Contributions to Management Science

Hasan Dinçer
Serhat Yüksel *Editors*

Clean Energy Investments for Zero Emission Projects

An Analysis on How to Reduce the Carbon Footprint

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Contents

The Effect of the Carbon Tax to Minimize Emission

Serhat Yüksel and Alexey Mikhaylov

Abstract Carbon emission refers to the release of carbon gas into the atmosphere. As can be understood from the definition, carbon emissions mainly cause air pollution. Polluted air also threatens the health of living things. As can be seen, carbon emission is a problem that needs to be solved urgently. In this context, many countries are trying to take measures to reduce carbon emissions. Carbon emissions do not only cause air pollution. For example, carbon emissions cause significant problems in the country's economy. First, because of the increase in people getting sick due to air pollution, serious job losses occur in the country. This situation leads to a decrease in the production volume of the country. In addition, the profitability of firms with reduced workforce is likely to decline. As a result, the country's economic growth will be negatively affected. In addition, the increase in the number of patients in the country because of carbon emissions will increase the health expenditures of the country. Finally, carbon emissions cause a decrease in foreign investments in the country. It is obvious that air pollution caused by carbon emissions reduces the quality of life in the country. In this context, there has been an increase in sensitivity to environmental factors worldwide, especially in recent years. This situation makes the carbon emission problem more important. The amount of carbon emission has started to affect the image of countries. In this framework, foreign investors have started to pay attention to environmental pollution issues while choosing the country they will invest in. As can be understood from this, it is obvious that countries that do not take measures to address the carbon emission problem will experience a decrease in their foreign investments soon. Therefore, it is necessary to avoid the carbon emission problem. Carbon emissions can be prevented by legal regulations and sanctions. Sanctions may be imposed on companies that cause carbon emissions. Additional tax may be imposed on nonrenewable energies. Since these types of

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energy pollute the air with carbon emissions, it may be possible to collect a carbon tax. In this way, the cost advantage of nonrenewable energy types will disappear.

1 Introduction

The problem of global warming has become quite dangerous around the world. This situation brings with it many problems. It is obvious that global warming also creates some social and economic problems. Drought caused by global warming adversely affects agricultural production (Yüksel et al., 2020). In other words, there is a significant decrease in the supply of products due to drought. Due to global warming, there is a significant decrease in water resources. If this problem cannot be prevented, the water problem will become very dangerous worldwide. As a result, drought because of global warming causes a decrease in both agricultural production and water resources (Li et al., 2021). This situation also leads to an increase in diseases. Both poor quality nutrition and difficulty in accessing water sources cause people to get sick. If this situation cannot be controlled, there will be an increase in death rates worldwide.

Fossil fuels are mostly preferred in energy use. Fossil fuels consist of resources such as oil, coal, and natural gas. The most important disadvantage of using fossil fuels is carbon emissions. In the process of obtaining energy by burning fossil fuels, a significant amount of carbon gas is formed (Zhou et al., 2020). This situation causes serious air and environmental pollution. Carbon emissions are one of the biggest causes of global warming. The use of fossil fuels is also the most important cause of carbon emissions. In this process, a very serious paradox occurs. In this context, the costs of fossil fuels are much lower than clean energy sources (Karlsson et al., 2021). For this reason, fossil fuels are mostly preferred by investors in energy production. On the other hand, cheap fossil fuels generate carbon emissions. Carbon emission also constitutes the problem of global warming.

In this section, the issues related to the solution of the global warming problem are examined. One of the measures that can be taken to prevent the problem of global warming is the use of renewable energy sources. In renewable energy alternatives, the energy source is supplied from nature (Haiyun et al., 2021). In this process, no carbon gas is released into the atmosphere since fossil fuels are not burned. This situation is considered as one of the biggest advantages of using renewable energy (An et al., 2021). Energy saving has a very important role in solving the global warming problem. Energy saving means reducing the amount of energy used while performing a job.

It is also very important to increase the awareness level of people to solve the global warming problem. Global warming is a very important problem affecting the whole world today. To combat the global warming problem effectively, these negative aspects of this problem must be understood by people (Yüksel et al., 2019). In other words, people need to have a clear understanding of the negative effects of global warming. On the other hand, it is essential to introduce legal

regulations to reduce carbon emissions originating from fossil fuels (Gao, Yang, et al., 2021, Gao, Yue, & Chen, 2021). In addition to the mentioned issues, carbon tax is proposed in this section to deal with the carbon emission problem.

2 Social and Economic Problems Caused by Global Warming

The global warming problem has become quite dangerous. The temperature figures around the world are increasing every year. This situation poses a very serious danger to the world. Rising temperatures are upsetting the balance of the world (Zhao et al., 2021). This situation brings with it many problems. For example, a significant increase in temperatures also causes the problem of drought. This puts the lives of living things at risk. In addition, some natural disasters occur with global warming (Yu & Zhang, 2021). For example, the occurrence of floods poses a very serious danger to the inhabitants of the region.

It is obvious that global warming also creates some social and economic problems. Drought caused by global warming adversely affects agricultural production. In this context, there is a significant decrease in the number of products produced (Yüksel et al., 2021). This situation creates an imbalance of supply and demand for products. In other words, there is a significant decrease in the supply of products due to drought. However, the population is increasing worldwide. As a result of this increasing population, the demand for products is increasing (Rehman et al., 2021). As a result, the amount of production becomes unable to meet the demand.

As the demand for the products is higher than the supply, the inflation problem will occur. This will lead to many other problems. High inflation increases the uncertainty in the markets. This situation leads to a decrease in investments throughout the country (Liu et al., 2021). In summary, high inflation disrupts the macroeconomic balances of countries. On the other hand, the occurrence of inflation because of drought brings along some social problems. The quality of life of people who cannot consume some products due to price increases will decrease (Xie et al., 2021). This will lead to a decrease in unhappiness across the country.

Due to global warming, there is a significant decrease in water resources. If this problem cannot be prevented, the water problem will become very dangerous worldwide. Global warming disrupts the balance of nature (Zhou et al., 2021). In this context, there is a serious decrease in the amount of precipitation across the world. Decreased precipitation also causes a decrease in water resources. Therefore, this problem needs to be solved urgently (Nawaz et al., 2021). Otherwise, this problem will threaten the lives of many people around the world.

As a result, drought because of global warming causes a decrease in both agricultural production and water resources. This situation also leads to an increase in diseases (Yu et al., 2019). Both poor quality nutrition and difficulty in accessing water sources cause people to get sick. If this situation cannot be controlled, there

will be an increase in death rates worldwide. As a result, global warming is a problem that puts everyone's life in danger and needs to be solved urgently (Fu et al., 2021).

3 Global Warming and Fossil Fuel Relationship

Energy is an important need for everyone. This applies to both individuals and companies. Individuals need energy while meeting their daily needs. On the other hand, industrial companies also use energy to produce. In other words, energy has become one of the most important raw materials in industrial production (Shang et al., 2021). In summary, energy is an indispensable need for a country. Therefore, this energy need must be met regardless of its price.

This situation can be managed more easily for countries that have their own energy resources. These countries can meet their energy needs with their own means. In other words, these countries are not dependent on other countries for energy supply. On the other hand, if there is not enough energy source within the borders of the country, this situation is very difficult for the countries. As stated before, energy must be supplied regardless of its price (Berger & Wyss, 2021). Therefore, countries that do not have their own reserves have to import the energy they need from abroad.

Fossil fuels are mostly preferred in energy use. Fossil fuels consist of resources such as oil, coal, and natural gas. Fossil fuels can be used if they are available within the borders of the country. In other words, countries do not have a chance to produce fossil fuels themselves. The resources of fossil fuels are decreasing as they are used. As can be understood from here, fossil fuels are examples of nonrenewable energy types (Liu et al., 2020). In summary, the resources of fossil fuels will 1 day come to an end as they are used up.

The biggest advantage of fossil fuels is their low cost. This situation causes investors to turn to this area. This leads to an increase in the use of fossil fuels in energy production. On the other hand, the most important disadvantage of fossil fuel use is carbon emissions. In the process of obtaining energy by burning fossil fuels, a significant amount of carbon gas is formed. This situation causes serious air and environmental pollution. This gas is poisonous and dangerous for living things (Hao et al., 2021). Therefore, in this process, very serious damage is given to the environment while generating energy.

Carbon emissions are one of the biggest causes of global warming. The use of fossil fuels is also the most important cause of carbon emissions. In this process, a very serious paradox occurs. Energy is a need that countries must provide. Fossil fuels or clean energy sources can be preferred when supplying energy (Du et al., 2020). In this context, the costs of fossil fuels are much lower than clean energy sources. For this reason, fossil fuels are mostly preferred by investors in energy production. On the other hand, cheap fossil fuels generate carbon emissions. Carbon emission also constitutes the problem of global warming. In summary, fossil fuels will continue to be used if they are cheap, and this will increase the global warming

problem. Therefore, to reduce the global warming problem, first, it is necessary to provide a cost advantage to clean energy sources compared to fossil fuels.

4 How Can Global Warming Be Stopped?

Under this title, the issues related to the solution of the global warming problem will be presented in subtitles.

4.1 Use of Clean Energy

One of the measures that can be taken to prevent the problem of global warming is the use of renewable energy sources. In renewable energy alternatives, the energy source is supplied from nature. For example, electricity is produced by using the blowing power of the wind and the sun's rays. In this process, no carbon gas is released into the atmosphere since fossil fuels are not burned (Ma et al., 2021). This situation is considered as one of the biggest advantages of using renewable energy. Therefore, renewable energy alternatives are energy types that produce clean energy and are environmentally friendly.

Another advantage of renewable energy sources is that countries can produce their own energy. For renewable energy production, there is no need to have reserves such as coal and oil within the borders of the country. Factors such as sun, wind, and river are sufficient to produce electricity with renewable energy alternatives. Therefore, it is possible for these energy projects to be implemented in every country (Dinçer et al., 2022). In this way, countries will be able to produce their own energy. As a result, the dependence of countries on abroad for energy supply will be eliminated.

This will also bring some economic advantages. First, countries that produce their own energy with renewable energy alternatives will not pay other countries for energy supply. Considering that this payment is in foreign currency, the use of renewable energy will significantly reduce the exchange rate risk of countries. In addition to the mentioned issues, energy imports of countries will decrease thanks to the use of renewable energy (Gao, Yang, et al., 2021, Gao, Yue, & Chen, 2021). This will help to manage the current account deficit problem effectively. In this way, the economic fragility of the countries will be eliminated.

Another advantage of using renewable energy is to increase foreign direct investments of countries. Thanks to renewable energy alternatives, the use of clean energy in countries is increasing significantly. This situation affects the image of countries positively. Many foreign investors attach importance to the use of clean energy while choosing the countries they will invest in. Therefore, the use of renewable energy contributes to the increase of foreign investments (Qiu et al., 2020). This will help increase trade between countries. In this way, new job

opportunities will emerge, and this will contribute to reducing the unemployment problem.

As can be seen, the use of renewable energy contributes to the solution of the global warming problem in every sense. In this context, increasing these projects is of vital importance for countries. However, there are some important obstacles to the increase of renewable energy alternatives. First, the installation cost of renewable energy projects is quite high compared to fossil fuels (Wang et al., 2019). This still makes fossil fuels more attractive to investors. Therefore, it would be appropriate to take some measures that can provide cost advantages to renewable energy projects.

Another disadvantage of renewable energy projects is that they involve complex processes. In this context, companies must have technical competence to use these projects effectively. Otherwise, it will not be easy to solve the problems that may occur in the processes. This will lead to customer dissatisfaction. In this context, companies should actively follow current technological developments to increase the effectiveness of renewable energy projects. In this way, technological developments will be able to be adapted to the projects in a timely manner. In addition, there is a serious need for qualified personnel to carry out this process successfully.

4.2 Energy Saving

Energy saving has a very important role in solving the global warming problem. Energy saving means reducing the amount of energy used while performing a job. This situation contributes to the more efficient use of depleted energy resources. Reducing the amount of energy used contributes to reducing the damage to the environment because of energy consumption. This helps to reduce the global warming problem significantly (Sarkar et al., 2021).

In this context, it is possible to talk about some measures for energy saving. For example, the use of energy efficient electronic devices helps this process. Thanks to these tools, much less energy will be used while doing the same work. If this situation is implemented in every house in the country, it will be possible to save very serious energy throughout the country.

In addition to the mentioned point, it is necessary to remove the plugs of unused electrical appliances from the socket. In this way, unnecessary use of electricity will be avoided. Insulation of buildings is also very important in terms of energy efficiency. Less heating will be needed in insulated buildings. This will also contribute to increasing energy savings. It is very important in this process that the doors in houses and workplaces are not kept open unless they are used. In addition, the maintenance of electrical appliances should be done periodically. In this way, it will be possible for these devices to work more effectively and consume much less electricity.

As a result, it is necessary to save energy for the solution of the global warming problem. Energy consumption is one of the biggest causes of the global warming problem. The carbon emission that occurs in the process of energy use causes the

problem of global warming. Therefore, to solve this problem, energy consumption should be reduced. Thanks to the energy saving policies to be implemented, it will be possible to consume less energy, and this will contribute to the solution of the global warming problem.

4.3 Increasing the Consciousness of People

It is also very important to increase the awareness level of people to solve the global warming problem. Global warming is a very important problem affecting the whole world today. If the measures to solve this problem are not taken on time, many new problems will occur. For example, agricultural production will decrease significantly due to drought. This will lead to the problem of scarcity. As a result, many people around the world will face the problem of hunger.

Another problem that will occur because of global warming is the decrease in water resources. Drought occurs due to global warming and the amount of precipitation decreases. This situation causes a significant decrease in water resources. Decreased water resources are a very serious threat to the future of the world. There is a possibility that many epidemics will increase due to insufficient water resources. This means that many people die.

To combat the global warming problem effectively, these negative aspects of this problem must be understood by people. In other words, people need to have a clear understanding of the negative effects of global warming. In this way, people will take precautions against the factors that cause global warming by their own will (Mukhtarov et al., 2022). Therefore, people should be told in detail how dangerous global warming is. By actively using television channels and social media in this process, awareness of the global warming problem can be increased.

4.4 Legal Regulations

One of the main reasons for global warming is the preference of fossil fuels in energy production. The biggest advantage of fossil fuels compared to clean energy sources is their lower costs. This situation causes investors to turn to these projects. Fossil fuels are becoming more attractive to for-profit investors. Considering that the main purpose of enterprises is to make profit, they will not prefer clean energy projects that do not have cost advantages, even if they are more environmentally friendly. This situation constitutes an important obstacle to the solution of the global warming problem.

Considering the abovementioned issues, it is essential to introduce legal regulations to reduce carbon emissions originating from fossil fuels. Otherwise, it will not be possible to reduce the use of fossil fuels. The main reason for this is that it will not be enough to prefer renewable energies just for being environmentally friendly

(Rehman et al., 2021). Therefore, it should be made compulsory to take necessary actions with legal regulations. Penal sanctions to be applied because of noncompliance with the rules will be a deterrent for companies. In this framework, the relevant companies will take the necessary measures to reduce the carbon emission problem.

5 Carbon Tax: As a Solution for Carbon Emission Problem

Carbon emissions cause serious environmental pollution. Therefore, some social and economic problems arise. As a result of carbon gas released into the atmosphere, a significant portion of people become ill. This situation reduces people's quality of life. This situation is considered as an important social problem for countries. In addition, it is obvious that people getting sick create some economic problems. For example, the increase in the number of sick people will result in significant job losses in the country. This situation will adversely affect the amount of industrial production. As a result of the shrinkage of industrial production, some of the companies will not be able to make a profit and this will cause the economy to shrink (Cheng et al., 2021).

Another economic problem caused by the increase in the number of sick people because of carbon emissions is related to the health expenditures of the country. More people getting sick will lead to higher health expenditures. The increase in the government's health expenditures will create a burden on the budget. If these expenditures increase too much, there is a risk that countries will encounter a budget deficit problem. The budget deficit problem makes the economy of a country more fragile. To close the mentioned budget deficit, states may have to borrow money.

It is seen that carbon emissions cause serious problems for the country's economy. In other words, fossil fuels, which are thought to be less costly compared to clean fuels, have additional costs caused by the problems they cause. It is seen that fossil fuels do not actually have a significant cost advantage compared to clean energy investments. The important issue here is that the initial cost of fossil fuels is covered by companies, and the long-term indirect costs incurred are covered by the states (Nong et al., 2021). As a result of the use of fossil fuels, which are cost advantages for companies, extra costs arise for states.

To eliminate this imbalance mentioned above, the carbon tax issue can be considered. In this context, tax is imposed on the amount of carbon emissions created by fuels, especially in the energy and transportation sector. In other words, extra taxes should be levied on companies that generate more carbon emissions in the production process. Because the carbon emissions created by these companies have a significant impact on the state budget. It is thought that this application will significantly reduce the carbon emission problem (Cao et al., 2021). In this way, it will be much easier to reduce the global warming problem.

6 Conclusion

In this section, the issues related to the solution of the global warming problem are examined. One of the measures that can be taken to prevent the problem of global warming is the use of renewable energy sources. In renewable energy alternatives, the energy source is supplied from nature. In this process, no carbon gas is released into the atmosphere since fossil fuels are not burned. This situation is considered as one of the biggest advantages of using renewable energy. Energy saving has a very important role in solving the global warming problem. Energy saving means reducing the amount of energy used while performing a job.

It is also very important to increase the awareness level of people to solve the global warming problem. Global warming is a very important problem affecting the whole world today. To combat the global warming problem effectively, these negative aspects of this problem must be understood by people. In other words, people need to have a clear understanding of the negative effects of global warming. On the other hand, it is essential to introduce legal regulations to reduce carbon emissions originating from fossil fuels.

In addition to the mentioned issues, carbon tax is proposed in this section to deal with the carbon emission problem. It is seen that fossil fuels do not actually have a significant cost advantage compared to clean energy investments. The important issue here is that the initial cost of fossil fuels is covered by companies, and the long-term indirect costs incurred are covered by the states. As a result of the use of fossil fuels, which are cost advantages for companies, extra costs arise for states.

To eliminate this imbalance, the carbon tax issue can be considered. In this context, tax is imposed on the amount of carbon emissions created by fuels, especially in the energy and transportation sector. In other words, extra taxes should be levied on companies that generate more carbon emissions in the production process. Because the carbon emissions created by these companies have a significant impact on the state budget, it is thought that this application will significantly reduce the carbon emission problem. In this way, it will be much easier to reduce the global warming problem.

References

An, Y., Zhou, D., Yu, J., Shi, X., & Wang, Q. (2021). Carbon emission reduction characteristics for China's manufacturing firms: Implications for formulating carbon policies. *Journal of Environmental Management, 284*, 112055.

Berger, S., & Wyss, A. M. (2021). Measuring pro-environmental behavior using the carbon emission task. *Journal of Environmental Psychology, 75*, 101613.

Cao, J., Dai, H., Li, S., Guo, C., Ho, M., Cai, W., He, J., Huang, H., Li, J., Liu, Y., Qian, H., Wang, C., Wu, L., & Zhang, X. (2021). The general equilibrium impacts of carbon tax policy in China: A multi-model comparison. *Energy Economics, 99*, 105284.

Cheng, Y., Sinha, A., Ghosh, V., Sengupta, T., & Luo, H. (2021). Carbon tax and energy innovation at crossroads of carbon neutrality: Designing a sustainable decarbonization policy. *Journal of Environmental Management, 294*, 112957.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Du, L., Dinçer, H., Ersin, İ., & Yüksel, S. (2020). IT2 fuzzy-based multidimensional evaluation of coal energy for sustainable economic development. *Energies, 13*(10), 2453.

Fu, Y., Huang, G., Liu, L., & Zhai, M. (2021). A factorial CGE model for analyzing the impacts of stepped carbon tax on Chinese economy and carbon emission. *Science of the Total Environment, 759*, 143512.

Gao, M., Yang, H., Xiao, Q., & Goh, M. (2021). A novel fractional grey Riccati model for carbon emission prediction. *Journal of Cleaner Production, 282*, 124471.

Gao, P., Yue, S., & Chen, H. (2021). Carbon emission efficiency of China's industry sectors: From the perspective of embodied carbon emissions. *Journal of Cleaner Production, 283*, 124655.

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Hao, L. N., Umar, M., Khan, Z., & Ali, W. (2021). Green growth and low carbon emission in G7 countries: How critical the network of environmental taxes, renewable energy and human capital is? *Science of the Total Environment, 752*, 141853.

Karlsson, J., Serikova, S., Vorobyev, S. N., Rocher-Ros, G., Denfeld, B., & Pokrovsky, O. S. (2021). Carbon emission from Western Siberian inland waters. *Nature Communications, 12*(1), 1–8.

Li, Z. Z., Li, R. Y. M., Malik, M. Y., Murshed, M., Khan, Z., & Umar, M. (2021). Determinants of carbon emission in China: How good is green investment? *Sustainable Production and Consumption, 27*, 392–401.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*(5), 3687–3701.

Liu, H., Yüksel, S., & Dinçer, H. (2020). Analyzing the criteria of efficient carbon capture and separation technologies for sustainable clean energy usage. *Energies, 13*(10), 2592.

Ma, J., Hou, Y., Wang, Z., & Yang, W. (2021). Pricing strategy and coordination of automobile manufacturers based on government intervention and carbon emission reduction. *Energy Policy, 148*, 111919.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy*.

Nawaz, M. A., Hussain, M. S., Kamran, H. W., Ehsanullah, S., Maheen, R., & Shair, F. (2021). Trilemma association of energy consumption, carbon emission, and economic growth of BRICS and OECD regions: Quantile regression estimation. *Environmental Science and Pollution Research, 28*(13), 16014–16028.

Nong, D., Simshauser, P., & Nguyen, D. B. (2021). Greenhouse gas emissions vs CO2 emissions: Comparative analysis of a global carbon tax. *Applied Energy, 298*, 117223.

Qiu, D., Dinçer, H., Yüksel, S., & Ubay, G. G. (2020). Multi-faceted analysis of systematic risk-based wind energy investment decisions in E7 economies using modified hybrid modeling with IT2 fuzzy sets. *Energies, 13*(6), 1423.

Rehman, A., Ma, H., & Ozturk, I. (2021). Do industrialization, energy importations, and economic progress influence carbon emission in Pakistan. *Environmental Science and Pollution Research, 28*(33), 45840–45852.

Sarkar, B., Sarkar, M., Ganguly, B., & Cárdenas-Barrón, L. E. (2021). Combined effects of carbon emission and production quality improvement for fixed lifetime products in a sustainable supply chain management. *International Journal of Production Economics, 231*, 107867.

Shang, H., Su, F., Yüksel, S., & Dinçer, H. (2021). Identifying the strategic priorities of the technical factors for the sustainable low carbon industry based on macroeconomic conditions. *SAGE Open, 11*(2), 21582440211016345.

Wang, S., Liu, Q., Yuksel, S., & Dincer, H. (2019). Hesitant linguistic term sets-based hybrid analysis for renewable energy investments. *IEEE Access, 7*, 114223–114235.

Xie, Z., Wu, R., & Wang, S. (2021). How technological progress affects the carbon emission efficiency? Evidence from national panel quantile regression. *Journal of Cleaner Production, 307*, 127133.

Yu, Z., Liu, W., Chen, L., Eti, S., Dinçer, H., & Yüksel, S. (2019). The effects of electricity production on industrial development and sustainable economic growth: A VAR analysis for BRICS countries. *Sustainability, 11*(21), 5895.

Yu, Y., & Zhang, N. (2021). Low-carbon city pilot and carbon emission efficiency: Quasi-experimental evidence from China. *Energy Economics, 96*, 105125.

Yüksel, S., Dinçer, H., Karakuş, H., & Ubay, G. G. (2020). The negative effects of carbon emission on FDI: A comparative analysis between E7 and G7 countries. In *Handbook of research on sustainable supply chain management for the global economy* (pp. 20–35). IGI Global.

Yüksel, S., Dinçer, H., & Meral, Y. (2019). Financial analysis of international energy trade: A strategic outlook for EU-15. *Energies, 12*(3), 431.

Yüksel, S., Ubay, G. G., & Çelebi, B. (2021). The negative role of environmental pollution on international trade: Strategy recommendation to solve this problem. In *Handbook of research on recent perspectives on management, international trade, and logistics* (pp. 122–138). IGI Global.

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhou, C., Liu, D., Zhou, P., Luo, J., Yuksel, S., & Dincer, H. (2020). Hybrid predictive decision-making approach to emission reduction policies for sustainable energy industry. *Energies, 13*(9), 2220.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

Selecting the Optimal Clean Energy Projects for Emerging Economies

Serkan Eti

Abstract In this study, it is aimed to determine the most accurate renewable energy investment alternative for developing economies. In this context, firstly, a very large-scale literature analysis was made. As a result, four different issues were identified that could have an impact on this decision. Financial analysis contributes to the determination of the efficiency of investments. Another factor to be considered in the selection of the optimal clean energy investment is customer satisfaction. Customer expectations should be taken into consideration when making investment decisions. Technological investments are also very important in this process because renewable energy investments involve complex engineering steps. Additional factor to consider in the selection of the most suitable renewable energy investment is personnel quality. By considering these four different factors, a decision-making model is created to identify the most optimal renewable energy alternative. For this ranking, the MAIRCA method based on expert opinion was preferred. The most optimal renewable energy alternative has been determined as geothermal energy. Secondly, biomass was determined as the most suitable renewable energy type. Geothermal energy and biomass energy types were followed by wind, solar and hydroelectricity energy types, respectively. It has been determined that hydroelectricity energy type is the most unsuitable renewable energy type. Considering the results obtained, it would be appropriate for developing countries to prioritize their geothermal energy investments. In this context, the types of risks encountered in this process should be determined. In addition, actions specific to these risk types need to be taken. This will allow the risks to be managed effectively. In this way, it will be possible to increase the performance of geothermal energy investments. One of the most important risks in geothermal energy investments is the damage of water resources. Otherwise, there will be significant reductions in water resources. This situation will cause some problems especially in agricultural production. Insufficient water resources will lead to a decrease in the production of agricultural products.

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Therefore, it would be appropriate to pay attention to this issue in geothermal energy investments.

1 Introduction

Energy is one of the key factors in human history. Throughout history, energy has been an indispensable concept for people to survive. Energy can be found in different forms such as nuclear energy, chemical energy, electrical energy, heat energy, mechanical energy, and light energy. Depending on the form of energy, its use and importance can vary (Smil, 2004). Energy can be used for many purposes such as heating, lighting, and operating electronic devices. First, electrical energy has serious importance for countries and businesses. As it is the raw material of the industry, it has increased the investments in the countries and increased the profit margin of the energy sector (Dinçer et al., 2019).

Energy is examined in 2 classes according to the source from which it is produced. These are renewable energy and conventional energies. Renewable energy is an energy resource that does not have a finite life and is a type of energy whose source is assumed to be inexhaustible. The energies obtained from sources such as sun, wind, and water are evaluated in this type of energy category. Solar energy, wind energy, hydroenergy, tidal energy, geothermal energy, and biomass energy are subcategories of this type (Fridleifsson, 2001). Fossil fuels are considered conventional energy sources. These energy sources are energies stored underground with accumulations throughout history. They have a limited amount. Energy obtained from sources such as oil and coal can be considered in this context (Du et al., 2020).

As countries around the world face energy resource shortages, there is a need for more sustainable energy sources. In this context, although the trend towards renewable energy sources has increased recently, these energy sources have some difficulties. Chief among these are difficulties such as installation cost and storage (Muruganantham et al., 2017). There are also many studies showings that geographical conditions are an effective factor in the selection of renewable energy (Bao, & Fang, 2013).

Due to such difficulties in the establishment of renewable energy, it is an important problem to determine the type of source to be selected. Such difficulties are considered in determining the optimal energy source over countries in academic studies and field applications (Liu et al., 2021). Similar studies in the literature reveal the selection of the most appropriate energy for countries and businesses. Choosing the most suitable renewable energy source is important because not every country is equal in terms of energy resources and the financial infrastructure to meet the installation costs is limited. If the said energy sources are not selected correctly, energy efficiency will not be in question. This will lead to a longer return on energy investments and an increase in energy-related costs. Thus, the desired efficiency from renewable energy will not be achieved.

Correct planning of energy investments is important in terms of efficiency. In this context, this study aims to determine the most suitable renewable energy project for developing countries. For this purpose, the four criteria that are taken into consideration most in the selection of renewable energy are taken as a basis. Within the framework of these criteria, renewable energy alternatives will be listed with the MAIRCA (Multi-Attributive Ideal–Real Comparative Analysis) method, which is one of the multi-criteria decision-making methods.

2 General Information About Energy Production

The concept of energy is an indispensable raw material for both businesses and countries in daily life. In this context, energy production is of great importance. The basic principle in energy production is to move dynamos with steam power by utilizing heat. The basic structure here is the conversion of kinetic energy by the action of dynamos. Renewable resources such as water, nuclear, and the solar wind can be used for the movement of these dynamos. Apart from such renewable energy sources, fossil fuels have been preferred for a long time. These are the method of obtaining by using underground resources such as oil and coal. Whether renewable or derived from fossil fuels, both types of energy have advantages and disadvantages.

Fossils are the remains of extinct creatures that have survived for many years without deterioration. Fossil fuels are energy sources that result from the decomposition of living remains (animal and plant remains) under the ground for millions of years. The excess of harmful gases that arise during the acquisition of the said energy is one of the biggest disadvantages of such energy sources. In other words, such gases are released into the air as a result of the chemical reaction that occurs in obtaining energy from fossil fuels. Unless correct filtering and precautions are taken, these gases can harm both nature and human health (Zhou & Li, 2018). It has harmful effects on nature such as thinning the ozone layer and causing acid rain. Another disadvantage is that the fossil resources used to obtain these fossil energies are limited (Najafi et al., 2011). One of the advantages of these fuels is their low investment costs (Caineng et al., 2021; Lively, 2021).

Unlike the energy obtained from fossil fuels, renewable energy is environmentally friendly. Its effect on greenhouse gas emissions and other air pollution is minimal. Thus, it can be said that it is harmless to both the environment and human health. In addition, turning unlimited energy sources into electrical energy ensures that it is long term. Another advantage is the promotion of economic development. Research has shown that renewable resources have a significant multiplier effect on countries whose industries can produce and produce energy machinery and equipment based on technological innovations, especially in their exports (Maradin, 2021). Despite these advantages of renewable energy types, there are also disadvantages. These energy resources are completely dependent on geographical location and weather conditions. This can present a significant limitation

and difficulty. But this can be mitigated by quality planning and careful site selection.

Another disadvantage is that they cannot produce as much energy as fossil fuel power plants. To reduce this deficiency, more investments and construction of power plants may be required. Production cost can be shown as the biggest disadvantage of renewable energy. The literature suggests that there is a higher cost to build a renewable power plant compared to fossil power plants (Risto & Aija, 2008). In summary, renewable energy types have disadvantages such as being dependent on weather conditions, low energy production ability, efficiency, and capacity, as well as high investment costs. However, it has benefits such as being harmless to the environment and human health, reducing import dependency, encouraging innovation and economic development, enabling rural development, and reducing energy shortage (Akhtar et al., 2021; Maradin, 2021; Wu et al., 2021).

3 The Importance of Clean Energy Investments

Many numerical models are considered when making investment decisions (Eti, 2021). Whether it is fossil fuels or renewable energy types, both types have their advantages and disadvantages. Today, it is possible to see that countries and businesses are moving away from the types of energy obtained from fossil fuels and turning to more renewable energy sources. The main reasons for this are its environmental friendliness, and it is minimally affected by energy price fluctuations (Yuan et al., 2021). Generally, it is aimed to stabilize the costs arising from energy prices in production enterprises. Businesses and countries can produce their energy with renewable energy. Thanks to this, external dependency is reduced, and it can strengthen its hands in price policy. In addition, it is environmentally friendly because it does not emit carbon emissions and does not release other air pollution-causing gases into nature. One of the reasons for preferring renewable energy is the employment provided by these facilities in countries (Li et al., 2021). Establishing renewable energy power plants and facilities instead of importing energy will contribute significantly to the employment of the country. Thus, domestic and national energy production will be provided while contributing to employment. Another benefit is its contribution to the image of the country. It has been shown by studies that renewable energy is stimulating economic development (Baloch et al., 2022; Felice et al., 2021; Maradin, 2021).

Investments in renewable energy sources have benefits for the country, the environment, and people. Therefore, investments in renewable energy facilities are important. With these investments, serious contributions will be made to both the employment of the country and the economic independence of the country (Li et al., 2021). Studies in the literature have shown that renewable energy investments have a positive effect on economic growth and employment (Azretbergenova et al., 2021; Baş & Ersin, 2021; Eyuboglu & Uzar, 2021; Kirikkaleli et al., 2021; Zhe et al., 2021). In addition to the financial contributions of renewable energy investments,

there are also benefits in terms of country image. It is both an indicator of economic development and can be seen as an indicator of independence (Hussain et al., 2021; Wang et al., 2022).

Renewable energy investments, such as energy investments from fossil fuels, also have disadvantages. The cost in the facility or power plant is one of these disadvantages. The high cost of this makes investors hesitant (Dinçer et al., 2021; Karatop et al., 2021). Besides the high initial cost, renewable energy sources may not have a stable efficiency due to climate instability. This may prolong the return on costs (Sendstad et al., 2022). Investors may therefore abstain due to the uncertainty of the return on their investments. In addition, the storage of energy to be obtained from renewable energy sources is a separate problem. Storage units to be established for this also create costs. Energy obtained from renewable energy sources must be stored before distribution. The facility to be established for the storage of energy also creates additional costs (Meng et al., 2021).

After the cost of establishing renewable energy sources, fixed costs can also be an effective factor in investment decisions. Maintenance and repair costs and difficulties of renewable power plants are also included in the literature as a disadvantage. It can be difficult to find spare parts and equipped personnel for maintenance and repair. Such difficulties can be effective in making the renewable energy decision (Babatunde et al., 2020; Kan et al., 2020). Another disadvantage of renewable energy is that technical competence is required. Personnel working for fossil fuels may not generally be expected to be qualified. Academic success is not expected in the employment of personnel to work in coal mines and similar places. However, this is the opposite in renewable energy production facilities. The personnel who will work here must be experts and equipped. In addition to personnel, technical products and materials are also required. These two technical requirements increase fixed costs. In this case, it is considered a negative criterion in making investment decisions (Li et al., 2020).

4 An Evaluation for Emerging Economies

The MAIRCA method is a multi-criteria decision-making method that was first introduced to the literature in 2014. The method in question provides the ranking of alternatives with the help of determined criteria and weights like the TOPSIS method (Pamučar et al., 2014). The basis of the MAIRCA method lies in determining the gap between ideal and empirical evaluations. The sum of the gaps for each criterion is calculated and evaluated for each observed alternative. The highest ranked alternative is treated as the alternative with the lowest value for total clearance. The alternative with the lowest total gap is interpreted as having values closest to the ideal estimates (Chatterjee et al., 2018; Gigovic et al., 2016).

Many criteria affect renewable energy investments. The advantages and disadvantages of renewable energy sources can affect these decisions. In this context, it is important to consider these criteria carefully to obtain maximum efficiency from

Table 1 Decision matrix

	Financial issues	Technologic development	Customer satisfaction	Personnel quality
Wind	7.48	9.00	5.48	7.00
Solar	7.48	9.00	5.48	6.48
Hydroelectricity	6.48	7.48	4.00	6.48
Biomass	7.48	9.00	5.48	7.48
Geothermal	8.00	9.00	6.00	6.93

Table 2 Scores and ranking

Renewable energy alternatives	Score	Ranking
Wind	0.054	3
Solar	0.080	4
Hydroelectricity	0.200	5
Biomass	0.030	2
Geothermal	0.028	1

renewable energy sources. Considering these criteria, the determination of the type of renewable energy has serious importance in terms of investment decisions. For this purpose, financial issues, technologic development, customer satisfaction, and personnel quality criteria were taken into consideration. Under these criteria, renewable energy alternatives such as wind, solar, hydroelectricity, biomass, and geothermal are listed. For this ranking, the MAIRCA method based on expert opinion was preferred. The study took evaluations from expert academicians experienced in renewable energy investments. The decision matrix of expert opinions is given in Table 1. The 9-point scale was used in the evaluation. On the scale, 1 corresponds to very low expression, while 9 corresponds to very high expression.

The decision matrix shown in Table 1 was created by taking the average of the experts. Then, the MAIRCA method was applied. Thanks to the method in question, the difference between the theoretical value and the actual evaluation value was calculated. In other words, the gap between the theoretical value and the expert value was determined for each alternative. Afterwards, the alternatives are ranked in such a way that the least gap is the best alternative. The order of renewable energy alternatives is given in Table 2.

When Table 2 is examined, the most optimal renewable energy alternative has been determined as geothermal energy. Secondly, biomass was determined as the most suitable renewable energy type. Geothermal energy and biomass energy types were followed by wind, solar, and hydroelectricity energy types, respectively. It has been determined that hydroelectricity energy type is the most unsuitable renewable energy type.

According to the results obtained from the MAIRCA method, developing countries should focus on geothermal energy as a renewable energy type. Thus, they can get more effective results in their investments. With this result, they will make the right choice in terms of financial, technological, customer, and personnel quality with the investments to be made in geothermal energy.

Consideration can be given to the type of geothermal energy in terms of renewable energy alternatives, in order to shed light on future studies. With the new studies to be done, the most suitable location for this type of energy can be determined. In addition, emphasis can be placed on issues that will increase productivity for production. In addition, renewable energy alternatives can be reviewed for both developed and developing countries by using different numerical methods in new studies.

5 Conclusion

In this study, it is aimed to determine the most accurate renewable energy investment alternative for developing economies. In this context, firstly, a very large-scale literature analysis was made. As a result, four different issues were identified that could have an impact on this decision. Financial analysis contributes to the determination of the efficiency of investments. In this context, it is important to conduct a comprehensive cost analysis (Dong et al., 2022). Otherwise, there is a risk that the costs of investments without a correct financial analysis will exceed the income. This situation leads to low profitability of renewable energy investments (Zhang et al., 2022).

Another factor to be considered in the selection of the optimal clean energy investment is customer satisfaction. Customer expectations should be taken into account when making investment decisions (Kou et al., 2022). In this context, a comprehensive study should be carried out in order to determine customer demands. After that, choices should be made in accordance with the expectations of the customers while making the investment decision (Mukhtarov et al., 2022). For some renewable investments, customer expectations may be more important. This should be taken into account in the selection of investment type. Otherwise, the probability of ensuring the continuity of investments where the expectations of customers are not met is very low (Kostis et al., 2022).

Technological investments are also very important in this process. Renewable energy investments involve complex engineering steps. Therefore, investors need to have technological development in order to be successful in this process (Bhuiyan et al., 2022). This will provide investors with a significant cost advantage. This may be even more important for some renewable energy investments (Yüksel & Dinçer, 2022). Thus, this issue should be taken into account in the selection of the appropriate renewable energy investments (Wan et al., 2022). Otherwise, there is a risk of failure of companies that are not sufficient in terms of technological innovation.

Another factor to consider in the selection of the most suitable renewable energy investment is personnel quality. Compared to fossil fuels, there are more specific applications that require expertise in renewable energy investments (Dinçer et al., 2022). Therefore, more qualified personnel are needed in renewable energy investments. In this context, renewable energy companies should pay attention to these issues when employing personnel (Yüksel, Dinçer, Çağlayan, et al., 2022; Yüksel,

Dinçer, Mikhaylov, et al., 2022). Employment of personnel who have a good command of business processes contributes to the increase of success in projects (Adalı et al., 2022). On the other hand, thanks to the presence of these personnel, the problems that occur in the business processes will be solved more quickly. This will help ensure customer satisfaction (Haiyun et al., 2021; Zhao et al., 2021).

By considering these four different factors, a decision-making model is created to identify the most optimal renewable energy alternative. For this ranking, the MAIRCA method based on expert opinion was preferred. The study took evaluations from expert academicians experienced in renewable energy investments. The most optimal renewable energy alternative has been determined as geothermal energy. Secondly, biomass was determined as the most suitable renewable energy type. Geothermal energy and biomass energy types were followed by wind, solar, and hydroelectricity energy types, respectively. It has been determined that hydroelectricity energy type is the most unsuitable renewable energy type.

Considering the results obtained, it would be appropriate for developing countries to prioritize their geothermal energy investments. In this process, it is also very important for countries to have geothermal resources. In countries such as Turkey, geothermal resources are very abundant compared to other countries. Therefore, it is seen that such countries are more suitable for geothermal energy investments. On the other hand, it would be appropriate to conduct an effective risk analysis while making geothermal energy investments. In this context, the types of risks encountered in this process should be determined. In addition, actions specific to these risk types need to be taken. This will allow the risks to be managed effectively. In this way, it will be possible to increase the performance of geothermal energy investments.

One of the most important risks in geothermal energy investments is the damage of water resources. In these types of energy, underground hot spring waters are brought to the surface. In this process, electricity is produced by utilizing the steam of this hot water. Afterwards, this water has to be sent back underground again. Otherwise, there will be significant reductions in water resources. This situation will cause some problems especially in agricultural production. Insufficient water resources will lead to a decrease in the production of agricultural products. Therefore, it would be appropriate to pay attention to this issue in geothermal energy investments.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Akhtar, I., Kirmani, S., & Jameel, M. (2021). Reliability assessment of power system considering the impact of renewable energy sources integration into grid with advanced intelligent strategies. *IEEE Access, 9*, 32485–32497.

Azretbergenova, G., Syzdykov, B., Niyazov, T., Gulzhan, T., & Yskak, N. (2021). The relationship between renewable energy production and employment in European Union Countries: Panel data analysis. *International Journal of Energy Economics and Policy, 11*(3), 20–26.

Babatunde, O. M., Munda, J. L., & Hamam, Y. (2020). A comprehensive state-of-the-art survey on hybrid renewable energy system operations and planning. *IEEE Access, 8*, 75313–75346.

Baloch, Z. A., Tan, Q., Kamran, H. W., Nawaz, M. A., Albashar, G., & Hameed, J. (2022). A multi perspective assessment approach of renewable energy production: Policy perspective analysis. *Environment, Development and Sustainability, 24*, 2164–2192.

Bao, C., & Fang, C.-L. (2013). Geographical and environmental perspectives for the sustainable development of renewable energy in urbanizing China. *Renewable and Sustainable Energy Reviews, 27*, 464–474.

Baş, H., & Ersin, İ. (2021). The impact of energy investments on employment: A study on the OECD. In S. Yüksel & H. Dinçer (Eds.), *Strategic approaches to energy management* (pp. 285–299). Springer.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Caineng, Z., Bo, X., Huaqing, X., Dewen, Z., Zhixin, G., Ying, W., Luyang, J., Songqi, P., & Songtao, W. (2021). The role of new energy in carbon neutral. *Petroleum Exploration and Development, 48*(2), 480–491.

Chatterjee, K., Pamucar, D., & Zavadskas, E. K. (2018). Evaluating the performance of suppliers based on using the R'AMATEL-MAIRCA method for green supply chain implementation in electronics industry. *Journal of Cleaner Production, 184*, 101–129.

Dinçer, H., Yüksel, S., & Karakuş, H. (2021). The role of green sukuk for sustainable energy production. In U. Akkucuk (Ed.), *Disruptive technologies and eco-innovation for sustainable development* (pp. 42–55). IGI Global.

Dinçer, H., Yüksel, S., & Martinez, L. (2019). Balanced scorecard-based analysis about European energy investment policies: A hybrid hesitant fuzzy decision-making approach with quality function deployment. *Expert Systems with Applications., 115*, 152–171.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Du, L., Dinçer, H., Ersin, İ., & Yüksel, S. (2020). IT2 fuzzy-based multidimensional evaluation of coal energy for sustainable economic development. *Energies, 13*(10), 1–21.

Eti, S. (2021). The use of quantitative methods in investment decisions: A literature review. In H. Dinçer & S. Yüksel (Eds.), *Research anthology on personal finance and improving financial literacy* (pp. 1–20). IGI Global.

Eyuboglu, K., & Uzar, U. (2021). Asymmetric causality between renewable energy consumption and economic growth: Fresh evidence from some emerging countries. *Environmental Science and Pollution Research., 29*, 21899–21911.

Felice, A., Rakocevic, L., Peeters, L., Messagie, M., Coosemans, T., & Camargo, L. R. (2021). An assessment of operational economic benefits of renewable energy communities in Belgium. *Journal of Physics: Conference Series., 2042*, 1–6. IOP Publishing.

Fridleifsson, I. B. (2001). Geothermal energy for the benefit of the people. *Renewable and Sustainable Energy Reviews, 3*(5), 299–312.

Gigovic, L., Pamucar, D., Bajic, Z., & Milicevic, M. (2016). The combination of expert judgment and GIS-MAIRCA analysis for the selection of sites for ammunition depots. *Sustainability, 8*(4), 1–30.

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval

valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Hussain, J., Zhou, K., Muhammad, F., Khan, D., Khan, A., Ali, N., & Akhtar, R. (2021). Renewable energy investment and governance in countries along the belt & Road Initiative: Does trade openness matter? *Renewable Energy, 180*, 1278–1289.

Kan, C., Devrim, Y., & Eryılmaz, S. (2020). On the theoretical distribution of the wind farm power when there is a correlation between wind speed and wind turbine availability. *Reliability Engineering & System Safety, 203*, 1–8.

Karatop, B., Taşkan, B., Adar, E., & Kubat, C. (2021). Decision analysis related to the renewable energy investments in Turkey based on a Fuzzy AHP-EDAS-Fuzzy FMEA approach. *Computers & Industrial Engineering, 151*, 1–15.

Kirikkaleli, D., Güngör, H., & Adebayo, T. S. (2021). Consumption-based carbon emissions, renewable energy consumption, financial development and economic growth in Chile. *Business Strategy and the Environment.*, 1–15. https://doi.org/10.1002/bse.2945

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of European economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy.*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Li, Y. X., Wu, Z. X., Dinçer, H., Kalkavan, H., & Yüksel, S. (2021). Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling. *Energy Reports, 7*, 95–108.

Li, X., Zhu, S., Yüksel, S., Dinçer, H., & Ubay, G. G. (2020). Kano-based mapping of innovation strategies for renewable energy alternatives using hybrid interval type-2 fuzzy decision-making approach. *Energy, 211*, 1–16.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*, 3687–3701.

Lively, R. P. (2021). The refinery of today, tomorrow, and the future: A separations perspective. *AICHE Journal, 67*(7).

Maradin, D. (2021). Advantages and disadvantages of renewable energy sources utilization. *International Journal of Energy Economics and Policy, 11*(3), 176–183.

Meng, Y., Zhou, R., Dinçer, H., Yüksel, S., & Wang, C. (2021). Analysis of inventive problem-solving capacities for renewable energy storage investments. *Energy Reports, 7*, 4779–4791.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy*.

Muruganantham, B., Gnanadass, R., & Padhy, N. P. (2017). Challenges with renewable energy sources and storage in practical distribution systems. *Renewable and Sustainable Energy Reviews, 73*, 125–134.

Najafi, G., Ghobadian, B., & Yusaf, T. F. (2011). Algae as a sustainable energy source for biofuel production in Iran: A case study. *Renewable and Sustainable Energy Reviews, 15*(8), 3870–3876.

Pamučar, D., Vasin, L., & Lukovac, V. (2014). Selection of railway level crossings for investing in security equipment using hybrid DEMATEL-MARICA model. In *XVI international scientific-expert conference on railway* (pp. 89–92). Railcon.

Risto, T., & Aija, K. (2008). Comparison of electricity generation costs. Lappeenranta: Faculty of Technology. *Department of Energy and Environmental Technology.*

Sendstad, L. H., Hagspiel, V., Mikkelsen, W. J., Ravndal, R., & Tveitstøl, M. (2022). The impact of subsidy retraction on European renewable energy investments. *Energy Policy, 160*, 1–8.

Smil, V. (2004). World History and Energy. *Encyclopedia of Energy, 6*, 549–561.

Wan, Q., Zhao, X., Liu, H., Dinçer, H., & Yüksel, S. (2022). Assessing the new product development process for the industrial decarbonization of sustainable economies. *SAGE Open, 12*(1), 21582440211067231.

Wang, Q., Dong, Z., Li, R., & Wang, L. (2022). Renewable energy and economic growth: New insight from country risks. *Energy, 238*, 1–10.

Wu, Y., Hu, M., Liao, M., Liu, F., & Xu, C. (2021). Risk assessment of renewable energy-based island microgrid using the HFLTS-cloud model method. *Journal of Cleaner Production, 284*(15), 1–17.

Yuan, G., Xie, F., Dinçer, H., & Yüksel, S. (2021). The theory of inventive problem solving (TRIZ)-based strategic mapping of green nuclear energy investments with spherical fuzzy group decision-making approach. *International Journal of Energy Research, 45*(8), 12284–12300.

Yüksel, S., & Dinçer, H. (2022). Identifying the strategic priorities of nuclear energy investments using hesitant 2-tuple interval-valued Pythagorean fuzzy DEMATEL. *Progress in Nuclear Energy, 145*, 104103.

Yüksel, S., Dinçer, H., Çağlayan, Ç., Uluer, G. S., & Lisin, A. (2022). Bitcoin mining with nuclear energy. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022). Key issues for the improvements of shallow geothermal investments. In *Sustainability in energy business and finance* (pp. 183–194). Springer.

Zhang, Y., Zhang, Y., Gong, C., Dinçer, H., & Yüksel, S. (2022). An integrated hesitant 2-tuple Pythagorean fuzzy analysis of QFD-based innovation cost and duration for renewable energy projects. *Energy, 248*, 123561.

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 1–9.

Zhou, D., & Li, Z. (2018). Environmental aspects of high-temperature conversion of petroleum-based fuels. *Petroleum Science and Technology, 36*(15), 1120–1124.

The Importance of Green HR Activities to Manage Carbon Emission Problem

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Abstract Carbon emissions seriously harm the environment. Countries have started to take different actions to solve this problem. Green HRM is one of the measures to be taken to solve this problem. For environmentally friendly energy consumption, the quality of the personnel working in the enterprises is also important. The solution of the carbon emission problem will be easier if the environmental awareness of the employees is high. In this context, businesses should pay attention to these issues in the recruitment process. In other words, candidates with a high level of this awareness should be preferred. On the other hand, necessary training on environmental issues should be given to the personnel currently working in the enterprises. In this way, it will be much easier to save energy. This will contribute to environmentally friendly energy consumption.

1 Introduction

Global warming has become a huge problem around the world. This situation upsets the natural balance. As a result, many problems occur in both social and economic terms (Adalı et al., 2022). As a result of global warming, water resources are damaged. This situation causes problems in people's access to water (Ding et al., 2021). This also leads to an increase in diseases. The increase in the number of sick people reduces the quality of life in countries (Haiyun et al., 2021). On the other hand, temperature differences as a result of global warming also damage agricultural products that lead to famine. As a result, it is inevitable for countries to experience economic problems.

It is obvious that the problem of global warming needs to be solved urgently. In this context, many countries and organizations take important measures to prevent this problem. Carbon emission is the most important cause of this problem (Zhao et al., 2021). The use of fossil fuels in energy production also causes carbon

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emissions. Therefore, in order to eliminate the global warming problem, either energy savings should be made or clean energy sources should be preferred. As a result of the use of renewable energy sources, the amount of carbon emissions decreases significantly (Yuan et al., 2021). This helps to solve the global warming problem.

On the other hand, it is possible to take other measures to solve the carbon emission problem. For example, thanks to carbon capture and sequestration technology, fossil fuels can be prevented from emitting carbon gas (Li et al., 2021). However, a significant technology investment is required for this application to be realized. Thanks to new technologies, it will be possible to reduce the costs of these applications. Moreover, energy-saving practices will also help reduce the energy that harms the environment (Xie et al., 2021). In this context, it is necessary to determine the applications that will provide energy savings and implement them in a timely manner.

Green human resource practices are also an application that can contribute to this process. In this context, attention should be paid to the fact that the personnel to be recruited to the enterprises have this awareness (Meng et al., 2021). On the other hand, necessary training should be provided in order to increase the awareness level of the personnel currently working in the company. Furthermore, businesses are required to provide legal regulations for environmentally friendly practices (Fang et al., 2021). This will help reduce actions that harm the environment (Yüksel & Ubay, 2021).

In this study, a review of green HRM applications will be made. In this framework, first of all, what green HRM applications cover will be stated. After that, detailed explanations about possible actions will be given. Finally, the applications that businesses can make to adapt to the green HRM system will be mentioned.

2 General Information About Human Resource Activities

Humans are social beings. We plan, develop, and manage our relationships consciously and unconsciously. Relationships are the result of our actions and are largely dependent on our ability to direct our actions. Since childhood, each individual gains knowledge and experience about understanding others and how to behave in every situation in life. In fact, all functions of human resource management (HRM) are gathered around these issues. Since the mid-1980s, HRM has gained acceptance in both academic and business circles. HRM is a multidisciplinary organizational function fueled by theories and ideas from various fields such as management, psychology, sociology, and economics. There is no best way to manage people, and no manager has ever formulated how to manage people effectively because people are complex beings with complex needs. Effective HRM largely depends on the causes and conditions an organizational environment will provide.

HRM refers to the policies, practices, and systems that affect the behavior, attitudes, and performance of employees (Soeters, 2020). Armstrong considered human resource management as a strategic, integrated, and consistent approach to the employment, development, and well-being of people working in organizations. Boxall and Purcell (2016) defined it as the process by which management creates the workforce and tries to create the human performances that the organization needs. Storey (1995), on the other hand, considers the primary goal of human resource management as providing competitive advantage through strategic positioning of a devoted and talented employee using integrated techniques.

In addition, Buchanan and Huczynski (2004) accept human resource management as a managerial approach that requires establishing a set of integrated employee policies in accordance with the organizational strategy. If we need to make different definitions, it can be defined as the process of managing people in organizations in a structured and comprehensive way (Cvenkel, 2020). In line with this point of view, human is not considered a cost element, but an important resource as it creates creativity and value (Andersen et al., 2019). As can be understood from the definitions listed above, human resource management focuses on people in organizations. Human resource management designs management systems to ensure that human talent is used effectively and efficiently to achieve organizational goals.

Opatha (2021) associates human resource management with the most effective use of people to achieve organizational and individual goals. This is the way to manage people at work, so they can give the best of their ability to the organization. In general, HRM refers to the management of people in organizations. It consists of activities, policies, and practices related to the acquisition, development, use, evaluation, maintenance, and retention of appropriate resources. In short, HRM can be defined as the art of sourcing, developing, and maintaining a competent workforce to achieve an organization's goals effectively and efficiently.

Human resource management plays a key role in the strategic management of businesses. The term, which was previously used as personnel management, was later replaced by human resource management. This not only is a name change, but also reflects a changing management paradigm. For example, personnel management tends to adopt a short-term and reactive time and planning perspective, while human resource management adopts a long-term and proactive perspective. Therefore, HRM is the result and reflection of the changes that occur in the enterprises. The scope of this concept is quite wide. All important activities in an employee's working life fall within the scope of human resource management. Major HRM activities include HR planning, job analysis, job design, employee recruitment, employee and manager compensation, employee motivation, and industrial relations. The role of human resource management is to plan, develop, and manage policies and programs designed to make optimum use of a business' human resources.

3 The Significance of Green HRM

The word green means environmentally friendly in its most basic sense. This concept has three meanings in human resource management. The first of these is the protection of the natural environment. Everything in the world that is not controlled by humans and includes land, forest, plants, animals, and other natural phenomena is called the natural environment. It means keeping nature in its original form and protecting it from damage, loss, or adverse change, paying great attention to the way of using nature in order for it to last as long as possible, and using it at the minimum level so that future generations can benefit. The second is the prevention or minimization of environmental pollution (Farooq et al., 2021). It is to stop polluting the water, air, and atmosphere through unpleasant and toxic substances and wastes and to protect against the consequences that will ultimately endanger the world in which people live. The third and last is the creation of gardens and natural-looking areas. It is used to create parks and places with plants, trees, and grass.

For long-term sustainability and development, businesses should not only focus on financial performance, but also actively consider all social and environmental aspects that can be influenced and controlled by them. The environment can create threats and opportunities for a business, so it should be actively considered by decision makers and the management team. Green HRM refers to all activities related to the development, implementation, and ongoing maintenance of an organization's system aimed at making its employees green (Ali et al., 2021). It aims to transform regular employees into green employees in order to achieve the environmental goals of the business and ultimately make a significant contribution to environmental sustainability. It refers to the policies, practices, and systems that make the employees of the organization green for the benefit of the individual, society, natural environment, and business. The aim of green human resource management is to create, develop, and maintain greening within every employee of the organization.

Green HRM is an element of sustainable human resource management to create value for company stakeholders by simultaneously considering efficiency and social and environmental aspects in HR processes. HR processes play an important role not only in the practical implementation of sustainable development policies, but also in the building of a sustainable development culture. Therefore, the human resource management method is a very important function to achieve environmental goals (Sabokro et al., 2021). Although the term green HRM is a newly emerging concept in today's business world, its importance and popularity are increasing day by day. Due to the increasing awareness of environmental management and sustainable development all over the world, this term is also among the popular topics recently researched in the literature. Today, the concept of Green HRM not only includes awareness of environmental issues, but also represents the social and economic well-being of both the organization and its employees in a broader perspective. Moreover, it is claimed that green human resource management is the most important element of sustainability.

Environmentally friendly activities are seen as a means to gain a new business opportunity and competitive advantage with the increasing popularity of the concept of sustainable development. According to eco-friendly principles, businesses should focus on not only economic but also social and environmental factors in order to achieve success. The main theme of the relevant activities is to increase the value of a business by: development of an effective business model based on environmental criteria, creation of environmental innovations related to permanent corporate development, distribution of tangible and intangible assets in the context of adopted environmental criteria, and environmental standard reporting (Marrucci et al., 2021).

