes) of energy policy in the European Union, the paper will present an approach to create a regional energy strategy for Lower Silesia (Poland). This is a special region because of its location, as it is bordered by Germany and by the Czech Republic. There are similar geographical characteristics (climate conditions and energy sources) near the border with the German region (Saxony), but there is a completely different structure of energy sources (energy mix), because in Germany the share of renewable energy sources (RES) is much higher. The domestic and regional policy influence this situation. Therefore, the paper presents the selected results of foresight research conducted by our team at Wroclaw University of Technology (WUT, Poland), which were obtained during the project *Energy Development Strategy of Lower Silesia by Using Foresight Methods*, co-funded by the European Regional Development Fund (ERDF)[1].

The research was based on Delphi methods and the experts were able to identify the most sophisticated theses according to previously identified energy problems which take place in Lower Silesia. For each thesis they identified, inter alia, the most probable time period required for completion, positive factors for its implementation as well as possible barriers and negative factors. Based on the results of three rounds of the Delphi survey the research team created a proposal of strategy for the researched region and it selected the groups which are:

- the most important for the region,
- supporting energy security in the region,
- supporting innovation in the regional energy sector,
- the most economic for regional society and the most important for ecological aspects.

In the next step of our research key actions for local authorities were defined. We used a mix of quantitate, semi-quantitative and qualitative research methods. Because

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of the specification of our research, which was focused on innovative energy technologies, the use of quantitative methods was limited to a narrow dimension in order to forecast key energy parameters in the consumption and production of: electricity, gas, heat.

Three years after finishing the foresight project the author [5] performed the quantitative research using the logistic substitution model (LSM) for the verification of the results of the semi-qualitative method – Delphi method – for one selected thesis dedicated to the development of renewable energy sources in Lower Silesia.

The main aims of the paper are to present the research method and the key results of the foresight project; and the comparison of the results for semi-quantitative and quantitative methods for the selected thesis. In the last part of this paper we present some comments about the barriers to implementing the whole strategy at regional level.

II. The Energy strategy for lower silesia

2.1. The Energy sector in Poland and Lower Silesia – main challenges

The Polish territory totals to 322.75 thousand km^2. The population was 38,478,602 in 2014 and its density – 123 persons per km^2. Poland is not a rich country, the GDP in 2014 was 1 728,676.6 m PLN (it is circa £309 m) and GDP per capita – 44,919 PLN. Polish GDP per capita in relation to the wealthiest country in the EU (at PPP) in 2013 year equalled 51%, but the growth rate in 2014 was 3.2 %.

In 2013 the key data for the energy sector was as follows:

- total energy production – 3006 PJ
- primary energy consumption – 4 465 PJ
- the share of RES in gross final energy consumption – 11.3%
- electricity generated from RES – 17 066.6 GWh
- energy intensity of the economy – 333.2 kgoe/1000 EUR.

There is much emission of greenhouse gases in Poland, e.g. in the year 2012 the total emission of CO_2 totalled 320,862 thousand tonnes and the emission of CO_2 per capita reached 8.6 t in the year 2011. This is the result of the large portion of fossil fuels (like coal and lignite) used in the production and consumption of primary energy as well as in electricity and heat. For example in 2013 50% of electricity came from coal, 34% from lignite, 3% from gas fuel, 10% from RES and 3% from the other energy sources. The greates part of renewable energy comes from solid biofuels (80.3% of RES) [1]. The energy produced from biomass is made by conventional power stations and CHP plants. These companies either burn conventional fossil fuels and biomass together, or only biomass. Because they produce ‘green energy’ according to current regulation they obtain support in the form of ‘green certificates’. This is a process of displacing the small independent RES by big energy companies. In addition the biomass is transported from remote areas, which is not neutral for the environment. Other RES that have undergone dynamic development in Poland are wind farms. In 2013 more than 35% of renewable energy in electricity production came from wind. This situation draws the need to develop grids. However, the number of new wind turbines planned by potential investors are much bigger than the TSO and DSOs can technically connect to grids.

Other problems in Poland connected with the energy sector are: the depreciation of infrastructure, the number of international electricity grid connections and the lack of gas supply diversification. These facts influence the energy security.

