Implementation of the 2030 sustainable development goals - affordable and clean energy in Poland

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Abstract. One of the most serious challenges facing the world, including the European Union and Poland, is the climate crisis and environmental pollution. The article presents an analysis of the implementation of sustainable development goals in the field of Affordable and clean Energy in Poland. The Sustainable Development Goals have replaced the Millennium Goals and enable their continuation. They were defined at the United Nations Conference in 2012. 17 goals and 169 actions were set. Sustainable Development Goals are a set of activities, the implementation of which is to lead to the development of sustainable development in the environmental, social and economic terms. Achieving the goals will be possible among others through changes in the field of climate, education, poverty or the natural environment. The study analyses, inter alia, such indicators related to the discussed objectives like energy import dependency by products, energy productivity, share of renewable energy in gross final energy consumption by sector, final energy consumption in households per capita were analysed. This made it possible to indicate the level of achievement of the set goals, as well as to determine the possibility of achieving the goals set by 2030. The authors also presented the results of the generated for the analysed indicators forecasts. The presented results were obtained with the use of mathematical models, which were finally selected by the authors after the validation process. The time horizon of the forecasts was adjusted to the requirements of sustainable development goals. Countermeasures that can be taken to accelerate the deadline for achieving the targets were also outlined.

1. Introduction
The term sustainable development was created several decades ago and has been constantly evolving since then. Initially, it meant taking actions that would make it possible to meet the needs of society today, but also in the future. It mainly related to achieving economic growth from which modern generations can benefit while at the same time caring for the natural environment.

Currently, sustainable development takes into account the previous postulates, but a total of 17 goals have been set, the implementation of which is to ensure comprehensive actions for the environment, well-being and humanity. They were included in The 2030 Agenda for Sustainable Development. The agenda was developed in 2015 by the United Nations. It covers wide-ranging activities with a global reach. It is a continuation and extension of the so-called Millennium Goals, the implementation of which was to end in 2015 [1].
Achieving the set goals is intended to create a new type of economy that will ensure a balanced and undisturbed growth, while ensuring a high standard of living and health and the absence of negative impact of economic development on the environment. The goals are to be achieved through the implementation of 169 undertaken tasks. Each of them will allow the above-mentioned goals to be attained in the environmental, economic and social dimensions.

This study focuses on the analysis of the seventh of the 17 goals, i.e. Affordable and clean Energy in Poland. For this purpose, the indicators proposed by Eurostat were used. They include:

- Primary energy consumption.
- Final energy consumption.
- Final energy consumption in households per capita.
- Energy productivity.
- Share of renewable energy in gross final energy consumption by sector.
- Energy import dependency by products.
- Population unable to keep home adequately warm by poverty status.
- Greenhouse gas emissions intensity of energy consumption [2].

In Affordable and clean Energy, the following goals were set to be achieved by 2030:

- Universal access to affordable, reliable and modern energy services, the long-term target for this indicator is 100%.
- Increasing the share of renewable energy sources in the global energy mix. This increase was determined to be significant. By 2030, this is to be a share of 20%. The long-term goal is a 51% share level [3].
- Doubling of the global energy efficiency growth rate.
- Establishing and expanding the already existing international cooperation to conduct research on clean technologies, including Clean Coal Technologies.
- Providing access to modern energy services and to energy infrastructure.
- For the Greenhouse gas emissions intensity of energy consumption indicator, the long-term target was set at 0.

The study focuses on energy productivity, the share of renewable energy sources in Poland's energy mix, greenhouse gas emissions and the availability of energy at an acceptable price.

