Economic Impact of using Biomass for Biogas Production in the Context of Sustainable Development

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Abstract: - The negative effects of fossil fuels use on the environment and their non-renewability force economists to think about other options and ways of obtaining energy, on the one hand, from sources that are quickly renewable and, on the other hand, from those that during the process of obtaining energy do not cause excessive environmental pollution. The importance of the circular economy as a new direction of economic development is increasingly contributing to sustainable development. The diversification and expansion of economic activities are considered through biofuel production to be an effective way of increasing the share of renewable sources in solving the world's ecological problems. For governments to guarantee clean home energy access, biogas energy must be produced and used sustainably. The production of biogas from biomass has various economic effects that can significantly support sustainable development objectives. Strategic planning, cooperation, and innovation are required to optimize these economic gains to overcome governmental and regulatory difficulties, market dynamics, technological restrictions, and budgetary restraints. Market risks—classified as political, economic, social, technological, legal, and environmental (PESTLE)—impact this. To determine the PESTLE restrictions and evaluate their effects on the sustainable development of technology in the EU, this study reviews peer-reviewed literature. The Pestel method is used to identify strengths, weaknesses, opportunities, and threats because the market is subject to constant changes and is characterized by dynamics. PESTEL analysis can detect new opportunities in the biofuels market that a company can use for its growth and overtake potential competition in strategic steps.

Key-Words: - Circular Economy, Pestel analysis, Sustainable Development, Sustainability, Renewable energy, Biogas, Biomass.

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1 Introduction

In the EU countries, the bioeconomy is considered the "knowledge-based economy," and in the US, the "bio-source-based economy". The bioeconomy has moved from a theoretical concept to the level of reality of the modern economy, in which renewable biological sources, their wastes, and biotechnologies are used for the production of high-tech products and clean types of energy.

The shift towards the biological economy, mostly connected with the production of farms from renewable sources (biomass), follows the concept of deepening agriculture and provides further scope for diversification along the primary production and agro-food-energy system, [1].

Biomass is used for the production of feed, food, raw materials, pulp, and paper (fibers originating from crushed biomass). Biomass is also the primary raw material for biofuel production from oilseeds, starch, and sugar crops. It can also be used for the production of heat, electricity, combined heat and electricity, and a wide variety of gaseous and liquid fuels for transportation, [2]. These represent 13% of the world's final energy consumption (other renewable energy sources add another 5% to the total final energy consumption).

Currently, the dominant global trend is the use of biomass to replace expensive gas and reduce carbon emissions into the atmosphere, which is gaining momentum. Increasing the use of biomass will contribute to the reduction of CO^2 emissions and the reduction of fuel consumption for various purposes, which corresponds to the strategic objectives, [3]. In addition, the EU set a goal of zero greenhouse gas emissions by 2050. Biomass is an alternative to fossil fuels and its transformation into food, feed, and bioproducts such as bioplastics, biofuels, and bioenergy, [4].

Biogas production is also a prospective area of biomass utilization. At the beginning of the 21st century, many countries realized that many problems could be solved by producing biogas. The current potential of renewable gases in the world remains largely unused. The International Energy Agency (IEA) estimates biogas and biomethane could meet a fifth of global natural gas demand by 2040. The IEA agency has published a special report on the prospects of biomethane and biogas until 2040. The report is based on scenarios and data that are part of the latest edition of the World Energy Outlook, [5].

Biomass-based bioenergy production is widespread in many countries with developed economies, including Austria, Brazil, Denmark, Finland, Sweden, India, the USA and Great Britain. Back in 1998, authors proved the need to transition to the use of alternative energy sources and indicated that the potential sources of bioenergy in this area are significant, especially in countries rich in forests and in highly developed countries where there is an excess of agricultural land, as well as in many other countries where high biomass yields are possible, [6].

According to the Bioenergy European Association, bioenergy provides approximately 60% of the renewable energy consumed in EU countries, and thanks to it, 66 million European households are heated. Poland, Germany, Sweden, and Greece are the leaders among EU countries in terms of the total area of energy crop cultivation, [7].

Almost all EU member states consider power plants to be a promising area of bioenergy, and they already have about 118,000 hectares of plantations in their territories. In general, the use of biomass for energy purposes is entirely in line with the objectives of sustainable development, as it covers economic (reduction of costs), environmental (reduction of greenhouse gas emissions), and social (job creation and rural development) aspects. A multifunctional and integrated approach to the use of biomass will help solve global environmental problems such as climate change and environmental pollution, [8].

The manuscript aims to review the use of renewable energy resources as well as identify the potential development factors and components affecting the formulation of the strategy of biogas/biofuels from agrobiomass.

2 Methodology

To define the object of research, scientific contribution is focused on analyzing and investigating the economic impact of using biomass for biogas production in the context of sustainable development. The subject of the analysis is the development of renewable energy sources in the EU. The material for processing the scientific contribution is the available data obtained from Eurostat and IEA statistical databases. The analysis resulted in determining the competitive advantage of the monitored renewable energy sources in the conditions of the European Union based on selected indicators. To provide deep analysis and thus meet the paper's aim, the analysis method was used to closely examine the market for agricultural commodities and their development over time. A comparison method was used to compare the markets between selected countries. The graphic representation method was used to create graphs and tables using Microsoft Excel and Microsoft Word programs.

Biogas production is influenced by many external factors that can support or hinder its development. Understanding these factors through a PESTLE analysis helps stakeholders make informed decisions and strategically navigate the complex landscape of the biogas industry.

According to the literature, the PESTEL framework generally shows the most significant strategic topics, observes constraints and strategies, and identifies potential and trials for implementing something new, [9]. PESTEL framework consists of 6 related but different areas – 1) political area, 2) economic area, 3) social area, 4) technological area, 5) environmental area, 6) legal area. It can help with making decisions within a company. However, since it helps with the identification of macroeconomic factors in particular areas, it can even impact the observed industry as a whole, [10]. This framework is a great tool to point out the areas to be improved, [11]. The guidance for making high-quality PESTEL analysis is offered in the following points:

1. Brainstorming ideas, consulting and gathering opinions,
2. Researching information for each area in the framework,
3. Evaluation of the size of the impact and refining ideas, [12].

