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Sustainable Energy in Island States: Comparative Analysis of New Trends in Energy Digitalization and the Experience of the UK, Japan, Indonesia and Cyprus

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ABSTRACT

Island states such as the ones discussed in this article are dependent on energy imports, which puts a lot of pressure on their budgets. In addition, limited land areas and difficult environmental conditions contribute to the need to transform the energy sector. Such a transformation in modern conditions is possible only in the direction of sustainable energy. This transition is complex and requires several parallel processes, one of which is the digitalization of the energy sector. The countries studied in this article started the process of transforming their energy sectors, and the results are different. The article is aimed at disclosing the current state and prospects in the energy sector in the context of developing a universal strategy for sustainable energy transformation. The authors point out the main achievements and barriers in this area and develop a multiplier to find out the real situation in the sector in island states. The key findings of the article include the development of a multiplier, evidence that institutional barriers are central to sustainable energy development, and a comprehensive analysis of the role of digitalization in shaping a sustainable energy system.

Keywords: Sustainable Energy, Digitalization, Institutions, Energy costs, Island States
JEL Classifications: O13, Q42

1. INTRODUCTION

Sustainable energy is the new dominant trend in the energy industry today. It allows the countries that previously did not have natural resources for energy production (primarily hydrocarbons) to become significant players in the global energy market or reduce energy imports. In this regard, special attention to sustainable energy comes from those countries that, for whatever reason, cannot use traditional sources or are limited by the environmental situation or standards.

Island states are limited by both factors: the environment and the availability of natural resources. While the UK and Indonesia have some hydrocarbons, Cyprus and Japan lack hydrocarbons worth mentioning. As a result, all these countries are interested in and investing in sustainable energy development (Cherp et al., 2017; Hasan et al., 2012; Soni and Ozveren, 2007; Tsangas et al., 2018).

The article is devoted to the study of ways of the sustainable energy development and introduction into these countries' economies and forecasting the future of sustainable energy in island states. The practical relevance of the article is the development of a successful model for the development of alternative energy in developed and developing countries, especially if the economy is closely related to maritime activities or is an island state. In this regard, the Caribbean and Pacific small island states can introduce the developed model. In addition, the article provides an institutional analysis of sustainable energy use, which is extremely important for the development of policy and legal framework for sustainable energy transformation of the energy sector.

Studies on sustainable energy in island states are numerous (more than 200 in Scopus database). However, they have one important characteristic: they reflect economic, environmental, social, etc. effects for an individual state. This article focuses more on identifying common features to incorporate into the strategy. The general opportunities of digital energy are described in (Britton, 2019; KAS – RECAP, 2020).

1.1. The UK

Price et al. (2018) argued that the transition to sustainable energy will increase the cost of energy production and that the current situation in this field is good enough for the UK. This conclusion is questionable, and the LCOE calculations do not provide sufficient information about the economic consequences. The high role of SMEs in the transition to sustainable energy was discussed in (Ball and Kittler, 2019), where the authors considered SMEs in green energy as new drivers of the economy. Owen et al. (2019) expressed the same idea.

1.2. Cyprus

Taliotis et al. (2020) discussed the Cyprus sustainable energy sector and argued the importance of sustainable energy for the Cyprus economy. Papageorgiou et al. (2018) provided recommendations for transforming energy demand by the corporate sector. However, both articles lack a fundamental analysis of the reasons why Cyprus does not achieve its full potential in the field of sustainable energy.

1.3. Japan

Japan's sustainable energy sector was analyzed from different perspectives, but the main focus was on the digital grid (Abe et al., 2019) and the financial impact of renewable energy on the population (Myojo and Ohashi, 2018), whereas the economic and energy sector were missed.

1.4. Indonesia

Guild (2020) discussed the situation in Indonesia and argued that the financial boom in green bonds does not reflect the real situation in the country's sustainable energy sector and is limited by institutional and economic barriers. At the same time, the author did not cover the opportunities for the Indonesian economy. Nugraha and Osman (2017) stated the need for green energy in the country; Hidayatno et al. (2019) proposed options for the development of the digital energy sector.

2. METHODOLOGY

All selected countries are island states with different approaches to economic development and sustainable energy development. The term "sustainable energy" used in the article is synonymous with "alternative energy." The analysis of the results of the sustainable energy introduction in these countries is based on a comparison of the institutional development of alternative energy according to Table 1.

Table 1 explains the selection of countries studied in this article.

The authors rely on an empirical analysis of the main factors affecting the current state of the energy sector of the studied countries, as well as the main barriers, in order to form a score that varies in values (1, 0.5 and 0). The score allows to form a proportion multiplier, consisting of 7 factors (Equation 1).

$$PM = \frac{g}{7} * \sum f \tag{1}$$

where g is the average growth rate in 2010–2020, f is the value of the factor.