Lower Silesia is a region in south-western Poland. According to the macroeconomic indices the region is one of the best developed in Poland but the German regions (e.g. bordering Saxony) and the Czech regions (Kraj Liberecki and Kraj Kralowohradecki) have better value in macroeconomic indices. The population density in Lower Silesia is larger than the average population density in Poland, and it is similar to one in Kraj Liberecki. The global irradiation and solar electricity potential of Lower Silesia nearly amounts to 1,200 kWh/m^2 and is similar to Czech regions and Saxony in Germany, but the insolation in Leipzig and Dresden is smaller than in Lower Silesia [2]. This data is interesting because the value of installed solar capacity in Saxony is much larger than in Lower Silesia. Moreover, there are the autonomous local areas where 100% or almost 100% of energy comes from RES in Saxony, but in Lower Silesia there are none. There are some reasons for this situation, which are shortly described below:

- financial support addressed to local society in order to install the RES is bigger in Germany,
- development of RES investments, an education process about RES and ecological issues, which started earlier in Germany than in Poland,
- higher average income per capita in Saxony, e.g. the Gross Regional Product (GRP) per capita for Lower Silesia is comparable with its value for Czech regions but it is two times lower than in Saxony,
- a different system of regulation at local and state levels in Germany. In Poland regulations support mainly big energy companies and for this reason they make RES investments.

If we compare the regional growth rate, we can see that Lower Silesia is developing faster than bordering regions in the Czech Republic and Germany, which shows the higher development potential of the Polish region.

Looking at characteristics of the energy sector in Poland, and especially in Lower Silesia, we see that the main challenges are connected with:

- providing energy security,

[2] The values taken to the comparison come from yearly electricity generated by 1kW$_{peak}$ system with performance ratio 0.75 kWh/kW$_{peak}$ [re.jrc.ec.europa.eu/esti/index_en.htm].

- improvement of energy efficiency in whole energy logistic chain, from the energy production to energy consumption (at user level),
- bigger share of the RES in total energy production and consumption.

In these conditions the foresight research has sophisticated function for strategic approach at regional and state levels.

2.2. The characteristic of methodology to build the regional-energy strategy for Lower Silesia

The project *Energy Development Strategy of Lower Silesia by Using Foresight Methods* was conducted by an interdisciplinary team from WUT from 2009 to 2011. We realised 5 tasks (T) and used complementary foresight methods, which is in accordance with Popper's approach who recommends not only mixed-method based on quantitative and qualitative methods, but, mainly, the mixed-method based on two dimensions [4]:

- expertise versus interaction,
- creativity versus evidence.

These tasks are:

- T1: The analysis of the present situation of the energy market on Lower Silesia (a survey, a lecture review, an analysis of historical data, expertises, a "good practices" conference)[3],
- T2: The questionnaire study among the experts and its analysis and verification (a few expertises, a survey research using Delphi method, a survey, 4 experts' panels (dedicated to technology, economic, ecological and local self-government aspects as well as social issues)),
- T3: The stochastic analysis of the real data from the energy sector – a forecast (extrapolation of trends, time series forecasting),
- T4: The preparation of the document *The energy development strategy on the Lower Silesia* (scenarios, a SWOT analysis, brainstorming, expertises),
- T5: The preparation of the monitoring system of strategy implementation (benchmarking).

In Delphi research two kinds of experts participated:

- 83 experts from industry (including researchers) who completed Delphi surveys. The experts were divided into 4 topical groups: electro-energy, gas, heating and renewable energy,
- 18 key experts who wrote analyses, some of them supported the research team as advisers.

The central and most important part of our research was task No. 2. The first step was to define the theses. We defined 73 theses which were assigned to one of 15 topical groups. The base of the theses and their assignment, which was input to the first Delphi survey, was finished after the consultations with key experts and after the first technological experts' panel. Finally, in the next step of our research, we took one thesis less, namely 72 theses which were indicated by experts as supporting innovative solutions (including technologies[4]) for our region and divided them into the 15 topical groups: (1) Energy production based on coal and lignite, (2) Energy technologies using biomass, (3) Energy technologies using biogas, (4) Energy systems based on wind, (5) Energy systems based on water, (6) Energy systems based on solar energy, (7) Energy production based on nuclear power engineering, (8) Technologies in natural gas industry, (9) Innovative technologies of energy storage, transmission and distribution, (10) Technologies of heat, heating and cooling systems, (11) Fuel cells, (12) Smart Grids (SG), (13) The behaviour of users and technologies improving the efficiency of energy use, (14) Transport and energy based on hydrogen and synthetic fuels , (15) Organizational and structural changes at regional and local levels. The last group of theses (the 15th one) was added after the 1st experts' panel.

