

Article

Varying the Energy Mix in the EU-28 and in Poland as a Step towards Sustainable Development

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Abstract: The demand for clean energy is a key global issue requiring global ideas to be implemented through local action. This is particularly important in Poland's energy transition, since the country produces energy mainly from conventional sources, i.e., coal, gas, and crude oil. Adverse climate change caused by high emissions of the economy based on the combustion of hydrocarbons as well as the growing public awareness have made it necessary to look for new environmentally friendly energy sources. The aim of the paper is to demonstrate that the use of alternative energy sources, biomass in particular, is compatible with sustainable development policy. Eight indicators for the EU-28 and for Poland were analysed in order to verify the progress in modifying the energy mix between 2010 and 2018 in the context of implementing Sustainable Development Goals (SDGs). The analysis showed that both in the EU-28 and in Poland, the aggregated indicator taking into account the positive and negative change in the values of individual indicators improved between 2010 and 2018. In the EU-28, this indicator is higher (180.1) than in Poland (152.3). The lower value for Poland is mainly due to the fact that the main source of energy in Poland remains hard coal and lignite. However, the noticeable increase in recent years in the share of energy from renewable sources, biomass included, allows us to look with hope to a rapidly growing indicator measuring progress towards a sustainable development goal, and to improving environmental standards.

Keywords: sustainable development; climate and energy policy; indicators; renewable energy; biomass



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1. Introduction

Adverse climate change caused by carbon dioxide emissions and the burning of fossil fuels has been a major global economic, ecological, and social problem for several decades. Developing global economies need electricity and heat as well as the security of its supply while in parallel maintaining the principles of sustainable development [1]. This is the main goal of energy policy and environmental policy in European Union (EU) countries, including Poland. Sustainable energy management is undoubtedly associated with an increased share of renewable energy sources that ensure energy security, diversification of energy supply, and improve the quality of the environment and the life of local communities [2,3].

The European Union's consistent policy on limiting carbon dioxide emissions has forced the Member States to take various measures. This has resulted in the development of a low-carbon power sector. These low-carbon sources include wind power, solar power, geothermal power, tidal power, hydropower, and biomass power. The use of renewable energy sources brings many benefits, contributes to reducing the emission of harmful substances into the air, and enables the creation of new jobs. Furthermore, increasing the share of renewable energy sources in the energy mix contributes to increased energy security, reduces dependence on imported energy carriers, and saves fossil resources.

The issues related to modifying the structure of sources from which energy is produced, and the necessity to look for new and environmentally friendly energy sources in the context of sustainable development have been discussed in numerous publications.

This particularly applies to countries where energy is obtained mainly from conventional sources, e.g., China, Turkey, and EU countries, including Poland. A very interesting thing is the comparison of the state of sustainable development of the energy sector in the European Union countries and in China [4]. The analysis of the work shows that China lags behind the EU countries in terms of sustainability of the energy sector, but the country made very good progress in the analysed period 2005–2016. The research also investigated the relationship between renewable energy consumption and economic growth for the EU-28 between 1995 and 2015 over a longer time horizon [5]. The research shows that the use of renewable energy sources in the EU-28 is the only way to reduce environmental pollution. The European Union is the undisputed leader in introducing the idea of sustainable economy [1]. Practically all EU-28 countries pursue a policy of increasing electric power capacity from renewable sources [6]. Moreover, candidate countries for European Union membership, such as Turkey, have to attach increasing importance to sustainable development. The research for determining the renewable energy perspective in Turkey used the energy indicators for sustainable development, which were introduced by the International Atomic Energy Agency in 2005 [7]. Growing social awareness and increasingly restrictive climate strategies adopted by the EU make it necessary to change the structure of energy generation in Poland as well. The use of conventional energy sources should be limited and replaced by RES [3]. There is a clear process of gradual transformation from a coal-based economy to an economy using green, low-carbon technologies that meet social needs, ensure energy diversification, energy security not only on a local scale, but also on a regional scale and even in the long-term perspective [2].

During the preparation of the bibliography review, we did not find results of scientific research on estimating the dynamics of changes in the structure of energy production in the context of achieving sustainable development goals, and this paper makes such an attempt for the EU-28 countries and for Poland.

The actual implementation of the sustainable development strategy consists in harmonising economic, environmental, and social criteria and treating the natural environment as an entity that evolves and is subject to change (in most cases anthropogenic change) [8–10].

The World Commission on Environment and Development [8] defines sustainable development as: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. From the very beginning, environmental considerations have been studied in conjunction with human activities, i.e., social, cultural, ethical, economic, and technological aspects [11,12]. Since then, our understanding of the concept of sustainable development has evolved significantly [13].

In 2015, the United Nations (UN) General Assembly formally adopted “The 2030 Agenda for Sustainable Development”, providing a shared blueprint for “peace and prosperity for people and the planet, now and into the future” [14]. As part of this agreement, all UN member states agreed on sustainable development goals that could be used to measure progress towards the main goal of sustainable development.

There are currently 17 Sustainable Development Goals (SDGs), including 169 targets, and as many as 232 sustainable development indicators [15]; the range of goals and indicators is constantly updated and redesigned.

Sustainable development indicators are an information and diagnostic tool that facilitates the assessment and management of the social, economic, and environmental spheres on a local, regional, and national scale. Many scholars emphasise the need for indicators, pointing to elements arising from the definition of sustainable development, namely long-term effects, recognition of the needs of future generations, and identification of relationships between economic, social, and environmental issues [8,11,13].

Different methods are used to assess progress towards the SDGs. Quantitative assessment of the 17 SDGs involves the formulation of appropriate targets and indicators to monitor final success, and the collection of comprehensive and reliable data [16,17]. At this stage, the selection and assessment of the relevance of indicators are crucial [1,18]. There is no single universally accepted data source representing each of the 17 SDGs. In the absence

of such data, it is difficult to select an appropriate indicator or group of indicators for each goal and to access reliable data for that indicator or group of indicators [19]. Selecting any one indicator or combination of indicators from a range of available indicators reflecting the performance of single SDGs is problematic, and any analysis of the selected indicator will only reflect a particular aspect of the broader SDG.

A very important issue in the analyses of progress towards a selected SDG is a parallel consideration of interactions in the achievement of other SDGs. This aspect was highlighted by Barbier E.B and Burgess J. C. [13,20], who measured the change in well-being for no poverty improvement (SDG1) taking into account interactions with other sustainable development goals.

A growing number of studies have attempted to develop an analytical framework for the formal analysis of possible trade-offs and complementarities in achieving various sustainable development goals to support decision making. Multicriteria analysis methods are used to assess and priorities the SDGs [21] in the context of parameterizing low carbon energy sources [7].

To evaluate progress towards sustainable development, the Human Development Index (HDI) is also used [22]. In order to create a full sustainable HDI that reflects the state and process of achieving sustainable development while taking into account environmental aspects, the authors extended the basic three-dimensional HDI (health, education, standard of living) with a fourth component: Environmental.

The research objective of this paper is to answer the question of whether obtaining energy from low-carbon sources (biomass in particular) is an appropriate solution in the energy policy of the EU and of Poland, and whether it is consistent with sustainable development indicators. In order to achieve this goal, an analysis was carried out of the values of eight selected indicators for the years 2010–2018 for the EU countries and for Poland. A methodology was developed to estimate changes in the values of the indicators in achieving the six sustainable development goals.