Based on the statistical and empirical analysis presented above, the authors form a universal strategy for sustainable energy development.

3. RESULTS

3.1. European Countries

The drive for green energy in Europe has become extremely intense following Germany's success in building electricity grids based on the redistribution of sustainable energy sources (Chen et al., 2019).

Historically, the situation in the UK has been quite difficult. Energy consumption in the country is relatively high (Department of Business, Energy and Industrial Strategy, 2019). Due to the industrial nature of the country's economy, energy demand is stable and cannot bear the risk of unstable energy supply. The cold season is relatively long and the private sector's energy demand increases significantly during this season. The lack of the central heating system availability and the overall tradition of low heat supplies to households (Hanmer et al., 2019) lead to an increase in electricity use for heating.

Coal is the traditional source of energy in the UK; the country's path dependence led to the extensive use of this resource in the 20th and early 21st century. As a result, the environmental situation in the regions producing coal and electricity has been and remains very difficult. Oil is another important source of energy production, as well as natural gas also related to hydrocarbons. The significant influence of multinational oil and gas companies on the British economy led to the formation of a powerful lobby for these energy sources.

Table 1: Comparison of institutions by country

Region	Developing economy	Developed economy
Europe	Cyprus	Great Britain
Asia	Indonesia	Japan

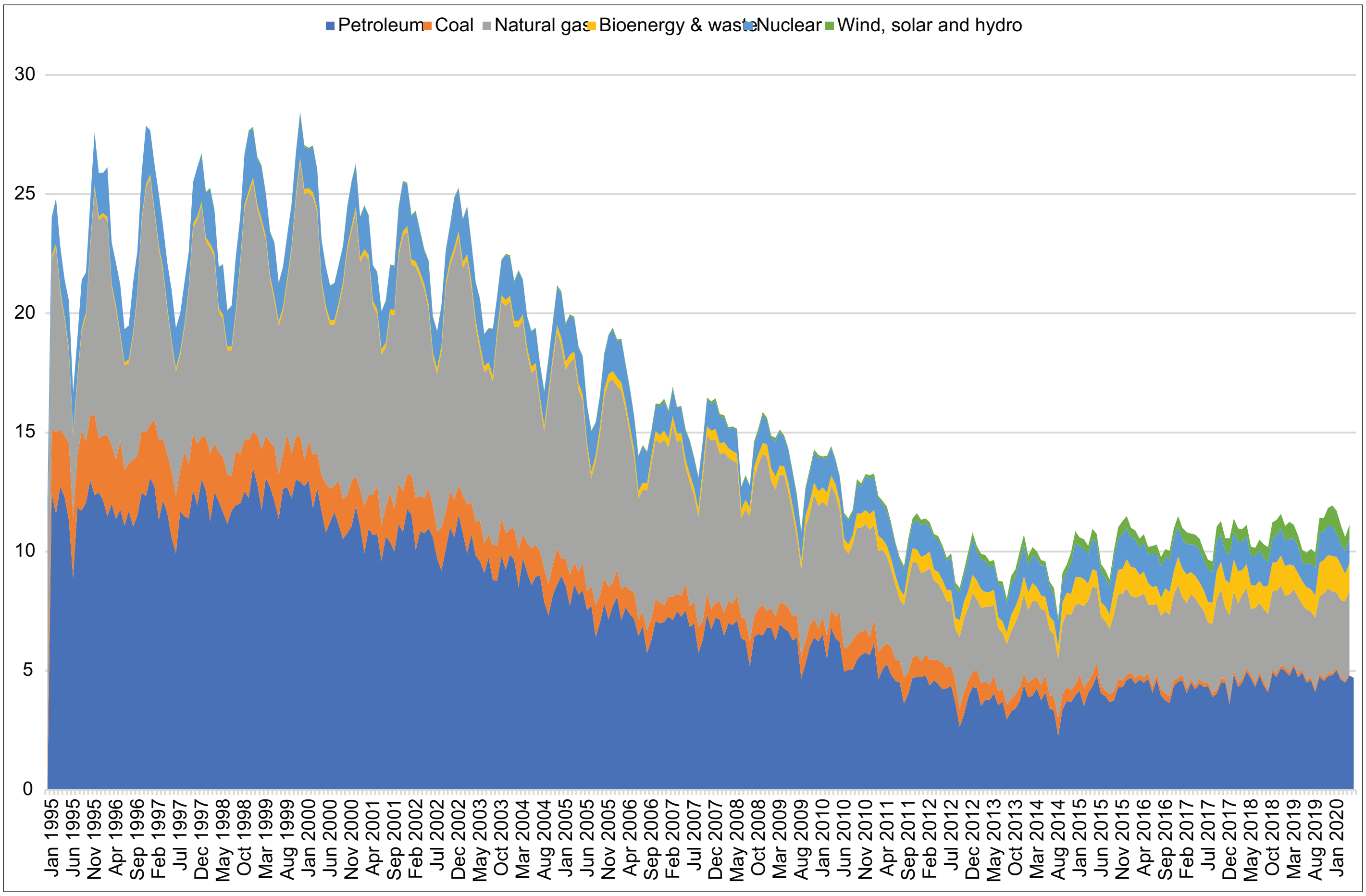
These trends led to a general negative attitude towards green energy sources in the country until the European Union introduced Directive 2009/28 / EC obliging the UK to bring green energy production to 15% of the country's total energy production (European Parliament and Council European Union, 2009). The UK's National Renewable Energy Action Plan (NREAP) provides a regulatory framework for greener energy sources as well as a support system for small energy producers (Department of Energy and Climate Change, 2010). Figure 1 shows the current state of energy production in the country, as well as the final transition of a highly industrial economy to digital and service economy at the beginning of the new millennium.

