

Could renewable sources achieve an energy independence?

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Abstract: In a modern and constantly developing society, electrical energy plays a pivotal role in its development. Nowadays, due to the Ukraine-Russia military conflict, ensuring energy independence and security is more important than ever. Subsequently, the transition from the energy obtained from fossil fuels to green energy must become a priority for decisionmakers. This transition not only contributes to diminishing dependence on Russian gas, but it could also provide stability in the economic sector, produce a positive impact on the environment, reduce the occurrence of disruptive attacks on the networks, and contribute to ensuring energy independence. Another asset of renewable energies lies in the fact that they are diversified (wind energy, solar energy, hydraulic energy, energy obtained from biogas) and can be installed in hard-to-reach areas. Therefore, this article explores the sources of renewable energy and the significant advantages they bring to society in times of peace/war.

Keywords: biogas, energy independence, energy security, renewable sources

Introduction

Electrical energy plays a key role in the socio-economic development of each country, emerging as a vital component in its development [1]. Furthermore, in a modern society, electrical energy has become indispensable to life. It supports all economic activities ranging from production to transport, access to modern education and communication [2]. That is why energy independence can positively impact the economic development of each country, by ensuring an affordable energy price. Therefore, the price of energy is considered the development engine of modern economies [3]. Energy independence refers to ensuring the necessary amount of energy from own sources [4]. Basically, every country provides its own transport base, maintenance and workforce [5]. Moreover, energy independent countries can create a "shield" in order to defend their national interests. Likewise, these countries can be considered real pawns, which can exert a significant impact on the economy and politics worldwide [6]. Unfortunately, this is not applicable to countries which are energy dependent on fossil fuel imports. The dependence can generate serious problems in terms of energy security [6]. As a result, ensuring energy security is one of the most important tasks of every state, as it ensures the continuous operation of the economy and the population's access to modern and clean energy [7]. Therefore, energy security has nowadays become a topical issue worldwide, being featured in multilateral discussions and international forums [8].

Energy security does not only entail the ability to maintain the constant supply of energy at reasonable prices, but it is also considered a much more complex concept [9], given its connections with the diversity of fuels, physical risks [10], the threat of suspending or even canceling deliveries [11].

While the transportation of oil, gas and coal is relatively easy on water or land, this is not applicable to electrical energy, which must be transmitted through physical cables. This is why countries which are dependent on electricity imports are forced to import only from their neighbors [12].

Figures 1, 2 and 3 below depict the country of origin corresponding to the primary energy imports to the European Union (EU) between 2018 and 2020.

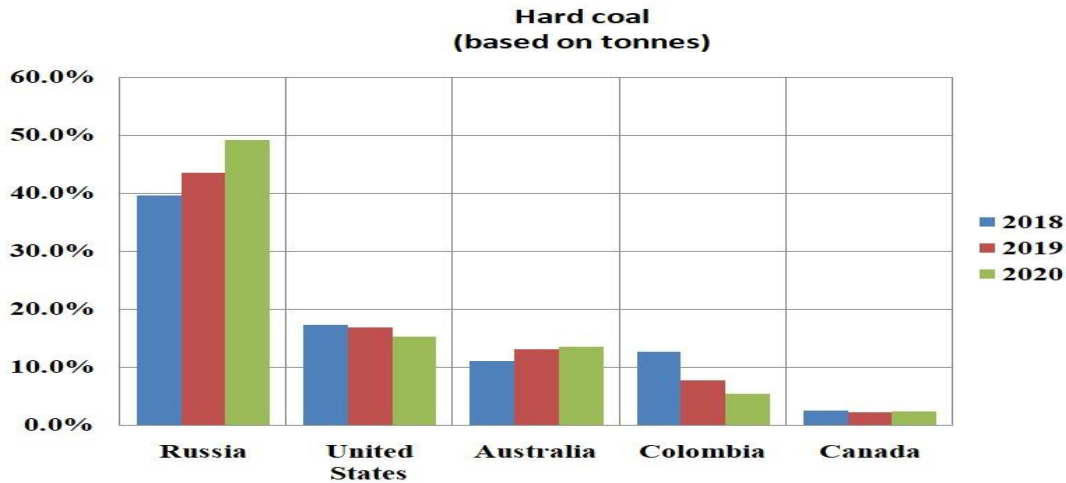


Figure 1. The main exporting countries of hard coal to the EU [13].

Figure 1 depicts the main exporting countries of hard coal to the EU between 2018 and 2020. This graph shows that Russia and Australia were the main exporting countries of hard coal between 2018 and 2020. Referring to the year 2020, one can see that Russia exported hard coal in 49.1 percent, Australia exported 15.2 percent, with Canada occupying the last position with 2.3 percent in relation to the primary energy imports.

