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Research Article

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Improving energy efficiency and building a low-emission economy based on example of Lesser Poland Voivodeship

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Abstract: Improving energy efficiency and building a low-emission economy are fundamental elements of sustainable development. The concept is based on a rational-energy economy and is aimed at limiting the negative consequence of the impact of energy on the environment. The main purpose of the paper is to assess the application of activities for both improving energy efficiency and building a low-emission economy, undertaken in Małopolska. Thermomodernization, installations of renewable energy sources, replacement of inefficient heating sources, and low-emission transport are among the cofinanced activities in the implemented programs. The first section of this paper discusses existing legal acts in the European Union, at the national and provincial levels, related to the analyzed issue. The second section contains description of the actions undertaken for improving energy efficiency and air quality, as well as for increasing the use of renewable energy sources, in Małopolska. The third section includes a qualitative assessment of the effects obtained and further directions for activities in this field.

Keywords: energy efficiency, low-carbon economy, low emission, sustainable development, Lesser Poland

1 Introduction

The correlation between the state of the natural environment and socioeconomic development was first observed in the sixties of the past century. It was found that the activities carried out at the time resulted in environmental degradation and translated into the weak state of the economy and affected the prospects for its development. The idea of “sustainable development” appeared for the first time in 1980. It was used in a document entitled “World Conservation Strategy – Living Resource Conservation for Sustainable Development”, drawn up by the International Union for Conservation of Nature and Natural Resources, which primarily concerned environmental aspects. Then, the World Commission on Environment and Development referred to sustainable development in terms of both environmental and economic issues. The current definition was disseminated at the United Nations Conference on Environment and Development, in Rio de Janeiro, in 1992. According to the explanation, sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. The transformation process, ensuring that the current generation satisfies its needs without diminishing the opportunities for further development, should be implemented by integrating the following developmental activities:

- a) economic – satisfying the basic material needs of the world using technology and development of technology that does not damage the environment (the issue of energy economics is discussed in more detail by Paska (2007);
- b) social – a social security (the elimination of hunger and poverty) and the protection of health, safety, access to education, and culture;

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c) environmental – based on the elimination of phenomena that threaten the environment and thereby stopping the latter's degradation.

One of the activities undertaken for sustainable development was to define an ambitious plan aimed at improving the lives of people anywhere in the world. It happened in 2015, during the United Nations Sustainable Development Summit. Targets contained in the 2030 Agenda for Sustainable Development are presented in Table 1. Implementation of the agenda aims to reduce social inequalities, combat climate change, and ensure a consistent and sustainable economic growth.

Table 1. The Sustainable Development Number [The United Nations, 2015]

Number	Name	Description
1	No poverty	Eliminate poverty in all its forms around the world
2	Zero hunger	Eliminate hunger, achieve food security and better nutrition, and promote sustainable agriculture
3	Good health and well-being	Ensure healthy lives for all people of all ages and promote well-being
4	Quality education	Ensure high-quality education for all and promote lifelong learning
5	Gender equality	Achieve gender equality and empower all women and girls
6	Clean water and sanitation	Ensure access to water and sanitation for all through sustainable water management
7	Affordable and clean energy	Ensure access to affordable, reliable, sustainable, and modern energy for all people
8	Decent work and economic growth	Promote sustainable and inclusive economic growth, full and productive employment, and decent work for all
9	Industry, innovation, and infrastructure	Build stable infrastructure, promote sustainable industrialization, and support innovation
10	Reduced inequalities	Reduce inequality within and among countries
11	Sustainable cities and communities	Make cities and human settlements safe, inclusive, stable, and sustainable
12	Responsible consumption and production	Ensure sustainable consumption and production patterns
13	Climate action	Take urgent action to combat climate change and its consequences
14	Life below water	Protect the oceans, seas, and marine resources and use them in a sustainable way
15	Life on land	Protect, restore, and promote the sustainable use of terrestrial ecosystems, ensure sustainable forest management, combat desertification, restrain and reverse land degradation, and halt the biodiversity loss
16	Peace, justice, and strong institutions	Promote peaceful and inclusive societies, ensure access to justice for all people, as well as build effective and accountable, inclusive institutions at all levels
17	Partnership for the goals	Strengthen implementation measures and revive global partnership for sustainable development