The second stage was Delphi surveys consisting of three rounds. In the first Delphi survey 11 questions was assigned to each thesis. In the first round of survey the experts could also modify the theses. The questions concerned: the period when the thesis will be realised, business which may develop if the thesis will be implemented, the benefits for the region as the results of its implementation, positive and negative factors, and the cost of its realization. The second survey was similar to the first one but it was more detailed, and the number of theses was reduced because the least important theses for the region were not taken into account. The questions concerning on benefits, and barriers were more accurate. However, the third survey was different because it had other goals. It concentrated on three scenarios regarding ecological, business (economic) and social aspects. In the third survey there were only three questions to each scenario. The experts marked the relevance of each thesis for a researched scenario in the first question. In the second one they chose the period when every thesis would need to be realized for each researched scenario. In the last question they marked activities (like: financial, educational, related to the regional law and other) which could be introduced if the scenario were to be realised. In this way some important information was obtained to construct energy strategy based on the scenarios.

The experts fulfil two functions in the foresight research. They are sources of tacit knowledge and they are the group representing the society (local authorities, regulators, energy companies, scientists, business connected with energy services and equipment). The experts participate indirectly in the construction of the scenarios and the energy strategy addressed to Lower Silesia.

The proposal of the regional-energy strategy was the main result of our foresight project. The approach to build the strategy – including its mission, main aims and actions dedicated to different kinds of participants – is presented in

[3] There is the list of methods used in the brackets.

[4] The experts assigned the technologies to one of 4 phases of technology life cycle. We selected only technologies belongs, according to experts opinions, to the first, second or third phases which means the most innovative technologies for the region.

Fig. 1. Fig. 2 shows the mission as well as main and detailed goals of this strategy.

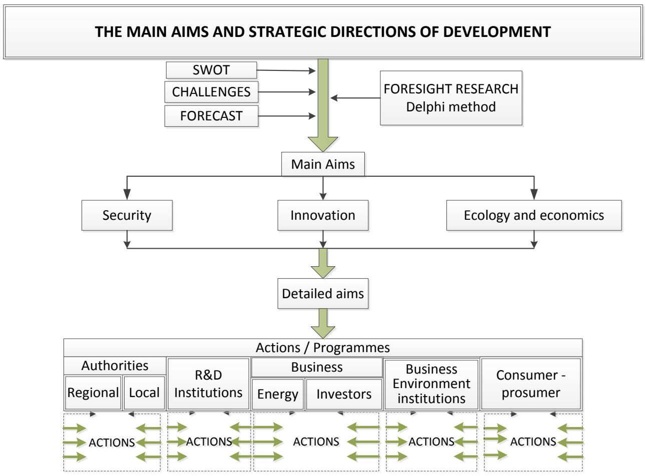
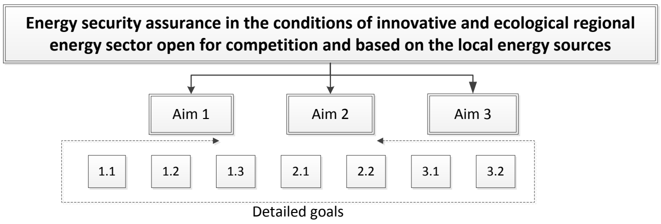


Fig.1, The method of building the energy strategy for Lower Silesia
Source: [6, pp. 18]



Legend: Aim 1 - Ensuring energy security; Aim 2 - The intensification of the innovation processes in the regional energy sectors; Aim 3 - The minimalisation of the effects on the natural environment and the introduction of the activities to economize the energy production and consumption; 1.1 - The energy security – current level; 1.2 - The energy security – medium – term level; 1.3 - The energy security – strategy level; 2.1 - The innovative research and implementation; 2.2 - The innovation – Smart Grids; 3.1 - Conducting the ecological actions in the energy sector; 3.2 - The efficiency of the demand side and of the suply side in the regional energy sector

Fig.2, The mission and aims of energy strategy for Lower Silesia
Source: [7, pp. 271]

2.3. Important Theses According to Experts' Opinion

As it was mentioned above, the obtained results of the foresight research, based on Delphi surveys, allowed us to select seven sets of theses which:

- (1) are the most important for Lower Silesia,
- (2) support changes in the shortest period and influence the region to the greatest extent,
- support the realization regarding: (3) economic, (4) ecological, (5) social, (6) energy security, and (7) innovative scenarios.