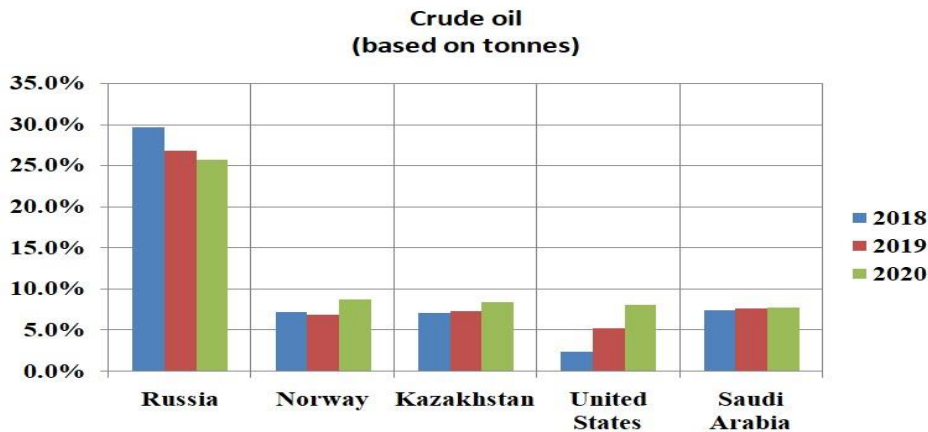


Figure 2. The top 5 exporting countries of crude oil to the EU [13].

Figure 2 shows the most important primary energy suppliers across the EU. Analyzing this graph carefully, it should be noted that Russia holds the monopoly regarding the export of crude oil. The deliveries of this country (between 2018 and 2020) range between 29.6 and 25.7 percent. While in Norway, Kazakhstan and Saudi Arabia, there were no significant differences between 2018 and 2020, the United States increased its supply, rising from 2.4 percent in 2018 to 8.1 percent in 2020.

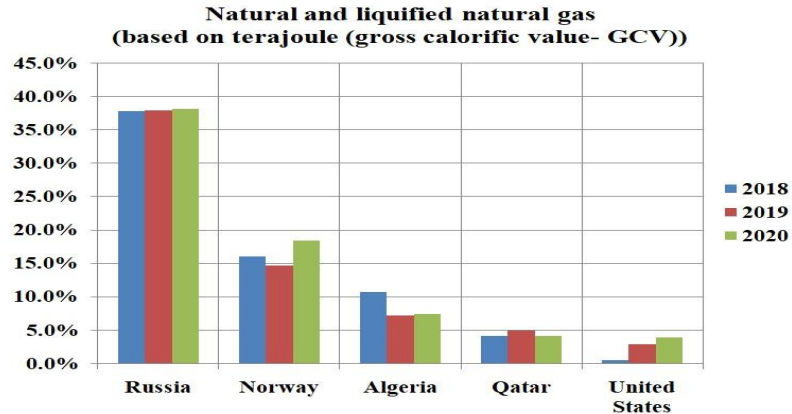


Figure 3. Graphical representation of the natural and liquified gas supplier countries [13].

The leading natural and liquefied gas supplier countries are illustrated in Figure 3 above. Russia emerges as the top supplier followed by Norway and Algeria, with the United States occupying the last position. The difference between Russia and the United States is very big, particularly if considering the year 2020, as it can be noticed that Russia supplied natural and liquefied gas at a rate of 38.2% of the raw energy imports for the EU. By contrast, the United States exported 4.0 percent to the EU in 2020. Figures 1, 2 and 3 depict Russia as the main supplier of fossil fuels between 2018 and 2020.

Due to the tense relationship recently established between the EU and Russia, EU countries must immediately identify potential solutions in order to give up the primary energy imports from Russia. Otherwise, the economy of many EU countries will be affected, in terms of availability, lack of independence and non economic prices. These aspects are also illustrated in Figure 4.