The concept of sustainable development is implemented through strategic documents at the levels of regions, cities, and rural areas in Poland. The information included in this paper is consistent with the following national and European Union (EU) strategic documents:

- Communication from the Commission – Europe 2020 – A strategy for smart, sustainable, and inclusive growth [European Commission, 2010];
- National Development Strategy 2020 [The Council of Ministers, 2012];
- National Spatial Development Concept 2030 [Ministry of Regional Development, 2012];
- Poland 2030 “Long-term National Development Strategy 2030”. Third Wave of Modernity (LTNDS);
- Strategy for Responsible Development [Ministry of Infrastructure and Development, 2017].

All mentioned documents indicate the requirement to create economic growth scenarios using the sustainable development concept. Accordingly, it is possible to use the entire potential of each area. On the other hand, on analyzing the practice of regional development, the aim of increasing each region's competitiveness is stressed, which seems to be somewhat contradictory to the idea of sustainable development [Czarnecka et al., 2017].

Considering the negative effects of satisfying the energy demand in the field of energy production and consumption, the sustainable development concept has also been implemented in the energy sector. The term “sustainable energy development” means energy management in such a way as to ensure access to a sufficient amount of energy, both current generation and future, eliminating the negative impact on the environment.

Sustainable development is also one of the factors affecting the improvement of energy security. Other factors used to assess energy security can be found in a previous work [Staśko and Kaliski, 2006]. The authors make an attempt to assess energy security by assigning weights to specific indicators.

2 Activities in the field of sustainable energy development in Lesser Poland Voivodeship

A multitude of activities have been undertaken to improve energy efficiency and build a low-emission economy, because of the insufficient quality of air, especially in the autumn and winter seasons. There are notorious exceedances of the permissible concentrations of the following pollutants: particulate matter (PM₁₀ and PM_{2.5}), benzo(a)pyrene, and nitrogen dioxide. The highest exceedances occur in the case of benzo(a)pyrene (85% of the Lesser Poland Voivodeship, which is inhabited by 94% of the population).

The occurrence of these pollutants results in low emissions in the Lesser Poland Voivodeship. This phenomenon is defined as the emission of harmful dusts and gases from emitters located at heights of up to 40 m, and this is the biggest problem regarding the quality of air in this area. The source of pollutants is primarily the inefficient combustion process in residential and public buildings. The buildings usually require thermomodernization and exchange of boilers [Mirowski and Orzechowska, 2015]. In addition, residents also burn prohibited items, such as garbage, industrial waste, or fuel of very poor quality. Pollution from the transport sector is accountable for the formation of low emissions as well.

There has been an intensification of activities aimed at improving air quality in this region in recent years because the low emissions have negative effects on the health and life of residents. The purpose of this article is to enumerate the actions taken and provide a qualitative assessment of their implementation. The first section contains the analysis of the legal acts in the field of air protection at the EU, national, and provincial levels. An analysis of the implemented repair programs is provided in the second section. The third section contains a summary and indication of further directions for activities in this field.

2.1 Legislation

2.1.1 At the EU level

Poland, as an affiliate state of the EU, is obliged to comply with the legal acts in force within it. One of the superior features of the European Commission is the energy union and actions in the field of climate protection. The aim of the EU programs being implemented is to strive for universal access to safer, affordable, and sustainable energy. The most important fields of activity in the EU energy union strategy include improving energy efficiency and lowering the economy's emissions. Improving energy efficiency leads to reduction in emissions and improvement in air quality, while an ambitious policy to tackle climate change aims to decrease greenhouse gas emissions, as well as to expand low-emission transport and technologies based on renewable energy sources (RESs). Activities have already been taken in the assumed directions by signing the following legal acts in the discussed field:

- 2020 Climate & Energy Package [European Commission, 2009] – the document sets out a set of rules that guarantee climate and energy targets for the EU by 2020. The three most important targets defined in this package are as follows: 20% reduction in greenhouse gas emissions compared to 1990 levels, 20% share of EU energy from RESs in the total energy consumption, and an increase of 20% in energy efficiency.
- 2030 Climate & Energy Framework [European Commission, 2014] – the document sets three targets for greenhouse gas emissions, share of RESs in total energy consumption, and improvement of energy

efficiency by 2030: At least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 27% share for renewable energy, and at least 27% improvement in energy efficiency.