Figure 1 shows the following trends:

1. Smoothing production peaks in winter due to higher energy distribution efficiency and private household energy production;
2. Growth in sustainable energy production in the UK, most significant growth came from bioenergy and waste;
3. Smoothing the demand for natural gas in the country through innovations in the energy reserve system (Foxon et al., 2005).

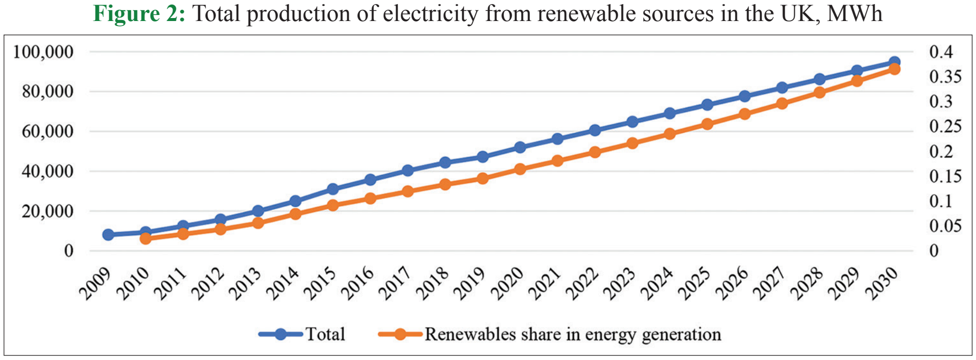
Consequently, the result of the policy of promoting renewable energy sources in the country is very significant. Despite the difficulties, the share of renewable energy in the country grows; its growth rates also tend to increase (Figure 2).

Figure 1: Energy production by source in the UK, 1995-2020, mln tons of oil equivalent



Source: Created by the authors, based on (Department for Business, Energy and Industrial Strategy, 2020).

Figure 2: Total production of electricity from renewable sources in the UK, MWh



Source: Created and forecasted by authors, based on (Department for Business, Energy and Industrial Strategy, 2020).

Wind and solar power have been the main contributors to sustainable energy production in the UK; while the former is heavily invested and largely owned by the corporate sector, the latter is owned by the private sector and is used as an additional (in some cases the main) source of energy in households that can generate income.

The authors have figured out the main factors contributing to a higher share of renewable energy in the UK and a better situation in the country's energy market.

The first important factor contributing to sustainable energy production in the UK is the producers' incentive system. It includes renewable obligations to create a pool of financial resources for medium and large power generation facilities, a green tariff that can reduce energy costs and generate additional revenue for households or small power facilities, and incentives to use renewable heat sources that work in the same way as the green tariff but aims at sustainable heat production. These measures allow to distribute the financial burden of introducing renewable energy sources into the economy among all consumers, forming a stable and socially responsible solution for introducing sustainable energy into the country's economy.

The second factor is digitalization in the energy sector, which has at least two significant outcomes. The first is a better supply of energy authorities with information on energy issues and a faster response to problems in this field. The second, less obvious, concerns the field of energy distribution: a large share of energy production in the UK is represented by small enterprises or even households. This system needs to be regulated so that the energy distribution efficiency is high. Such regulation requires large amounts of data and a heuristic system designed to analyze and solve many transport problems in a short time. Such problem is solved by Google DeepMind, which could have been used in the UK National Grid (Northern Ireland is not connected to the National Grid, so it is not the subject of analysis here) (Küfeoğlu et al., 2019). The results of this cooperation are significant: artificial intelligence can reduce the cost of grid exploitation by 10%.