The paper is structured as follows. In the Section 2, we describe the assumptions of the energy policy in the EU and in Poland and the changes that have taken place in the share of renewable energy in final energy consumption in the EU countries and in Poland since 2010. Section 3 provides a methodology for measuring progress towards sustainable development goals in the context of energy diversification. We describe representative indicators for individual pillars of sustainable development. Using these indicators, Section 4 provides a quantitative assessment of the current progress between 2010 and 2018 in achieving the Sustainable Development Goals for the EU-28 and for Poland. We conclude our paper by discussing the results of our research and their implications for the country's environmental and energy policies.

2. Assumptions of the Energy Policy

2.1. The Climate and Energy Policy of the European Union

The main goal of this policy is to counteract climate changes. The document “An Energy Policy for Europe” [23] specifies the EU objectives:

- reduction of greenhouse gases (GHG) emissions in developed countries by 30% until 2020 (compared to the 1990 level) and reduction of global emissions by 50% until 2050 (including the reduction of emissions in industrialized countries by 60–80%), to reduce global warming to 2 °C;
- domestic reduction of greenhouse gases emissions by at least 20% when compared to the 1990 levels;
- increase of the share of renewable energy in the total energy balance of the European Union, from the current level of less than 7% to 20% until 2020, and at least a 10% share of biofuels (the objectives after 2020 will be analysed in the light of technological progress, and the contribution of each Member State to achieving the EU goals must take into account the diverse conditions and different starting points in different countries);

- implementation of a strategic plan in the field of energy technologies which will lower the cost of clean energy (what is meant here are initially renewable energy sources, and in 2050 hydrogen energy, nuclear power, and fourth generation nuclear fusion power) coupled with increasing the energy efficiency of buildings, appliances, equipment, industrial processes, and systems of transport;
- development of an EU framework for nuclear energy, subject to the most stringent safety standards, including nuclear waste management and decommissioning of nuclear facilities;
- pursuing an active, common European Union foreign policy in the field of energy.
- nowadays, in terms of reduction of GHGs emissions, the action plan sets the goals:
- reduction of domestic GHGs emissions by 80% until 2050 when compared with emissions in 1990 (in all EU Member States);
- program of obligatory reduction of GHGs emissions in the subsequent years: 25% in 2020, 40% in 2030, 60% in 2040, 80% in 2050.

More widespread utilization of low-emission technologies is emphasized in particular. In terms of energy generation, using energy from renewable sources and other low-emission solutions will be promoted. Strong support for renewable energy sources is reflected in its enormous share in the gross final energy consumption: Approx. 75% in 2050, with a 97% share of renewable energy sources in electricity production.

Regarding the energy supply sector, member states are obliged to: (a) Adopt national plans to ensure high-efficiency local heating and cooling; (b) adopt licensing schemes to guarantee that the installations will be located in the vicinity of heat receiving points and that all new electricity generating installations (as well as existing installations undergoing substantial renovation) will be equipped with highly efficient cogeneration units.

2.2. Energy Policy of Poland

Poland is now faced with the task of developing a long-term energy policy for decades to come, a strategy capable of reconciling the security of power supplies as well as effective economic processes, ensuring adequate standards of environmental protection.

For decades, the Polish economy has relied heavily on utilizing abundant resources of hard and brown coal. The document adopted by the Council of Ministers on 10 November 2009: “Poland Energy Policy until 2030” stipulates that in order to ensure energy security for the state, coal shall remain in use as the main source of fuel for the power and heat industries [24]. However, the extraction and combustion of this raw material to utilize the energy stored within it poses a number of problems in terms of environmental protection.

Each passing year sees the establishment of more and more stringent EU standards and regulations—also resulting from international agreements. As an EU member state, Poland is obliged to take subsequent steps to bring the goal of achieving a sustainable, low-emission economy closer each year. It is also one of the conditions of the Accession Treaty [25], and the basis of the EU Climate and Energy Package that was adopted on 23 April 2009 [26]. The strong emphasis placed on cutting down CO₂ emissions resulting from EU climate and energy policy may lead to technological and economic deterioration in the Polish coal industry, as well as damaging the Polish economy in general. Poland will not be able to meet the objectives stipulated in the Kyoto Protocols without detriment to its national economy. The only thing that can be done is to work towards reducing the scope of economic losses, estimating them, and finding sources of their compensation.

However, in accordance with the Charter of the United Nations and the principles of international law, “the States have the sovereign right to exploit their own resources pursuant to their own environmental and developmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction” [27].

2.3. Energy from Renewable Sources

Energy from renewable sources means energy from natural processes, energy produced from non-fossil energy sources. The reserves from these sources complement each other in natural processes, which makes it possible to consider them as inexhaustible ones [28]. The European Green Deal [29], which provides guidance for a sustainable eco-friendly transformation, plans that by 2050 Europe will become the world's first climate-neutral continent.

With energy consumption forecast to continue to grow, the energy sector needs to be reoriented in such a way as to cover demand and minimize the adverse impact on the climate. The use of energy from renewable sources has a number of benefits, including the reduction of greenhouse gas emissions, diversification of energy supply, and independence from fossil fuel supply. The development of renewable energy sources ensures increased employment in the green technology sector [30].

Between 2010 and 2018, total primary energy generation in most EU-28, also in Poland, decreased by almost 11% from 35100 PJ to 31510 PJ, while in Poland by 8% from 2780 PJ to 2560 PJ [31] (Table 1, Figure 1).

Table 1. Total primary energy generation in EU-28 and in Poland [31].

Specification	2010	2018	2010	2018	2010	2018
	Total Primary Energy Generation				Share of Renewables in Total Primary Energy Generation (%)	
	Total (PJ)		Renewable Energy Sources (PJ)			
Poland	2784	2559	288	371	10.3	14.5
EU-28	35,103	31,510	7261	9749	20.7	30.9

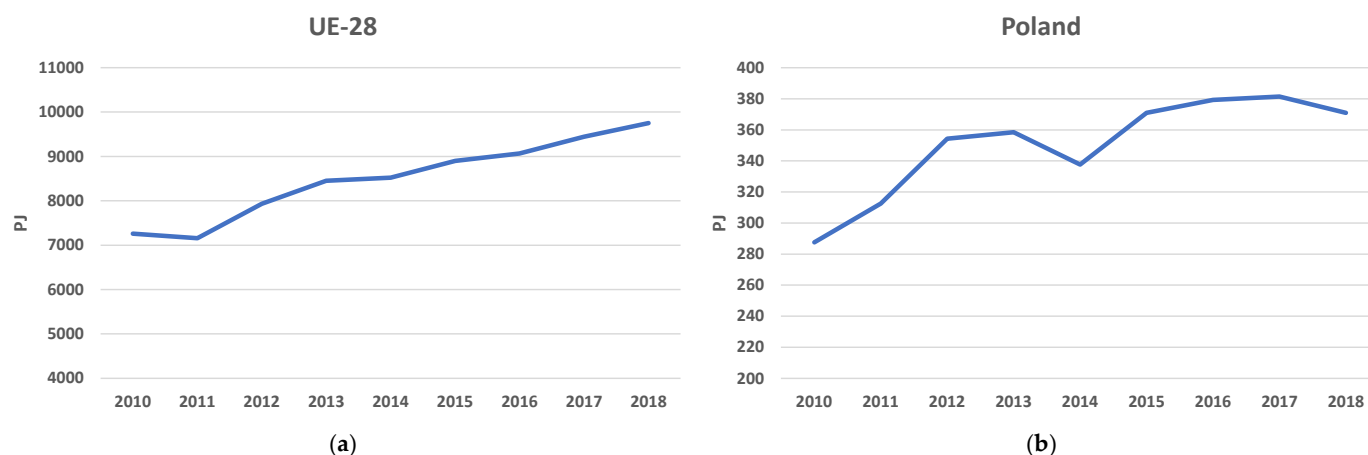


Figure 1. Total primary energy generation of renewables in EU-28 (a) and in Poland (b) (in PJ). Own study, based on [31].