The concept of green management for sustainable development tries to explain the need for a balance between industrial growth to create wealth and protecting the natural environment so that future generations can thrive. Implementing corporate green management initiatives requires high levels of technical and managerial skills among employees to develop innovation-driven environmental initiatives and programs that have a significant impact on businesses achieving sustainable competitive advantage. In this direction, it is important to implement rigorous recruitment and placement practices, performance-based evaluation systems, and training programs to raise environmental awareness of employees and to implement training materials for the development of new technical and managerial competencies.

Green human resource management (GHRM) can be defined as a set of policies, practices, and systems that promote the green behavior of a company's employees in order to create an environmentally responsible, resource-efficient, and socially responsible organization. In other words, it refers to the efforts to manage the effective human resource processes created in businesses in a way that does not harm the environment and even contributes to the environment. Green HRM is referred to as the implementation of policies and tools used to implement these efforts.

GHRM is a manifesto that helps create a green workforce that understands and appreciates green culture in an organization. Such a green venture can sustain its green goals throughout the company's HRM process such as recruiting, recruiting and training, compensating, developing, and advancing human capital. A company's HR department plays an important role in establishing a culture of sustainability within the company. HR processes play an important role in transforming the green HR policy into practice, so human capital and management are highly effective in achieving environmental management goals. It can be said that the human resource function is effective in realizing organizational change aimed at adapting to newly discovered requirements for companies and thus makes a potentially important contribution to such a strategic issue.

Green HRM emerges as a new concept in management and HRM literatures. The concept of green HRM should typically be integrated into functions of human resources such as recruitment and selection, training, performance appraisal, training and development, remuneration and benefits, and work–life balance to provide sustainable, environmentally friendly, and competitive advantage through employee engagement. Businesses can achieve significant success in participation, commitment, motivation, quality of work life, and retention through fair and equitable green

human resource management (Aboramadan & Karatepe, 2021). Green recruitment can be considered as one of the HRM practices that provide a business with an opportunity to promote green HRM initiatives to potential job applicants. Recruiting and retaining talented employees are recognized as the most challenging issues facing human resource managers in the global environment. On the other hand, job seekers also prepare themselves as green workers according to the international green culture standard. Environmentalist employees prefer businesses that provide environmental protection and social responsibility.

During the job analysis process, businesses should include environmental aspects in their job descriptions and clearly explain what is expected from the candidate in recruitment interviews. Secondly, in the orientation training given for new recruits, information should be given about the environmental protection policies, values, and green goals of the enterprise. Third, recruitment interviews should be designed to assess candidates' qualifications with business greening plans (Ansari et al., 2021). When interviewing candidates, environmental questions should form part of the interview process. In the studies conducted, it has been stated that in order for businesses to focus on environmental management aspects, they can design new jobs related to the environment or achieve success in their efforts to protect the environment by linking environmental tasks to job descriptions and performance targets. During the shortlisting of candidates, the selection criteria should be set up to select the best environmentally friendly candidate who is interested in the greening programs of businesses. Businesses are now beginning to understand the fact that building a reputation as a green employer is an effective way to attract new talent.

Green education and development stands out as one of the most important green human resource management practices needed for the success of green management in businesses. Environmental education is also considered as one of the most important tools for the development of human resources. It aims to draw people's attention to environmental concerns, to create a positive attitude, to take a proactive approach to greening initiatives, and to develop behavior to reduce waste and save energy (Parida et al., 2021). Green education and development develops employees on the value of environmental management, provides training opportunities in working methods that save energy, reduce waste, spread environmental awareness within the business, and provides an opportunity for employees to be involved in environmental problem-solving.

Studies have emphasized that environmental education is very effective in supporting the performance of the environmental management system. In addition, environmental education has a key role in the successful implementation of the environmental management system and the creation of a green organizational culture (Hooi et al., 2021). It has also been determined by the researches that it is important to evaluate the efficiency of the specialized and customized green employee training practices of the enterprises and also the effectiveness of the training program with a valid tool. It would be appropriate to include training on environmental protection, recycling, energy efficiency and safety, green analysis of the workplace, waste management, and environmental training in the training and development process.

The green reward system plays a vital role in motivating people and helps identify key performances toward environmental management. The purpose of introducing award criteria is to motivate people to perform well and understand the importance of environmental protection. The green reward system means aligning the system used by the business with green policies and practices (Ahmad et al., 2021). The reward system should be designed for the workplace, lifestyle, and reduction of carbon footprints. People should be rewarded for their interest in understanding and developing eco-friendly culture. There are many types of reward applications that businesses can use for green skills acquisition. The awards can be in the form of financial-based environmental management awards, nonfinancial environmental management awards, and environmental management awards for recognition.

Organizational performance is defined as the final result of the activities of all businesses. Organizational performance evaluates the current state of the business in terms of its efficiency and effectiveness. The resource-based theory states that synergy can be achieved by managing business resources in a way that will enable them to create positive performance and become the market leader (Nisar et al., 2021). The extent to which commercial enterprises implement environmentally friendly activities is an indicator of eco-performance, which leads to reducing the negative effects of production activities on the environment. Organizational environmental performance means the implementation of initiatives that positively affect the environment. Therefore, in order to enjoy protecting the environment, it is vital that businesses adopt effective environmental management practices. In the studies, it has been concluded that different green human resource management practices have a positive and significant effect on corporate performance and environmental performance. Green human resource management practices in the form of green recruitment, green training, and green rewards can improve and support corporate environmental performance and create competitive advantage.

4 The Influence of Green HRM on Carbon Emission Reduction

Understanding why it should be green illustrates the importance of green human resource management. To put it another way, greening is essential for the listed issues. These practices are essential to prevent or minimize global warming and to prevent natural disasters such as acid rains, red rains, floods, hurricanes, and droughts due to unrecorded, harmful, and excessive use of natural resources for production and consumption (Muisyo et al., 2021). The substances listed above are common causes of greening. When it comes to a particular business, we come across a concept called corporate social responsibility. This concept is defined as the extent to which an organization strives to improve the general well-being of society. To achieve corporate environmental goals or greening, green human resource requirements need to be defined.

Green human resource requirements can be examined under four headings: green competencies, green attitudes, green behaviors, and green outcomes. While these main types of green human needs are interrelated, each should be considered separately. The employee must have sufficient knowledge and skills on greening, and without these knowledge and skills, it is not possible for the employee to be a green employee (Rubel et al., 2021). Human resource management needs to have an active role in the development of cleaner technologies. Based on an organization's environmental strategy, HRM should provide the competencies needed to continually improve the organization's environmental performance. In addition, the employee must have the right greening attitude. Right attitude means appropriate beliefs, feelings, and intention to act about greening. Whatever the employee's job or area of expertise, it is important to have the right attitude toward greening.

Since environmental sustainability requires behavioral change of employees, all employees at all levels of an organization must exhibit a positive behavioral change. A critical green human resource requirement is green behavior, one dimension of which is green organizational citizenship behavior. The employee takes positive actions aimed at helping the business as a whole become environmentally friendly. These actions should not become part of formal business requirements (Paulet et al., 2021). First of all, voluntary green actions need to be carried out. Examples of such actions can be cited as follows. Electricity consumption can be reduced by using natural water instead of chilled water for drinking. Using both sides of the paper while making copies contributes to electricity savings. Coming to work by walking or public transport as much as possible will reduce carbon emissions. It is also important to shut down the computer when it is not working, rather than putting it into hibernation. This helps to reduce air pollution.

To ensure that the business receives the right green inputs and the right green business performance, it is imperative that HRM functions be adapted or modified to be green. Making an HRM function green requires incorporating policies, procedures, and practices that ensure the right green inputs and the right green business performance. Ideally, it is possible to make every function green. Below are suggestions on how to green some key HRM functions.

In job analysis studies, it would be meaningful and appropriate to include the environmental dimension in the job description and to include green competencies as a special clause in the employment contract. Including environmental criteria in the recruitment processes and emphasizing the employer's work on greening in job interviews will accelerate the transition to green human resource management. In training and development studies, it is important to conduct training needs analyzes in order to provide each employee with the right knowledge and skills about greening and to determine the green training needs of employees through a training program specially designed for greening (Molina-Azorin et al., 2021). While performing the performance evaluation, it is necessary to evaluate the job performance of the employee according to the criteria related to green and to add a separate title to the performance feedback interview for progress in greening. In discipline management, formulate and publish a code of conduct related to greening and

develop an advanced disciplinary system to penalize employees who violate the green code of conduct.

5 Conclusion

Carbon emissions harm the environment in a serious manner. Countries aimed to take various actions to solve this problem (Dong et al., 2022). Green HRM is one of the measures to be taken to solve this problem. For environmentally friendly energy consumption, the quality of the personnel working in the enterprises is also important (Zhang et al., 2022). The solution of the carbon emission problem will be easier if the environmental awareness of the employees is high. In this context, businesses should pay attention to these issues in the recruitment process (Kou et al., 2022). In other words, candidates with a high level of this awareness should be preferred. On the other hand, necessary training on environmental issues should be given to the personnel currently working in the enterprises (Mukhtarov et al., 2022). In this way, it will be much easier to save energy. This will contribute to environmentally friendly energy consumption (Bhuiyan et al., 2022). In the literature, many different scholars pointed out the importance of technological development in this area. For instance, Yüksel and Dinçer (2022), Dinçer et al. (2022), and Yüksel et al. (2022) identified that technological development is necessary for the improvement of the clean energy investment projects.

References

Aboramadan, M., & Karatepe, O. M. (2021). Green human resource management, perceived green organizational support and their effects on hotel employees' behavioral outcomes. *International Journal of Contemporary Hospitality Management.* https://doi.org/10.1108/IJCHM-12-2020-1440

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Ahmad, S., Islam, T., Sadiq, M., & Kaleem, A. (2021). Promoting green behavior through ethical leadership: A model of green human resource management and environmental knowledge. *Leadership & Organization Development Journal.* https://doi.org/10.1108/LODJ-01-2020-0024

Ali, M., Puah, C. H., Ali, A., Raza, S. A., & Ayob, N. (2021). Green intellectual capital, green HRM and green social identity toward sustainable environment: A new integrated framework for Islamic banks. *International Journal of Manpower*. https://doi.org/10.1108/IJM-04-2020-0185

Andersen, L. B., Leisink, P., & Vandenabeele, W. (2019). Public personnel policies and HRM: Developments within the field and in the (Long History) of the EGPA study group on public personnel policy. In *Public administration in Europe* (pp. 123–134). Palgrave Macmillan.

Ansari, N. Y., Farrukh, M., & Raza, A. (2021). Green human resource management and employees pro-environmental behaviours: Examining the underlying mechanism. *Corporate Social Responsibility and Environmental Management, 28*(1), 229–238.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Boxall, P., & Purcell, J. (2016). *Strategy and human resource management*. Palgrave Macmillan.

Buchanan, D., & Huczynski, A. (2004). *Organizational behaviour: An introductory text (instructor's manual)*. Financial Times/Prentice Hall.

Cvenkel, N. (2020). Historical and theoretical debates in human resources management and high-performing organisations. *Well-Being in the Workplace: Governance and Sustainability Insights to Promote Workplace Health* (pp. 11–24).

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Ding, Z., Yüksel, S., & Dinçer, H. (2021). An Integrated Pythagorean fuzzy soft computing approach to environmental management systems for sustainable energy pricing. *Energy Reports, 7*, 5575–5588.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Fang, S., Zhou, P., Dinçer, H., & Yüksel, S. (2021). Assessment of safety management system on energy investment risk using house of quality based on hybrid stochastic interval-valued intuitionistic fuzzy decision-making approach. *Safety Science, 141*, 105333.

Farooq, R., Zhang, Z., Talwar, S., & Dhir, A. (2021). Do green human resource management and self-efficacy facilitate green creativity? A study of luxury hotels and resorts. *Journal of Sustainable Tourism, 30*, 1–22.

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Hooi, L. W., Liu, M. S., & Lin, J. J. (2021). Green human resource management and green organizational citizenship behavior: Do green culture and green values matter? *International Journal of Manpower*. https://doi.org/10.1108/IJM-05-2020-0247

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Li, Y. X., Wu, Z. X., Dinçer, H., Kalkavan, H., & Yüksel, S. (2021). Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling. *Energy Reports, 7*, 95–108.

Marrucci, L., Daddi, T., & Iraldo, F. (2021). The contribution of green human resource management to the circular economy and performance of environmental certified organisations. *Journal of Cleaner Production, 319*, 128859.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., & Yüksel, S. (2021). A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financial Innovation, 7*(1), 1–34.

Molina-Azorin, J. F., López-Gamero, M. D., Tarí, J. J., Pereira-Moliner, J., & Pertusa-Ortega, E. M. (2021). Environmental management, human resource management and green human resource management: A literature review. *Administrative Sciences, 11*(2), 48.

Muisyo, P. K., Qin, S., Ho, T. H., & Julius, M. M. (2021). The effect of green HRM practices on green competitive advantage of manufacturing firms. *Journal of Manufacturing Technology Management.* https://doi.org/10.1108/JMTM-10-2020-0388

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy*.

Nisar, Q. A., Haider, S., Ali, F., Jamshed, S., Ryu, K., & Gill, S. S. (2021). Green human resource management practices and environmental performance in Malaysian green hotels: The role of

green intellectual capital and pro-environmental behavior. *Journal of Cleaner Production, 311*, 127504.

Opatha, H. H. D. N. P. (2021). A simplified study of definitions of human resource management. *Sri Lankan Journal of Human Resource Management, 11*(1).

Parida, S., Ananthram, S., Chan, C., & Brown, K. (2021). Green office buildings and sustainability: Does green human resource management elicit green behaviors? *Journal of Cleaner Production, 329*, 129764.

Paulet, R., Holland, P., & Morgan, D. (2021). A meta-review of 10 years of green human resource management: Is Green HRM headed towards a roadblock or a revitalisation? *Asia Pacific Journal of Human Resources, 59*(2), 159–183.

Rubel, M. R. B., Kee, D. M. H., & Rimi, N. N. (2021). The influence of green HRM practices on green service behaviors: The mediating effect of green knowledge sharing. *Employee Relations: The International Journal*. https://doi.org/10.1108/ER-04-2020-0163

Sabokro, M., Masud, M. M., & Kayedian, A. (2021). The effect of green human resources management on corporate social responsibility, green psychological climate and employees' green behavior. *Journal of Cleaner Production, 313*, 127963.

Soeters, J. (2020). Economics, logistics, and (human resources) management in military sciences. *Handbook of Military Sciences*, 1–16.

Storey, J. (1995). *Human resource management: A critical text*. International Thomson.

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Yuan, G., Xie, F., Dinçer, H., & Yüksel, S. (2021). The theory of inventive problem solving (TRIZ)-based strategic mapping of green nuclear energy investments with spherical fuzzy group decision-making approach. *International Journal of Energy Research, 45*(8), 12284–12300.

Yüksel, S., & Dinçer, H. (2022). Identifying the strategic priorities of nuclear energy investments using hesitant 2-tuple interval-valued Pythagorean fuzzy DEMATEL. *Progress in Nuclear Energy, 145*, 104103.

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022). Key issues for the improvements of shallow geothermal investments. In *Sustainability in energy business and finance* (pp. 183–194). Springer.

Yüksel, S., & Ubay, G. G. (2021). Determination of optimal financial government incentives in wind energy investments. In *Strategic outlook in business and finance innovation: Multidimensional policies for emerging economies*. Emerald Publishing Limited.

Zhang, Y., Zhang, Y., Gong, C., Dinçer, H., & Yüksel, S. (2022). An integrated hesitant 2-tuple Pythagorean fuzzy analysis of QFD-based innovation cost and duration for renewable energy projects. *Energy, 248*, 123561.

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

The Role of European Green Deal for Carbon Emission Reduction

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Abstract Global warming causes drought in the world so that agricultural production will decrease. With less production level, people's access to food will be difficult. As a result, there will be an imbalance of supply and demand and the problem of inflation will arise. Furthermore, health problems will occur as people cannot eat properly. Due to climate changes caused by global warming, there is also a decrease in water resources. The preference of fossil fuels in energy production is one of the most important reasons for this. As a result of the burning of resources such as coal and oil to produce electricity, a significant amount of carbon gas is released into the atmosphere. Therefore, countries need to increase their clean energy investments. However, the costs of these energy alternatives are very high compared to fossil fuels. This situation does not attract the attention of investors. Therefore, to use clean energy instead of fossil fuels in energy production, the level of awareness on this issue should be increased. The European Green Deal also focuses on solving this climate crisis. In this context, it is aimed to use environmental resources more consciously and efficiently. It is possible to mention certain aims of this study. First, the European Green Deal aims to produce without harming the environment and nature. On the other hand, the elimination of pollution is one of the aims of this study. In this framework, it is argued that the energy sector should be decarbonized and investments in environmentally friendly technologies should be increased.

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1 Introduction

Humanity always needs to produce with the aim of developing their nations and live with high-quality life standards. In order to produce, it is needed to consume natural resources. Until twenty-first century, there is no importance which resources should be used for producing and consuming products. However, natural disasters, rapidly increasing temperatures, forest fires, diseases, pandemic, energy wars, aridness, economic recessions, electricity cuts, and breakdowns in supply chains have given a signal about the future of the world.

The countries, international institutions, and unions have been attempting to prevent climate crisis. In 1972, the report of "Limits to Growth" was published by the Club of Rome and "sustainability" was investigated as a concept for the first time. Then, sustainable development was defined in Brundtland Report/Our Common Future in 1987 as: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987).

Also, international conferences maintained in 90s. After, Kyoto Protocol was in 1997 and it is going to be entered into focus in 2005. As one the one of the latest and most important progress in global sustainable development area is Paris Agreement and it was signed by 195 countries. Furthermore, 17 United Nations Sustainable Goals are published in order to realize until 2030. In 2019, The European Green Deal (EGD) was published. All of them is a guide for the activities and policies put forward to reduce socio-economic injustice from energy and create a sustainable world within the scope of combating and adapting to the climate crisis.

2 General Information About European Green Deal

European Green Deal is announced by European Commission in December 2019. As it is discussed before, the aim of the Paris Climate Agreement is to keep increase in temperature at 1,5oC and hold below 2oC (United Nations, 2015). Also, the common goal of EGD is to reduce carbon emission by 55% in 2030 and become zero-carbon economy in 2050 all European Union region (Gonzalez, 2021; Munta, 2020; Sikora, 2021). Furthermore, EGD is a roadmap to achieve carbon neutrality by setting a sustainable economy model. The aim of the EGD is "to transform the EU into a fair and prosperous society, with a modern, resource-efficient, and competitive economy where there are no net emissions of greenhouse gases (GHG) in 2050 and where economic growth is decoupled from resource use, to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts" (European Commission, 2019).

However, it is aimed to act together with all countries and their citizens, because it is stated that climate change and biodiversity loss are common problems for all world. So, collaborative movements are planning to achieve net-zero-carbon

emission in 2050. As Adams et al. (2020) said that the management of climate change adaptation (CCA) and disaster risk reduction (DRR) is significant for future. Therefore, cooperation of societies within all the world is required to achieve the EGD. On the other hand, the EGD put several elements such as supplying clean energy, creating sustainable circular economy and supply chain, toxic-free environment, setting healthy and environment-friendly food system, and enriching and protecting biodiversity. In this section, the subjects mentioned in the EGD will be discussed.

Policies and laws ensure formality and give ambition to implement their objectives. According to the roadmap for the EGD targets, policies will have made increasing EU's climate ambition for 2030 and 2050. As it is written in the EGD, Climate Law will have made in 2020. However, it is published on 9 July 2021 and entered into force on 29 July 2021 (European Commission, 2021). Within the scope the Climate Law, it is presented a legal objective to decrease net emission by 55% in 2030 when compared total GHG emission rate in 1990 and to reach carbon neutrality target for 2050. In addition to that, the Law mentioned about establishment European Scientific Advisory Board on Climate Change, provisions on adaptation to climate change, commitment for preparing roadmaps for sectors to set circular economy by keeping touch with sector players. According to the EGD, all policies for making happened. The Just Transition will be executed with a green oath: "Do no harm" which will consider sustainable environment, economy, and society.

On the other hand, energy consumption is one of the most critical issues to be net-zero emission. The EGD prioritizes energy efficiency. After industrial revolution, coal usage in production was rapidly increased. With regard of thar, CO_2 emission rate has started to rise in the world. Increasing CO_2 emission rate has been causing to increase temperature. So, energy resources, their emission rate, consumption style, and sustainability are crucial for green environment and economy. Within the scope of the EGD, it is denoted that coal mining will phase out and will use renewable energy (RE) resources which benefit consumer by decreasing energy bills derived by renewable resources. Also, renovating households' houses will reduce bills to the deal. Moreover, technologies for energy infrastructure such as energy storage and smart grid will be supported.

On the other hand, EU plans to become circular economy which is sustainable model of inclusive growth. In this point, industrial strategies are so important. The EGD stated that sustainable products which can recycle or reuse, supply chain, and trade policies will be supported to the eco-friendly economy. Thus, action will start from resource-intensive sectors such as textiles, construction, electronics, and plastics as first. To achieve the climate ambition, the additional fund is needed. So, the commission established and announced "The European Green Deal Investment Plan" as at least €1 trillion on 14 January 2020. Also, The Just Transition Fund is planned to assess between 2021 and 2027. These funds will be used in sustainable project for transition to circular economy within the carbon neutrality in EU. However, all of these cannot be only achieved if the European regions consider and comply with the practices of the EGD.

As it is discussed about what is the EGD and what it is included, there should be stated investment plan about the EGD. To adopt climate change, public and private investment plans are needed for being ready to any negative impacts such as building rainwater accumulation infrastructures against drought. EU would like to be world leader in circular economy and sustainable finance. They introduced themselves as a global leader for sustainable development and stated that they will work with international institutions such as United Nations, the G7, G20, the World Trade Organization. It is remarked that the commission is going to try to engage with G20 countries which are responsible for 80% of GHG in the world. Also, well-designed tax reforms will be in consideration for The Just Transition to ensure fair society and economic growth. Moreover, they give a commitment that all countries are going to comply to their standard, while they are making trade of products such as chemicals, iron, and steel.

Thus, it is thought and stated that it is necessary to act collaboratively with the whole world, and all societies should adopt and act these practices. In this context, it is decided to share funds, financial supports and without losing leadership, competitive advantage, and control of the EU. In addition to funding, policies, standards, taxonomies, and eco-labelling, new free trade agreements with countries that do not ratify the Paris Agreement and carbon border adjustment mechanism will be enabled for global climate action (Bektaş, 2021).

Carbon Border Adjustment Mechanism is going to be implemented, and it is going to be entered into focus in 2026. This mechanism is important to protect international competitiveness because current carbon pricing for decarbonization in the industry and trade system can negatively affect the competitiveness and cause a high risk which is carbon leakage to avoid carbon cost. Thus, new carbon pricing instrument is designed to omit carbon leakage problem for fair trade and achieve climate action. So, Carbon Border Adjustment Mechanism solves the problem and protects international competitiveness in trade. In imported products such as iron and steel, chemical will be levied to the quantity of their carbon emissions and goods will be taxed to their shortfall in carbon pricing. Therefore, domestic producers can be protected by preventing unfair carbon price mechanism across countries. The system is developing for setting fair pricing system in keeping balance export and import (Evans et al., 2021).

Within the scope of the circular economy action plan in the EGD, incentives will be given to sell and promote sustainable products by removing greenwashing. Also, waste management is in the scope of the EGD. Besides, reduction of wastes and usage as secondary raw material are going to be provided. Additionally, carbon capture technologies, energy storages, and R&D studies on technologic tools such as sustainable batteries, 5G, and ICT technologies will be supported. With regard of that, EU Emissions Trading System Innovation Fund also will use in order to contribute studies. Another planned action within the frame of the EGD is to renovate houses. According to the research, many of people do not keep warm their houses. Sustainable building constructions and regulations about buildings will provide efficiency. For instance, energy bills will reduce, they will be resilient and

adoptable to the climate change, construction sector, SMEs and local jobs will have supported.

Transportation system is another trigger for climate change. Particularly, globalization has increased mobility and become more intensive the supply chain mechanism in the world. In detail of transportation, the EGD included practices for rail and waterways and traffic management. As a goal in transportation is to end fossil-fuel subsidies. Also, healthy and environment-friendly food system is discussed in the EGD by denoting the "farm to fork" expression. With the suggested sustainable food system, it is aimed to rise soil and sea biodiversity. Also, it is planned Maritime Fisheries Fund for 2021–2027. Moreover, afforestation, forest preservation, oceans, and seas preservation within the scope of "blue economy" are in the plan of the EGD to protect forest, agricultural, aquatic, and marine resources. It is aimed to prevent and end air, water, soil, and consumer products pollution. Also, it is added in the EGD that is going to follow World Health Organization recommendations for air quality standards (European Commission, 2019).

3 The Role of European Green Deal to Reduce Carbon Emission

In the literature, there are vast of research about EGD. According to Claeys et al. (2019), they categorized the deal into four pillars as carbon pricing, sustainable investment, industrial policy, and transition. Carbon pricing is related to European trading system (ETS). In that point, it is referred that carbon border tax implementation will be getting more critical issue for importers and environmental standard should be determined. In second, social investment in a position to complete carbon pricing implementation. High carbon pricing can increase cost of products. Therefore, social and green investments should be promoted by giving incentives to keep balance of prices through banks and other financial institutions should be supported with European funds. With regard of these, it is needed to industrial policy for supporting technological infrastructures, green innovation, new implementations, and standards within the scope carbon pricing and investments. Lastly, it is suggested that European Globalisation Adjustment Fund might be expanded for easing transition from coalmining.

Furthermore, Eckert and Kovalevska (2021) investigated EGD discourse which is an official discourse included economics, business, and environmental science by announced Europe Commission. Moreover, it is about transition from unsustainable society to a sustainable society. However, some discourses in EGD can be ended up and understood opposed way. Besides, Sikora also argued that how EGD will be enforced in a fair way without being victimized no one. Its financial liabilities for green transition should be undertaken by all EU countries, states, and their citizens.

Also, circular economy model includes in the EGD. Within the scope of circular economy in EGD, raw material recycling, waste management, and mineral resources

are important elements for circular economy and transition to sustainable society (Smol et al., 2020). According to, Andreucci and Marvuglia (2021) it is emphasized that to achieve urban transition, the United Nations Sustainable Development Goals (SDGs) and the EGD in 10 years while they can be achieved in 30 years, might be possible with only green technological and R&D investment. In this context, these initiatives will become more easier for succeeding to combat and prepare against to climate change.

With EGD, social and green investments have started. However, pandemic has some negative impact on investment process. On the other hand, it is stated that environmental problem' importance has understood properly in post-pandemic term and EGD is needed to relaunch in order to realize Paris decarbonization agenda (Elkerbout et al., 2020; Fetting, 2020). EU should give importance to transformational technologies such as environmental buildings and low-carbon infrastructure for stimulating industry and trade system. Therewithal, environmental buildings are one of the key indicators in the EGD because of energy and GHG. In that point, Bonoli et al. (2021) stated that life cycle thinking and life cycle assessment are supportive tools for sustainable building and waste recycling.

There are discussions about energy transition for the EGS. As it is researched that changes effectiveness in energy sector have significant impact on sustainable development and have a key role for realizing the EGD. Hence, EU is a leader position for sustainable development. However, some EU member countries such as Poland, Bulgaria, Greece, Czech Republic, Luxembourg, and Lithuania are not able to make investment for realizing sustainable development within the scope of the EGD and Agenda 2030. Also, there are other factors such as geological conditions and having experience for energy transition. To realize green energy transition, technologic and social developments and strong policies are necessary (Hainsch et al., 2022; Tutak et al., 2021).

On the other hand, Leonard et al. (2021) remarked that energy transition will affect economy and trade balance in different geographies and relationships can change between EU and different countries in the world. EU should improve its relationship with oil–gas exporters such as Russia, USA, Algeria, and Saudi Arabia to expand economic diversification including green energy trade. Also, raw material dependency to China must be minimized and options to import raw material should be enriched. In sustainable finance and energy transition, global standards can be set. Moreover, climate clubs are important for carbon border adjustment. Additionally, global coalitions and making international EU budget, the EU Recovery and Resilience Fund, and EU policies are another partner strategies for EU and other countries.

Also, among member countries with Russia, energy transition can create problems because of divergent interests such as cost of energy (Hafner & Raimondi, 2020). According to Bektaş (2021), carbon border adjustment implementation is critical for export countries to make trade with EU. For example, Turkey is an important export country to EU in iron and steel industry. Energy intensities in iron and steel industry have the most significant impact on GHG emission and

low-carbon policies, and energy consumption should consider in Turkey for these sectors in order not to affect negatively by carbon border adjustment.

In this context, Simionescu et al. (2020) researched the effect of the RE in final consumption on GDP and global competitiveness index (GCI) within the scope of the EGD. Further, RE consumption positively influences economic growth and GCI. After the publication of the EGD, European Recovery Fund was established in 2020. Energy transition has one of the most important central roles in The Just Transition. Hence, photovoltaics can support the transition dramatically (Kougias et al., 2021). In another research, it is denoted that social inequalities must be reduced in order to get support for EGD. It is suggested that 1.8% of pre-COVID-19 GDP for public investment for realizing EGD in the next decades (Wolf et al., 2021). With regard of these, the persistence to EGD is another discussion topic because of economic crisis after pandemic.

As Siddi (2020) stated that European Commission is pursuing the climate actions by complying the EGD although there are obstacles in international level such as climate change deniers, economic slowdowns, pandemic, geographical crisis and so on. In that point, policy priority and green fund allocation should be supported to suit the EGD matters. Also, the additional allocation of funds for the EGD should be put to pre-existing budget and technologic and financial transfers to south countries can be useful for the climate action. Moreover, investment should be regulated and strong legal mandate for EU can provide to promote joining climate action for high emission countries such as USA, China, and Russia.

Furthermore, the policies in the climate action of the EGD are critical to be supported and ensured to join the movement and The Just Transition (Sabato & Fronteddu, 2020). Besides, EU policy mixes increased climate action ambitions. On the other hand, pandemic and its negative impacts are used by the EU as a strategy for empowering climate action (Skjærseth, 2021). In that point, different policy mechanisms are suggested. For example, Schoenefeld (2021) proposed that policy monitoring mechanism found suitable for the EGD governance through collecting and analysing data continuously to compare with expected and realized results. Although it is noted that policies will assure implementation of the EGD fast, Pianta and Lucchese (2020) said that current policies and regulations are not enough to create fair and sustainable economic outcomes for countries and to achieve socio-ecological goals in EU. Therefore, EU needs broader range of green industrial policies to obtain efficient and fair results from the EGD in terms of being carbon neutral in industry and economy. Also, LaBelle et al. (2021) stated about The Just Transition in the EGS and paid attention for energy justice, economy, and employment for coal-dependent countries such as Romania.

To achieve net-zero emission to the EGD, all fossil fuels and nuclear power plants have to be changed with 100% RE in Germany, and German EU Council Presidency should promote it by dealing with the member states to be part of the EGD's economic stimulus packages (Hainsch et al., 2020). Furthermore, Fleming and Mauger (2021) discussed The Just Transition by considering its aims, implementation, and who gets benefits. There are regions which will affect from the EGD a lot and the transition implementations cannot be fair for them. Thus, only proper

policies and legal framework can provide positive development for just and green transition. Also, it seems that citizens are highly complying the requirements of the energy efficiency and RE policies in the EGD (Ringel et al., 2021). As Piontek (2020) stated that, the EGD has positive and negative impacts for environment, economy, new industry and related jobs, society, and cultures.

4 Conclusion

The problem of global warming threatens the world very seriously. This problem causes drought in the world. As a result, agricultural production will decrease. With less production level, people's access to food will be difficult (Adalı et al., 2022; Dong et al., 2022; Du et al., 2020). As a result, there will be an imbalance of supply and demand and the problem of inflation will arise. In addition, health problems will occur as people cannot eat properly. Due to climate changes caused by global warming, there is also a decrease in water resources (Li et al., 2020; Li et al., 2021). If this problem is not resolved, people's access to water will be reduced. This situation will cause both social and economic problems to arise.

The preference of fossil fuels in energy production is one of the most important reasons for this. As a result of the burning of resources such as coal and oil to produce electricity, a significant amount of carbon gas is released into the atmosphere (Yüksel, Dinçer, Çağlayan, et al., 2022; Yüksel, Dinçer, Mikhaylov, et al., 2022). This gas causes significant environmental pollution. Therefore, to solve the global warming problem, alternatives should be preferred instead of fossil fuels in energy consumption (Haiyun et al., 2021; Kostis et al., 2022; Kou et al., 2022). The most popular alternatives in this process are renewable energy sources. These types of energy both contribute to the use of clean energy and help countries to produce their own energy.

It is clear that countries need to increase their clean energy investments. However, the costs of these energy alternatives are very high compared to fossil fuels (Liu et al., 2021; Meng et al., 2021; Mukhtarov et al., 2022). This situation does not attract the attention of investors. Therefore, to increase renewable energy investments, these projects should be provided with a cost advantage (Bhuiyan et al., 2022; Zhe et al., 2021). Nevertheless, significant technology investments are required to achieve this goal. In other words, it is not possible to reduce the costs of renewable energy projects significantly in a short time (Wan et al., 2022; Yuan et al., 2021; Zhao et al., 2021).

Therefore, to use clean energy instead of fossil fuels in energy production, the level of awareness on this issue should be increased (Yüksel & Dinçer, 2022; Zhang et al., 2022). The European Green Deal also focuses on solving this climate crisis. In this context, it is aimed to use environmental resources more consciously and efficiently. It is possible to mention certain aims of this study. First, the European Green Deal aims to produce without harming the environment and nature. On the other hand, the elimination of pollution is one of the aims of this study. In this

framework, it is argued that the energy sector should be decarbonized and investments in environmentally friendly technologies should be increased.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Adams, K. M., Klein, R. J., Pulquério, M., Bachofen, C., Barrott, J., Bentz, J., Bharwani, S., Bojovic, D., Brandon, K., Buschmann, D., Capela Lourenço, T., Coninx, I., Curl, M., Giupponi, C., Houtkamp, J., Karali, E., Leitner, M., Lokers, R., Michalek, G., et al. (2020). *Adapting to extremes: Key insights for bridging climate change adaptation and disaster risk reduction in the European Green Deal*. Placard.

Andreucci, M. B., & Marvuglia, A. (2021). Investigating, implementing and funding regenerative urban design in a post-COVID-19 pandemic built environment: A reading through selected UN sustainable development goals and the European green deal. In *Rethinking sustainability towards a regenerative economy* (pp. 395–413). Springer.

Bektaş, A. (2021). The impact of European green deal on Turkey's iron and steel industry: Decomposition analysis of energy-related sectoral emissions. *Celal Bayar University Journal of Science, 17*(1), 17–29.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Bonoli, A., Zanni, S., & Serrano-Bernardo, F. (2021). Sustainability in building and construction within the framework of circular cities and European new green deal. The contribution of concrete recycling. *Sustainability., 13*(4), 2139.

Claeys, G., Tagliapietra, S., & Zachmann, G. (2019). *How to make the European Green Deal work*. Bruegel.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Du, L., Dinçer, H., Ersin, İ., & Yüksel, S. (2020). IT2 fuzzy-based multidimensional evaluation of coal energy for sustainable economic development. *Energies, 13*(10), 1–21.

Eckert, E., & Kovalevska, O. (2021). Sustainability in the European Union: Analyzing the discourse of the European green deal. *Journal of Risk and Financial Management, 14*(2), 80.

Elkerbout, M., Egenhofer, C., Núñez Ferrer, J., Catuti, M., Kustova, I., & Rizos, V. (2020). The European green deal after corona: Implications for EU climate policy. *CEPS Policy Insights, 6*.

European Commission, (Regulation (EU) 2021/1119: European Climate Law), 2021, [Accessed 20.02.2022].

European Commission, (European Green Deal, https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf), 2019, [Accessed 19.02.2022].

Evans, S., Mehling, M. A., Ritz, R. A., & Sammon, P. (2021). Border carbon adjustments and industrial competitiveness in a European Green Deal. *Climate Policy, 21*(3), 307–317.

Fetting, C. (2020). *The European green deal*. ESDN Office.

Fleming, R. C., & Mauger, R. (2021). Green and just? An update on the 'European Green Deal'. *Journal for European Environmental & Planning Law, 18*(1), 164–180.

Gonzalez, C. I. (2021). Overview of global and European institutional sustainable finance initiatives. *Banco de Espana Article, 30*, 21.

Hafner, M., & Raimondi, P. P. (2020). Priorities and challenges of the EU energy transition: From the European Green Package to the new Green Deal. *Russian Journal of Economics, 6*, 374.

Hainsch, K., Göke, L., Kemfert, C., Oei, P. Y., & von Hirschhausen, C. R. (2020). European green deal: Using ambitious climate targets and renewable energy to climb out of the economic crisis. *DIW Weekly Report, 10*(28/29), 303–310.

Hainsch, K., Löffler, K., Burandt, T., Auer, H., del Granado, P. C., Pisciella, P., & Zwickl-Bernhard, S. (2022). Energy transition scenarios: What policies, societal attitudes, and technology developments will realize the EU Green Deal? *Energy, 239*, 122067.

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of european economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Kougias, I., Taylor, N., Kakoulaki, G., & Jäger-Waldau, A. (2021). The role of photovoltaics for the European Green Deal and the recovery plan. *Renewable and Sustainable Energy Reviews, 144*, 111017.

LaBelle, M. C., Bucată, R., & Stojilovska, A. (2021). Radical energy justice: a Green Deal for Romanian coal miners? *Journal of Environmental Policy & Planning*, 1–13.

Leonard, M., Pisani-Ferry, J., Shapiro, J., Tagliapietra, S., & Wolff, G. B. (2021). The geopolitics of the European green deal (No. 2021/04). Bruegel Policy Contribution.

Li, Y. X., Wu, Z. X., Dinçer, H., Kalkavan, H., & Yüksel, S. (2021). Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling. *Energy Reports, 7*, 95–108.

Li, X., Zhu, S., Yüksel, S., Dinçer, H., & Ubay, G. G. (2020). Kano-based mapping of innovation strategies for renewable energy alternatives using hybrid interval type-2 fuzzy decision-making approach. *Energy, 211*, 1–16.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*, 3687–3701.

Meng, Y., Zhou, R., Dinçer, H., Yüksel, S., & Wang, C. (2021). Analysis of inventive problem-solving capacities for renewable energy storage investments. *Energy Reports, 7*, 4779–4791.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy*.

Munta, M. (2020). The European Green Deal. Climate Change Energy and Environment.

Pianta, M., & Lucchese, M. (2020). Rethinking the European green deal: An industrial policy for a just transition in Europe. *Review of Radical Political Economics, 52*(4), 633–641.

Piontek, W. (2020). The European green deal and its impact on regional development processes. Rocznik Ochrona Środowiska, 22.

Ringel, M., Bruch, N., & Knodt, M. (2021). Is clean energy contested? Exploring which issues matter to stakeholders in the European Green Deal. *Energy Research & Social Science, 77*, 102083.

Sabato, S., & Fronteddu, B. (2020). A socially just transition through the European Green Deal?. ETUI Research Paper-Working Paper.

Schoenefeld, J. J. (2021). The European Green Deal: What prospects for governing climate change with policy monitoring? *Politics and Governance, 9*(3), 370–379.

Siddi, M. (2020). The European Green Deal: Assessing its current state and future implementation.

Sikora, A. (2021). European Green Deal–legal and financial challenges of the climate change. In *Era forum* (Vol. 21, pp. 681–697). Springer.

Simionescu, M., Păuna, C. B., & Diaconescu, T. (2020). Renewable energy and economic performance in the context of the European Green Deal. *Energies, 13*(23), 6440.

Skjærseth, J. B. (2021). Towards a European Green Deal: The evolution of EU climate and energy policy mixes. *International Environmental Agreements: Politics, Law and Economics, 21*(1), 25–41.

Smol, M., Marcinek, P., Duda, J., & Szołdrowska, D. (2020). Importance of sustainable mineral resource management in implementing the circular economy (CE) model and the European green deal strategy. *Resources, 9*(5), 55.

Tutak, M., Brodny, J., & Bindzár, P. (2021). Assessing the level of energy and climate sustainability in the European Union countries in the context of the European green deal strategy and agenda 2030. *Energies, 14*(6), 1767.

United Nations, (Our Common Future, https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf), 1987, [Accessed, 13.03.2022].

United Nations, (Paris Agreement, https://unfccc.int/sites/default/files/english_paris_agreement.pdf), 2015, [Accessed, 19.02.2022].

Wan, Q., Zhao, X., Liu, H., Dinçer, H., & Yüksel, S. (2022). Assessing the new product development process for the industrial decarbonization of sustainable economies. *SAGE Open, 12*(1), 21582440211067231.

Wolf, S., Teitge, J., Mielke, J., Schütze, F., & Jaeger, C. (2021). The European Green Deal—more than climate neutrality. *Intereconomics, 56*(2), 99–107.

Yuan, G., Xie, F., Dinçer, H., & Yüksel, S. (2021). The theory of inventive problem solving (TRIZ)-based strategic mapping of green nuclear energy investments with spherical fuzzy group decision-making approach. *International Journal of Energy Research, 45*(8), 12284–12300.

Yüksel, S., & Dinçer, H. (2022). Identifying the strategic priorities of nuclear energy investments using hesitant 2-tuple interval-valued Pythagorean fuzzy DEMATEL. *Progress in Nuclear Energy, 145*, 104103.

Yüksel, S., Dinçer, H., Çağlayan, Ç., Uluer, G. S., & Lisin, A. (2022). Bitcoin mining with nuclear energy. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022). Key issues for the improvements of shallow geothermal investments. In *Sustainability in energy business and finance* (pp. 183–194). Springer.

Zhang, Y., Zhang, Y., Gong, C., Dinçer, H., & Yüksel, S. (2022). An integrated hesitant 2-tuple Pythagorean fuzzy analysis of QFD-based innovation cost and duration for renewable energy projects. *Energy, 248*, 123561.

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 1–9.

The Dynamic Links Among Demand for International Reserves, Economic Growth and Clean Energy Consumption

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Abstract In this study, we use monetarist approach to answer the question of what determines the demand for international reserves. We show that real imports, volatility of balance of payments and import propensity are important determinants for the demand for international reserves. The negative sign we found for elasticity of average propensity to import supports that it is not a measure of openness but a proxy for adjustment cost. Additionally, significant and high value of coefficient of volatility of balance of payments shows that a rise in international capital mobility did not make volatility less important for central banks for their international reserve demand. Additionally, we discuss that level of reserves is crucial for a stable and sustainable economic growth. With the results showing that import propensity is a proxy for adjustment cost, we underline that holding optimal level of reserves is as important as sustainable energy consumption for stable growth.

1 Introduction

IMF (2011) defines reserves as foreign assets that are readily available and under control of monetary authorities to be able to fulfil balance of payments financing needs, to intervene in foreign exchange markets to influence the exchange rate, to

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sustain confidence in the currency and the economy and to serve as a base for foreign borrowing. This all can be summed up as stable growth.

A country's foreign reserves are the stock of foreign assets held by its central bank. They should be available to be transformed with certainty into another financial instrument and to be used to affect the value of that country's exchange rate (Cohen, 1975). International reserves are interpreted as unconditional liquidity and defined as gross reserves (Bahmani-Oskooee & Brown, 2002).

As detailed in the guidelines by the IMF (2011), reserves must be in foreign currency and should be in reach of the authority in case of a need. All should be marked-to-market. Contingent lines of credit should be excluded from foreign reserves unless they give immediate right to withdraw without any condition.

International reserve demand reflects the policy judgements of the reserve holders themselves and may or may not correspond to any objective assessment such as adequacy or optimality. So, the question should be what determines the level of international reserves held by the central banks. International reserve holdings can be regarded as a result of explicit policy decisions. The specification of alternative means of handling payment imbalances yields a demand function depending on the relative benefits and costs of the alternatives.

In this study, we test the determinants of the demand for international reserves. While doing this, we apply to the global monetarism from Johnson (1965).[1] Within this discussion, we underline the importance of propensity to import and show that propensity to import is not a measure for openness of the economy but a proxy for adjustment cost.

In the second chapter, we summarise the theory of macroeconomic approach to the demand for international reserves with specification to propensity to import. Third chapter gives the model, data and estimation result. In the fourth chapter, we will elaborate on the demand for international reserves, economic growth and energy consumption relations. In the last chapter, we discuss the results and conclusion.

2 The Demand for International Reserves

For almost all economies, holding prudent amounts of international reserves brings considerable advantages in conjunction with sound policies and fundamentals. IMF (2011) underlines smoothing the impact of external shocks as the main reason for the demand for international reserves. Generally accepted objective of holding international reserves is to prevent a crisis. Additionally, it is aimed to lower the sovereign risk premium by demonstrating payment capacity. Temporary balance of payments shocks may be financed either with reserves or with domestic tunings that can lead to

[1] In this study, following Bahmani-Oskooee and Brown (2002), we use the terminology as micro-economic and macroeconomic approach. However, Hipple (1974) names them as transactions and disturbances, respectively.

volatility in GDP. Reserves make it possible to smooth this adjustment, but holding them is not costless either.

After Triffin (1946)'s introduction, it is possible to divide the theory of demand for international reserves into two main branches. The microeconomic approach can be started with Heller (1966) who proposed a measure for optimal level for reserves and Olivera (1969) who offered a theory on demand for international reserves using Baumol (1952)'s square root rule where main determinants are adjustment and opportunity costs. And, the macroeconomic approach can be started with global monetarism from Johnson (1965). Johnson (1977) argued that balance of payment problems is monetary problems in a monetary world and should be analysed using models that explicitly specify monetary behaviour and integrate it to the real economy. This argument had its roots in Triffin (1946)'s proposal that the demand for reserves could be expected to increase over time with growth in global trade. The implied supposition that international reserves being related to money supply in one way or another allowed the argument to be named as international quantity theory (Williamson, 1973).

2.1 Macroeconomic Approach to the Demand for International Reserves

Demand for international reserves reflects the policy judgements of the reserve holders themselves and may or may not correspond to any objective assessment of the adequacy. So, the real question is what determines the level of international reserves that governments hold. International reserve holdings can be regarded as resulting from explicit policy decisions. The specification of alternative means of handling payments imbalances yields a demand function depending on the relative benefits and costs of the alternatives.

It is possible to classify policies for reducing current account deficits into two categories as expenditure-reducing policies and expenditure switching policies (Cooper, 1968). Monetary policy could be used to attract foreign capital, and the unwanted effect on the economy could be offset by a more expansionary fiscal policy. However, this does not only require a very flexible policy and well-developed credit markets but also creditors that are ready to invest into the country.

The relation between income and trade and economic disturbances and payment imbalances is highly complex. Cooper (1968) identifies balance of payments disturbances with respect to three aspects. First is exogenous disturbance arising from changes in tastes, technology, and government demand. Second one is the disturbances coming from a disturbance in another country, and the last one is the ones arising from the effects of policy responses. About the second one, marginal propensities to import, price elasticities of demand for import and supply of exports and the interest sensitivity of capital become the important issues. For the last one, the main problem is that sometimes governments think that they can solve their

balance of payments problems independently from the world economy. This may cause heavy burden on the international reserves. Otherwise, country has to face big adjustment costs by a big volatility in the growth, rise in unemployment rate, and even a reduction in the GDP.

Johnson (1965), by employing $\Delta R = \Delta M^d - \Delta M^s$, argued that if money supply ΔM^s grows slower than demand ΔM^d, then international reserves of the country will go up as the excess demand is satisfied by the inflows. On the contrary, if money supply is more than the money demand, money will run out and the country's international reserves will decline.

Macroeconomic approach does not differentiate the current account from capital account. It looks balance of payments in total. Additionally, it accepts the country's international reserve size not as an objective but as a constraint. The standard approach is that the international reserve demand is a result of rise in the global trade (Williamson, 1973). There is a consensus that the demand for international reserves can be explained by the changes in the domestic money supply (Bahmani-Oskooee & Brown, 2002).

Machlup (1966) examined Triffin's reserves to imports ratio and argued that the demand for reserves is linked not on Triffin's level but on the variability of trade. Heller (1966) argued that optimal level of international reserves emerges when the total cost of adjusting and financing a payment disequilibrium is minimum. Accordingly, a country that accumulates international reserve as insurance, such as financing deficits and speculation, will discover that the marginal benefit of keeping extra international reserve goes down, as the marginal cost of not keeping them goes up. Cost of adjustment is equal to inverse of the propensity to import (1/m).

Clark (1970) added stochastic model on Heller's approach and argued that to optimize, each central bank selects a target level of international reserves with a preferred level of correction, γ. At the same time, γ is a component of inconsistency between the actual international reserve level and the target level R^*. He argued that there is a utility curve with different combinations of target average reserve level and a preferred level of correction, maintaining a stationary probability of international reserve depletion. Higher target foreign reserve means less rapid adjustment (smaller γ), whereas a higher R^* also means less income in terms of foregone investment.

Lizondo and Mathieson (1987) added an optimizing module to the Heller's (1966) model, and by this way, the pace of adjustment for net international reserve position has been added into the function. Ben-Bassat and Gottlieb (1992) claimed that the adjustment costs of a fall in central banks' international reserves, reducing GDP and so imports, cannot catch the cost of default matched by an economy that is borrowing international reserves. Anayiotos (1992) offered a maximizing scenario suggesting that, because speed of adjustment to desired international reserves is much higher, an economy can afford to hold international reserve if its capital account is flexible with regard to interest rates. Following Miller and Orr's (1966) approach, Claassen (1975) accepted the international reserve issue is an inventory problem. Grimes (1993) discussed that, if the cost of opportunity is not small or monetary authorities do not have elevated risk-averse preferences regarding an

international reserve exhaustion, central bank international reserve-holding behaviours differ among a floating and a fixed rate regime.

2.2 Propensity to Import and International Reserves

During this discussion, along with other variables, the import propensity (m) attracted particular interest. It has been suggested that the demand for international reserve function depends also on the propensity to import (Britto & Heller, 1973; Clark, 1970; Flanders, 1971; Frenkel, 1974; Heller, 1966; Hipple, 1974; Iyoha, 1976; Kelly, 1970).

While choosing a variability measure as an argument for the international reserve demand function arises from the role of them serving as a buffer stock accommodating fluctuation in foreign imbalances, the justification for the use of the import propensity as an argument is not that simple (Frenkel, 1978). Keynesian priceless foreign trade multiplier[2] suggests that if there is a foreign deficit and the authorities do not prefer or cannot use either international reserves or foreign borrowing to finance this deficit, the deficit will be reduced only by a decline in output proportional to foreign trade multiplier (Frenkel, 1978). As Heller (1966) argued, the marginal adjustment cost is equal to the inverse of its marginal import propensity and it affects the demand for international reserves negatively. As a result of excepting the primary purpose of international reserves to protect current consumption from a shock to the current account, the net deficit is accepted as the cost of international reserves (Landell-Mills, 1989).

Higher propensity means smaller multiplier. This implies lower adjustment cost of an external deficit and less demand of international reserves (multiplier = 1/(sum (import propensity + save + tax)). Marginal cost of an adjustment is given by the size of the foreign trade piece in the expenditure multiplier ($1/m$). Whereby relatively small changes in income would cause considerably large adjustments in imports, higher marginal propensity to import would allow fewer international reserves. Larger the (m), the smaller the marginal cost of adjustment ($1/m$), implying that a country can use expenditure-reducing policies less costly.

Contrariwise, if this ratio is taken to represent the openness, and so indicating the vulnerability of the economy to external shocks, as has been argued by Cooper (1968) and Iyoha (1976), then the relationship would be a positive one. A rise in openness must be related to higher international reserve holdings. Accordingly, the demand for international reserves must be positively linked with the import propensity.

[2] An increase in exports results in an increase in the income of all export-related agents. This increases the demand for goods. However, here marginal propensity to save and import is decisive. The smaller they are, the larger the value of multiplier will be and vice versa.

Kelly (1970)'s results with a positive relationship between import propensity and foreign reserve demand supported the openness idea. Frenkel and Jovanovic (1981) and Frenkel (1983) also found positive elasticity and interpret average import propensity as a proxy of the openness. Cohen (1975) and Lizondo and Mathieson (1987) found similar results supporting this idea.

However, Heller and Khan (1978) found a negative result and evaluate the average import propensity as a proxy for the marginal adjustment cost. Additionally, Bahmani-Oskooee (1985), and Landell-Mills (1989) all backed Heller (1966) and found a negative causality between propensity to import and international reserve demand. They underlined that Keynesian adjustment route is valid. In this study, we test this argument with a much wider and up-to-date data.

3 Research Model and Estimation Results

As we discussed above, Heller (1966) argued that the cost of an adjustment is given by the size of the trade piece of a country's expenditure multiplier. Britto and Heller (1973) added that the optimal amount of adjustment is inversely related to the stock of reserves. It will be advantageous for a country, with large amounts of international reserves, to do less adjusting. Consequently, the common view was that the propensity to import is an important determinant of the demand for international reserves, and it was accepted to be a sign of adjustment cost. However, Kelly (1970) unexpectedly found a positive relationship between the demand for international reserves and the propensity to import. Cooper (1968) offered an alternative explanation as that shows the openness of a country to external disturbances.

Kelly (1970)'s model yields an optimal level of reserves for a government attempting to maintain external and internal balance. The cost of international reserves is the income lost incurred by holding them. This is the social opportunity cost of capital less any yield obtained on the international reserve holdings themselves. The higher this capital cost, the greater is the incentive to economize on international reserve holdings and to allow greater fluctuations in income. This model yields an optimum average level of international reserves using exogenous changes in the balance of payments, the marginal propensity to import, the opportunity cost of capital, and preferences between the level of income and its volatility. Using the standard deviation of exports provided the advantage of reducing the simultaneity problem arising from the possibility that, instead of being exogenous, parts of the payments balance such as imports can be influenced by adjustment policies. Assuming such preferences is similar across countries, average international reserve holdings can be attributed to three variables.

$$\ln R_t = \beta_0 + \beta_1 \ln M_t + \beta_2 \ln VR_t + \beta_3 \ln m_t + \varepsilon_t \tag{1}$$

where, R represents the real international reserves of the country, M the real imports, and VR the balance of payments volatility and m the average import propensity.

With the assumption that as real imports go up, a country requires more international reserves, and the sign of β_1 must be positive. The existence of a volatility measure of balance of payments is a result of the demand for international reserve function stemming from the role of international reserves as a buffer stock necessary to compensate for fluctuations in external transactions. The higher the volatility of balance of payments, the more the need for international reserves, implying a positive β_2. The reasoning for inclusion of the average import propensity comes from the Keynesian trade multiplier. As the propensity goes up, smaller is the multiplier implying lower adjustment cost because of an imbalance and less international reserve demand. As a result, β_3 is expected to have a negative sign.

Kelly (1970), using annual data of 46 countries for over 13 years between 1953 and 1965, regressed international reserve demand on import propensity and opposite to expectation, found positive relation between demand for international reserves and for marginal propensity to import. Cooper (1968) tried to explain this arguing that propensity to import is a proxy for the openness of a country to external imbalances. Cooper (1969) even provides a numerical example. Separately, Williamson (1973) argued that this relation can show that authorities opt expenditure switching policies to the expenditure-reducing policies for effecting adjustment.

In this study, we apply Kelly's model to find out what determines the international reserve demand and how does the import propensity affect the international reserve demand. Following Kelly (1970) and Bahmani-Oskooee and Brown (2004), we measure the exogenous shock disturbances in the balance of payments with the standard deviation of exports of goods and services over the former 4 years and the prevailing year. Kelly (1970) claims that exports may not be completely exogenous and not all imports endogenous, but this bifurcation allows direct measurement and is more reasonable than any simple alternative.

Data cover 177 countries of 58 years for the period between 1960 and 2018. The data used in the study are obtained from the World Bank. An important reason for using panel data is to solve the omitted variables problem. It is important to know if the unobserved effect is correlated or uncorrelated with the explanatory variables (Wooldridge, 2002). If it is not correlated, fixed-effects model can be applied. Otherwise, random-effects model is preferred. Under the random-effects model, the goal is not to estimate one true effect but to estimate the mean of a distribution of effects. Random-effects model assumes that each series of data provides information about a different effect size, and so we prefer to make sure that all these effect sizes are presented in the estimate. But so, the standard error and the confidence intervals are wider under the random-effects model. However, fixed-effects model assigns more precise weights to each series and has smaller standard errors and tighter confidence intervals. This makes fixed-effects model more suitable if the goal is to estimate the true effect.

The Durbin–Wu–Hausman (DWH) test detects endogenous predictors in a regression model. Since OLS assumes no correlation among a predictor and the error term, endogenous predictors in a model will produce a failure in ordinary least-squares regressors. In this case, instrumental variables regressors can be used as an option. But first, one must find out if the predictors are endogenous or not

Table 1 Estimation results

Variable	Number of observations	Mean (thousand)	Standard deviation	Coefficient	Maximum (million)	Adf (p value)
Total real reserves	5204	26,916,619	137,467,943			
Real imports	5204	86,823,942	337,497,978	0.2323*	0.0852	0.00
Variability measure	5204	6,979,629	27,822,259	0.8669*	0.0066	0.00
Average Propensity to import	5204	0.47	0.50	−0.3335*	0.0265	0.00

Note: * denotes the level significance at 1%

(Wooldridge, 2002). Hausman test is considered, and it was possible to reject the null hypothesis that error terms and constants of each country are related to each other, so the fixed-effects model is preferable. We run the estimation with fixed effects. Unit root tests are carried out, and all variables are found to be stationary (Table 1).

$$\ln R_t = 3.9335 + 0.2323 \ln M_t + 0.8669 \ln VR_t - 0.3335 \ln m_t + \varepsilon_t \qquad (2)$$

$$\text{Adj}R^2 = .79 \quad n = 5204$$

The standard errors for Eq. (2) show that all three independent variables are statistically significant with a confidence level of 99%. Moreover, the results implicate that the variables are economically significant with expected signs.