The third factor is the state priority of introducing sustainable energy into the national economy. This results in quick solutions and extensive financial support for the sector. For example, the recent COVID-2019 crisis affected the country's energy industry, but due to a new incentive, the recovery of the UK's green economy, it cannot seriously harm the industry in the long term. This incentive includes measures such as financial support for the green fuels sector (£350 million), support for new fast charging technologies (£100 million) and other measures (Prime Minister's Office, 2020).

The situation with sources of sustainable energy production for the UK is quite obvious; it is wind, solar and waste energy, arising from the significant potential of these sources in the country – partly geographic and natural, partly technical (this is true for waste energy production). When discussing the UK, the obvious conclusion on the distribution of sources of green energy production is that the sustainable energy system is highly regulated. In Cyprus, the situation is rather different.

The energy sector in the country is not very developed. Cyprus's electric grid is isolated (Poullikkas et al., 2014), so most of the energy redistribution measures in Europe are not available to the country. At the same time, energy imports into the country are insignificant due to the isolation of the grid, this may be a statistical error. At the same time, the production of energy by sources in the country demonstrates a much more complex situation (Figure 3).

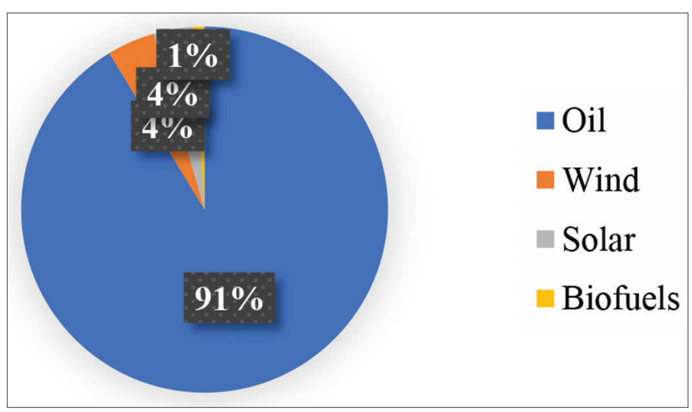
The country is highly dependent on oil imports, which account for 20.2% of the country's total imports (CYSTAT, 2020). This situation leads to a high price for electricity in the country; on average, it is about 130 euros per MWh. Sustainable energy could have changed the situation if it was produced on a mass scale.

The overall situation with the use of produced energy is such that 10% (53.7 MWh) of all sustainable energy is used for private purposes and the rest is exported to the Electricity Authority of Cyprus (EAC) grid, where it is redistributed. This fact indicates that the private sector has an extremely high potential to produce energy that is not used properly. This arises to measures to stimulate the sector. According to Directive 2009/28/EC, the share of sustainable energy in the energy balance of Cyprus should be 13% by 2020, the goal has not been achieved. The country's incentive measures include net energy metering, which allows to pay less for electricity from the grid in case sustainable energy is sold to the EAC, and temporary subsidies limited to €1,000 for the installation of sustainable energy capacities. These measures are not efficient enough; Figure 4 shows the dynamics of the growth of energy production from sustainable sources and the forecast for the future.

Figure 4 demonstrates that the aim of the EU Directive will be achieved in Cyprus by 2022–2023, depending on the volume of investment, which is required in the amount of 0.7–1.55 billion euros (IRENA, 2015). The return on this investment will be relatively fast due to reduced electricity production costs and low maintenance costs: by 2030, the price per MWh will drop to € 83, according to the same source. The average ROI, calculated by the authors on the basis of an economic forecast of energy prices, will be 186.67% in 2030, which is a good result, especially given the stable nature of investments.

As a result, the authors point to the following weaknesses in the alternative energy strategy of Cyprus.

Figure 3: Electricity production by source in Cyprus, GWh



Source: Developed by the authors, based on (IEA, 2020a).

The first barrier is the lack of investment and misuse of those that come to the country (Kyriakides, 2016). Investors are not focused on the development of alternative energy in the country, but on the financial sector and the tourism services sector. This barrier can be overcome by introducing financial measures such as additional taxes on tourism facilities that do not use sustainable energy. Tax revenues can be invested in the development of energy infrastructure.

The second barrier is the lack of incentives for the private sector to go green. The UK example demonstrates a sophisticated and balanced policy for sustainable energy production, diversified according to the size of the facility. In Cyprus, the system is focused on private producers and has no financial motivation for them; discounts on energy prices to supply energy to the EAC grid are far from enough to form a stable long-term public-private partnership. Subsidies according to (Barich-Chivikova, 2019; Noothout et al., 2016) account for 18% of the facility installation cost, which is far from sufficient to stimulate the private sector.