In the past, authors saw the biggest advantages of the mentioned analysis as having enough information about potential opportunities and threats and understanding external trends, [13]. Nowadays, it is a valuable tool in decision-making, even in wide and complicated areas, such as the healthcare system, [14], [15]. Also, some of the dimensions included in the PESTEL framework can be even more interesting than before, minding the environmental problems in the world that affect not only the environment and its dimension but also society as a whole, which is also related to the legal dimension, these relations, and their impacts show us even different perspective on this analysis and its meaning, [16].

3 Results and Discussion

Biomass is considered a renewable energy source because it takes a relatively short time to restore the used stock. In the case of using plant biomass, it is important that the carbon returns to the natural cycle through photosynthesis so that the burden of greenhouse gases on the environment will be minimal. This means biomass has energy, economic, and environmental effects, which is highly accurate.

In the EU, almost 59% of biomass is used for feed and food production, followed by the production of bioenergy (21%) and biomaterials such as wood products and wood pulp (20%). Total biomass production in the EU represents 9% of world biomass production. The EU is almost self-sufficient in biomass supply and use but remains highly dependent on fossil fuels.

According to the source of origin, biomass used for energy purposes can be divided into the following sectors:

1. agricultural biomass - cereals, rapeseed, corn straw, hemp, animal excrement, garden and vineyard waste, and specially grown energy crops (willow, poplar, licorice, sorrel...).
2. Forest biomass - firewood, branches, stumps, roots, bark, chips, fast-growing wood.
3. waste from the woodworking industry - shavings, chips, sawdust.
4. municipal waste - solid combustible waste, biodegradable waste, landfill gas, and sludge gas.

From the point of view of the intended purpose, agricultural biomass can be divided into three main groups:

1) combustion and production of heat for heating, heating hot water and processes, drying of products, and producing electricity. These include plant phytomass (straw), dendrimers (waste from gardens and vineyards, woody encroachment on permanent meadows, and fast-growing trees grown on agricultural land), energy crops (Chinese sorghum, sorghum, sap, hemp, etc.).
2) production of liquid biofuel in the form of methyl esters of vegetable oils as a component of diesel fuel (rapeseed, grain), in the form of bio-oil and bioethanol as a component of gasoline (corn, cereals, sugar beet, potatoes).
3) production of biogas with subsequent combined production of heat and electricity by cogeneration (cattle excrement, green plants, silage, food waste), [17].

The geopolitical problems of the current world, as well as the high costs of fossil fuel sources on the one hand and the development of technological progress on the other, have stimulated the creation of energy systems from biomass, which make it possible to obtain energy directly or indirectly through combustion, pyrolysis or gasification processes. These systems are becoming more and more efficient, reliable, and ecological, enabling efficient disposal of agricultural and municipal waste.

Among the bioenergy sources, the most important in the EU-27 was wood and other solid biofuels, which accounted for 47.0% of primary renewable energy in 2021 (Figure 1).

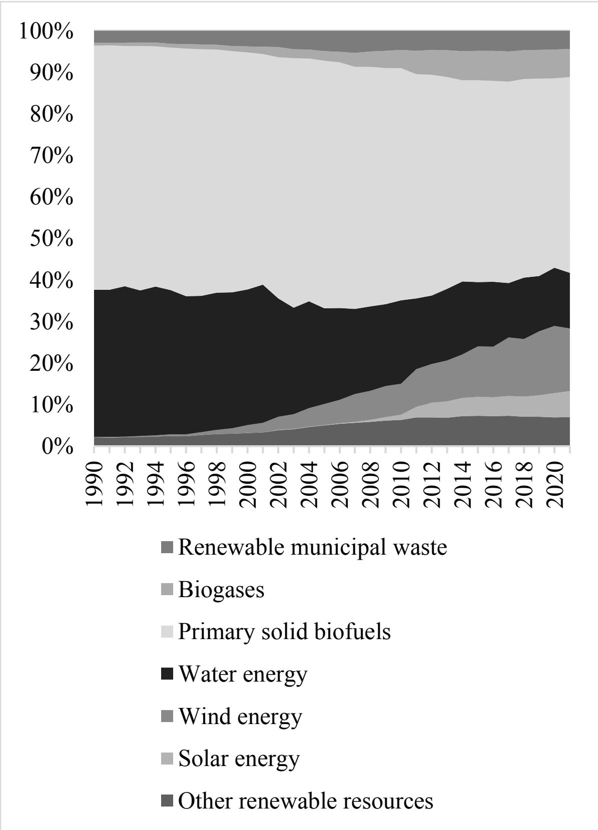

Fig. 1: Structure of renewable energy sources in the EU-27 in 1990-2020 [18]

Figure 1 shows the increase in the production of biogas, wind and solar energy, and other renewable sources in the years 1990-2021, which represented 6.76%, 15.14%, and 6.24%, 7.00% of the share of renewable energy in the EU-27 produced in 2021. In 2021, the share of energy from renewable sources in gross final energy consumption in the European Union (EU) reached 21.78% compared to 17.82% in 2015 and more than double the share in 2004 (9.61 %). The structure of energy sources of EU-27 in comparison to the world in 2021 is presented in Figure 2.

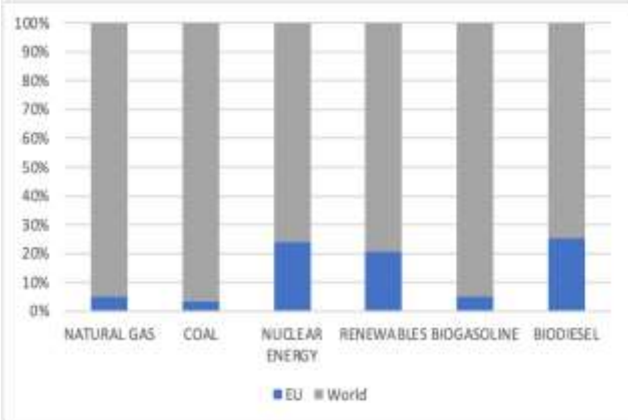

Fig. 2: Structure of energy sources of EU-27 and the world in 2021, [19]

In 2021, EU-27 generated 5% of the world's natural gas production, 3% of the world's coal production, 32% of the world's nuclear energy, and 26% of the world's renewable energy. Regarding biofuels, European countries generated 5% of total world biogasoline production and 34% of total world biodiesel production.