2. Analysis of the selected indicators

The time series of the indicators selected for the analysis are presented below. It should be noted that since 2000 Poland's dependence on energy imports has been constantly increasing (Figure 1). Over the last few years, it has become more and more important and in 2015-2019 it increased threefold. This phenomenon indicates that Poland has been increasingly using energy obtained from abroad. Additionally, the import of electricity has also been growing. It has been growing as a result of the gap that arose as a result of the decline in production in power plants in Poland, although, according to the assumptions of the Ministry of Energy, it was supposed to have only regulatory significance.
Energy productivity is the total monetary value of goods and services produced in a country based on the unit of primary energy used at the same time. The indicator measures the efficiency of energy consumption and determines the degree of independence of GDP growth from energy consumption. Energy productivity is increasing, and in the years 2000-2019 this increase reached 70% (Figure 2). Thanks to this, it is possible to obtain a higher level of production of goods using at most a constant amount of energy. This has a positive effect on the cost of producing goods and reduces the negative impact of production on the natural environment. Using energy in a rational and justified way contributes to the reduction of its consumption, thanks to which any economic or communal activity contributes to building a country that cares for the environment, with an efficient economy that meets EU requirements. Additionally, the increase in productivity translates directly into the country's energy security.
In the light of the need to reduce CO$_2$ emissions and the EU policy promoting renewable energy sources (RES), their share in the structure of energy production has increased significantly in the last decade (figure 3). Until now, renewable energy sources in Poland were based mainly on wind farms, the development of which was supported by the state. Other energy sources used in Poland are biomass and hydropower. In the context of continued growth of demand for energy, renewable energy sources have become a permanent element of the energy sector. Over the past 12 years, the increase in the use of renewable energy in Poland has been around 400%, but it is still insufficient for renewable energy sources to take over the role of coal in the energy mix within the next ten-odd years. In 2019, their share in gross final energy consumption was only 12%.

![Figure 3](image.png)

**Figure 3.** Share of renewable energy in gross final energy consumption, own study based on [2]

Final energy consumption in households per capita remains at a constant level, as presented in Figure 4. This is due to the activities undertaken in Poland, including the thermal modernization of buildings, as well as sound and efficient heating devices [4]. In Poland, households consume about 20% of the energy used throughout the country. It is a significant share compared to the EU average. Households mainly use fuels such as hard coal and firewood. Natural gas is used primarily for preparation of meals. The vast majority of households in Poland are also well-equipped with household appliances powered by electricity [5].
Figure 4 Final energy consumption in households per capita, own study based on [2]

Figure 5 presents Greenhouse gas emissions intensity of energy consumption. The indicator was determined in relation to the base year, which 2000. Greenhouse gas emissions in Poland have been falling intensively since the 1990s. Currently, this decline is much less dynamic (11% in the analysed period), and its acceleration requires taking further steps and actions both in terms of the use of modern technology and organizational changes, e.g. limiting unnecessary transport.

Figure 5. Greenhouse gas emissions intensity of energy consumption, own study based on [2]

Economic development is inextricably linked with an increase in energy consumption. This is also illustrated in Figure 6. Temporary drops in energy consumption were related to the economic crisis. However, the overall trend in the time series final Energy consumption is increasing. In the years 2000-2019, final energy consumption increased by almost 30%.
3. Results and discussions
For some indicators, long-term quantitative targets are set in the Sustainable Development Report 2020. For Objective 7, they are: greenhouse gas emissions intensity of energy consumption, share of renewable energy in gross final energy consumption by sector, population with access to electricity and population with access to clean fuels and technology for cooking. For the remaining indicators, they were not specified. Therefore, the authors set trends shaping selected indicators in accordance with the methodology defined by Eurostat in the document: Sustainable development in the European Union. The Compound Annual Growth Rate (CAGR) was determined and was determined as follows:

\[
CAGR = \left(\frac{y_t}{y_{t_0}}\right)^\frac{1}{t-t_0} - 1
\]

where:

- \( t \) – most recent year,
- \( y_t \) – value of the analysed variable in base year,
- \( y_{t_0} \) - value of the analysed variable in most recent year,
- \( t_0 \) - base year.

Compound Annual Growth Rate is not the actual rate of return, but a value describing the rate at which the analysed variable would grow if it increased at the same rate each year. The determined value of the indicator is additionally marked with a graphic symbol of an arrow, which is presented in the table 1.
Table 1. Graphical markings of the indicator CAGR.

| CAGR (%) | Symbol |
|----------|--------|
| >= 1     |        |
| 0 < CAGR < 1 |        |
| -1 < CAGR < 0 |        |
| < -1     |        |

Source: [6]

According to the data contained in the Sustainable Development Report 2020, the achievement of goal 7 shows insufficient progress. However, this indicator does not include all the variables determined by Eurostat. Those that were are: population with access to electricity, population with access to clean fuels and technology for cooking, CO$_2$ emissions from fuel combustion for electricity and heating per total electricity output, share of renewable energy in total primary energy supply [6].

It should be noted that in case of the indicators population with access to electricity and population with access to clean fuels and technology for cooking, Poland has already achieved the target (100%). Therefore, they were omitted in the study. The indicators presented in the table 2 were further analysed.