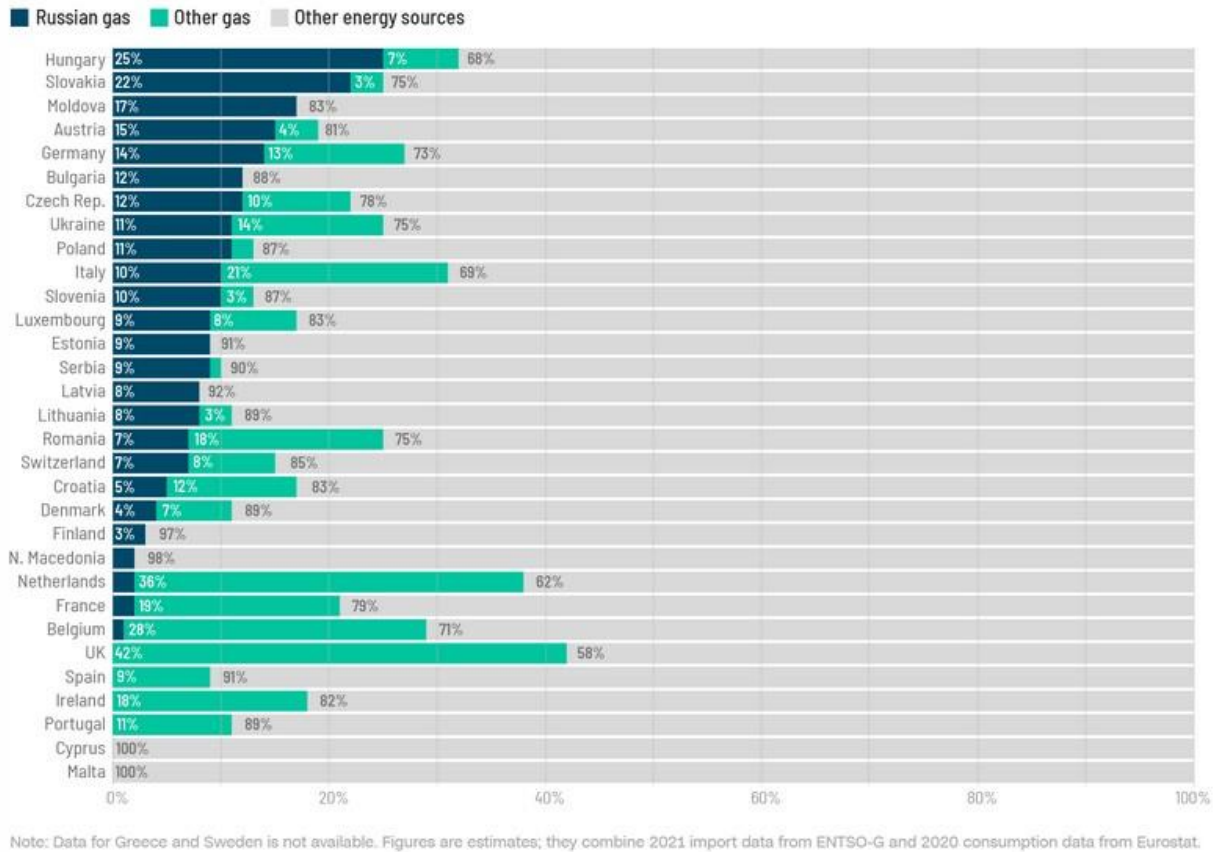


Figure 4. European countries' dependence on Russian imports [14].

Nowadays, due to geopolitical conflicts, achieving energy independence has become the main goal pursued by many countries. Achieving energy independence has become a very attractive and appealing target [15]. Countries like the Republic of Moldova, Macedonia, Bosnia and Herzegovina are almost entirely reliant on the gas supply from a single supplier. Similarly, more developed countries like Germany and Italy depend on Russian gas at a rate of 14% and 10%, respectively [14].

The outbreak of military conflicts jeopardized the energy security of several countries, which were forced to review their energy supply policy. A potential solution to diminish or even remove the dependence on the import of fossil fuels is represented by renewable energy sources. These now have two uses: reducing pollution and ensuring energy independence to a lesser or greater extent.

Until quite recently (three months ago), renewable energy sources were talked about as the only solution to replace fossil fuels, as they were considered non-renewable and limited [16]. At the same time, fossil fuels are known to exert a negative impact on the environment, contributing to global warming and air pollution. Not only do they affect the environment, but they can also negatively impact human health [17]. Studies have shown that inhaling polluted air affects the lungs, causing diseases such as asthma, lung cancer and respiratory infections [18].

1.1. Potential renewable energy sources

Renewable energy represents the energy obtained from inexhaustible energy sources with a low level of greenhouse gases [19].

Renewable energy resources include: wind energy, solar energy, hydraulic energy, energy produced from biogas [20].

Solar energy constitutes a renewable energy source, which exerts no negative effects on the environment and which is inexhaustible [21]. This type of energy is particularly used to generate electricity for lighting [22]. In order to obtain as much energy as possible, the following aspects must be taken into account: wind speed, environmental temperature and solar radiation intensity [23]. It should also be stressed that both energy sources (wind and photovoltaic) generate a reduced amount of energy in the summer when temperatures reach over 36 degrees Celsius [24].

Wind energy: The construction of wind power plants is based on an ancient technique of several millennia that emerged with the first windmills [25]. The main advantage of wind power plants is that they can be built even in the middle of the sea, which means that no land is needed [26].

Wind energy production is greatly impacted by the wind (at least 20 km/hour) [27] and by different natural conditions and seasonal influences [28]. Although the use of wind and solar energy can be very extensive, non-polluting, and sustainable [29], these two energy sources pose a significant disadvantage. The disadvantage lies in the fact that they cannot ensure a continuous supply of energy. In order to overcome these disadvantages, there are two solutions: creating an energy mix and energy storage.

The energy mix entails a multiple energy combination, sold as a package []

Energy storage is the key to maximizing the potential of these two energy sources [31]. It must, however, be noted that energy storage cannot be implemented at the moment, because maintenance costs and storage technologies are very expensive.