The coefficient of real imports has expected positive sign, supporting the aspect that a country will need more international reserves as real imports go up. The coefficient of variability measure (volatility of balance of payments) being positive and much larger than the other two coefficients, shows that, opposite of Heller (1966)'s classical claim, international reserves' role as buffer stock is still the most important determinant.[3] The coefficient of average propensity to import having a negative sign supports that it is not a measure of openness but a proxy for adjustment cost. So, it is possible to say that the Keynesian adjustment route is valid.

[3] Arslan and Cantu (2019) recommend countries take alternative policies such as macroprudential policies to lower their demand for international reserves with precautionary motives.

4 International Reserves and Energy Consumption

Optimal reserve formulas are derived by a cost–benefit approach (Frenkel & Jovanovic, 1981; Hamada & Ueda, 1977; Jeanne & Rancire, 2011). The cost of international reserves is described as the difference of the return on capital from return on international reserves, while benefit is minimizing the adjustment cost. Alias, marginal productivity of capital takes part in the optimal level of international reserve formula within the description of the cost of international reserves (Mihailov & Nasir, 2020).

4.1 Productivity, Economic Growth and International Reserves

Edwards (1985) describes the cost of international reserves with the gap between the borrowing rates of a country from the return on its international reserves. Ben-Bassat and Gottlieb (1992) add a condition to this idea that the marginal borrowing rate is not smaller than the marginal productivity of capital. They argue that this is a result of market defects. With globalization, the opportunity cost of international reserves has begun to be calculated with the difference of the interest paid on external borrowings of a country from return on its international reserves (Garcia & Soto, 2004; Jeanne & Rancire, 2011; Rodrik, 2006). Mihailov and Nasir (2020) claim that recent studies on optimal levels of international reserves, disregard the relation between capital productivity and the international reserve demand.

Bonfiglioli (2008) defines total factor productivity and capital accumulation as the major sources of growth and investigates the effects of financial globalization on growth with regard to these sources. She analyses the impacts of financial globalization on aggregate productivity and capital accumulation. Regressing investment and productivity on international liberalization, she studies if total factor productivity and capital response differently between developed and developing economies. She concludes that international liberalization has a positive effect on total factor productivity. Financial crises damage not only capital accumulation but also productivity. She cannot find enough support for the hypothesis that financial integration affects productivity and investment by assisting financial deepness.

Kose et al. (2009) investigate the relation between financial openness and total factor productivity growth. They find that financial openness has a positive effect on total factor productivity growth. They also find strong support that foreign direct investments and equity liabilities strengthen total factor productivity growth while external debt negatively affects.

Mourmouras and Russel (2009) examine the demand for international reserve with regard to capital liquidation and short-term liabilities of a small open economy. They propose that short-term debt help countries to increase investment and reach better real wages in good times. However, capital inflows may be a reason for

instability if a country faces a sudden stop. To prevent from that, countries need international reserves. With enough amount of international reserves, central banks can reduce and even remove the impacts of capital liquidation on wage volatility and prosperity.

Cheng (2015) argues that international reserve demand is a result of the interaction between productivity growth and underdeveloped financial market. Exhibiting that the emerging market firms with external credit constraint need domestic saving instruments, he defines the role of central bank to be a financial intermediary and supply liquidity to the firms to relax the external constraint. He establishes his model on three facts of emerging market economies. First, emerging market economies experimented rapid growth and gathered big amounts of international reserves. Relation between the growth and the reserves' level can be accepted as part of a catch-up strategy for emerging market countries. Second, these economies lack foreign capital. Third, there is big gap between domestic savings and loans in many emerging market economies. Cheng (2015) discusses that international reserves determine growth by fixed capital formation. There is a relation between the international reserve demand and gross fixed capital information. To be able to lower the demand for international reserves, Cheng (2015) argues that financial market deepness in the country should be developed.

Benigno et al. (2021) offer a model for rapid-growing emerging market economies with current account surpluses that have high levels of international reserves and had inflows. They characterize the monetary system with rapidly growing emerging economies that have positive current accounts, accumulating international reserves and receiving net private inflows. They investigate the private and public inflows in emerging market economies underlining distinctions across the tradable sector and non-tradable sector. Tradable sector has growth externality, and agents have imperfect access to financial markets. With international reserves, governments stimulate a real exchange rate depreciation and cause orientation of production to the tradable sector boosting growth. Benigno et al. (2021) argue that international reserves are crucial instruments in governments' strategies with regard to growth externalities and financial stabilization. A rise in international reserves leads to depreciation in the currency and to orientation of production to the tradable sector, increasing the need for intermediate imports, for the foreign know-how and induces growth in productivity. Whereby, this relies on faulty sustainability of private and public flows.

Using a simple neoclassical investment framework that allows to investment projects, capital liquidation, and short-term foreign currency debt, Gourinchas and Jeanne (2013) question high amounts of international reserves held by indebt countries. They implicitly assume that productivity growth pulls inflows. They intend this as an explanation of infrequent but severe shocks that cause creditors to call loans early and force firms to liquidate.

They exhibit that liquidation and debt are helpful in good times. Companies increase investment and workers enjoy capital intensity and get better wages with regard to an equilibrium in which fire sales are not possible. Whereby, they find opposite results for bad times. Liquidation generates instability if the economy is hit

by large shocks. Capital–labour ratio goes down because of liquidation. While the wage volatility increases, workers cannot insure against it. Since labour market frictions prohibit rapid wage adjustments, workers loss increases.

They name this as 'allocation puzzle' and offer a solution, where growth, savings and international reserve accumulation work together. They show that it is more related to saving and the reserve accumulation than to investment.

4.2 Energy Consumption, International Reserves and Economic Growth

Increasing efficiency in energy consumption is accepted to be a result of more efficient production methods that have evolved over time, implying sustainability in the production process. Rajaguru and Khan (2021) analyse the decreasing trend of energy intensity and the related volatilities in energy consumption and income growth. They show that there is both long- and short-run causal connection between growth and energy use in terms of energy intensity. Their results suggest that energy intensity is falling. They find remarkable reduction in energy use as a response to rising volatility in income.

As we discussed in the previous chapters, international reserves do not only have positive effect on the economic growth but also help to stabilize by preventing the crisis and so the adjustment costs that may arise. Energy consumption, international reserves and economic growth are related and significantly important in a nation's prosperity. The studies on the relation between GDP and energy consumption (oil, electricity, natural gas and coal) and international reserve display contrasting results (Khan et al., 2015).

It is important to identify the nature of relation between the economic growth and energy and reserves. This knowledge is critical for sustainable growth. The different direction of causal relation between energy consumption and economic growth is found to be bidirectional in India (Paul & Bhattacharya, 2004). But this is not same in all studies, but there is only one concrete conclusion that demands for international reserves, economic growth and energy consumption are all related to each other (Khan et al., 2015).

It is important to find out the dynamics of this relation for both sustainable energy consumption and growth. While growth is very important for every country, sustainable growth requires energy. Shortcoming in energy or international reserves adversely affects the economic growth and so the employment. On the other side, as economy grows, both demand for international reserves and for energy consumption rises.

The relation between international reserves, economic growth and energy consumption is important not only for the government and the citizens of the country but also for the potential investors to the country. We have shown that having sufficient international reserves is essential for stable growth. The same is true for energy

resources. Investors prefer countries that have sustainable growth and have the capacity to pay their debts. This makes the topic more crucial.

While there is a consensus on the strength of the relation between economic growth and energy consumption, causality is not that clear. Khan et al. (2015) argue that, in addition to trade openness and inflation, international reserves are also a significant factor on the economic growth. They claim that international reserves accelerate the economic growth. Reserves do this by building confidence in the country, thus creating a favourable environment for both domestic and foreign investors.

Khan et al. (2015) study economic growth, oil consumption, electricity consumption, natural gas consumption, coal consumption and international reserves for energy–growth relationship. They conclude that international reserve is the major indicator causing an impact on GDP and recommend to government to take an action to reduce taxation on foreign remittances and to increase the level of international reserves.

5 Conclusion and Discussion

International reserves have a role in achieving policy targets and preventing potential financial crises. The demand function should depend on the relative benefit and cost of the alternatives. The higher the costs, the greater the incentives to economize on international reserves and to allow greater fluctuations in income. With this approach, exogenous disruptions in the balance of payments, the average propensity to import, the opportunity cost of capital and the preferences between level of income and its volatility are tested in this study. For the estimation, fixed-effects panel data methodology is used.

The import propensity attracted particular interest due to the uncertainty of its sign in the demand for international reserve function. While some argue it is a sign of openness, others argue that is a proxy for the adjustment cost measure. With wide, long and up-to-date data set, we have found that propensity to import has negative, while other variables had coefficient estimates with positive signs. Thus, we have shown that average propensity to import is not a sign of openness, but it is a proxy for the adjustment cost. As the Keynesian priceless foreign trade multiplier suggests, if there is a foreign deficit and the authorities do not prefer or cannot use either international reserves or foreign borrowing to finance this deficit, the deficit will be reduced only by a decline in output relative to foreign trade multiplier.

Coefficient of variability measure (volatility of balance of payments) being positive and much larger than the other two coefficients showed that international reserves' role as buffer stock is still the most important determinant. It is still a crucial issue for monetary authorities. High international capital mobility does not allow central banks to ignore volatility. They still prefer to hold more reserves to reduce adjustment costs that can arise from an external imbalance. And this is consistent with the central banks' motives for their reserves, ranking them in terms

of security, liquidity and returns, respectively. Central banks invest their reserves in safe instruments. They want them to be liquid so that they can always be referenced. The return can be considered only after these conditions are met.

Lastly, we discussed that international reserves are also related to marginal productivity of capital. Adequate level of international reserves is crucial for a stable and sustainable economic growth. Indispensability of stable growth is evident for sustainable energy consumption, vice versa. Import propensity by being proxy of adjustment cost, instead of being a measurement of openness, supported the importance of international reserves in achieving this steady growth path. International reserves by helping to smooth the GDP growth will support to achieve sustainable energy consumption. Being a major indicator on GDP, we recommended developing countries' governments to hold adequate levels of international reserves.

References

Anayiotos, C. A. (1992). Capital account effects on optimum international reserves and the speed of adjustment. *Economic Notes, 21*, 330–340.

Arslan, Y. & Cantu, C. (2019). The size of foreign exchange reserves. *BIS Paper*s, No: 104a.

Bahmani-Oskooee, M. (1985). Demand of and supply of international reserves: A simultaneous approach. *Journal of Post Keynesian Economics, 7*(4), 493–503.

Bahmani-Oskooee, M., & Brown, F. (2002). Demand for international reserves: A review article. *Applied Economics, 34*(10), 1209–1226.

Bahmani-Oskooee, M., & Brown, F. (2004). Kalman filter approach to estimate the demand for international reserves. *Applied Economics., 36*(15), 1655–1668.

Baumol, W. J. (1952). The transactions demand for cash: An inventory theoretic approach. *Quarterly Journal of Economics, 66*(4), 545–556.

Ben-Bassat, A., & Gottlieb, D. (1992). Optimal international reserves and sovereign risk. *Journal of International Economics, 33*(3–4), 345–362.

Benigno, G., Fornaro, L. & Wolf, M. (2021). Reserve accumulation, growth and financial crises (Updated version). *Economic Working Paper Series* Working Paper No. 1795, Universitat Pompeu Fabra.

Bonfiglioli, A. (2008). Financial integration, productivity and capital accumulation. *Journal of International Economics, 76*(2), 337–355.

Britto, R., & Heller, H. R. (1973). International adjustment and optimal reserves. *International Economic Review, 14*(1), 182–195.

Cheng, G. (2015). A growth perspective on foreign reserve accumulation. *Macroeconomic Dynamics, 19*(6), 1358–1379.

Claassen, E. M. (1975). Demand for international reserves and the optimum mix and speed of adjustment policies. *American Economic Review, 65*(3), 446–453.

Clark, P. B. (1970). Demand for international reserves: A cross-country analysis. *Canadian Journal of Economics, 3*(4), 577–594.

Cohen, B. J. (1975). International reserves and liquidity, in the International trade and finance: Frontiers for research, ed. by P.B. Kenen, Cambridge University Press.

Cooper, R. (1968). The relevance of international liquidity to developed countries. *American Economic Review, 58*(2), 625–636.

Cooper, R. (1969). Macroeconomic policy adjustment in interdependent economies. *The Quarterly Journal of Economics, 83*(1), 1–24.

Edwards, S. (1985). On the interest-rate elasticity of the demand for international reserves: Some evidence from developing countries. *Journal of International Money and Finance, 4*(2), 287–295.

Flanders, M. J. (1971). *The demand for international reserves*, Princeton Studies in International Finance No: 27.

Frenkel, J. (1974). The demand for international reserves by developed and less-developed countries. *Economica, 41*(161), 14–24.

Frenkel, J. (1978). International reserves under alternative exchange rate regimes and aspects of the economics of managed float. *NBER Working Paper*, No: 287.

Frenkel, J. (1983). International liquidity and monetary control. *NBER Working Paper*, No: 1118.

Frenkel, J. A., & Jovanovic, B. (1981). Optimal international reserves: A stochastic framework. *The Economic Journal, 91*(362), 507–514.

Garcia, P. & Soto, C. (2004). Large hoardings of international reserves: Are they worth it?. *Central Bank of Chile Working Paper*, No: 299.

Gourinchas, P. O., & Jeanne, O. (2013). Capital flows to developing countries: The allocation puzzle. *Review of Economic Studies, 80*(4), 1484–1515.

Grimes, A. (1993). International reserves under floating exchange rates: Two paradoxes explained. *The Economic Record, 69*(4), 411–415.

Hamada, K., & Ueda, K. (1977). Random walks and the theory of the optimal international reserves. *Economic Journal, 87*(348), 722–742.

Heller, H. R. (1966). Optimal international reserves. *The Economic Journal, 76*(302), 296–311.

Heller, R., & Khan, M. (1978). The demand for international reserves under fixed and floating exchange rates. *IMF Staff Papers, 25*(4), 623–649.

Hipple, F. S. (1974). *The disturbances approach to the demand for international reserves*. Princeton Studies in International Finance No:35.

International Monetary Fund. (2011). *Assessing reserve adequacy*, Washington, DC.

Iyoha, M. A. (1976). Demand for international reserves in less developed countries: A distributed lag specification. *The Review of Economics and Statistics, 58*(3), 351–355.

Jeanne, O., & Rancire, R. (2011). The optimal level of international reserves for emerging market countries: A new formula and some applications. *Economic Journal, 121*(555), 905–930.

Johnson, H. H. (1965). *International trade and economic growth: Studies in pure theory* (2nd ed.). Allen and Unwin.

Johnson, H. G. (1977). The monetary approach to balance of payments theory and policy: Explanation and policy implications. *Economica, 44*(175), 217–229.

Kelly, M. G. (1970). The demand for international reserves. *The American Economic Review, 60*(4), 655–667.

Khan, F., Haider, A., Shaheen, F., & Zaman, M. (2015). Energy resources, foreign exchange reserves and economic growth: Empirical evidence from Pakistan. *American-Eurasian Journal of Agriculture and Environmental Science, 15*(9), 1740–1752.

Kose, A. M., Prasad, E. S., & Terrones, M. E. (2009). Does openness to international financial flows raise productivity growth? *Journal of International Money and Finance, 28*(4), 554–580.

Landell-Mills, J. M. (1989). The demand for international reserves and their opportunity cost. *IMF Staff Papers, 36*(3), 708–732.

Lizondo, J. S., & Mathieson, D. J. (1987). The stability of the demand for international reserves. *Journal of International Money and Finance, 6*(3), 251–282.

Machlup, F. (1966). The need for monetary reserves. *Banca Nazionale Del Lavoro Quarterly Review, 19*(78), 175–222.

Mihailov, A. & Nasir, H. (2020). Sudden stops, productivity and the optimal level of international reserves for small open economics. Economics Discussion Papers em-dp2020-24, Department of Economics, University of Reading.

Miller, M. H., & Orr, D. (1966). A model of the demand for money by firms. *The Quarterly Journal of Economics, 80*(3), 413–435.

Mourmouras, A. & Russel, S. H. (2009). Financial crises, capital liquidation and the demand for international reserves. *Centre for European, Governance and Economic Development Research (CEGE) Discussion Paper* No: 88, University of Goettingen.

Olivera, H. G. (1969). A note on the optimal rate of growth of international reserves. *Journal of Political Economy, 77*(2), 245–248.

Paul, S., & Bhattacharya, R. N. (2004). Causality between energy consumption and economic growth in India: A note on conflict results. *Journal of Energy Economics, 26*(6), 977–983.

Rajaguru, G., & Khan, S. U. (2021). Causality between energy consumption and economic growth in the presence of growth volatility: Multi-country evidence. *Journal of Risk and Financial Management, 14*(10), 471.

Rodrik, D. (2006). The social cost of foreign exchange reserves. *International Economic Journal, 20*(3), 253–266.

Triffin, R. (1946). National central banking and the international economy. *The Review of Economic Studies, 14*(2), 53–75.

Williamson, J. (1973). Surveys in applied economics: International liquidity. *The Economic Journal, 83*(331), 685–746.

Wooldridge, J. M. (2002). *Econometric analysis of cross section and panel data*. MIT Press.

The Role of Organic Products in Preventing the Climate Crisis

Pelin Vardarlıer and Nilüfer Girgin

Abstract The aim of this study is to determine the motivational factors affecting the intention of buying organic food consumer profile in Turkey. At the same time, it is to determine how these factors affect the purchase intention. It is determined that the motivation factor that most affects the consumers' intention to purchase organic food is the natural ingredient element. Other effective motivational elements following the natural content are the following. It has been observed that the good physical health of the products, the price of the products, and familiarity with the products are effective. The results of the research will contribute to the determination of marketing strategies of organic food brands and the policies of the authorities regarding organic agriculture. Organic products also help to achieve energy efficiency. Thanks to organic farming, energy use is significantly reduced. Using less energy will also reduce carbon emissions. This will facilitate the fight against the climate crisis. Therefore, it is important for states to support investments in organic agriculture. In this context, lower taxes from these investors will help the projects to provide cost advantages. In addition, it is important to increase technological investments on this issue. These points will contribute to the reduction of the climate crisis problem.

1 Introduction

In the twentieth century, the rapid increase in the world population and the concern to meet the demand as soon as possible arose. As a result, food producers have turned to industrial agriculture practices where they obtain lower cost, faster and higher amount of products. In this respect, it is possible to say that chemical fertilizers, drugs, and other chemicals used in industrial agriculture and feed

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additives such as hormones and antibiotics used in animal production are attractive because they increase production efficiency and reduce costs (Bayram et al., 2007). However, it is seen that the widespread use of these substances causes many damages to both humans and the ecological system due to reasons such as damage to human health, climate change, global warming, damage to agricultural areas, and environmental pollution. It has been proven in many studies that hormones and chemicals used in agriculture cause heart diseases, cancer, digestive disorders, depression, skin diseases, obesity, and genetic diseases in humans (Erkmen, 2010).

When the damage caused by conventional agriculture to human health and the ecological system in the world began to be noticed, the concept of organic agriculture, which does not create these effects and is a sustainable production method, emerged (Kotler & Armstrong, 2004). With this method, all foods that are produced without using chemical inputs in production, adhering to natural production methods, protecting human health and the environment, and being produced in a controlled and certified manner are defined as "organic food" (Deniz, 2009). In our country, the demand for organic foods has started to increase with the awareness of people about healthy nutrition and consumption. Turkey has started organic food production in order to meet the demands of the importing country in the mid-1980s. However, after the organic food sector in Turkey as well as in the domestic market increased with the increase of consumers who are conscious of being healthy and safe, food concerns are increasingly sophisticated. Turkey Republic topic entered to Turkey's political agenda and awareness of the importance of the issue In the Strategic Plan of the Ministry of Health between 2013 and 2017, the item "To improve the health literacy to increase the responsibility of individuals on their own health" was emphasized (Çakır Arıca et al., 2016).

As the damage caused by industrial agriculture to human health and the ecological system in the world began to be known, the interest in organic agriculture and organic foods has gradually increased as a result of the increase in health awareness in the society. But the organic food sector in Turkey is not yet considered mature enough to access that is consumers' buying behavior that triggered the motivations sufficiently known. Therefore, in this study, it is aimed to examine the motivations that direct consumers to organic food consumption.

2 Theoretical Information

The activities of the consumer in the decisions made while purchasing or using the products and services are defined as consumer behavior. These activities are called selecting, purchasing, using, and disposing of products, services, or experiences to meet the needs of the consumer (Solomon, 2011). Studies conducted in the field of consumer behavior examine how consumers use their resources such as money, energy, and time on their way to purchasing behavior (Odabaşı & Barış, 2010). Understanding and modeling the behavior of the consumer is the most important factor affecting the competitiveness in the competitive world where the consumer

profile is deepening and the brands are increasing rapidly (Kotler & Armstrong, 2004). However, unfortunately, it is not easy to understand what, why, and how the consumer buys (Kıncal, 2006).

As a result, researching the driving forces and motivations that direct the consumer for organic food consumption and make decisions while purchasing has become an important marketing research topic in recent years (Baker et al., 2004; Squires et al., 2001). Motivation is the motives behind people's behavior (Şeker, 2015). The definition of motive is also defined by Pardee (1990) as "the forces that push or drive the individual to fulfill the basic needs and desires." Purchasing motivations are the driving forces that cause the consumer to tend to buy a certain product or brand. The organic food market has become a developing and growing sector all over the world. Most of the consumer research on organic food has addressed the incentives that encourage or limit the consumption of organic food (Honkanen et al., 2006). Topics such as health anxiety, environmental concerns, food safety, sensory variables, or ethics and value structure are the main motivations identified and addressed in studies (Tregear et al., 1994; Chinnici et al., 2002; Magnusson et al., 2003; Lockie et al., 2004).

When the international literature is examined, it is seen that there are various factors that direct consumers to buy organic foods. (Chinnici et al., 2002; Honkanen et al., 2006; Hughner et al., 2007; Tregear et al., 1994). In most of the studies, it has been revealed that the most important factors affecting the consumer's purchase intention, attitude toward organic foods, or organic food purchasing behavior are health awareness and ecological concerns (Cengiz & Şenel, 2017; Karabaş & Gürler, 2012; Lavuri & Susandy, 2020; Suprapto & Wijaya, 2012; Yadav & Pathak, 2016). However, although the results are not the same in every country, they differ depending on the culture, lifestyle, diet, socio-economic status, and demographic structure of the consumer mass.

Accordingly, Tregear et al. (1994) found in their study in England that organic products are perceived as healthy, environmentally friendly, and tastier by consumers and that these three factors mostly affect purchasing behavior positively. Price, on the other hand, took place in the research results as the secondary factor that determines the purchasing behavior. In addition, Chinnici et al. (2002) made the classification of organic food consumers in their study in Italy. According to the analysis of the data obtained from the survey results, they revealed that organic food consumers are divided into four main segments. These segments are as follows: "Pioneers," "nostalgic," "health conscious," and "utilitarians." According to this classification, it is reflected in the results of the research that the main reasons for organic food consumers to experiment with organic foods are health, curiosity, and environmental issues. The results of these two studies conducted in England and Italy show us that the health and environmental awareness in the society in developed countries is high and these factors are the main factors affecting organic food purchasing behavior.

In another study, Honkanen et al. (2006) conducted a survey in Norway to investigate the effect of ecological, political, and religious motivations on organic food attitude and organic food purchase intention. According to the results of the

research, it was reported that there is a significant relationship between these three motivational factors and the attitude toward organic foods, and there is also a significant relationship between organic food consumption attitude and organic food purchase intention. It has been determined that the most important motivation factor among these factors is ecological motivations in a way that supports the above studies. In addition, it has been stated that political motivations are moderately effective, but the conformity of food to religious values has almost no effect on the purchasing intention of the consumer.

There are also studies that argue that health awareness is the most effective factor, but that environmental or ecological concerns are ineffective or much less effective. Accordingly, Magnusson et al. (2003) stated that the perceived benefit for human health as a result of their study in Switzerland has proved to be the most powerful factor affecting organic food buying behavior, attitude toward organic food, purchase frequency, and purchase intention. However, on the contrary, it has been argued that although environmentally friendly behavior patterns are found to be associated with the frequency of purchasing organic food, health concerns are much more determinant in organic food purchasing behavior than environmental concerns. In addition, in this study, it was stated that age has a significant effect on all these results in demographic characteristics, and young consumers have more positive attitudes toward organic food purchasing.

Paul and Rana (2012) interviewed consumers in India and examined the effects of demographic characteristics, health benefit, accessibility, ecological awareness, ecological consumer behavior, quality, taste, freshness, diversity factors on organic food satisfaction, and organic food purchase intention. As a result of the study, they proved that demographic factors are effective on organic food purchasing intention, especially education level is the most effective demographic factor on organic food purchasing intention. The results of this study showed that the health benefit issue comes before the environmental concerns factor for consumers in India. It has been observed that consumers think that organic foods are expensive, but at the same time, it has been revealed that they think they can pay higher prices for healthy ingredients and environmental friendliness of the product. In a similar study, Yadav and Pathak (2016) investigated the effects of consumers' mood, subjective norms, perceived behavior control, attitudes toward organic foods, health awareness, accessibility perception, demographic characteristics, and environmental concerns in India and they found that it positively affected the purchase intention of organic food. However, they emphasized that health-related issues are more important than environmental concerns when making purchasing decisions of consumers in India among developing countries.

Yadav and Pathak (2016) also proved that high prices and poor availability of organic food are major barriers in organic food consumption. They argued that consumers in India are price-sensitive in the organic food sector, high prices negatively affect their intention to purchase organic food and that consumers have a general perception that they cannot easily access organic food, and this situation negatively affects organic food consumption. There are also studies that prove that different factors, apart from health awareness, environmental or ecological concerns,

play a determining role in the purchasing behavior of the consumer. In this context, in the study conducted by Ustaahmetoğlu and Toklu, it was found that the attitude toward organic foods was quite effective on the intention to buy organic food. Food safety is another effective factor. In this study, unlike the general public, health awareness has not been found to have an effect on the intention to purchase organic food. The reason for this is thought to be that the sample chosen in the study was mostly chosen from students. According to the results of the study within the scope of demographic characteristics, it was determined that there is a relationship between gender and purchase intention, but not between age and profession and purchasing intention.

In another study conducted by Smith and Paladino (2010) in Australia, health awareness, quality, social pressure, and familiarity with taste emerged as the factors that most affect purchase intention, while the single and most dominant factor affecting organic food purchasing behavior was found to be familiarity. As the awareness of health, familiarity with taste and product quality increases, the purchase intention increases, and the stronger the subjective norms, the higher the purchase intention. The results of the study showed that environmental concerns, attitude toward organic products, availability, organic knowledge, price awareness, risk aversion, and perceived control did not affect the intention to buy organic food. Within the framework of the results of the studies in all these literatures, it is seen that there are quite different and different results according to the demographic characteristics of the consumers and the country where the research is conducted. Hughner et al. (2007) made general inferences by examining the research and results of many studies on this subject in the world. In general, the factors that positively affect the consumer's intention to purchase organic food products; health awareness, environmental awareness, food safety, the perception of organic products as nutritious and nostalgic feelings. In the same study, they argued that the intention to purchase organic food was negatively affected by concerns about high prices, limited distribution channels, and labels indicating the ingredients of organic products (Hughner et al., 2007).

Another study, which is a reference in determining the model of this research and will be important in terms of comparing the results for this reason, is the study that Chen carried out in Taiwan in 2007. Chen (2007) discussed the motivational elements of health, mood, convenience, sensory appeal, natural content, price, weight control, familiarity, political values, religion, environmental protection, and animal rights, which are exactly the same as the elements used in this study. According to the results of the study, food neophobia and food interest are factors affecting both motives and organic food attitudes. According to this result, information and promotion activities about organic foods will support the positive attitude of both consumers with high food interest and consumers with high neophobia. Mood, natural ingredients, animals and environmental protection, political values, and religion are effective motives. Convenience is one of the most important factors affecting purchase intention and attitude toward organic products. Political values are another factor that positively affects the attitude of the consumer. Price does not

play a determining role, among other factors, on the consumer's purchase intention. Unlike other studies, health is not effective on organic food attitude, because the consumer group in Taiwan is aware that healthy supplements are only products that have been approved by the relevant authorities and have scientific prescriptions.

3 The Role of Organic Food to Handle Climate Change Problem

Global warming has become a huge problem around the world. Because of this problem, climate changes occur. If measures are not taken to solve this problem, the lives of many people will be in danger (Dong et al., 2022; Kou et al., 2022; Zhang et al., 2022). Drought occurs due to temperature differences. This will lead to a decrease in agricultural production. A significant majority of people are likely to be malnourished, as there will not be enough products around the world. In addition, there is a risk of significant reduction in water resources as a result of global warming (Bhuiyan et al., 2022; Kostis et al., 2022; Mukhtarov et al., 2022). Therefore, if the necessary precautions are not taken, some of the people in the world will have difficulties in accessing water resources. In summary, it is obvious that the problems related to the climate crisis need to be solved urgently (Wan et al., 2022; Yüksel & Dinçer, 2022).

One of the most important causes of the climate crisis is energy production and consumption. In this process, the carbon emission problem occurs as a result of the preference of fossil fuels (Dinçer et al., 2022; Yüksel, Dinçer, Çağlayan, et al., 2022; Yüksel, Dinçer, Mikhaylov, et al., 2022). The carbon gas released into the air causes significant environmental pollution and this causes people to experience health problems. In this context, basically two different actions can be taken to combat the climate crisis: using clean energy and using less energy (Adalı et al., 2022; Haiyun et al., 2021). Thanks to the use of clean energy, the amount of carbon emissions can be reduced. This situation helps to prevent the problem of climate crisis.

Another way to deal with the climate crisis problem is energy efficiency. Doing the same job using more energy will contribute to achieving this goal (Yuan et al., 2021; Zhao et al., 2021). Organic products also help to achieve energy efficiency. Thanks to organic farming, energy use is significantly reduced. Using less energy will also reduce carbon emissions (Li et al., 2021). This will facilitate the fight against the climate crisis. Therefore, it is important for states to support investments in organic agriculture. In this context, lower taxes from these investors will help the projects to provide cost advantages. In addition, it is important to increase technological investments on this issue. These points will contribute to the reduction of the climate crisis problem.

4 Conclusion

In this study, which influences consumer motivation intention of buying organic food consumers in Turkey was examined. It is divided into internal and external (ethical) motivations. While physical health, mental health, mood (mood), convenience, sensory appeal, natural content, price, weight control, and familiarity constitute the group of internal motivational elements, ecological concerns, political values, and religion (compliance with religious values) are defined as external motivational factors. As a result of the analysis, it can be said that the participants, on average, attach importance to the fact that the products have natural content, good physical health, care about ecological concerns, and good mood in food shopping. However, looking at the results of the regression analysis, it is seen that the motivation factor that most affects the consumers' intention to buy organic food is the natural content. In many studies conducted in the world, health awareness or health concerns are the most important factor affecting the behavior of the consumer toward organic foods, while the natural content of the products in this research has clearly prevented health motivation. This explains what to do in Turkey of consumers prefer organic food because of the natural ingredients of the content, but that content will come good physical health, they are not exactly sure or more preferences accordingly.

Other most effective motivational elements following natural content are as follows: the good physical health condition of the products, the price of the products, and familiarity with the products. Among these motivational factors, it has been observed that the natural content, the good physical health of the products, and the more familiarity, the more the purchase intention increases. People's re-finding of the flavors they were used to in their childhood (familiarity with the taste) is a psychological motivation that positively triggers the purchase intention. As expected, the increase in product prices is a strong factor that negatively affects the purchase intention. As the prices of organic foods increase, the purchasing motivation of the consumer decreases. The fact that product prices have a significant effect on purchasing is important in terms of showing that consumers have a certain price scale in purchasing organic food.

On the other hand, external motivation elements consisting of ecological concerns, conformity with political values, and conformity with religious values remained weak in terms of explaining the purchase intention. Especially ecological concerns, which include sensitivity to the environment and animal rights, are among the most important factors affecting the purchasing behavior of the consumer in developed countries such as England and Italy. In this study conducted in Turkey, India, Greece, and the intention of buying as well as in Australia it is not among the factors explaining enough. Political values and ecological concerns have a significant and positive effect on purchase intention. In this respect, it can be said that the more the products are produced in accordance with the political values and with an approach that cares about ecological concerns, the more the purchase intention will increase. Political values have been seen to be more effective than ecological

concerns. Therefore, the agricultural strategies of the state and state authorities to support domestic production will both reduce foreign dependency in the food sector, contribute to the strengthening of the country's economy, and encourage the consumer mass, who are sensitive to political values and have a negative attitude toward imported products, to local organic foods. In addition, with the encouragement and support of domestic production, organic foods can be produced at lower costs compared to imported products, and this will increase the intention of the price-sensitive consumer group to purchase organic food, and this will ensure the growth and development of the domestic market. The fact that the standard deviation is mostly high in the religious values variable in the sample participating in the survey indicates that consumers are the most disaggregated point in terms of the conformity of products to religious values in food shopping. However, because of the regression analysis, it was seen that the conformity of the products with religious values did not have a significant effect on the purchasing intention of the consumer. Therefore, it would be an unnecessary effort for organic food businesses to highlight this information by emphasizing the suitability of the products with religious values in marketing. However, since the external (ethical) motivational elements can explain the purchase intention at a very low rate, these elements are weak to interpret their effects on the purchase intention fully.

When the differences between demographic characteristics were examined, it was observed that there were significant differences in terms of female and male groups for convenience, sensory appeal, ecological concerns, political values, and religion variables. It can be said that women care more about convenience and sensory appeal than men in their food selection. In addition, women care more about the ecological concerns of the products in choosing organic food and the conformity of the products with political and religious values. This situation may be a result of the fact that the kitchen shopping in our country is undertaken mostly by women.

It can be said that consumers with children attach more importance to the product's physical health and natural content than those who do not have children, as expected. This situation undoubtedly explains that those who have children pay more attention to these elements in products due to their concerns about the health of their children. Therefore, organic food brands that produce special products for children or mothers should emphasize the benefits of these products on physical health and in what proportion and what natural ingredients they contain when marketing their products. Groups that do not have children attach more importance to the mood of the product and its high sensory appeal in food selection than those with children. Therefore, it would be more effective to highlight content-related information rather than sensory features such as taste, smell, and image in mother–child products.

The product preferences of the 18- to 25-year-olds give more importance to improving the mood of the product than the older consumers. In addition, while younger consumers care about the sensory appeal and easy accessibility of the products, older consumers care more about the naturalness of the products' content. In the light of this information, it would be appropriate for organic food marketing companies targeting young people to produce products that will make them feel

better, attractive in taste, smell, appearance, and that can be sold in easily available channels. For example, easy, nutritious, and delicious organic snacks to be prepared for students on university campuses can be a project that can both bring commercial success and be considered as a social responsibility for organic food brands. As the level of education increases, the importance of the natural content of the product and the intention to buy organic products increase. Therefore, it is obvious that the consumer should be informed about this issue for the organic food sector to develop. In this regard, both businesses, relevant authorities and non-governmental organizations, have a duty to raise public awareness and direct them to natural nutrition.

When the groups related to the income level are analyzed, it is seen that the intention to buy organic food is lower in the low-income group. However, it has been observed that groups with different income levels do not differ much from each other in terms of price sensitivity. It has been determined that both high-income consumers and low-income consumers care about price when purchasing organic products. It is also confirmed by these data that there is a certain price scale that consumers assign to products regardless of their income level in the purchase of organic food.

Within the framework of all these comments, organic food businesses should try to offer maximum quality at minimum cost and price, as in many sectors. For this, as mentioned above, agricultural strategies that reduce costs, produce high-quality but reasonably priced products, encourage and support domestic production; It is critical in terms of both the development of the economy, public health, and social welfare. It is aimed that this study will be a source for domestic and foreign studies, policies to be established, and measures to be taken in the future in the field of determining consumer preference and marketing strategies by organic food businesses. Among the limitations of the study is that the data were collected in a limited period. Collecting data, collected data into a series of long-term space year, reaching more consumer profile in Turkey to investigate the motivational factors affecting the intention of buying organic food issues will allow us to see more clearly.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Baker, S., Thompson, K. E., Engelken, J., & Huntley, K. (2004). Mapping the values driving organic food choice. *European Journal of Marketing, 38*(8), 995–1012. https://doi.org/10.1108/03090560410539131. Editör T. K. E. Emerald Group Publishing Limited.

Bayram, B., Yolcu, H., & Aksakal, V. (2007). Türkiye'de organik tarım ve sorunları. *Atatürk Üniversitesi Ziraat Fakültesi Dergisi, 38*(2), 203–206.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Çakır Arıca, Ş., Güreş, N., & Arslan, S. (2016). Tüketicilerin Sağlıklı Beslenmeye Yönelik Tutumlarının İncelenmesine Yönelik Bir Araştırma. *Çukurova Üniversitesi İİBF Dergisi, 20*(2), 99–110.

Cengiz, H., & Şenel, M. (2017). Tüketicilerin Organik Gıda Satın Alma Motivasyonlarının Zaltman Metafor Çıkarım Tekniği Aracılığıyla İncelenmesi. *Sosyal Bilimler Enstitüsü Dergisi Karabük Üniversitesi, 7*(1), 56–69.

Chen, M. F. (2007). Consumer attitudes and purchase intentions in relation to organic foods in Taiwan: Moderating effects of food-related personality traits. *Food Quality and Preference, 18*(7), 1008–1021. https://doi.org/10.1016/j.foodqual.2007.04.004

Chinnici, G., D'Amico, M., & Pecorino, B. (2002). A multivariate statistical analysis on the consumers of organic products. *British Food Journal, 104*(3/4/5), 187–199. https://doi.org/10.1108/00070700210425651. Editör D. Mario. MCB UP Ltd.

Deniz, E. (2009) Organik tarım sektör raporu, *Avrupa İşletmeler Ağı-Karadeniz*.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Erkmen, O. (2010). Gıda kaynaklı tehlikeler ve güvenli gıda üretimi. *Çocuk Sağlığı ve Hastalıkları Dergisi, 53*(3), 220–235.

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Honkanen, P., Verplanken, B., & Olsen, S. O. (2006). Ethical values and motives driving organic food choice. *Journal of Consumer Behaviour, 5*(ss), 420–430.

Hughner, R. S., et al. (2007). Who are organic food consumers? A compilation and review of why people purchase organic food. *Journal of Consumer Behaviour, 6*, 1–17.

Karabaş, S., & Gürler, A. Z. (2012). Organik Ürün Tercihinde Tüketici Davranışları Üzerine Etkili Faktörlerin Logit Regresyon Analizi İle Tahminlenmesi. *Adıyaman Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 5*(10), 129–156.

Kıncal, Ö. D. (2006). *Tüketici davranışlarının saat tasarımına etkisi (kol saati örneği)*. Marmara Üniversitesi.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-Based Energy Investments of European Economies and Policy Recommendations for Sustainable Development. *Journal of the Knowledge Economy*. 1–33.

Kotler, P. & Armstrong, G. (2004) *Principles of marketing. Tenth International Edition.* 10 baskı. Pearson Education Inc. .

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Lavuri, R., & Susandy, G. (2020). Green products: Factors exploring the green purchasing behavior of South Indian shoppers. *Indonesian Journal of Sustainability Accounting and Management, 4*(2), 174–191.

Li, Y. X., Wu, Z. X., Dinçer, H., Kalkavan, H., & Yüksel, S. (2021). Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling. *Energy Reports, 7*, 95–108.

Lockie, S., et al. (2004). Choosing organics: A path analysis of factors underlying the selection of organic food among Australian consumers. *Appetite, 43*(2), 135–146. https://doi.org/10.1016/j.appet.2004.02.004

Magnusson, M. K., Arvola, A., Hursti, U. K. K., Aberg, L., & Sjödén, P. O. (2003). Choice of organic foods is related to perceived consequences for human health and to environmentally friendly behaviour. *Appetite, 40*(2), 109–117. https://doi.org/10.1016/S0195-6663(03)00002-3

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy*.

Odabaşı, Y. & Barış, G. (2010) Tüketici davranışı. MediaCat. Available at: https://bproxy.bahcesehir.edu.tr/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat03891a&AN=bah.135835&site=eds-live.

Pardee, R. L. (1990) *Motivation Theories of Maslow, Herzberg, McGregor & McClelland. A Literature Review of Selected Theories Dealing with Job Satisfaction and Motivation.* https://doi.org/10.5539/gjhs.v4n2p2.

Paul, J., & Rana, J. (2012). Consumer behavior and purchase intention for organic food. *Journal of Consumer Marketing, 29*(6), 412–422. https://doi.org/10.1108/07363761211259223

Şeker, S. E. (2015). Motivasyon Teorisi (Motivation Theory). *YBS Ansiklopedi, 2*(1), 22–26.

Smith, S., & Paladino, A. (2010). Eating clean and green? Investigating consumer motivations towards the purchase of organic food. *Australasian Marketing Journal, 18*(2), 93–104. https://doi.org/10.1016/j.ausmj.2010.01.001. Australian and New Zealand Marketing Academy.

Solomon, M. R. (2011) *Consumer behaviour: Buying, having, and being.* Prentice Hall. Available at: https://bproxy.bahcesehir.edu.tr/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat03891a&AN=bah.102280&site=eds-live

Squires, L., Juric, B., & Cornwell, T. B. (2001). Level of market development and intensity of organic food consumption: Cross-cultural study of Danish and New Zealand consumers. *Journal of Consumer Marketing, 18*(5), 392–409. https://doi.org/10.1108/07363760110398754. Editör J. Biljana. MCB UP Ltd.

Suprapto, B., & Wijaya, T. (2012). Intentions of Indonesian consumers on buying organic food. *International Journal of Trade, Economics and Finance, 3*(2), 114–119. https://doi.org/10.7763/ijtef.2012.v3.183

Tregear, A., Dent, J. B., & McGregor, M. J. (1994). The demand for organically-grown produce. *British Food Journal, 96*(4), 21–25. https://doi.org/10.1108/00070709410061032. Editör D. J. B. MCB UP Ltd.

Wan, Q., Zhao, X., Liu, H., Dinçer, H., & Yüksel, S. (2022). Assessing the new product development process for the industrial decarbonization of sustainable economies. *SAGE Open, 12*(1), 21582440211067231.

Yadav, R., & Pathak, G. S. (2016). Intention to purchase organic food among young consumers: Evidences from a developing nation. *Appetite, 96*, 122–128. https://doi.org/10.1016/j.appet.2015.09.017. Elsevier.

Yuan, G., Xie, F., Dinçer, H., & Yüksel, S. (2021). The theory of inventive problem solving (TRIZ)-based strategic mapping of green nuclear energy investments with spherical fuzzy group decision-making approach. *International Journal of Energy Research, 45*(8), 12284–12300.

Yüksel, S., & Dinçer, H. (2022). Identifying the strategic priorities of nuclear energy investments using hesitant 2-tuple interval-valued Pythagorean fuzzy DEMATEL. *Progress in Nuclear Energy, 145*, 104103.

Yüksel, S., Dinçer, H., Çağlayan, Ç., Uluer, G. S., & Lisin, A. (2022). Bitcoin mining with nuclear energy. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022). Key issues for the improvements of shallow geothermal investments. In *Sustainability in energy business and finance* (pp. 183–194). Springer.

Zhang, Y., Zhang, Y., Gong, C., Dinçer, H., & Yüksel, S. (2022). An integrated hesitant 2-tuple Pythagorean fuzzy analysis of QFD-based innovation cost and duration for renewable energy projects. *Energy., 248*, 123561.

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Determining the Right Location for Turkey's Nuclear Energy Investment Projects Based on Zero-carbon Emission Purposes

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Abstract Turkey's energy needs are increasing in parallel with the increasing industrialization and population. To meet its increasing energy needs, Turkey needs energy sources that are more sustainable and in line with zero-carbon emission targets. Although fossil fuels can meet the energy needs, they are not energy sources suitable for Turkey's targets. Because there are not enough fossil fuel reserves in Turkey, fossil fuels are not sustainable and fossil fuels cause high carbon emissions. Therefore, renewable energies and nuclear energy come to the fore. Turkey continues to invest in renewable energy, but renewable energy investments in the country will not be sufficient to meet the anticipated energy demand in the future. Thus, the best alternative option for Turkey is nuclear power plants. The main purpose of Turkey's nuclear power plant projects is to protect energy resources, ensure energy security, reduce environmental pollution, and reduce the total cost of all electricity generation, but deciding for a nuclear power plant site is a very strategic and complex process. In this study, criteria for determining the right location in Turkey's nuclear energy investment projects were determined and the relevant literature was examined. The seismic activity and population density of the region where the power plant will be established should be low, and the availability and sufficiency of cooling water in the said region should be high. Appropriate topography of the region will increase the safety of the reactor to be established and environmental sensitivity will protect the biodiversity and natural resources of the region. In addition, the power plant area should be built away from airports and areas of high terrorist activity to prevent aircraft crashes and terrorist attacks. Finally, cost is an important criterion for nuclear power plant projects. A cost-oriented approach to site selection will increase the efficiency of these projects.

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1 Introduction

Energy can be defined as the ability to do work in the most general sense. Energy is vital for all humanity. People have always needed and still need energy in their lives. Energy has led to an increase in the quality of life all over the world. At the same time, it is possible to say that energy has great social and economic contributions to global development (Li et al., 2021; Zhao et al., 2021; Zhou et al., 2021). After the transition to the agricultural economy, a strong industrialization revolution began. Thanks to industrialization, energy production and consumption increased. Therefore, there was an increase in human welfare (Liu, Gong, et al., 2021; Liu, Lv, et al., 2021; Xie et al., 2021). The concept of energy will become even more important in the coming centuries because there is a human population that continues to increase and a booming industry (Li & Lin, 2015; Madlener & Alcott, 2009). Energy resources are divided into two according to their usage areas. The first is non-renewable energy sources and the other is renewable energy sources. Non-renewable energy sources are also divided into two. It is possible to rank them as Fossil origin and Core origin. Coal, natural gas, and oil are examples of fossil sources. Core-based ones are uranium and thorium. Renewable energy sources can be said as wind, solar, biomass, wave, geothermal, hydraulic, and hydrogen (Liu et al., 2010; Ünak, 2000; Waldrop, 2012). In addition to these, energy sources are divided into commercial energy sources and non-commercial energy sources. Commercial energy sources can be listed as natural gas, oil, nuclear energy. These types of energy sources are among the energy types that meet the international needs of industrialized countries (Sarkar et al., 2003). It is possible to say that the energy sources consisting of agricultural and animal wastes are non-commercial energy sources. As nations and economies developed, supply and demand for non-commercial energy sources decreased. The supply and demand for commercial energy sources has increased.

Fossil fuels are the primary energy source among the energy sources used today (Ağbulut & Sarıdemir, 2021). Fossil fuels are resources needed in every moment of life on earth. Coal, oil, and natural gas are fossil fuels. The element carbon forms the basis of these fuels. Fossil fuels are fuels that will run out after a certain time. In other words, they are considered as non-renewable energy sources because they cannot exist continuously in nature. They are formed by exposure to heat and pressure. Plant and animal remain constitute the raw material of these resources (Mikayilov et al., 2020). Since the oil crises of the 1970s, reliance on fossil fuels has dwindled. The demand for coal in the past has started to give way to natural gas and oil today (Ediger, 2019). The advantages of fossil fuels include being used for heating, being easily transported, and being cheap. Although the need for fossil fuels has increased in today's industrializing world, the disadvantages of fossil fuels are just as great. (Du et al., 2020). Although the most important disadvantage is air pollution, fossil resources are limited resources. It has significant environmental effects that cause climate change and various health problems (Abdelkareem et al., 2021). They increase carbon emissions in nature and cause acid rain. They cause a decrease in

oxygen in the air, and it is possible to say that this will cause serious harm to human health (Doğan & Erol, 2019; Liu, Gong, et al., 2021; Liu, Lv, et al., 2021). They cause various heart and respiratory diseases. As a result, it is possible to say that fossil fuels can make countries uninhabitable (Kampa & Castanas, 2008). Considering all these negative effects, it is possible to say that it would be right to turn to alternative energy sources for fossil fuels. Renewable energy and nuclear energy can be shown as alternative energy sources to fossil fuels. It can be said that this will pave the way for the circular economy and sustainable development.

The need for energy, which does not threaten the environment, is constantly increasing due to reasons such as the increase in the world population, industrialization, and the development of technology day by day. Investments in renewable energy have increased due to the increase in this energy need and the decrease in the reserves of fossil fuels day by day (Komendantova et al., 2012). Hydro, wind, geothermal, biomass, and solar are the most used renewable energy types (Bull, 2001; Dinçer et al., 2021; Dong et al., 2022; Zhang et al., 2022). As a result of the use of renewable energy, no carbon gas is released into the atmosphere. This situation contributes to minimizing the environmental pollution problem. Therefore, renewable energy sources are accepted as environmentally friendly energy types. Another advantage of renewable energy types is that they produce national energy for countries. In other words, countries with renewable energy sources do not have to import energy abroad (Kou et al., 2022). Thanks to this issue, the current account balance of the country will be positively affected. On the other hand, renewable energy types also have some disadvantages (Mukhtarov et al., 2022). First, the costs of renewable energy investments are quite high. The energy obtained from renewable energy sources changes according to the weather conditions (Bhuiyan et al., 2022; Kostis et al., 2022). For this reason, problems can be experienced at the point of uninterrupted energy production (Yüksel & Çağlayan, 2020). In this context, nuclear energy is still of great importance for countries due to the disadvantages of fossil fuels and renewable energies.

2 General Information About Nuclear Energy Investments

The economic growth experienced in recent years has increased the energy need at the same rate. Although the economic growth of developed countries is not reflected in the energy demand, the energy demand in developing countries is increasing very rapidly (Adamantiades & Kessides, 2009). Especially in underdeveloped and developing countries, energy consumption is increasing with economic growth. Energy is the building block of economic activities in all countries. It has been stated by various studies that fossil resources are depleted, and alternative energy sources play an important role in meeting the energy need. One of these alternative energy sources is nuclear energy. Nuclear energy is a type of energy supplied from the nucleus of the atom. The energy produced during fission and fusion in the nucleus of an atom is called nuclear energy. The nuclei of some atoms, such as uranium or

plutonium, explode and break apart when collided with neutrons, yielding countless particles of much smaller mass than these nuclei (Menyah & Wolde-Rufael, 2010).

Nuclear power plants have benefited in many ways since they started to be used in the world. Nuclear energy also provides many benefits to the environment. Because they do not produce greenhouse gases, nuclear power plants help maintain air quality and reduce climate change. Nuclear energy is one of the least damaging types of energy to the environment. The safety assessment of nuclear power plants is carried out by independent licensing agencies. In addition, these power plants are under constant control while they are in operation. For this reason, the risk of accidents in nuclear power plants that can harm the environment and people is very low compared to other technological products used today. The annual dose imposed on the people living around a nuclear power plant is far below the natural radiation. Nuclear energy is an indispensable energy source for France, Germany, Italy, England, USA, some Scandinavian countries, Bulgaria, Russia, Armenia, and many more countries. Nuclear power plants do not harm the environment like other thermal power plants. Nuclear energy is a type of energy that has not been known and used until now, has very widespread natural reserves, and can be applied not only in real production, but also in transportation, space heating, and other economic activities (Yüksel & Dinçer, 2022). It plays a very important role in economic geography (Chontanawat et al., 2008). Nuclear power plants can produce large amounts of electricity without interruption. The geopolitical and environmental consequences of the energy consumption necessitate the transition to an energy policy that no longer jeopardizes the quality of life, and in various scenarios, nuclear power plays an important role in making this happen. However, for nuclear power to be successful as a sustainable energy source, five key aspects must be guaranteed: nuclear safety, non-proliferation, minimal production of radioactive waste, availability of natural resources, and economic competitiveness (Sari & Soytas, 2007).

Taken as a whole, the nuclear power generation chain is the cleanest option for greenhouse gas emissions. Nuclear energy has a great role in reducing the greenhouse gas concentration in the atmosphere, which causes climate change (Nisan et al., 2003). Today, nuclear power plants provide an annual reduction of approximately 17% in greenhouse gas emissions from the electricity sector (Hamit-Haggar, 2012). If electricity was obtained from fossil fuel plants instead of these plants, 1.2 billion tons of carbon would be released into the atmosphere every year. The management of wastes and spent fuels generated in the nuclear power generation process aims to protect human health and the environment without leaving too much burden on future generations (Halicioglu, 2009). However, the inability to implement the final storage of nuclear wastes (high-level wastes and spent fuels) is still a disadvantage in terms of nuclear energy (Sato et al., 1998).

The adequacy of energy resources for future generations is an important issue in terms of sustainable development. Especially fossil resource reserves are limited. Uranium and thorium reserves, which are nuclear fuel raw materials, are quite high (Pao & Tsai, 2011). The Kyoto Protocol, which entered into force on February 16, 2005, aimed to ensure that in 2012 all signatories' greenhouse gas emissions were not higher than in 1990. Many countries pursuing this goal are focusing on

three key approaches to reduce their CO_2 emissions: better energy production efficiency, recycling, capture, utilization, disposal/storage, and use of renewable and nuclear energy sources (Gessinger, 1997). It has been shown that the operation of nuclear power plants in the world contributes to the reduction of greenhouse gas emissions and saves 10% of the CO_2 emissions from the energy use of today's nuclear power plants (Apergis et al., 2010). The European Union has stated that it would not be possible to reduce CO_2 emissions without nuclear power (Hossain, 2011). Although a reliable alternative energy source may become one of the potential solutions for greenhouse gas reduction, its risks should not be ignored (Wolde-Rufael, 2010).

3 Some Criteria to Determine the Right Location for Nuclear Energy Investments

The location of nuclear power plants is a strategic choice that has a substantial influence on the plant's economic operation and the region's long-term development. Therefore, choosing a location for a nuclear power plant to be built in Turkey is one of the most important decisions that the Turkish government and the company that will make an investment will face (Ekmekçioglu et al., 2011). In parallel, deciding for a nuclear power plant site is a rather complex process. The main purpose of nuclear power construction is to protect energy resources, ensure energy security, reduce environmental pollution, and reduce the total cost of all electricity generation (Uluer & Çağlayan, 2021; Yüksel et al., 2022). Therefore, the location to be decided for the construction of the nuclear power plant should be the safest and most efficient location for the said investment. Thus, there are various criteria for determining the right location for nuclear energy investment projects based on Turkey's zero-carbon emission target. This section includes some significant criteria with the following subtitles.

Seismic Activity: Nuclear power plants produce energy with high temperatures because of fission reactions. An out-of-control chain of nuclear reactions could cause the reactor to explode, releasing huge amounts of radioactive waste around the world. The resulting radioactive pollution can cause serious losses. Therefore, the safety of nuclear power plants is one of the most important criteria in nuclear energy investments (Dinçer et al., 2020; Xie et al., 2020). The most important factor that threatens the said security is seismic activities. Since the presence of active faults will directly affect the safety of the nuclear power plant with the earthquakes it will cause, it has a high importance in terms of the location of the power plant. The Fukushima Nuclear Power Plant, located on the east coast of Japan, is the largest example of nuclear accidents because of seismic activity. The accident in question is defined as the biggest accident after the Chernobyl nuclear accident (Cardin et al., 2017; Jewell & Ates, 2015). Considering Japan's earthquake experience, the Fukushima Nuclear Power Plant was built in a way that is highly resistant to

earthquakes. After the 9.0 magnitude earthquake on March 11, 2011, the reactors of the Fukushima nuclear power plant were automatically disabled. Since the core of the reactors was still very hot, the cooling process was continued by the generators. However, the earthquake caused a tsunami that reached a height of 14 meters. The tsunami severely damaged power grids and flooded the power plant's generators. There was a major power outage at the power plant because of the generators being damaged. In parallel, the power outage caused a lack of cooling in the reactor and partial meltdowns and explosions occurred in the plant. As the reactor centers melted, radioactive fuels began to leak into the atmosphere and ocean. Thereupon, the area was depopulated and gradually expanded forbidden zones were declared. In the immediate aftermath of the nuclear disaster, tens of workers were exposed to radiation and thousands were removed from their homes (Strickland, 2011; Yamamoto et al., 2014). All these show that seismic activity is one of the most important location criteria in Turkey's nuclear energy investments. To minimize the risk of earthquakes and tsunamis, places close to the seismic fault line should be avoided (Frano et al., 2010; James et al., 2014; Xu et al., 2020).

Availability and Sufficiency of Cooling Water: Radioactively rich elements (uranium or thorium) are decomposed by fission reaction in nuclear power plants in a controlled manner. This decomposition process takes place in the reactor, which is a very special part of the power plant. A high amount of heat is obtained through the fission reaction. This temperature is converted into electrical energy because of the evaporation of water and the rotation of the turbines by the steam. Accordingly, it is necessary to control the temperature in order to control the energy produced because atoms such as uranium used in nuclear power plants make the water reach very high temperatures (Yüksel et al., 2021). Therefore, cooling towers or cooling systems are needed to reprocess water vapor. Sea water is one of the most widely used cooling systems. In this respect, although it is the cheapest choice, the temperature of the discharged water and the amount of water needed are higher than other systems (Byers et al., 2014; Mochizuki et al., 2014). Another method is to use systems with cooling chimneys. In these systems, the use of fresh water is preferred. This system can consume more electricity for cooling than other cooling systems. Considering all these, since a large amount of water is needed to cool the heat released in nuclear power plants, it is necessary to install the power plant on the water edges such as sea and river where there is sufficient and continuous water source for the power plant (Martín & del Mar Rubio-Varas, 2017). On the other hand, cooling water is necessary not only for normal operating conditions, but also for heat dissipation and protection from fires when the reactor is closed or in the worst accident situations. Finally, another important method among cooling systems is dry cooling systems. Although this method consumes less water, construction costs are high. In this method, besides the environmental benefits, the successful use of dry cooling can provide the safety advantage as it prevents water-related events such as tsunamis (Yan et al., 2014). Although advanced dry cooling systems have the potential to eliminate the need for a cooling water source in nuclear power plants, considering the high cost of these systems, it should be said that the need for cooling water resources for nuclear power plants continues.