Since the 1990s, Poland has been undergoing significant economic transformations and developing new, renewable energy sources. The generation of this form of energy has shown an upward trend in recent years: From 10.3% in 2010 to 14.5% in 2018. The structure of energy production from renewable sources for Poland results from the development of the existing resources.

In 2018, the amount of primary energy produced from renewable sources in Poland was 371 PJ. It comes from solid biofuels (69.3%), wind energy (12.4%), and liquid biofuels (10.2%) (Figure 2).

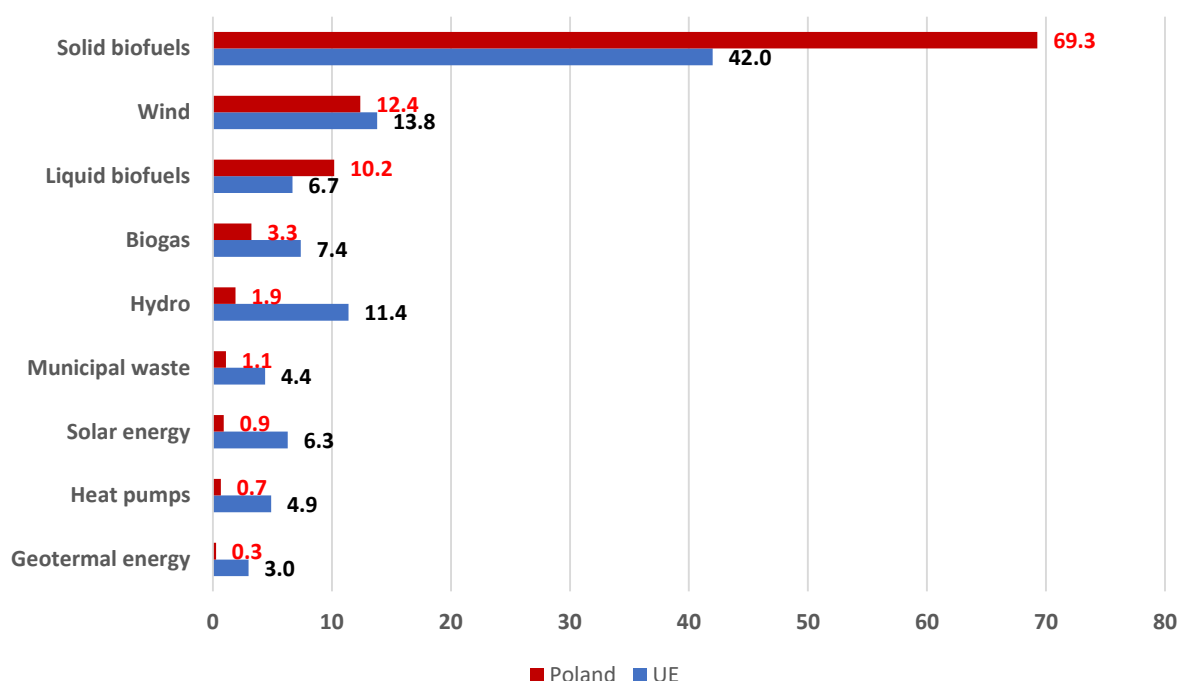


Figure 2. Kinds of energy obtained from renewable sources in Poland and in the EU by carriers in 2018 in relation to 100% primary energy production. Own study, based on [28].

Solid biofuels include organic non-fossil fuels used as a fuel for the production of heat or electricity. Solid biofuel includes firewood (wood chips, briquettes, pellets and forestry waste, shavings, sawdust), energy crops (fast-growing trees, dicotyledonous plants, perennial grasses, cereals grown for energy purposes), and organic residues from agriculture and horticulture (e.g., waste from horticulture, animal faeces, straw) [28].

3. Purpose and Research Methods

The following article has several objectives. First, we develop an analytical framework to describe changes in the value of indicators in achieving the six SDGs. We analyse the value of eight indicators between 2010 and 2018 for EU countries and Poland. We base this approach on standard methods for measuring the indicators, and then assess whether the analysed groups (EU, Poland) make progress in implementing SDGs. We used representative indicators for each goal we had selected. The selection of indicators was dictated by the following criteria:

- The indicator should show everyday life, not just an idea (regional social policy);
- achieving the indicator is possible in a moderately prosperous country (Poland);
- achieving the indicator shows how, in small steps, a great goal can be achieved (regional economic policy);
- achieving the indicator has a measurable impact on improving the condition of the environment (regional environmental policy).

We are aware of how problematic it is to choose any one indicator from a number of indicators reflecting the implementation of individual sustainable development goals. The analysis of a selected indicator reflects one specific aspect of a broader sustainable development goal. Nevertheless, we decided to choose these very indicators, which are achieved directly or indirectly in energy policy, particularly in renewable energy. Our criterion for selecting biomass was the fact that this alternative energy carrier is the most widely used in the world, EU, and Poland.

The research objective is to answer the question of whether the production of energy from biomass is compatible with the sustainable development indicators adopted by the UN Statistical Commission in 2016 [32]. Moreover, the purpose of the study is to

show that when implementing the global idea of sustainable development, the right solutions are specific solutions included in the regional ecological, social, and economic policy. As emphasised by Udo and Pawłowski, “From a global public policy perspective, it is posited that sustainable development can be used as a goal for local and global governance.” [11].

The research was conducted using the following methods: Examination of documents, examination of individual cases, analysis, and logical construction. The research technique consisted of observation and analysis of documents, and in the past, of sociometric techniques.

3.1. The Analysis of the Implementation of the Selected Indicators of the Social, Economic, and Environmental Pillars by the Biomass-Based Power Industry

3.1.1. Implementation of Social Pillar Indicators

Indicator: The exposure of urban population to the excessive effects of particulate matter PM10 (domain: Public health) is shown by the annual weighted average concentrations of PM10 at urban background stations located in agglomerations. Particulate matter is a mixture of very small solid and liquid particles, composed of organic and inorganic compounds. Despite actions taken to reduce PM10, exceeding the standards is one of the most important air quality issues in Poland. Out of 46 zones subject to air quality assessment in Poland in terms of average 24-h PM10 pollution, exceedances of the admissible level were found in 38 zones. In most zones the limit values for PM10 and PM2.5, and for benzo(a)pyrene are exceeded [33].