Table 1. Ranking of countries for the production of bioethanol and biodiesel, [20]

Ranking of countries by production			**The main raw material**	
country	**Bioethanol**	**Biodiesel**	**Bioethanol**	**Biodiesel**
USA	1(48.2%)	2 (19.5%)	Corn	Soybean oil
EU	4 (4.9%)	1 (34.1%)	Sugar beet/wheat/corn	Rapeseed oil/fats used
Brazil	2 (26.2%)	4 (12.0%)	Sugar cane/maize	Soybean oil
China	3 (8.1%)	8 (2.2%)	Maize/cassava	Consumed fats
India	6 (2.1%)	11 (0.4%)	molasses	Used oils
Canada	7 (1.4%)	10 (0.7 %)	Maize/wheat	Rapeseed oil/soybean oil
Indonesia	21 (0.2%)	3 (12.3%)	Molasses	Palm oil/soybean oil
Argentina	9 (0.9%)	5 (6.6%)	Molasses/corn	Soybean oil
Thailand	8 (1.4%)	6 (3.6%)	Molasses/cassava	Palm oil
Colombia	13 (0.4%)	9 (1.4%)	Reed	Palm oil
Paraguay	14 (0.4%)	17 (0.03%)	Reed	Soybean oil

The USA is the leader in bioethanol and biodiesel production (1st respectively 2nd place), the EU is the leader in biodiesel production and 4th in bioethanol (Table 1).

In order to achieve the EU's climate and energy goals, it is necessary to increase the share of renewable energy sources. The revised Directive 2009/28/EC of the European Parliament and the Council introduced a new mandatory EU renewable energy target of at least 32% of the whole energy mix will be produced from renewables by 2030, including a revision to raise the target at the European Union level by 2023. Amendments to the European Parliament Directive and Council 2012/27/EU set a target to improve energy efficiency at the Union level to at least 32.5% by 2030, including a provision for a review to increase the targets at the Union level. This goal is distributed among the EU member states and included in national action plans developed to determine the direction of renewable energy development in each member state.

The share of renewable resources in gross final energy consumption has been identified as a critical indicator for measuring progress under the Europe 2020 strategy for smart, sustainable, and inclusive growth. This indicator can be considered an estimate to monitor Directive 2009/28/EC. The share of energy from renewable sources is divided into three different components: the share of electricity, the share of heating and cooling, and the share of transport. The 2030 energy and climate framework for the Union is based on four key objectives at the Union level: to reduce greenhouse gas (GHG) emissions across the economy by at least 40%; a target to increase energy efficiency by at least 27%, which should be revised to 30% by 2030; the share of renewable energy consumed in the Union is at least 27%; and electrical - not less than 15%. It states that the renewable energy target is mandatory at the Union level and will be achieved through Member States' contributions, guided by the need to achieve the Union's target collectively. Figure 2 shows the share of renewable energy sources in gross final energy consumption and the targets set for 2020 for EU countries.

One of the prospective areas of using biomass for the production of biofuels is the production of bioethanol, which is an alternative to petroleum gasoline. Currently, bioethanol production is the most dynamic branch of the biofuel industry in the world. It represents 85% of the world's production of biofuels. The properties of bioethanol make it possible to increase the octane number and eliminate the use of toxic anti-knock agents such as tetraethylol, benzene, toluene, etc. This reduces the toxicity of exhaust gases. In the Figure 3 is shown real and target share of renewable energy sources in gross final energy consumption in European countries.

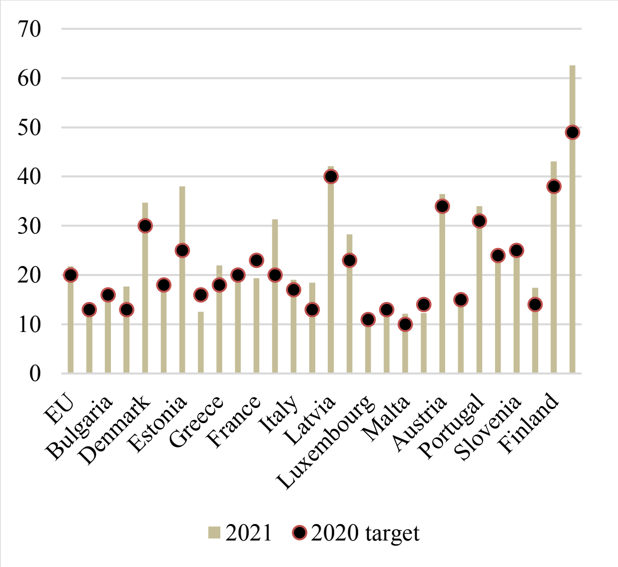

Fig. 3: Real and target share of renewable energy sources in gross final energy consumption in EU-27 countries, [5], [20]

It can contribute to lower emissions of greenhouse gas into the atmosphere (mainly methane released into the atmosphere from untreated manure storage), can be a source of renewable energy (electricity, heat, or for the transport sector), and can lead to a reduction in the effects of pollution from waste accumulation. It is crucial that while processing, the waste is converted into a product (biogas) and a valuable organic fertilizer, thus closing the cycle from soil to crop, to product, to waste, and back to soil.

Renewable and decarbonized gases are at the intersection of today's critical challenges: the need to lessen CO^2 emissions from the growing amount of organic waste. In practice, the principle of the circular economy is applied, in which the demand for energy services can be satisfied and, at the same time, bring environmental benefits. According to the available data, the global production of biogas and biomethane in 2018 was approximately 35 million tons of oil equivalent (Mtoe), which, according to IEA estimates, is only a fraction of its real potential. According to analysts, if it could be fully utilized, it would be possible to cover up to 20% of global demand in this way. The global potential for biomethane is 730 Mtoe. In the case of biogas, it can reach 570 Mtoe, [21].

Understanding the circular nature of processing biomass into biogas led to a fast rise in the biogas sector over the past two decades, driven by legislative changes to various renewable energy and greenhouse gas reduction targets worldwide.

Biogas technologies have developed significantly in North America, Europe, and Asia, [22]. At the same time, the question of finding raw materials - biomass in sufficient volume - arose. After all, a crucial imperative for a country's success in the transition to biofuels is the availability of local resources (biomass, energy equipment, waste) in a particular area.