Hydropower: Hydropower plants constitute an important source of renewable energy, providing 19% of energy production worldwide [32]. Moreover, the use of hydropower to obtain electricity instead of coal is very useful, because it prevents the release of 148 million tons of particles, 62 million tons of sulfur dioxide and 8 million tons of nitrogen oxide per year [33]. Although the energy produced by hydropower plants is a clean energy, their construction can exert negative effects on the ecosystem [34].

Biogas production may represent an important source of worldwide renewable energy supply, also contributing to diminishing climate change [35].

Biogas can be obtained through anaerobic digestion using biodegradable food waste, waste from the agro-zootechnical industry, municipal waste [36] sewage treatment plants. Through the biological conversion of the waste, biogas rich in methane (CH₄) [37], carbon dioxide (CO₂) and nitrogen (N₂) [38] is obtained.

Compared to the other sources of renewable energies presented previously, biogas production contributes to the development of the circular economy. This is thanks to the use of biodegradable waste in the process of obtaining biogas and the recycling of nutrients in agriculture [39]. At the same time, biogas provides a wide range of uses: it generates electricity and thermal energy, biomethane, bio-fertilizers. All these uses make biogas production a sustainable and competitive source of energy [40].

The main advantage of renewable resources is that they are inexhaustible. The quantities consumed are only temporarily depleted, they do not generate a fixed quantity, but they can be regenerated at any time in larger quantities [41, 42]. Renewable energy is a source of domestic energy [43], which can simultaneously replace domestic consumption of fossil fuels and fuel imports. At the same time, research has indicated that they are less harmful, often cheaper [44], (in 2020 solar energy became the cheapest electrical energy in the world) [45], more durable [46] and contribute significantly to environmental security [47]. These resources have the ability to be converted in order to produce heat, electricity and

liquid fuels [48]. By replacing oil with biofuels, greenhouse effect emissions are reduced, and costs and sales prices are acceptable [49]. It should be noted that renewable energy can be used both in rural areas and in urban areas [50], regardless of the landforms.

Renewable energy does not only exert a positive impact on the environment, it can also have positive effects on the macro economy [51].

In order for the energy from renewable energy sources to be profitable, the specificity of the location must be taken into account. This entails complex resource evaluation research [52].

Even though renewable energy sources were not as attractive for investors and companies at the beginning, they have recently changed their opinion thanks to the government subsidies and major investments associated with the production of solar energy, photovoltaics and wind turbines [53, 54]. It is hence estimated that by (year) 2040 the renewable energy industries could become very profitable businesses generating huge amounts of money [55].

The development of the renewable energy industry contributes significantly to raising the living standard of the population by creating new jobs, especially in those areas where the renewable energy source is located [41].

So far, several benefits provided by renewable energy to the environment and the economy have been briefly described. Now, the time has come to review the impact these sources have on energy dependence.

To be able to understand the importance that renewable sources have on energy dependence, one must first define energy dependence.

Energy dependence occurs when a country fails to meet the energy demands from its own sources, being forced to supplement the energy difference with imported energy [56].

In order to reduce or even eliminate energy dependence, each country must implement policies to find solutions to adequately use indigenous energy resources [57].

These resources have the ability to actively contribute to energy security through the variation of energy sources. An additional key aspect points towards the fact that renewable energy sources are independent from the point of view of supply. This aspect is essential in ensuring good conditions for any economy [58]. By contrast, the energy supply from fossil fuels can be intentionally disrupted [59].

Ensuring energy independence from renewable sources leads to avoiding price fluctuations [60]. Furthermore, the risks of accidents, terrorist attacks or natural disasters are relatively low [61].

1.2. Romania's renewable energy situation

As with other countries, the energy sector in Romania is paramount for the development of the industrial and agricultural sector, for raising the standard of living and providing environmental protection. Moreover, Romania had to align its energy policy with European policies, which have three benchmarks: achieving energy security, competitiveness and sustainability [62]. Compared to other countries, our country has managed to ensure its energy security. Thanks to the landform diversity, Romania is rich both in renewable energy resources [63] and in fossil fuel resources. Since the demand for fossil fuels is very high, they are quickly depleted before new sources are discovered [64]. Thus, fossil fuels constitute a limited source of energy, which contributes to global warming [17] and accelerates the process of environmental degradation [65]. That is why the diversity of renewable energy sources is an asset for our country, as they can accelerate the transition to an economy with low carbon emissions [66]. Romania is part of the countries that have reached their 2020 target of 24% for renewable resources [63]. For 2030, Romania has set itself the goal of reducing ETS emissions by 43.9% compared to the values recorded in 2005 [67].

Figure 5 shows the breakdown of energy production, occurring in Romania on 29.01.2023. It can be noticed that Romania acquires a significant amount of energy from hydropower plants. Another important

energy generating source is fossil energy (coal). Therefore, Romania has a great advantage in that it has both fossil and renewable energy sources.