Population Density: Although nuclear power plants are extremely safe energy investments, there is always a risk of explosion in the power plant. Therefore, it is vital to consider the population density of the power plant site while deciding on the selection of a suitable site for nuclear energy investments. The population density of the area where nuclear power plants will be established should be in accordance with the emergency action plans to be implemented in case of a possible accident. Therefore, population density is important for the feasibility of site-specific emergency plans and radiation protection. In addition, the population density of the region directly affects the size of the emergency in the event of a possible accident. Population assessments of the field should be made. Determining important segments such as the number of sick, elderly, and disabled individuals within this evaluation will increase the effectiveness of the human-oriented approach in nuclear energy investment. Thus, it is an important requirement that nuclear power plants be built in remote areas. Nuclear power plants far from settlements have several advantages. In the event of a possible accident in nuclear power plants located far from residential areas, the applicability of emergency plans will be easier. The fact that the resident population in the region where the power plant will be established is extremely low will minimize the number of external human-induced events that may pose a threat to the power plant. Considering the effects of possible radioactive materials that may be released from the power plant after an accident on individuals, the sparse population in the said region will prevent people's lives from being endangered. Considering all these conditions, population density and distance from settlements are the most important factors in evaluating the suitability of a place as a nuclear power plant site (Devanand et al., 2019; Mohammed Saeed et al., 2020).

Topographic Structure and Environmental Sensitivity: The structure and environmental conditions of the land where nuclear power plants are planned to be established are one of the most important criteria. For example, the topographic structure of the area where the nuclear reactor will be built is a vital element for reactor safety. The main reason for this factor is the slope instability of the region in question. Steeply sloping and mountainous areas pose a risk of landslides. A landslide that may occur around the power plant will be one of the most important factors that endanger the reactor safety. In addition, excessive excavation in mountainous areas will increase costs excessively. Therefore, the inadequacy of the topographic structure of the region where the nuclear power plant will be established will both endanger the safety of the reactor and make the realization of the project impossible by causing high costs. Environmental sensitivity is one of the most important factors in the selection of energy sources. Therefore, it will be important to develop environmental sensitivities for nuclear energy investments as well. It is necessary to understand the ecological importance of the places considered for the installation of the power plant for the country or the world. Therefore, nuclear power plants should not threaten the biodiversity, natural resources, and related cultural resources in their region so that they can reach future generations. The planned project should be carried out in accordance with the principles determined for the protection of the area where it is located. Therefore, the field studies to be conducted

for the suitability of the nuclear power plant site should not be restricted due to the protection areas. According to all these, topographic structure and environmental sensitivity constitute an important criterion for nuclear energy investments to be made in Turkey for the purpose of zero carbon (Baskurt & Aydin, 2018; Kutbi, 1987; Soydan, 2021).

Human-based External Factors: Nuclear power plants are energy investments where security is applied at a high level. However, it can be said that there are also human-induced external factors that threaten the safety of nuclear power plants. Aircraft crashes and terrorist attacks are some of them. Power plants can be strengthened against aircraft collisions so that the reactor is not damaged in a possible accident. The construction of nuclear power plants in areas far from airports is another measure that will help minimize the risk. Nuclear power plants can be a clear target of terrorist organizations. Therefore, in order to ensure the safety of the nuclear power plant, the location where the security of the power plant can be ensured in the easiest way should be selected (Basu, 2019; Chapin et al., 2002; Leventhal & Hoenig, 1990).

Installation and Operational Cost: The installation and operational costs of Nuclear Power Plant investments are affected by the location of the plant. For example, a cost increase may be experienced due to the topographic features of the region. If the location where the power plant is planned to be built has a steep slope, it may cause more excavation. Therefore, a sloping location increases installation costs even more. In addition, if the region where the power plant will be built does not meet the necessary infrastructure requirements, infrastructure expenditures will increase the cost even more. Another important point in choosing a cost-oriented location is proximity to raw materials. Proximity to raw materials will reduce both the installation and operational costs of the nuclear power plant. All these factors show that cost is an important criterion for the development of nuclear power plant projects. A cost-oriented approach in location selection will increase the efficiency of these projects (Santini et al., 2016; Sovacool et al., 2014).

4 Conclusion

In this study, the literature on choosing the right location for nuclear power plant investments in line with Turkey's zero-carbon objectives was searched. Fossil fuels will not be able to meet Turkey's increasing energy needs in line with its zero-carbon objectives. Renewable energies, on the other hand, are not sufficient to meet both the increasing energy demand and the energy deficit due to non-use of fossil fuels (Meng et al., 2021; Shang et al., 2021). Therefore, nuclear energy investments are of great importance for Turkey. In this context, deciding on the nuclear power plant site in Turkey is a very strategic and complex process. First of all, the seismic activity and population density of the place where the power plant project will be established should be low, and the availability and sufficiency of cooling water in the said region should be high. Appropriate topography of the region will increase the safety of the

reactor to be established. Because mountainous regions with a high slope are at risk of landslides. Environmental awareness will protect the biodiversity and natural resources of the region and ensure that these resources are transferred to new generations. Also, the power plant area should be built away from airports and areas with high terrorist activity to prevent plane crashes and terrorist attacks. Finally, cost is an important criterion for nuclear power plant projects. Proximity to raw materials and having the necessary infrastructure in the power plant area will increase the efficiency of the project by reducing the installation and operational costs.

References

Abdelkareem, M. A., Elsaid, K., Wilberforce, T., Kamil, M., Sayed, E. T., & Olabi, A. (2021). Environmental aspects of fuel cells: A review. *Science of the Total Environment, 752*, 141803.

Adamantiades, A., & Kessides, I. (2009). Nuclear power for sustainable development: Current status and future prospects. *Energy Policy, 37*(12), 5149–5166.

Ağbulut, Ü., & Sarıdemir, S. (2021). A general view to converting fossil fuels to cleaner energy source by adding nanoparticles. *International Journal of Ambient Energy, 42*(13), 1569–1574.

Apergis, N., Payne, J., Menyah, K., & Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics., 69*, 2255–2260. www.elsevier.com/locate/ecolecon, (10.12.2011)

Baskurt, Z. M., & Aydin, C. C. (2018). Nuclear power plant site selection by Weighted Linear Combination in GIS environment, Edirne, Turkey. *Progress in Nuclear Energy, 104*, 85–101.

Basu, P. C. (2019). Site evaluation for nuclear power plants–The practices. *Nuclear Engineering and Design, 352*, 110140.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Bull, S. R. (2001). Renewable energy today and tomorrow. *Proceedings of the IEEE, 89*(8), 1216–1226.

Byers, E. A., Hall, J. W., & Amezaga, J. M. (2014). Electricity generation and cooling water use: UK pathways to 2050. *Global Environmental Change, 25*, 16–30.

Cardin, M. A., Zhang, S., & Nuttall, W. J. (2017). Strategic real option and flexibility analysis for nuclear power plants considering uncertainty in electricity demand and public acceptance. *Energy Economics, 64*, 226–237.

Chapin, D. M., Cohen, K. P., Davis, W. K., Kintner, E. E., Koch, L. J., Landis, J. W., Levenson, M., Mandil, I. H., Pate, Z. T., Rockwell, T., Schriesheim, A., Simpson, J. W., Squire, A., Starr, C., Stone, H. E., Taylor, J. J., Todreas, N., Wolfe, B., & Zebroski, E. L. (2002). Nuclear power plants and their fuel as terrorist targets. *Science, 297*(5589), 1997–1999.

Chontanawat, J., Hunt, L. C., & Pierse, R. (2008). Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries. *Journal of Policy Modeling, 30*(2), 209–220.

Devanand, A., Kraft, M., & Karimi, I. A. (2019). Optimal site selection for modular nuclear power plants. *Computers & Chemical Engineering, 125*, 339–350.

Dinçer, H., Lisin, A., Ubay, G. G., & Çağlayan, Ç. (2021). Identifying the best financing sources for renewable energy companies in Latin American Countries. In *Strategic approaches to energy management* (pp. 1–12). Springer.

Dinçer, H., Yüksel, S., Çağlayan, Ç., & Uluer, G. S. (2020). The contribution of nuclear energy investment on sustainable financial and economic development. *Journal of Financial Economics and Banking, 1*(1), 39–51.

Doğan, B., & Erol, D. (2019, October). The future of fossil and alternative fuels used in automotive industry. In *2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)* (pp. 1–8). IEEE.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Du, L., Dinçer, H., Ersin, İ., & Yüksel, S. (2020). IT2 fuzzy-based multidimensional evaluation of coal energy for sustainable economic development. *Energies, 13*(10), 2453.

Ediger, V. Ş. (2019). An integrated review and analysis of multi-energy transition from fossil fuels to renewables. *Energy Procedia, 156*, 2–6.

Ekmekçioglu, M., Can Kutlu, A., & Kahraman, C. (2011). A fuzzy multi-criteria SWOT analysis: An application to nuclear power plant site selection. *International Journal of Computational Intelligence Systems, 4*(4), 583–595.

Frano, R. L., Pugliese, G., & Forasassi, G. (2010). Preliminary seismic analysis of an innovative near term reactor: Methodology and application. *Nuclear Engineering and Design, 240*(6), 1671–1678.

Gessinger, G. (1997). Lower CO2 emissions through better technology. *Energy Conversion and Management, 38*, S25–S30.

Halicioglu, F. (2009). An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy, 37*(3), 1156–1164.

Hamit-Haggar, M. (2012). Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. *Energy Economics, 34*(1), 358–364.

Hossain, M. S. (2011). Panel estimation for CO2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. *Energy Policy, 39*(11), 6991–6999.

James, N., Sitharam, T. G., Padmanabhan, G., & Pillai, C. S. (2014). Seismic microzonation of a nuclear power plant site with detailed geotechnical, geophysical and site effect studies. *Natural Hazards, 71*(1), 419–462.

Jewell, J., & Ates, S. A. (2015). Introducing nuclear power in Turkey: A historic state strategy and future prospects. *Energy Research & Social Science, 10*, 273–282.

Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. *Environmental Pollution, 151*(2), 362–367.

Komendantova, N., Patt, A., Barras, L., & Battaglini, A. (2012). Perception of risks in renewable energy projects: The case of concentrated solar power in North Africa. *Energy Policy, 40*, 103–109.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of European economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Kutbi, I. I. (1987). A pragmatic pairwise group-decision method for selection of sites for nuclear power plants. *Nuclear Engineering and Design, 100*(1), 49–63.

Leventhal, P. L., & Hoenig, M. M. (1990). Nuclear terrorism: Reactor sabotage and weapons proliferation risks. *Contemporary Economic Policy, 8*(3), 106–121.

Li, K., & Lin, B. (2015). Impacts of urbanization and industrialization on energy consumption/CO2 emissions: Does the level of development matter? *Renewable and Sustainable Energy Reviews, 52*, 1107–1122.

Li, Y. X., Wu, Z. X., Dinçer, H., Kalkavan, H., & Yüksel, S. (2021). Analyzing TRIZ-based strategic priorities of customer expectations for renewable energy investments with interval type-2 fuzzy modeling. *Energy Reports, 7*, 95–108.

Liu, Y., Gong, X., Yüksel, S., Dinçer, H., & Aydın, R. (2021). A multidimensional outlook to energy investments for the countries with continental shelf in East Mediterranean Region with Hybrid Decision Making Model based on IVIF logic. *Energy Reports, 7*, 158–173.

Liu, Y., Langer, V., Høgh-Jensen, H., & Egelyng, H. (2010). Life cycle assessment of fossil energy use and greenhouse gas emissions in Chinese pear production. *Journal of Cleaner Production, 18*(14), 1423–1430.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*, 1–15.

Madlener, R., & Alcott, B. (2009). Energy rebound and economic growth: A review of the main issues and research needs. *Energy, 34*(3), 370–376.

Martín, D. S., & del Mar Rubio-Varas, M. (2017). Freshwater for cooling needs: A long-run approach to the nuclear water footprint in Spain. *Ecological Economics, 140*, 146–156.

Meng, Y., Dincer, H., & Yüksel, S. (2021). Understanding the innovative developments with two-stage technology S-curve of nuclear energy projects. *Progress in Nuclear Energy, 140*, 103924.

Menyah, K., & Wolde-Rufael, Y. (2010). CO2 emissions, nuclear energy, renewable energy and economic growth in the US. *Energy Policy, 38*(6), 2911–2915.

Mikayilov, J. I., Mukhtarov, S., Dinçer, H., Yüksel, S., & Aydın, R. (2020). Elasticity analysis of fossil energy sources for sustainable economies: A case of gasoline consumption in Turkey. *Energies, 13*(3), 731.

Mochizuki, M., Singh, R., Nguyen, T., & Nguyen, T. (2014). Heat pipe based passive emergency core cooling system for safe shutdown of nuclear power reactor. *Applied Thermal Engineering, 73*(1), 699–706.

Mohammed Saeed, I. M., Saleh, M. A. M., Hashim, S., Hama, Y. M. S., Hamza, K., & Al-Shatri, S. H. (2020). The radiological assessment, hazard evaluation, and spatial distribution for a hypothetical nuclear power plant accident at Baiji potential site. *Environmental Sciences Europe, 32*(1), 1–12.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy*. https://doi.org/10.1016/j.renene.2022.01.061

Nisan, S., Caruso, G., Humphries, J. R., Mini, G., Naviglio, A., Bielak, B., & Volpi, L. (2003). Sea-water desalination with nuclear and other energy sources: The EURODESAL project. *Nuclear Engineering and Design, 221*(1–3), 251–275.

Pao, H. T., & Tsai, C. M. (2011). Modeling and forecasting the CO2 emissions, energy consumption, and economic growth in Brazil. *Energy, 36*(5), 2450–2458.

Santini, L., Accornero, C., & Cioncolini, A. (2016). On the adoption of carbon dioxide thermodynamic cycles for nuclear power conversion: A case study applied to Mochovce 3 Nuclear Power Plant. *Applied Energy, 181*, 446–463.

Sari, R., & Soytas, U. (2007). The growth of income and energy consumption in six developing countries. *Energy Policy, 35*(2), 889–898.

Sarkar, M. A. R., Ehsan, M., & Islam, M. A. (2003). Issues relating to energy conservation and renewable energy in Bangladesh. *Energy for Sustainable Development, 7*(2), 77–87.

Sato, O., Tatematsu, K., & Hasegawa, T. (1998). Reducing future CO2 emissions—the role of nuclear energy. *Progress in Nuclear Energy, 32*(3–4), 323–330.

Shang, H., Su, F., Yüksel, S., & Dinçer, H. (2021). Identifying the strategic priorities of the technical factors for the sustainable low carbon industry based on macroeconomic conditions. *SAGE Open, 11*(2), 21582440211016345.

Sovacool, B. K., Gilbert, A., & Nugent, D. (2014). An international comparative assessment of construction cost overruns for electricity infrastructure. *Energy Research & Social Science, 3*, 152–160.

Soydan, O. (2021). Solar power plants site selection for sustainable ecological development in Nigde, Turkey. *SN Applied Sciences, 3*(1), 1–18.

Strickland, E. (2011). 24 hours at Fukushima. *IEEE Spectrum, 48*(11), 35–42.

Uluer, G. S., & Çağlayan, Ç. (2021). The economic and environmental importance of Akkuyu NUCLEAR Power Plant in Turkey. In *Handbook of research on strategic management for current energy investments* (pp. 300–319). IGI Global.

Ünak, T. (2000). What is the potential use of thorium in the future energy production technology? *Progress in Nuclear Energy, 37*(1–4), 137–144.

Waldrop, M. M. (2012). Nuclear energy: Radical reactors. *Nature News, 492*(7427), 26.

Wolde-Rufael, Y. (2010). Bounds test approach to cointegration and causality between nuclear energy consumption and economic growth in India. *Energy Policy, 38*(1), 52–58.

Xie, Y., Peng, Y., Yüksel, S., Dınçer, H., Uluer, G. S., Çağlayan, Ç., & Li, Y. (2020). Consensus-based public acceptance and mapping of nuclear energy investments using spherical and pythagorean fuzzy group decision making approaches. *IEEE Access, 8*, 206248–206263.

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Xu, B., Zhou, Y., & Pang, R. (2020). Seismic stability reliability assessment of nuclear power plant's bank revetment considering unreinforced and reinforced situations. *Annals of Nuclear Energy, 136*, 107025.

Yamamoto, M., Sakaguchi, A., Ochiai, S., & Imanaka, T. (2014). Isotopic compositions of transuranic nuclides released by the Fukushima Dai-ichi Nuclear Power Plant accident: With emphasis on Cm isotopes. *Journal of Radioanalytical and Nuclear Chemistry, 300*(3), 1045–1052.

Yan, X., Sato, H., Inaba, Y., Noguchi, H., Tachibana, Y., & Kunitomi, K. (2014). Evaluation of GTHTR300A nuclear power plant design with dry cooling. *International Journal of Energy Research, 38*(11), 1467–1477.

Yüksel, S., & Çağlayan, Ç. (2020). The factors affecting the investors' decisions: A study on nuclear energy investments. *Economics Literature, 2*(2), 177–185.

Yüksel, S., & Dinçer, H. (2022). Identifying the strategic priorities of nuclear energy investments using hesitant 2-tuple interval-valued Pythagorean fuzzy DEMATEL. *Progress in Nuclear Energy, 145*, 104103.

Yüksel, S., Dinçer, H., Çağlayan, Ç., & Uluer, G. S. (2021). Determining the optimal financial strategies for nuclear energy companies. In *Financial strategies in competitive markets* (pp. 1–16). Springer.

Yüksel, S., Dinçer, H., Çağlayan, Ç., Uluer, G. S., & Lisin, A. (2022). Bitcoin mining with nuclear energy. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Zhang, Y., Zhang, Y., Gong, C., Dinçer, H., & Yüksel, S. (2022). An integrated hesitant 2-tuple Pythagorean fuzzy analysis of QFD-based innovation cost and duration for renewable energy projects. *Energy, 248*, 123561.

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

Potential Impacts of Economic Growth, Energy Use, and Urbanization on Zero-carbon Emissions

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Abstract One of the primary objectives is to achieve a stable and sustainable growth of the economies. Economic sustainability will be possible with a clean and sustainable environment. Therefore, minimizing carbon emissions caused by economic growth should be the primary goal of sustainability. This study examines the effects of economic growth and energy use on carbon emissions in the countries with the highest carbon emissions, based on the environmental Kuznets curve (EKC). The analysis period of the study covers the years 1990–2016. According to empirical findings, the variables of GDP per capita (lnkbgsyih) and energy use (lneuse) are statistically significant. There is a statistically significant relationship between these two variables and the dependent variable. When there is a 1% increase in the lnkbgsyih variable, there is a 1.3% increase in the lnco2 variable. A 1% increase in the lneuse variable results in a 0.7% increase in lnco2.

1 Introduction

The issue of global warming has become one of the most important and critical issues of the current century. The continuous increase in the amount of carbon dioxide (CO_2) that causes the greenhouse effect makes this problem more and more serious. As a result of both industrialization and rapidly increasing technological developments in the world, rapid increases have been experienced in production amounts and economies have entered a growth trend. On the other hand, this growing growth process has also led to large increases in energy demand, which is an indispensable element for the production and use of goods and services. This

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increasing energy demand in the world is still largely met by non-renewable energy sources, which are fuels with high-carbon content (Gülmez, 2015). The use of high-carbon fuels has increased carbon dioxide emissions. This situation caused environmental problems and led to discussion of the relationship between environment and growth. For a sustainable growth and development, it is an important element not to ignore the environmental effects arising from economic activities. For this reason, besides the sustainable economy, the importance of the sustainable environment is increasing day by day. Sustainable economic growth is the ultimate goal in the economic policy of many countries in the world. For this reason, the carbon emission factor, which is one of the issues that will affect global warming and climate change, is a very important factor in shaping economic growth policies.

In recent years, it is seen that studies investigating environmental effects have increased in order to achieve sustainable economic growth. It is known that this effect is investigated, especially through energy consumption and emissions, and these elements are becoming determinants of special interest. Because global warming is increasing in the world, it causes bigger environmental problems day by day. Although measures to combat these environmental effects seem to be increasing in the world, deterrent sanctions are still not implemented. The main factor causing global warming is greenhouse gases and at the beginning of these gases is CO_2 gas, which is produced by fossil fuels, which is widely used in the economy (Aydın, 2013). Therefore, it is essential to reduce the amount of these gases in solving the environmental problems caused by global warming.

The low carbon emission thesis is also defended by international circles. The Kyoto Protocol signed in 1997 is the guarantor of this thesis. With this Protocol, sustainable green growth is aimed by reducing CO_2 and different greenhouse gases (Obradović & Lojanica, 2017). However, with the realization of the industrial revolution, there is an increasing energy demand day by day. This increase rapidly increases the CO_2 emission rates in the world. In the 2021 report of the Intergovernmental Panel on Climate Change, it is accepted that the increase in emissions accelerates global warming. The Paris Convention on climate change, approved at COP21, agrees to combat the consequences of climate change and continues the necessary initiatives to limit global warming above 2 °C (Azam et al., 2021).

The EKC hypothesis, which is based on the assumption that the relationship between economic growth and emission amount is in an inverted U shape, is widely discussed in the literature, and the relationship between the variables of this study is tried to be explained through the EKC hypothesis. Accordingly, the amount of emissions increases in parallel with economic growth at the beginning; then, the amount of emissions decreases after a certain point is reached (Salari et al., 2021). As a result, although the increases in economic growth cause environmental degradation at first, environmental pollution will disappear over time with the improvement that growth will bring about.

In addition to growth, many factors such as population, poverty, industrialization, urbanization, energy consumption can be effective on the amount of emissions. It is known that factors such as population, industrialization, and urbanization have a direct impact on economic growth and energy use. The more the population in a

country increases, the more the production and consumption activities will increase, which will directly increase the demand for energy. On the other hand, since the increase in industrialization and improvements in urbanization will lead to economic growth in order to meet this production demand, it is expected that the demand for energy will increase directly. Due to the environmental damage caused by the use of energy along with economic growth, countries make commitments to reduce the amount of carbon emissions in the context of climate agreements on behalf of the sustainability of the environment. In the Sustainable Development Goals, many countries have committed to carbon neutrality by 2060.

Attention is drawn to the increase in the amount of carbon emissions with the increasing energy use since the first industrial revolution. However, there are optimistic thoughts that the fourth industrial revolution, together with the innovations brought by the current century, can turn the negative effects on the environment into positive. These effects are expected to have profound effects on the global economy, society, and financial system. It is predicted that artificial intelligence, Internet of things, and machine learning will achieve this with revolutionary and disruptive technological developments. The direction and impact of these developments contain uncertainty. However, if these developments are utilized effectively, it will contribute not only to the environment but also to the development of humanity (Herweijer et al., 2018).

In this context, this study examines the effects of the variables, which are considered within the scope of the commitment to reduce carbon emissions, on carbon emissions in countries that have a large place in the world economy and cause the most carbon emissions.

The study is to determine whether there is a long-term relationship between the economic growth and amount of CO_2 emissions, which is one of the biggest factors affecting global warming. In addition, urbanization and energy use variables are also evaluated and examined as factors affecting CO_2 emissions. The study considers this relationship as the sample countries of China, USA, India, Russia, and Japan, which cause the most emissions according to the ranking of the World Economic Forum. The period of the study covers the years 1990–2016. In this direction, the first part of the study is reserved for the introduction, and the study consists of four parts in total. In the second part of the study, a large literature is included. While econometric analysis is included in the third section, analysis results and policy proposals are included in the fourth and final section.

2 Literature Review

Three important developments in the world have led to an increase in studies on energy. The first of these is the oil shock of the early 1970s. The first study examining the relationship between energy consumption and growth in this crisis period was carried out by Kraft and Kraft (1978) on the US economy. In the period covering 1947–1974, one-way causality from economic growth to energy

consumption was determined. Akarca and Long (1980) reached different analysis results in their study. The second significant development was the Kyoto Protocol, which was put into effect in 1997, while the third was the increase in energy prices caused by the increase in oil prices. These important events contributed to the increase in the work done in the field of energy (Obradović & Lojanica, 2017).

There are many studies in the literature examining the relationship between energy use in different country groups and in different periods, on both economic growth and emission volumes. In this section, a summary of the studies examining the relationship between energy use, economic growth, and CO_2 is given.

Ozturk and Acaravci (2010) test the relationship between economic growth and carbon emissions using the data set between 1968 and 2005. In the study using the ARDL model, a long-term relationship is determined between the series. However, it is concluded that the EKC hypothesis is not valid. Borhan et al. (2012) use the data set between 1965 and 2010 to reach results that support the EKC hypothesis in ASEAN-8 countries.

Altıntaş (2013) determines the relationship between the amount of CO_2, per capita income and energy consumption in Turkey for the period 1970–2008. The test results show a unidirectional causality from economic growth and energy consumption variables to carbon dioxide emissions. Salahuddin and Gow (2014) find a positive relationship between CO_2 amount, economic growth, and energy consumption between 1980–2012 by using the PMG (pooled average group) estimator method in Gulf cooperation member countries.

Shahbaz et al. (2014) investigate the EKC hypothesis in Tunisia between 1971 and 2010. In the study using the ARDL model, a long-term positive relationship was determined. In addition, results supporting the EKC hypothesis are reached. Bozkurt and Okumuş (2015) test the validity of the EKC hypothesis in the Turkish economy between 1966 and 2011. In the study using Hatemi-J cointegration test, a long-term relationship between the variables is detected. In addition, economic growth in Turkey positively affects CO_2 emissions and supports the EKC hypothesis.

Saidi and Hammami (2015) investigate the EKC hypothesis in 58 countries' economies. Generalized moments method (GMM) is used for the period of 1990–2012. Empirical evidence shows the positive effect of CO_2 emissions and economic growth on energy consumption for the panel and is statistically significant.

Bouznit and Pablo-Romero (2016) reached results that support the EKC hypothesis in their studies using the ARDL model in the Algerian economy between 1970 and 2010. Antonakakis et al. identify results that may vary according to the heterogeneity of country groups in 106 countries' economies between 1971 and 2011.

Alper and Alper (2017) concluded that between 1985 and 2014, economic growth and energy consumption in the Turkish economy increased environmental pollution in the long run. Al-Mulalı and Che Sab (2018) examine the relationship between financial development, energy consumption, and CO_2 in the UAE. They found a long-term relationship between variables between 1980 and 2008.

Chen (2018) finds out vary according to regions that the effects of economic growth, foreign trade, carbon emissions, and urbanization variables on renewable energy consumption in the Chinese economy in the period covering the years

1996–2013. Temelli and Şahin (2019) analyze the possible factors that can determine environmental quality in 10 emerging market economies using the dataset between 1995 and 2014. Westerlund and Edgerton and Durbin-H panel cointegration tests are used in the study. From the results of the analysis, a long-term relationship is determined between economic growth, technological development, financial development, and CO_2 emissions. In addition, it has been determined that economic growth reduces environmental quality.

Shahbaz et al. (2020), The UK economy aims to achieve a net-zero emissions target by 2050. In line with this goal, the study analyzes the possible effects of economic growth, financial development, energy consumption, and R&D expenditure variables on carbon emissions. As a result of the analyses made with the limit test approach in the period of 1870–2017, cointegration is detected between CO_2 emissions and variables. In addition, it is seen that the variables of financial development and energy consumption have detrimental effects on the environment, but R&D expenditures have a positive effect by reducing CO_2 emissions. Economic growth, on the other hand, supports the EKC hypothesis in terms of its environmental effects.

Zmami and Ben-Salha (2020) investigate the determinants of CO_2 emissions in Gulf Cooperation Council countries between 1980 and 2017. They determine the validity of the EKC hypothesis in their studies where they use the PMG-ARDL approach. In addition, while energy consumption and foreign direct investments increase environmental degradation in the long term in these countries, urbanization reduces it.

Salari et al. (2021) examine the relationship between CO_2, energy consumption, and economic growth in the USA in 1997–2016. The analysis results show a long-term relationship between energy consumption and CO_2. Shabir et al. (2022) examined the effect of economic policy uncertainty and foreign direct investment on CO_2 emissions in 24 developed and developing countries between 2001 and 2019 with VECM analysis. Economic policy uncertainty, economic growth, trade, and energy consumption negatively affect the environment. However, foreign direct investments increase the environmental quality of sample countries.

Duran and Bozkaya (2022), in their study using the Augmentation Average Group (AMG) method, found the effect of energy consumption on growth in the BRICS country group to be positive and significant. Dkhili (2022) tests the validity of the EKC hypothesis for MENA countries. It finds that the relationship between renewable energy, economic growth, and CO_2 emissions between 1990 and 2018 is in an inverted U shape, which supports the EKC hypothesis.

The studies examined in the literature try to explain the relationship between growth, energy, and environmental quality on the basis of the EKC hypothesis. While some of the studies examined have obtained results that support the EKC hypothesis, it is generally determined that the studies in the literature do not support the EKC hypothesis assumption. Studies using regression analysis seem to confirm the existence of a long-term relationship between variables. Therefore, it can be said that there is a strong relationship between energy use, economic growth, and carbon

emission variables. As a result, research supports the assumption that growth and energy use increase carbon emissions.

Studies that do not support the EKC curve reveal that long-term growth causes carbon emissions while increasing energy demand. Therefore, it draws attention to the importance of carbon emissions in terms of the sustainability of growth. It also reveals the importance of environmental sustainability in order to transfer the desired growth to future generations in a stable manner. The policies implemented for growth should minimize carbon emission levels for the continuity of growth and should even be implemented in parallel with the necessity of reducing it to zero-carbon level if possible. However, growth will be achieved with a clean and sustainable environment that can be transferred to future generations with zero carbon.

3 Data Definition, Model and Method, Empirical Findings

The study takes the top five countries with the highest carbon emissions in the world as a sample. These countries are China, USA, India, Russia, and Japan, respectively. According to the World Economic Forum (waeforum) 2019 data, the global emission rates of these countries are as follows: China 27.2%, USA 14.6%, India 6.8%, Russia 4.7%, and Japan 3.3%, making up the top five in the world ranking. The period of the study covers the years 1990–2016. In the study, carbon emission (CO_2) is the dependent variable. In addition, the model has been expanded by including per capita GDP, energy use, and urbanization population. Table 1 represents the broad definitions of the variables discussed in our study and the database obtained.

The natural logarithm of the variables used in our model was taken. The model used in our study is as follows;

$$\text{lnglnco2}_t = \beta_0 + \beta_1 \text{lngdppc} + \beta_2 \text{lneuse} + \beta_3 \text{lnurbanpop} + \varepsilon_t \quad (1)$$

In the panel data analysis, firstly, the CD test, which tests the relationship between horizontal sections, was applied. This test determines the existence of the relationship between the horizontal sections and decides to determine the method to be used

Table 1 Variable Definitions and Source

Variables	Variable Definition	Source
Carbon emission (lnco2)	CO_2 emissions (kt)	World Bank Indicator
GDP per capita (lnkbgsyih)	GDP per capita, PPP (constant 2017 international $)	World Bank Indicator
Energy Use (lneuse)	Energy use (kg of oil equivalent) per $1000 GDP (constant 2017 PPP)	World Bank Indicator
Urban Population (lnurbanpop)	Urban population	World Bank Indicator

in the study. The CD test was applied to the variables individually and also to the whole panel, and it was concluded that there was no cross-sectional dependence in only the CO_2 variable according to the probability values. However, for other variables and the panel as a whole, the existence of a horizontal cross-section was accepted according to the LM test statistic (p-value 0.000 <0.05) (since $T = 27 > N = 5$). In the second step of the application, the unit root test was applied to the variables. For this purpose, CADF test was used. While the variables lnco2 and lnkbgsyih become stationary at the level, lneuse and lnurbanpop are integrated at the I (1) level. The stationarity levels of the variables differ and are at a mixed level.

After determining the stationarity levels of the variables, the homogeneity test was performed to determine whether the slope coefficients of the variables used in the model were homogeneous or heterogeneous. Pesaran and Yamagata (2008) homogeneity test was used to determine homogeneity. According to the probability value of the delta test statistic (0.000 < 0.005), the null hypothesis of "H_0: = β the slope coefficients are homogeneous" was rejected and it was decided that the slope coefficients of the variables in the model were heterogeneous. At this stage, the second-generation cointegration test was used with the presence of cross-section dependency. In the applied cointegration test, since the probability value of the Gt statistic (the statistic that detects the presence of cointegration in at least one cross-section) is 0.000 <0.005, the null hypothesis of no cointegration was rejected and the alternative hypothesis was accepted. In the third step, the cointegration test was applied to the variables. Finally, the coefficients of this long-term relationship were estimated.

Due to the presence of horizontal cross-section and heterogeneity of slope coefficients in the model, it was decided to use the DCCEMG ((Dynamic) Common Correlated Effects Estimator - Mean Group/Dynamic Mean-Related Effects Mean Group Estimator) method applied to heterogeneous series.

Studies using the first panel analysis method have accepted the existence of homogeneous slopes, ignoring the relationship of cross-section units with each other. In our study, the dynamic co-correlation method developed by Chudik and Pesaran (2015a), which takes into account the importance of cross-sectional dependence, was used. The DCCE approach allows homogeneous and heterogeneous coefficients/dynamic co-related effects and is also sensitive to the cross-sectional situation. This approach is also based on heterogeneous slopes and cross-section dependence, including cross-section means and lags. Also, in addition to these possibilities it provides, the other important aspect of this approach is that it allows it to be equally applicable using the roof correction approach in the case of small sample sizes (Chudik & Pesaran, 2015b). Supporting evidence for this method was put forward in the study of Ditzen (2016). Another important benefit of the DCCE approach is that it is a robust and consistent predictive method in the presence of structural breaks (Kapetanios et al., 2011). In addition, the DCCE model performs well in the case of unbalanced panel data (Ditzen, 2016). Table 2 shows the estimation results of the long-term coefficients (DCCEMG) in line with the explanations.

Table 2 DCCEMG Results

Variables	Statics	*P*-value
Lnkbgsyih	1.329	0.000*
Lneuse	0.701	0.001**
Lnurbanpop	−1.433	0.276
Constant	2.354	0.791

Note: * denotes significance at the 1%, ** 5% level. Average group variables: lnkbgsyih, lneuse, lnurbanpop _cons. Cross-sectional mean variables: lnkbgsyih, lnCO2, lneuse, lnurbanpop. The test statistics were obtained from the Stata 15 package program

$$\text{lnglnco2}_t = 2.354 + 1.329\text{lngdppc} + 0.701\text{lneu} - 1.433\text{lnurbanpop}$$

Based on the results in the table, with lnco2 being the dependent variable; GDP per capita (lnkbgsyih) and energy use (lneuse) variables are statistically significant. There is a statistically significant relationship between these two variables and the dependent variable. When there is a 1% increase in the lnkbgsyih variable, an increase of 1.3% occurs in the lnco2 variable. A 1% increase in the Lneuse variable causes an increase of 0.7% in lnco2. No statistically significant long-term relationship was found between urbanization population (Lnurbanpop) and carbon emissions.

According to these results obtained from the empirical findings, the existence of a strong relationship between the mentioned variables is supported in the sample group countries considered in our study. The dependence of production and growth on energy demand and the resulting carbon emissions are confirmed by the results of this study.

4 Conclusion and Evaluation

Since the first industrial revolution, first gradually and then a rapid growth process has gradually increased the amount of carbon emissions that cause global warming. Therefore, it is known that the energy used in industry has a great effect on the amount of carbon emissions. Increasing carbon emissions increase global warming and jeopardize the sustainability of the environment. The increase in the global average temperature is accelerating the climate crisis. These effects from production and growth are important for understanding a sustainable environment. In this context, zero-carbon emission, which means reducing the amount of carbon emissions, which is one of the sustainable development goals, and ultimately eliminating it completely, is increasing its importance in today's world. But, although the interest in renewable energy sources has increased in recent years, the dependence on fossil fuels continues. The use of fossil resources increases the effect of greenhouse gases in the world, and this leads to a negative impact on the environment. Global

warming, climate change, and environmental degradation, which are increasing every year, are taking resources away from being sustainable. In terms of countries, the cost of these situations is getting heavier. On the other hand, the growth race of their countries, developments in industrialization and technology activities, increase in production and consumption amounts, rapidly increasing world population, etc., many factors increase the demand for energy day by day. This increasing demand increases the use of fossil fuels and continuously increases the amount of CO_2.

In the economic literature, it is accepted to explain the effect of environmental degradation on income and economic growth through the EKC. This hypothesis assumes an inverted U-shaped relationship between per capita income and environmental quality. According to this, environmental pollution initially increases depending on the increase in per capita income, and after a certain point, it reverses. Increasing studies after the determination of this relationship show that the relationship between GDP and environmental quality is in an inverted U shape. In the measurement of environmental quality, the amount of CO_2 emission, which is also an indicator of the amount of global warming, is used. In this study, it is aimed to analyze the relationship between CO_2 and GDP in countries with the highest amount of emissions in the world (China, USA, India, Russia, and Japan). For this purpose, the Dynamic Mean-Related Effects Mean Group Estimator was used in the study. According to the results of the application, the per capita gdp (lnkbgsyih) and energy use (lneuse) variables are statistically significant. There is a statistically significant relationship between these two variables and the dependent variable. When there is a 1% increase in the lnkbgsyih variable, an increase of 1.3% occurs in the lnco2 variable. A 1% increase in the Lneuse variable causes an increase of 0.7% in lnco2. No statistically significant long-term relationship was found between urbanization population (Lnurbanpop) and carbon emissions.

The empirical findings of our study show parallelism with many studies in the literature. These results support the literature. In addition, when these results are evaluated according to the sample group we discussed in the study; draws attention to the strong impact of growth and energy use of countries, which have a large place in the world economy, on carbon emissions.

In the light of the results of the application on the sample group, there is a strong relationship between the gross domestic product per capita and carbon emissions. Likewise, there is a significant positive relationship between carbon emissions and energy use. Dependence on energy in line with the economic growth policies and objectives of the countries paves the way for an increase in carbon emissions. While the production is increasing, the increase in energy use and the corresponding increase in the volume of emissions show parallelism. Based on the countries discussed in the study, these countries occupy a large place in the world production volume. Therefore, the negative costs of this production volume on the world ecosystem are also great.

Minimizing carbon emissions is vital for sustainable growth and sustainable environment. Therefore, it is important to develop policies that will reduce carbon emissions, which is the primary objective. At the same time, investment incentives should be developed for zero-carbon emissions.

Although both academics and policymakers agree to reduce the effects of global warming, it would be incomplete to say that the serious dimension of the problem can be reduced. Within the scope of the sustainable development goal, it is necessary to reduce carbon emissions first. In order to achieve the targeted level of carbon emissions, the practices must be followed. Sustainability of the environment is a responsibility and necessity for everyone living in the world.

The more important economic growth is for countries, the more important is the sustainability of the environment. Studies and policies have been developed for sustainable environment and sustainable growth. However, in terms of being cheap, economies continue to demand fossil fuels and ignore their devastating effects on the environment. However, both for the sake of our world and for their own economic sustainability, countries need to turn toward renewable and clean energy economies. Some countries are in search of clean, renewable energy sources and are taking successful steps in this regard. However, some large economies direct their production systems to countries where environmental taxes-costs are lower. Changing the location of production unfortunately does not change the cost to the environment and our world. Therefore, all countries as a whole should agree on this problem and find a common solution. Only in this way can we live in a cleaner, more sustainable world.

References

Akarca, A. T., & Long, T. V. (1980). On the relationship between energy and GNP: A reexamination. *Journal of Energy and Development, 5*, 326–331.

Al-Mulalı, U., & Che Sab, C. N. B. (2018). Energy consumption, CO2 emissions, and development in The UAE. *Energy Sources, Part B: Economics, Planning, and Policy, 13*(4), 231–236.

Alper, F. Ö., & Alper, A. E. (2017). Karbondioksit emisyonu, ekonomik büyüme, enerji tüketimi ilişkisi: Türkiye için bir ARDL sınır testi yaklaşımı. *Sosyoekonomi, 25*(33), 145–156.

Altıntaş, H. (2013). Türkiye'de Birincil Enerji Tüketimi, Karbondioksit Emisyonu ve Ekonomik Büyüme İlişkisi: Eşbütünleşme ve Nedensellik Analizi. *Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi, 8*(1), 263–294.

Aydın, D. (2013). Ülkeler Arası Co2 Emisyonun Azaltılması Yönde Etkinlik Çalışması. *Muğla Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 30*, 120–135.

Azam, A., Rafiq, M., Shafique, M., Zhang, H., & Yuan, J. (2021). Analyzing the effect of natural gas, nuclear energy and renewable energy on GDP and carbon emissions: A multi-variate panel data analysis. *Energy, 219*, 119592.

Borhan, H., Ahmed, E. M., & Hitam, M. (2012). The impact of CO2 on economic growth in ASEAN 8. *Procedia-Social and Behavioral Sciences, 35*, 389–397.

Bouznit, M., & Pablo-Romero, M. D. P. (2016). CO2 emission and economic growth in Algeria. *Energy Policy, 96*, 93–104.

Bozkurt, C., & Okumuş, İ. (2015). Türkiye'de Ekonomik Büyüme, Enerji Tüketimi, Ticari Serbestleşme ve Nüfus Yoğunluğunun CO2 Emisyonu Üzerindeki Etkileri: Yapisal Kirilmali Eşbütünleşme Analizi. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 12*(32), 23–35.

Chen, Y. (2018). Factors influencing renewable energy consumption in China: An empirical analysis based on provincial panel data. *Journal of Cleaner Production, 174*, 605–615.

Chudik, A., & Pesaran, M. H. (2015a). Commoncorrelatedeffectsestimationof heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics, 188*(2), 393–420.

Chudik, A., & Pesaran, M. H. (2015b). Large panel data models with cross sectional dependence: A survey. In B. Baltagi (Ed.), *The Oxford handbook of panel data* (pp. 82–99). Oxford University Press.

Ditzen, J. (2016). XTDCCE: Estimating dynamic common correlated effects in Stata. *SEEC Discussion Papers*, 1601.

Dkhili, H. (2022). Investigating the Theory of Environmental Kuznets Curve (EKC) in MENA Countries. *Journal of the Knowledge Economy*, 1–18.

Duran, M. S., & Bozkaya, Ş. (2022). Examination of the Relationship between Economic Growth, Natural Resources, Energy Consumption, Urbanization, and Capital. In *Sustainability in energy business and finance* (pp. 83–93). Springer.

Gülmez, A. (2015). OECD ülkelerinde ekonomik büyüme ve hava kirliliği ilişkisi: Panel veri analizi. *Kastamonu Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 9*(3), 18–30.

Herweijer, C., Combes, B., Johnson, L., McCargow, R., Bhardwaj, S., & Jackson, B. (2018). Enabling a sustainable Fourth Industrial Revolution: How G20 countries can create the conditions for emerging technologies to benefit people and the planet. Economics E-Journal Discussion Paper, No. 2018-32.

Kapetanios, G., Pesaran, M. H., & Yamagata, T. (2011). Panels with nonstationary multifactor error structures. *Journal of Econometrics, 160*, 326–348.

Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *Journal of Energy and Development, 3*, 401–403.

Obradović, S., & Lojanica, N. (2017). Energy use, CO2 emissions and economic growth–causality on a sample of SEE countries. *Economic Research-Ekonomska istraživanja, 30*(1), 511–526.

Ozturk, I., & Acaravci, A. (2010). CO2 emissions, energy consumption and economic growth in Turkey. *Renewable and Sustainable Energy Reviews, 14*(9), 3220–3225.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics, 142*(1), 50–93.

Saidi, K., & Hammami, S. (2015). The impact of CO2 emissions and economic growth on energy consumption in 58 countries. *Energy Reports, 1*, 62–70.

Salahuddin, M., & Gow, J. (2014). Economic growth, energy consumption and CO2 emissions in Gulf Cooperation Council countries. *Energy, 73*, 44–58.

Salari, M., Javid, R. J., & Noghanibehambari, H. (2021). The nexus between CO2 emissions, energy consumption, and economic growth in the US. *Economic Analysis and Policy, 69*, 182–194.

Shabir, M., Ali, M., Hashmi, H. S., & Bakhsh, S. (2022). Heterogeneous effects of economic policy uncertainty and foreign direct investment on environmental quality: Cross-country evidence. *Environmental Science and Pollution Research, 29*, 2737–2752. https://doi.org/10.1007/s11356-021-15715-3/

Shahbaz, M., Khraief, N., Uddin, G. S., & Ozturk, I. (2014). Environmental Kuznets curve in an open economy: A bounds testing and causality analysis for Tunisia. *Renewable and Sustainable Energy Reviews, 34*, 325–336.

Shahbaz, M., Nasir, M. A., Hille, E., & Mahalik, M. K. (2020). UK's net-zero carbon emissions target: Investigating the potential role of economic growth, financial development, and R&D expenditures based on historical data (1870–2017). *Technological Forecasting and Social Change, 161*, 120255.

Temelli, F., & Şahin, D. (2019). Yükselen piyasa ekonomilerinde finansal gelişme, ekonomik büyüme ve teknolojik gelişmenin çevresel kalite üzerine etkisinin analizi. *Karabük Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 9*(2), 577–593.

Zmami, M., & Ben-Salha, O. (2020). An empirical analysis of the determinants of CO2 emissions in GCC countries. *International Journal of Sustainable Development & World Ecology, 27*(5), 469–480.

Risk Management in Russian Renewable Energy Projects

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Abstract Financial methods of risk management are considered in detail. The analysis of foreign studies on the application of mathematical methods of risk management has shown high prospects for using the method of network analysis (ANP) in the renewable energy sector. Examples of new forms of risk management are given, such as the use of weather derivatives, climate modeling, and integrated multi-risk contracts. The current state of renewable energy shows the significant place that this industry has occupied in the global energy markets. The established total capacity of renewable energy projects and the amount of electricity generated by them already allow us to talk about the creation of a new energy transition, which is taking an increasingly important place in the energy complexes of many countries around the world. In the period 2000–2019, the total capacity of renewable energy plants (solar, wind, and biomass power, excluding traditional hydropower) increased by more than a third of the previous year. 22 times from 56 GW in 2000 to 1246 GW in 2019. In 2018, more than 180 GW of renewable energy capacity was put into operation, including 100 GW of solar photovoltaic installations. Globally, more renewable energy capacity is now being introduced annually (about 67% in 2018) than all new fossil fuel capacity. By 2019, the total capacity of renewable power plants in the world was 1246 GW, including wind power-591 GW, solar power-505 GW. Wind farms (WPPs) operated in more than 90 countries, with wind power generating up to 5% of total energy consumption in 24 countries, and more than 10% in 13 countries. Nine countries now have more than 20% of solar photovoltaic and wind generation in their energy mix. In 17 countries, the capacity of renewable energy (excluding large hydroelectric power plants) exceeds 10 GW, and in 45 countries, it exceeds 1 GW. In Africa and developing Asia, nearly 150 million people have gained access to electricity using autonomous solar photovoltaic systems.

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1 Introduction

In Russia, thanks to the current system of competitive selection for the construction of renewable energy facilities and state measures to support the PDM of investment in renewable energy, a significant breakthrough in the development of renewable energy in the country has taken place over the past 2 years (Liu et al., 2021a; 2021b; 2021c; Mukhtarov et al., 2022; Xie et al., 2021). Domestic production of wind turbine and tower components has been established, which ensures the required level of localization. In the country, solar photovoltaic plants certified in the market of additional capacity as renewable energy facilities have already been installed and operate efficiently in a number of regions (Kou et al., 2022; Zhe et al., 2021; Zhou et al., 2021). By 2020, the total installed capacity of solar power plants (SPP) in Russia was 1265.67 MW; 568.5 MW was commissioned in 2019, or 45%. In 2019, the increase was 81.5% of the total capacity in 2018.

Hevel Group of Companies has developed and set up production in Novocheboksarsk (260 MW year) of innovative heterostructured solar modules with increased efficiency and efficiency of more than 22%. Plans to reach the planned capacity in Russia by 2024. The capacity of renewable power plants in 4 GW and the subsequent development of renewable energy in the country is determined by the further increase in investment and the level of localization of production. The intensity of investment flows is determined by the level of reliability of investments in renewable energy, related to the state of development of risk management methods in this industry.

2 Research Goals and Objectives

Activation of the RES development process in Russia requires studying the risk factors that arise during the creation and operation of energy facilities, as well as analyzing the main risk management methods applicable in the renewable energy sector. In recent years, due to the availability of extensive factual material on renewable energy facilities, foreign researchers have been actively developing the topic of risk management methods in the renewable energy sector. For the territory of Russia, it is of great importance to solve the problems of risks of instability of the necessary resources to ensure the profitability of the project due to the uneven distribution of the energy potential of renewable energy sources in time and space. The analysis of the problems of RES development in our country indicates the need for methodological developments on managing possible risks of various types for the safe and cost-effective use of these energy sources in the regions of Russia.

3 External and Internal Risks

To develop a risk management methodology, it is necessary to pre-evaluate possible risks at all stages of the development of a renewable energy facility project. The risks of RES facilities, as well as other energy facilities, can be divided into external risks (independent of the project developer) and internal risks (related to the developer's project activities) (Dinçer et al., 2022; Ding et al., 2021; Meng et al., 2021). The main risk register we have compiled is presented in Table 1. It should be noted that resource and environmental risks have both internal and external components. The risk of a shortage of necessary resources to ensure the profitability of the project is due to the uneven distribution of the energy potential of renewable energy sources in time and space. However, carrying out additional measurements, accurate selection of parameters of power plants that allow you to get the highest K_{ium}—significantly reduces this type of risk. Natural and environmental risks are associated with the possibility of catastrophic events (hurricanes, heavy rains, snowfalls, tornadoes, earthquakes). This type of risk also includes possible consequences for the environment due to routine operation or emergencies at renewable energy facilities (Baboshkin et al., 2022; Baig et al., 2022a, 2022b; Barykin et al., 2022; Bhuiyan et al., 2021, 2022a; Candila et al., 2021; Danish et al., 2022; Dong et al., 2021; Liu et al., 2022a, 2022b; Mikhaylov, 2021b; Mikhaylov & Grilli, 2022; Mukhametov et al., 2021; Saqib et al., 2021; Yüksel et al., 2021a, 2021b, 2021c).

4 Risk Management in the Renewable Energy Sector

Investors make decisions about supporting renewable energy projects based on an analysis of future revenues and an assessment of the main risks that may potentially affect the project. The amount and conditions of financing are closely related to the high level of risk of the project and the availability of tools to reduce them. Thus, the ability to obtain the necessary investments and loans for renewable energy projects depends on the effectiveness of risk management in this industry. For renewable energy facilities, it is necessary to take risks into account at all stages of project development: when preparing a feasibility study, when designing, when organizing investments and conducting tenders, directly during construction, as well as at the operational stage (Dong et al., 2022; Haiyun et al., 2021; Li et al., 2022). Currently, there is a distinction between qualitative and quantitative risk assessment.

Qualitative analysis involves identifying:

- sources of risk;
- stages and works that pose a risk (identification of potential risk zones, changes in risk dynamics, identification of all positive and negative aspects related to the implementation of a solution containing a risk).

Quantification allows you to:

- identify the mathematical probability of occurrence of the identified risks;
- determine the values of losses (or profits) from actions in a risky situation, which will be the object of further analysis for making decisions on managing these risks;
- determine the degree of influence of various factors on the risk situation;
- prepare an optimal RES project management plan in a risky situation;

Analysis of the experience of foreign renewable energy projects has shown that when solving the following tasks: *risk management system* you can select *non-financial assets* and *financial services* risk management mechanisms (Kostis et al., 2022; Zhao et al., 2021a, 2021b). Non-financial methods are mainly aimed at the actions of the developer of the project on renewable energy sources to prevent or reduce the loss of internal risks during the technological process of the object's operation. They include the following: *technical measures* reduce the probability of negative events or minimize losses; *organizational arrangements* assume the use of a set of measures aimed at the optimal construction of technological processes and individual operations, as well as the development of security and preventive measures; *legal measures* include the development and approval of relevant regulatory documents that regulate certain situations and impose responsibility for violation or improper performance of assigned duties; and *staff training* can also be attributed to specific measures to influence risk situations, since the risk is often based on a human or subjective factor (Bhuiyan et al., 2022b; Conteh et al., 2021; Daniali et al., 2021; Denisova et al., 2019; Huang et al., 2021a, 2021b; Khan et al., 2021; Liu et al., 2021a, 2021b; Mikhaylov, 2018a, 2018b, 2022a, 2022b; Mikhaylov et al., 2019; Nyangarika et al., 2019a, 2019b; Sediqi et al., 2022).

5 Analysis of Financial Methods of Risk Management

In financial methods, there are three main strategies for managing risks in the renewable energy sector: *risk acceptance, mitigation, and transfer.* Risk acceptance usually means leaving all or part of the risk to the entrepreneur, i.e., on his responsibility. In this case, the entrepreneur makes a decision to cover possible losses as a result of a risk event at the expense of his own funds, for example, self-insurance (the developer creates his own insurance funds that are intended to cover losses), compensation (covering the risk at the expense of the current cash flow), and reservation (creating a fund of funds to cover unforeseen expenses).

When constructing a renewable energy facility, the distribution of risk among project participants is an effective way to reduce it. It consists in the distribution of risk between the owner, investor, and executor of the project. In most cases, the relationship between the project owner and the project executor is based on a contractual relationship. Therefore, when entering into a contract, all penalties that will be applied to the contractor for non-fulfillment of contractual obligations are

stipulated in advance. Thus, the risk will be distributed among the parties to the agreement and compensated in some way. Analysis of the experience of foreign renewable energy projects has shown that the most applicable methods of risk reduction are such as long-term agreements on the purchase of electricity, contracts for operation and maintenance, as well as the transfer of part of the risks to third parties.

The question of what risk should be assumed is one of the most difficult and important in the practice of risk management. The current understanding of risk management is based on the so-called "acceptable risk concept," according to which the main goal of the risk management process is to give maximum stability to all types of company activities by keeping the total risk (expected level of losses) within the limits set by the development strategy.

Risk transfer is a method of insuring the construction of renewable energy facilities, their operation, and the issuance of guaranteed capacity. Insurance allows the developer (developer) of the project to compensate for losses that may arise in the event of negative consequences of existing risks. Risks accepted by insurance companies usually include those developed for traditional industries. These include the following: technological risks (equipment failure), organizational risks (delays in delivery), natural disasters, human factors, as well as some legal and financial risks.

Climate variability is partly predictable and is a fundamental factor in explaining financial risk in renewable energy projects. In recent years, a risk assessment methodology has been developed that takes climate predictability into account. The paper describes a method for reducing the risk of using the following methods: PV projects by modeling predictable components of solar radiation and atmospheric fluctuations. The new profit model for photovoltaic installations takes predictable climate information into account. The model was adapted for risk assessment PV-Developed and applied in more than 10 geographical areas throughout Chile, where the climate is strongly influenced by three oceanic atmospheric fluctuations (southern El Nino oscillation, Southern Ring Regime, and Indian Ocean Dipole). Using the model in these regions reduces monthly financial risk by 60–81% compared to the traditional methodology. Modeling of ocean–atmospheric fluctuations makes it possible to achieve the greatest reduction in risks for the southern regions of the country, with extreme climatic conditions. This methodology is potentially applicable to hydropower, wind, and other renewable resources and allows you to exclude forecast climate components from the project risk calculation.

In quantitative methods, risks are mainly measured using the variance or probability density distribution of technical and economic parameters, while semi-quantitative methods, such as scenario analysis and multi-criteria analysis of decisions, can also take into account non-statistical parameters, such as socio-economic factors. For risk assessment and mathematical analysis of solutions, Monte Carlo stochastic process modeling methods are most widely used and the network analysis method (MAC) is used in the English-language literature—analytical network process (ANP). The method is used to assess key risk factors and analyze the consequences of selected alternative solutions. The MAC also allows you to

introduce various factors and criteria—tangible and intangible-that characterize the risk assessment.

Not all types of risks inherent in renewable energy facilities are subject to insurance. Insurance companies, as a rule, cover only those risks that can be used to assess the probability of an insured event, assess the amount of possible damage, and calculate the corresponding insurance premium. A number of risk factors specific to the operation of renewable energy projects, primarily changes in legislation and the economic and political climate in the country, usually go beyond insurance. This also applies to certain projects using new renewable energy technologies, the implementation of which does not meet the basic requirements of insurance companies. In this regard, many projects in the field of renewable energy have a high level of risk, which reduces their prospects for investing and obtaining loans from the point of view of banks (Adalı et al., 2022; An et al., 2021; Danish et al., 2020, 2021; Mikhaylov et al., 2018; Nyangarika et al., 2018; Shaikh et al., 2021; Tamashiro et al., 2021; Uyeh et al., 2021; Yüksel et al., 2022).

6 Modern Forms of Risk Management in the Renewable Energy Sector

Analysis of existing renewable energy projects shows that a number of large developers are actively using alternative risk transfer tools adapted for renewable energy. Let's look at some alternative risk transfer mechanisms in addition to traditional insurance, which can increase the investment attractiveness of renewable energy projects.

Weather derivatives. For many decades, the only way to reduce weather risks was to insure them and only in the late 90s of the last century did such a concept as a "fixed-term weather contract" appear, which is currently intensively used by foreign companies to reduce the risk associated with changes in weather conditions. Resource weather risks affect the reliability of generation of most renewable energy systems and, consequently, the planned profit. Weather derivatives are financial futures contracts whose payouts directly depend on weather conditions: the number of sunny days, fluctuations in wind speed and precipitation, and deviations from a given temperature value.