Biomass contains on average four times more oxygen compared to thermal coal and twice less carbon, but also less sulphur, nitrogen, and ash (on average 5 to 10 times less depending on the type of biomass). Moreover, it is characterised by a high volatile matter content (65–80%) and high reactivity that determine the need to use appropriate technical solutions guaranteeing its energy-efficient processing. The consequence is a higher proportion of emitted PM10 and PM2.5 particles, however, biomass fly ash contains significantly less metal atoms (Ti, Al, Fe) in the elemental composition than coal fly ash [24]. On the other hand, when burning biomass, much more charcoal is released into the atmosphere than when burning conventional fuel [34,35].

Indicator: The long-term unemployment rate (domain: Access to the labour market) is calculated as the share of the number of unemployed persons looking for a job for 12 months or more in the population of unemployed persons. Since Poland’s accession to the EU, the share of the unemployed looking for a job for 12 months or more among the active population has been systematically decreasing [36]. In 2018, this share in Poland was lower than the average for EU countries (Table 2).

Table 2. Long-term unemployment in EU and Poland [31].

Long-Term Unemployment (%)			
EU-28		Poland	
2010	2018	2010	2018
42.9	44.7	37.2	26.9

Around 40% of Poland’s population is made up of people living in rural areas. The most important real problems of the Polish countryside and agriculture are high unemployment, registered and hidden, low level of income limiting the demand for non-agricultural goods and services, and the employment of rural household members in the grey market [37]. The low level of activity of the rural community and the relatively low level of education exacerbated by the lack of vocational background complicate the situation on the labour market.

It is difficult to improve the financial situation of rural inhabitants by increasing agricultural production. An increase in the standard of living is possible if new sources of

income are provided, in other words, new jobs are created in the non-agricultural sector. One of the proposals is to grow energy crops [38,39].

The well-being of the population is reflected in the availability of energy services. Energy supply is just as important for rural development as technical and social infrastructure. The production in rural areas of food and raw materials of agricultural origin requires an uninterrupted supply of energy. However, integrated and reliable power grids in Polish rural areas still await investment. The power industry in rural areas should develop towards diversification of energy sources and increased energy efficiency. Polish rural areas need access to modern renewable energy sources, which will increase security of supply.

Research on social and environmental factors of agricultural development was carried out several times in 2002–2004 in different regions of Poland, Ukraine, Belgium, and France. In 2005–2017, in the Małopolska region (Poland), empirical research was carried out on a plantation of fast-growing willow trees whose cultivation and energetic use influenced the economic activation of rural residents. The research confirmed that investments in RES, resulting from smart use of diversified sources for energy production, provide economic benefits for consumers [40–45].

Moreover, in 2016, a sociological survey was conducted among 177 inhabitants of rural areas of the Pomeranian region (Poland) [46]. The sustainable development of rural areas is associated with the possibility of using crop residues and livestock residues. The majority of respondents (70%) considered that energy from renewable sources has a significant impact on ensuring electricity supply (energy security). Energy from RES increases the thermal comfort of farmers' households, supports sources of lighting and water heating. More than three quarters of the respondents considered energy from RES to be a guarantee of social welfare. They claim that renewable energy has a positive impact on improving the economic situation of the inhabitants of the regions with a low level of development, since those are often rich in renewable energy sources.

In order to create new jobs, schemes are needed to facilitate the creation of companies employing more people. In addition to simple workshops, medium-sized companies, which are most susceptible to technical progress, should also be established. The Polish rural landscape is dominated by one-man operations or at most very small firms [39,42]. Increasing the production of biomass for energy needs is an important element of multi-functional rural development and has a positive impact on farmers' income.

The International Renewable Energy Agency (IRENA) has published statistics on global employment in the renewable energy sector. In 2017, the sector created more than 500,000 new jobs worldwide, and the total number of people employed in the sector exceeded 10 million. In 2012, the employment in the RES sector amounted to 7.14 million people, and in 2017 to 10 million [47]. An increase of 38% was recorded over 4 years. Poland was one of the European leaders of employment on the RES market (4th rank behind Germany, Great Britain, and France). More than 30,000 jobs have been created in biofuel-related sectors (8th rank in the world) and more than 10,000 jobs in wind energy (14th rank in the world).

Indicator: Household electricity consumption per capita (domain: Consumption patterns) represents the quantitative households consumption of electricity per capita. Household electricity consumption is the most important indicator for monitoring consumption. In Poland, a systematic increase in electricity consumption in households was observed in the years 2002–2018, resulting from, but not limited to, the widespread use of power equipment. Average electricity consumption in 2018 increased by 14% compared to 2002 and amounted to 2.9 GJ per capita [48]. In the structure of energy consumption in Polish households, solid fuels—mainly hard coal (which is the exception in the European Union) and firewood—are the most important. They were most often used for space heating (by 45% of households). These fuels were also used to heat water (25% of households).

Despite the fact that energy produced from biomass is able to meet the energy demand, the share of biomass consumption in the energy sector is decreasing. In the first quarter of

2017, the production of electricity from this source decreased by 30%. The reason for this was a reduction in the prices of green certificates, i.e., the basic support scheme.

3.1.2. Implementation of Economic Pillar Indicators

Indicator: Eco-innovation (domain: Innovation) is based on 16 indices from five areas: Three of them directly relate to eco-innovation. These are: Inputs, activities, and results. The other two groups of indices are the effects of introducing eco-innovation: Environmental and socio-economic effects. Innovation is strongly linked to sustainable development. Eco-innovation slows down the exploitation and use of natural resources and the release of harmful substances into the environment.

An example of an eco-innovation process is the use of biomass in energy production. By using biomass in the power industry, we prevent waste of food surpluses, manage production waste from the forestry and agricultural industries, and dispose of municipal waste [33]. However, Poland is one of the least eco-innovative countries in the European Union: In 2018, our country was ranked only 26th among 28 countries in the community [27].

Indicator: Percentage of the total utilised agricultural area of organic farms in the total utilised agricultural area (domain: Production patterns). An organic farm is certified by an authorised certification body or is in the process of converting to organic farming methods. Organic farming is a rapidly growing sector of conventional agriculture. It reduces the burden on the environment, contributing to the improvement of ecosystems. In organic farming, production and consumption take place in a closed loop. The requirement is to use at least 80% of the yield for processing, feeding the animals or transferring to other farms or sale [33]. According to the data of the Ministry of Agriculture, the years 2003–2013 saw a boom in organic farming in Poland, and the number of these farms increased 11 times (from 2300 to almost 27,000). In 2018, only just over 20,500 farms were operating in organic farming [49].

3.1.3. Implementation of Environmental Pillar Indicators

Indicator: Greenhouse gas emissions in CO₂ equivalent (domain: Climate change) determine total annual man-made greenhouse gas emissions in relation to base year 1988, in accordance with the Kyoto Protocol, excluding emissions from international aviation and maritime transport, land use change, and forestry. The Kyoto basket encompasses the following six greenhouse gases: Carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and F-gases: Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF₆). Greenhouse gas emissions are defined as the aggregated emission of the six greenhouse gases listed, weighted by global warming potentials on a 1988 basis equal to 100 [50]. Carbon dioxide equivalent shall be 1 Mg or an amount of another greenhouse gas equivalent to 1 Mg of carbon dioxide calculated using global warming potentials, e.g., one ton of methane corresponds to 25 tons of CO₂. The combustion of fossil fuels causes 70% of global CO₂ emissions [51]. Poland has a 10% share in CO₂ emissions in the European Community.