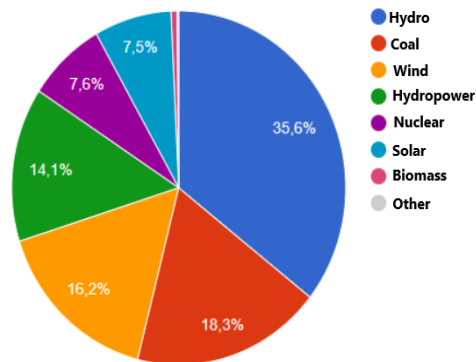


Figure 5. Installed power in electricity production capacities [68].

1.3. Achieving energy independence in the agro-zootechnical sector through biogas production

Biogas production represents a new means of generating renewable energy resulting from the decomposition of biomass [69]. Biomass includes all plant resources, human and animal plant and biological residues, capable of generating energy [70]. Additional sources of biogas production are: household waste, municipal waste and industrial waste.

Compared to other renewable energy sources, biogas can be processed in order to generate electrical energy, it can be used for heating/cooling or for generating fuel for vehicles [71]. Another advantage is that biogas production is not influenced by the state of the weather as it happens in the case of solar and wind energy. Additionally, the biogas production process can be carried out on a household, agricultural and industrial scale [72]. Biogas production also helps in terms of reducing waste disposal costs, creating new jobs and ensuring energy independence.

The agro-zootechnical sector does not only constitute a source of food for the population, it also emerges as a source of waste and pollution. It is estimated that by 2050 the planet's population will increase to approximately 9-9.5 billion inhabitants. As a result, the strengthening of the agro-zootechnical sector is extremely necessary, as it ensures the food security of the country [73].

The modernization of the agro-zootechnical sector fostered its consolidation as a significant consumer of energy. The main energy-consuming sources are: grain drying, lighting and heating, fertilizer production [74], food preparation and grain grinding.

In order to avoid unintentional disconnection and cyber attacks on the energy system, but also to reduce costs, it is necessary for the agro-zootechnical sector to direct its attention to biogas production and implement projects, which foresee and ensure low costs of obtaining energy.

Conclusions

The expansion of the electricity network has steadily led to the economic development of modern society. Electrical energy is used for lighting, for powering household and industrial appliances and for heating. It hence significantly contributes to the comfort associated with the everyday life. This is why it is difficult to imagine the chaos that could be caused if one runs out of energy. It is not an exaggeration to say that electricity has nowadays become indispensable.

Unfortunately, the EU is currently facing a double energy crisis. The first stems from the uncontrolled closure of power plants operating on coal. Such decision was reached in order to reduce carbon emissions and save fossil fuels (sources considered exhaustible). The second crisis has been caused by the Russian invasion in Ukraine, which has since generated insecurity regarding the supply of natural gas to the EU, further aggravating the already existing energy crisis. The negative effects of this crisis are experienced in the substantial increase in the price of energy. The increase has inevitably produced major effects on prices in general, leading to higher prices for all products and services and affecting both producers and consumers.

In order to be able to reduce the dependence on the import of Russian gas and halt the increase in energy prices, the decisionmakers are forced to find solutions to these two major problems immediately.

A potential measure could be the reopening and modernization of coal-fired power plants, which until recently have been considered "dead-end resources", and the support for hydropower plants. Additional steps include supporting mining by increasing the exploitation capacity and creating new jobs in the mining areas.

The second measure consists of supporting economic agents and vulnerable consumers by capping the price of energy and allocating subsidies. Through the aforementioned measures, the bankruptcy of many companies can be avoided, the unemployment rate kept at a low level and implicitly ensuring a decent living standard for the population.

Concurrently, it is necessary to accelerate the transition process towards green energy sources (considered inexhaustible and cheap). The transition from fossil energy to green energy will bring many advantages. It stabilizes the economic sector, reduces the import of Russian gas, and energy sources will be diversified. It also provides the opportunity of being installed in hard-to-reach areas for fossil energy. They can provide the necessary heat and electricity and ensure the creation of jobs. It eliminates the probability of intentional disruptive attacks and reduces the risks of natural disasters. It also ensures the possibility of reducing the amount of waste, eliminates greenhouse effect emissions, ensures and strengthens energy security and independence.

Achieving energy independence brings numerous advantages to a country. Here one mentions the possibility of offering citizens and the industrial sector affordable prices for the purchase of electricity, the elimination of vulnerability and constraints in case of war or other political decisions.

Unfortunately, the transition to renewable energy cannot be undergone abruptly. This must be achieved gradually by maintaining the energy mix, with the tendency to reduce fossil fuels. It is hence crucial to find substitutes for fossil fuels with other fuels that can ensure continuity in the process of transformation into thermoelectric energy.

It is also necessary to support green energy investors by simplifying the procedures for granting licenses and authorizations in the energy sector. Additional solutions should consider the development of the industry producing equipment for energy systems, energy efficiency and the development of energy accumulators.