Five theses were assigned to the 4 of the 7 sets above. They are:

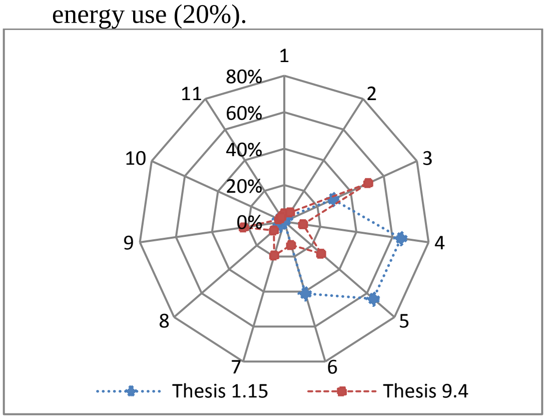
- Thesis 1.15[5]: There will be first attempts to extract the lignite localized near Legnica (a city in Lower Silesia).
- Thesis 7.2: The first small capacity nuclear reactor (10-40 MW) will be installed in Lower Silesia
- Thesis 9.4: 20% of electricity in Lower Silesia will come from scattered RES
- Thesis 13.1: The consumption of primary energy in the industry in Lower Silesia will decrease by 20% thanks to energy-saving processes.
- Thesis 13.3: The waste segregation technologies will be widely used.

Because the technologies based on fossil fuel and RES to produce electricity were chosen for quantitative analysis in this article, we should know what experts said about theses 1.15 and 9.4. 50% of experts indicated that thesis 9.4 could be achieved in the period of 2021-2030. 33% of respondents said it couldn't be comprehended until after 2030. The total costs of the implementation of this thesis are:

- the high cost of implementation proper (60%),
- the R&D cost (40%),
- high cost of living – exploitation (30%).

The benefits of the implementation of thesis 9.4 are (like on Fig. 3]:

- the growth of efficiency, production, transmission and distribution of energy (50%),
- the security of energy dispatch will improve (25%),
- saving fossil fuels (20%),
- the development of innovative processes related to energy use (20%).



Legend: 1 - Creating behaviours of economical energy usage; 2- The improvement of energy consumption efficiency by citizens (small consumers); 3 - The improvement of efficiency in producing, transmission and/or the distribution of energy; 4 - The growth of regional product; 5 - The improvement in the security of energy supply; 6 - The improvement in the access to energy; 7 - Saving fossil fuels; 8 - Achieving emission standards of CO_2, SO_x, NO_x and dusts; 9 - The development of innovative processes of energy use; 10 - Ecological education; 11 - The development of RES and distributed energy sources

Fig.3, Benefits of the realization theses 1.15 and 9.4
Source: The authors' concept

The main barriers to the realization of this thesis are the high costs of purchasing or/and implementing the technologies associated with the thesis (50 %).

The experts see thesis 1.15 as very important for Lower Silesia. More than 60% of experts pointed out this thesis as supporting energy security. 54% of experts indicated that this thesis could be achieved by 2020, and the next 23% in the years 2021-2030 predicted its completion. The last 23% of respondents say it couldn't be realised until after 2030. The cost of implementing this thesis includes:

- (very) high economic costs (73%),
- high social cost (73%),

[5] The number of the theses are the same as in original research.

- high environmental cost (84%).

The main benefits for the region relating to the implementation of this thesis are (Fig. 3):

- the growth of regional product (60%),
- the improvement in the security of energy supply (68%),
- the improvement in the access to energy (40%),
- the growth of efficiency in production, transmission and distribution of energy (20%).