- 2050 Low-Carbon Economy [European Commission, 2011] – the document contains a low-carbon economy roadmap and suggests the following: by 2050, the EU should reduce greenhouse gas emissions to 80% compared to 1990 levels, and the milestones to achieve this are 40% emissions cuts by 2030 and 60% by 2040. It was pointed out that all sectors need to contribute to the reduction of greenhouse gases, and the measures need to be feasible and affordable.
- The Clean Air for Europe (CAFE) Program: Towards a Thematic Strategy for Air Quality [European Commission, 2001] – the CAFE directives divided the EU into vulnerable zones according to population density, as well as by using standardized methods for measuring pollution and data collection. The main objectives of the CAFE directives are to define air-quality objectives and to develop, collect, and validate scientific information on the effects of air pollution.
- The Energy Efficiency Directive 2012/27/EU [The European Parliament and the Council of the EU, 2012] – the document imposes on the Member States the following objectives: to establish indicative national targets for energy efficiency based on their primary or final energy consumption and to establish a long-term strategy to support investments in the renovation of utility buildings and households.

At the national level

- The Environmental Protection Law [The Chancellery of the Sejm, 2017a] – it introduces solutions related to improving the condition of air and methods for air pollution measurements in Poland.
- The Renewable Energy Sources Act [The Chancellery of the Sejm, 2017b] – it includes support mechanisms and instruments for the production of electricity and heat from RESs.
- The Energy Efficiency Act [The Chancellery of the Sejm, 2016] – it contains the duties of public sector entities in the field of energy efficiency.
- The Regulation of the Ministry of Environment [The Ministry of Environment, 2012] about assessment of levels of dangerous substances in the air.
- The Regulation of the Minister of Development and Finance on the requirements for solid fuel boilers [The Minister of Development and Finance, 2017] – the purpose of this regulation is to allow only the best boilers that meet stringent emission standards in the municipal and home markets.
- The proposal for the Regulation of the Minister of Energy on quality requirements for solid fuels [The Minister of Energy, 2018] – currently, the energy sector is completing work on the completion of regulations aimed at, among others, elimination of solid, poor-quality fuels from the incineration processes in the municipal and living sectors.
- National Program for Air Protection [The Ministry of Environment, 2015] – this document has been developed by the Ministry of the Environment, because pollutant levels in the air exceeding the permissible concentrations occur in a large area of Poland, and the actions taken by local self-governments do not affect the change of this state. Therefore, its implementation should make it possible to reach acceptable levels of harmful compounds and dust in the perspective of 2030. The levels indicated by the World Health Organization (WHO) are accepted as acceptable levels.

2.1.2 At local level

The issues of air protection are also considered in air protection programs at the voivodeship or local level. The effectiveness of the actions taken depends on both the policies and solutions adopted at the local level, as well as on the possibility of obtaining funds and the level of public awareness [Klojzy-Kaczmarczyk and Mazurek, 2009]. The improvement of air quality is a substantial component of the policy of the Lesser Poland Voivodeship. The Małopolska authorities were the first to sign the so-called “anti-smog resolution”. In addition, there is also the Air Protection Program (POP), which is cyclically evaluated and updated:

- The Resolution No. XXXII/452/17 of the Regional Assembly of the Małopolska Region regarding the introduction of limits and prohibitions in the field of use of installations in which the fuel is burning on 23

January 2017 in the Małopolskie Voivodeship [2017] – the document limits the creation of new sources of pollution, sets transitional periods for currently used coal and wood boilers, and introduces requirements for the quality of fuels used so as to eliminate carbon waste and wet wood.