Another barrier is the lack of a digital component to sustainable energy transmission. Transmission losses are comparable to the country's solar energy production, which is extremely inefficient, especially given the relatively simple distribution scheme (small territory, isolated grid, very limited number of large consumers and cities).

3.2. Asian Countries

The Japanese way of developing sustainable energy was different from the previously studied countries. This was due to the rapid growth in energy production from nuclear power plants built by Japanese companies in the 1970–1990s (Matsuo and Nei, 2018). This rapid growth led to a decline in the quality of these power plants, resulting in the Fukushima accident in 2011. This accident prompted the Japanese community to begin the energy sector's transition from nuclear power to sustainable and carbon-free development. Japan's focus on carbon-free energy is driven by high oil and gas prices in the country (Japan does not have its own hydrocarbons and has to rely on imports, especially imports from countries with unstable political situations). Another factor is that prices in the oil market are fluctuating, so the country's budget must adapt to high price risks.

The country has a specific formula for energy resources. Japan has a significant potential in the production of geothermal energy, as there are many volcanoes on its territory. Another important source of energy is tidal energy. The potential for wind and solar energy in the country is also quite high. The specificity of sustainable energy production in Japan is that most of this type of energy is produced in small facilities, therefore, expensive types of energy production are not available to them. Consequently, geothermal and tidal energy in Japan is not developed at the same pace as energy sources that require less investment.

Figure 5 shows the growth of sustainable energy use in Japan. Most of Japan's sustainable energy sources are used by SMEs and households; therefore, the dynamics in Figure 5 closely correlates with the dynamics of the implementation of incentives for sustainable energy development.

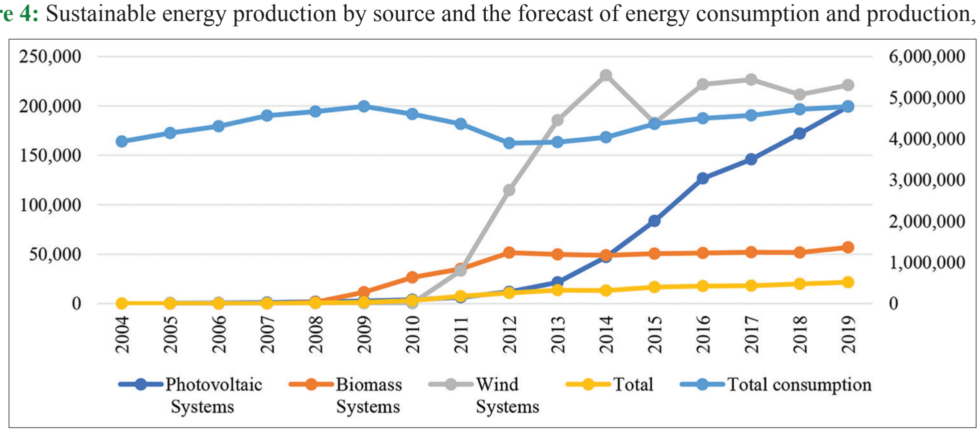
Zhu et al. (2020) discussed measures and timelines for their implementation in the Japanese economy, especially the New Basic Energy Plan 2010 and the Strategic Energy Plan 2014, which reform incentives for the energy sector, especially system of FIT. In addition, Japan has introduced tax discounts and social benefits for households using renewable energy.

Another important factor in the development of renewable energy in Japan is the corporate sector, which is forced and motivated to develop the sustainable energy sector (Vigot, 2014). Furthermore, Japan's sustainable energy balance includes hydropower. The share of this method of energy production in Japan is relatively high, especially given the fact that most power plants are small (producing <7 MWh of electricity) (Thollander et al., 2015). Figure 6 demonstrates the general trend in Japanese hydropower production – stability.

As follows from Figure 6, hydropower does not have much potential for development in Japan, especially given the relatively small number of natural resources suitable for it.

As a result, the analysis of the renewable energy sector in Japan shows that it has significant differences from the British and Cypriot ones, has its own benefits and barriers. The latter include:
1. Low share of large enterprises in the sector; most energy

Figure 4: Sustainable energy production by source and the forecast of energy consumption and production, MWh



Source: created by the authors, based on (CYSTAT, 2020).

is produced by SMEs, which cannot afford significant investments. This leads to the second barrier.
2. Inefficient use of geothermal and tidal energy due to the lack of economic agents that can afford it.
3. Rapid transition from nuclear energy development to sustainable energy. This barrier creates both challenges and opportunities. The most significant challenges are high demand for financial resources and high risks of unbalanced development of the sector. Opportunities, on the other hand, include the possibility of rapidly developing the sustainable energy sector (the fastest among all the studied countries) and its high priority for the state (ISEP, 2019).