The acceleration in the number of European biogas stations in the last years indicates the industry's sustainable development. By the end of 2018, almost 18,202 biogas stations were operating in EU countries, which is by 2% (419 units) more than in 2017. The total installed electric power of biogas stations was 11,082 MW, and the total biogas production was 63,511 GW per year, [23]. Among the EU countries, the leaders in the number of biogas stations are Germany (11 084 units) and Italy (1 655 units), followed by France (837 units), Great Britain (715 units) and Switzerland (634 units), [24].

Undoubted advantages of biogas production include: 1) low toxicity, 2) possible rise in the efficiency of the agricultural resources use, 3) reduction in dependence on oil, and reduction of the greenhouse effect. On the other side, the most considerable drawbacks of this direction are the following: 1) high cost of production, 2) unstable yields of some types of biomasses, and 3) hygroscopicity and raised fuel consumption.

Biogas consists of 60–70 % of methane gas and carbon oxides, hydrogen sulfide, nitrogen, and hydrogen. The materials that can be used in the biogas production process include the waste materials of livestock and poultry farms, animal waste materials, vegetable materials, solid waste materials, organic waste, solid materials, and waste from food processing factories, [24].

Methods used in the biogas controlling biogas that come from biomass should be merged, [25]. Also, there is a need to unify the methodology to understand the advantages and disadvantages in the context of the environment of chosen methods in biogas production. The crucial factor is a suitable evaluation process of social and environmental areas.

As shown in Figure 4, European countries produce the most significant proportion of biogas from agricultural crops compared to China, the USA, and other countries. China leads the biogas production from sewage and produces a similar proportion of biogas from livestock waste and household waste as Europe.

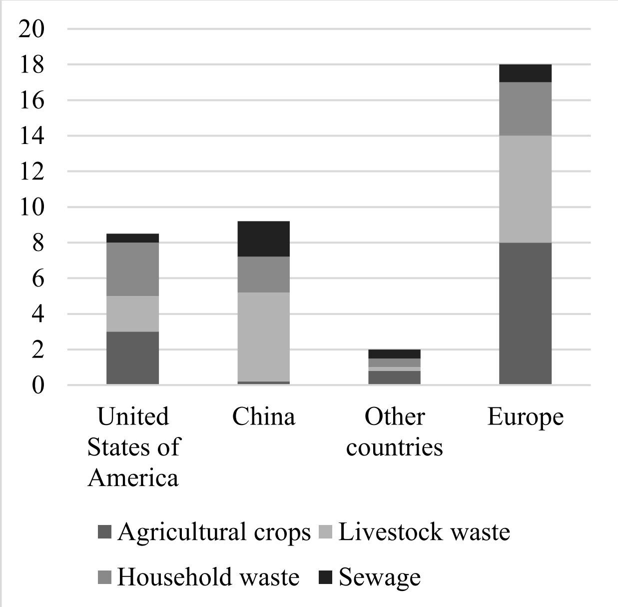

Fig. 4: Biogas production by region and type of raw material in 2020, Mtoe, [5]

The global biogas market was valued at 8 billion USD in 2020, and it is projected to reach 13.8 billion USD by 2027 at a compound annual growth rate (CAGR) of 8.1% from 2020-2027. In 2020, the US biogas stations market was valued at 2.4 billion USD. China, the world's second-largest economy, is expected to reach a projected market size of 2.4 billion USD by 2027, representing a 7.6% compound annual growth rate over the period 2020-2027, [26].

The market for biogas technologies in the EU is estimated at 3 billion USD. The statistics on using raw materials for biogas production are as follows: 75% of biogas is produced from agricultural waste; 17% – from the organic waste of private households and businesses; and 8% - from wastewater treatment plants. In total, EU countries produced 30.9 billion m3 of biogas with an energy equivalent of 0.71 EJ in 2018. Biogas production in Europe accounted for more than half of world biogas production, while Asian countries ranked second with a share of 32% (19.3 billion m3). The third place in the world in 2018 in terms of biogas production was occupied by the countries of North and South America (8.34 billion m3), [27].

It is worth mentioning the use of biogas stations for electricity production. A new fuel type was introduced – liquids originating from biomass, which accounted for 19.7% of electricity production from renewable sources in 2020. The largest share of electricity production from renewable sources comes from biomass (28.1%), photovoltaic energy (25.6%), and biogas (23.2%).

The average installed capacity of biogas stations in European countries was 0.61 MW, and the total amount of electricity produced from biogas was 63,511 GWh in 2018. Electricity production from biogas is growing in many countries, including Croatia (234 GWh), France (116 GWh), Serbia (71 GWh), Denmark (29 GWh), and Greece (26 GWh) (Figure 5).

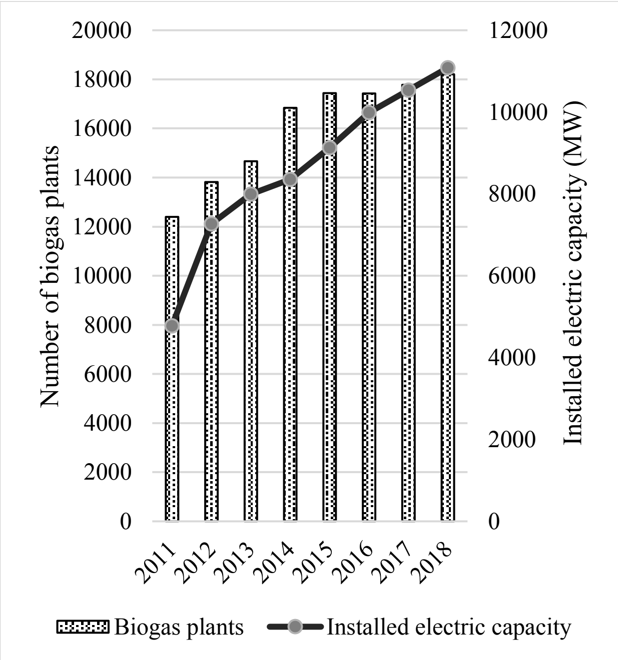

Fig. 5: Number of biogas stations in European countries and electrical output, [25]

The advantages of using individual biogas stations in rural areas are undeniable, as evidenced by the experience of countries that have introduced biogas technologies. Among these countries are the USA, China, India, Denmark, Austria, Sweden, Germany, the Czech Republic, and many others. For example, the US Energy Information Administration estimates that in 2019, 25 large US dairy and livestock operations produced approximately 224 million kWh (or 0.2 billion kWh) of electricity from biogas . About 28 million biogas plants have been installed in China, producing 18 billion cubic meters of biogas per year; in India - 3.8 million biogas stations; in Germany - 8 thousand, including hundreds in the Netherlands, Canada, Russia, Belarus, Kyrgyzstan, and Kazakhstan, [28], [29].