The year 1988 has been adopted for Poland as the base year for accounting for the fulfilment of the commitments of the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol [33]. The Kyoto agreement is considered to be one of the first steps of the international community towards formalised action for effective environmental protection.

After the ratification of the Kyoto Agreement, Poland adopted several documents and implemented new regulations on energy development and climate protection, such as Polish Energy Policy until 2030 [24], the National Energy and Climate Plan 2021–2030 [52], Polish Energy Policy until 2040 [53], and Polish Energy Policy until 2050 [54].

The main objective of energy policy is to ensure the country's energy security, to increase the competitiveness of the economy and its energy efficiency, and to protect the environment from the effects of the power sector. The share of RES in the national energy

balance is estimated at 15% (the target is 20%). It is also predicted that by 2050, dispersed photovoltaics and wind power plants will have become the leaders of RES.

Regulations that have been introduced relate both to industrial activities, including power industry, and to energy consumers (energy savings in individual farms, change of heating system, e.g., phasing out of solid fuel boilers and furnaces, connection to the district heating, gas boilers, low-emission solid fuel boilers, electric heating). With the implementation of the anti-smog resolution [55], 43,600 boilers and furnaces using solid fuels were phased out in the Małopolska region in 2013–2018, of which over 22,000 in Krakow. Renewable energy sources have been installed in more than 13,000 facilities (mostly solar collectors and photovoltaic panels). As a result of these activities, air pollution emission rates have significantly decreased in both large cities and small towns. In the last decade, dust emissions in the Małopolska Province were reduced by 70%. The improvement of air quality in the Małopolska region and Krakow is observed in the heating period from October to March. Average PM10 concentration between the winter season 2014–2015 and 2019–2020 dropped by 30% in the Małopolska region and by 45% in Krakow [56].

In order to increase the effectiveness of activities carried out as part of the implementation of the Air Protection Programme in Poland, financial mechanisms have been created to increase the effectiveness of the implementation of low emission reduction programmes, the inventory of low emission sources, and the functioning of local heat generation.

The commitment to reduce greenhouse gas emissions in the first period (2008–2012) was more than met by Poland (29% reduction) [57]. This has been achieved through the use of alternative energy sources, including biomass, which has a great advantage: When burned, CO₂ emissions are equivalent to the amount of CO₂ taken up during photosynthesis.

The source of pollutant emissions is also urban transport, which in large cities is responsible for up to 40% of pollutant emissions. The modernisation of the transport fleet is a great challenge for the city authorities. The focus was on low-emission and zero-emission transport. The Act of 11 January 2018 on e-mobility and alternative fuels [58] informs about the minimum share of electric vehicles in the fleets of official vehicles of state administration bodies and local government units: 10% from 1 January 2022; 20% from 1 January 2023. The document also mentions the share of zero-emission buses in the fleet of vehicles used: At least 5% from 1 January 2021; 10% from 1 January 2023; 20% from 1 January 2025.

As stated in the Act, it obliges local governments to have 10% of zero-emission vehicles from 2022, but the Krakow authorities took up this challenge much earlier. The Municipal Transport Company (MPK) in Krakow has purchased modern trams and buses: 364 of them meet the Euro 6 emission standard. The MPK fleet is equipped with 34 hybrid buses and 28 electric buses (a further 50 electric vehicles will be purchased in 2021). The share of zero-emission vehicles will be 14%. At the end of 2019, the city of Krakow had 39 electric vehicle charging stations.

Since the costs of technology for reducing traffic smog are very high, it is necessary to switch to alternative means of transport. The public bicycle has been included in the public transport system. Currently, the network of bicycle routes in Krakow is 235 km long. 65 km of contraflow bike lanes have been created on 270 one-way roads. Over the last seven years, 8000 bicycle racks and several dozen stands have been installed in Krakow. The inhabitants of Krakow have bicycle shelters and self-service bicycle repair points at their disposal.

Other pro-environmental solutions in large cities consist in implementing “green roofs” which have a large share, for example, in the filtration of air pollution, in reducing the discharge of rainwater, in mitigating the effect of “urban heat island”. The modelling of the environmental impact of green roofs in the Opole agglomeration (southern Poland) is dealt with by Suszanowicz and Kolasa-Więcek [59,60]. They confirm the potential of green roofs in sequestering CO₂, NO_x, SO₂, and heavy metals in plants and soils. They emphasise that in Polish conditions, the use of green roofs in cities contributes to the protection of biodiversity threatened by urban trends. Nevertheless, the implementation of green

roof systems involve high maintenance costs, significantly higher than in the case of conventional roofing.

A very important element of the pro-ecological regional policy of the city of Krakow is the information and education campaign under the slogan #EKOrevolution. The campaign consists of four spheres of the city's green activities related to the seasons: Winter—clean energy, autumn—traffic and transport, spring—greenery, summer—water. The campaign makes residents aware of how much everyone can do for the environment and what the city's pro-environmental actions are [61,62].

The need to diversify the electricity generation structure will contribute to reducing the role of coal in the energy balance. According to the proposal presented in the Polish Energy Policy until 2040 [53], the share of coal in electricity production by 2040 will be reduced to 28% in the case of a gradual (sustainable) increase in the prices of CO₂ emission allowances. In the case of the scenario of high prices of CO₂ emission allowances the projected share of coal may drop even to 11% (Figure 3). At the same time, it was announced that all mines using thermal coal would be closed by 2049. During the last summit of the European Council (December 2020), the heads of governments of the European Union member states adopted a new CO₂ reduction target for 2030. The Council decided that this target will be at least 55% compared to 1990. The EU's adoption of a new level of emission reduction may lead to a sudden increase in the price of emission allowances, even up to EUR 76 per ton of CO₂ [63], and consequently to a rapid dismantling of the Polish mining industry.

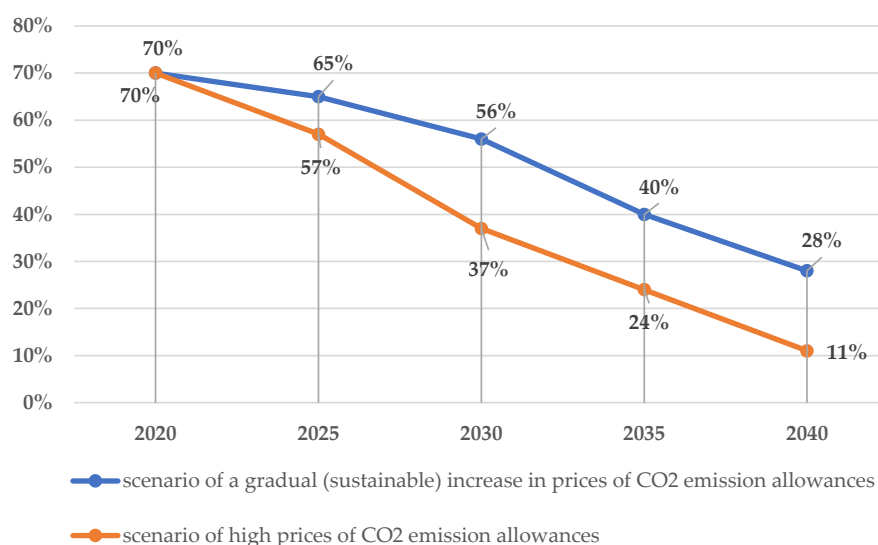


Figure 3. Forecast of the share of coal in electricity production until 2040 according to two scenarios [53].