- Air Quality Plan (POP) [2017] – the purpose of this document is to achieve in the Małopolska Region, by 2023, admissible levels of the following air pollutants: PM₁₀, PM_{2.5}, benzo(a)pyrene, nitrogen dioxide, and ozone. The essential activities focused on air-quality improvement set out in the Air Quality Plan include the following:
 - introducing restriction on the use of heating devices fired by solid fuels;
 - implementation of local low-stack emission reduction programs – elimination of inefficient devices based on solid fuels;
 - development and modernization of municipal heating network and gas distribution networks to connect new consumers;
 - thermomodernization of buildings and support of energy-efficient buildings in housing and public utilities;
 - reduction of emissions from transport vehicles;
 - reduction of industrial emissions;
 - education in the field of environmental protection for inhabitants;
 - improving the conditions for ventilation of the cities and protection of urban green areas.

In addition, the municipalities of the Małopolskie Voivodeship are obliged to prepare Low-Emission Economy Plans (PGN), in which they define the vision of the commune's development toward a low-emission economy.

3 Conclusion from the analysis in the field of energy and air protection

A common practice in combating low emissions is to use district heat for space heating. However, it should be borne in mind that hard coal is the main fuel for heat production in heat and power plants in the Małopolskie Voivodeship. Nevertheless, the combined heat and power (CHP) operators are obliged to fully report their activities, so that there are data on the amount of pollutants emitted by them to the atmosphere. This information is not available for the combustion of solid fuels in residential buildings.

The next step in the combat against low emissions is the use of natural gas for space heating. The Lesser Poland Voivodeship has the best-developed infrastructure of gas network in Poland [Łysik and Zyśk, 2017]. The gasification rate in this case amounts to 85% (for Poland, it is 58%). The Polish gas distribution system operator Polska Spółka Gazownictwa (PSG) declares that, by 2022, gas will flow to municipalities, which it does not yet reach. According to the plan, PSG will implement five large investment projects, under which 150 km of gas network and six gas stations will be built. The company is planning to gasify 74 municipalities in Małopolska. In connection with this plan, residents of the new areas will have the opportunity to choose a more environment-friendly fuel than coal.

In the combat against low emissions, installations based on RESs also play an important role. Currently, there are 141 RES installations in Małopolska. The number of installations and the installed capacity depending on the kind of RES is presented in Table 2. The largest number of installations generates energy from solar radiation.

Table 2. RES installations in the Lesser Poland Voivodeship in 2017 [URE - Urząd Regulacji Energetyki, 2017]

Installation	Number of installations	Capacity, MW
Produced from biogas from wastewater treatment plants	10	4.9
Produced from landfill biogas	5	3.2
Producing from agricultural biogas	2	1.2
Produced from mixed biomass	1	3.2
Manufacture from biomass from solid municipal waste, among others from sewage treatment plants	1	16.9
Wind farms on land	13	6.7
Production from solar radiation	53	9.2
Hydroelectric power plants up to 0.3 MW	32	2.8
Hydroelectric power plants up to 1 MW	9	5.5
Hydroelectric power plants up to 5 MW	10	27.4
Hydroelectric power plants up to 10 MW	1	8
Hydroelectric power plants >10 MW	1	56
Pumped or hydroelectric power plants with a pump member	1	92.5

The signing of the mentioned legal acts at the European, national, and provincial levels means that local governments are obliged to take actions in the field of air protection. Conducting thermomodernization investments, installing RESs, or introducing low-emission transport requires high financial outlays, which cannot be covered from the own resources of communes. Therefore, a very important task for local authorities is to raise funds for the implementation of planned projects. In previous years, many support mechanisms for these investments have been launched. Measures to improve air quality could be obtained from both domestic and international funds. Table 3 contains a summary of the implemented programs, along with the effects achieved. The acquired funds were intended primarily for thermomodernization tasks, such as replacement of windows and doors, insulation of walls, and replacement of heat sources. The financial support extended included both public utility buildings and the residential sector. Reduced energy demand as a consequence of thermal modernization translates into a reduction in the emission of harmful compounds to the atmosphere and, thus, leads to improved air quality. Part of the funds was earmarked for the installation of RESs, mainly solar collectors. The smallest support was intended for low-emission transport.