A firm that owns a wind farm can purchase an annual futures contract or an option that fixes a certain index value. If the wind speed becomes lower than this value, the company receives compensation from the option seller, thereby reducing the risk of financial losses. Thus, developers of renewable energy projects can hedge (insure) their risks in the event of an unfavorable event for them. Events, however, give up excess profits in the event of a favorable event. The growing production of electricity from renewable sources in recent years, combined with uncertain weather conditions in Germany and Austria, has led to increased risks for energy companies when increasing the number of wind farms. In 2016, the EEX Exchange offered an

effective innovative hedging tool for risk management in the form of futures (weather derivatives). As the underlying asset of wind energy futures EEX, the wind index is calculated by EuroWind. The model changes every 15 min, based on data from the weather service located in Germany.

Multi-risk contracts allow companies to combine different risks inherent in a particular project. Obviously, the probability that several events will occur simultaneously is much lower than the probability that they will occur separately. Therefore, the cost of multi-risk contracts is significantly lower than insurance rates. In addition, these agreements may include risks that, as a rule, are not covered by insurance companies (political and business risks, currency exchange rate fluctuations, and commodity prices). The concept *risk capital* includes various schemes for financing unforeseen losses, which are used as an alternative to traditional insurance. Risk capital can take the form of options, convertible debt, hybrid securities, and preferred shares. *Pledge of shares* allows the project developer to use a portion of their shares as collateral for the loan. The lender can get ownership of the shares only if the project developer fails to fulfill its obligations under the loan. Currency swap—a trade and financial transaction between two partners for the exchange of various financial assets, in order to reduce or change the nature of risks. In the renewable energy sector, currency swap agreements are usually used in international projects, when changes in the exchange rate play an important role. *Securitization of loans*—attracting financing through the issuance of securities backed by assets that generate stable cash flows and allows for the conversion of non-market assets into marketable securities. So, in 2013, the company SolarCity issued a $54 million package of securities backed by assets that include solar power plants, leasing contracts, and long-term electricity supply contracts.

The main obstacle to the wider use of alternative methods of financial risk management in the renewable energy sector and the development of new products for managing the development of renewable energy sources in Russia is the lack of industry-specific information. The financial sector requires a deeper understanding of the renewable energy industry, its existing technologies, and operational processes. In order to calculate risk premiums, insurance companies must have a complete set of information that allows them to estimate the probability of occurrence of an insured event, as well as the amount of possible damage from it. The solution to this situation may be closer cooperation between developers of renewable energy projects and representatives of the financial sector. Since renewable energy is a relatively young sector, many industry data have not yet been widely disseminated among specialists in other fields. Therefore, project developers should initiate the transfer of information about their technologies and operational activities to representatives of various financial institutions. This collaboration should help insurance companies, banks, and other private lenders better understand and understand all the risks associated with renewable energy projects.

An important factor in reducing risks and improving the company's credit rating when creating renewable energy facilities is also *guarantees of international institutions and the public sector.* These guarantees play a key role in reducing political risk, as today traditional insurance products do not cover the risks associated with

changes in the political situation and legislation in a particular country. This is particularly important when attracting financing for renewable energy projects in developing countries with a high level of political risk (An et al., 2019a, 2019b, 2020a, 2020b, 2020c; An & Mikhaylov, 2020, 2021; Dooyum et al., 2020; Grilli et al., 2021; Gura et al., 2020; Mikhaylov, 2020a, 2020b, 2020c, 2021a; Mikhaylov & Tarakanov, 2020; Mikhaylov et al., 2022; Moiseev et al., 2020, 2021; Morkovkin et al., 2020a, 2020b; Mutalimov et al., 2021; Varyash et al., 2020; Yumashev et al., 2020; Yumashev & Mikhaylov, 2020; Zhao et al., 2021a, 2021b).

7 Conclusions

The high-risk level of renewable energy projects reduces their creditworthiness and, consequently, makes it difficult to obtain borrowed capital. A fundamental requirement for attracting funding is to reduce the risks that are most likely to have a negative impact on the project. The construction of renewable energy facilities currently receives a large amount of state support in Russia, which reduces the risks in the operation of power plants, but the support program is drawn up until 2024. As part of the second renewable energy support program for the period 2025–2035, renewable energy should become a full-fledged market participant with an increased level of localization and the possibility of entering the export market. Therefore, it is particularly important to develop and adapt the existing risk management methodology for using all types of renewable energy sources, both for grid and for autonomous power supply, to the Russian reality at the present stage.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In H. Dinçer & S. Yüksel (Eds.), *Multidimensional strategic outlook on global competitive energy economics and finance* (pp. 1–11). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80117-898-320221002

An, J., & Mikhaylov, A. (2020). Russian energy projects in South Africa. *Journal of Energy in Southern Africa, 31*(3). https://doi.org/10.17159/2413-3051/2020/v31i3a7809

An, J., & Mikhaylov, A. (2021). Analysis of energy projects financial efficiency and renewable energy generation in Russia. *Finance: Theory and Practice, 25*(5), 79–91.

An, J., Mikhaylov, A., & Sokolinskaya, N. (2019a). Machine learning in economic planning: Ensembles of algorithms. *Journal of Physics: Conference Series, 1353*, 012126.

An, J., Mikhaylov, A., & Moiseev, N. (2019b). Oil price predictors: Machine learning approach. *International Journal of Energy Economics and Policy, 9*(5), 1–6.

An, J., Mikhaylov, A., & Richter, U. H. (2020a). Trade war effects: Evidence from sectors of energy and resources in Africa. *Heliyon, 6*, e05693. https://doi.org/10.1016/j.heliyon.2020.e05693

An, J., Mikhaylov, A., & Jung, S.-U. (2020b). The strategy of South Korea in the global oil market. *Energies, 13*(10), 2491.

An, J., Mikhaylov, A., & Kim, K. (2020c). Machine learning approach in heterogeneous group of algorithms for transport safety-critical system. *Applied Sciences, 10*(8), 2670.

An, J., Mikhaylov, A., & Jung, S.-U. (2021). A linear programming approach for Robust network revenue management in the airline industry. *Journal of Air Transport Management, 91*, 101979.

Baboshkin, P., Mikhaylov, A., & Shaikh, Z. A. (2022). Sustainable cryptocurrency growth is not possible? Impact of network power demand on bitcoin price. *Financial Journal, 14*(2), 39–55.

Baig, U., Hussain, B. M., Khan, A. A., Shaikh, Z. A., Mikhaylov, A., Chao, C.-C., & Barykin, S. E. (2022a). Research on investors of the reginal stock exchange: An influence of behavioral finance on investment decision making. *Risks, 10*(4), 116.

Baig, U., Khan, A. A., Abbas, M. G., Shaikh, Z. A., Mikhaylov, A., Laghari, A. A., & Hussain, B. M. (2022b). Crucial causes of delay in completion and performance management of the construction work: Study on the base of relative importance index. *Journal of Tianjin University Science and Technology, 55*(6).

Barykin, S., Mikheev, A., Kiseleva, E., Putikhin, Y., Alekseeva, N., & Mikhaylov, A. (2022). An empirical analysis of Russian regions' debt sustainability. *Economies, 10*(4), 296.

Bhuiyan, M. A., An, J., Mikhaylov, A., Moiseev, N., & Danish, M. S. S. (2021). Renewable energy deployment and COVID-19 measures for sustainable development. *Sustainability, 13*, 4418.

Bhuiyan, M. A., Khare, V., Mikhaylov, A., Pinter, G., & Zhang (2022a) Does renewable energy consumption affect economic growth? A systematic literature review. *Frontiers in Environmental Science*.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022b). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*(2022), 561–570.

Candila, V., Maximov, D., Mikhaylov, A., Moiseev, N., Senjyu, T., & Tryndina, N. (2021). On the relationship between oil and exchange rates of oil-exporting and oil-importing countries: From the great recession period to the Covid-19 era. *Energies, 14*, 8065.

Conteh, F., Takahashi, H., Hemeida, A. M., Krishnan, N., Mikhaylov, A., & Senjyu, T. (2021). Hybrid grid-connected renewable power generation for sustainable electricity supply in Sierra Leone: Case study Lungi Town. *Sustainability, 13*(18).

Daniali, S. M., Barykin, S. E., Kapustina, I. V., Khortabi, F. M., Sergeev, S. M., Kalinina, O. V., Mikhaylov, A., Veynberg, R., Zasova, L., & Senjyu, T. (2021). Predicting volatility index according to technical index and economic indicators on the basis of deep learning algorithm. *Sustainability, 2021*(13), 14011.

Danish, M. S. S., Bhattacharya, A., Stepanova, D., Mikhaylov, A., Grilli, M. L., Khosravy, M., & Senjyu, T. (2020). A systematic review of metal oxide applications for energy and environmental sustainability. *Metals, 10*(12), 1604.

Danish, M. S. S., Estrella-Pajulas, L. L., Alemaida, I. M. A., Grilli, M. L., Mikhaylov, A., & Senjyu, T. (2022). Green synthesis of silver oxide nanoparticles for photocatalytic environmental remediation and biomedical applications. *Metals, 12*(4). https://doi.org/10.3390/met12050769

Danish, M. S. S., Senjyu, T., Sabory, N. R., Khosravy, M., Grilli, M. L., Mikhaylov, A., & Majidi, H. (2021). A forefront framework for sustainable aquaponics modeling and design. *Sustainability, 13*, 9313.

Denisova, V., Mikhaylov, A., & Lopatin, E. (2019). Blockchain infrastructure and growth of global power consumption. *International Journal of Energy Economics and Policy, 9*(4), 22–29.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Ding, Z., Yüksel, S., & Dincer, H. (2021). An Integrated Pythagorean fuzzy soft computing approach to environmental management systems for sustainable energy pricing. *Energy Reports, 7*, 5575–5588.

Dong, B., Ikonnikova, I., Rogulin, R., Sakulyeva, T., & Mikhaylov, A. (2021). Environmental economic approach to optimization of transport communication in megacities. *Journal of Environmental Science and Health, Part A, 56*(6), 660–666.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Dooyum, U. D., Mikhaylov, A., & Varyash, I. (2020). Energy security concept in Russia and South Korea. *International Journal of Energy Economics and Policy, 10*(4), 102–107.

Grilli, M. L., Valerini, D., Rizzo, A., Yilmaz, M., Song, C., Hu, G., Chierchia, R., Mikhaylov, A., & Rinaldi, A. (2021). A comparative study of the mechanical and tribological properties of thin Al2O3 coatings fabricated by atomic layer deposition and radiofrequency sputtering. *Physica Status Solidi (A), 218*(24), 1–25.

Gura, D., Mikhaylov, A., Glushkov, S., Zaikov, M., & Shaikh, Z. A. (2020). Model for estimating power dissipation along the interconnect length in single on-chip topology. *Evolutionary Intelligence*, s12065. https://doi.org/10.1007/s12065-020-00407-7

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Huang, Y., Masrur, H., Shigenobu, R., Hemeida, A. M., Mikhaylov, A., & Senjyu, T. (2021a). A comparative design of a campus microgrid considering a multi-scenario and multi-objective approach. *Energies, 14*, 2853.

Huang, Y., Yona, A., Takahashi, H., Hemeida, A. M., Mandal, P., Mikhaylov, A., Senjyu, T., & Lotfy, M. E. (2021b). Energy management system optimization of drug store operate electric vehicles charging station. *Sustainability, 14*, 1217836.

Khan, A. A., Shaikh, Z. A., Baitenova, L., Mutaliyeva, L., Moiseev, N., Mikhaylov, A., Laghari, A. A., Idris, S. A., & Alshazly, H. (2021). QoS-Ledger: Smart contracts and metaheuristic for secure quality-of-service and cost-efficient scheduling of medical-data processing. *Electronics, 10*, 3083.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of European economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Li, J., Yüksel, S., Dınçer, H., Mikhaylov, A., & Barykin, S. E. (2022). Bipolar q-ROF hybrid decision making model with golden cut for analyzing the levelized cost of renewable energy alternatives. *IEEE Access, 10*, 42507–42517.

Liu, L., Kato, T, Mandal, P., Mikhaylov, A, Hemeida, A. M., & Senjyu T. (2021a). Multi-area power system load frequency control by using model predictive control by introducing renewable energy sources. *2021 International Conference on Science & Contemporary Technologies (ICSCT)* (pp. 1–6). https://doi.org/10.1109/ICSCT53883.2021.9642521.

Liu, L., Kato, T., Mandal, P., Mikhaylov, A., Hemeida, A. M., Takahashi, H., & Tomonobu, S. (2021b). Two cases studies of model predictive control approach for hybrid renewable energy systems. *AIMS Energy, 9*(6), 1241–1259.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021c). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*(5), 3687–3701.

Liu, Z.-J., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022a). COVID-19 crisis impact on the stability between parties in crowdfunding and crowdsourcing. *Wireless Personal Communications, 122*, 915–930.

Liu, Z.-J., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022b). Assessing stability in relationship between parties in crowdfunding and crowdsourcing projects during the COVID-19 crisis. *Journal of Global Information Management, 30*(2), 1.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., & Yüksel, S. (2021). A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financial Innovation, 7*(1), 1–34.

Mikhaylov, A. (2018a). Volatility spillover effect between stock and exchange rate in oil exporting countries. *International Journal of Energy Economics and Policy, 8*(3), 321–326.

Mikhaylov, A. (2018b). Pricing in oil market and using probit model for analysis of stock market effects. *International Journal of Energy Economics and Policy, 8*(2), 69–73.
Mikhaylov, A. (2020a). Cryptocurrency market analysis from the open innovation perspective. *Journal of Open Innovation: Technology, Market, and Complexity, 6*(4), 197.
Mikhaylov, A. (2020b). Geothermal energy development in Iceland. *International Journal of Energy Economics and Policy, 10*(4), 31–35.
Mikhaylov, A. (2020c). Cryptocurrency market development: Hurst method. *Finance: Theory and Practice, 24*(3), 81–91.
Mikhaylov, A. (2021a). Development of Friedrich von Hayek's theory of private money and economic implications for digital currencies. *Terra Economicus, 19*(1), 53–62.
Mikhaylov, A. (2021b). Lichens as indicators of atmospheric pollution in urban ecosystems. *Israel Journal of Ecology & Evolution, 67*(1–2), 60–68. https://doi.org/10.1163/22244662-bja10016
Mikhaylov, A. (2022a). Efficiency of renewable energy generation in Russia. *Annals of the Brazilian Academy of Sciences, 94*(3), 1–22.
Mikhaylov, A. (2022b). Sustainable development and renewable energy: A new view to a global problem. *Energies, 15*, 1397. https://doi.org/10.3390/en15041397
Mikhaylov, A., Burakov, D., & Didenko, V. (2019). Relationship between oil price and macro-economic indicators in Russia. *Finance: Theory and Practice, 23*(2), 105–116. https://doi.org/10.26794/2587-5671-2019-23-2-105-116
Mikhaylov, A., & Grilli, M. L. (2022). Machine learning methods and sustainable development: Metal oxides and multilayer metal-oxides. *Metals, 12*(4), 17–33.
Mikhaylov, A., Sokolinskaya, N., & Nyangarika, A. (2018). Optimal carry trade strategy based on currencies of energy and developed economies. *Journal of Reviews on Global Economics, 7*, 582–592.
Mikhaylov, A., & Tarakanov, S. (2020). Development of Levenberg-Marquardt theoretical approach for electric network. *Journal of Physics: Conference Series, 1515*, 052006.
Mikhaylov, A., Yumashev, A., & Kolpak, E. (2022). Quality of life, anxiety and depressive disorders in patients with extrasystolic arrhythmia. *Archives of Medical Science, 18*(2). https://doi.org/10.5114/aoms.2020.101359
Moiseev, N., Mikhaylov, A., Varyash, I., & Saqib, A. (2020). Investigating the relation of GDP per capita and corruption index. *Entrepreneurship and Sustainability Issues, 8*(1), 780–794.
Moiseev, N., Sorokin, A., Zvezdina, N., Mikhaylov, A., Khomyakova, L., & Danish, M. S. S. (2021). Credit risk theoretical model on the base of DCC-GARCH in time-varying parameters framework. *Mathematics, 9*, 2423. https://doi.org/10.3390/math9192423
Morkovkin, D. E., Gibadullin, A. A., Kolosova, E. V., Semkina, N. S., & Fasehzoda, I. S. (2020a). Modern transformation of the production base in the conditions of Industry 4.0: Problems and prospects. *Journal of Physics: Conference Series, 1515*, 032014.
Morkovkin, D., Lopatkin, D., Sadriddinov, M., Shushunova, T., Gibadullin, A., & Golikova, O. (2020b). Assessment of innovation activity in the countries of the world. *E3S Web of Conferences, 157*, 04015. https://doi.org/10.1051/e3sconf/202015704015
Mukhametov, A., Bekhorashvili, A., Avdeenko, A., & Mikhaylov, A. (2021). The impact of growing legume plants under conditions of Biologization and Soil Cultivation on Chernozem fertility and productivity of rotation crops. *Legume Research, 44*, 12.
Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy, 187*, 169–176.
Mutalimov, V., Kovaleva, I., Mikhaylov, A., & Stepanova, D. (2021). Assessing regional growth of small business in Russia. *Entrepreneurial Business and Economics Review, 9*(3), 119–133. https://doi.org/10.15678/EBER.2021.090308
Nyangarika, A., Mikhaylov, A., & Richter, U. (2019a). Influence oil price towards economic indicators in Russia. *International Journal of Energy Economics and Policy, 9*(1), 123–129.
Nyangarika, A., Mikhaylov, A., & Richter, U. (2019b). Oil price factors: Forecasting on the base of modified auto-regressive integrated moving average model. *International Journal of Energy Economics and Policy, 9*(1), 149–159.

Nyangarika, A., Mikhaylov, A., & Tang, B.-J. (2018). Correlation of oil prices and gross domestic product in oil producing countries. *International Journal of Energy Economics and Policy, 8*(5), 42–48.

Saqib, A., Chan, T.-H., Mikhaylov, A., & Lean, H. H. (2021). Are the responses of sectoral energy imports asymmetric to exchange rate volatilities in Pakistan? Evidence from recent foreign exchange regime. *Frontiers in Energy Research, 9*, 614463. https://doi.org/10.3389/fenrg.2021.614463

Sediqi, M. M., Nakadomari, A., Mikhaylov, A., Krishnan, N., Lotfy, M. E., Yona, A., & Senjyu, T. (2022). Impact of time-of-use demand response program on optimal operation of Afghanistan real power system. *Energies, 15*, 296.

Shaikh, Z. A., Moiseev, N., Mikhaylov, A., & Yüksel, S. (2021). Facile synthesis of copper oxide-cobalt oxide/nitrogen-doped carbon (Cu2O-Co3O4/CN) composite for efficient water splitting. *Applied Sciences., 11*, 9974. https://doi.org/10.3390/app11219974

Tamashiro, K., Alharbi, T., Mikhaylov, A., Hemeida, A. M., Krishnan, N., Lotfy, M. E., & Senjyu, T. (2021). Investigation of home energy management with advanced direct load control and optimal scheduling of controllable loads. *Energies, 14*, 7314. https://doi.org/10.3390/en14217314

Uyeh, D. D., Asem-Hiablie, S., Park, T., Kim, K.-M., Mikhaylov, A., Woo, S., & Ha, Y. (2021). Could Japonica rice be an Alternative variety for increased global food security and climate change mitigation? *Food, 10*, 1869. https://doi.org/10.3390/foods10081869

Varyash, I., Mikhaylov, A., Moiseev, N., & Aleshin, K. (2020). Triple bottom line and corporate social responsibility performance indicators for Russian companies. *Entrepreneurship and Sustainability Issues, 8*(1), 313–331.

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Yuksel, S., Khomyakova, L., & Mikhaylov, A. (2021a). Energy center selection in G7 Industry with Fuzzy MOORA. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 87–106). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch006

Yüksel, S., Mikhaylov, A., Ubay, G. G., & Uyeh, D. D. (2021b). The role of hydrogen in the black sea for the future energy supply security of Turkey. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 1–15). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch001

Yüksel, S., Mikhaylov, A., & Ubay, G. G. (2021c). Factors causing delay in the installation of nuclear power plants. In S. Yüksel & H. Dinçer (Eds.), *Strategic approaches to energy management. Contributions to management science.* Springer. https://doi.org/10.1007/978-3-030-76783-9_7

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022). Key issues for the improvements of shallow geothermal investments. In H. Dinçer & S. Yüksel (Eds.), *Sustainability in energy business and finance. Contributions to Finance and Accounting*. Springer. https://doi.org/10.1007/978-3-030-94051-5_16

Yumashev, A., & Mikhaylov, A. (2020). Development of polymer film coatings with high adhesion to steel alloys and high wear resistance. *Polymer Composites, 41*(7), 2875–2880.

Yumashev, A., Ślusarczyk, B., Kondrashev, S., & Mikhaylov, A. (2020). Global indicators of sustainable development: Evaluation of the influence of the human development index on consumption and quality of energy. *Energies, 13*, 2768.

Zhao, Q., Cherkasov, S., Avdeenko, A., Kondratenko, L., & Mikhaylov, A. (2021a). Integral estimate of the added value of agricultural crops in the synergetic agriculture on the example of Vicia faba (Vicia faba L.). *Polish Journal of Environmental Studies, 30*(5), 1–9. https://doi.org/10.15244/pjoes/131949

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021b). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 21582440211040133.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

Environmental and Economic Efficiency of Nuclear Projects

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Abstract An analysis of environmental and economic efficiency, risks, and prospects for the development of energy based on various types of energy carriers, starting from the 1960s, is carried out. It is shown that the decline in the share of nuclear power in the global energy balance cannot yet be compensated by renewable energy sources and leads to an increase in the use of fossil energy carriers. It is concluded that in order to achieve sustainable development of non-carbon energy, it is necessary to develop renewable and nuclear energy where the risks of environmental consequences of energy production are minimal. The purpose of this work is to identify and compare the role of nuclear power plants (NPPs) and various types of renewable energy sources (RES) in the formation of a non-carbon energy system, the growth of ecological and economic efficiency and to analyze the risks and prospects for the development of multipolar energy. Based on statistical and analytical data, this article examines the dynamics of global non-carbon energy development in the second half of the year XX—the beginning XXI V., comparative assessment of trends and patterns of development, correlation of nuclear power development with changes in environmental parameters and environmental efficiency of various types of energy. Comparative estimates of the economic efficiency of energy based on various energy sources are presented, with a discussion of uncertainties and risks in relation to nuclear power plants and renewable energy sources and their impact on the prospects for the development of energy based on non-carbon energy sources. A comparative assessment of the economic and environmental-economic parameters of nuclear and RES power plants indicates the continued high competitiveness of nuclear power plants both in the economic sense and in terms of minimizing environmental damage. The identified trends and analysis of environmental and economic indicators indicate that nuclear energy is a necessary component, along

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with renewable energy, of the process of transition to a non-carbon regime and reducing risks to the environment. Analysis of data from the last 50–55 years and current trends indicates the feasibility of developing both renewable and nuclear energy on the basis of mutual complementarity rather than confrontation.

1 Introduction

The share of nuclear energy in world energy production in the period from 1965 to 2014 increased from 0.2 to 4.4%, or from 6 to 574 million tons of oil equivalent. The nuclear power industry has experienced two periods: strong growth until the early 1990s and stagnation since the 2000s. The share of nuclear power in the global structure of energy consumption reached its maximum value in 1995–2002—6.1–6.3%, after which it began to decline. The maximum amount of nuclear energy consumption was reached in 2006–635 million tons of oil equivalent. After that, the absolute indicators also began to decline, which later stabilized and even showed a slight increase in 2012–2014.

The maximum share of nuclear power in global electricity production was reached in 1993–1999, after which it declined from 2012 and then stabilized. In relation to other types of energy production, the maximum share of nuclear energy coincided with the minimum share of generation based on fossil energy carriers. The decline in the share of nuclear power, on the contrary, has strengthened the role of fossil energy carriers in the global energy balance. Their share in total energy consumption increased to 87.6% by 2007 and fell again to below 87% after 2002.

The decline in the share of nuclear energy was partially offset by the development of renewable energy, but to a greater extent this was due to the growth of fossil energy (Kou et al., 2022; Liu et al., 2021a; Liu et al., 2021b; Liu et al., 2021c; Mukhtarov et al., 2022; Xie et al., 2021). First of all, in the electric power industry, as well as the reduction of its share was achieved mainly due to the development of nuclear energy (An et al., 2019b; An et al., 2019a; Mikhaylov, 2020a, Mikhaylov, 2020b, Mikhaylov, 2020c; Mikhaylov & Tarakanov, 2020; An et al., 2020c; An et al., 2020a; An et al., 2020b; Moiseev et al., 2020; Moiseev et al., 2021; Grilli et al., 2021; Gura et al., 2020; Dooyum et al., 2020; Mikhaylov et al., 2022; Mikhaylov, 2021a; Varyash et al., 2020; Zhao et al., 2021a; Zhao et al., 2021b; An & Mikhaylov, 2020; Alwaelya et al., 2021; Yumashev & Mikhaylov, 2020; Yumashev et al., 2020; Mutalimov et al., 2021; Morkovkin et al., 2020a; Morkovkin et al., 2020b; An & Mikhaylov, 2021).

In general, in 1980–2014, the share of fossil hydrocarbons in global primary energy consumption decreased from 91.7% to 86.3%, while the share of renewable energy sources, including hydropower, increased from 5.9% to 9.3%. At the same time, electricity production grew at a rate faster than total energy consumption, and this increase was achieved either at the expense of nuclear power during the period of its active growth, or at the expense of fossil hydrocarbons during the period of stagnation and reduction of nuclear power (Bhuiyan et al., 2022b; Conteh et al.,

2021; Daniali et al., 2021; Denisova et al., 2019; Huang et al., 2021a; Huang et al., 2021b; Khan et al., 2021; Liu et al., 2021a; Liu et al., 2021b; Mikhaylov, 2018a; Mikhaylov, 2018b; Mikhaylov, 2022a; Mikhaylov, 2022b; Mikhaylov et al., 2019; Nyangarika et al., 2019a; Nyangarika et al., 2019b; Sediqi et al., 2022).

It is noteworthy that in the period 1980–2014, the share of renewable energy sources (including hydropower) in global electricity production increased by only 0.6%—from 21.9 to 22.5%, while the share of hydropower decreased significantly—from 21.5 to 16.5%, and the growth of other types of renewable energy mainly compensated for the reduction in the share of hydropower. At the same time, it should be noted that in the period from 1973 to 2019, the share of renewable energy sources in the structure of world energy production increased from 12.4% to 13.3%, against the background of a more noticeable increase from 0.9% to 4.8% of nuclear power.

Thus, the actual dynamics of the development of renewable energy does not fully correspond to the widespread ideas about its rapid growth, and nuclear energy plays a key role in reducing the share of energy based on fossil energy carriers.

2 Environmental Efficiency of Various Types of Energy

The dynamics of nuclear power development reveals a correlation with changes in environmental parameters of the environment. In particular, the period of active growth of the nuclear power industry coincides with a lower rate of growth of the CO_2 content in the atmosphere. In addition, the group of the most developed countries has significantly lower emission values CO_2 Per capita, France is the country with the highest share of nuclear power plants in electricity production—more than 70%.

At the same time, the share of renewable energy sources—about 16%, including hydropower—is lower in France than in most leading countries (for comparison, in Germany-about 25%).

In general, the analysis of the entire life cycle of production (from energy extraction and equipment manufacturing to waste disposal and decommissioning) gives the following average (median) emission indicators [8] for different types of current electricity production in grams of CO_2 equivalent per 1 kWh of electricity produced (CO_2 eq/kWh):

- thermal (coal and gas) power plants—490–820;
- biomass heating stations—230–740;
- photovoltaic systems—41–48;
- geothermal—38;
- solar concentrators—27;
- HPP—24;
- NPP—12;
- wind farms—11–12.

An integral indicator of environmental and economic efficiency can be considered the value of external (external) costs for the production of a unit of production. For the EU countries, the range of external costs of electricity production (eurocent/kWh) for various energy sources as of 2003 was estimated in the following values:

- coal—from 2 to 15 euro cents/kWh;
- oil—from 3 to 11;
- gas—from 1 to 4;
- solar (photovoltaic) energy—0.6;
- biomass—from 0 to 5;
- hydroelectric power—from 0 to 1;
- nuclear power—from 0.2 to 0.7.
- wind—from 0 to 0.25.

Thus, nuclear power plants are quite environmentally competitive with renewable energy plants, almost surpassing them all, except for wind farms, in terms of environmental and economic efficiency in the complex and long-term plan (Bhuiyan et al., 2021; Dong et al., 2021, Mikhaylov, 2021b; Baboshkin et al., 2022; Barykin et al., 2022; Baig et al., 2022a; Liu et al., 2022a, Liu et al., 2022b; Bhuiyan et al., 2022a; Danish et al., 2022; Baig et al., 2022b; Saqib et al., 2021; Yüksel et al., 2021b; Yüksel et al., 2021a; Yuksel et al., 2021; Mukhametov et al., 2021, Candila et al., 2021; Mikhaylov & Grilli, 2022).

As for the actual economic efficiency of energy, leveled costs are used as an integral indicator for the production of a unit of energy (Dinçer et al., 2022; Meng et al., 2021; Zhe et al., 2021; Zhou et al., 2021). Aligned costs combine the investment, operational, and organizational components of costs. Total costs, including construction costs, maintenance of the power plant, organizational and transaction costs, are distributed over the entire period of operation of the power plant, during which it generates a certain amount of energy.

To calculate the leveled costs, you need to take into account or accept as assumptions a series of data. Among them: the period of time for which equalized costs are calculated; investment costs per unit of installed capacity; CIUM of power plants and energy production per unit of time; energy prices; financial coefficients related to the time value of money and the discount rate, the price of capital, etc. In particular, it provides calculated data on the equalized costs of electricity production by various types of power plants that will be put into operation by 2020 (Table 1). Assuming the following assumptions: time period-30 years; weighted average price of capital-6.5%; CIUM-see Table 4. Based on this, the total leveled costs of generating electricity at thermal power plants vary in a wide range from $72 to $145/MWh (7–15 cents per 1 kWh) with a total capacity of 1 GW (the capacity of a relatively small nuclear power plant) would require an area of 100 km.^{2}, and at the CIUM, which is 0.7 of the calculated value, it is already 143 km^2. And the answer to the question of whether the service life of wind and photovoltaic capacities will reach 30 years should, at the moment, be considered open.

Table 1 Estimated equalized costs of producing a unit of energy (2013, USD)/MWh) for various types of power plants to be commissioned in the United States in 2020

Type power plants	KIUM, %	Aligned ones investment projects expenses	Permanent users operating systems expenses	Variables operating systems expenses (including fuel)	Transactional services expenses	Total expenses aligned ones expenses
Thermal (coal and gas various	30–85	14.4–97.3	1.7–9.8	30.7–94.6	1.2–3.5	72.6–144.4
Atomic ones	90	70.1	11.8	12.2	1.1	95.2
Geothermal facilities	92	34.1	12.3	0.0	1.4	47.8
Biomass	83	47.1	14.5	37.6	1.2	100.5
Wind farms (onshore and offshore)	36–38	57.7–168.6	12.8–22.5	0.0	3.1–5.8	73.6–196.9
Solar (photo-voltaic and thermal) systems	20–25	109.8–191.6	11.4–42.1	0.0	4.1–6.0	125.3–239.7
Hydroelectric power station	54	70.7	3.9	7.0	2.0	83.5

3 Uncertainties, Risks, and Prospects for Energy Development

An additional argument in favor of the prospects of nuclear energy as an ecological and economic alternative to traditional hydrocarbon energy is the uncertainty that has emerged in recent years about the prospects for renewable energy (Ding et al., 2021; Dong et al., 2022; Haiyun et al., 2021; Li et al., 2022; Zhao et al., 2021a). From an environmental point of view, a number of unforeseen consequences are identified (unintended consequences) energy based on.

It cannot be ruled out that over time, new unforeseen consequences will be identified with an impact on the dynamics of renewable energy development. It should be noted that in recent years, against the background of the growth of commissioned capacities, a slowdown in the growth rate of renewable energy has been indicated (Dayong et al., 2020; Mikhaylov et al., 2018; Nyangarika et al., 2018; Danish et al., 2020; Danish et al., 2021; An et al., 2021; Uyeh et al., 2021; Tamashiro et al., 2021; Shaikh et al., 2021).

For example, in the solar power industry, production capacities were used from 1996 to 2014. The increase in capacity in the solar energy sector was 72.5%; by 2014, it decreased to 28.7%). In the wind power industry, the overall trend towards a decrease in the growth rate of capacity and output has been recorded since

2000–2001, with some strengthening after 2009 (the increase in capacity in the wind power industry in 2009 was 31.5%; by 2014, it decreased to 16.2%).

Based on the available data on production capacities and production volumes by year, the authors calculated the average global CIM. To calculate the CIM for a given year, the volume of output was compared with the average value of existing capacities for the previous and given year, taking into account the extended commissioning of new stations during a given year. For example, to calculate the average CIM of solar power plants in the world for 1997, we take the arithmetic average of the capacities operating in 1996–386 MW, and in 1997–502 MW, equal to 444 MW. Next, the amount of electricity generated by solar panels power plants of the world for 1997, equal to 732 GWh, divided by 444 MW. Thus, the output of 1 W of installed capacity will be 1649 W. The maximum annual output of 1 watt of power is equal to the number of hours in a year-8760 and corresponds to the CIM equal to 100%. The actual CIUM is calculated by dividing the actual electricity production by the maximum theoretically possible and is in this case 18.8% (the average CIUM of solar power plants in 1997). In this way, the CIUM of solar and wind power plants for 1997–2014 was calculated.

Calculations show that at the end of this period, the CIM of solar power plants decreased from 19% to 13%, while the minimum CIM was 9.5% in 2004, then a gradual increase was indicated, although the maximum values of the late 1990s were not reached. For the wind power industry, there is a trend towards a weak growth of CIM over the same period—from 20% in the late 1990s to 23–25% in the last few years.

Calculated values US EIA according to the CIUM for solar and wind power plants under construction, the figures of 20–25% and 36–38%, respectively, are somewhat overestimated.

Thus, there is no reason to expect that the hypothetical curtailment of nuclear power in the world can be compensated by the development of renewable energy sources. In this case, it is highly likely that energy needs will be met mainly by increasing the use of fossil hydrocarbon energy carriers. The juxtaposition of nuclear and renewable energy seems counterproductive. A more constructive approach is to develop nuclear and renewable energy in parallel and complement each other (Adalı et al., 2022; Yüksel et al., 2022).

During the transition from one technological mode to another, in the 1970s, an optimistic opinion prevailed about the imminent replacement of oil with nuclear energy, which then showed exponential growth. Nuclear power claimed to be the basic energy carrier in the new technological order. But the well-known tragic events related to accidents at nuclear power plants have revealed real risks and imperfections of nuclear energy technologies. Nuclear power has not become a basic energy technology. The nuclear power industry, of course, has its own set of problems, among which the key ones are the uneconomical use of nuclear fuel in water-cooled nuclear reactors and the problem of storing spent nuclear fuel.

Currently, the leading nuclear energy countries are working on implementing the concept of safe operation of a new generation of nuclear power plants. Therefore, the main factor in the formation of the modern global energy space is still natural gas.

Thanks to its high economic efficiency and relative environmental friendliness, natural gas continues to replace oil and coal in the world's energy mix. With the increase in the share of gas and renewable energy sources, the preservation of the share of nuclear energy, and the reduction in the share of coal and oil in the energy balance, the basic energy carrier will be allocated it will not be the same as it was during the change of technological structures in the industrial economy (Fang et al., 2021; Kostis et al., 2022; Serezli et al., 2021). The structure of the world's energy sector is strongly diversified in the next decade, which will contribute to the development of competition between different types of energy, between countries and regions. In addition, as a dynamically growing industry, both renewable energy and the nuclear industry have significant potential for innovative development due to improved technologies.

4 Conclusions

Analysis of the dynamics of the development of energy based on nuclear energy and renewable sources, since the 1960s, shows the key role of nuclear energy in the formation of a non-carbon structure in the energy sector and reducing the negative environmental impact on the environment.

The decline in the share of fossil fuels in global electricity generation since the 1960s, as well as a slight slowdown in CO emissions. In the period from the mid-1960s to the early 2000s, the total share of other non-carbon energy carriers decreased, primarily due to the decline in the share of hydroelectric power.

Since the mid-1990s, there has been a decrease in the share of nuclear energy in the global energy balance, and since the 2000s, there has been an absolute decrease in electricity generation at nuclear power plants. This was not offset by an increase in renewable energy production, but rather led to an increase in the share of fossil hydrocarbons in global electricity production, and also correlates with a new acceleration in CO_2 emissions into the atmosphere. At the same time, since the 2010s, there has been a steady slowdown in the growth of renewable energy. There is also a lag in the growth rate of electricity generation at wind and solar power plants from the growth rate of production capacity in wind and solar energy. This indicates certain barriers in the development of renewable energy, which may become more pronounced in the near future.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In H. Dinçer & S. Yüksel (Eds.), *Multidimensional strategic outlook on global competitive energy economics and finance* (pp. 1–11). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80117-898-320221002

Alwaelya, S. A., Yousif, N. B. A., & Mikhaylov, A. (2021). Emotional development in preschoolers and socialization. *Early Child Development and Care, 191*, 16.

An, J., & Mikhaylov, A. (2020). Russian energy projects in South Africa. *Journal of Energy in Southern Africa, 31*(3), 58–64.

An, J., & Mikhaylov, A. (2021). Analysis of energy projects financial efficiency and renewable energy generation in Russia. *Finance: Theory and Practice, 25*(5), 79–91.

An, J., Mikhaylov, A., & Jung, S.-U. (2020a). The strategy of South Korea in the global oil market. *Energies, 13*(10), 2491.

An, J., Mikhaylov, A., & Jung, S.-U. (2021). A linear programming approach for Robust network revenue management in the airline industry. *Journal of Air Transport Management, 91*, 101979.

An, J., Mikhaylov, A., & Kim, K. (2020b). Machine learning approach in heterogeneous group of algorithms for transport safety-critical system. *Applied Sciences, 10*(8), 2670.

An, J., Mikhaylov, A., & Moiseev, N. (2019a). Oil price predictors: Machine learning approach. *International Journal of Energy Economics and Policy, 9*(5), 1–6.

An, J., Mikhaylov, A., & Richter, U. H. (2020c). Trade war effects: Evidence from sectors of energy and resources in Africa. *Heliyon, 6*, e05693. https://doi.org/10.1016/j.heliyon.2020.e05693

An, J., Mikhaylov, A., & Sokolinskaya, N. (2019b). Machine learning in economic planning: Ensembles of algorithms. *Journal of Physics: Conference Series, 1353*, 012126.

Baboshkin, P., Mikhaylov, A., & Shaikh, Z. A. (2022). Sustainable cryptocurrency growth is not possible? Impact of network power demand on bitcoin price. *Financial Journal, 14*(2), 39–55.

Baig, U., Hussain, B. M., Khan, A. A., Shaikh, Z. A., Mikhaylov, A., Chao, C.-C., & Barykin, S. E. (2022a). Research on investors of the reginal stock exchange: An influence of behavioral finance on investment decision making. *Risks, 10*(4), 116.

Baig, U., Khan, A. A., Abbas, M. G., Shaikh, Z. A., Mikhaylov, A., Laghari, A. A., & Hussain, B. M. (2022b). Crucial causes of delay in completion and performance management of the construction work: Study on the base of relative importance index. *Journal of Tianjin University Science and Technology, 55*(6), 75–102.

Barykin, S., Mikheev, A., Kiseleva, E., Putikhin, Y., Alekseeva, N., & Mikhaylov, A. (2022). An empirical analysis of Russian regions' debt sustainability. *Economies, 10*(4), 296.

Bhuiyan, M. A., An, J., Mikhaylov, A., Moiseev, N., & Danish, M. S. S. (2021). Renewable energy deployment and COVID-19 measures for sustainable development. *Sustainability, 13*, 4418.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022a). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*(2022), 561–570.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., et al. (2022b). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Bhuiyan, M. A., Khare, V., Mikhaylov, A., Pinter, G., & Zhang. (2022c). Does renewable energy consumption affect economic growth? A systematic literature review. *Frontiers in Environmental Science*.

Candila, V., Maximov, D., Mikhaylov, A., Moiseev, N., Senjyu, T., & Tryndina, N. (2021). On the relationship between oil and exchange rates of oil-exporting and oil-importing countries: from the great recession period to the Covid-19 era. *Energies, 14*, 8065.

Conteh, F., Takahashi, H., Hemeida, A. M., Krishnan, N., Mikhaylov, A., & Senjyu, T. (2021). Hybrid grid-connected renewable power generation for sustainable electricity supply in Sierra Leone: Case study Lungi Town. *Sustainability, 13*(18).

Daniali, S. M., Barykin, S. E., Kapustina, I. V., Khortabi, F. M., Sergeev, S. M., Kalinina, O. V., Mikhaylov, A., Veynberg, R., Zasova, L., & Senjyu, T. (2021). Predicting volatility index according to technical index and economic indicators on the basis of deep learning algorithm. *Sustainability, 2021*(13), 14011.

Danish, M. S. S., Bhattacharya, A., Stepanova, D., Mikhaylov, A., Grilli, M. L., Khosravy, M., & Senjyu, T. (2020). A systematic review of metal oxide applications for energy and environmental sustainability. *Metals, 10*(12), 1604.

Danish, M. S. S., Estrella-Pajulas, L. L., Alemaida, I. M. A., Grilli, M. L., Mikhaylov, A., & Senjyu, T. (2022). Green synthesis of silver oxide nanoparticles for photocatalytic environmental remediation and biomedical applications. *Metals, 12*(4). https://doi.org/10.3390/met12050769

Danish, M. S. S., Senjyu, T., Sabory, N. R., Khosravy, M., Grilli, M. L., Mikhaylov, A., & Majidi, H. (2021). A forefront framework for sustainable aquaponics modeling and design. *Sustainability, 13*, 9313.

Dayong, N., Mikhaylov, A., Bratanovsky, S., Shaikh, Z. A., & Stepanova, D. (2020). Mathematical modeling of the technological processes of catering products production. *Journal of Food Process Engineering, 43*(2), 1–9.

Denisova, V., Mikhaylov, A., & Lopatin, E. (2019). Blockchain infrastructure and growth of global power consumption. *International Journal of Energy Economics and Policy, 9*(4), 22–29.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Ding, Z., Yüksel, S., & Dincer, H. (2021). An Integrated Pythagorean fuzzy soft computing approach to environmental management systems for sustainable energy pricing. *Energy Reports, 7*, 5575–5588.

Dong, B., Ikonnikova, I., Rogulin, R., Sakulyeva, T., & Mikhaylov, A. (2021). Environmental economic approach to optimization of transport communication in megacities. *Journal of Environmental Science and Health, Part A, 56*(6), 660–666.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Dooyum, U. D., Mikhaylov, A., & Varyash, I. (2020). Energy security concept in Russia and South Korea. *International Journal of Energy Economics and Policy, 10*(4), 102–107.

Fang, S., Zhou, P., Dinçer, H., & Yüksel, S. (2021). Assessment of safety management system on energy investment risk using house of quality based on hybrid stochastic interval-valued intuitionistic fuzzy decision-making approach. *Safety Science, 141*, 105333.

Grilli, M. L., Valerini, D., Rizzo, A., Yilmaz, M., Song, C., Hu, G., Chierchia, R., Mikhaylov, A., & Rinaldi, A. (2021). A comparative study of the mechanical and tribological properties of thin Al2O3 coatings fabricated by atomic layer deposition and radiofrequency sputtering. *Physica Status Solidi (A), 218*(24), 1–25.

Gura, D., Mikhaylov, A., Glushkov, S., Zaikov, M., & Shaikh, Z. A. (2020). Model for estimating power dissipation along the interconnect length in single on-chip topology. *Evolutionary Intelligence*, s12065. https://doi.org/10.1007/s12065-020-00407-7

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Huang, Y., Masrur, H., Shigenobu, R., Hemeida, A. M., Mikhaylov, A., & Senjyu, T. (2021a). A comparative design of a campus microgrid considering a multi-scenario and multi-objective approach. *Energies, 14*, 2853.

Huang, Y., Yona, A., Takahashi, H., Hemeida, A. M., Mandal, P., Mikhaylov, A., Senjyu, T., & Lotfy, M. E. (2021b). Energy management system optimization of drug store operate electric vehicles charging station. *Sustainability, 14*, 1217836.

Khan, A. A., Shaikh, Z. A., Baitenova, L., Mutaliyeva, L., Moiseev, N., Mikhaylov, A., Laghari, A. A., Idris, S. A., & Alshazly, H. (2021). QoS-Ledger: Smart contracts and metaheuristic for secure quality-of-service and cost-efficient scheduling of medical-data processing. *Electronics, 10*, 3083.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of European economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Li, J., Yüksel, S., Dınçer, H., Mikhaylov, A., & Barykin, S. E. (2022). Bipolar q-ROF hybrid decision making model with golden cut for analyzing the levelized cost of renewable energy alternatives. *IEEE Access, 10*, 42507–42517.

Liu, L., Kato, T, Mandal, P., Mikhaylov, A, Hemeida, A.M., & Senjyu T. (2021a). Multi-area Power System Load Frequency Control by using Model Predictive Control by Introducing Renewable Energy Sources. *2021 International Conference on Science & Contemporary Technologies (ICSCT)*, (pp. 1–6), https://doi.org/10.1109/ICSCT53883.2021.9642521.

Liu, L., Kato, T., Mandal, P., Mikhaylov, A., Hemeida, A. M., Takahashi, H., & Tomonobu, S. (2021b). Two cases studies of Model Predictive Control approach for hybrid Renewable Energy Systems. *AIMS Energy, 9*(6), 1241–1259.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021c). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*(5), 3687–3701.

Liu, Z.-J., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022a). COVID-19 crisis impact on the stability between parties in crowdfunding and crowdsourcing. *Wireless Personal Communications, 122*, 915–930.

Liu, Z.-J., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022b). Assessing stability in relationship between parties in crowdfunding and crowdsourcing projects during the COVID-19 crisis. *Journal of Global Information Management, 30*(2), 1.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., & Yüksel, S. (2021). A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financial Innovation, 7*(1), 1–34.

Mikhaylov, A. (2018a). Volatility spillover effect between stock and exchange rate in oil exporting countries. *International Journal of Energy Economics and Policy, 8*(3), 321–326.

Mikhaylov, A. (2018b). Pricing in oil market and using probit model for analysis of stock market effects. *International Journal of Energy Economics and Policy, 8*(2), 69–73.

Mikhaylov, A., Burakov, D., & Didenko, V. (2019). Relationship between oil price and macroeconomic indicators in Russia. *Finance: Theory and Practice, 23*(2), 105–116. https://doi.org/10.26794/2587-5671-2019-23-2-105-116

Mikhaylov, A. (2020a). Cryptocurrency market analysis from the open innovation perspective. *Journal of Open Innovation: Technology, Market, and Complexity, 6*(4), 197.

Mikhaylov, A. (2020b). Geothermal energy development in Iceland. *International Journal of Energy Economics and Policy, 10*(4), 31–35.

Mikhaylov, A. (2020c). Cryptocurrency market development: hurst method. *Finance: Theory and Practice, 24*(3), 81–91.

Mikhaylov, A. (2021a). Development of Friedrich von Hayek's theory of private money and economic implications for digital currencies. *Terra Economicus, 19*(1), 53–62.

Mikhaylov, A. (2021b). Lichens as indicators of atmospheric pollution in urban ecosystems. *Israel Journal of Ecology & Evolution, 67*(1–2), 60–68. https://doi.org/10.1163/22244662-bja10016

Mikhaylov, A. (2022a). Efficiency of renewable energy generation in Russia. *Annals of the Brazilian Academy of Sciences, 94*(3), 1–22.

Mikhaylov, A. (2022b). Sustainable development and renewable energy: A new view to a global problem. *Energies, 15*, 1397. https://doi.org/10.3390/en15041397

Mikhaylov, A., & Grilli, M. L. (2022). Machine learning methods and sustainable development: Metal oxides and multilayer metal-oxides. *Metals, 12*(4), 17–33.

Mikhaylov, A., Sokolinskaya, N., & Nyangarika, A. (2018). Optimal carry trade strategy based on currencies of energy and developed economies. *Journal of Reviews on Global Economics, 7*, 582–592.

Mikhaylov, A., & Tarakanov, S. (2020). Development of Levenberg-Marquardt theoretical approach for electric network. *Journal of Physics: Conference Series, 1515*, 052006.

Mikhaylov, A., Yumashev, A., & Kolpak, E. (2022). Quality of life, anxiety and depressive disorders in patients with extrasystolic arrhythmia. *Archives of Medical Science, 18*(2). https://doi.org/10.5114/aoms.2020.101359

Moiseev, N., Mikhaylov, A., Varyash, I., & Saqib, A. (2020). Investigating the relation of GDP per capita and corruption index. *Entrepreneurship and Sustainability Issues, 8*(1), 780–794.

Moiseev, N., Sorokin, A., Zvezdina, N., Mikhaylov, A., Khomyakova, L., & Danish, M. S. S. (2021). Credit risk theoretical model on the base of DCC-GARCH in time-varying parameters framework. *Mathematics, 9*, 2423. https://doi.org/10.3390/math9192423

Morkovkin, D. E., Gibadullin, A. A., Kolosova, E. V., Semkina, N. S., & Fasehzoda, I. S. (2020a). Modern transformation of the production base in the conditions of Industry 4.0: problems and prospects. *Journal of Physics: Conference Series, 1515*, 032014.

Morkovkin, D., Lopatkin, D., Sadriddinov, M., Shushunova, T., Gibadullin, A., & Golikova, O. (2020b). Assessment of innovation activity in the countries of the world. *E3S Web of Conferences, 157*, 04015. https://doi.org/10.1051/e3sconf/202015704015

Mukhametov, A., Bekhorashvili, A., Avdeenko, A., & Mikhaylov, A. (2021). The impact of growing legume plants under conditions of Biologization and Soil Cultivation on Chernozem fertility and productivity of rotation crops. *Legume Research, 44*, 12.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy, 187*, 169–176.

Mutalimov, V., Kovaleva, I., Mikhaylov, A., & Stepanova, D. (2021). Assessing regional growth of small business in Russia. *Entrepreneurial Business and Economics Review, 9*(3), 119–133. https://doi.org/10.15678/EBER.2021.090308

Nyangarika, A., Mikhaylov, A., & Richter, U. (2019a). Influence oil price towards economic indicators in Russia. *International Journal of Energy Economics and Policy, 9*(1), 123–129.

Nyangarika, A., Mikhaylov, A., & Richter, U. (2019b). Oil price factors: Forecasting on the base of modified auto-regressive integrated moving average model. *International Journal of Energy Economics and Policy, 9*(1), 149–159.

Nyangarika, A., Mikhaylov, A., & Tang, B.-J. (2018). Correlation of oil prices and gross domestic product in oil producing countries. *International Journal of Energy Economics and Policy, 8*(5), 42–48.

Saqib, A., Chan, T.-H., Mikhaylov, A., & Lean, H. H. (2021). Are the responses of sectoral energy imports asymmetric to exchange rate volatilities in Pakistan? Evidence from recent foreign exchange regime. *Frontiers in Energy Research, 9*, 614463. https://doi.org/10.3389/fenrg.2021.614463

Sediqi, M. M., Nakadomari, A., Mikhaylov, A., Krishnan, N., Lotfy, M. E., Yona, A., & Senjyu, T. (2022). Impact of time-of-use demand response program on optimal operation of Afghanistan real power system. *Energies, 15*, 296.

Serezli, E., Yüksel, S., Tamer, İ., & Dinçer, H. (2021). The role of innovative renewable energy investment strategies on macroeconomic stability. In *Financial strategies in competitive markets* (pp. 165–178). Springer.

Shaikh, Z. A., Moiseev, N., Mikhaylov, A., & Yüksel, S. (2021). Facile synthesis of copper oxide-cobalt oxide/nitrogen-doped carbon (Cu2O-Co3O4/CN) composite for efficient water splitting. *Applied Sciences., 11*, 9974. https://doi.org/10.3390/app11219974

Tamashiro, K., Alharbi, T., Mikhaylov, A., Hemeida, A. M., Krishnan, N., Lotfy, M. E., & Senjyu, T. (2021). Investigation of home energy management with advanced direct load control and optimal scheduling of controllable loads. *Energies, 14*, 7314. https://doi.org/10.3390/en14217314

Uyeh, D. D., Asem-Hiablie, S., Park, T., Kim, K.-M., Mikhaylov, A., Woo, S., & Ha, Y. (2021). Could Japonica rice be an Alternative variety for increased global food security and climate change mitigation? *Food, 10*, 1869. https://doi.org/10.3390/foods10081869

Varyash, I., Mikhaylov, A., Moiseev, N., & Aleshin, K. (2020). Triple bottom line and corporate social responsibility performance indicators for Russian companies. *Entrepreneurship and Sustainability Issues, 8*(1), 313–331.

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022). Key issues for the improvements of shallow geothermal investments. In H. Dinçer & S. Yüksel (Eds.), *Sustainability in energy business and finance. Contributions to finance and accounting*. Springer. https://doi.org/10.1007/978-3-030-94051-5_16

Yuksel, S., Khomyakova, L., & Mikhaylov, A. (2021). Energy center selection in G7 Industry with Fuzzy MOORA. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 87–106). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch006

Yüksel, S., Mikhaylov, A., & Ubay, G. G. (2021a). Factors causing delay in the installation of nuclear power plants. In S. Yüksel & H. Dinçer (Eds.), *Strategic approaches to energy management. Contributions to management science*. Springer. https://doi.org/10.1007/978-3-030-76783-9_7

Yüksel, S., Mikhaylov, A., Ubay, G. G., & Uyeh, D. D. (2021b). The role of hydrogen in the black sea for the future energy supply security of Turkey. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 1–15). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch001

Yumashev, A., & Mikhaylov, A. (2020). Development of polymer film coatings with high adhesion to steel alloys and high wear resistance. *Polymer Composites, 41*(7), 2875–2880.

Yumashev, A., Ślusarczyk, B., Kondrashev, S., & Mikhaylov, A. (2020). Global indicators of sustainable development: Evaluation of the influence of the human development index on consumption and quality of energy. *Energies, 13*, 2768.

Zhao, Q., Cherkasov, S., Avdeenko, A., Kondratenko, L., & Mikhaylov, A. (2021a). Integral estimate of the added value of agricultural crops in the synergetic agriculture on the example of Vicia faba (Vicia faba L.). *Polish Journal of Environmental Studies, 30*(5), 1–9. https://doi.org/10.15244/pjoes/131949

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021b). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 21582440211040133.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

Hydrogen Energy and Decarbonisation: Evidence from Regions of the World

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Abstract Hydrogen, as a potential energy carrier, has certain physical and environmental advantages, and the promotion of ideas and plans for the development of the "hydrogen economy" is most often explained by environmental considerations—the need to decarbonize the economy. Currently, a number of regions, primarily in the Western Europe and Japan, have announced large-scale plans to increase the production of hydrogen, with the implementation of ambitious scenarios—by an order of magnitude, and the share of hydrogen in the energy balance should grow to 20% or more by the middle of this century. The chapter discusses plans for the development of the hydrogen economy in the world and in a number of regions. Technological, environmental, and economic barriers to implement ambitious growth scenarios for hydrogen production and consumption are identified, and the feasibility of these scenarios is assessed. The widespread claim about hydrogen as a decarbonizing agent and the validity of the ecological argument of the hydrogen economy are disputed. A number of possible real reasons for promoting the ideas and plans of the hydrogen economy are considered. Hydrogen has been produced and used for a long time, but in recent years there has been a strong increase in interest in it as a potential energy resource, and the term "hydrogen economy" has become widespread, and a number of countries have announced plans to multiply the production of hydrogen. In recent years, many publications have appeared on hydrogen topics in various formats, including books, articles, and materials from numerous forums and conferences. We can say that the interest in hydrogen as a potential energy source has become explosive. First of all, hydrogen is positioned as an environmental-friendly fuel that does not leave a "carbon footprint when burned", and the growth of its production and use is considered in the context of "decarbonization" (decarbonization) and reduces resource consumption.

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1 Introduction

Finally, hydrogen can be used in various ways—both for generating thermal and electrical energy—including as a battery of energy and as a transport fuel.

In this regard, a number of countries are now adopting or developing programs for the development of the hydrogen economy.

In addition, the prospects of creating a global hydrogen market with the conversion of hydrogen into an exchange commodity [2] with large trading volumes are considered.

Currently, the total volume of hydrogen production in the world is 55–65 million tons, with an average annual growth rate over the first two decades, i.e. XXI centuries did not exceed 2%.

Its main consumers are the chemical and oil refining industries, and the main method of producing almost 70% of all hydrogen is methane conversion, while electrolysis accounts for only 5%.

Until recently, the energy use of hydrogen, in particular as a transport fuel, was rather experimental in nature, represented by separate projects—in particular, the hydrogen highway project HyNor in Norway and similar projects in other European countries, the USA, and Japan.

Currently, a number of countries have adopted large-scale hydrogen programs that involve a multiple increase in the production of hydrogen with the prospects of using it already for energy purposes—for generating heat and electricity, as well as a transport fuel (Bhuiyan et al., 2022b; Conteh et al., 2021; Daniali et al., 2021; Denisova et al., 2019; Huang et al., 2021a; Huang et al., 2021b; Khan et al., 2021; Liu et al., 2021a; Liu et al., 2021b; Mikhaylov, 2018a; Mikhaylov, 2018b; Mikhaylov, 2022a; Mikhaylov, 2022b; Mikhaylov et al., 2019; Nyangarika et al., 2019a; Nyangarika et al., 2019b; Sediqi et al., 2022).