The main barriers to the realization of thesis 1.15 are the introduction of new regulations connected with coal tax, the limits of greenhouse gas emissions and access to capital and the lack of following items: social acceptance for its realization, appropriate regulations (e.g. spatial development plans), the clear competences of local authorities in this range.

We can perceive that theses 1.15 and 9.4 are competitive to one another because thesis 1.15 supports the status quo and the interest groups related to conventional energy but the introduction of the 9.4 thesis changes the situation completely. On the other hand, they could be complementary to each other, and changes to the energy resources structure would be systematically made – the RES would replace fossil fuels.

2.4. Quantitative analysis – Logistic substitution model

Quantitative analysis was made based on the logistic substitution model (LSM) and IIASA *Logistic Substitution Model II* Version 0.9.87 application. The analysis was carried out for two kinds of electricity sources: independent RES and conventional power plants. The analysis was made for the value of electricity coming from generators located in Lower Silesia. The conventional power plants produce electricity mainly from lignite and coal, but recently from biomass as well. They also produce energy from wind farms and water turbines. The independent RES are alternative sources of electricity and we could match this situation to thesis 9.4. The availability of statistical data for Lower Silesia was the reason to choose these kinds of energy sources. The input data for the simulation was from 2000 to 2013. Nowadays, only slightly more than 2% of electricity is produced from independent RES in Lower Silesia. But we should remember that the significant part of Delphi experts said that 20% of electricity can be produced from independent RES.

Generally, a number of technology replacement processes as well as biological phenomenon, i.e. development of some kinds of population, show that these processes usually proceed in a similar way. Statistical data shows that in the first stage the researched variable increases at the same percentage rate each year. It is a typical situation for exponential function. After some period of time the increase becomes slower and slower. The growth function curves asymptotically and the curve has an S-shaped logistic curve. The LSM has some assumptions[6]:

- new technology (e.g. independent RES) enters the market and grows at logistic rates according to S-shaped logistic curve,
- declining technology fades away steadily at logistic rates uninfluenced by competition from new technology.

The logistic function is according to Eq (1):

$$N(t) = \frac{K}{1+e^{-\frac{\ln(81)}{\Delta t}(t-t_m)}}, \qquad (1)$$

Where:
K – limit of growth
Δt – duration of time – the period needed for the $N(t)$ value to increase from 10% to 80% of K
t_m – midpoint, the period after which the curve (value of $N(t)$) reaches 50% of K

A transformed formula according to Fischer and Pry is often used to demonstrate the substitution of technologies. As a result of this transformation, the data is presented on a linear scale and it is not presented in absolute values. The Fischer-Pry transform (FP(t)) is like Eq (2) and Eq (3):

$$FP(t) = \frac{f}{1-f} \qquad (2)$$

$$\ln(FP(t)) = \frac{\ln(81)}{\Delta t}(t - t_m) \qquad (3)$$

Where:

$$f(t) = \frac{N(t)}{K} \qquad (4)$$

Function *FP(t)* is plotted on a semi-logarithmic scale and the S-shaped logistic is rendered linear. The effect of simulation for statistical data for Lower Silesia is presented on Fig. 4.

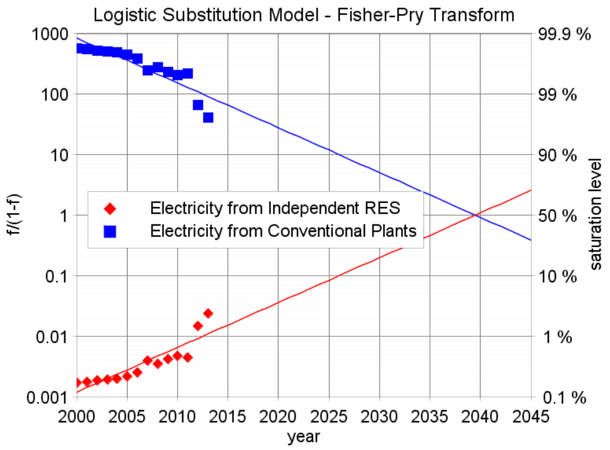


Fig.4, The substitution of researched sources of electricity production on Lower Silesia
Source: The authors' concept

[6] More information about the assumption of the LSM and models is presented in [2], [3].