As for digitalization, Japan has the opportunity to introduce efficient digital systems into the energy sector. Like the UK, Japan has tested the digital capabilities of the energy sector. KEPCO, one of the major energy operators in the country, has tested Blockchain technologies in energy distribution in Kyoto, Kobo and Osaka – large industrial cities (KAS-RECAP, 2020). In this regard, Japan is not too far from the adoption of digital technologies in energy distribution, but has more corporate developments in the field of industrial energy saving.

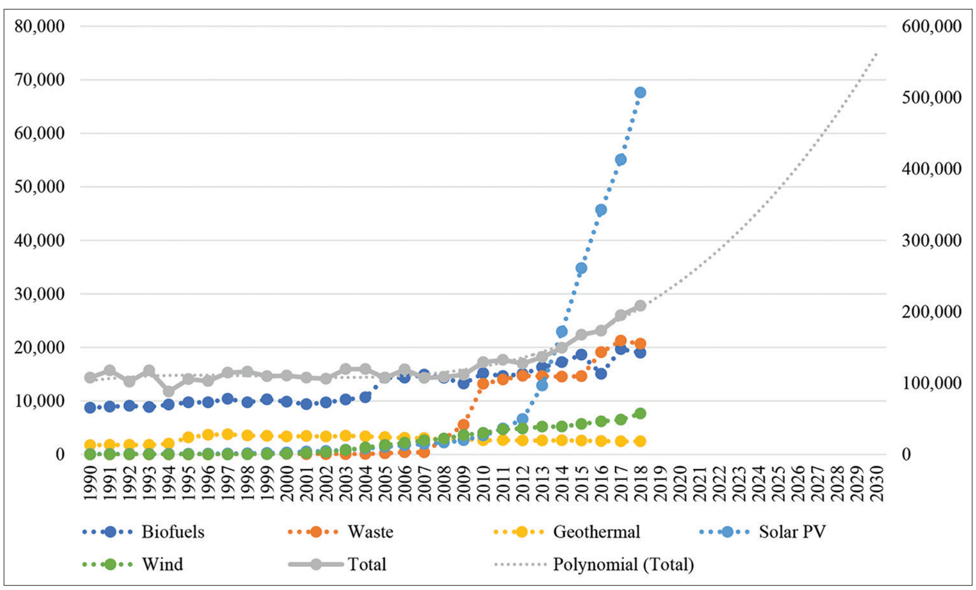
Indonesia is, in some way, similar to Japan, since it pursues a fast transition to renewable energy from the coal-oriented energy sector (Richter, 2020). The geographic conditions in the country are extremely favorable for the development of sustainable energy. First, Indonesia is a large archipelago with many islands and large territories. This results in the need for a divided electric grid, which is difficult to operate from one center. As a result, the state grid operator PLN has to operate several isolated networks. Another factor is that Indonesia is located in the tropical and subtropical zone with a significant amount of sunny days. In addition, it possesses large areas of inland seas and water resources (about 93,000 square kilometers of sea (Kuipers, 1993)) and has the potential to install large capacities of sustainable energy facilities. The country's geothermal resources are as rich as those of Japan.

The country's rapid economic development (Nugraha and Osman, 2017) allows it to invest significant resources in the development of sustainable energy, while the legal framework for energy (described and analyzed in (Gielen et al., 2017)) is developed enough to boost centralized sustainable energy development in the country. Figure 7 demonstrates the dynamics of sustainable energy production in the country.

As shown in Figure 7, the country cannot boast of high sustainable energy growth rate. In this regard, it is necessary to pinpoint the major problems.

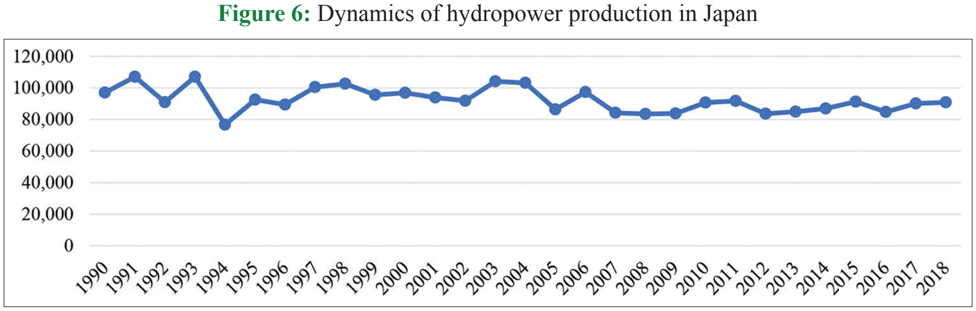
Firstly, the political situation in the country raises doubts among investors. Investing in Indonesia is risky due to fears of a

Figure 5: Dynamics of the sustainable energy production in Japan, MWh



Source: Created by the authors, based on (IEA, 2020c).