In particular, the EU adopted a Roadmap for the development of the hydrogen economy. According to the European roadmap, as of 2015, the total final energy demand in the EU was about 14,000 TWh, of which hydrogen accounts for 2%, or 325 TWh (equivalent to about 8 million tons of hydrogen). Next, we consider two scenarios: inertial—business as usual and ambitious—ambitious (Table 1). In all cases, the use of hydrogen is expected to increase in all sectors of the economy. At the same time, an overall reduction in energy demand is expected-by 35% by 2050. Under the inertial scenario, the annual volume of hydrogen supplies to the EU market should reach 12 million tons by 2030, more than 18 million tons by 2050; under the ambitious scenario, more than 16 million and about 55 million tons, respectively (Adalı et al., 2022; Yüksel et al., 2022a; Yüksel et al., 2022b).

Japan has a similar Roadmap—Strategic Roadmap for Hydrogen and Fuel Cells assumes an increase in the use of hydrogen to 10 million tons per year by 2050.

A total of 228 hydrogen projects have been announced worldwide on all continents, with most of them in the Western Europe and the East Asia.

Table 1 Growth plans for the use of hydrogen according to the EU Hydrogen Roadmap

Indicator	2015	2030		2050	
Total energy demand, TWh	14,100	11,500		9300	
The script	–	Business as usual	Ambitious	Business as usual	Ambitious
Hydrogen content, %	2	4	6	8	24
Amount of hydrogen, TWh	325	481	665	780	2251
Equivalent in tons	8 million rubles	12 million rubles	16 million rubles	19 million rubles	55 million rubles
Including by sector:					
Existing industrial plants	325	427	427	391	391
New industrial production facilities	–	11	62	1	257
Industrial power engineering	–	11	8	53	237
Heat and electricity for buildings	–	11	33	207	579
Transport	–	11	70	85	675
Power generation, storage (buffering)	–	11	65	43	112

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In Russia, in turn, a program for the development of hydrogen energy is under development. The Energy Strategy of the Russian Federation until 2035 also provides for the promotion of hydrogen production in Russia, the development of low-carbon technologies for its production, and the tasks of increasing exports (up to 0.2 million tons by 2024 and up to 2 million tons by 2035). So far, only the Sakhalin hydrogen cluster project can be named among specific large-scale hydrogen projects in Russia.

As a result, the market for hydrogen is expected to grow by tens of millions of tons annually in the next decades. At the same time, market forecasts vary dramatically.

According to the relatively conservative estimates IRENA, Shell, ARENA the annual volume of the global hydrogen market will be 500–2000 TWh by 2050.

Note that this means an increase in the share of hydrogen in the global energy balance to only 0.251.0%. This also means an increase in global hydrogen production of 12–50 million tons per year, or 20–80% relative to the current level, which is lower even than the single ambitious European scenario. At the same time, more ambitious forecasts for the global market are 5–10 times higher, up to 15,000 TWh (400 million tons), or 7–8% in the global energy balance, and higher (Dayong et al., 2020; Mikhaylov et al., 2018; Nyangarika et al., 2018; Danish et al., 2020; Danish

et al., 2021; An et al., 2021; Uyeh et al., 2021; Tamashiro et al., 2021; Shaikh et al., 2021).

Furthermore, by some estimates, up to 24% of global energy consumption by 2050 will be covered by hydrogen (which is equivalent to the production of about 40,000 TWh or 1 billion tons of hydrogen). However, there is currently no answer to the question of the availability of resources for such a powerful increase, especially if we are talking about the production of exclusively "green" hydrogen at the expense of renewable energy sources. We will come back to that later (An et al., 2019b; An et al., 2019a; Mikhaylov, 2020a, Mikhaylov, 2020b, Mikhaylov, 2020c; Mikhaylov & Tarakanov, 2020; An et al., 2020c; An et al., 2020a; An et al., 2020b; Moiseev et al., 2020; Moiseev et al., 2021; Grilli et al., 2021; Gura et al., 2020; Dooyum et al., 2020; Mikhaylov et al., 2022; Mikhaylov, 2021a; Varyash et al., 2020; Zhao et al., 2021a; Zhao et al., 2021b; An & Mikhaylov, 2020; Alwaelya et al., 2021; Yumashev & Mikhaylov, 2020; Yumashev et al., 2020; Mutalimov et al., 2021; Morkovkin et al., 2020a; Morkovkin et al., 2020b; An & Mikhaylov, 2021).

A wide range in estimates is inevitable, based on the fact that the plans for the development of the hydrogen economy do not yet have enough specifics, and the figures presented are mostly declarative in nature.

3 Problems of Using and Increasing Hydrogen Production

Plans for a strong increase in hydrogen production, primarily in the Western Europe and Japan, and their motivation (decarbonization of the economy) raise questions (Fang et al., 2021; Kostis et al., 2022; Serezli et al., 2021; Zhao et al., 2021a; Zhao et al., 2021b).

The main problem is that hydrogen is not a primary energy carrier, and its production itself is energy intensive and requires a developed energy infrastructure and the involvement of large energy resources.

A method of producing hydrogen that is considered environmental friendly—water electrolysis—requires about 40–50 MWh of electricity per 1 ton of hydrogen, while the calorific value of 1 ton of hydrogen is lower than 40 MWh (about 36 MW) even at 100% efficiency. Thus, the energy cost of producing hydrogen during electrolysis is higher than the energy value of the resulting hydrogen (Bhuiyan et al., 2021; Dong et al., 2021, Mikhaylov, 2021b; Baboshkin et al., 2022; Barykin et al., 2022; Baig et al., 2022a; Liu et al., 2022a, Liu et al., 2022b; Bhuiyan et al., 2022a; Danish et al., 2022; Baig et al., 2022b; Saqib et al., 2021; Yüksel et al., 2021b; Yüksel et al., 2021a; Yuksel et al., 2021; Mukhametov et al., 2021, Candila et al., 2021; Mikhaylov & Grilli, 2022).

At the same time, it is unlikely that hydrogen, even obtained by electrolysis, can be considered "green" if the electricity for its production is generated on fossil fuels. Its production makes ecological sense only on the basis of renewable energy sources.

The EU's ambitious plans call for an increase in annual hydrogen consumption to 50 million tons by 2050. To produce such an amount of hydrogen by electrolysis of

water, at least 2000 TWh of electricity will be required. In 2019, electricity production in the EU countries amounted to less than 4000 TWh, of which RES, including hydropower, accounted for about 1500 TWh, or 38%. Thus, to produce the claimed amount of hydrogen, it would be necessary to use more than 50% of all electricity currently produced, and all electricity generation from renewable energy sources would not be enough.

The same is true for Japan. The production of 10 million tons of hydrogen by electrolysis requires more than 400 TWh of electricity. In 2019, a total of 1040 TWh was produced in Japan, including about 200 TWh from renewable energy sources (including hydroelectric power plants), or about 20%. The declared production of hydrogen, in this case, requires 40% of all electricity produced in the country and is two times higher than all the electricity production due to renewable energy sources.

Thus, the stated ambitious plans, first of all, do not have a resource base; second, they would not mean decarbonization, but the reverse process—an increase in carbon emissions due to an increase in the production of electricity—needed to produce hydrogen from non-renewable sources (Kou et al., 2022; Liu et al., 2021a; Liu et al., 2021b; Liu et al., 2021c; Meng et al., 2021; Mukhtarov et al., 2022; Xie et al., 2021; Zhe et al., 2021; Zhou et al., 2021).

If we consider the import of hydrogen by these countries as an option, then carbonation is simply "dumped" into exporting countries, and the EU and Japan maintain or even increase their dependence on energy imports.

Technological problems are largely related to the physical properties of hydrogen with a high-heat transfer per mass as it has a low density: 0.09 kg/m^3, which is 8 times lower than that of the natural gas (0.75 kg/m^3 Thus, the heat transfer per volume of hydrogen is 2.5–3 times lower than that of the natural gas. However, hydrogen is also a highly explosive gas. All this creates great difficulties with the storage and transportation of hydrogen.

The existing gas infrastructure is not suitable for transporting and storing hydrogen. The creation of the actual hydrogen infrastructure is associated with high costs. In particular, only the construction of a hydrogen gas transmission network in Europe (with a length of more than 20,000 km) is estimated at $27–64 billion. A 3–4-fold increase in the world's hydrogen storage infrastructure will require more than $600 billion in investment by 2050.

The total cost of producing hydrogen by electrolysis is 2–6 €/kg or 5–15 euro cents/kWh in terms of energy equivalent with an efficiency of 100%. By data IEA, the cost of producing "green" hydrogen from renewable energy sources in 2018 was $3.0–7.5/kg. Thus, the cost of producing 1 million tons of hydrogen at current prices will amount to more than €2 billion, and for 50 million tons more than €200 billion per year. This does not take into account the cost of storing and transporting hydrogen.

In addition, in the future, hydrogen transport is considered as a competitor to electric transport. However, as recent research conducted by Scania, hydrogen engines are losing to electric ones both in terms of cost and other indicators.

Finally, the question of the environmental consequences of large-scale use of hydrogen, including the inevitable leakage of a certain amount, remains unresolved.

In particular, concerns are expressed, which are not excluded at the moment, about the possible negative impact of hydrogen on the stratosphere.

Based on this, the idea of a large-scale increase in hydrogen production for the purpose of decarbonizing the economy seems unfounded.

4 Possible Real Reasons for the Growing Interest in Hydrogen

It is possible that the growing interest in hydrogen is not due to environmental reasons, but due to some other, though less frequently named, reasons.

First of all, hydrogen can be considered as an energy accumulator. The growing share of renewable energy sources in energy consumption increases the instability of the energy system and the increased need for storage (Dinçer et al., 2022; Ding et al., 2021; Dong et al., 2022; Haiyun et al., 2021; Li et al., 2022). Hydrogen can be considered as a way to solve this problem. In other words, the development of the hydrogen economy should go hand in hand with renewable and, possibly, nuclear energy.

Renewable energy is the basis for a new technological breakthrough.

In 2014, it was impossible to abandon Russian oil.

In 2021, the excess supply of oil is 8%. The share of Russian oil is 11% of the demand.

In the United States, Japan, and Western Europe, energy consumption is declining. In the EU countries (including the UK), the peak of energy consumption occurred in 2006—21.9 thousand tons TWh, after which it gradually decreases up to 20.5 thousand rubles TWh in 2019; electricity consumption—respectively, from 3.7 thousand TWh in 2008, up to 3.5 thousand TWh in 2019. In Japan, total energy consumption decreased from 6.2 thousand tons TWh in 2005 to 5.2 thousand TWh in 2019; electricity—from 1.2 thousand TWh in 2008 to 1.04 thousand TWh in 2019. In the US, annual energy consumption since 2000 varies in the range of 25–27 thousand rubles TWh with a peak in 2007 of 26.9 thousand TWh; electricity—since 2007 fluctuates around the level of about 4.4 thousand tons TWh-h. A further decline in energy production and consumption in the western countries is likely.

This can be attributed both to success in energy conservation and to changes in the economic structure—the shift of energy-intensive industries to other regions and general economic problems. This may result in the formation of an excess of generating capacity that requires loading. In addition, the creation of a new growth zone—hydrogen production—can be considered as an incentive for economic development and a means of overcoming economic stagnation, possibly in conjunction with any other areas of technological development.

Finally, in the long run, hydrogen is seen as an exchange-traded commodity, which means that it can be used as a new global financial instrument.

At the same time, this set of reasons can hardly fully explain the ambitious plans and maximum forecasts for increasing hydrogen production. Also, the transition to a "hydrogen economy" does not have a clear positive economic and environmental impact on society as a whole, which raises additional questions.

Based on this, the most realistic are the moderate, conservative forecasts of global hydrogen production growth presented above.

5 Conclusions

At the same time, hydrogen is not a primary energy carrier, but, on the contrary, requires high-energy costs during production, exceeding the energy value of the resulting hydrogen, which in itself means not decarbonization, but the opposite process—an increase in emissions to the environment. Moreover, there is insufficient energy capacity in the Western Europe and Japan to produce the declared amounts of hydrogen.

In addition, the creation of an infrastructure for storing, transporting, and using hydrogen will require high costs, and the operation of this system may be associated with unrecognized negative environmental effects.

Based on this, it can be assumed that the real reasons for the promotion of hydrogen differ from those most often declared and are primarily related to the need to accumulate energy, in a broader sense—to revive the economy of western countries, and possibly other motives that are not yet fully understood and require further research. At the moment, conservative forecasts of an increase in global hydrogen production by the middle of the year seem to be the most adequate. Within 20–80% of where we are now in the twenty-first century.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In H. Dinçer & S. Yüksel (Eds.), *Multidimensional strategic outlook on global competitive energy economics and finance* (pp. 1–11). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80117-898-320221002

Alwaelya, S. A., Yousif, N. B. A., & Mikhaylov, A. (2021). Emotional development in preschoolers and socialization. *Early Child Development and Care, 191*, 16.

An, J., & Mikhaylov, A. (2020). Russian energy projects in South Africa. *Journal of Energy in Southern Africa, 31*(3), 58–64.

An, J., & Mikhaylov, A. (2021). Analysis of energy projects financial efficiency and renewable energy generation in Russia. *Finance: Theory and Practice, 25*(5), 79–91.

An, J., Mikhaylov, A., & Jung, S.-U. (2020a). The strategy of South Korea in the global oil market. *Energies, 13*(10), 2491.

An, J., Mikhaylov, A., & Jung, S.-U. (2021). A linear programming approach for Robust network revenue management in the airline industry. *Journal of Air Transport Management, 91*, 101979.

An, J., Mikhaylov, A., & Kim, K. (2020b). Machine learning approach in heterogeneous group of algorithms for transport safety-critical system. *Applied Sciences, 10*(8), 2670.

An, J., Mikhaylov, A., & Moiseev, N. (2019a). Oil price predictors: Machine learning approach. *International Journal of Energy Economics and Policy, 9*(5), 1–6.

An, J., Mikhaylov, A., & Richter, U. H. (2020c). Trade war effects: Evidence from sectors of energy and resources in Africa. *Heliyon, 6*, e05693. https://doi.org/10.1016/j.heliyon.2020.e05693

An, J., Mikhaylov, A., & Sokolinskaya, N. (2019b). Machine learning in economic planning: Ensembles of algorithms. *Journal of Physics: Conference Series, 1353*, 012126.

Baboshkin, P., Mikhaylov, A., & Shaikh, Z. A. (2022). Sustainable cryptocurrency growth is not possible? Impact of network power demand on bitcoin price. *Financial Journal, 14*(2), 39–55.

Baig, U., Hussain, B. M., Khan, A. A., Shaikh, Z. A., Mikhaylov, A., Chao, C.-C., & Barykin, S. E. (2022a). Research on investors of the reginal stock exchange: An influence of behavioral finance on investment decision making. *Risks, 10*(4), 116.

Baig, U., Khan, A. A., Abbas, M. G., Shaikh, Z. A., Mikhaylov, A., Laghari, A. A., & Hussain, B. M. (2022b). Crucial causes of delay in completion and performance management of the construction work: Study on the base of relative importance index. *Journal of Tianjin University Science and Technology, 55*(6), 75–102.

Barykin, S., Mikheev, A., Kiseleva, E., Putikhin, Y., Alekseeva, N., & Mikhaylov, A. (2022). An empirical analysis of russian regions' debt sustainability. *Economies, 10*(4), 296.

Bhuiyan, M. A., An, J., Mikhaylov, A., Moiseev, N., & Danish, M. S. S. (2021). Renewable energy deployment and COVID-19 measures for sustainable development. *Sustainability, 13*, 4418.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022a). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*(2022), 561–570.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., et al. (2022b). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Bhuiyan, M. A., Khare, V., Mikhaylov, A, Pinter, G., & Zhang. (2022c) Does renewable energy consumption affect economic growth? A systematic literature review. *Frontiers in Environmental Science*.

Candila, V., Maximov, D., Mikhaylov, A., Moiseev, N., Senjyu, T., & Tryndina, N. (2021). On the relationship between oil and exchange rates of oil-exporting and oil-importing countries: From the great recession period to the Covid-19 era. *Energies, 14*, 8065.

Conteh, F., Takahashi, H., Hemeida, A. M., Krishnan, N., Mikhaylov, A., & Senjyu, T. (2021). Hybrid grid-connected renewable power generation for sustainable electricity supply in Sierra Leone: Case study Lungi Town. *Sustainability, 13*(18).

Daniali, S. M., Barykin, S. E., Kapustina, I. V., Khortabi, F. M., Sergeev, S. M., Kalinina, O. V., Mikhaylov, A., Veynberg, R., Zasova, L., & Senjyu, T. (2021). Predicting volatility index according to technical index and economic indicators on the basis of deep learning algorithm. *Sustainability, 2021*(13), 14011.

Danish, M. S. S., Bhattacharya, A., Stepanova, D., Mikhaylov, A., Grilli, M. L., Khosravy, M., & Senjyu, T. (2020). A systematic review of metal oxide applications for energy and environmental sustainability. *Metals, 10*(12), 1604.

Danish, M. S. S., Estrella-Pajulas, L. L., Alemaida, I. M. A., Grilli, M. L., Mikhaylov, A., & Senjyu, T. (2022). Green synthesis of silver oxide nanoparticles for photocatalytic environmental remediation and biomedical applications. *Metals, 12*(4). https://doi.org/10.3390/met12050769

Danish, M. S. S., Senjyu, T., Sabory, N. R., Khosravy, M., Grilli, M. L., Mikhaylov, A., & Majidi, H. (2021). A forefront framework for sustainable aquaponics modeling and design. *Sustainability, 13*, 9313.

Dayong, N., Mikhaylov, A., Bratanovsky, S., Shaikh, Z. A., & Stepanova, D. (2020). Mathematical modeling of the technological processes of catering products production. *Journal of Food Process Engineering, 43*(2), 1–9.

Denisova, V., Mikhaylov, A., & Lopatin, E. (2019). Blockchain infrastructure and growth of global power consumption. *International Journal of Energy Economics and Policy, 9*(4), 22–29.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Ding, Z., Yüksel, S., & Dincer, H. (2021). An Integrated Pythagorean fuzzy soft computing approach to environmental management systems for sustainable energy pricing. *Energy Reports, 7*, 5575–5588.

Dong, B., Ikonnikova, I., Rogulin, R., Sakulyeva, T., & Mikhaylov, A. (2021). Environmentaleconomic approach to optimization of transport communication in megacities. *Journal of Environmental Science and Health, Part A, 56*(6), 660–666.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Dooyum, U. D., Mikhaylov, A., & Varyash, I. (2020). Energy security concept in Russia and South Korea. *International Journal of Energy Economics and Policy, 10*(4), 102–107.

Fang, S., Zhou, P., Dinçer, H., & Yüksel, S. (2021). Assessment of safety management system on energy investment risk using house of quality based on hybrid stochastic interval-valued intuitionistic fuzzy decision-making approach. *Safety Science, 141*, 105333.

Grilli, M. L., Valerini, D., Rizzo, A., Yilmaz, M., Song, C., Hu, G., Chierchia, R., Mikhaylov, A., & Rinaldi, A. (2021). A comparative study of the mechanical and tribological properties of thin Al2O3 coatings fabricated by atomic layer deposition and radiofrequency sputtering. *Physica Status Solidi (A), 218*(24), 1–25.

Gura, D., Mikhaylov, A., Glushkov, S., Zaikov, M., & Shaikh, Z. A. (2020). Model for estimating power dissipation along the interconnect length in single on-chip topology. *Evolutionary Intelligence*, s12065. https://doi.org/10.1007/s12065-020-00407-7

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Huang, Y., Masrur, H., Shigenobu, R., Hemeida, A. M., Mikhaylov, A., & Senjyu, T. (2021a). A comparative design of a campus microgrid considering a multi-scenario and multi-objective approach. *Energies, 14*, 2853.

Huang, Y., Yona, A., Takahashi, H., Hemeida, A. M., Mandal, P., Mikhaylov, A., Senjyu, T., & Lotfy, M. E. (2021b). Energy management system optimization of drug store operate electric vehicles charging station. *Sustainability, 14*, 1217836.

Khan, A. A., Shaikh, Z. A., Baitenova, L., Mutaliyeva, L., Moiseev, N., Mikhaylov, A., Laghari, A. A., Idris, S. A., & Alshazly, H. (2021). QoS-Ledger: Smart contracts and metaheuristic for secure quality-of-service and cost-efficient scheduling of medical-data processing. *Electronics, 10*, 3083.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of european economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Li, J., Yüksel, S., Dınçer, H., Mikhaylov, A., & Barykin, S. E. (2022). Bipolar q-ROF hybrid decision making model with golden cut for analyzing the levelized cost of renewable energy alternatives. *IEEE Access, 10*, 42507–42517.

Liu, L., Kato, T, Mandal, P., Mikhaylov, A, Hemeida, A. M., & Senjyu T. (2021a). Multi-area power system load frequency control by using model predictive control by introducing renewable energy sources. *2021 International Conference on Science & Contemporary Technologies (ICSCT)* (pp. 1–6). https://doi.org/10.1109/ICSCT53883.2021.9642521.

Liu, L., Kato, T., Mandal, P., Mikhaylov, A., Hemeida, A. M., Takahashi, H., & Tomonobu, S. (2021b). Two cases studies of Model Predictive Control approach for hybrid Renewable Energy Systems. *AIMS Energy, 9*(6), 1241–1259.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021c). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*(5), 3687–3701.

Liu, Z.-J., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022a). COVID-19 crisis impact on the stability between parties in crowdfunding and crowdsourcing. *Wireless Personal Communications, 122*, 915–930.

Liu, Z.-J., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022b). Assessing stability in relationship between parties in crowdfunding and crowdsourcing projects during the COVID-19 crisis. *Journal of Global Information Management, 30*(2), 1.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., & Yüksel, S. (2021). A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financial Innovation, 7*(1), 1–34.

Mikhaylov, A. (2018a). Volatility spillover effect between stock and exchange rate in oil exporting countries. *International Journal of Energy Economics and Policy, 8*(3), 321–326.

Mikhaylov, A. (2018b). Pricing in oil market and using probit model for analysis of stock market effects. *International Journal of Energy Economics and Policy, 8*(2), 69–73.

Mikhaylov, A. (2020a). Cryptocurrency market analysis from the open innovation perspective. *Journal of Open Innovation: Technology, Market, and Complexity, 6*(4), 197.

Mikhaylov, A. (2020b). Geothermal energy development in Iceland. *International Journal of Energy Economics and Policy, 10*(4), 31–35.

Mikhaylov, A. (2020c). Cryptocurrency market development: Hurst method. *Finance: Theory and Practice, 24*(3), 81–91.

Mikhaylov, A. (2021a). Development of Friedrich von Hayek's theory of private money and economic implications for digital currencies. *Terra Economicus, 19*(1), 53–62.

Mikhaylov, A. (2021b). Lichens as indicators of atmospheric pollution in urban ecosystems. *Israel Journal of Ecology & Evolution, 67*(1–2), 60–68. https://doi.org/10.1163/22244662-bja10016

Mikhaylov, A. (2022a). Efficiency of renewable energy generation in Russia. *Annals of the Brazilian Academy of Sciences, 94*(3), 1–22.

Mikhaylov, A. (2022b). Sustainable development and renewable energy: A new view to a global problem. *Energies, 15*, 1397. https://doi.org/10.3390/en15041397

Mikhaylov, A., Burakov, D., & Didenko, V. (2019). Relationship between oil price and macroeconomic indicators in Russia. *Finance: Theory and Practice, 23*(2), 105–116. https://doi.org/10.26794/2587-5671-2019-23-2-105-116

Mikhaylov, A., & Grilli, M. L. (2022). Machine learning methods and sustainable development: Metal oxides and multilayer metal-oxides. *Metals, 12*(4), 17–33.

Mikhaylov, A., Sokolinskaya, N., & Nyangarika, A. (2018). Optimal carry trade strategy based on currencies of energy and developed economies. *Journal of Reviews on Global Economics, 7*, 582–592.

Mikhaylov, A., & Tarakanov, S. (2020). Development of Levenberg-Marquardt theoretical approach for electric network. *Journal of Physics: Conference Series, 1515*, 052006.

Mikhaylov, A., Yumashev, A., & Kolpak, E. (2022). Quality of life, anxiety and depressive disorders in patients with extrasystolic arrhythmia. *Archives of Medical Science, 18*(2). https://doi.org/10.5114/aoms.2020.101359

Moiseev, N., Mikhaylov, A., Varyash, I., & Saqib, A. (2020). Investigating the relation of GDP per capita and corruption index. *Entrepreneurship and Sustainability Issues, 8*(1), 780–794.

Moiseev, N., Sorokin, A., Zvezdina, N., Mikhaylov, A., Khomyakova, L., & Danish, M. S. S. (2021). Credit risk theoretical model on the base of DCC-GARCH in time-varying parameters framework. *Mathematics, 9*, 2423. https://doi.org/10.3390/math9192423

Morkovkin, D. E., Gibadullin, A. A., Kolosova, E. V., Semkina, N. S., & Fasehzoda, I. S. (2020a). Modern transformation of the production base in the conditions of Industry 4.0: Problems and prospects. *Journal of Physics: Conference Series, 1515*, 032014.

Morkovkin, D., Lopatkin, D., Sadriddinov, M., Shushunova, T., Gibadullin, A., & Golikova, O. (2020b). Assessment of innovation activity in the countries of the world. *E3S Web of Conferences, 157*, 04015. https://doi.org/10.1051/e3sconf/202015704015

Mukhametov, A., Bekhorashvili, A., Avdeenko, A., & Mikhaylov, A. (2021). The impact of growing legume plants under conditions of Biologization and Soil Cultivation on Chernozem fertility and productivity of rotation crops. *Legume Research, 44*, 12.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy, 187*, 169–176.

Mutalimov, V., Kovaleva, I., Mikhaylov, A., & Stepanova, D. (2021). Assessing regional growth of small business in Russia. *Entrepreneurial Business and Economics Review, 9*(3), 119–133. https://doi.org/10.15678/EBER.2021.090308

Nyangarika, A., Mikhaylov, A., & Richter, U. (2019a). Influence oil price towards economic indicators in Russia. *International Journal of Energy Economics and Policy, 9*(1), 123–129.

Nyangarika, A., Mikhaylov, A., & Richter, U. (2019b). Oil price factors: Forecasting on the base of modified auto-regressive integrated moving average model. *International Journal of Energy Economics and Policy, 9*(1), 149–159.

Nyangarika, A., Mikhaylov, A., & Tang, B.-J. (2018). Correlation of oil prices and gross domestic product in oil producing countries. *International Journal of Energy Economics and Policy, 8*(5), 42–48.

Saqib, A., Chan, T.-H., Mikhaylov, A., & Lean, H. H. (2021). Are the responses of sectoral energy imports asymmetric to exchange rate volatilities in Pakistan? Evidence from recent foreign exchange regime. *Frontiers in Energy Research, 9*, 614463. https://doi.org/10.3389/fenrg.2021.614463

Sediqi, M. M., Nakadomari, A., Mikhaylov, A., Krishnan, N., Lotfy, M. E., Yona, A., & Senjyu, T. (2022). Impact of time-of-use demand response program on optimal operation of afghanistan real power system. *Energies, 15*, 296.

Serezli, E., Yüksel, S., Tamer, İ., & Dinçer, H. (2021). The role of innovative renewable energy investment strategies on macroeconomic stability. In Financial strategies in competitive markets (pp. 165–178) Springer, .

Shaikh, Z. A., Moiseev, N., Mikhaylov, A., & Yüksel, S. (2021). Facile synthesis of copper oxide-cobalt oxide/nitrogen-doped carbon (Cu2O-Co3O4/CN) composite for efficient water splitting. *Applied Sciences., 11*, 9974. https://doi.org/10.3390/app11219974

Tamashiro, K., Alharbi, T., Mikhaylov, A., Hemeida, A. M., Krishnan, N., Lotfy, M. E., & Senjyu, T. (2021). Investigation of home energy management with advanced direct load control and optimal scheduling of controllable loads. *Energies, 14*, 7314. https://doi.org/10.3390/en14217314

Uyeh, D. D., Asem-Hiablie, S., Park, T., Kim, K.-M., Mikhaylov, A., Woo, S., & Ha, Y. (2021). Could Japonica rice be an Alternative variety for increased global food security and climate change mitigation? *Food, 10*, 1869. https://doi.org/10.3390/foods10081869

Varyash, I., Mikhaylov, A., Moiseev, N., & Aleshin, K. (2020). Triple bottom line and corporate social responsibility performance indicators for Russian companies. *Entrepreneurship and Sustainability Issues, 8*(1), 313–331.

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Yüksel, S., Dinçer, H., Çağlayan, Ç., Uluer, G. S., & Lisin, A. (2022a). Bitcoin mining with nuclear energy. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022b). Key issues for the improvements of shallow geothermal investments. In H. Dinçer & S. Yüksel (Eds.), *Sustainability in*

energy business and finance. Contributions to finance and accounting. Springer. https://doi.org/10.1007/978-3-030-94051-5_16

Yuksel, S., Khomyakova, L., & Mikhaylov, A. (2021). Energy center selection in G7 Industry with Fuzzy MOORA. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 87–106). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch006

Yüksel, S., Mikhaylov, A., & Ubay, G. G. (2021a). Factors causing delay in the installation of nuclear power plants. In S. Yüksel & H. Dinçer (Eds.), *Strategic approaches to energy management. Contributions to management science*. Springer. https://doi.org/10.1007/978-3-030-76783-9_7

Yüksel, S., Mikhaylov, A., Ubay, G. G., & Uyeh, D. D. (2021b). The role of hydrogen in the black sea for the future energy supply security of Turkey. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 1–15). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch001

Yumashev, A., & Mikhaylov, A. (2020). Development of polymer film coatings with high adhesion to steel alloys and high wear resistance. *Polymer Composites, 41*(7), 2875–2880.

Yumashev, A., Ślusarczyk, B., Kondrashev, S., & Mikhaylov, A. (2020). Global indicators of sustainable development: Evaluation of the influence of the human development index on consumption and quality of energy. *Energies, 13*, 2768.

Zhao, Q., Cherkasov, S., Avdeenko, A., Kondratenko, L., & Mikhaylov, A. (2021a). Integral estimate of the added value of agricultural crops in the synergetic agriculture on the example of Vicia faba (Vicia faba L.). *Polish Journal of Environmental Studies, 30*(5), 1–9. https://doi.org/10.15244/pjoes/131949

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021b). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 21582440211040133.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

Crop Production Waste Projects in Russia

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Abstract The results of calculations of the energy potential of crop production waste for municipalities of the Krasnodar Territory are presented in this article. The analysis was carried out for the main agricultural crops such as cereals, sunflower, and corn. The results show a significant amount of potential of the region in comparison with other agricultural regions of the South of Russia. The spatial distribution makes it possible to determine the localization of the most promising areas for the use of crop waste for energy production. The global use of bioenergy has reached almost 60 EJ, accounting for 10% of the world's total energy production. However, the plans of the world's leading bioenergy associations are even more ambitious: for example, the reference point for the development of bioenergy in Europe until 2030 is the Graz Declaration (2017), one of the main goals of which is to halve the use of fossil fuels by 2030 and replace it with energy from biomass. In practice, the implementation of these goals in the EU is carried out by a number of research and innovation programs, the largest of which is the Horizon 2020 program, for the implementation of which about 80 billion rubles were allocated in 2014–2020. In 2016, the project of this program has ended Euro Pruning, in 2019, the project was completed in January 2019, and the current project was launched Agro Bio Heat. The aim of this project is to ensure the widespread use of agricultural plant waste for energy production in the European Union. Within the framework of the projects, estimates were made of the amount of plant residues, including agricultural waste, pruning of perennial plants (orchards, olive groves, and vineyards), agricultural processing waste (olive seeds, nut shells, etc.), which accumulate in large volumes in rural areas. Efficient logistics schemes for short and reliable biomass supply and use are being developed use it as fuel. Logistics solutions include harvesting, transportation and storage of agricultural waste. It is expected

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that the energy use of agrobiomass will have a positive social impact on the regions, namely, it will create additional jobs and prevent the outflow of young people from rural areas.

1 Introduction

Currently, technologies for burning straw and other plant residues to generate heat and electricity have reached a commercial level and are widely used in European countries. The Russian market also includes a wide range of domestic energy complexes that use biofuels: wood waste, wood pellets, hop and grape vines, straw, sunflower seed husks, etc. Research on thermochemical processes of biomass-to-energy conversion continues. In particular, it is of interest to create gas-generating domestic biomass stoves, which, due to their high-energy efficiency and environmental friendliness, are significantly superior in quality to traditional direct-burning biomass stoves.

A technical and economic analysis of crop waste incineration technologies in countries with already existing experience in their use has shown that the calorific value of raw materials, the efficiency of power plants, capital costs, and operating costs play a crucial role in determining the cost of energy from biomass. The experience of implemented bio-energy projects shows that if there is no need to transport fuel (when it is processed into energy at the waste site), then the cost of energy is significantly reduced (Baig et al., 2022; Candila et al., 2021; Danish et al., 2022; Mikhaylov & Grilli, 2022; Mukhametov et al., 2021; Saqib et al., 2021; Yuksel et al., 2021; Yüksel et al., 2021; Yüksel et al., 2021).

The most promising areas for implementing renewable energy technologies in Russia are the southern regions. The necessity and expediency of using alternative energy sources in them was analyzed in a number of works. However, most of the research is devoted to assessing the potential of solar and wind energy in the South of Russia. At the same time, these regions are characterized by a high level of agro-industrial production, which is accompanied by the formation of significant volumes of organic waste (An et al., 2019; An et al., 2019; Mikhaylov, 2020a, Mikhaylov, 2020b, Mikhaylov, 2020c; Mikhaylov & Tarakanov, 2020; An et al., 2020; An et al., 2020; An et al., 2020; Moiseev et al., 2020; Moiseev et al., 2021; Grilli et al., 2021; Gura et al., 2020; Dooyum et al., 2020; Mikhaylov et al., 2022; Mikhaylov, 2021a; Varyash et al., 2020; Zhao et al., 2021; Zhao et al., 2021; An & Mikhaylov, 2020; Alwaelya et al., 2021; Yumashev & Mikhaylov, 2020; Yumashev et al., 2020; Mutalimov et al., 2021; Morkovkin et al., 2020; Morkovkin et al., 2020; An & Mikhaylov, 2021).

High-population density and significant recreational potential of these territories determine the relevance of the problem of efficient waste management for both environmental and energy problems (Dinçer et al., 2022; Ding et al., 2021; Dong et al., 2022; Haiyun et al., 2021; Kostis et al., 2022; Li et al., 2022; Meng et al., 2021; Zhao et al., 2021; Zhao et al., 2021). To make decisions regarding the processing of

organic waste, a method of comprehensive analysis of the territory is required, identifying the features of energy consumption and factors that limit the creation of bioenergy facilities. However, first of all, to determine the prospects for the development of bioenergy, it is necessary to assess its raw material base—the volume and energy content of agrobiomass, which is available to the region for energy and heat production (Bhuiyan et al., 2022; Conteh et al., 2021; Daniali et al., 2021; Denisova et al., 2019; Huang et al., 2021; Huang et al., 2021; Khan et al., 2021; Liu et al., 2021b; Liu et al., 2021; Mikhaylov, 2018a; Mikhaylov, 2018b; Mikhaylov, 2022a; Mikhaylov, 2022b; Mikhaylov et al., 2019; Nyangarika et al., 2019a; Nyangarika et al., 2019b; Sediqi et al., 2022).

In this regard, an assessment of the energy potential of the main types of crop production waste in the Krasnodar Territory is presented in this article. The results are compared with earlier similar estimates for the Republics of Crimea and Dagestan and for the Volgograd region (Bhuiyan et al., 2021; Dong et al., 2021, Mikhaylov, 2021b; Baboshkin et al., 2022; Barykin et al., 2022; Baig et al., 2022; Liu et al., 2022a, Liu et al., 2022b; Bhuiyan et al., 2022; Yüksel et al., 2022; Adalı et al., 2022; Dayong et al., 2020; Mikhaylov et al., 2018; Nyangarika et al., 2018; Danish et al., 2020; Danish et al., 2021; An et al., 2021; Uyeh et al., 2021; Tamashiro et al., 2021; Shaikh et al., 2021).

2 Materials and Methods

The assessment methods used in this study were previously described and developed in many works. Calculations were made for the waste of certain types of agricultural crops. This is due to the fact that different types of waste differ in the standards of formation and specific energy content. To determine the energy contained in the waste biomass, the values of the waste mass and their specific energy content (or lowest calorific value) of the corresponding types of biomass are used. Mass of annually generated organic crop production waste, i (M_i), was calculated using statistical data on the annual harvest N_i and coefficients of the ratio of waste and useful part of the plant, L_i (Table 1):

$$M_i = N_i{}^* L_i, \tag{1}$$

Based on the mass of waste determined in this way, the energy potential was calculated as the product of the mass of waste and its specific energy content (K_i):

$$Q_i = M_i{}^* K_i \tag{2}$$

Official data from the Federal State Statistics Service (Rosstat) were used for calculations, namely, annual data on the gross harvest of agricultural crops. The obtained estimates of the bioenergetic potential are presented.

Table 1 Coefficients for calculating the mass of crop production waste and its energy content

Source page type of biomass	Waste-to-utility ratio plant parts, kg/kg	Specific energy content waste, kcal/kg
Grain crops	1.0	3500 (for dry straw)
Corn per grain (stalks)	1.2	3270 (for air-dry waste)
Winter rapeseed and springtime	1.8	3660
Soy	1.3	3800
Potato	0.33	2000 (for dry tops)
Vegetables	0.33	2000

3 Results

Previously, we evaluated the bioenergetic potential of a wide range of agricultural wastes in the southern regions of the Russian Federation—the Volgograd Region, the Republic of Crimea, and Dagestan. Comparison of the total gross potential shows that the Krasnodar Territory is significantly ahead of other regions of the Southern Russia in terms of grain (straw), sunflower (husk, stalks, and baskets), and corn waste.

The main type of crop production waste of the considered regions is straw of grain crops. This is explained by the specialization of agriculture in the South of Russia. For most part of this country, the main problem for agricultural production is the lack of moisture supply, and therefore grain farming has always been and remains the most important branch of the agro-industrial complex. The structure of the sown areas of grain crops in these regions is dominated by winter crops such as wheat and barley, which develop due to winter−spring moisture reserves and have time to form harvest before the onset of hot and dry weather. At the same time, calculations show that there is a significant territorial heterogeneity in the distribution of these resources within the regions. The features of intraregional distribution of bioenergy resources in the Volgograd region, in the Republics of Dagestan, and Crimea were analyzed earlier. The values of the gross energy potential of grain waste (energy content of straw), sunflower, and corn in the districts of the Krasnodar Territory are shown in Table 1.

About half of the districts of the Krasnodar Territory have grain yields of more than 4 million quintals per year, which corresponds to the energy content of waste (straw) of more than 170 thousand tons of CU/year for each of these districts. Of these, seven districts collect more than 5 million quintals per year and two districts collect more than 6 million, which provides a gross energy potential of waste of more than 213 thousand tons of cu. t./year and 298 thousand tons of cu.t./year, respectively. When calculating the technical potential, other areas of waste use (in animal husbandry, to increase the fertility of arable land, etc.) are taken into account—in addition to energy. However, even taking into account this non-energy use of waste, the remaining resources are sufficient for large-scale use in the production of heat and electricity.

4 Discussion

In accordance with the agroclimatic conditions and soil type, the areas located in the north and central part of the region have the greatest energy potential for grain waste. As for other plant waste that is significant in terms of annual production (sunflower and corn production waste), they are mainly concentrated in the northern and north-eastern regions of the region. The number of areas with a high-bioenergetic potential of these types of organic waste is more limited (compared to grain), respectively, their energy potential is less (Kou et al., 2022; Liu et al., 2021a; Liu et al., 2021b; Liu et al., 2021; Mukhtarov et al., 2022; Xie et al., 2021; Zhe et al., 2021; Zhou et al., 2021).

The development of wastewater treatment technologies using MCW is quite an urgent task. Real or artificial wastewater with different COD and BOD parameters, as well as concentrations of nitrogen, phosphorus, and dissolved carbon compounds, is used as models. The efficiency of microalgae consumption of these substances is estimated by the rate and total amount of nitrogen absorbed from wastewater (in the form of NH_4^+, NO_3^-, NO_2^-, total nitrogen), phosphorus (PO_4^{3-}, total phosphorus), dissolved and total carbon, etc. This takes into account that in addition to organic and inorganic chemicals, wastewater also contains bacteria and protozoa that compete for nutrients with microbes and even eat them. Based on the results of experiments, microbe strains are selected that demonstrate a significant growth rate and, accordingly, the absorption of biogenic elements and the most resistant to the effects of toxic components of wastewater. A number of studies also aim to improve methods for cultivating microalgae in wastewater, to study the effectiveness of using consortia of microalgae and bacterial organisms, and to analyze the possibility of cultivating microalgae in wastewater in open cultivators in a wide range of climatic conditions.

The water phase after hydrothermal liquefaction is formed as a by-product in large quantities (20–50%) due to the use of highly moist biomass and has a limited energy value, but contains a significant amount of nutrients suitable for growing microbeads, so the water phase requires repeated use.

Among the most important advantages of biofuels produced from MCW is the reduction of emissions of pollutants into the environment: when burning biofuels from MCW, 98% less sulfur-containing compounds, and 50% less solid particles are released into the atmosphere than when burning fuels based on fossil raw materials. Like other types of biomass, MCW as a raw material for the production of biofuels and energy are "CO2"neutral." In addition, technologies for the production of MCW biomass in open and closed systems can be optimized for the accumulation and capture of carbon dioxide in MCW biomass, followed by its conversion to geologically stable forms.

Many technologies are used to produce motor biofuels in the modern world. Microalgae biomass can be processed into a wide range of biofuels: bioethanol, biobutanol, biodiesel, bio-oil, biohydrogen, etc. The traditional technology is transesterification of microalgae lipids into biodiesel. However, the obvious

disadvantages of this method are the high-energy costs of separating the MCW biomass from the culture liquid and drying it, as well as the use of unsafe organic solvents (such as methanol) to extract lipids from the MCW biomass. In addition, in the production of biodiesel, only the lipid part is converted to fuel, while the remaining (b) part is converted to fuel. Most of the biomass (MCW), including proteins and carbohydrates, is not used for the production of liquid biofuels.

Thermochemical conversion technologies are largely devoid of these disadvantages; they are carried out by heating and decomposing biomass in the presence or absence of air (oxygen). Types of thermochemical conversion are direct combustion (the main product is electric energy), gasification (syngas), pyrolysis (syngas, bio-oil, and biochar), and hydrothermal liquefaction (bio-oil, syngas, and biochar). In recent years, technologies for pyrolysis and hydrothermal liquefaction of biomass MCW have been developing quite actively. In the pyrolysis of MCW for the production of solid, liquid, and combustible gases biomass products are heated to temperatures of 400–600 °C, but in some cases the temperature can reach 800 °C. The mode of pyrolysis of MCW, which is aimed at producing combustible gases with a high-content of hydrogen and methane and a high-calorific value, is less studied. Since the MCW cells are small in size and the dry MCW biomass is loose, no additional grinding is required, as for other types of biomass. However, for efficient pyrolysis, the MCW biomass must contain a minimum amount of moisture, which significantly increases the cost of implementing the technology. In the process of processing biomass by the method of HTL, no pre-drying of raw materials is required: MCW can be supplied to the reactor in a wet state, for example, in the form of an aqueous suspension. In addition, when obtaining fuel by the method of HTL not only lipids, but also carbohydrates and proteins contribute to the yield of bio-oil, which increases the total yield of the product.

5 Conclusions

Bioenergy using crop production waste is an actively developing branch of heat and electric energy production abroad. Significant volumes of crop production in the regions of the Southern Russia also require studying the potential use of this energy resource. Krasnodar Region is a leader in the production of crop products. In this regard, the gross potential of grain waste here is 5996 thousand tons of cu. t./year, sunflower waste: 1899 thousand tons of cu.t./year and corn: 1950 thousand tons of cu. t./year. These volumes of waste biomass exceed similar indicators for other major agricultural regions of the Southern Russia (Volgograd region, the Republic of Dagestan, and Crimea). The use of crop production waste is advisable for obtaining, first of all, thermal energy for the needs of agricultural enterprises, provided that transportation costs are minimal, i.e., in the places where this resource is formed.

Finally, the projects are designed to promote the dissemination of affordable modern technical solutions for heating systems that use agrobiomass with high

efficiency instead of traditional fuel, thereby reducing the level of harmful emissions and improving the ecological situation in the regions.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In H. Dinçer & S. Yüksel (Eds.), *Multidimensional strategic outlook on global competitive energy economics and finance* (pp. 1–11). Emerald Publishing Limited. https://doi.org/10.1108/978-1-80117-898-320221002

Alwaelya, S. A., Yousif, N. B. A., & Mikhaylov, A. (2021). Emotional development in pre-schoolers and socialization. *Early Child Development and Care, 191*, 16.

An, J., & Mikhaylov, A. (2020). Russian energy projects in South Africa. *Journal of Energy in Southern Africa, 31*(3), 58–64.

An, J., & Mikhaylov, A. (2021). Analysis of energy projects financial efficiency and renewable energy generation in Russia. *Finance: Theory and Practice, 25*(5), 79–91.

An, J., Mikhaylov, A., & Jung, S.-U. (2020). The strategy of South Korea in the global oil market. *Energies, 13*(10), 2491.

An, J., Mikhaylov, A., & Jung, S.-U. (2021). A linear programming approach for Robust network revenue management in the airline industry. *Journal of Air Transport Management, 91*, 101979.

An, J., Mikhaylov, A., & Kim, K. (2020). Machine learning approach in heterogeneous group of algorithms for transport safety-critical system. *Applied Sciences, 10*(8), 2670.

An, J., Mikhaylov, A., & Moiseev, N. (2019). Oil price predictors: Machine learning approach. *International Journal of Energy Economics and Policy, 9*(5), 1–6.

An, J., Mikhaylov, A., & Richter, U. H. (2020). Trade war effects: Evidence from sectors of energy and resources in Africa. *Heliyon, 6*, e05693. https://doi.org/10.1016/j.heliyon.2020.e05693

An, J., Mikhaylov, A., & Sokolinskaya, N. (2019). Machine learning in economic planning: Ensembles of algorithms. *Journal of Physics: Conference Series, 1353*, 012126.

Baboshkin, P., Mikhaylov, A., & Shaikh, Z. A. (2022). Sustainable cryptocurrency growth is not possible? Impact of network power demand on bitcoin price. *Financial Journal, 14*(2), 39–55.

Baig, U., Hussain, B. M., Khan, A. A., Shaikh, Z. A., Mikhaylov, A., Chao, C.-C., & Barykin, S. E. (2022). Research on Investors of the Reginal Stock Exchange: An Influence of Behavioral Finance on Investment Decision Making. *Risks, 10*(4), 116.

Baig, U., Khan, A. A., Abbas, M. G., Shaikh, Z. A., Mikhaylov, A., Laghari, A. A., & Hussain, B. M. (2022). Crucial causes of delay in completion and performance management of the construction work: Study on the base of relative importance index. *Journal of Tianjin University Science and Technology, 55*(6), 75–102.

Barykin, S., Mikheev, A., Kiseleva, E., Putikhin, Y., Alekseeva, N., & Mikhaylov, A. (2022). An empirical analysis of russian regions' debt sustainability. *Economies, 10*(4), 296.

Bhuiyan, M. A., An, J., Mikhaylov, A., Moiseev, N., & Danish, M. S. S. (2021). Renewable energy deployment and COVID-19 measures for sustainable development. *Sustainability, 13*, 4418.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*(2022), 561–570.

Bhuiyan, M. A., Khare, V., Mikhaylov, A., Pinter, G., and Zhang. (2022). Does renewable energy consumption affect economic growth? A systematic literature review. *Frontiers in Environmental Science*.

Candila, V., Maximov, D., Mikhaylov, A., Moiseev, N., Senjyu, T., & Tryndina, N. (2021). On the relationship between oil and exchange rates of oil-exporting and oil-importing countries: From the great recession period to the Covid-19 era. *Energies, 14*, 8065.

Conteh, F., Takahashi, H., Hemeida, A. M., Krishnan, N., Mikhaylov, A., & Senjyu, T. (2021). Hybrid grid-connected renewable power generation for sustainable electricity supply in Sierra Leone: Case study Lungi Town. *Sustainability, 13*(18).

Daniali, S. M., Barykin, S. E., Kapustina, I. V., Khortabi, F. M., Sergeev, S. M., Kalinina, O. V., Mikhaylov, A., Veynberg, R., Zasova, L., & Senjyu, T. (2021). Predicting volatility index according to technical index and economic indicators on the basis of deep learning algorithm. *Sustainability, 2021*(13), 14011.

Danish, M. S. S., Bhattacharya, A., Stepanova, D., Mikhaylov, A., Grilli, M. L., Khosravy, M., & Senjyu, T. (2020). A systematic review of metal oxide applications for energy and environmental sustainability. *Metals, 10*(12), 1604.

Danish, M. S. S., Estrella-Pajulas, L. L., Alemaida, I. M. A., Grilli, M. L., Mikhaylov, A., & Senjyu, T. (2022). Green synthesis of silver oxide nanoparticles for photocatalytic environmental remediation and biomedical applications. *Metals, 12*(4). https://doi.org/10.3390/met12050769

Danish, M. S. S., Senjyu, T., Sabory, N. R., Khosravy, M., Grilli, M. L., Mikhaylov, A., & Majidi, H. (2021). A forefront framework for sustainable aquaponics modeling and design. *Sustainability, 13*, 9313.

Dayong, N., Mikhaylov, A., Bratanovsky, S., Shaikh, Z. A., & Stepanova, D. (2020). Mathematical modeling of the technological processes of catering products production. *Journal of Food Process Engineering, 43*(2), 1–9.

Denisova, V., Mikhaylov, A., & Lopatin, E. (2019). Blockchain infrastructure and growth of global power consumption. *International Journal of Energy Economics and Policy, 9*(4), 22–29.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Ding, Z., Yüksel, S., & Dincer, H. (2021). An Integrated Pythagorean fuzzy soft computing approach to environmental management systems for sustainable energy pricing. *Energy Reports, 7*, 5575–5588.

Dong, B., Ikonnikova, I., Rogulin, R., Sakulyeva, T., & Mikhaylov, A. (2021). Environmentaleconomic approach to optimization of transport communication in megacities. *Journal of Environmental Science and Health, Part A, 56*(6), 660–666.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Dooyum, U. D., Mikhaylov, A., & Varyash, I. (2020). Energy security concept in Russia and South Korea. *International Journal of Energy Economics and Policy, 10*(4), 102–107.

Grilli, M. L., Valerini, D., Rizzo, A., Yilmaz, M., Song, C., Hu, G., Chierchia, R., Mikhaylov, A., & Rinaldi, A. (2021). A comparative study of the mechanical and tribological properties of thin Al2O3 coatings fabricated by atomic layer deposition and radiofrequency sputtering. *Physica Status Solidi (A), 218*(24), 1–25.

Gura, D., Mikhaylov, A., Glushkov, S., Zaikov, M., & Shaikh, Z. A. (2020). Model for estimating power dissipation along the interconnect length in single on-chip topology. *Evolutionary Intelligence*, s12065. https://doi.org/10.1007/s12065-020-00407-7

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Huang, Y., Masrur, H., Shigenobu, R., Hemeida, A. M., Mikhaylov, A., & Senjyu, T. (2021). A comparative design of a campus microgrid considering a multi-scenario and multi-objective approach. *Energies, 14*, 2853.

Huang, Y., Yona, A., Takahashi, H., Hemeida, A. M., Mandal, P., Mikhaylov, A., Senjyu, T., & Lotfy, M. E. (2021). Energy management system optimization of drug store operate electric vehicles charging station. *Sustainability, 14*, 1217836.

Khan, A. A., Shaikh, Z. A., Baitenova, L., Mutaliyeva, L., Moiseev, N., Mikhaylov, A., Laghari, A. A., Idris, S. A., & Alshazly, H. (2021). QoS-Ledger: Smart contracts and metaheuristic for

secure quality-of-service and cost-efficient scheduling of medical-data processing. *Electronics, 10*, 3083.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of european economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Li, J., Yüksel, S., Dınçer, H., Mikhaylov, A., & Barykin, S. E. (2022). Bipolar q-ROF hybrid decision making model with golden cut for analyzing the levelized cost of renewable energy alternatives. *IEEE Access, 10*, 42507–42517.

Liu, L., Kato, T, Mandal, P., Mikhaylov, A, Hemeida, A. M., & Senjyu T. (2021a). Multi-area Power System Load Frequency Control by using Model Predictive Control by Introducing Renewable Energy Sources. *2021 International Conference on Science & Contemporary Technologies (ICSCT)* (1–6). https://doi.org/10.1109/ICSCT53883.2021.9642521.

Liu, L., Kato, T., Mandal, P., Mikhaylov, A., Hemeida, A. M., Takahashi, H., & Tomonobu, S. (2021b). Two cases studies of Model Predictive Control approach for hybrid Renewable Energy Systems. *AIMS Energy, 9*(6), 1241–1259.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*(5), 3687–3701.

Liu, Z., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022a). Assessing stability in the relationship between parties in crowdfunding and crowdsourcing projects during the COVID-19 crisis. *Journal of Global Information Management (JGIM), 30*(4), 1–18. https://doi.org/10.4018/JGIM.297905

Liu, Z.-J., Panfilova, E., Mikhaylov, A., & Kurilova, A. (2022b). COVID-19 crisis impact on the stability between parties in crowdfunding and crowdsourcing. *Wireless Personal Communications, 122*, 915–930.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., & Yüksel, S. (2021). A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financial Innovation, 7*(1), 1–34.

Mikhaylov, A. (2018a). Volatility spillover effect between stock and exchange rate in oil exporting countries. *International Journal of Energy Economics and Policy, 8*(3), 321–326.

Mikhaylov, A. (2018b). Pricing in oil market and using probit model for analysis of stock market effects. *International Journal of Energy Economics and Policy, 8*(2), 69–73.

Mikhaylov, A. (2020a). Cryptocurrency market analysis from the open innovation perspective. *Journal of Open Innovation: Technology, Market, and Complexity, 6*(4), 197.

Mikhaylov, A. (2020b). Geothermal energy development in Iceland. *International Journal of Energy Economics and Policy, 10*(4), 31–35.

Mikhaylov, A. (2020c). Cryptocurrency market development: Hurst method. *Finance: Theory and Practice, 24*(3), 81–91.

Mikhaylov, A. (2021a). Development of Friedrich von Hayek's theory of private money and economic implications for digital currencies. *Terra Economicus, 19*(1), 53–62.

Mikhaylov, A. (2021b). Lichens as indicators of atmospheric pollution in urban ecosystems. *Israel Journal of Ecology & Evolution, 67*(1–2), 60–68. https://doi.org/10.1163/22244662-bja10016

Mikhaylov, A. (2022a). Efficiency of renewable energy generation in Russia. *Annals of the Brazilian Academy of Sciences, 94*(3), 1–22.

Mikhaylov, A. (2022b). Sustainable development and renewable energy: A new view to a global problem. *Energies, 15*, 1397. https://doi.org/10.3390/en15041397

Mikhaylov, A., Burakov, D., & Didenko, V. (2019). Relationship between oil price and macroeconomic indicators in Russia. *Finance: Theory and Practice, 23*(2), 105–116. https://doi.org/10.26794/2587-5671-2019-23-2-105-116

Mikhaylov, A., & Grilli, M. L. (2022). Machine learning methods and sustainable development: Metal oxides and multilayer metal-oxides. *Metals, 12*(4), 17–33.

Mikhaylov, A., Sokolinskaya, N., & Nyangarika, A. (2018). Optimal carry trade strategy based on currencies of energy and developed economies. *Journal of Reviews on Global Economics, 7*, 582–592.

Mikhaylov, A., & Tarakanov, S. (2020). Development of Levenberg-Marquardt theoretical approach for electric network. *Journal of Physics: Conference Series, 1515*, 052006.

Mikhaylov, A., Yumashev, A., & Kolpak, E. (2022). Quality of life, anxiety and depressive disorders in patients with extrasystolic arrhythmia. *Archives of Medical Science, 18*(2). https://doi.org/10.5114/aoms.2020.101359

Moiseev, N., Mikhaylov, A., Varyash, I., & Saqib, A. (2020). Investigating the relation of GDP per capita and corruption index. *Entrepreneurship and Sustainability Issues, 8*(1), 780–794.

Moiseev, N., Sorokin, A., Zvezdina, N., Mikhaylov, A., Khomyakova, L., & Danish, M. S. S. (2021). Credit risk theoretical model on the base of DCC-GARCH in time-varying parameters framework. *Mathematics, 9*, 2423. https://doi.org/10.3390/math9192423

Morkovkin, D. E., Gibadullin, A. A., Kolosova, E. V., Semkina, N. S., & Fasehzoda, I. S. (2020). Modern transformation of the production base in the conditions of Industry 4.0: Problems and prospects. *Journal of Physics: Conference Series, 1515*, 032014.

Morkovkin, D., Lopatkin, D., Sadriddinov, M., Shushunova, T., Gibadullin, A., & Golikova, O. (2020). Assessment of innovation activity in the countries of the world. *E3S Web of Conferences, 157*, 04015. https://doi.org/10.1051/e3sconf/202015704015

Mukhametov, A., Bekhorashvili, A., Avdeenko, A., & Mikhaylov, A. (2021). The impact of growing legume plants under conditions of Biologization and Soil Cultivation on Chernozem fertility and productivity of rotation crops. *Legume Research, 44*, 12.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy, 187*, 169–176.

Mutalimov, V., Kovaleva, I., Mikhaylov, A., & Stepanova, D. (2021). Assessing regional growth of small business in Russia. *Entrepreneurial Business and Economics Review, 9*(3), 119–133. https://doi.org/10.15678/EBER.2021.090308

Nyangarika, A., Mikhaylov, A., & Richter, U. (2019a). Influence oil price towards economic indicators in Russia. *International Journal of Energy Economics and Policy, 9*(1), 123–129.