Table 3. Programs implemented in Małopolska in the field of improving air quality

Program	Years	Funds	Impact of the program on improving air quality
The Regional Operational Program for the Małopolska Region for 2007–2013 [http://www.rpo.malopolska.pl/english]	2007–2013	129.4 million euros	Reduction of energy demand in thermomodernized buildings; reduction of emission of harmful compounds into the atmosphere by replacing inefficient heating sources with renewable energy sources; reduced emission of pollutants from the transport sector by introducing a low-emission bus fleet
Operational Program Infrastructure and Environment [https://www.pois.2007-2013.gov.pl/English/]	2007–2013	1.92 billion euros	Creation of the Low-emission Economy Program for the City of Krakow, reduction of pollutant emissions from the transport sector by increasing the number of routes, improving the capacity on existing routes, and creating parking lots at transport nodes

Program	Years	Funds	Impact of the program on improving air quality
LIFE Program [http://nfosigw.gov.pl/en/nfepwm/financing-environmental-protection/]	2014–2020	70 million PLN	Improvement of public awareness, and raising funds for activities aimed at improving air quality through the creation of a network of ecoadvisors in municipalities located in the Małopolska region.
Limitation of Low Emission Program (PONE) [http://www.niskaemisja.pl/program_ograniczenia_niskiej_emisji/]	2012–2018	2012–2015: 44 million PLN; 2016: 10 million PLN; 2017: 5 million PLN; 2018: 10 million PLN	Reduction of pollution emitted to the atmosphere from the municipal and household sector through cofinancing for the elimination of inefficient heating sources and the installation of boilers that meet environmental requirements
KAWKA Program [https://nfosigw.gov.pl/en/]	2014–2015	58.6 million PLN	Reduction of PM ₁₀ dust emission by about 123.763 Mg/year; reduction of dust emission PM _{2.5} by approximately 123.458 Mg/year; CO ₂ emission reduction by approximately 20,981.903 Mg/year.
Operational Program – Saving Energy and Promoting Renewable Energy Sources	2013–2016	12.6 million euros	Increased share of RESs; reduction of both energy consumption and emission of pollutants through thermal modernization of public buildings
SOWA Program	2013–2015	356 million PLN	Reduction of pollutant emissions by improving the energy efficiency of street lighting
Swiss–Polish Cooperation Program (SPPW) [https://www.programszwajcarski.gov.pl/en/]	2007–2017	489 million CHF	Increase in the share of RESs by installing solar installations for >25,000 buildings; reduction of energy consumption through thermal modernization of public buildings
EEA GRANTS [https://eeagrants.org/]	2004–2009; 2009–2014	324 million euros; 578 million euros	Improvement of social awareness in the field of air protection through the implementation of a project concerning the collection, modeling, and sharing of spatial data
Rural Development Program [http://www.minrol.gov.pl/eng]	2007–2013	13.2 billion euros	Increase in the share of RESs by installing solar installations on residential buildings

4 Conclusion

Since 2009, in Małopolska, the concentration of activities related to building a low-emission economy and improving energy efficiency in areas where air-quality standards are exceeded, as well as monitoring of the effects of these activities, is noticeable. The Regional Operational Program for the Małopolska Region implemented in 2007–2013, present for 2014–2020, and the WFOŚiGW programs in Kraków supported the financing of proecological investments in local government units, enterprises, and households. The next step should be the rational management of energy and fuels in order to improve local energy security.

Effective implementation of the principle of sustainable development in Poland should take place at the level of municipal governments, which are responsible under the Energy Law for preparing the draft assumptions for the program for the supply of heat, electricity, and natural gas. In particular, the drafts should contain the following:

- a) assessment of the current state and anticipated changes in the demand for heat, electricity, and gaseous fuels;
- b) projects that rationalize the use of heat, electricity, and gas fuels;

- c) the possibilities of using existing surpluses and local resources of fuels and energy, including combined heat and electricity production as well as management of waste heat from industrial installations; and
- d) the scope of cooperation with other municipalities.

In many cases, municipalities lack a strategy to implement energy and environmental projects. It should be assumed that the energy clusters that will be created will complement these gaps and will contribute to better achievement of the assumed objectives [Sołtysik et al., 2018] and development new technology, such as RESs, hydrogen-based energy market [Stygar and Brylewski, 2015], or energy storage.

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