Fortunately, Romania is one of the few countries that have diversified and complex landforms. This could help Romania benefit from all forms of renewable energy, thus ensuring the energy independence coveted by all countries in these turbulent times. Taking full advantage of this potential, our country could become an important player on the energy market. Unfortunately, however, it has not achieved

actually the most of this huge advantage. Renewable energy sources can cover all energy needs in Romania and in the EU countries only in parallel to developing new and cheaper technologies, especially for energy accumulators. Only reshaping the energy sector is not sufficient for assuring a reasonable CO₂ emission reduction world wide. It is important to keep in mind that using natural gas is only a transition to the final step for CO₂ neutral energy sources, even major investments are foreseen presently. A mix of energy sources, including the nuclear sources, must be fulfilled, in order to assure the stability, continuity, security and low price of the available sources in energy management.

All countries must make efforts in this direction, assuring local, long term, sustainability, by using country specific resources, Transportation systems must also be simultaneously “cleaned up”, in addition waste in all its forms must be much more used and turned into energy resources, including also industrial wastes.

References:

- [1] ***https://www.casamariinegre.ro/studii/geopolitica/205/securitatea-energetica-fisa-documentara#_ftn1, accessed: 28.01.2023
- [2] *** <https://www.opml.co.uk/blog/importance-energy-security>, accessed: 28.01.2023
- [3] Volintiru C, Stoian M and Diaconu-Pintea L 2019 *Energia: concept si instrumente operationale*, ISBN 978-606-94561-6-3, Ed. a 2-a, rev. Bucuresti: Club Romania pp 729- 734
- [4] Iuga V 2014 *Independenta energetica vs. securitate energetica ENERGY POLICYGROUP*
- [5] ***<https://thehill.com/opinion/energy-environment/574737-no-country-is-an-energy-island>, accessed: 26.01.2023
- [6] ***<https://www.caixabankresearch.com/en/economics-markets/commodities/geopolitics-energy>, accessed: 28.01.2023
- [7] Ayoo C 2020 *Towards Energy Security for the Twenty-First Century. Energy Policy*(IntechOpen)
- [8] Mara D, Nate S, Stavvitsky and Kharlamova 2022 The Place of Energy in the National Security Framework: An Assessment Approach *Energies* **15** p 658
- [9] *** <https://www.americansecurityproject.org/energy-security/>, accessed 07.03.2022
- [10] Energy security in Ireland 2020 Report SUSTAINABLE ENERGY AUTHORITY OF IRELAND, accessed: 14.03.2023
- [11] Sfetcu N 2018 *Coruptie- Globalizare- Neocolonialism* (MultiMedia Publishing), accessed: 12.03.2023
- [12] Tutak M and Brodny J 2022 Analysis of the level of energy security in the three seas initiative countries *Journal Applied Energy* **311** p 118649
- [13] ***[https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Main origin of primary energy imports, EU, 2010-2020 \(%25 of EU imports\) v6.png](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Main_origin_of_primary_energy_imports,_EU,_2010-2020_(%25_of_EU_imports)_v6.png), accessed: 13.03.2022
- [14] ***<https://edition.cnn.com/2022/03/05/business/russia-gas-eu-ukraine-energy-climate-cmd-intl/index.html>, accessed: 26.01.2023
- [15] Zhao H 2019 *Energy Security: From Energy Independence to Energy Interdependence. The Economics and Politics of China's Energy Security Transition* (London, United Kingdom: Academic Press)
- [16] Sallem M 2022 Possibility of utilizing agriculture biomass as a renewable and sustainable future energy source *Journal Heliyon* **8** p e08905
- [17] Martins F, Felgueiras C, Smitkova M and Caetano N 2019 Analysis of Fossil Fuel Energy Consumption and Environmental Impacts in European Countries *Energies* **12** p 964
- [18] Gasparotto J and Da Boit Martinello K 2021 Coal as an energy source and its impacts on human health *Energy Geoscience* **2** pp 113-120