Nyangarika, A., Mikhaylov, A., & Richter, U. (2019b). Oil price factors: Forecasting on the base of modified auto-regressive integrated moving average model. *International Journal of Energy Economics and Policy, 9*(1), 149–159.

Nyangarika, A., Mikhaylov, A., & Tang, B.-J. (2018). Correlation of oil prices and gross domestic product in oil producing countries. *International Journal of Energy Economics and Policy, 8*(5), 42–48.

Saqib, A., Chan, T.-H., Mikhaylov, A., & Lean, H. H. (2021). Are the responses of sectoral energy imports asymmetric to exchange rate volatilities in Pakistan? Evidence from recent foreign exchange regime. *Frontiers in Energy Research, 9*, 614463. https://doi.org/10.3389/fenrg.2021.614463

Sediqi, M. M., Nakadomari, A., Mikhaylov, A., Krishnan, N., Lotfy, M. E., Yona, A., & Senjyu, T. (2022). Impact of time-of-use demand response program on optimal operation of Afghanistan real power system. *Energies, 15*, 296.

Shaikh, Z. A., Moiseev, N., Mikhaylov, A., & Yüksel, S. (2021). Facile synthesis of copper oxide-cobalt oxide/nitrogen-doped carbon (Cu2O-Co3O4/CN) composite for efficient water splitting. *Applied Sciences., 11*, 9974. https://doi.org/10.3390/app11219974

Tamashiro, K., Alharbi, T., Mikhaylov, A., Hemeida, A. M., Krishnan, N., Lotfy, M. E., & Senjyu, T. (2021). Investigation of home energy management with advanced direct load control and optimal scheduling of controllable loads. *Energies, 14*, 7314. https://doi.org/10.3390/en14217314

Uyeh, D. D., Asem-Hiablie, S., Park, T., Kim, K.-M., Mikhaylov, A., Woo, S., & Ha, Y. (2021). Could Japonica rice be an Alternative variety for increased global food security and climate change mitigation? *Food, 10*, 1869. https://doi.org/10.3390/foods10081869

Varyash, I., Mikhaylov, A., Moiseev, N., & Aleshin, K. (2020). Triple bottom line and corporate social responsibility performance indicators for Russian companies. *Entrepreneurship and Sustainability Issues, 8*(1), 313–331.

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Yüksel, S., Dinçer, H., Mikhaylov, A., Adalı, Z., & Eti, S. (2022). Key issues for the improvements of shallow geothermal investments. In H. Dinçer & S. Yüksel (Eds.), *Sustainability in energy business and finance. Contributions to finance and accounting*. Springer. https://doi.org/10.1007/978-3-030-94051-5_16

Yuksel, S., Khomyakova, L., & Mikhaylov, A. (2021). Energy center selection in G7 Industry with Fuzzy MOORA. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 87–106). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch006

Yüksel, S., Mikhaylov, A., & Ubay, G. G. (2021). Factors causing delay in the installation of nuclear power plants. In S. Yüksel & H. Dinçer (Eds.), *Strategic approaches to energy management. Contributions to management science*. Springer. https://doi.org/10.1007/978-3-030-76783-9_7

Yüksel, S., Mikhaylov, A., Ubay, G. G., & Uyeh, D. D. (2021). The role of hydrogen in the black sea for the future energy supply security of Turkey. In S. Yüksel & H. Dinçer (Eds.), *Handbook of research on strategic management for current energy investments* (pp. 1–15). IGI Global. https://doi.org/10.4018/978-1-7998-8335-7.ch001

Yumashev, A., & Mikhaylov, A. (2020). Development of polymer film coatings with high adhesion to steel alloys and high wear resistance. *Polymer Composites, 41*(7), 2875–2880.

Yumashev, A., Ślusarczyk, B., Kondrashev, S., & Mikhaylov, A. (2020). Global indicators of sustainable development: Evaluation of the influence of the human development index on consumption and quality of energy. *Energies, 13*, 2768.

Zhao, Q., Cherkasov, S., Avdeenko, A., Kondratenko, L., & Mikhaylov, A. (2021). Integral estimate of the added value of agricultural crops in the synergetic agriculture on the example of Vicia faba (Vicia faba L.). *Polish Journal of Environmental Studies, 30*(5), 1–9. https://doi.org/10.15244/pjoes/131949

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 21582440211040133.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

An Analysis of the Relationship Between Sustainable Fuel Management and Competitive Strategy in the Aviation Industry

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Abstract Air transport is currently carried out with conventional aviation fuel derived from petroleum. However, it has been known that this fuel is not sustainable. The sector functions with many constraints due to its nature. Many problems need to be considered, such as mandatory aerodromes, capacity constraints, high labor costs, and of course, mandatory rules that must be endured for safe flight. When fuel, which is the biggest cost item, is added to all these, the strategic side of the management perspective becomes a more sensitive issue. In this context, the aim of the study is to develop various strategies to provide competitive advantage to airline companies with sustainable fuel management. The latest studies in the literature have been analyzed in this respect and as a result, various strategies have been proposed for airline companies to provide sustainable competitive advantage.

1 Introduction

The number of strategic parameters is increasing as the companies that must act in line with their commercial objectives such as making profit, growing, and operating continuity. Considering the value of increasing environmental awareness in the eyes of customers, it has become necessary to carry out studies on the production and use of sustainable fuel in addition to commercial targets to ensure satisfaction. The efficient allocation of resources, which is defined as the safety dilemma in aviation, reveals that companies in this sector need to design their strategic management processes more deeply, from a dual perspective (Fernandes, 2017).

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Considering the aviation industry as a traditional scale, there is safe flight on one side of this scale and profit on the other. In other words, companies should use the resources they have in such a way that neither their safety is ignored, nor their profits are given up. However, the point to be noted is that the balance remains in balance, that is, creating value in the eyes of the customer, who is the determinant of service quality. This is how companies can provide both safe and affordable service. However, with the increasing environmental awareness, this is thought to be insufficient, and in this context, another variable called "sustainability" has come to the fore (Dahal et al., 2021).

Responsibilities to nature, responsibilities to customers, and even to people who do not have to fly have completely changed the corporate social strategies of businesses. In fact, some strategies are mentioned as the leading role of corporate social responsibility in the reports of airline companies. As a result of this, the issue of how alternative fuels should be developed instead of the fuel obtained from petroleum has gained importance (Tao, 2020).

In their study, Hari et al. (2015) showed that replacement aviation fuel can be produced using renewable biological resources, especially camelina (camelina), algae (algae), jatropha (jatropha), wastes from different sources (industrial, domestic, agricultural, and animal wastes), and halophyte. They stated that renewable biological resources (such as halophyte) can be used. These and similar studies may cause the use of alternative fuels to be perceived as volunteering at a certain point. However, the launch of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) program related to the reduction of CO emissions by the aviation authority ICAO, to which the states are members, emphasizes the importance of the issue.

The CORSIA bill, created in 2021, is a study on reducing carbon emissions from airplanes in the airline industry. According to the bill, when an airplane flies within the borders of the European Union, the amount it must pay to the union is calculated based on the amount of fuel it consumes and the amount of carbon it emits. This situation forces companies to invest in aircraft with lower fuel consumption in the medium and long term. The corporate strategy that needs to be put forward at this point has become not only a social responsibility, but also a corporate necessity for economic sustainability. In other words, the necessity of choosing the right corporate social strategy to develop an energy strategy arises from this (Maertens et al., 2019).

In this scope, the purpose of this study is to develop various strategies to provide competitive advantage to airline companies with sustainable fuel management. In this respect, a detailed literature review on the relationship between aviation industry and sustainability has been done. This study is expected to contribute to the literature well with the strategies developed for the companies functioning in the aviation industry.

The study consists of four parts. In the following section, a detailed analysis on the aviation industry and its relationship with the sustainability has been made. Moreover, in the same section, the fuels currently used in aviation and alternative ones have been discussed. In the third section, possible corporate strategy recommendations have been evaluated. Finally, in the conclusion part, some strategies for

the aviation companies to manage the fuel used in their operations have been put forward.

2 Literature Review

2.1 Aviation Industry and Sustainability

The aviation industry is by far the most developed of any other mode of transport. Aviation has a different position in terms of creating service diversity compared to other transportation systems. About 33% of the world trade volume receives a share from the transportation sector. About 33% of this slice is supported by the aviation industry. Due to the rapid growth of the sector, the importance of sustainability in the aviation sector is increasing day by day. On the one hand, international political factors, on the other hand, increased fuel consumption and fluctuating oil prices due to the significant increase in the number of aircraft used have affected airlines in recent years. Factors such as the sector's low profit margin, long and high fixed investment requirements, exchange rate changes, and fuel prices affect costs (Lee et al., 2016).

All these variables show that the sector is open to negative economic effects and is susceptible to rapid deterioration. In addition to these, the sector is in a rapidly changing structure due to its nature. Ecological adaptation becomes an important paradigm in this industry, which has an intense technological and scientific infrastructure. Although the view that economic sustainability is more important, especially in terms of continuing operations, seems to be supported, corporate sustainability means more than this (Karaman et al., 2018).

Koc and Durmaz define corporate sustainability as a new and evolving corporate governance paradigm. Stating that it was realized that corporate sustainability is important for the growth and profitability of the company, Koc and Durmaz also state that the company should pursue objectives such as environmental protection, economic development, social rights and justice, which are related to sustainable development. Studies on the subject reveal that the concept of corporate sustainability benefits from four more established and common concepts. In this context, sustainable development, corporate social responsibility, stakeholder theory, and corporate accountability theory form the basis of this perspective.

Basically, the source of the problem seems to be the inverse movement of economic sustainability and environmental sustainability. All kinds of economic gains in industrial societies cause negative and permanent damage to the environment to a certain extent. For example, according to a report published by IATA, the aviation industry is responsible for 2% of global carbon dioxide (CO_2) emissions in the world. With the rapid growth of the sector, the number of aircraft and the amount of fuel consumed accordingly increase. At the same time, CO_2 emissions cannot be reduced to the expected level due to the use of fossil fuels and the greenhouse gas

released. In Turkey, the share of carbon footprint originating from the transportation sector in the energy sector is 22.2%, and its share in national total emissions is 15%.

The industry's need for sustainable practices is becoming more evident every day, and many companies that produce both products and services around the world are putting forward many new practices in the name of sustainability. For example, while designing the A320 family, which Airbus called Neo, the "Sharklet", which it developed with inspiration from shark fins, provides fuel savings of up to 4% depending on the distance flown with its 2.40-meter wing structure and reduces CO_2 emissions. According to the information given by Airbus, the savings to be achieved from CO_2 emissions are around 1000 tons per aircraft per year (Cansino & Román, 2017).

On the subject, Turkish Airlines announced in its 2017 sustainability report that they achieved 46,757 tons of fuel savings as a result of their efforts on fuel efficiency (https://investor.turkishairlines.com/tr/mali-ve-operasyonel-veriler/faaliyet-raporlari). Accordingly, 147,283 tons of carbon emissions were prevented. This study of THY was selected as the most successful project in the Carbon and Energy Management category within the scope of the Fuel Saving Project. There is a difference between being a manufacturer-designer company and a service-providing company in the sector where each company takes different measures. These differences bring about different practices in the way companies manage energy savings (Selimoglu & Caliskan, 2018).

As a service provider, Emirates saved 1170 tons of fuel according to its 2017 reports by turning off an engine while taxiing, while saving nature from the burden of approximately 3686 tons of CO_2 emissions. Again, thanks to the reverse thrust method used by Emirates pilots during landing, 4941 tons of fuel was saved, while approximately 15,564 tons of CO_2 emissions were avoided. Boeing, one of the oldest manufacturers in the aviation industry, has managed to save up to 3% fuel with the curved wing-tip airplanes it has designed, while also managing a significant amount of CO_2 emissions. Considering the critical role and importance of the aviation industry in the world's logistics movement and supply chain, the economic sustainability of companies, close contact with ecological sustainability has an increasing importance (Dray et al., 2018).

2.2 Fuels Used in Aviation Industry and Alternative Fuels

In aviation industry, kerosene or naphtha type fuels produced from petroleum and called jet fuel are used. Kerosene fuels are Jet A, Jet A-1, JP 5, and JP 8 fuels with carbon numbers between 8 and 16. Naphtha type fuels are Jet B and JP-4 fuels with a wide carbon range such as 5–15. At the same time, these fuels are used as a mixture of kerosene-naphtha and kerosene-gasoline (JP-4). Kerosene is a derivative of petroleum, often used in industries, and is a flammable hydrocarbon mixture obtained from the distillation of petroleum (Bauen et al., 2020).

When paraffin is used in diesel vehicles, it loses its liquidity in low-temperature conditions. Therefore, diesel-style fuel models are not used in aircraft engines. In addition to the fact that this type of energy is a nonrenewable energy source, the effect of damage to the environment is quite high. All harmful chemicals expressed as "HCS" are related to the type of fuel used. The emissions, which spread into the atmosphere, directly and indirectly change the chemical composition of the atmosphere. Emissions spread to the upper part of the troposphere, 9 to 13 km above the earth's surface, during plane flight. The most known emission is carbon emission and as a result of the combustion of 1 kg of jet fuel, 3.16 kg of carbon dioxide (CO2) is produced (Turnock et al., 2018).

It is stated that the transportation sector accounts for approximately 25% of the world's carbon dioxide emissions. In this context, in 2018, it was stated that the transportation sector ranked second after the industry sector and it was determined that it contributed 27.6% to energy consumption. For this reason, the transportation sector and, accordingly, the aviation sector have a close relationship with the environment. According to research, 2% of the CO_2 in the atmosphere originates from aviation and it is predicted that this rate will be 5% in 2050 (Abrantes et al., 2021).

Aircraft carbon emissions cause serious pollution. In this context, climatologists have reported that one of the biggest causes of global warming is airplanes. Carbon emissions in the European region have increased significantly since 1990 and increased by 87%. It has been determined that most of this increase is due to aviation, and this rate is expected to double in the 2050s. The European Union sets limits on carbon emissions for airline operators and allows them to fly within these limits. Civil aviation accounts for 3% to 8% of greenhouse gas emissions in Europe. While approximately 70% of the emitted emissions are carbon dioxide, 29% is water vapor, and 1% is carbon monoxide, sulfur oxides, nitrogen oxides, nonmethane volatile organic compounds, other gases, and particles (Brugnoli et al., 2015).

In short, the reduction in fuel consumption in airplanes means a decrease in emissions, as well as a decrease in the negative effects on the environment. At this point, optimizing fuel consumption has become a necessity for almost all businesses in aviation. Businesses make this optimization not only to reduce fuel expenditures, but also to increase efficiency and minimize environmental concerns. In this context, environmental sustainability and economic concerns have encouraged airline companies to improve fuel efficiency in recent years (Edwards et al., 2016).

Although efficiencies have been taken to the upper level, they have not yet reached the desired levels. There are many reasons behind this. These are the raw material selection and production model of alternative fuels to be produced. At the same time, there are many parameters such as being able to meet the standards of fuel properties, being able to be stored, being easily transported, and having a widespread usage network (Timmis et al., 2015).

As a sustainable energy source, biofuels can significantly reduce greenhouse gas emissions. In addition, biofuels can improve air quality, provide less dependency on oil imports, and are considered an important source of energy for new markets. In countries with high biomass potential, vegetable oils, inedible oils, and bioalcohols

come to the fore as biofuels. According to classification made, primary biofuels are used for heating, cooking, and electricity generation directly without applying a chemical process. Secondary biofuels are listed as products such as vegetable oil, biodiesel, ethanol, methanol, and biogas. However, secondary fuels are produced by improving primary ones. In alternative fuels, some vegetable oils stand out compared to those used for food purposes. Fuels such as canola oil, soybean oil, sunflower oil, cottonseed oil, palm oil, jatropha oil, and coconut oil are used as biofuels (Mousavi & Bossink, 2017).

Studies in terms of fuel efficiency and reduction of carbon emissions through technology include improved aircraft engine technologies, aircraft design, use of new composite lightweight materials in aircraft construction and the use of biological fuels. In this respect, when one of the multistakeholder approaches, "Midwest Aviation Sustainable Biofuels Initiative (MASBI)" is evaluated, it is seen that some of the stakeholders are British Petroleum (BP), Renewable Energy Group, SkyNRG, and Airlines for America representing airline companies in the USA (Fontaras et al., 2017).

Moreover, some of the stakeholders in the Brazilian Biojetfuel Platform established in Brazil; Boeing, General Electric and Gol Airlines companies come together to conduct research on new generation fuels. In Australia, the "Australian Initiative for Sustainable Aviation Fuels" conducts research on new generation fuels with the collaboration of Qantas Airlines, Virgin Australian Airlines, Boeing Australia, and other relevant stakeholders (Moncada et al., 2019).

The Lufthansa Group has created a fuel efficiency department covering all its companies. In particular, the airline companies in the group have taken the necessary steps to renew their fleets with the latest technology aircraft that consume less fuel. Group companies, which started to work by selling some of their aircraft, expect to receive their new aircraft by 2025. The airline companies in the group support the production of airplanes using technologies with low nitrogen oxide content in their engines and try to reduce the emissions of this material for their aircraft. The group has also started testing the sugar-based biological aviation fuel "Farnesan" for the development of biosynthetic aviation fuels instead of conventional aviation fuel to reduce carbon dioxide emissions (Mendes, 2021).

Air France contributes to the "SYNDIESE" project, which is working on the production of biological aviation fuel using forest waste. It has also been involved in the "FCA" working group to develop biofuels. KLM, on the other hand, supports the "ITAKA" project, allowing this fuel to be tested on its own aircraft. It also provides support to SkyNRG for the sale of biofuels. By joining the SAFUG group, both Air France and KLM have been involved in the development, acceptance, and trade of low-carbon biofuels derived from environmentally friendly sustainable sources. Air France and KLM have decided to modernize their aircraft fleet as an extension of their corporate social strategy. In this context, companies have withdrawn some of their aircraft from use and ordered new generation aircraft (Ko et al., 2017).

British Airways is working on a low-carbon biofuel to be produced from biorecyclable waste. The company has also started to renew its fleet with new generation aircraft. THY has ordered 75 new generation aircraft to Boeing and

92 new generation aircraft to Airbus. These planes are B737 MAX 8, B737 MAX 9, and A 321 NEO. Although the arrival of these aircraft was interrupted by the effect of the pandemic, as of 2022, the THY fleet reached 370 with its incoming aircraft. With this modernization, the company achieved a maximum efficiency of 15% and made an important attempt to reduce carbon dioxide emissions.

It seems that such organizational collaborations are both a necessity for the development of corporate strategies and important steps for the supply of environmentally friendly aviation fuel. The equivalent of all these interactions in economic practice is to reduce foreign dependency based on conventional fuel for countries without oil resources and to take precautions for the future by putting forward a sustainable strategy on underground reserves (Qiu et al., 2021).

3 Corporate Strategy Recommendations

The to-do list is quite large due to economic pressures, environmental practices, and the sanctions of institutions in authority. The most important point is that these resources are limited and companies with fleets that need energies that are not produced from renewable resources cannot continue in the sector. There are also issues that companies should consider regarding which renewable source they will prefer. First of all, when determining the biological resource, this resource should be sustainable, renewable, the production technology used to leave a carbon footprint should be environmentally friendly and reduce the dependency on oil supplying countries (Yilmaz & Atmanli, 2017).

In this context, when the Alternative Fuel Reports published by IATA in 2012, 2013, and 2014 are examined, it is seen that the number of airline companies that contribute to and are stakeholders in alternative aviation fuel production have been increasing in the last 3 years. In addition, in the report titled "Aircraft Fuel Roadmap for Sustainable Aviation" published by IATA in 2015, it is stated that some airline companies have started trial flights using sustainable alternative fuels since 2008. However, the contribution of airline companies to the creation of sustainable alternative aviation fuel has not been limited to test flights. At the same time, various partnerships have been established under the title of "Multi-Stakeholder Initiatives for Sustainable Aviation Fuel Production" for the development of sustainable alternative aviation fuel worldwide (IATA, 2015).

The most destructive competition in aviation is over prices. Therefore, there are many examples of cooperation in the aviation industry at the regional and global level. In the postliberation period, applications such as code sharing, multiline interlining, and collaborations such as star alliance have come to the fore. Since competing by merging is of course a limiting factor, companies aimed to stand out by increasing their service quality. Corporate social responsibilities have turned into corporate social strategies, as all these variables alone do not give priority to competition, and especially as the negative aspects of the aviation industry in environmental sustainability come to the fore (Law & Breznik, 2018).

The competition of companies with each other in the fields of corporate social responsibility, just like their other economic competition, does not seem possible only with their own company responsibilities. This situation can be understood by looking at the share of the transportation economy in the world trade volume. At this point, the first corporate strategy proposal is to establish strategic cooperation at regional, companies, and institutions level. In a way, this strategy is similar to competence development by outsourcing. For example, the production technologies of manufacturers such as Boeing and Airbus can be combined with the operational capabilities of Airline companies. In fact, the establishment of specialized departments within the supervision duties of international organizations such as ICAO and IATA can support these developments (Castiglioni et al., 2018).

Another corporate strategy proposal should be on the fleet planning of airlines, especially since it is known that airports that do not allow landing permits or slots for nonenvironmental aircraft will increase in the post-2022 period. It also has an economic sustainability dimension. It is known that such fleet rejuvenation pressures and proposals increase the pressure on the assets of the companies (Tan et al., 2017).

There are 42 airline companies that went bankrupt in 1 year, especially with the effect of the pandemic. To what extent would such a drastic transition be possible in an industry where costs are so high? At this point, it is necessary to evaluate the arguments that the fuel item, which takes the first place in the cost item, is most affected. Aircraft take-off and landing weights, current weights, and friction ratios according to the density of the air affect both fuel efficiency and the increase in carbon emissions negatively (Karaman & Akman, 2018).

The institutional strategy proposal to be made at this point is to limit the materials that must be present in the cabin to the minimum level. In particular, the service vehicles used for serving the treats should be made of light material and the forks, knives, spoons, and food containers used in the catering service should be preferred from recyclable materials. At the same time, encouraging the containers used in cargo operations to be made of composite materials will directly affect the weight of the operation and will contribute positively to both environmental and economic sustainability (Elhmoud & Kutty, 2021).

It is clear that these strategy proposals will obviously need an effective new system fleet planning. Although this may cause high economic pressures in the short term, the effective safety dilemma balance to be achieved with a correct risk management will be in the interests of the enterprises in the medium-long term, thanks to the economy of scale. At this point, it is a fundamental requirement for companies to order new generation aircraft, not only in terms of reducing environmental obligations and fuel consumption, but also in terms of customer satisfaction, which is another pillar of corporate social responsibility (Flouris & Oswald, 2016).

4 Conclusion

The technology and equipment used in aviation today are not sufficient to use pure fuel in the flights. However, it seems that the obligations will increase in the near future in terms of international authority pressures and the recovery of investments. The industry's commitment to creative destruction technology, the innovation statements made by the manufacturing companies require companies to develop their social responsibility strategies and make innovation management. Airbus aims to put hydrogen-fueled airplanes into service in 2035 with the support of governments and industrial stakeholders. Boeing, its biggest rival in the industry, has announced that all of its aircraft will be able to fly with 100% biofuel technology by 2030 (Kousoulidou & Lonza, 2016).

All of these developments are evaluated within the scope of corporate social responsibility, both as a cost and innovation strategy, with a focus on the fuel management system. In this context, correct management and sustainability over fuel are very important in terms of economy and ecology. That is, an implemented fuel management strategy also offers an ecological response.

The aviation industry, in today's conditions, evaluates growth over cost, not profitability. As a matter of fact, under the effect of the pandemic, the best announced airline companies were chosen among those who made the least loss. This situation is explained that the fuel management strategy to be put forward is more than a set of rules and a continuous improvement should be made on these strategies. For this reason, the new paradigm in the competitive strategy of companies cannot be explained with a single point of view, such as growing or earning an above-average return compared to the competitor.

In sustainability, which is the new paradigm of the sector, there is ecological and economic continuity, which are intertwined with each other. From this point of view, it is argued that companies related to existing aircraft and new generation aircraft are both open to scientific research for the right fuel management strategies and to be on the side of supporting this research. In addition, it is recommended that companies take a long-term view of the issue and not just leave it to the advent of creative destruction technology.

Considering that creative disruptive technology can only be benefited in the next 15 years, it is recommended that companies start their fleet rejuvenation work quickly. In addition, the management of the internal weights of the existing aircraft, which are outside of their own structural weights, is very important in terms of fuel consumption. It is recommended to limit the number of magazines, to encourage the catering vehicles to be made of light material, and to prefer lighter cargo containers made of composite material in cargo planes.

However, since the weight management in aircraft also means fuel management, it is recommended that companies support the researches for aircraft to be made of composite materials by meeting with the manufacturers in the construction of new generation aircraft. Although the technologies to be used in the new generation aircraft mean high costs and expenses in the near term, it is necessary to explain that

it is an investment in a young fleet, a new image, service quality, comfort and speed opportunities, and customer satisfaction in the medium and long term.

As a result, it should be known that the investment made by a company in the continuity of the ecological chain actually means the investment made in the future of the company. As the theory of population ecology reveals, it is necessary for the sectors to keep up with all the changes under the influence of the fact that it will not be possible for those who cannot adapt to the ecosystem to continue. From this point of view, being able to compete with sustainable fuel management in aviation should be handled with a corporate social obligation strategy rather than a corporate social responsibility perspective.

References

Abrantes, I., Ferreira, A. F., Silva, A., & Costa, M. (2021). Sustainable aviation fuels and imminent technologies-CO2 emissions evolution towards 2050. *Journal of Cleaner Production, 313*, 127937.

Bauen, A., Bitossi, N., German, L., Harris, A., & Leow, K. (2020). Sustainable Aviation Fuels: Status, challenges and prospects of drop-in liquid fuels, hydrogen and electrification in aviation. *Johnson Matthey Technology Review, 64*(3), 263–278.

Brugnoli, A., Button, K., Martini, G., & Scotti, D. (2015). Economic factors affecting the registration of lower CO2 emitting aircraft in Europe. *Transportation Research Part D: Transport and Environment, 38*, 117–124.

Cansino, J. M., & Román, R. (2017). Energy efficiency improvements in air traffic: The case of Airbus A320 in Spain. *Energy Policy, 101*, 109–122.

Castiglioni, M., Gallego, Á., & Galán, J. L. (2018). The virtualization of the airline industry: A strategic process. *Journal of Air Transport Management, 67*, 134–145.

Dahal, K., Brynolf, S., Xisto, C., Hansson, J., Grahn, M., Grönstedt, T., & Lehtveer, M. (2021). Techno-economic review of alternative fuels and propulsion systems for the aviation sector. *Renewable and Sustainable Energy Reviews, 151*, 111564.

Dray, L. M., Schäfer, A. W., & Al Zayat, K. (2018). The global potential for CO2 emissions reduction from jet engine passenger aircraft. *Transportation Research Record, 2672*(23), 40–51.

Edwards, H. A., Dixon-Hardy, D., & Wadud, Z. (2016). Aircraft cost index and the future of carbon emissions from air travel. *Applied Energy, 164*, 553–562.

Elhmoud, E. R., & Kutty, A. A. (2021, December). Sustainability assessment in aviation industry: A mini-review on the tools, models and methods of assessment. In *Proceedings of the 2nd African International Conference on Industrial Engineering and Operations Management, Harare, Zimbabwe* (pp. 7–10).

Fernandes, A. A. R. (2017). The mediating effect of strategic orientation and innovations on the effect of environmental uncertainties on the performance of business in the Indonesian aviation industry. *International Journal of Law and Management.* https://doi.org/10.1108/IJLMA-10-2016-0087

Flouris, T. G., & Oswald, S. L. (2016). *Designing and executing strategy in aviation management*. Routledge.

Fontaras, G., Zacharof, N. G., & Ciuffo, B. (2017). Fuel consumption and CO2 emissions from passenger cars in Europe–Laboratory versus real-world emissions. *Progress in Energy and Combustion Science, 60*, 97–131.

Hari, T. K., Yaakob, Z., & Binitha, N. N. (2015). Aviation biofuel from renewable resources: Routes, opportunities and challenges. *Renewable and Sustainable Energy Reviews, 42*, 1234–1244.

International Air Transportation Association (IATA). (2015). 2015 Report on Alternative Fuels.

Karaman, A. S., & Akman, E. (2018). Taking-off corporate social responsibility programs: An AHP application in airline industry. *Journal of Air Transport Management, 68*, 187–197.

Karaman, A. S., Kilic, M., & Uyar, A. (2018). Sustainability reporting in the aviation industry: Worldwide evidence. *Sustainability Accounting, Management and Policy Journal, 9*(4), 362–392.

Ko, Y. D., Jang, Y. J., & Kim, D. Y. (2017). Strategic airline operation considering the carbon constrained air transport industry. *Journal of Air Transport Management, 62*, 1–9.

Kousoulidou, M., & Lonza, L. (2016). Biofuels in aviation: Fuel demand and CO2 emissions evolution in Europe toward 2030. *Transportation Research Part D: Transport and Environment, 46*, 166–181.

Law, K. M., & Breznik, K. (2018). What do airline mission statements reveal about value and strategy? *Journal of Air Transport Management, 70*, 36–44.

Lee, P. T. W., Chung, Y. S., & Lam, J. S. L. (2016). Transportation research trends in environmental issues: A literature review of methodology and key subjects. *International Journal of Shipping and Transport Logistics, 8*(6), 612–631.

Maertens, S., Grimme, W., Scheelhaase, J., & Jung, M. (2019). Options to Continue the EU ETS for Aviation in a CORSIA-World. *Sustainability, 11*(20), 5703.

Mendes, D. V. D. M. (2021). CO2 emissions reduction through creating a more sustainable airline's network operation for Europe. *International Journal of Sustainable Aviation, 7*(2), 123–136.

Moncada, J. A., Verstegen, J. A., Posada, J. A., Junginger, M., Lukszo, Z., Faaij, A., & Weijnen, M. (2019). Exploring the emergence of a biojet fuel supply chain in Brazil: An agent-based modeling approach. *GCB Bioenergy, 11*(6), 773–790.

Mousavi, S., & Bossink, B. A. (2017). Firms' capabilities for sustainable innovation: The case of biofuel for aviation. *Journal of Cleaner Production, 167*, 1263–1275.

Qiu, R., Hou, S., Chen, X., & Meng, Z. (2021). Green aviation industry sustainable development towards an integrated support system. *Business Strategy and the Environment, 30*(5), 2441–2452.

Selimoglu, S. K., & Caliskan, A. O. (2018). Sustainability reporting in airlines industry: Evidence from Turkey. *International Journal of Sustainable Aviation, 4*(2), 114–132.

Tan, S. H., Habibullah, M. S., Tan, S. K., & Choon, S. W. (2017). The impact of the dimensions of environmental performance on firm performance in travel and tourism industry. *Journal of Environmental Management, 203*, 603–611.

Tao, Y. (2020, September). Analysis method for customer value of aviation big data based on LRFMC model. In *International Conference of Pioneering Computer Scientists, Engineers and Educators* (pp. 89–100). Singapore.

Timmis, A. J., Hodzic, A., Koh, L., Bonner, M., Soutis, C., Schäfer, A. W., & Dray, L. (2015). Environmental impact assessment of aviation emission reduction through the implementation of composite materials. *The International Journal of Life Cycle Assessment, 20*(2), 233–243.

Turnock, S. T., Wild, O., Dentener, F. J., Davila, Y., Emmons, L. K., Flemming, J., Folberth, G. A., Henze, D. K., Jonson, J. E., Keating, T. J., Kengo, S., Lin, M., Lund, M., Tilmes, S., & O'Connor, F. M. (2018). The impact of future emission policies on tropospheric ozone using a parameterised approach. *Atmospheric Chemistry and Physics, 18*(12), 8953–8978.

Yilmaz, N., & Atmanli, A. (2017). Sustainable alternative fuels in aviation. *Energy, 140*, 1378–1386.

Wind Energy as a Zero-Emission Energy Source: Evaluation in the Framework of Turkish Law

Ergün Dilaveroğlu

Abstract In today's world, the use of fossil fuels continues intensively. However, the decrease in raw materials and the damage caused by fossil fuels to the environment every day encourage countries to develop policies toward sustainable energy resources and to introduce legislation for the use of these resources in their domestic legal systems. Another situation that encourages the orientation toward sustainable energy sources is the military intervention of countries against each other or the possibility of such a possibility occurring at any time. It can be said that this situation also caused unpredictable increases in fossil fuel prices. In addition, a country's dependence on foreign energy is a situation that directly affects its economic independence. As a result, the use of clean energy resources is increasing day by day due to many reasons mentioned above, and legal regulations are made for this. In this context, the main purpose of the study is to try to deal with wind energy, which is one of the sustainable clean energy sources, and its application and procedure in Turkey in the context of the Turkish legal system. In addition, the choice of wind energy in the study can be expressed as the most common among renewable energy sources.

1 Introduction

Energy is accepted as a factor that significantly affects the independence of countries. The main reason behind its increasing importance day by day is the need for energy both in production processes and in consumption (Bayramoğlu, 2017). When countries do not have access to energy in their own land, they buy it from international markets within their economic possibilities. This situation causes a serious burden on the country's economies and indirectly leads to discussions about economic independence.

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Energy is obtained from various sources, the largest of which is fossil fuels (Aydın, 2014). Fossil fuel production in Turkey is well below the amount it needs. In addition, the decrease in these fuels day by day causes the costs to increase at the same rate as fossil fuels are used in energy production to a significant extent. As a result, these situations have become triggering factors for turning to alternative energy production sources.

Developing technology, industry-oriented production strategy, and growth plans increase the need for energy day by day, and as this need increases, foreign dependency changes to the detriment of the country (Oskay, 2014). This situation reveals the need for Turkey to produce domestic and renewable energy policies, make legislative changes in the legal system, and to expand the use of such energy resources.

In this context, the main contribution of the study to the literature is to determine the legal procedure to be considered for wind energy investments in the context of Turkish law. Thus, it will be determined what should be paid attention to those who are considering making such investment decisions and starting their activities.

In the first part of this study, the energy market will be discussed in the context of the basic principles of public service, and then the advantages and disadvantages of wind energy will be explained and explanations will be made about obtaining a wind energy license in the Turkish legal system.

2 Evaluation of the Energy Market in the Context of the Public Service

It should be evaluated whether the generation, transmission, and distribution of energy is a public service. Under this title, the concept of public service will be defined and explanations will be made about the energy market in the context of the basic elements and basic principles of public service.

2.1 Public Service Concept

The concept of public service is used in the sense of "material and organic". According to this, it refers to an activity that meets the social needs that are in the public interest in the satisfaction of the material use of the public service. In organic terms, it refers to an organization or an organization (Gözler & Kaplan, 2018). Public services are known as activities performed directly by the administration, apart from being fulfilled by concession method. However, the changes that took place over time have led to the emergence of different legal regimes regarding the participation of private persons in public services. This situation does not remove the obligations of the administration, which is the main owner and responsible of the service (Tan,

2020). The Constitutional Court expresses this situation in various decisions. In one of the decisions, "Public services are a whole. *The fulfillment of this, in principle, belongs to the State. However, the condition that the public services that increase with the expansion of social life are no longer required by the classical administration institutions, it is accepted that they can also be carried out by private individuals. In other words, public service units can be structured in a mixed nature, consisting of public and private law rules, to the extent that they are compatible with their qualifications and characteristics. For this reason, no matter how public services are carried out, as long as public institutions and organizations have the authority to direct the service with their supervision and control, the service will maintain its public character"* (T.12.4.1990, E.1990/4, K.1990/6). It was stated that the service performed by private legal persons would preserve the public service quality. In a different decision, the Supreme Court tried to define the concept of public service in the broadest sense by stating that there is a consensus in the doctrine about the ambiguity of the concept of public service. The relevant definition is as follows: "*are continuous and regular activities made and presented to the society by the state or other public legal entities or under their supervision and control, to meet general and common needs, to provide public interest or benefit.*" (Constitutional Court, T.09.12.1994, E.1994/43, K.1994/42-2).

There have been serious changes in the establishment of public services in Turkey recently. Accordingly, the responsible wing of the executive is now the President alone (Özdemir, 2019). In addition, the president was given authority to establish public services. In this framework, after 2017, the Turkish Grand National Assembly (TBMM) can establish a public service as the legislative body, and the President will be able to establish a public service as he has the authority to establish a public legal entity (Tan, 2020).

In this context, with the Law No. 3096 dated 04.12.1984 on the Assignment of Electricity Generation, Transmission, Distribution, and Trade of organizations other than the Turkish Electricity Authority, the Ministry of Energy and Natural Resources has been contracted to a private law capital company and a limited period of 99 years, and may provide public service regarding the establishment and operation of production facilities. Accordingly, private law capital companies will operate the business for their profit and loss within the period within the scope of the contract and will transfer it to the administration free of charge at the end of the period. Then, with the Electricity Market Law dated 14.03.2013 and numbered 6446, the subject was rearranged and the licensing procedure took its place in the legislation. Accordingly, the assignment/contract/licensing procedures in the period of Law No. 3096 started to be applied in a uniform manner (Gözler & Kaplan, 2018). The subject of licensing will be discussed in detail in the following parts of the study.

2.2 *Evaluation of the Energy Market in the Framework of the Basic Principles of the Public Service*

The basic principles of public services; can be expressed under four headings as continuity, variability, equality, and freedom.

Public services are services provided to meet the common needs of society in general. For this reason, it is expressed as activities that must be carried out continuously and regularly (Akyılmaz et al., 2021; Günday, 2017; Özay, 2017; Tan, 2020; Ulusoy, 2019; Zabunoğlu, 2012).

According to the Constitutional Court, services that meet social needs should be defined as public services by their nature. According to this, "*Regularity and continuity constituted one of the important elements of public service. Because the absence of it turns the social life upside down. A public service can respond to the needs of all people throughout the country; It can also meet the needs of a certain community in a certain region. In other words, the fact that the service is in question for a country, local or a part of the society does not affect its quality as a public service*".

Within the scope of the continuity principle, public service should be carried out regularly, adequately, and well, without interruption. Under normal conditions, what should be understood from the definition of continuity here is that this is sufficient if public services are fulfilled to meet the needs (Akyılmaz et al., 2021). However, this may vary depending on the content of the service. In other words, what the service is important here. If a public service is a public service that the society expects to be provided uninterruptedly, then it will be accepted as a service that should be provided to the society whenever it needs it. For example, in the delivery of health services. In addition, for example, education services are a constitutional right that must be fulfilled on certain days of the week and at certain times and regulated in Article 42 of the Constitution. The fact that education services are not provided at night will not create a situation contrary to the principle of continuity of public services. According to the Council of State, health services are directly related to the right to life of the society, and it is a service that people should be able to access when they need it. While this is a duty of the state, it is a right of the citizen (Council of State Administrative Litigation Chambers, T.24.02.2011, E.2007/1884, K.2011/88).

At this point, the question that needs to be answered is meeting the energy needs of the society a public service that should be provided at every moment of the day, as in health services, or is it a public service that can be interrupted at certain times of the day? It should be noted that the fulfillment of electricity services is a public service that the society will need at any time. In this sense, electricity service should be provided whenever the society needs it, and otherwise, it may conflict with the continuity principle. In other words, the person should be able to access the electricity service at any time and under any condition.

In addition, the service should be carried out regularly and with the quality expected from the administration. If a public service is always fulfilled but not

provided in a good and qualified manner, this may also constitute a violation of the principle of continuity (Akyılmaz et al., 2021). For example, if the electricity service is cut off continuously during the day or if it is not sufficient to meet the energy needs of the households, this situation can be considered a disruption in the provision of the service and a situation against the continuity principle will arise.

It is also stipulated in Law No. 4628 on the Organization and Duties of the Energy Market Regulatory Authority that energy services should be provided in a reliable, high quality, uninterrupted, and low-cost manner (Law No. 4628 m.4/c). Accordingly, while providing energy service, both the quality of the energy offered and its uninterrupted presentation to the public are important. Otherwise, it can be described as a malfunction in the provision of the service.

In addition, it should be stated that noncontinuous interruptions in energy will not constitute a violation of the continuity principle. Accordingly, a short-term cut-off of the energy for the elimination of a fault does not constitute a situation contrary to the continuity principle.

The second of the basic principles of civil service is variability and adaptation. What should be understood from the principle of variability and adaptation is that public service can change over time, depending on the way it was first established. Continuous performance of the service does not mean that it will be performed as it was originally established. Accordingly, a public service will be able to change in parallel with the change in social needs and developing technology. In other words, it has to be modernized (Akyılmaz et al., 2021). Otherwise, problems arise in the provision of the service, which violates the principle of variability.

For example, in the face of a change in the number of beneficiaries of public service, the administration needs to be re-adapted according to the changing population, taking into account the new situation. In this context, it is necessary to increase both the financial resources transferred to the service and the number of personnel and the public goods allocated to the service (Yasin, 2018). It should be stated that the jurisprudence of the Council of State is in this direction. Accordingly, the high court stated in a decision that: "*...While a public institution should adapt its dynamics to the conditions of the day in the face of an increase in services and changing conditions, it is not compatible with the concept of public duty and public administration to cause the services to be protracted by not changing the facilities of the institution and freezing it, because the city grows, the population increases and in this case, there is no opportunity to meet the service.*" (Council of state,11.D., T.4.5.1977, E. 1974/4855, K.1977/1704).

Undoubtedly, those who benefit from public services do not have the right to demand that the quality, content, and conditions of this service be offered in the same way all the time. Accordingly, the service may be changed and updated by the administration according to the conditions of the day. Considering the contrary, it will not be possible to adapt the service delivery according to changing conditions. In addition, the changes made by the administration in the provision of the service will be the changes made in the future, not in the past (Yasin, 2018).

As a matter of fact, with the fifth article of the Law on the Organization and Duties of the Energy Market Regulatory Authority No. 4628, the Duties of the

Energy Market Regulatory Board and the Board Presidency are regulated, and one of the duties of the board is according to the article, "*To develop and implement the infrastructure for the implementation of new trade methods and sales channels depending on the development of the market*" has been determined as. In this framework, the Board will monitor the development of the market and work on strengthening and implementing the infrastructure. This situation clearly shows that the administration is responsible for the variability and adaptation to the new situation in the provision of electricity service.

Another principle is the principle of equality. As it is known, public services are carried out to meet social needs. The administration, which is the executive of the public service, is obliged to act objectively and to act equally in terms of both those who benefit from the service and those who participate in the service (Akyılmaz et al., 2021; Günday, 2017). In other words, the administration, which is the execution of the public service, should act within the framework of the principle of "equality before the law", which is also included in Article 10 of the Constitution. However, this does not mean a mathematical equation. It should be noted that the equality here is the equality that exists between those in a similar situation (Akyılmaz et al., 2021).

There are provisions in Law No. 4628 that require acting within the framework of the principle of equality. One of these is the audit that must be carried out to ensure that legal entities operating in the energy market act following the rules of transparency and equality. Accordingly, the Energy Market Regulatory Board is charged with inspecting the activities, practices, and compliance of the legal entities operating in the energy market (Law No. 4628, article 4/i).

Finally, the electricity market should be evaluated within the framework of the free-of-charge principle. In the classical public administration approach, it is not possible to charge a fee for the services provided as a public service. Even today, some public services are offered free of charge (Akyılmaz et al., 2021). For example, primary education activities are like a constitutional public service that should be provided without any charge to the beneficiaries of the service.

However, since the emergence of public services, both the number of public services offered and the quality of the services have changed. In this context, in parallel with the developments in technology, changes have occurred in the way public services are provided. In this context, the cost required for service delivery has increased. At this point, a fee has started to be collected from those who benefit from the services in terms of both meeting the cost of public services and providing new investments and financing them. The price received from the beneficiaries of the services not only covers the cost of the service but also constitutes a price for providing "equality" (Akyılmaz et al., 2021).

The price to be collected from those who benefit from public services must be a price that will not prevent people from benefiting from the services and will not cause inequality and injustice (Akyılmaz et al., 2021). In addition, it is stated that the principle of free of charge is no longer valid for industrial and commercial services. However, it can be said that the effects of these services continue (Kır, 2013). One of the duties of the Energy Market Board, which will be established following the Law

on the Organization and Duties of the Energy Market Regulatory Authority No. 4628, is to deliver reliable, high quality, uninterrupted, and low-cost electrical energy service to consumers.

It is also an issue that needs to be evaluated whether public services are rendered by private law persons or not. Accordingly, to talk about public service, a service must be given to the administration as a duty. In this case, the administration will be the main authorized and responsible administration at the point of performing the service, but if it wants to have this service performed by private law persons, the service can be performed by private law persons under the supervision and supervision of the administration.

In addition to performing a public service as a public service within the framework of the classical administrative law approach, in recent years, the method of licensing certain public services to private law persons and subsequently assigning licensees to certain public services has become widespread (Yasin, 2018). We see this situation in Turkey both in the Law No. 4628 on the Organization and Duties of the Energy Market Regulatory Authority, as well as in the Natural Gas Market Law No. 4646 and the Petroleum Law No. 5015.

On the other hand, it should be noted that the procedure for issuing licenses and assigning licensee companies to perform a public service is a different aspect of the licensing procedure, which is one of the procedures in administrative law and is one of the procedures in which public services are rendered by private law persons (Yasin, 2018). In licensing procedure, a public service is performed directly by a private legal person (Yayla, 2010). Accordingly, it is possible for these public services to be fulfilled by private law persons, if a particular private legal person is not granted a privilege or a monopoly is not established for the fulfillment of the common and general needs of the society (Özay, 2017). In this sense, if the service is aimed at meeting the general and common needs of the society, and if they are not met, the possibility of unrest in the society leads to the realization of these services subject to permission (Özay, 2017). In this context, the administration has the authority to make necessary arrangements regarding the service, since it is primarily responsible for the provision of the service (Akyılmaz et al., 2021). In addition, the license holder is also obliged to bear this situation. It is understood from this that the administration has control over those who perform such services, which exceeds the control of the law enforcement and reaches to the regulation of the content of the service.

As a result, it was stated above that there is a different version of the licensing procedure in the services performed by the licensing procedure. Accordingly, in the next part of the study, explanations will be made about how the licensing procedures for wind energy, which is expressed as clean energy in the Turkish legal system, should be carried out.

3 Evaluation of Wind Energy as a Zero-Emission Energy Source in the Framework of Turkish Law: Wind Energy License

The need for energy in the global world continues to increase. To meet this energy need, high amounts of carbon-based fuels (coal- and petroleum-based products can be given as examples) are consumed and this causes carbon dioxide-induced energy loading in the atmosphere (Kou et al., 2022). It is known that this energy accumulated in the atmosphere causes floods and unexpected climatic events in various parts of the World (Dinçer et al., 2022; Ekonomi Dünya, 2021).

The wind is the horizontal movement of air mass from areas of high pressure to areas of low pressure (Döner, 2018; İlkılıç, 2003; Sekin, 1999). The main source of wind energy is the sun. As the sun heats the air around the world, some areas get hotter and some areas get less hot. Accordingly, low pressure occurs in areas that are heated, and high pressure occurs in areas that remain cold, and the movement from high-pressure areas to low-pressure areas is called wind (İlkılıç, 2003).

The factor that makes wind energy important is that it does not have a certain life as a renewable energy source. In other words, renewable energy sources are constantly renewing themselves (Ayanoğlu, 2018; Bayraç et al., 2018) and cannot be permanently consumed by humans (Ağaçbiçer, 2010). This situation is also important in terms of the economic growth of countries (Bórawski et al., 2020).

The fact is that Turkey is a developing country, its ever-increasing population, and its growing economy constantly increase its energy needs. It should be noted that the country does not have enough domestic production energy to meet the ever-increasing energy needs (Bayramoğlu, 2017). This situation causes foreign dependency on energy and affects decision-making processes at the point of political independence. It imports fossil fuels such as oil or natural gas and uses them to generate electrical energy, and this brings along significant foreign trade deficits.

In this context, renewable energy is important in meeting both energy needs and environmental problems (Ağaçbiçer, 2010). The fact that wind is an energy production source that does not pollute the environment and does not produce greenhouse gases harmful to human health makes wind energy advantageous (Atay & Acaroğlu, 2017). At the same time, wind energy, being a renewable energy source, increases energy security. In this way, it plays an important role in reducing the need for imported fuels and therefore not wasting the country's resources (Kandpal & Dhingra, 2021). In this context, renewable energy projects should be increased to eliminate primarily climatic, economic, and therefore political problems arising from fossil fuels (Muhhtarov et al., 2022). In this context, serious steps have been taken over the years regarding wind energy investments in Turkey in terms of both reducing the number of emissions released to nature and meeting the energy need. According to this, while the installation of wind power plants in MWm in Turkey was 1375.80 in 2010, 1865.70 in 2011, 2355.35 in 2012, 3019.35 in 2013, 3834.80 in 2014, 4732.85 in 2015, 6135.30 in 2016, 6843.30 in 2017, 7408.70 in 2018, 8080.20 in 2019, and 9030.02 in 2020.

As can be seen, there is a steady increase in the installation of wind power plants between 2010 and 2020 in Turkey. It is stated that as of 2020, 245 companies have participated in wind energy production activities, and 41 companies are at the installation stage in their power plant with a power of 1872.13 MW. However, it can be stated that this orientation is insufficient when compared to the total wind energy potential of the country. Accordingly, it can be said that the trend toward wind energy as a clean energy source in Turkey continues steadily.

3.1 Advantages of Wind Energy

One of the most important advantages of wind energy is that it does not produce greenhouse gases (Atay & Acaroğlu, 2017; Zhang et al., 2022). Greenhouse gas emission, which is shown as the most important cause of global warming, significantly damages the development of both societies and civilizations (Vadikkeettil et al., 2022). Even this situation alone indicates that wind energy is an important clean energy.

At the same time, wind energy is not radioactive. It does not cause acid rain and is not one of the sources of warming of the atmosphere. It does not cause carbon dioxide emission and does not harm nature and human health (Kaygusuz, 2010; Zhang et al., 2022).

In addition to the advantages mentioned above, it is also advantageous because it is easy to install and the commissioning time is short. Requirements for maintenance and operation are low (Atay & Acaroğlu, 2017).

3.2 Disadvantages of Wind Energy

One of the most important disadvantages of wind energy can be expressed as noise pollution. The fact that there was a serious noise from the mechanical system was seen as an important effect that could prevent the formation of settlements near the turbines. However, there are important studies to eliminate the sound problem of the system, and it is stated that this problem has been eliminated in new systems (Ağaçbiçer, 2010). In addition to these disadvantages, it is also stated that the radio and television systems in the vicinity of the regions where the turbines are installed also damage the signals and if they are installed on the migration routes of the birds, they cause harm to the animals (Dong et al., 2022).

3.3 Wind Energy License in Turkish Law

To regulate the energy market in Turkish law, the Energy Market Law dated 14.06.2013 and numbered 6446 was enacted. The general purpose of the law is again expressed in article 1 of the law as follows: "*Establishing a financially strong, stable, and transparent electricity energy market that operates following the provisions of private law in a competitive environment, and ensuring that an independent regulation and audit are carried out in this market, to provide sufficient, high-quality, continuous, low-cost and environmentally compatible electricity to consumers*". Accordingly, electricity service should be provided at a sufficient level to meet the social energy need and at the same time with high quality, in a continuous manner at the point of fulfillment of the service, and in an economically low-cost manner.

According to the Electricity Market Law, legal entities must obtain permission to operate in the energy market. The name of the permission to be obtained according to the law is license. By obtaining a license, legal entities may carry out the activities specified in the law in the market. These eight different types of activities, namely generation activity, transmission activity, distribution activity, wholesale activity, retail sale activity, market operation activity, import activity, and export activity can be carried out by license holders. In addition, it is stipulated that the procedures and principles that license holder legal entities must comply with while carrying out their activities should also be regulated by a regulation.

According to the provisions of private law, legal entities that will operate in the market must be established as either a joint-stock company or a limited liability company. In addition, it has been stipulated that the shares of those established as joint-stock companies, excluding those that are stipulated within the framework of the capital market legislation, must be registered (Law No. 6446 4/3).

In addition, legal entities that have applied for a generation license must obtain permits, approvals, licenses, etc. A prelicense is given for a certain period of time in order to have the opportunity to obtain the documents and to obtain the use or ownership rights of the area where the production facility can be used. In addition, legal entities that want to operate in the market must obtain a license before starting their activities. In addition, it is not possible to transfer the license obtained by legal entities. In addition, legal entities that want to engage in generation activities are given a fixed-term permit to start their investments in the relevant generation facility. Within the scope of this permission, legal entities carry out the necessary approvals, permits, licenses, and similar procedures in order to produce. The name of the permission granted in this context is an associate license and is given for a certain period of time.

In this context, first of all, how to apply for an associate degree should be examined, and then the license application and the evaluation process of this application should be emphasized.

According to this, legal entities that will apply for an associate license are required to submit the information and documents to the Energy Market Regulatory

Authority (EMRA) within the framework of the "Procedures and Principles Regarding Applications for Associate Degree and License Transactions" put into effect by the Energy Market Board (Energy Market License Regulation (EPLY) m.12). In addition, the prelicense application procedure regulated under Article 12 of the EPLY must be complied with.

Associate licenses are given to relevant legal entities for a certain period. This period will be determined by the board, depending on the type and installed power of the related production project, and in a maximum of 36 months, excluding force majeure.

In case the prelicense application is made in full within the framework of the provisions of the regulation, the relevant application will be evaluated. The decision taken as a result of the evaluation carried out by the institution is presented to the board and the prelicense application is finalized with the board's decision. The transactions that the legal person receiving the prelicense must perform within the scope of the EPLY are detailed in Article 17 of the relevant regulation.

It is also possible to amend the associate license. Accordingly, the founder can amend his associate license in two cases. First of all, if there is something it wants to amend, she should request it and her request should be approved. The second situation is the necessity of amending the prelicense as a result of a change in the legislation or a change in the practices within the scope of the legislation. In the end, it is also possible to terminate and cancel the prelicense. Accordingly, if the given period expires, the prelicense will automatically expire if the legal person holding the prelicense requests or goes bankrupt and if the legal person obtains a license.

After obtaining an associate license, it is necessary to complete the licensing procedures. Legal entities wishing to operate in the market make their applications by submitting the documents required for obtaining a license to the Energy Market Regulatory Authority. Legal persons who will operate in the market following the provisions of private law within the scope of the Turkish Commercial Code numbered 6102, there must be joint-stock companies or limited liability companies, the shares of the companies established as joint-stock companies, other than the shares traded in the stock exchange, must be registered, and the share certificates other than the shares to be traded in the stock exchange must not be the bearer. In addition, those who will apply for a license must apply for a license by acting within the framework of the rules set in Article 20 of the Electricity Market License Regulation. After the application, an examination and then an evaluation are made.

During the examination and evaluation phase of the application, it is examined whether the documents submitted to the institution in the application for license are suitable or not. This examination must be completed within ten working days after the documents are submitted to the institution. The application status that is not made properly is notified to the person concerned. Deficiencies must be completed within 15 working days from the notification. Otherwise, the application will be deemed not done and the documents will be returned. After that, the documents delivered within 15 working days are examined within ten days and if it is understood that the deficiencies are not corrected, the application is deemed not made and the documents are returned (EPLY m.21).

It should also be noted that the evaluation of the license application does not mean that the relevant person is entitled to receive a license. Accordingly, the institution will evaluate the license applications according to the 22nd article of the Energy Market Regulation and will finalize the relevant applications according to the 23rd article of the same regulation.

Apart from these, the legal entity that has obtained a license may apply for a license amendment or license renewal. Accordingly, the aforementioned regulation, "*Examination, evaluation and conclusion of license amendment applications*" according to article 24, which is titled, amendments must be carried out. Again, the regulation, "*Evaluation and conclusion of license renewal applications*" is possible to evaluate and finalize license renewal applications of license holders according to Article 25 entitled.

Finally, the expiration and revocation of the license should be addressed. Accordingly, when the License is purchased for a certain period, it will automatically expire upon the expiration of this period. In addition, according to Article 26 of the regulation, the license shall expire if it is determined that the sale of the generation facility has been finalized as a result of the bankruptcy of the licensee or the execution proceeding. This expiration may be requested by the license holder, or in case of loss of the conditions for granting a license, it will also be terminated by the decision of the board. The cancellation of the license is regulated in detail in the 27th article of the regulation. In this context, in cases specified in the relevant article, it may be possible to impose sanctions on license holders and to cancel the license.

3.4 Discussion and Conclusion

Energy is among the most important needs of countries. When this situation is combined with the possibility of depletion of fossil fuels and the damage it causes to the atmosphere, there is a constant trend toward new energy sources.

At this point, it is seen that wind energy investments are increasing day by day. It has been determined that Turkey's wind energy potential is 48,000 MW. As mentioned above, according to the data for 2020, the installed wind power plant power in our country is known as 9.305.02 kWm. This situation shows that Turkey produces wind energy well below its potential.

In the period we live in, there are also problems in transportation to fossil fuels. This situation significantly increases the energy costs of the countries, as well as problems in accessing energy due to political preferences.

All these reveal the need for renewable and clean energy. Access to clean energy is of vital importance in terms of reaching clean energy and meeting the needs, reducing the use of fossil fuels, thus reducing greenhouse gas emissions, and achieving energy independence for countries. In this sense, new policies should be developed to accelerate clean energy investments and investors should be encouraged in this regard.

References

Ağaçbiçer, G. (2010). Yenilenebilir enerji kaynaklarının Türkiye ekonomisine katkısı ve yapılan SWOT analizler [Çanakkale 18 Mart Üniversitesi]. İçinde *Çanakkale 18 Mart Üniversitesi Sosyal Bilimler Enstitüsü*. https://www.golder.com/insights/block-caving-a-viable-alternative/

Akyılmaz, B., Sezginer, M., & Kaya, C. (2021). *Türk İdare Hukuku* (13. Baskı). Savaş Yayınevi.