Indicator: Share of energy from renewable sources in gross final consumption of energy from all sources (domain: Energy). Gross final energy consumption means the use of energy carriers for energy purposes (production of electricity, heat, and cooling) in industry, transport, households, public services, agriculture, forestry, and fisheries, together with losses of electricity and heat during transmission and distribution [64]. Poland as a country is systematically increasing the share of energy from renewable sources (Table 2) both in primary energy generation and in gross final energy consumption. The observed growth is also reflected in the increased diversification of these sources. The share of energy from renewable sources in gross final energy consumption in 2018 was 11.28% (Figure 4). According to the assumptions of the “Energy Policy of Poland until 2040”, adopted by the Polish government on 2 February 2021 [65], the share of renewable energy in gross final energy consumption in 2030 will be at least 23%, not less than 32% in the electricity sector, 28% in heating, and 14% in transport.

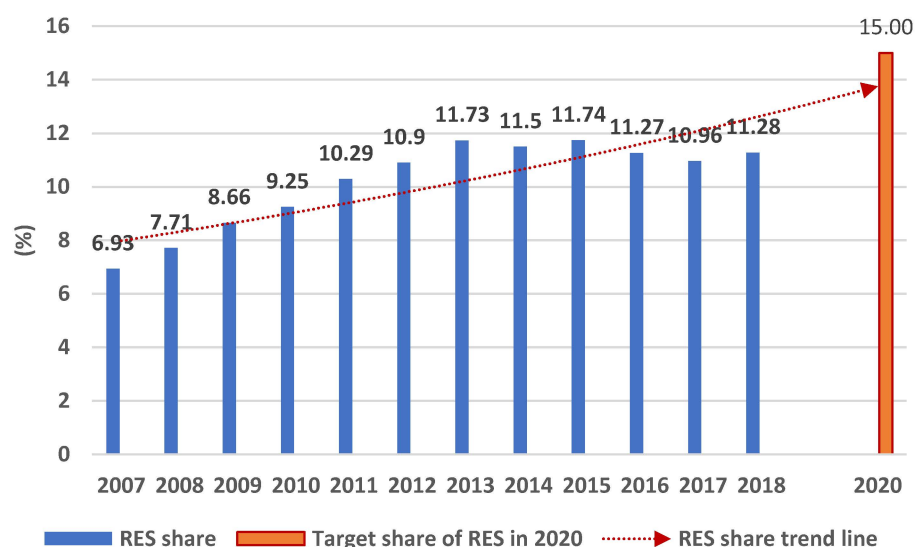


Figure 4. The share of energy from renewable sources in gross final energy consumption in 2018. Own study, based on [31].

The rationale for using this indicator results from the challenges facing Poland in reducing energy intensity of the economy. Solid biofuels occupy a dominant position in Poland in the acquisition and use of energy: In 2018, their share amounted to nearly 70% in the structure of renewable sources (Figure 3). They are mostly used in the heating and cooling sectors. There has been a decrease in the share of wind and water energy. Despite the fact that energy produced from biomass allows to meet the energy demand, the price reduction of green certificates, i.e., the basic support system in the power industry, has resulted in a decrease in the share of biomass consumption.

Indicator: The state of the air quality (domain: Air protection) allows monitoring the progress towards meeting EU air quality standards. Air quality has a significant impact on human living conditions, the condition of ecosystems, as well as processes relating to climate change. The effects of air pollution are particularly felt by the elderly, the sick, and children. Poland is divided into 46 zones where 12 air pollutants are monitored [66]. On the basis of the survey results, a ranking of the zones in terms of human health protection (classes: A, B, C) is prepared. Of all the zones, only one has been defined as class A (no exceedances were found). As many as 38 zones have been classified as class C (exceedance of the limit level plus margin of tolerance or target level).

Polish power plants are supported by alternative fuel coming from biomass, of which millions of tons are burnt each year. Unfortunately, a very large part of it has to be imported. According to the Renewable Energy Institute, by importing biomass the CO₂ emission is increased instead of being reduced. Transportation of this raw material means that tons of conventional fuel are burnt by trucks and ships, tons of carbon dioxide are released into the atmosphere [67]. Nevertheless, energy obtained from biomass has a significant positive impact on the implementation of this indicator.

All selected and most important indicators that were used to assess the progress in varying the energy mix in the context of achieving the sustainable development goals are presented in Figure 5.