- [19] Karacan R, Mukhtarov S, Baris I and Yardimci M E 2021 The Impact of Oil Price on Transition toward Renewable Energy Consumption? Evidence from Russia *Energies* **14** p 2947
- [20] Mamur H, Dilmac O F and Bhuiyan M R A 2021 Thermoelectric generators act as renewable energy sources *Cleaner Materials* **2** p 100030
- [21] Török B and Dransfield T 2018 *Chapter 2.1- Environmental Chemistry, Renewable Energy, and Global Policy Green Chemistry* (Washington DC: Elsevier)
- [22] Amo-Aidoo A, Kumi E N, Hensel O, Korese J K and Sturm B 2022 Solar energy policy implementation in Ghana: A LEAP model analysis *Scientific African* **16** p e01162
- [23] Hassan Q, Abbas M K, Abdulateef A M, Abdulateef J and Mohamed A 2021 Assessment the potential solar energy with the models for optimum angles of maximum solar irradiance for Iraq *Case Studies in Chemical and Environmental Engineering* **4** p 100140
- [24] ***<https://www.national.ro/social/regenerabilele-destabilizeaza-sistemul-energetic-eolienele-si-fotovoltaicele-nu-produc-vara-763807.html>, accessed: 28.01.2023
- [25] Moriarty P and Honnery D 2019 *6- Global renewable energy resources and use in 2050 Managing Global Warming* (London: Academic Press)
- [26] Syahputra R, Purwanto K and Soesanti I 2022 Performance investigation of standalone wind power system equipped with sinusoidal PWM power inverter for household consumer in rural areas of Indonesia *Energy Reports* **8** pp 4553-4569
- [27] Pimental D, Herz M, Glickstein M, Zimmerman M, Allen R, Becker K, Evans J, Hussain B, Sarsfeld R, Grosfeld A and Seidel T 2002 Renewable Energy: Current and Potential Issues: Renewable energy technologies could, if develop and implemented, provide nearly 50% of US energy needs; this would require 17% of US land resources *BioScience* **52** pp 1111-1120
- [28] Zhang J, Lu J, Pan J, Tan Y, Cheng X and Li Y 2022 Implications of the development and evolution of global wind power industry for China- An empirical analysis is based on public policy *Energy Reports* **4** pp 205-219
- [29] Lohani S P and Blakers A 2021 100% renewable energy with pumped-hydro-energy storage in Nepal *Clean Energy* **5** pp 243-253
- [30] Chen Y, Wei W, Liu F, Shafie- Khah M, Mei S and Catalão J P S 2018 Optimal contracts of energy mix in a retail market under asymmetric information *Energy* **165** pp 634-650
- [31] De Luiz- Ruiz J M, Carcedo- Haya J, Pereda- Garcia R, Castro- Alonso P and Perez- Alvarez R 2022 Optimal location of hydraulic energy storage using geographic information systems and multi-criteria analysis *Journal of Energy Storage* **49** p 104159
- [32] Igliński B 2019 Hydro energy in Poland: the history, current state, potential, SWOT analysis, environmental aspects *International Journal of Energy and Water Resources* **3** pp 61-72
- [33] Doso O and Gao S 2020 An overview of small hydro power development in India *AIMS Energy* **8** pp 896-917
- [34] Hossain M F 2019 *Energy Sustainable design and build Building, Energy, Roads, Bridges, Water and Sewer Systems* (Butterworth-Heinemann)
- [35] Tiwari P, Wang T, Indlekofer J, El Haddad I, Biollaz S, Prevot A SH and Lamkaddam H 2022 Online detection of trace volatile organic sulfur compounds in a complex biogas mixture with proton-transfer- reaction mass spectrometry *Renewable Energy* **196** pp 1197-1203
- [36] Alam M, Sultan M B, Mehnaz M, Fahim C S U, Hossain S and Anik A H 2022 Production of biogas from food waste in laboratory scale dry anaerobic digester under mesophilic condition *Energy Nexus* **7** p 100126
- [37] Cui W, Li S, Xie M, Chen Q, Li G and Luo W 2022 Performance of coagulant-aided biomass filtration to protect ultrafiltration from membrane fouling in biogas slurry concentration *Environmental Technology & Innovation* **28** p 102659

- [38] Liu Y, Sim J, Hailemariam R H, Lee J, Rho H, Park K- D, Kim D W and Woo Y C 2022 Status and future trends of hollow fiber biogas separation membrane fabrication and modification techniques *Chemosphere* **303** p 134959
- [39] Messineo A, Kabeyi M J B, Olanrewaju O A 2022 Biogas Production and Application in the Sustainable Energy Transition *Journal of Energy* **2022** pp 1- 43
- [40] Metson G S, Feiz R, Lindegaard I, Ranggård T, Quttineh N-H and Gunnarsson E 2022 Not all sites are created equal- Exploring the impact of constraints to suitable biogas plant locations in Sweden *Journal of Cleaner Production* **349** p 131390
- [41] Maradin D 2021 Advantages and Disadvantages of Renewable Energy Sources Utilization *International Journal of Energy Economics and Policy* **11** pp 176-183
- [42] ***https://energyeducation.ca/encyclopedia/Renewable_and_sustainable_energy, accessed: 16.03.2022
- [43] Ozturk I 2014 The Role of Efficiency and Renewable Energy Sources Energy Dependency and Security *International Growth Centre*
- [44] Kumar J C R and Majid M A 2020 Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities *Energy, Sustainability and Society* **10** pp 1-36
- [45] Kim S Y, Ganesan K, Dickens P and Panda S 2021 Public Sentiment toward Solar Energy-Opinion Mining of Twitter Using a Transformer-Based Language Model *Sustainability* **13** p 2673
- [46] Rahman M M, Shakeri M, Tiong S K, Khatun F, Amin P, Pasupuleti J and Hasan M K 2021 Prospective Methodologies in Hybrid Renewable Energy Systems for Energy Prediction Using Artificial Neural Networks *Sustainability* **13** p 2393
- [47] Gyimah J, Yao X, Tachea M A, Sam Hayford I and Opoku- Mensah E 2022 Renewable energy consumption and economic growth: New evidence from Ghana *Energy* **248** p 123559
- [48] Diaz M N 2021 U. S. Energy in the 21st Century: A Primer Congressional Research Service Information the legislative debate since 1914
- [49] Salman D and Hosny N A 2021 The nexus between Egyptian renewable energy resources and economic growth for achieving sustainable development goals *Future Business Journal* **7** p 47
- [50] Dincer I and Rosen M A 2021 *Chapter 4- Energy, environment, and sustainable development* Exergy (Third Edition) (Canada- Third Edition)
- [51] Arroyo M F R and Miguel L J 2020 The Role of Renewable Energies for the Sustainable Energy Governance and Environmental Policies for the Mitigation of Climate Change in Ecuador *Energies* **13** p 3883
- [52] Østergaard P A, Duic N, Noorollahi Y, Mikulcic H and Kalogirou S 2020 Sustainable development using renewable energy technology *Renewable Energy* **146** p 2430-2437
- [53] Danilina N and Reznikova I 2021 Renewable energy technologies on the path towards decentralized low-carbon energy systems *E3S Web Conf.* **250** p 03001
- [54] Włodarczyk B, Firoiu D, Ionescu G H, Ghiocel F, Szturo M and Markowski L 2021 Assessing the Sustainable Development and Renewable Energy Sources Relationship in EU Countries *Energies* **14** p 2323
- [55] Vivek C M, Ramkumar P, Srividhya P K and Sivasubramanian M 2021 Recent strategies and trends in implanting of renewable energy sources for sustainability-A review *Materials Today: Proceedings* **46** pp 8204-8208
- [56] Berk C and Cin O K 2018 On Energy Dependence, Current Account Deficit and Population in Turkey *Open Journal of Business and Management* **6** pp 183-192
- [57] Khatib H, Barnes A, Chalabi I, Steeg H and Yokobori K 2000 *Chapter 4- Energy Security* (Washington D. C.- Communications Development Incorporated)