Table 2. Possibilities and limitations of biogas production, [30]

Topic	***Discussion point***
Sources	Change of perspective: from the use of the best raw materials for energy production to the optimal use of all biomass sources
	Better use of residual biomass: combining the efficient treatment of organic waste streams with the creation of added value through the extraction of valuable components and the production of renewable energy
	From today: using all available biomass for currently feasible processes, thereby mobilizing biomass and creating a springboard to a more integrated use of biomass sources
Products	Context: adapting the choice between biogas and green gas to the local and regional landscape
	Function in the energy system: from inflexible renewable energy source to system service provider, using biogas where it offers advantages over other renewable sources, e.g., benefit from flexibility and application for heavy energy carriers
	Multiple products: no longer just energy, but multiple products that integrate into bioeconomy concepts such as biorefinery
Technologies	Shifting focus: from increasing biogas yields to improving the front and back of the production chain
	More variety: more products and more diverse business cases. Fermentation as a processing step, creating technologies enabling the bioeconomy
	Unclear logistics: appropriate dimensions, logistics, and integration into the country need more attention
Financing and regulation	Grant-related funding: focusing on specific technologies or products leaves little room for experimentation and innovation
	Same conditions: subsidies prefer energy production over new or additional products, and inflexible financing options hinder innovative business cases
	Complications: bureaucratic obstacles and international differences hinder expansion and innovation

The general possibilities and limitations of biogas production from biomass are shown in Table 2. Also, there are issues related to the inconvenience of transport cost or seasonality of agri-food waste availability. However, characteristics of the areas with small farms may cause input instability and can be clarified by cooperation between farmers, producing different biomass, [31]. Therefore, the decision regarding the selection of the place for the biogas installation should consider the social aspect in addition to the technological, environmental, and legal issues. Following PESTEL FAMILY analysis of potential development factors and components affecting the formulation of the strategy of biogas/biofuels from agrobiomass consists of these factors:

1) Political

Political factors significantly influence the development and success of biogas production. These factors encompass government policies, regulations, political stability, and international agreements, which can either support or hinder the biogas industry.

Contributing factors: State support for energy supply and the transition to alternative energy sources. Financing, grants, government regulations, and implementing measures for introducing biofuel production and improving the waste management system. It is becoming increasingly clear that structural changes in the states are necessary for the development of the bioeconomy. Cooperation with international organizations and partner countries. Support for agricultural production. Development of international cooperation

Obstacles: Low interest in the development of the bioeconomy and high preferences for the automotive industry. Insufficient subsidy system for the development of the bioeconomy. Unresolved ownership relation to agricultural and forest land. Insufficient anti-erosion measures. Lack of coordination of rural development. Frequently changing legislation. Lack of circular agricultural policy measures.

2) Economic

Contributing factors: Strengthening energy and economic security by increasing the share of energy from renewable sources. Economic efficiency of biofuel production from crops and waste. Transition to a circular economy. Availability of building materials, forests, and water resources. Constant increase in energy prices. Long-standing tradition in waste management. Status forestry. The established first and second generation of bioethanol production.

Obstacle factors: Predominance of export of raw materials and import of finished products. Lack of investment funds. Insufficient subsidy systems for the installation of equipment for the processing of biogas stations. High dependence on foreign chains of food sales. Limitation of agriculture and reduction of building materials. Low investments in ecology and eco-technologies.

3) Social

Social factors are essential in understanding the broader impact of biogas production on communities and society as a whole. These factors encompass public perception, community benefits, health impacts, and social equity considerations.

Contributing factors: Availability of trained employees. Lower incomes of farmers compared to average wages. Possibility of creating new jobs by introducing energy production from renewable sources. The activity of young and highly qualified employees and ambition to create positive changes. Possibility of using available bio-raw materials for bioconversion with the involvement of labor resources and the possibility of obtaining other financial benefits. Increasing the qualifications of employees and the level of satisfaction of social needs. Obstacle factors: The European population is aging, and there is an increase in the number of older people. Migration processes, the departure of the working population, and youth abroad. Lack of qualified human capacities in the field of eco-innovation.

4) Technological

The successful implementation and operation of biogas-generating systems heavily relies on technical considerations. Optimizing processes, managing feedstock well, utilizing strong monitoring and control systems, and leveraging technological advancements are all critical to optimizing biogas yield, guaranteeing operational effectiveness, and getting scalable. The potential and sustainability of biogas generation are further enhanced by ongoing innovation and integration with other energy systems.

Contributing factors: The development of new technologies for the production of biogas/biofuels from bio-raw materials and agricultural waste. The rapid pace of development of scientific and technological progress and innovations. Automatization and mechanization of all production processes.

Obstacle factors: Weak links between science and technology in the real sector of the economy. Low supply level for the conversion process line.

5) Ecological

Ecological factors play a significant role in the biogas production process. These factors relate to the environmental impact and sustainability of biogas production.

Contributing factors: General ecological situation in the country and regions. Ecological efficiency of the use of fuels obtained from agricultural crops and waste. Reduction of the negative impact on the environment due to the reduction of emissions of carbon dioxide (CO^2), methane (CH^4), and other greenhouse gases. The possibility of obtaining organic fertilizers. Safe processing and disposal of agricultural waste and producer responsibility. Favorable climatic conditions. Biogas production uses organic waste materials such as agricultural residues, animal manure, and food waste, helping to manage waste effectively and reduce landfill use. Biogas systems can support climate adaptation strategies by improving agricultural resilience through enhanced soil fertility and water retention.

Obstacle factors: Insufficient effectiveness of incentives to reduce negative impacts on the environment. Insufficient recycling of municipal solid waste.

6) Legal

A key aspect in determining how the biogas production landscape is shaped is law. The development and management of biogas projects depend heavily on the following: managing contractual agreements, preserving intellectual property, navigating land use and zoning laws, maintaining health and safety standards, and adhering to energy and environmental regulations. Comprehending and tackling these legal factors aids in risk reduction and promotes an atmosphere that is favorable for the production of biogas.