Figure 6: Dynamics of hydropower production in Japan



Source: Created by the authors, based on (IEA, 2020c).

resurgence of national conflict (Morel et al., 2017). Moreover, the future of sustainable energy in the country is unclear. The legal framework is changing rapidly, and it is impossible to predict unambiguously what measures will be taken to develop the Indonesian energy market.

The second important point is that sustainable energy regulation, despite being sufficient, is inefficient. MEMR Regulation No. 49/2018 did not provide sufficient information on operation costs for solar panels; it was subsequently amended, however, still needs clarification, for example, presented in (Gielen et al., 2017).

Finally, the government does not pay enough attention to the issue of decarbonization and sustainable energy development. PLN's monopoly on the energy market hinders innovative development.

The digital component of the Indonesian energy system is low and underdeveloped. Despite the introduction of the "2020 Go Digital Vision" program, the focus continues to be on e-commerce and interconnection of SMEs. Energy remains outside the scope of the project. Hidayatno et al. (2019) presented an analysis of the positive effects of digitalization in the country's energy sector, but again focused on other economic implications, putting forward digital metering. As a result, the Indonesian energy sector is similar in this aspect to the Cypriot one – isolated and non-digital.

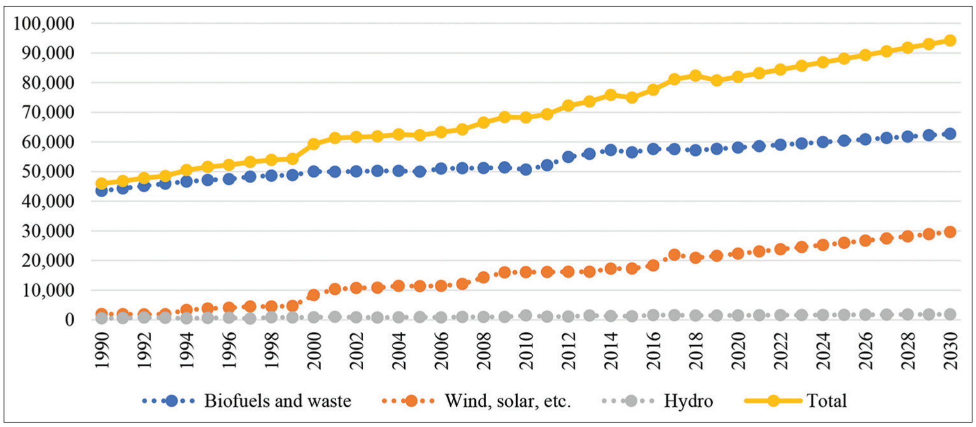
3.3. Comparison of Regions

Comparing regions and countries should start with comparing the characteristics of developed and developing economies, especially in the context of their island location. Table 2 presents the results of the comparison.

Table 2 proves that developing countries are more motivated by the implications of sustainable energy for their budget than for their populations.

The linear forecast (except for the exponential for Japan) presented above should be adjusted using the multiplier proposed by the authors. To calculate it, refer to Table 3.

Figure 7: Sustainable energy production in Indonesia, MWh



Source: Created by the authors, based on (IEA, 2020b).

Table 2: Comparison of the characteristics of sustainable energy development in developed and developing countries

Characteristic	Developed	Developing
Digitalization	High share of the digital component in the energy sector, either introduced or tested. This improves the efficiency of energy saving and distribution.	The digital component of the energy sector is weakly developed, the sector suffers significant losses in the transmission and metering of energy due to the low level of development of the sector.
Grid characteristics	The grid is highly developed, centralized, operated by one company, but includes numerous producers, including SMEs.	The grid is sufficiently developed for the normal functioning of cities and towns, it is highly centralized, usually includes only a few or one big energy producer; SMEs and private initiatives are in a worse position compared to these big producers.
Sustainable energy production opportunities	Usually moderate due to the high population density and strict regulations; the country does not focus on a single sustainable energy source and seeks ways to diversify sustainable energy production by source.	Usually moderate to high; large volumes of investment are needed. The country tends to focus on one source of sustainable energy, which creates problems with dependence on weather conditions.
Sustainable energy production development	Generally, it relies on two main sectors: corporate, which provides tax benefits and lending opportunities, and private, which provides numerous opportunities for the development of small energy facilities through FIT, subsidies, tax discounts, etc.	It focuses on the corporate and public sector, fostering the formation of monopolies. The private sector is lagging behind in energy production; subsidies and FIT are not balanced with the cost of maintaining energy facilities.
Financial effects from the sustainable energy introduction	High due to the reduction in electricity costs and the increase in the population's disposable income, as well as due to the reduction in energy imports.	High due to the inflow of investments into the economy and reduction of energy imports.