- [58] Milojević M, Nowodziński P, Terzić I and Danshina S 2021 Households' Energy Autonomy: Risks or Benefits for a State? *Energies* **14** p 2026
- [59] *** https://acore.org/wp-content/uploads/2018/10/ACORE_Issue-Brief_-The-Role-of-Renewable-Energy-in-National-Security.pdf, accessed: 11.03.2023
- [60] Kumar M 2020 *Social, Economic, and Environmental Impacts of Renewable Energy Resources* Wind Solar Hybrid Renewable Energy System (IntechOpen)
- [61] Escribano G 2021 *Chapter 13- Beyond energy independence: the geopolitical externalities of renewable* Handbook of Energy Economics and Policy (Academic Press)
- [62] ***<https://www-pub.iaea.org/MTCD/publications/PDF/cnpp2019/countryprofiles/Romania/Romania.htm>, accessed: 29.01.2023
- [63] Cîrstea Ș D, Martiș C S, Cîrstea A, Constantinescu- Dobra A and Fülöp M T 2018 Current Situation and Future Perspectives of the Romanian Renewable Energy *Energies* **11** p 3289
- [64] Luo X and Deng F 2019 Nanomaterials for the Removal of Pollutants and Resource Reutilization (India- SPI Global- India)
- [65] Li B and Haneklaus N 2021 The role of renewable energy, fossil fuel consumption, urbanization and economic growth on CO2 emissions in China *Energy Reports* **7** pp 783-791
- [66] Gricorescu I, Micu D, Dumitrascu M, Mitrica B, Mocanu I, Serban P, Dumitrica C and Havris L 2019 Renewable Energy Sources in Romania: Progress and Perspectives Towards the EU Targets Aerul si Apa: Componente ale Mediului **2019** pp 9-18
- [67] ***<https://www2.deloitte.com/ro/ro/pages/strategy/articles/tranzitia-energetica-a-romaniei-in-lumina-noilor-tinte-climatice.html>, accessed: 29.01.2023
- [68] <https://www.anre.ro/ro/energie-electrica/rapoarte/puterea-instalata-in-capacitatiile-de-productie-energie-electrica>, accessed: 29.01.2023
- [69] Berthe A, Grouiez P and Fautras M 2022 Heterogeneity of Agricultural Biogas Plants in France: A Sectoral System of Innovation Perspective *Journal of Innovation Economics & Management* **38** pp 11- 34
- [70] Solaymani S 2021 A Review on Energy and Renewable Energy Policies in Iran *Sustainability* **13** p 7328
- [71] Jain S 2019 Global Potential of Biogas WORD BIOGAS ASSOCIATION
- [72] Petravić- Tominac V, Nastav N, Buljubašić M and Šantek B 2020 Current state of biogas production in Croatia *Energy, Sustainability and Society* **10**
- [73] Stoin M and Anitei M 2019 Caiet documentar 4 Agricultura Concepte si instrumente operationale (Bucuresti- Club Romania)
- [74] Rahman, Md Momtzur, Khan I, Field D L, Techato K and Alameh K 2022 Powering agriculture: Present status, future potential, and challenges of renewable energy applications **188** pp 731-749