The structure of electricity sources will be changed by 2039. Since 2039 more energy will be produced by independent RES and 20% of electricity will come from independent RES in 2033. The Δt equals 25 years and more than 8 months. When we compare the results of the quantitative methods (LSM) with the experts' opinion we can say that the regulation process supporting the development of RES should be more intensive in order to achieve 20% of electricity from independent RES.

III. THE STRATEGY IMPLEMENTATION PROSPECTS

The foresight research method made it possible to obtain a great deal of information and provided an opportunity to build a strategy proposal. Combining different research methods, data monitoring and making inferences based on quantitative methods enables regional authorities to modify instruments supporting the development of preferred technologies.

However, it should be noted that more than three years have passed since the completion of works on the Energy Strategy for Lower Silesia using foresight methods. This should have been sufficient for the assessment of conditions, opportunities and effects as well as the scale of the implementation of the strategy. In general, the scope and scale of the strategy implementation has been rather limited. However, to properly assess the causes of such situation and further potential of the use of the strategy it seems advisable to view the issue in three contexts, namely: international, national and regional.

3.1. THE INTERNATIONAL CONTEXT

In the international scene, particularly in Europe, there has been an increase of belief in the need to speed up the processes aimed at increasing the use of RES and maximization of the opportunities to increase energy efficiency. In general terms, one could venture a thesis that many EU countries are expressing the advisability or rather the necessity of energy transition that would result in re-industrialization processes through technological innovations allowing to carry out this transformation. The above thesis seems to be confirmed by the substantive and political content of the Transition to Energiewende conference in Berlin 23 – 26 March 2015 attended by dozens of ministers and deputy ministers of economy and energy management from many countries around the world. At the conference, both representatives of governments and of the academy expressed the need – necessity to transform the energy sector, including decarbonisation of energy processes.

Another conference to be mentioned here took place in Aberdeen; 7 – 9 July 2015, where scientists as well as economists from many countries were arguing for energy transition and the need to conduct research in the field of energy recovery processes (including the use of CCS), energy efficiency improvements as well as the social and economic impact of the changes occurring in the energy sector.

3.2. THE POLISH CONTEXT

Poland is a special country as far as its use of coal and lignite as primary energy sources is concerned. In terms of electricity production the share of coal is relatively very high (compared to other European countries) and amounts to about 90%. In Poland, the coal and lignite sector and the power generation sector using these two sources have been intensively developed since the fifties of the twentieth century. Some Polish regions (Silesia) and sub-regions such as the area of Bełchatów, Konin or Turoszów have lignite mines closely cooperating with power plants. It can be said that there is a kind of production monoculture in these regions. Hence, power and coal sectors have large political significance which under certain conditions can hardly be overestimated. As a result, the process of moving away from coal as the primary energy carrier is questioned in Poland and a number of significant bodies refer to the ideas resulting from the climate-energy package as if they were a kind of religion which does not necessarily have to be followed. This process is amplified by formal and institutional regulations. In fact, in Poland there is the phenomenon of regulation capture which consists in appropriating the regulation processes by the energy sector. As a result, it is difficult to find stimulators in Poland that would lead to a more extensive use of RES. It can be concluded that at present it will be difficult to find strong stimulants in Poland, including public support, for the intensification of the processes characteristic of the "energy transition".

3.3. REGIONAL CONTEXT

The Energy Strategy developed was clearly addressed to one of the 16 Polish regions, namely the region of Lower Silesia in the south-western part of the country. From the beginning of the strategy development the regional authorities have declared a keen interest in the document being prepared and to some extent supported the work on it. In Poland, local elections at the regional level are held every 4 years. The latest took place one and a half years ago. They brought a change of people in the authorities and a decrease of interest in energy policy in the region. As a result, the operational program for the region of Lower Silesia contained provisions which directly or indirectly referred to the Energy Strategy being developed. In this context the following aspects of the operational programme for Lower Silesia deserve special attention: the programme to improve energy efficiency, especially in the use of the buildings managed by local authorities and, to a limited extent, promotion of renewable energy installations. However, it can hardly be concluded that the region of Lower Silesia is prepared to fully implement intensive activities leading to the maximum use of the energy strategy discussed here or to the transformation of the processes of energy acquisition, transmission and consumption.

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