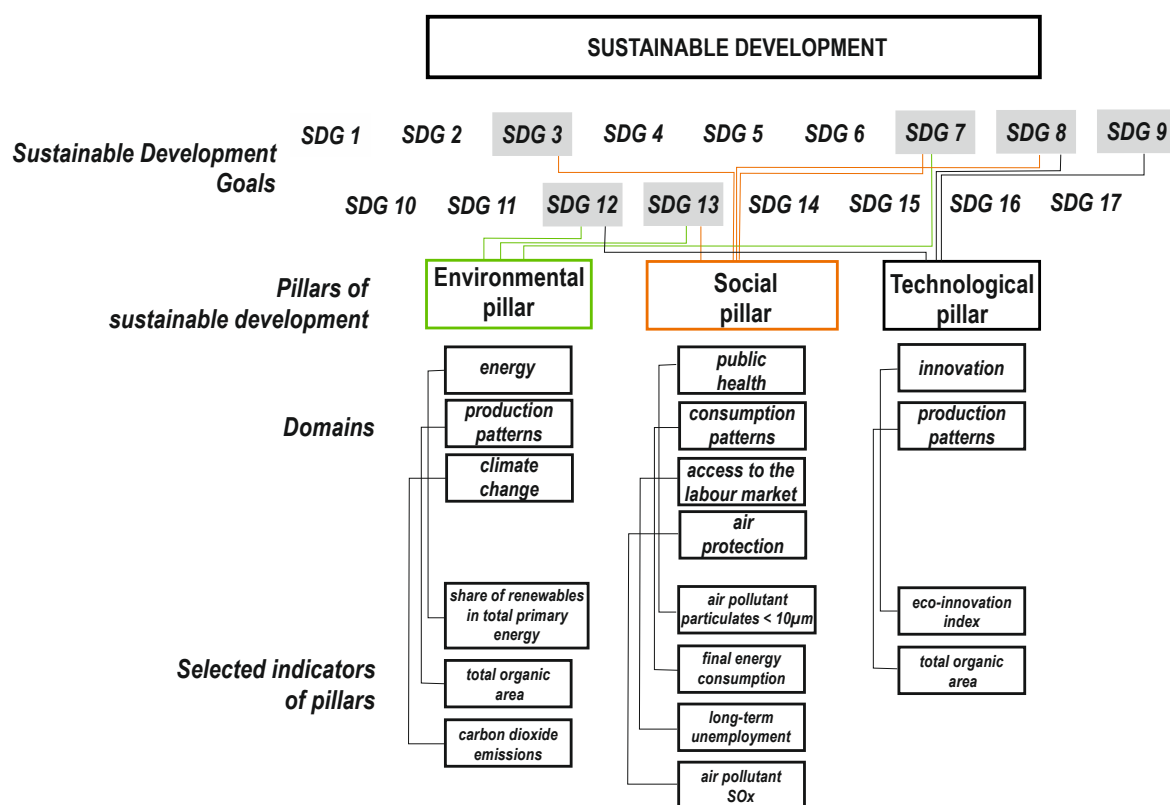


Figure 5. A flow chart showing the pursuit of sustainable development through the implementation of selected indicators in the context of diversification of energy sources. Own study, based on [10]. SDG 1: No poverty, SDG 2: Zero hunger, SDG 3: Good health and well-being, SDG 4: Quality education, SDG 5: Gender equality, SDG 6: Clean water and sanitation, SDG 7: Affordable and clean energy, SDG 8: Decent work and economic growth, SDG 9: Industry, innovation and infrastructure, SDG 10: Reduced inequalities, SDG 11: Sustainable cities and communities, SDG 12: Responsible consumption and production, SDG 13: Climate action, SDG 14: Life below water, SDG 15: Life on land, SDG 16: Peace, justice and strong institutions, SDG 17: Partnerships for the goals.

4. Analysis of Selected SDGs for EU-28 and Poland—Results and Discussion

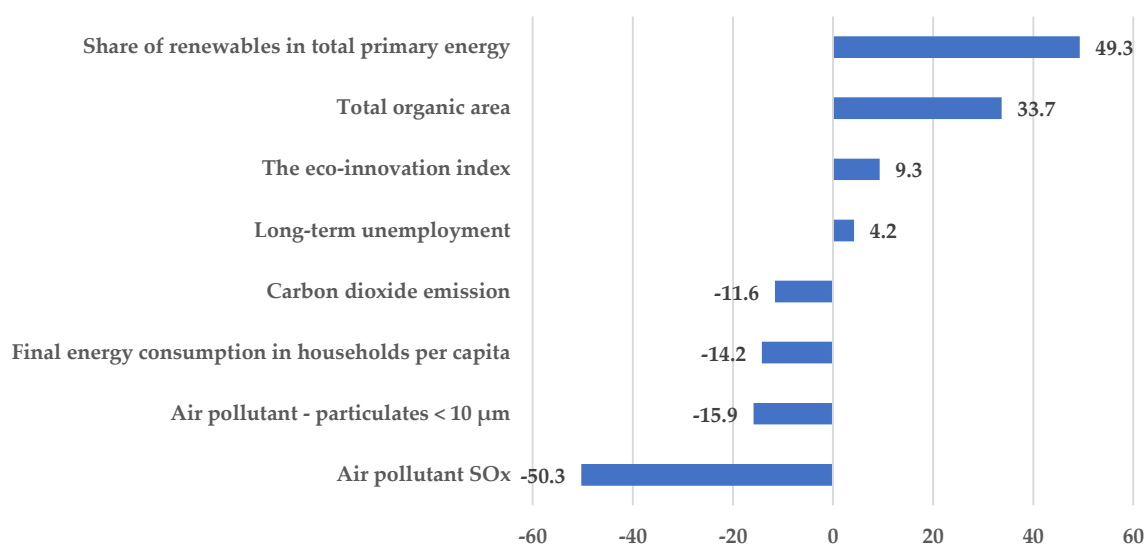
In order to verify the progress in varying the energy mix in the context of achieving the sustainable development goals, an analysis was carried out of the indicators we had selected for the EU-28 and for Poland. In our analysis, we combine information about the absolute variation in the actual value of the indicators with the percentage change in these values compared to 2010. This allows us to assess whether the sustainable development goal improves or deteriorates while the result of the examined indicator is changed [13].

Table 3 shows the changes in the values of individual indicators in 2010 and 2018.

Figures 6 and 7 illustrate the percentage change in the levels of individual indicators between 2010 and 2018, from the highest increases to the highest decreases, for the EU-28 and Poland, respectively. As described in the research methodology, improving indicators have been given a positive rating and deteriorating indicators a negative rating. Both in the EU-28 and in Poland, the aggregate indicator taking into account positive and negative changes in the values of individual indicators improved between 2010 and 2018.

Table 3. Selected indicators of Sustainable Development Goals (SDG), EU-28 countries, and Poland in 2010–2018. Own study, based on [13,31].

Indicator	EU-28				Poland			
	2010	2018	% Change	Outcome	2010	2018	% Change	Outcome
The eco-innovation index	86.0	94.0	9.3	Improving	40.0	59.0	47.5	Improving
Total organic area (mln ha)	10.05	13.4	33.7	Improving	0.65	0.48	−26.1	Declining
Long-term unemployment (%)	42.9	44.7	4.2	Declining	37.2	26.9	−27.7	Improving
Carbon dioxide emissions (Mt)	3922.9	3466.5	−11.6	Improving	323.8	319.5	−1.3	Improving
Final energy consumption in households per capita (kgoe)	643.0	552.0	−14.2	Improving	578.0	508.0	−12.1	Improving
Air pollutant SO _x (Mt)	4.1	2.04	−50.3	Improving	0.82	0.50	−38.5	Improving
Air pollutant-particulates < 10 µm (Mt)	2.4	1.99	−15.9	Improving	0.27	0.24	−11.3	Improving
Share of renewables in total primary energy (%)	20.7	30.9	49.3	Improving	10.3	14.5	39.9	Improving
Composite Index			180.1				152.3	

**Figure 6.** Net change (%) in SDG indicators, EU-28, 2010–2018. Own study, based on [31].

In the EU-28 this indicator is higher (180.1) than in Poland (152.3). This suggests that all the countries concerned are progressing in achieving their sustainable development goals.

In the case of the EU-28, the progress is significant, while in the case of Poland—despite the many positive actions which have been taken to protect the environment in recent years—progress towards the sustainable development goals concerned can be considered moderate. This is mainly due to the fact that the main source of energy in Poland remains hard coal and lignite. However, the noticeable increase in recent years in the share of energy from renewable sources, biomass included, allows us to look forward to a faster increase in the indicators measuring progress towards a sustainable development goal and to improvements in environmental standards.

In the EU-28, the greatest benefits between 2010 and 2018 were recorded in the indicators measuring progress in the environmental pillar, the SDG 7 “Affordable and Clean Energy” in particular. The final energy consumption in households per capita decreases (kgoe): −14.2%), while the share of renewables in total primary energy generation increases: 49.3%. Very good progress is also noted in the indicators for the SDG 13 “Climate Action” DG 3. The greatest improvement is observed in air protection: SO_x emission: −50.3%, PM < 10 µm emission: −15.9, CO₂ emissions: −11.6%. Indicators on air purity also relate to progress in the social pillar (SDG 3 “Good Health and Well-being”).