Contributing factors: Legislative and regulatory documents in the field of alternative energy and biofuels. Special tax conditions for the support of biofuels. Implementation of programs and support for the use of biofuels in transport. Introduction of additional tax incentives for the production of biogas/biofuels for own use. in the domestic environment for bioenergy production. Future policies should focus on clusters: pairing innovation centers with industry and the state.

Obstacle factors: No new policies and legislation specific to the bioeconomy (status quo). Ignoring awareness raising about the need for structural changes in policy

7) Financial

In order for biogas production initiatives to be successful, finances play a critical role. Many factors are important, including high startup and operating costs, capital accessibility, financial incentives, revenue possibilities, and market dynamics. Enhancing the sustainability and feasibility of biogas production can be achieved by efficient financial management, risk reduction, and utilization of relevant economic incentives.

Contributing factors: Introduction of financial incentives and support for investments and innovations in biogas/biofuel production. Lower costs of produced biofuel compared to oil. Possibility of obtaining additional funds for introducing organic waste processing technologies into biogas/biofuels. Strengthening the energy security of the enterprise by using additional funds obtained for energy production from its own resources.

Obstacle factors: Difficulties in finding additional funds for investments in biotechnology. High dependence on the state, low competition, and low productivity, especially in agriculture and subsequent processing industries. Low transparency of structural funds. Gradual increase of the landfill tax. Absence of a capital market. Financial restrictions prevent the broader use of modern technologies. A lot of money is needed for investments in technology wood biomass. Low access to finance and low level of synergies in public-private funds and investments.

8) Managerial

Projects aimed at producing biogas must be successfully planned, carried out, and operated, and this requires managerial elements. Strategic planning, project management, operational effectiveness, stakeholder involvement, and continuous improvement are all included in this list.
Contributing factors: The possibility of implementing the Strategy for the production of biogas/biofuels from agrobiomass. The optimal possibility of biofuel production must be determined by considering territorial and raw material factors. The high potential of available organic raw materials for conversion into an energy source and the built network of facilities for treating organic waste. Obstacle factors: Insufficient number of effective strategies and tactical plans for the development of energy independence of agricultural enterprises. Insufficient manager's awareness of the strategy for the production of biogas/biofuels from biomass and waste. Strong financial competition with foreign companies.

9) Marketing

Marketing elements are essential to the manufacturing of biogas because they create demand, establish brand awareness, and guarantee consumer satisfaction. To acquire and expand the market for biogas products and services, one must employ strong distribution networks, competitive pricing, strategic branding, efficient market research, and focused marketing initiatives.

Contributing factors: Advertising and public relations, public awareness of the benefits of biotechnology, support for the sale and use of biofuels (television, transport, internet, etc.). High potential of available bio-raw materials for transformation into an energy source. Diversification of production activities and access to new markets. Stimulating the use of energy produced from bioresources to reduce the negative impact on the environment in order to obtain state support. The creation of regional development programs with the definition of priorities for regions.

Obstacle factors: Low efficiency of the marketing network of biogas/biofuels in the domestic and foreign markets. Lack of long-term contracts for the supply of raw materials to conversion to biofuels. Competition with producers of petroleum fuels.

10) Innovative

In order to advance biogas production and overcome its obstacles, innovation is essential. Enhanced microbial processes, feedstock pretreatment, advanced digester technology, biogas upgrading, and system integration all lead to increased sustainability and efficiency. The viability and impact of biogas production are further enhanced by digitalization, circular economy techniques, new applications, economic innovations, and environmental advances.

Contributing factors: The innovation potential of the biogas/biofuel production sector. The opportunity to attract foreign investment. The possibility of producing biogas/biofuels for own use in agriculture. The potential for the growth of professional knowledge and skills. An extensive network of adult education institutions. Research and educational activity at the national research centers.

Obstacle factors: Innovators, intellectual assets, and attractive research systems are developing slowly. Countries lack qualified human resources in the field of eco-innovation. Decline in the quality of vocational education and employment. Negative development in the practice of educational institutions and other population groups.

11) Logistic

Logistics factors are essential for the efficient management of feedstock supply, biogas distribution, and by-product utilization in biogas production. These factors encompass transportation, storage, handling, and coordination of materials and resources throughout the production process.

Contributing factors: Gradual streamlining of agrobiomass waste management. Ability to export fuels made from renewable raw materials. Telecommunications market bringing above-standard innovations. International transport corridors - highways, ports, railway network.

Obstacle factors: Low efficiency of supply logistics agricultural waste for the production of biofuels. No liquid biofuel mixing system; high level of export of biofuels, which may lead to the conclusion of long-term contracts with biofuel producers. Unstable supply of raw materials for conversion into energy. Increased costs for maintenance of railway infrastructure and road infrastructure

12) Risk factors

For biogas production projects to be developed and run successfully, these risk concerns must be addressed and mitigated. Ensuring the long-term sustainability and viability of biogas production requires robust risk management techniques that include detailed feasibility evaluations, contingency planning, regulatory compliance, and stakeholder involvement. These measures are important to limit the impact of hazards.

Economic competition (export of raw materials/processing for biogas/biofuels, oil fuels). Unpredictable impact of natural phenomena (climate change, drought, storms). Non-compliance with certain deadlines for the implementation of strategic, tactical, and operational planning. Quality standards. Obstacle factors: Low level of power supply to the conversion line. Financing of development activities in forestry and agri-business. Insufficient grant, capital, and loan funds for biological initiatives. Transport of exported raw materials, e.g., cereals, over the export of domestic biological products.

4 Discussion

Sustainable development is an approach to development that takes the finite resources of the Earth into consideration. This can mean many different things to different people, but it most commonly refers to using renewable energy resources and sustainable agriculture or forestry practices. The necessary goals are to achieve economic and environmental benefits through sustainable projects for resource recovery and utilization, as well as programs for developing countries, [32]. In contrast to fossil fuels like natural gas, which is produced through a geographical process, biogas is produced by the biological process of organic materials decomposing through bacteria. Up to 60% of biogas [33] and 90% of natural gas [34] are made up of methane. Biogas has a calorific value of 5000 kcal/m3, while natural gas has a calorific value of 8600 kcal/m3, [35].