Table 3: Assessment of factors contributing to sustainable energy development

Characteristic	The UK	Japan	Cyprus	Indonesia
Digitalization	1	0.5	0	0
Grid characteristics	1	1	0.5	0.5
Sustainable energy production opportunities	1	1	1	1
Sustainable energy production development	1	1	0.5	0.5
Financial effects from sustainable energy introduction	0.5	1	1	0.5
Efficiency in the use of natural resources	1	0.5	0.5	0.5
The legal component	1	1	0.5	0
The average growth in 2010–2020	20.71%	6.82%	41.14%	1.85%
The multiplicator (see Methodology)	19.23	5.84	23.51	0.79

According to Table 3, the most promising use of sustainable energy is in Cyprus, despite significant problems in its promoting, the second result is in the UK.

4. DISCUSSION

The general conclusion, which follows from the above analysis, is that creating a sustainable energy economy requires significant and bold measures that can be implemented if the country has a long-term plan and significant financial resources, or at least access to big financial market.

The major steps to create the conditions for sustainable energy economy are as follows:

1. Forming a long-term plan based on the inflow of financial resources and reserves available during the planning period;
2. Creating a stimulus for the private sector's transition to sustainable energy, including:
   - Tax benefits and refunds in case the country is developed;
   - FIT, which are returned in money, not energy;
   - Subsidies to individuals for the installation of sustainable energy production facilities in case the country is developing;
3. Creating a single and efficient grid by the state;
4. Promoting digitalization of the grid;
5. Creating an additional stimulus for the corporate sector's transition to sustainable energy for in the form of:
   - Support for SMEs;
   - Additional opportunities for obtaining a loan;
   - Lower taxes and easier certification of sustainable production.

The studied countries are island states, therefore, the specifics of this strategy for island states is in:

1. Isolated grid, which is easier to centralize;
2. High costs of energy, which give a significant room for price maneuver;
3. Access to significant water areas, providing the possibilities of placing power generation facilities on the water;
4. Higher safety and reliability standards for energy facilities;
5. Seasonal component of energy consumption: on islands in colder climates peaks occur in winter due to heating, while in tropical climates – in summer due to tourism.

All of these factors allow to form a new approach to the financial side of the transition to sustainable energy. According to factors 1 and 2, the introduction of sustainable energy and the first steps in the implementation of the green strategy is easier and cheaper. Factors 3 and 4, on the contrary, increase the cost of creating sustainable energy facilities. At the same time, tourism revenues can be used to finance more expensive sustainable energy projects. In addition, island states can build a sustainable energy sector by starting with self-sufficiency in energy outside peak periods.

5. CONCLUSION

Developed countries have more opportunities and a better legal and financial basis for sustainable energy transformation of the economy. At the same time, developing countries usually start from a low base, with an impressive start in introducing sustainable energy into their economies.

An important factor contributing to the development of sustainable energy is the institutional and market situation in the country. When comparing Cyprus and Indonesia, the common EU sustainable energy strategy appears to be more efficient than the individual strategy in Indonesia, while developed countries do not have such a massive effect from institutions. The abundance of financial resources and economic growth (the example of the UK) allow developed countries to quickly create a sustainable energy sector.

Another important part is the attitude towards SMEs. The analysis shows that they hold a significant share of the sustainable energy market and play a big role in the transition to sustainable energy due to their mobility and ability to adapt to market conditions.

Digitalization plays an important role in the formation of an efficient grid in island states, as it allows to reduce transmission losses and more efficiently distribute energy. This factor plays a significant role in creating a sustainable energy economy, as the results of its implementation allow to cut down energy costs for consumers.

Sustainable energy brings several important benefits to island economies. First, it allows to cut budget expenditures in the long run. Second, consumers pay less for electricity due to falling energy costs. Third, private sector energy producers generate additional income from sustainable energy facilities, which in turn offers them the opportunity to install more sustainable energy production facilities, thus supplying the corporate sector or smoothing out peaks of energy production from non-renewable sources during seasonal peaks.

Island economies benefit greatly from sustainable energy production due to their natural conditions and overall higher energy costs.

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