In case of the long-term CAGR index presented in this article, the last 15 years are taken into account. Data were obtained from Eurostat databases [2]. The last known observation is from 2019. Therefore, the base year is 2005.

Table 1. CAGR values for Poland

| Indicator                                      | CAGR (%) | Symbol | Charakter (Ch) |
|------------------------------------------------|----------|--------|----------------|
| Energy import dependency                       | 7        | ↑      | -- (-2)        |
| Energy productivity                            | 3        | ↑      | ++ (+2)        |
| Final energy consumption in households per capita | -0.45    | ↓      | + (+1)         |
| Final energy consumption                       | 1.39     | ↑      | ++ (+2)        |
| Share of renewable energy in gross final energy consumption | 4        | ↑      | ++ (+2)        |
| Greenhouse gas emissions intensity of energy consumption | -0.88   | ↓      | + (+1)         |

It should be noted that the energy import dependency by product shows an upward trend. However, it must be remembered that this indicator is a destimulant. Therefore, its rapid growth is a negative phenomenon. Poland has been becoming more and more dependent on energy from abroad, and this lowers the country's energy security indicators. In contrast, final energy consumption in households per capita and greenhouse gas emissions intensity of energy consumption show a downward trend, which is a positive phenomenon. Energy consumption is reduced due to the use of energy-saving devices, which is directly related to the decline in greenhouse gas emissions. This is also confirmed by the increase in Energy productivity. The share of renewable energy in gross final energy consumption
by sector has also grown for the past 15 years. Therefore, the authors introduced an additional marking presented in the last column of the table. The blue plus means the positive nature of the trend shaping the analysed phenomenon, while the red minus means the opposite situation. There were two pluses to the rapid growth of stimulants, the rapid growth of destimulants two disadvantages, and the slow decline of destimulants one plus. These markings were assigned numerical values. The maximum value of the Ch index for the selected set is 12. The value of Ch for Poland is 6. It therefore reaches the value of 50%. The most problematic development trend among the indicators selected for the analysis is characterized by energy import dependency by product. Therefore, a time series forecast up to 2030 was made for this indicator (figure 7). The ARIMA model was used (1,2,1) [7, 8, 9]. The model's MAPE error is 6%.

![Figure 7. Forecast of energy import dependency in Poland up to a year 2030](image)

The created forecast indicates a further increase in Poland's dependence on energy imports. In relation to the chosen base year in 2030, this dependence will be four times greater if the current growth rate is maintained. As Poland is to gradually resign from the use of coal, the share of other fossil fuels will increase, however, they are mostly imported. This is especially true of crude oil. Therefore, in order to be able to reduce the amount of used energy carriers or the energy itself, it will be necessary to increase the share of RES in Poland's energy mix.

4. Conclusions

Energy production is one of the main factors influencing climate change. Additionally, over 10% of humanity is cut off from access to modern electricity. Therefore, the seventh goal of The Sustainable Development Goals is to ensure the use of clean and available energy. The article presents the indicators describing the degree and pace of the implementation of the seventh goal in Poland. For this purpose, the indicators proposed by Eurostat were adopted. For 2020, the Sustainable Development Report 2020 was prepared, which, however, did not take into account all the indicators included in the Eurostat databases. Therefore, the authors determined the value of the Compound Annual Growth Rate for the supplemented set of indicators. It was designated for the period of the last 15 years. Its value is particularly adversely affected by energy import dependency by product. Therefore, the forecast for this indicator was made until 2030, i.e. the year in which the sustainable development goals are to be achieved. It was noted that the level of imports will continue to increase, and in 2030 it will be four times higher than in 2005. This is a negative phenomenon, because Poland is thus losing
energy security. In order to prevent this, it is necessary to cover the energy demand gap by introducing a new source to the country's energy mix. It is planned that by 2030 it will be nuclear energy. In addition, the share of renewable energy in the mix is also expected to increase. The CAGR for RES is 2%, which means that the rate of growth of this share is fast. However, in order to achieve the set goals (20% by 2030), additional measures should be taken to develop renewable energy sources in Poland. This requires help from the European Union and the State. These technologies require financial investments, and in case of most of them, the production generated using other carriers is significantly cheaper. As the demand for final energy continues to grow, it will be necessary to use new combustion technologies, which will, firstly, be more effective, and secondly, will also be low-emission. [10]. As a result, the emission of greenhouse gases will be reduced at the same time.

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