Furthermore, compared to fossil fuels, biogas has less influence on the environment. For example, the CO2 emissions from biogas are 81.5 g CO2/MJ energy, while the CO2 emissions from coal and liquefied petroleum gas (LPG) are 682 g CO2 and 139 g CO2, respectively. Additionally, biogas emits 0.11 g CO, as opposed to 26.2 and 0.82 g CO from coal and LPG, respectively, [36]. These characteristics point to biogas's potential to displace natural gas in many applications.

The ecological factors associated with biogas production highlight its potential to contribute positively to environmental sustainability. Biogas production supports both environmental protection and sustainable development by managing organic waste, reducing greenhouse gas emissions, enhancing soil health, and providing a renewable energy source.

From the above-discussed discussion, it is clear that biogas has several advantages over natural gas and has already shown a strong potential to replace natural gas in various applications, from household use to large-scale industrial electrical generation, such as power plants.

5 Conclusion

At the end of this study, it can be concluded that Using biomass for biogas production can have significant economic impacts within the context of sustainable development. In rural and agricultural areas, where biogas facilities are frequently located, job opportunities are created by the need for staff for plant operation, maintenance, and management associated with biogas generation. They generate extra income for farmers and farming communities by selling feedstock materials, such as energy crops, animal dung, and crop leftovers, and providing a locally produced, renewable energy source that may take the place of fossil fuels for transportation, heating, and electricity production, saving money for both businesses and consumers and generating chances for the production of biogas by-products with additional value, such as bioplastics, soil additives, and organic fertilizers, to boost economic activity even further. Provides funding for constructing biogas infrastructure, such as distribution networks, biogas plants, facilities upgrades, and storage infrastructure. By leveraging the increasing demand in both local and international markets for sustainable products and renewable energy sources, biogas may be positioned as a cost-effective and eco-friendly energy alternative.

1. Technologies for the use of biogas are changing rapidly, opening up the possibilities for more efficient use of biogas in the agricultural sector and energy. In the field of renewable energy, the transition to green gas could become a commodity for the system service provider, but the biogas business faces technical, financial, and logistical challenges.
2. Technical development is mainly focused on using cheaper and more complex resources and adapting biogas processing technology to produce several products that fit well into the bioeconomy policy.
3. Subsidy schemes and bureaucratic rules for the use of biogas stations prevent their active distribution. The use of alternative residual sources of biomass is hindered by the limited possibilities of farm financing.
4. World experience and used practices allow us to state that biogas technologies are developing relatively quickly; they are widely used not only on an industrial scale but also on a farm level. There is a positive trend in the growth of production volumes in the development of biogas technologies and an increase in the number of biogas stations. Most countries do not plan to reduce the volume of biogas production. Their plans include developing new types of raw materials, increasing the efficiency of methane fermentation, and transitioning to waste-free innovative technologies.
5. Biogas production and market development fulfill the goals of several policies – energy, environmental, agricultural, and innovation. Business practices offer many possibilities for expanding the use of biogas. However, to achieve this, barriers such as bureaucracy and inflexible financing systems need to be reduced, and subsidy systems must be based on the development of alternative business options in agriculture, including different opportunities for biomass use.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly in order to improve the readability and language of the manuscript. After using this tool the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References:

[1] Salvioni, C., Henke, R. & Vanni, F. (2020). The Impact of Non-Agricultural Diversification on Financial Performance:

Evidence from Family Farms in Italy. *Sustainability*, *12*(2), 486. https://doi.org/10.3390/su12020486.

[2] Scarlat, N., Dallemand, J.-F., Monforti-Ferrario, F. & Nita, V. (2015). The role of biomass and bioenergy in a future bioeconomy: policies and facts. *Environmental Development, 15*(1), 3–34. https://www.sciencedirect.com/science/article/pii/S2211464515000305.

[3] Gustavsson L., Holmberg, J., Dornburg,V., Sathre, R., Eggers, T., Mahapatra, K., Marland, G. (2007). Using biomass for climate change mitigation and oil use reduction. *Energy Policy, 35*(11), 5671-5691. https://doi.org/10.1016/j.enpol.2007.05.023.

[4] Popp, J., Kovács, S., Oláh, J., Divéki, Z. & Balázs, E. (2021). Bioeconomy: Biomass and biomass-based energy supply and demand. *New Biotechnology, 60*(1), 76-84. https://doi.org/10.1016/j.nbt.2020.10.004.

[5] IEA (2020), Outlook for biogas and biomethane: Prospects for organic growth Paris: IEA, [Online]. https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth (Accessed Date: June 12, 2024).

[6] Halla, D.O., Scrasea, J.I. (1998). Will biomass be the environmentally friendly fuel of the future? *Biomass and Bioenergy, 15*(4–5), 357-367. https://doi.org/10.1016/S0961-9534(98)00030-0.

[7] European Bioenergy Association. (2022). Bioenergy Europe, [Online]. https://bioenergyeurope.org/bioenergy/ (Accessed Date: June 12, 2024).

[8] Kumari, K., Singh, A., Marathe, D., Pariyar, P. (2021). Agricultural biomass as value chain developers in different sectors. *Advanced Technology for the Conversion of Waste into Fuels and Chemicals, 1(2021),* 467-509. https://doi.org/10.1016/B978-0-12-823139-5.00014-9.

[9] Pan W., Chen L. & Zhan W. (2019). PESTEL Analysis of Construction Productivity Enhancement Strategies: A Case Study of Three Economies. *Journal of Management Engineering, 35*(1), 4100. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000662.

[10] Sandberg A.B., Klementsen E., Muller G., De Andres A. & Maillet J. (2016). Critical Factors Influencing Viability of Wave Energy Converters in Off-Grid Luxury Resorts and Small Utilities. *Sustainability, 8*(12), 1274. https://doi.org/10.3390/su8121274.

[11] Matović, I. M. (2020). PESTEL analysis of external environment as a success factor of startup business. *ConScienS Conference Proceedings: Princeton, USA, 2020* (1), 96-102, [Online]. https://www.ceeol.com/search/chapter-detail?id=1022070 Accessed Date: February 5, 2024).

[12] Oxford College of Marketing (2023), [Online]. https://blog.oxfordcollegeofmarketing.com/2016/06/30/pestel-analysis/ (Accessed Date: June 12, 2024).

[13] Aguilar, F. J. (1967). *Scanning the Business Environment*. New York: Macmillan Company.