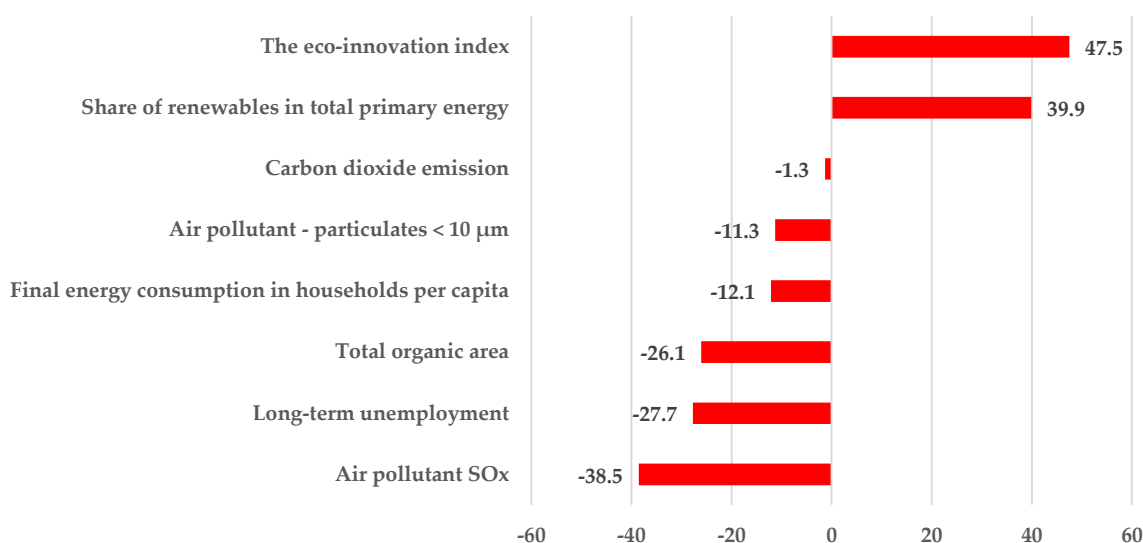


Figure 7. Net change (%) in SDG indicators, Poland, 2010–2018. Own study, based on [31].

It should be noted, however, that the social pillar has seen a significant increase in long-term unemployment in the EU-28: 4.2, the indicator which refers to the SDG 8 “Decent Work and Economic Growth”.

In the assessment of the economic pillar, the greatest benefits over the period 2010–2018 were recorded in the indicator measuring the SDG 12 “Responsible Consumption and Production SDG” (total organic area: 33.7%).

A similar pattern of improvement and decrease in SDG indicators between 2010 and 2018 was observed in Poland. An exception is the very large decrease in the share of long-term unemployment (−27.7%) in the population of all the unemployed (social pillar). This is a very good change.

Unfortunately, in the case of SDG 13 “Climate Action”, the Polish structure of energy production based on coal results in the analysed indicator “carbon dioxide emission” being decreased by only 1.3%. It is noteworthy that there has been a great deal of progress between 2010 and 2018 when it comes to SDG 9 “Industry, Innovation and Infrastructure”. The analysis took into account the eco-innovation index, which shows the country’s eco-innovation performance compared to the EU average, and includes 16 sub-indicators from five thematic areas: Eco-innovation inputs, eco-innovation activities, and eco-innovation outputs, as well as environmental outcomes and socio-economic outcomes. Compared to 2010, the value of this indicator has increased by 47.5%.

In the implementation of sustainable development goals in the context of diversification of energy sources, the quantitative assessment of changes in selected SD indicators in 2010–2018, shows a positive trend in both EU-28 and in Poland. The analysis shows that the goals can be achieved by means of various actions. Due to a large share of fossil fuels in energy generation, achieving the goals of the environmental pillar in our country is more difficult than in most of the EU-28 countries. However, the Polish economy is clearly changing positively towards reducing CO₂ emissions and slowing down global warming.

5. Conclusions

The article analyses selected indicators of social, economic, and environmental pillars in the context of biomass energy use. It has been shown that in a situation of a huge ecological crisis in the world, the use of biomass for energy production is in line with global trends in the development of global energy and climate protection. Biomass is the most frequently used unconventional energy source in the world, especially by the third world population, and this is where the chance to improve the environment should be seen.

Why should we go that way? What assumptions of the noble and laudable idea of sustainable development will be achieved? What reflection should accompany us in our daily, continuous use of energy in every area of life?

Sustainable development in the energy sector means finding a non-confrontational relationship between the social, economic, cultural, and natural aspects of energy production technology. Poland has one of the largest potential renewable energy resources in the EU. In order to be able to use it, it is necessary to increase financial outlays on research and technology development and to create a scheme of subsidies for projects. The actions should be modelled on the European Union that has been supporting the development of renewable energy sources for several years.

Attention is paid to the impact of the application of social governance assumptions on the health of society. It is necessary to ensure the conditions for the full combustion of the volatile products emitted from the decomposition of biomass.

The improvement of the economic situation of the inhabitants of rural areas can be sought in additional employment, which is the cultivation of energy crops. The household electricity consumption rate shows that the share of biomass consumption in the power industry is decreasing, which is due to unfavourable support schemes (reduced prices of green certificates). Among the indicators of the economic pillar, eco-innovativeness and production patterns are discussed. It is stressed that eco-innovations slow down the use of natural resources and thus reduce the emission of pollutants to the environment. The use of biomass in energy production is a good example of pro-environmental measures (carbon neutrality). The indicator “production patterns” is illustrated by organic farming where production and consumption take place in a closed loop. The presence of biomass determines the proper functioning of the farm.

To analyse the indicators of the environmental pillar, climate change, the share of renewable energy in final energy consumption, and air protection have been selected. Solid biofuels play an important role in the production and use of energy from renewable sources. The combustion of biomass has a net zero carbon footprint. In order to improve the quality of air, it is necessary to introduce clean combustion technologies that reduce pollutant emissions as well as to promote alternative energy sources such as biomass. The energetic use of biomass can significantly reduce the emission of greenhouse gases at several stages: The emission can be eliminated from the biological processing of biomass, from its storage, and can also be reduced at the transport stage. Through technical progress, this renewable energy source can be gradually integrated into the market.

Taking into account representative indicators, the progress towards the sustainable development goals in the context of diversification of energy sources was estimated. Using these indicators, a quantitative assessment of the current progress between 2010 and 2018 in the EU-28 and in Poland was carried out. Both in the EU-28 and in Poland, the summary indicator taking into account positive and negative changes in the values of individual indicators improves between 2010 and 2018. In the EU-28, this indicator is higher (180.1) than in the case of Poland (152.3). This suggests that all analysed countries are making progress in achieving sustainable development goals. The lower dynamics in the case of Poland results mainly from the fact that the basic source of power generation in Poland remains hard coal and lignite. However, the noticeable increase in recent years in the share of energy from renewable sources, including biomass, allows us to look with hope to a rapidly growing indicators measuring progress towards a Sustainable Development Goal, and to improving environmental standards.

Preserving the natural capital at the current or higher level is possible by putting in place an appropriate environmental and energy policy of the country. The strategy highlights that improved energy efficiency will reduce dependence on energy imports, reduce emissions, and drive jobs and growth, especially in a rural environment [68,69]. The implementation of sustainable development indicators must also be rooted in the social consciousness as environmental education is a factor of fundamental importance for environmental protection and preservation for future generations.

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