[14] Vojinović, N., Stević, Ž., & Tanackov, I. (2022). A Novel IMF SWARA-FDWGA-Pestel Analysis for Assessment of Healthcare System. *Operational Research in Engineering Sciences: Theory and Applications, 5*(1), 139–151. https://doi.org/10.31181/oresta070422211v.

[15] Siddiqui, A. A. (2021). The use of pestel analysis tool of quality management in the health care business and its advantages. *American Journal of Biochemistry and Biotechnology, 14*(6), 507-512. http://doi.org/10.34297/ajbsr.2021.14.002046.

[16] Kairuz, A. R. P., Ruiz, D. V. P., Pita G. F. V. & Mena, F. S. B. (2020). PESTEL analysis of environment state responsibility in Ecuador. Special issue Social Neutrospohy in Latin America. *Neurosophic Sets and Systems*. 34: 70-78.

[17] Ministerstvo životného prostredia SR (Ministry of the Environment of the Slovak Republic.). (2021). Biomasa, [Online]. https://www.minzp.sk/klima/obnovitelne-zdroje-energie/biomasa/ (Accessed Date: June 12, 2024).

[18] Statistical Review of World Energy. (2022), [Online]. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf (Accessed Date: June 12, 2024).

[19] Eurostat. (2022). European Commission. Bioeconomy. DataM, [Online]. https://datam.jrc.ec.europa.eu/datam/area/BIOECONOMY (Accessed Date: June 12, 2024).

[20] OECD-FAO. (2020). OECD-FAO Agricultural Outlook 2020-2029. Paris: OECD Publishing, Rome: FAO. https://doi.org/10.1787/1112c23b-en.

[21] ENERGOKLUB (2020). IEA: Biogas and Biomethane Can Replace 20% of Natural Gas Demand (IEA: Bioplyn a Biometán Môžu Nahradiť 20 % Dopytu po Zemnom Plyne), [Online]. https://energoklub.sk/sk/clanky/iea-bioplyn-a-biometan-mozu-nahradit-20-dopytu-po-zemnom-plyne/ (Accessed Date: June 12, 2024).

[22] Edwards, J., Othman, M. and Burn, S. (2015). A review of policy drivers and barriers for the use of anaerobic digestion in Europe, the United States and Australia. *Renewable and Sustainable Energy Reviews, 52(2015),* 815-828. https://doi.org/10.1016/j.rser.2015.07.112.

[23] World Biogas Association. (2021). France, [Online]. https://www.worldbiogasassociation.org/wlpga-annual-report-2021/ (Accessed Date: June 12, 2024).

[24] Wang, Q., Xia, Ch., Alagumalai, K., Thanh Nhi Le, T., Yuan, Y., Khademi, T., Berkani, M. & Lu, H. (2023). Biogas generation from biomass as a cleaner alternative towards a circular bioeconomy: Artificial intelligence, challenges, and future insights. *Fuel, 333*(2), 126456. https://doi.org/10.1016/j.fuel.2022.126456.

[25] Kasinath A., Fudala-Ksiazek S., Szopinska M., Bylinski H., Artichowicz W., Remiszewska-Skwarek A. & Luczkiewicz A. (2021). Biomass in biogas production: Pretreatment and codigestion. *Renewable and Sustainable Energy Reviews, 150*(2021), 111509. https://doi.org/10.1016/j.rser.2021.111509.

[26] European Biogas Association. (2021), [Online]. https://www.europeanbiogas.eu/eba-statistical-report-2021/ (Accessed Date: June 12, 2024).

[27] Zulauf, C., Prutska, O., Kirieieva, E. and Pryshliak, N. (2018). Assessment of the potential for a biofuels industry in Ukraine. *Problems and Perspectives in Management 16*(4), 83–90. https://doi.org/10.21511/ppm.16(4).2018.08.

[28] Kaletnik, G. (2018). Production and Use of Biofuels. (online) Vinnytsia: LLC Nilan-LTD, [Online]. http://socrates.vsau.org/repository/getfile.php/27846.pdf (Accessed Date: December 15, 2023).

[29] Pryshliak, N., Lutsiak V.,Tokarchuk, D., Semchuk, I. (2020). The empirical research of the potential, awareness and current state of agricultural waste use to ensure energy autonomy of agricultural enterprises of Ukraine. *Journal of Environmental Management and Tourism. 11*(7), 1634-1648. https://doi.org/10.14505//jemt.v11.7(47).04.

[30] Pfau, S.F., Hagens. J. E. And Dankbaar, B. (2017). Biogas between Renewable Energy And Bio-Economy Policies-Opportunities And Constraints Resulting From A Dual Role. *Energ Sustain Soc., 7*(17). https://doi.org/10.1186/s13705-017-0120-5.

[31] Koryś, K. A., Latawiec, A. E., Grotkiewicz, K., & Kuboń, M. (2019). The Review of Biomass Potential for Agricultural Biogas Production in Poland. *Sustainability, 11*(22), 6515. http://dx.doi.org/10.3390/su11226515.

[32] Alayi, R., Shamel, Ali., Kasaeian, A., Harasii, H., & Topchlar, M. A. (2016). The role of biogas to sustainable development (aspects environmental, security and economic). *Journal of Chemical and Pharmaceutical Research, 8*(4), 112-118.

[33] Ryckebosch, E. Drouillon, M. Vervaeren, H. (2011) Techniques for transformation of biogas to biomethane. *Biomass Bioenergy, 35*(5), 1633-1645. https://doi.org/10.1016/j.biombioe.2011.02.033.

[34] Mango F.D. (2001). Methane concentrations in natural gas: the genetic implications. *Org Geochem, 32*(10), 1283-1287. https://doi.org/10.1016/S0146-6380(01)00099-7.

[35] Abbasi T., Tauseef, S.M. Abbasi S.A. (2012). Anaerobic digestion for global warming control and energy generation-An overview. *Renew Sustain Energy Rev, 16(5),* 3228-3242. https://doi.org/10.1016/j.rser.2012.02.046.

[36] Bruun, S., Jensen, L.S., Khanh Vu V.T., Sommer, S. (2014) Small-scale household biogas digesters: an option for global warming mitigation or a potential climate bomb. *Renew Sustain Energy Rev, 33*(1), 736-741. https://doi.org/10.1016/j.rser.2014.02.033.

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The authors have no conflicts of interest to declare.

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