Atay, G., & Acaroğlu, H. (2017). *Rüzgar Enerjisinin Ekonomik Büyümeye Etkisi* (1. Baskı). Yason Yayınları.

Ayanoğlu, G. G. D. (2018). *Yenilenebilir Enerji Yatırımlarında Alternatif Model: Yenilenebilir Enerji Üretim Kooperatifleri* (1. Baskı). Cinius Yayınları.

Aydın, L. (2014). *Enerji Ekonomisi ve Politiaları* (1.Baskı). Seçkin Yayınları.

Bayraç, H. N., Çelikay, F., & Çildir, M. (2018). *Küreselleşme Sürecinde Sürdürülebilir Enerji Kaynakları* (1. Baskı). Ekin Basın Yayın Dağıtım.

Bayramoğlu, T. (2017). Enerji Bağımsızlığı İçin Temiz Kömür Teknolojileri: Türkiye Üzerine Bir Uygulama. *Internatıonal Journal of Economıc Studıes, 3*(2), 149–159. www.ekonomikarastirmalar.org

Bórawski, P., Bełdycka-Bórawska, A., Jankowski, K. J., Dubis, B., & Dunn, J. W. (2020). Development of wind energy market in the European Union. *Renewable Energy, 161*, 691–700. https://doi.org/10.1016/j.renene.2020.07.081

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389. https://doi.org/10.1016/j.egyr.2021.12.006

Döner, İ. (2018). *Yenlenebilir Enerji Kaynakları, Muhasebe, Vergi Uygulamaları, Sektöre Sağlanan Teşvik ve Hibeler* (1. Baskı). Gazi Kitabevi.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision-making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337. https://doi.org/10.1016/j.renene.2021.12.077

Ekonomi Dünya. (2021). *Hedef Sıfır Emisyon*. https://www.ekonomidunya.com/hedef-sifir-emisyon/33014/

Gözler, K., & Kaplan, G. (2018). *İdare Hukukuna Giriş*. Ekin Basın Yayın Dağıtım.

Günday, M. (2017). *İdare Hukuku* (11. Baskı). İmaj Yayınevi.

İlkılıç, C. (2003). Rüzga Enerjisi ve Kullanımı. *Fırat Üniversitesi Doğu Araştırmaları Dergisi2, 2*(1), 44–48.

Kandpal, D., & Dhingra, T. (2021). Migrating to reverse Auction mechanisms in wind energy sector: Status and challenges. *Energy Policy, 156*(April 2021), 112352. https://doi.org/10.1016/j.enpol.2021.112352

Kaygusuz, K. (2010). Wind energy status in renewable electrical energy production in Turkey. *Renewable and Sustainable Energy Reviews, 14*(7), 2104–2112. https://doi.org/10.1016/j.rser.2010.03.022

Kır, A. (2013). *Kamu Hizmetinin Görülme Usullerinden Ruhsat Usulü ve Elektrik Piyasası Örneği* (1. Baskı). Yetkin Yayınları.

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*(December 2021), 118680. https://doi.org/10.1016/j.apenergy.2022.118680

Muhhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy, 187*, 169–176. https://doi.org/10.1016/j.renene.2022.01.061

Oskay, C. (2014). Sürdürülebilir Kalkınma Çerçevesinde Rüzgar Enerjisinin Önemi ve Türkiye'de Rüzgâr Enerjisi Yatırımlarına Yönelik Teşvikler. *Niğde Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 7*(1), 76–94.

Özay, İ. H. (2017). *Günışığında Yönetim*. Filiz Kitabevi.

Özdemir, H. E. (2019). Cumhurbaşkanlığı Kararnamelerinin Hukuki Çerçevesi. *İstanbul Medipol Üniversitesi Hukuk Fakültesi Dergisi, 6*(1), 265–282. http://static.dergipark.org.tr/article-

download/b5c1/f790/c97c/JA46ER74DV/5e626a47ce832_7452471f5885509035ce51c1fb7fa22f.pdf?

Sekin, S. (1999). Rüzga Enerjïsï. *Öneri Dergisi, 2*(12), 113–117. https://doi.org/10.14783/maruoneri.691197

Tan, T. (2020). *İdare Hukuku*. Turhan Kitabevi.

Ulusoy, A. D. (2019). *Yeni İdare Hukuku* (2. Baskı (Ed.)). Yetkin Yayınları.

Vadikkeettil, Y., Subramaniam, Y., Murugan, R., Ananthapadmanabhan, P. V., Mostaghimi, J., Pershin, L., Batiot-Dupeyrat, C., & Kobayashi, Y. (2022). Plasma-assisted decomposition and reforming of greenhouse gases: A review of current status and emerging trends. *Renewable and Sustainable Energy Reviews, 161*(March), 112343. https://doi.org/10.1016/j.rser.2022.112343

Yasin, M. (2018). İdare Hukuku. Içinde T. Yıldırım (Ed.), *Kamu Hizmeti* (7. Baskı, ss. 411–468). Beta Yayınları.

Yayla, Y. (2010). *İdare Hukuku*. Beta Yayınları.

Zabunoğlu, Y. K. (2012). *İdare Hukuku Cilt 1* (1. Baskı). Yetkin Yayınları.

Zhang, Y., Zhang, Y., Gong, C., Dinçer, H., & Yüksel, S. (2022). An integrated hesitant 2-tuple pythagorean fuzzy analysis of QFD-based innovation cost and duration for renewable energy projects. *Energy, 248*, 123561. https://doi.org/10.1016/j.energy.2022.123561

Use of Renewable Energy Resources Within the Scope of Sustainable Energy Management at Airports

Fulya Almaz

Abstract Energy management is of critical importance for airports, whose amount of energy is almost equivalent to the energy consumption rate of a small city. Airports, which directly affect sustainability at social, economic, and environmental levels, are also closely monitored by environmental organizations. In recent years, airports have been taking energy-saving measures to reduce their emission rate and carbon footprint, as well as reducing energy costs, and tending to use renewable energy sources. In this study, it is aimed to discuss the renewable energy sources used in airports in the context of sustainable energy management through application examples. In this context, a deep literature review was made and airports using renewable energy sources were examined. As a result, it has been determined that which renewable energy sources can be used at airports varies according to the type of airport, the characteristics of the geography, and available resources, and many airports use renewable energy sources.

1 Introduction

Airports, which have the potential to create high added value, are areas that directly affect sustainability at social, economic, and environmental levels. Energy consumption is one of the important environmental issues for airports, which have to carry out their activities by almost needing the energy consumed by a small city. This is because activities such as heating, cooling, lighting, and transportation require intense energy consumption in airports, such as passenger terminals, areas where there are no passengers, runways, aircraft hangers, buildings, parking lots, service and transportation networks, and other airport facilities (Baxter et al., 2014; Costa et al., 2012; Kotopouleas & Nikolopoulou, 2016; Ortega Alba & Manana, 2016). Therefore, energy management gains critical importance in order to meet the service

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demands from stakeholders, optimize operational capacities, and provide the necessary comfort at airports (Baxter et al., 2014). Sustainability of energy management programs is a must for airports.

In recent years, airports have been taking energy-saving measures to reduce their emission rate and carbon footprint, as well as reducing energy costs, and tending to use renewable energy sources (Barrett et al., 2015; Baxter et al., 2015; Nam, 2019). Among the renewable energy sources widely used around the world are solar energy, wind energy, geothermal energy, biomass energy, and hydraulic energy (Saavedra et al., 2018).

Which of the renewable energy sources can be used at the airports varies according to the type of the airport, the characteristics of the geography, and the available resources (Radomska et al., 2018). When the relevant literature is examined, it is seen that renewable energy sources are used in many airports around the world. In this study, it is aimed to discuss the renewable energy sources used in airports in the context of sustainable energy management through application examples. In this context, after sustainability, sustainable energy management, energy efficiency, renewable energy resources are explained in detail, renewable energy resources used in airports within the scope of sustainable energy management are presented with examples from the world.

2 Literature Review

2.1 Sustainability and Sustainable Energy Management

Sustainability started to be talked about in the world with the 1987 United Nations World Environment and Development Commission's Report on Our Common Future (Brundtland Report). This concept is defined as the realization of all economic activities, including decision mechanisms and business processes, with environmental and social sensitivity (Torum & Yılmaz, 2009; Wced, 1987). In the said report, sustainability was evaluated within the scope of three basic dimensions: economic sustainability (profitability and efficiency), social sustainability (equality), and environmental sustainability (use of natural resources) (Caradonna, 2014).

In this context, it is aimed to create an environment where people and nature are intertwined by keeping a balance between economic, social, and environmental goals, and to engage in production activities by thinking about future generations (Clayton & Radcliffe, 2018; Gibson et al., 2013). In the report, the necessity of efficient use of natural resources, recycling of resources, reducing waste, and protecting the environment during the production activities are emphasized. Sustainable energy management needs to be activated in order to achieve these goals and transform the highlighted practices into a lifestyle. Energy management is defined as making the necessary planning for an organization to use the energy it needs in the organizational and technical processes at the optimum level while performing its activities (Fiedler & Mircea, 2012).

While sustainable energy management supports the sustainability of organizations, it ensures that energy resources are measurable, traceable, and controllable (Radovanovic et al., 2012; Stritih et al., 2015; Wu & Zhi, 2016). In this context, the following basic principles should be taken into account in order to plan and implement sustainable energy management in organizations (Adıgüzel, 2021; Afgan et al., 1998; Anderson et al., 1999; Jefferson, 2006):

- The principle of preserving existing nonrenewable resources
- The principle of using renewable energy sources
- Energy efficiency principles
- The principle of intergenerational justice
- The principle of harmonization of economic development and energy consumption
- The principle of compensation (caused by excessive and inappropriate use of energy sources)
- The principle of measurability and the need for sustainable strategic management
- Promotion and training principle

2.2 Energy Efficiency and Renewable Energy Resources

In order for organizations to meet the energy they need in a sustainable and environmentally friendly way, they need to focus on energy efficiency and the use of renewable energy sources (Cumo et al., 2012).

Energy efficiency aims to maintain and/or increase product quality with optimum energy use, and to reduce energy consumption independent of production processes, product quality, and energy savings (Almaz, 2021; Wymelenberg, et al., 2013; Çalıkoğlu, 2004; Sandberg & Soderstrom, 2003). Energy efficiency includes efficiency-enhancing measures such as waste recovery, energy recovery, prevention of possible energy losses in steam, gas, air, heat, and electricity production, reducing energy demand, and finding more efficient energy sources (Bayraç, 2010). Efficient energy management, which reduces energy use at the same production level or provides more economic benefits from the same energy input, is directly related to sustainability (Almaz, 2021; Smith & Kelly, 2015; Thollander & Palm, 2013).

Energy, which is defined as an important input in the realization of economic activities, produced, stored, purchased, used in a process, subjected to a certain process, and recovered, has a critical role for economic development and organizational activities (Almaz, 2021). Energy is classified as nonrenewable energy sources or renewable energy sources according to some criteria. Traditional fossil fuels such as coal, oil, and gas, which are expected to run out over time, are nonrenewable energy sources. Renewable energy is defined as alternative energy that reduces dependence on fossil fuels, can be obtained from limited resources, is self-renewable, alleviates the environmental effects of fossil fuels, and increases energy efficiency (Saavedra et al., 2018). Among the renewable energy sources widely used

around the world are solar energy, wind energy, geothermal energy, biomass energy, and hydroelectric energy. Since these renewable energy sources contribute to energy production security, are clean, reduce gas emissions, have economic value, and are sensitive to the environment, they should be included and implemented within the scope of sustainable energy management programs and policies at national and international level (Bayraç, 2010).

Solar energy is defined as the use of sun rays and heat by converting them into energy (Almaz, 2021; Kannan & Vakeesan, 2016; Wee et al., 2012). It arises as a result of the conversion of hydrogen gas in the center of the sun to helium (Acaroğlu, 2013). It has the characteristics of being renewable, convertible to electricity and heat, inexhaustible when used, being the root material of fossil and other renewable energy sources, accessible and cleanest energy source (Azadeh et al., 2008; Riahi Dehkordi et al., 2019; Zoghi et al., 2017).

Electricity can be produced from solar energy by obtaining steam and turbines or solar cells (Kocaman, 2003). Two systems are used for the use of solar energy, namely photovoltaic solar energy systems and concentrated solar energy systems.

Photovoltaic solar energy systems directly absorb solar energy through flat panels and convert it into electrical energy (Mills, 2011). They are preferred systems because they are quiet, do not consist of moving parts, do not produce air pollution and greenhouse gases, can be easily installed in buildings and require very little maintenance (Kandt & Romero, 2014). The performance of this system varies according to its type, direction, and the amount of rays coming from the sun. Therefore, more solar energy reaching the solar panels increases the performance of this system.

Concentrated solar energy systems produce energy by converting sunlight into heat (Özcan, 2013). This system is based on the production of steam by heating water with sunlight. It has three basic features: collecting the sun's rays by reflection or focusing, obtaining electricity by steam power, and storing the heat energy obtained by steam power. Unlike the photovoltaic system, this system has a steam turbine and a heat energy storage tank. Therefore, the installation cost is higher than the photovoltaic system. However, the energy efficiency is higher. Everett (2004) emphasized that the lifetime of solar energy systems is close to fossil fuel systems, but there is no fuel cost in solar energy systems. Therefore, it is a preferred renewable energy source due to the fact that the solar energy source is unlimited, inexhaustible, and the installation cost is low.

Another renewable energy source is *wind energy*. The fact that the sun's rays reach the earth at different angles causes the atmosphere and the earth to heat up at different degrees and create pressure. Air currents are formed by the pressure and the rotation of the earth around its axis, and these air currents create wind energy. Wind energy is a renewable energy source that converts the kinetic energy of the air (wind) into mechanical energy and then into electrical energy (Almaz, 2021; Wee et al., 2012). The conversion of kinetic energy to mechanical energy and then to electrical energy is carried out by wind energy systems, in other words, wind turbines. Wind energy systems are divided into two as horizontal and vertical axis systems according to their rotation axes.

Wind energy has advantages such as being environmentally friendly, low cost, reducing greenhouse gas emissions, long-term use of wind turbines, low maintenance costs of turbines (Bayraç et al., 2018). In addition, they have some disadvantages such as high installation costs, noise pollution, the need for large areas for their installation, variation in energy production depending on the changing wind.

Research has proven that wind energy has the largest use in the world in terms of renewable energy capacity (IEA, 2013). According to IEA data, it is estimated that 18% of the world's electricity needs will be provided by wind energy in 2050.

Geothermal energy is one of the renewable energy sources used to meet the needs such as heating and electricity of thermal energy collected at an accessible depth close to the earth's surface (Almaz, 2021; Jassim, 2013; Wee et al., 2012). It is obtained directly and indirectly by drilling wells in certain parts of the world (Malikoğlu, 2017; Yapraklı, 2013). There is direct use to obtain hot water and use for heating, and indirect use to generate electricity through steam power plants.

Although its usage area is not as common as other renewable energy sources, it is preferred by countries because it provides the opportunity to obtain energy continuously, safely, cheaply, and at low cost (Canik et al., 2000; Karagöl and Kavaz, 2017; Öztürk, 2013). It has advantages such as being a domestic resource for the country it is located, low installation and maintenance costs, short installation time, and not being affected by climate changes. In addition to these, clogging of wells, loss of energy, erosion of some minerals and environmental pollution, and limited usage area constitute the disadvantages of geothermal energy (Eroğlu, 2008).

Biomass energy is obtained from living organisms and organic wastes and converted into solid, liquid, gaseous fuels, and electricity (Almaz, 2021; Khan, 2009; Mafakheri & Nasiri, 2014; Wee et al., 2012). Organic materials such as some fast-growing trees and grasses, algae, and agricultural waste can be converted into biomass energy (Khan, 2009; Mohtasham, 2015). It has positive features such as being the largest renewable energy source in terms of potential, being storable, being able to be used with other energy sources, being clean and harmless, being able to transform into different energy sources, and knowing production techniques (Ladanai & Vinterbäck, 2009). Biomass energy has negative features such as low calorific value, need for water use in production, deterioration in soils, low production, competition in agricultural areas, high labor and transportation costs, some technical problems and political limitations (Saraçoğlu, 2008).

Hydraulic energy is a renewable energy source obtained by converting water energy into electricity (Bahadori et al., 2013; Karagöl and Kavaz, 2017). It is obtained by converting the kinetic energy generated by the power generated by the flowing water (Aydal & Cumalıoğlu, 2011). Depending on where they are installed, hydraulic energy is produced in dams and river power plants. The electrical energy produced in these power plants can be used directly or can be stored. In addition, it has the features of high efficiency, environment-friendly, clean, low maintenance costs, long-term use, and being domestic. Thanks to its cost advantage, it is the most widely used renewable energy source worldwide (Karagöl and Kavaz, 2017). Countries with rough lands and wetlands have an advantage in terms of the use of this energy.

As can be seen, renewable energy has an importance that supports sustainability and reduces the damage to the environment by increasing the diversity of resources in order to meet the energy needs around the world. Despite our high dependence on fossil fuels and the high rate of using them, the use of renewable energy sources is increasing day by day and is supported worldwide. At this point, airports take energy-saving measures and tend to use renewable energy sources in order to meet the increasing energy demand and minimize costs, reduce the emission rate and carbon footprint (Baxter et al., 2015; Nam, 2019).

3 Renewable Energy Resources Used at Airports Within the Scope of Sustainable Energy Management

Airports are one of the main branches of activity in the aviation industry (Torum & Yılmaz, 2009). Airports, which have the potential to create significant added value, are an area that directly affects sustainability at social, economic, and environmental levels. The aviation industry's creation of various service areas in logistics, its integration with other logistics systems, its pioneering and rapid growth in advanced technological applications increase the importance of sustainability in this area. Sustainability is considered as an integral part of routine business processes and corporate social responsibility activities for airports, which are also closely followed by environmental organizations.

At this point, although the sustainability practices of airports are diverse, they should include the following sustainability components:

- Good use of natural resources and protection of the environment
- Addressing the needs and expectations of all stakeholders as a social process
- Monitoring economic growth and employment

In this context, airports are expected to fulfill the following responsibilities:

- Respect people's right to live in a healthy and good environment
- To use and protect natural resources responsibly
- To ensure the protection and continuity of natural resources and biological diversity on earth
- Developing standards to protect the environment, complying with these standards and legal regulations
- To share information about resource use with the public

The issue of energy consumption is one of the important environmental effects of airports. Carrying out operations at airports, passenger terminals, nonpassenger areas, runways, aircraft hangers, buildings, parking lots, service and transportation networks, and other airport facilities, activities such as heating, cooling, lighting, transportation require intense energy consumption (Baxter et al., 2014; Costa et al., 2012; Kotopouleas & Nikolopoulou, 2016; Ortega Alba & Manana, 2016). This

density makes airports one of the energy-consuming centers. Therefore, energy management gains critical importance at airports in order to meet service demands from stakeholders, optimize operational capacities, and provide the necessary comfort (Baxter et al., 2014).

Airports are faced with change and growth in order to respond to the developments in aircraft designs and technology and increasing passenger demands. The increase in energy consumption brought by change and growth for airports necessitates the sustainability of energy management. In this context, the factors that push airports to consider and implement sustainable energy management programs can be summarized as follows (SAGA, 2009):

- Technological developments that facilitate sustainability
- Worldwide awareness and global economy
- Aging infrastructure
- Increasing energy costs
- Environmental legislation
- Conservation of resources
- Financial pressures in the airline industry
- Airport life cycle cost

The most commonly used energy sources at airports are electricity and fuels such as natural gas, petroleum, diesel, and propane (Ortega Alba & Manana, 2016). While electricity is used at airports for the safe continuation of the activities of systems and facilities and air traffic operations; fuels are used to run power plants, boilers, generators, and vehicles. In recent years, airports have been taking energy-saving measures to reduce the emission rate and carbon footprint, as well as reducing energy costs, and tending to use renewable energy sources (Barrett et al., 2015; Baxter et al., 2015; Nam, 2019).

As detailed in the previous title, renewable energy sources that are widely used around the world include solar energy, wind energy, geothermal energy, biomass energy, and hydraulic energy (Saavedra et al., 2018). Which of the renewable energy sources can be used at airports varies according to the type of airport, the characteristics of the geography, and available resources (Radomska et al., 2018). Therefore, in order to use renewable energy at an airport, the following questions must be answered first (Barrett et al., 2016; Li et al., 2018; Yıldız et al., 2020):

1. Are there enough natural resources at the airport?
2. If yes, what is the implementation potential of the project?
3. Is there the necessary infrastructure and capacity to use renewable energy?

When the relevant literature is examined, it is seen that renewable energy sources are used in many airports around the world. Airports can be suitable areas for the establishment of large lands and the capture of natural resources due to their geographical location (Baxter et al., 2018).

Research shows that the most widely used renewable energy source is solar energy. In this context, it is seen that solar energy systems can be easily installed

on the less-used air spaces, building bodies, and parking areas at airports (DeVita & Barrett, 2018; Zomer et al., 2013).

While the use of solar energy systems at airports offers advantages such as minimizing energy costs, reducing carbon footprint and emission rate, it also brings with it some problems (DeVita and Barrett, 2018; Wybo, 2013, Barrett et al., 2013). The fact that solar panels are at low altitudes, causing glare and radar disturbances, even if low, has led to discussion of the suitability of solar energy systems for airports, especially in terms of security. These problems and debates are tried to be overcome by installing solar energy systems on the roofs of buildings and parking lots.

The first airport in the world operated entirely by solar energy is Cochin International Airport in India (Sukumaran & Sudhakar, 2017). All of the energy needs of the airport are met by this photovoltaic solar energy system. In addition, George International Airport in Africa, Copenhagen Airport in Denmark, Adelaide Airport in Australia, Neuhardenberg Airport in Germany, Moshoeshoe International Airport in Lesotho, Kamuzu

International Airport in Malawi, South Incheon International Airport in Korea, Chattanooga Metropolitan Airport in the USA, Lakeland Linder International Airport, Indianapolis International Airport, Denver International Airport, San Diego International Airport, Fresno Yosemite International Airport are examples of airports that meet their energy needs with a photovoltaic solar energy system (Baek et al., 2016; Banda et al., 2019; Barrett et al., 2016; Dağlı & Rodoplu, 2021; Mpholo et al., 2015; Yıldız et al., 2020).

The first airport in Turkey to use photovoltaic solar energy systems is Erzincan Airport (URL 1, n.d.). This airport is at a level that can meet half of the energy needed with the established system. Antalya International Airport (URL 2, n.d.), İzmir Adnan Menderes Airport (URL 3, n.d.), and Milas Bodrum Airport (URL 4, n.d.) are other airports in Turkey that use the photovoltaic solar energy system.

In practice, it has been determined that photovoltaic energy systems are preferred more than concentrated solar energy systems. The reason for this is that the need for hot water at airports is less than the need for electricity and the installation costs of concentrated solar energy systems are higher than photovoltaic energy systems (ICAO, 2017). However, there are usage examples of concentrated solar energy systems at some airports in Minnesota, Geneva, and Toronto and at Vancouver International Airport (Yıldız et al., 2020).

It is known that there are airports that use wind energy in practice. Airports can meet some of their energy needs from vertical axis wind turbines installed on the roofs of buildings and large-scale wind turbines installed on the floors. However, there is a limitation for the heights of these turbines (Rowlings, 2016). Wind turbines installed at airports and especially close to runways cause turbulence and radar confusion, threatening flight safety. Therefore, wind energy can be used at airports within certain limitations. East Midlands International Airport in England and Burlington International Airport in the USA can be given as examples of airports using wind energy (Barrett et al., 2015; Yıldız et al., 2020).

The use of geothermal energy at airports depends on the geological structure of the area where the airport is built (Rowlings & Walker, 2008). Because the production of geothermal energy requires the existence of thermal energy collected at an accessible depth close to the earth's surface (Almaz, 2021; Jassim, 2013; Wee et al., 2012). Although the underground energy source is suitable for airports, the installation and use of these systems are not practical (Rowlings & Walker, 2008; Yıldız et al., 2020). Juneau International Airport and Portland International Airport in the USA meet some of their energy needs with geothermal energy (Yıldız et al., 2020).

Another renewable energy source that can be used at airports is biomass energy (ICAO, 2017; Ünlü & Hilmioğlu, 2018). Energy can be obtained by growing products that can be a source of biomass energy at airports and by converting various wastes. This energy can be used in various fields, especially in air conditioning. Heathrow International Airport in England and Grant County International Airport in the USA are airports that use biomass energy (Barrett et al., 2015; Yıldız et al., 2020).

The use of hydraulic energy as a renewable energy source at airports is limited to the presence of a running water source close to the airport (ICAO, 2017). It is seen that this practice, which is not practical in practice, is used in some Asian airports (Rowlings & Walker, 2008; Yıldız et al., 2020).

4 Conclusion and Discussion

In this study, it is aimed to discuss the renewable energy sources used in airports in the context of sustainable energy management through application examples. In this context, after sustainability, sustainable energy management, energy efficiency, renewable energy resources are explained in detail, renewable energy resources used in airports within the scope of sustainable energy management are presented with examples from the world.

When the relevant literature is examined, it is seen that renewable energy sources are used in many airports around the world. Within the scope of the research, it has been determined that the most widely used renewable energy source is solar energy. In this context, it is seen that solar energy systems can be easily installed on the less-used air spaces, building bodies, and parking areas at airports (DeVita & Barrett, 2018; Zomer et al., 2013). In the scope of the study, although the issues such as the low altitudes of the solar panels, the glare, and the low level of radar confusion are discussed, it has been determined that these problems can be overcome. In addition to solar energy, it has been determined that wind energy, geothermal energy, biomass energy, and hydraulic energy are used as renewable energy sources at airports. It is seen that which renewable energy sources can be used at airports varies according to the type of airport, the characteristics of the geography, and available resources (Radomska et al., 2018).

It is necessary to ensure sustainable energy use by diversifying energy sources for the whole world. It is extremely important to minimize the damage to the

environment while fulfilling these requirements. In this context, the use of renewable energy sources gains importance. The fact that airports, which have a consumption equivalent to the energy consumption of a small city, turn to renewable energy sources within the scope of sustainable energy management will reduce their energy costs, and sustainability will be ensured in the protection of the natural environment by reducing emission rates and reducing carbon footprints.

References

Acaroğlu, M. (2013). *Alternatif Enerji Kaynakları*. Nobel Yayınları.

Adıgüzel, Z. (2021). Strategic and management thinking: An examining of sustainable energy management. In S. Yüksel & H. Dinçer (Eds.), *Strategic Approaches to Energy Management*. Springer International Publishing.

Afgan, N. H., Gobaisi, A. D., Carvalho, M. G., & Cumo, M. (1998). Sustainable energy development. *Renewable and Sustainable Energy Reviews, 2*(3), 235–286.

Almaz, F. (2021). Energy-oriented management approach as a market activity tool in achieving competitive advantage. In S. Yüksel & H. Dinçer (Eds.), *Strategic Approaches to Energy Management*. Springer International Publishing.

Anderson, T., Doig, A., Rees, D., & Khennas, S. (1999). *Rural energy services: A handbook for Sustainable Energy Development*. Intermediate Technology Publications Ltd (ITP)..

Aydal, D., & Cumalıoğlu, Y. (2011). *Enerjiye Açılan Karanlık Kapılar*. Destek Yayınevi.

Azadeh, A., Ghaderi, S. F., & Maghsoudi, A. (2008). Location optimization of solar plants by an integrated hierarchical DEA PCA approach. *Energy Policy, 36*(10), 3993–4004.

Baek, S., Kim, H., & Chang, H. Y. (2016). Optimal hybrid renewable airport power system: Empirical study on Incheon International Airport, South Korea. *Sustainability, 8*, 1–13.

Bahadori, A., Zahedi, G., & Zendehboudi, S. (2013). An overview of Australia's hydropower energy: Status and future prospects. *Renewable and Sustainable Energy Reviews, 20*, 565–569.

Banda, M. H., Nyeinga, K., & Okello, D. (2019). Performance evaluation of 830 kWp grid-connected photovoltaic power plant at Kamuzu International Airport-Malawi. *Energy for Sustainable Development, 51*, 50–55.

Barrett, S. B., De Vita, P. M., & Miller, R. L. (2013). *Review of solar energy system projects on federally obligated airports*. Federal Aviation Administration.

Barrett, S. B., DeVita, P. M., Kenfield, J., Jacobsen, B. T., & Bannard, D. Y. (2016). *Developing a Business Case for Renewable Energy at Airports*. Airport Cooperative Research Program.

Barrett, S. B., DeVita, P. M., Whiteman, A., Bannard, D., Smalinsky, T., Korovesi, I., Plante, J. & DeVault, T. (2015). Renewable Energy as an Airport Revenue Source (No. Project 01-24).

Baxter, G., Sabatini, R., & Wild, G. (2015). Sustainable airport energy management: A case study of copenhagen airport. In *Proceedings of the International Symposium on Sustainable Aviation, Istanbul, Turkey*, 31.

Baxter, G., Srisaeng, P., & Wild, G. (2018). Sustainable airport energy management: The case of Kansai International Airport. *International Journal for Traffic & Transport Engineering, 8*(3). https://doi.org/10.7708/ijtte.2018.8(3).07

Baxter, G., Wild, G., & Sabatini, R. (2014, November). A sustainable approach to airport design and operations: Case study of Munich Airport. In *PRCC 2014 Engineers Australia Convention* (pp. 227–237).

Bayraç, H. (2010). Enerji Kullanımının Küresel Isınmaya Etkisi ve Önleyici Politikalar. *Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi, 11*(2), 229–259.

Bayraç, N., Çelikay, F., & Çıldır, M. (2018). *Küreselleşme Sürecinde Sürdürülebilir Enerji Politikaları*. Ekin Yayınevi.

Çalıkoğlu, E. (2004). *Enerji Verimliliği ve EİEİ Tarafından Yürütülen Çalışmalar, 23*. Ulusal Enerji Verimliliği Kongresi.

Canik, B., Çelik, M., & Arıgün, Z. (2000). Jeotermal Enerji, Ankara Üniversitesi Fen Fakültesi Döner Sermaye İşletmesi Yayınları.

Caradonna, J. L. (2014). *Sustainability: A history*. Oxford University Press.

Clayton, T., & Radcliffe, N. (2018). *Sustainability: A systems approach*. Routledge.

Costa, A. Blanes, L. M. Donnelly, C., & Keane, M. M. (2012). Review of EU Airport Energy Interests and Priorities with Respect to ICT Energy Efficiency and Enhanced Building Operation, 12th International Conference for Enhanced Building Operations, Manchester, UK.

Cumo, F., Garcia, D. A., Calcagnini, L., Rosa, F., & Sferra, A. S. (2012). Urban policies and sustainable energy management. *Sustainable Cities and Society, 4*, 29–34.

Dağlı, D., & Rodoplu, H. (2021). Havalimanlarında Sürdürülebilir Enerji Yönetimi Kapsamında Güneş Enerjisininin Kullanımı, International Marmara Social Sciences Congress Proceedings Book.

DeVita, P., & Barrett, S. (2018). Eugene airport solar feasibility study. Burlington, ABD: HMMH, Report No: 308220.

Eroğlu, V. (2008). Ülkemizde Termal Maden Suları, Kaynakları ve Kullanımı. Termal ve Maden Suları Konferansı Bildiriler Kitabı, Afyon Kocatepe Üniversitesi Yayınları.

Everett, B. (2004). Solar thermal energy. In D. Boyle (Ed.), *Renewable energy*. İngiltere.

Fiedler, T. & Mircea, P. M. (2012). *Energy Management Systems According to the ISO 50001 Standard Challenges and Benefits*. Paper Presented at the International Conference on Applied and Theoretical Electricity (ICATE), Craiova, Romania.

Gibson, B., Hassan, S., & Tansey, J. (2013). *Sustainability assessment: Criteria and processes*. Routledge.

ICAO. (2017). *A focus on the production of renewable energy at the airport site*. International Civil Aviation Organization.

International Energy Agency (IEA). (2013). Technology Roadmap: Wind Energy-2013 Edition, https://www.iea.org/publications/freepublications/publication/Wind_2013_Roadmap. (10.05.2022).

Jassim, H. (2013). Geothermal energy and possibility use it in Iraq. *The Islamic College University Journal, 8*(25), 193–213.

Jefferson, M. (2006). Sustainable energy development: Performance and prospects. *Renewable Energy, 31*(5), 571–582.

Kandt, A., & Romero, R. (2014). Implementing Solar Technologies at Airports (No. NREL/TP-7A40-62349). National Renewable Energy Lab. (NREL), Golden, CO (United States).

Kannan, N., & Vakeesan, D. (2016). Solar energy for future world: A review. *Renewable and Sustainable Energy Reviews, 62*, 1092–1105.

Karagöl & Kavaz. (2017). Dünyada ve Türkiye'de Yenilenebilir Enerji Kaynakları, (Raport No: 197), SETA, İstanbul.

Khan, A. (2009). Potential to use biomass for bio-energy in Ontario. *Guelph Engineering Journal, 2*, 39–44.

Kocaman, B. (2003). *Elektrik Enerjisi Üretim Santralleri*. Birsen Yayınevi.

Kotopouleas, A., & Nikolopoulou, M. (2016). Thermal comfort conditions in airport terminals: Indoor or transition spaces? *Building and Environment, 99*, 184–199.

Ladanai, S., & Vinterbäck, J. (2009). Global Potential of Sustainable Biomass for Energy.

Li, B. Zhang, W. Xu, J. & Wang, J. (2018). Research on Solar Photovoltaic Power Generation in the Airfield Area at Civil Airports. In *3rd International Conference on Electromechanical Control Technology and Transportation*, Chongqing, China.

Mafakheri, F., & Nasiri, F. (2014). Modeling of biomass-to-energy supply chain operations: Applications, challenges and research directions. *Energy Policy, 67*, 116–126.

Malikoğlu, M. (2017). Geothermal energy in Turkey and around the world: A review of the literature and an analysis based on Turkey's Vision 2023 energy targets. *Renewable and Sustainable Energy Reviews, 76*, 485–492.

Mills, R. (2011). *Airport Solar and Geothermal Power*.

Mohtasham, J. (2015). Review article-renewable energies. *Energy Procedia, 74*(2015), 1289–1297.

Mpholo, M., Nchaba, T., & Monese, M. (2015). Yield and performance analysis of the first grid-connected solar farm at Moshoeshoe I International Airport, Lesotho. *Renewable Energy, 81*, 845–852.

Nam, V. H. (2019). Green sustainable airports: The deployment of renewable energy at vietnam airports. is that feasible? *Journal of Mechanical Engineering Research and Developments., 42*, 61–65.

Ortega Alba, S., & Manana, M. (2016). Energy research in airports: A review. *Energies, 9*(5), 349.

Özcan, E. (2013). Dünyada ve Türkiye'de Güneş Enerjisi, TÜBİTAK Bilim ve Teknik Dergisi.

Öztürk, H. (2013). *Yenilenebilir Enerji Kaynakları*. Birsen Yayınevi.

Radomska, M., Chernyak, L., & Samsoniuk, O. (2018). The improvement of energy-saving performance at Ukrainian Airports. In *Advances in sustainable aviation* (pp. 189–203). Springer.

Radovanovic, M., Popov, S., & Dodic, S. (2012). *Sustainable energy management: Planning, implementation, control and strategy*. Academic Press.

Riahi Dehkordi, E., Karimi, A., Karimi, R., & Aslan Beygi, M. (2019). Sustainable design for airport terminals, by integrated photovoltaic (PV) system (Adopting Bench-Marking Approach). *International Journal of Green Energy, 16*(15), 1611–1616.

Rowlings, A. (2016). *Sustainable Energy Options for the Future Airport Metropolis*. Science and Engineering Faculty Queensland University of Technology, Master Thesis.

Rowlings, A. & Walker, A. (2008). Sustainable Energy Options for the Future Airport Metropolis, 4th International Conference on Energy, Environment, Ecosystems and Sustainable Development, Algarve, Portugal.

Saavedra, M. R., Fontes, C. H., & Freires, G. M. (2018). Sustainable and renewable energy supply chain: A system dynamics overview. *Renewable and Sustainable Energy Reviews, 82*, 247–259.

SAGA. (2009). Planning, Implementing and Maintaining a Sustainability Program at Airports. Sustainable Aviation Guidance Alliance.

Sandberg, P., & Soderstrom, M. (2003). Industrial energy eficiency: The need for investment decision support from a manager perspective. *Energy Policy, 31*(15), 1623–1634.

Saraçoğlu, N. (2008). Biyokütleden Enerji Üretiminde Enerji Ormancılığının Önemi. VII. Ulusal Temiz Enerji Sempozyumu Kitabı, İstanbul, (pp. 265–271).

Smith, C. B., & Kelly, E. P. (2015). *Energy management principles: Applications, benefits, savings* (2nd ed., p. 430). Elsevier.

Stritih, U., Paksoy, H., Turgut, B., Osterman, E., Evliya, H., & Butala, V. (2015). Sustainable energy management. *Management of Environmental Quality: An International Journal., 26*(5), 764–790.

Sukumaran, S., & Sudhakar, K. (2017). Fully solar-powered airport: A case study of cochin international airport. *Journal of Air Transport Management, 62*, 176–188.

Thollander, P., & Palm, J. (2013). Improving energy efficiency in industrial energy systems. In *An interdisciplinary perspective on barriers, energy audits, energy management, policies and programs*. Springer.

Torum, O., & Yılmaz, A. K. (2009). Havacılıkta Sürdürülebilirlik Yönetimi: Türkiye'deki Hava Limanları İçin Sürdürülebilirlik Uygulamaları Araştırması. *Journal of Aeronautics and Space Technologies, 4*(2), 47–58.

Ünlü, D., & Hilmioğlu, N. D. (2018). Review of renewable biofuels in the aviation sector. In *Advances in sustainable aviation* (pp. 25–39). Springer.

URL 1.: https://www.enerjigunlugu.net/erzincan-havalimani-ges-uretime-gecti-35679h.htm, (10.05.2022). (n.d.)

URL 2.: https://www.enerjigunlugu.net/antalya-havalimani-gunes-santrali-devrede-6963h.htm, (10.05.2022). (n.d.)
URL 3.: https://adnanmenderesairport.com/tr-TR/basin-odasi/basin-bultenleri/page/izmir-adnan-menderes-abdde-ornek-gosterildi, (10.05.2022). (n.d.)
URL 4.: https://www.solar.ist/gtcnin-cift-yuzlu-bifacial-gunes-panelleri-milas-bodrum-havalimaninda-kullaniliyor/, (10.05.2022). (n.d.)
Wced, S. W. S. (1987). World commission on environment and development. *Our Common Future, 17*(1), 1–91.
Wee, H. M., Yang, W. H., Chou, C. W., & Padilan, M. V. (2012). Renewable energy supply chains, performance, application barriers, and strategies for further development. *Renewable and Sustainable Energy Reviews, 16*(8), 5451–5465.
Wu, X., & Zhi, Q. (2016). Impact of shared economy on urban sustainability: From the perspective of social, economic, and environmental sustainability. *Energy Procedia, 104*, 191–196.
Wybo, J. (2013). Large-scale photovoltaic systems in airports areas: Safety concerns. *Renewable and Sustainable Energy Reviews, 21*, 402–410.
Wymelenberg, K., Brown, G. Z., Burpee, H., Djunaedy, E., Gladics, G., Kline, J., Loveland, J., Meek, C., & Thimmanna, H. (2013). Evaluating direct energy savings and market transformation effects: A decade of technical design assistance in the northwestern USA. *Energy Policy, 52*, 342–353.
Yapraklı, S. (2013). Enerjiye Dayalı Büyüme, Türk Sanayi Sektörü Üzerine Uygulamalar, İstanbul: Beta Yayınları.
Yıldız, Ö. F., Yılmaz, M., Çelik, A., & Edip, İ. M. İ. K. (2020). Havalimanlarında Yenilenebilir Enerji Kaynaklarının Kullanılması. *Journal of Aviation, 4*(1), 162–174.
Zoghi, M., Ehsani, A. H., Sadat, M., Javad Amiri, M., & Karimi, S. (2017). Optimization solar site selection by fuzzy logic model and weighted linear combination method in arid and semi-arid region: A case study Isfahan-IRAN. *Renewable and Sustainable Energy Reviews, 68*, 986–996.
Zomer, C. D., Costa, M. R., Nobre, A., & Rüther, R. (2013). Performance compromises of building-integrated and building-applied photovoltaics (BIPV and BAPV) in Brazilian Airports. *Energy and Buildings, 66*, 607–615.

Social Reflections of Renewable Energy: Wind Energy in Turkey

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Abstract The Renewable energy consumption is promoted nationally by various organizations and countries due to its environmentally friendly feature within the measures taken against the global climate crisis. Wind energy, which is one of the clean energy sources, can provide important environmental, economic, and social contributions. Wind power plants, which have been increased in Turkey, are causing social change within environmentalist views, thanks to the benefits. Social views on environmentalism can characterized as a driving force for development by forming the social footing for the spread of renewable energy. Thus, public consciousness is seen as with cause and effect. The environmental awareness of individuals living in Çanakkale city, where Çanakkale Wind Power Plant, one of the wind power plants producing the largest amount of electricity in Turkey, is located. The study was carried out with 591 participants by a survey method in Çanakkale. According to the results of the research, the education variable is the most important factor in environmental awareness. The place of residence of individuals is both the cause and the result of education.

1 Introduction

While the transition from fossil fuels to renewable energy production reduces the country's external dependence in economic terms, it has important advantages with regard to preventing the climate crisis and being environmentally friendly. Thus, some diseases have emerged asthma, cancer, and lung problems of people living in settlements near thermal power plants due to poor air quality. The diseases are expected to reduce thanks to renewable energy. Lungs and respiratory systems have become much more critical importance because of Covid-19 virus globally.

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Therefore, the transition and expansion of clean energy are issues that should be supported by the public as well as the management authorities and organizations.

The International Energy Agency (IEA) suggested a plan that foresees increasing the resilience of economic growth and energy systems during and after the Covid-19 period within sustainability reports (IEA, 2020). According to the report, accelerated deployment of wind energy is one of the necessary steps for sustainable electricity. Because, considering the large number of jobs that can be created by short construction times and decreasing costs, it is expressed as one of the energy technologies that most merit government support in many countries. According to another study, it has been found that Turkey is the fourth country with the newest wind investments among European countries. The top three countries are listed as the UK, Sweden, and Germany, respectively. In terms of foreign investments, the United Kingdom takes the first place, followed by Denmark. Turkey has carried out all its installations domestically. However, developing investors and equipment production have been paved the way for offshore installations in the future (Wind Europe, 2021a, 2021b).

According to the data of the sectoral research on the wind energy industry (Wind Europe, 2020), the largest wind turbine equipment manufacturers are listed by the number of facilities. According to the data, Germany is the first in the ranking, Turkey is fifth with the number of 12 wind turbine equipment production facilities.

Turkey has taken remarkable actions in wind energy, especially in the last 10 years, and reached a total wind energy capacity of 10 GW on last September (Wind Europe, 2021a, 2021b). The energy production has been increased 10 times in 10 years. The investments in onshore wind energy have been continued. But also, it is necessary to draw attention to the social effects of renewable energy.

2 The Wind Energy in Turkey

Besides Turkey having had wind energy facilities since 1998, the number of facilities and energy production capacity have gained significant acceleration in the last 10 years. The number of wind power plants concentrated in the Aegean Region have reached 272 today with government incentives and private sector investments (Turkish Wind Energy Association, n.d.).

Turkish Wind Energy Association has published the installation table of the power plants by years (TUREB, 2021a, 2021b). When the data for the last 19 years are examined cumulatively, 10 MW of electricity has been produced with the installation of wind power plants. Since the first installation, there were not carried out any installation in 1999, 2001, 2002, 2004, and 2005, but installations have increased regularly in the following years. Therefore, renewable energy production gained noteworthy speed from 2006 to 2021. Although the developments, Turkey's wind energy potential is promising for much more.

The wind energy potential table has been reached through the data published by the Ministry of Energy and Natural Resources of the Republic of Turkey (T.C. Kalkınma Bakanlığı, 2018). It is seen that Turkey has not yet utilized full

capacity of its wind potential while its growth and efficiency breakthroughs in wind energy are blossom forth regarding the table. However, the issue of energy supply security, which is one of the indispensable requirements of the energy strategy, is given priority in addition to production. The energy supply security is a strategic plan that takes place in economic, financial, and political areas (Hughes & Shupe, 2010) consisting of usability, reliability, affordability, and environmental components (Gürson et al., 2014). The Energy Supply Security and Efficiency Report was presented within the framework of the eleventh Development Plan of Turkey as paradigm of the energy sector (T.C. Kalkınma Bakanlığı, 2018).

3 Social Awareness

Social awareness constitutes the social basis of renewable energy. Public opinion is necessary to support economical and sustainable energy production and use, which is not harmful to the environment, nature, and living ecosystem. Therefore, changes in environmental awareness are required not only through states and companies but also individual basis.

In accordance with the social reflections on renewable energy in society, which is the focus of this research, the views of individuals on environmentally friendly and sustainable energy transformations are examined. Three different stages under the title of social consciousness are listed as trust, acceptance, and support. These stages are explained as follows.

Trust: The concept of trust arises from the need for safety. This concept, which is often associated with "knowing", is described as contingency (Chiles & Mcmackin, 1996; Rousseau et al., 1998). On the other hand, contingency refers to the risk of loss and the dependence of both parties on each other for gain. Thus, trust in environmental energy generation transformations is shaped by gain and risk.

Whether the concept of trust is in question due to gain or risk of loss, "knowing" is important. Societies that are informed about effects of the renewable energy can complete the trust stage and so the first of the social awareness phase.

Actions on the concept of trust are taken and reported by official authorities. For instance, it is stated under the title of Problems Caused by Public Relations, that the benefits and costs of energy investments are not adequately explained to the local people, in the Development Plan Report of the Government of the Republic of Turkey (T.C. Kalkınma Bakanlığı, 2018).

Acceptance: Social acceptance is described as nontechnical obstacle of the renewable energy implementations (Wüstenhagen et al., 2007) and it explained in three different dimensions. It can be listed as socio-political acceptance, community acceptance, market acceptance. Socio-political acceptance is based on the adoption of technological and political commitments and steps by politicians and sectoral stakeholders. Community acceptance refers to public and local stakeholder acceptance of all renewable energy organizational processes. It is important to have a

trustworthy and fair process for social acceptance. Market acceptance implies consumer acceptance.

Community acceptance is related to the consent of the local people living in the area where renewable energy plans to build. The concept requires people's trust in the information and intention of the investors, whom they considered foreigners (Huijts et al., 2007; Wüstenhagen et al., 2007). Thus, the importance of the concept of trust, which was mentioned in the first stage, is emphasized.

Support: Giving support requires an intellectual effort, like the other two stages, along with taking action and making sacrifices. Since it is impossible to acting without strong behavioral triggers. For example, the syndrome referred to as "not in my backyard" in the literature is associated with support. The NIMBY syndrome implies residents' opposition to conflict with their self-interest, even though they accept the change in their area (Wexler, 1996). However, labeling everyone who does not support or resists renewable energy plans with the syndrome can detract from understanding and analyzing the cause of obstacles (Wolsink, 2000).

The causes of resistance can be revealed and resolved through research such as interviews and surveys to be carried out on people who do not have sufficient motivation for support. Therefore, researchers, politicians, and investors need to work together. Social transformation becomes possible in individuals and societies that meet all the stages of trust, acceptance, and support. Although these steps of social transformation sometimes take place as an output after the energy transformation, sometimes they take place before the energy transformation, and play a leading role in the transition to clean energy.

4 Research Method

Survey research, which is one of the quantitative research methods, was used in the study. The online survey method was used to reach more participants quickly. Participants are living in Çanakkale, one of the provinces where the most renewable energy is produced in Turkey. Snowball sampling method was chosen to reach the participants. The more participants than the minimum sample size were included in the study to represent the universe. The minimum sample size is 384, according to the 95% confidence level of the population of 1 million people. About 591 people participated in the study. The generalizability of the study, which was carried out with more participants than the minimum sample size, was ensured. In addition to demographic questions, two scales were used in the study. The first of the scales is "Environmental Perception Scale: A Study of Reliability and Validity" developed by Mürşet Çakmak (2020), and the other scale is "Renewable Energy Perception Scale: Reliability" developed by Hilal Yakut İpekoğlu, İbrahim Üçgül, and Gamze Yakut and Validity scales were used. The scale developed by Çakmak (2020) consists of seven subtitles and 32 questions. These subheadings are; Perception of Environment Overview (PEO, eight questions), Environment Education Perception (EEP, seven questions), Environment Protection Perception (EPP, four questions), Environment

Issues Perception (EIP, four questions), Environment Awareness Responsibility Perception (EARP, three questions), Problems of Sensory Perception (EPSP, three questions), and Environment-Friendly Activities Perception (EFAP, three questions). The scale developed by Yakut İpekoğlu et al. (2014) consists of two subtitles and 16 questions. These subheadings are Technical Knowledge (11 questions) and Renewable Energy-Environment Relations (five questions). The 5-point Likert method was used in the study. The Cronbach Alpha reliability coefficient of the Environmental Perception Scale, which is developed by Çakmak (2020), is 0.93. The Cronbach Alpha reliability coefficient of Renewable Energy Perception Scale, which is developed by Yakut İpekoğlu et al. (2014), is 0.82. The Cronbach Alpha reliability coefficient of the scale of 48 questions and nine subtitles, formed from the combination of two scales, is 0.934. In short, the figures are similar to the level of reliability in both scales. Ethics permissions were obtained from the people who developed the scale. Before conducting the research, a pilot study consisting of five people was conducted to eliminate the obstacles arising from translation errors, since one of the scales was in a foreign language. Persons in the pilot study were not included in the population of the research.

About 591 people, 346 women and 245 men, participated in the study. While the percentage of women is 58.5%, the percentage of men is 41.5%. Therefore, it is not a homogeneous group on the gender variable. The most important variable in the study is the residence region of the participants. When examining where the participants live in the Çanakkale; 311 participants live in the city center of the Çanakkale, and 280 participants live in districts far from the city center. The percentage of participants living in the center of the Çanakkale city is 52.7, and the percentage of participants residing in districts is 47.3%. According to the findings of the research, when the education variable is examined, 317 participants' educational backgrounds are an associate degree or higher. The percentage of the participants in this group is 53.7%. The number of participants who graduated from primary, secondary, and high school equivalents are 274. The percentage of individuals in the primary, secondary, and high school groups is 46.3% (Table 1).

The Convergent Validity Fornell-Larcker (Fornell & Larcker, 1981) criterion is widely used to evaluate the degree of shared variance among the latent variables of the model. According to this criterion, the convergent validity of the measurement model can be evaluated by the Average Value of Variance (AVE) and the Composite Reliability (CR). The AVE measures the value due to measurement error versus the level of variance captured by a construct, values above 0.7 are considered very good, while a level of 0.5 is acceptable. CR is a less-biased estimate of reliability than Cronbach's Alpha, with an acceptable value of 0.7 and above.

It was investigated whether there is a 0.05 significance ratio difference between the opinions of the participants in the study living in the Çanakkale city center and living in the districts of the Çanakkale on the Renewable Energy Information Scale (Technical Data (TD), Renewable Energy-Environment Relationship (RE-ER)). Within the scope of the study, there are a total of 591 participants, 311 living in the city center of the Çanakkale and 280 living in the districts of the city center of the Çanakkale. Within the scope of the research, the difference in the two subtitles

Table 1 Information related to the scale

		KMO	AVE	CR	Item	Cronbach Alfa
Renewable energy information scale	TD	0.884	0.532	0.743	11	0.877
	RE-ER	0.894	0.486	0.698	5	0.815
Environmental perception scale	PEO	0.817	0.471	0.623	8	0.792
	EEP	0.847	0.517	0.703	7	0.829
	EPP	0.728	0.520	0.707	4	0.831
	EIP	0.809	0.520	0.708	4	0.832
	EARP	0.891	0.618	0.819	3	0.933
	EPSP	0.894	0.610	0.809	3	0.914
	EFAP	0.637	0.452	0.602	3	0.710

TD technical data, *RE-ER* renewable energy-environment relationship, *PEO,* perception of environment overview, *EEP* environment education perception, *EPP* environment protection perception, *EIP* environment issues perception, *EARP* environment awareness responsibility perception, *EPSP* problems of sensory perception, *EFAP* environment-friendly activities perception

(Technical Data (TD), Renewable Energy-Environment Relationship (RE-ER)) and the variable of residence in the Çanakkale in the renewable energy information scale were examined.

Environmental Perception Scale (Perception of Environment Overview (PEO), Environment Education Perception (EEP), Environment Protection Perception (EPP), Environment Issues Perception (EIP), Environment Awareness Responsibility Perception (EARP)), Problems of Sensory Perception (EPSP), Environment-Friendly Activities Perception (EFAP) were investigated whether there is a difference of 0.05 significance level. Within the scope of the study, 591 participants, 311 living in the city center of the Çanakkale and 280 living in the districts of the city center of the Çanakkale, took part in survey. There are two subtitles (Perception of Environment Overview (PEO), Environment Education Perception (EEP), Environment Protection Perception (EPP), Environment Issues Perception (EIP), Environment Awareness Responsibility Perception (EARP), Problems) in the renewable energy information scale. It was investigated whether there was a difference between the variables of Sensory Perception (EPSP), Environment-Friendly Activities Perception (EFAP), and residence in the Çanakkale.

According to the Independent *T*-test results, there is a significant difference between the opinions of the participants about the Technical Data ($t(591) = -9.421$; $p < 0.05$) living in the city center of the Çanakkale and living in the districts of the city center of the Çanakkale. However, there is no significant difference between the participants' opinions about Renewable Energy-Environment Relationship ($t(591) = 0.225$; $p > 0.05$) living in the Çanakkale city center and living in their districts of the Çanakkale city center. The average of the opinions on Technical Data of the participants living in the city center of the Çanakkale (Mean = 4.26; Std. Deviation = 0.74) was higher than the average of the opinions on the Technical Data (Mean = 4.01; Std. Deviation = 0.61) of the

participants living in their districts of the Çanakkale. This result shows that the participants living in the center of the Çanakkale have significantly more views on Technical Data than the participants living in the districts of the Çanakkale.

According to the Independent *T*-test results, there is no significant difference between the opinions of the participants who are living in the center of the Çanakkale and living in distant districts of Çanakkale about Environment Awareness Responsibility Perception (EARP) ($t(591) = 0.119$; $p > 0.05$), and Problems of Sensory Perception (EPSP) ($t(591) = 0.117$; $p > 0.05$). However, there is a significant difference between the opinions of the participants who are living in the center of the Çanakkale and living in distant districts of Çanakkale about Perception of Environment Overview (PEO) ($t(591) = -6.4728$; $p < 0.05$), Environment Education Perception (EEP) ($t(591) = -7.519$; $p < 0.05$), Environment Protection Perception (EPP) ($t(591) = -8.764$; $p < 0.05$), Environment Issues Perception (EIP) ($t(591) = -8.857$; $p < 0.05$), and Environment-Friendly Activities Perception (EFAP) ($t(591) = -9.125$; $p < 0.05$).

The average of the Perception of Environment Overview (Mean = 4.10; Std. Deviation = 0.61) of the participants living in the center of the Çanakkale was lower than the average of the participants living in the districts of the Çanakkale about Perception of Environment Overview (Mean = 4.48; Std. Deviation = 0.86). This result shows that the participants living in the center of the Çanakkale have a significantly more opinion Perception of Environment Overview than the participants living in the districts of the Çanakkale. The average of the opinions on Environment Education Perception of the participants living in the center of the Çanakkale (Mean = 3.91; Std. Deviation = 0.53) was lower than the average of the opinions of the participants living in the districts far from the city center on Environment Education Perception (Mean = 3.95; Std. Deviation = 0.87). This result shows that the participants living in the center of Çanakkale have significantly more opinions on Environment Education Perception than the participants living in the districts far from the city center. The average of the opinions on Environment Protection Perception of the participants living in the center of the Çanakkale (Mean = 3.39; Std. Deviation = 0.76) was lower than the average of the opinions of the participants living in the districts far from the city center on Environment Protection Perception (Mean = 4.45; Std. Deviation = 0.83). The result shows the participants living in the center of Çanakkale have significantly more opinions on Environment Protection Perception than the participants living in the districts outside of the Çanakkale. The average of the opinions on Environment Issues Perception of the participants living in the center of the Çanakkale (Mean = 4.41; Std. Deviation = 0.78) was more than the average of the opinions of the participants living in the districts far from the Çanakkale city center on Environment Issues Perception (Mean = 4.36; Std. Deviation = 0.67). This result shows that the participants living in the center of the Çanakkale have significantly more views on Environment Issues Perception than the participants living in the districts far from the city center, average of the views on Environment-Friendly Activities Perception of the participants living in the Çanakkale center (Mean = 4.36; Std. Deviation = 0.61) is lower than the average of the opinions of the participants living in

the districts far from the city center on Environment-Friendly Activities Perception (Mean = 4.55; Std. Deviation = 0.93). This result shows that the participants living in the center of the Çanakkale have a significantly higher opinion of Environment-Friendly Activities Perception than the participants living in the districts of the Çanakkale.

The opinions of the participants in the research on the Renewable Energy Information (Technical Data (TD), Renewable Energy-Environment Relationship (RE-ER)) scale were examined according to their educational status, whether there was a difference at a significant rate of 0.05. About 591 individuals participated in the study. Within the scope of the study, it was investigated whether there was a difference between the two subtitles (Technical Data (TD), Renewable Energy-Environment Relationship (RE-ER)) in the Renewable Energy Information scale and the education status variable.

According to the results of the Anova test, there is a significant difference between the opinions of the individuals on the Renewable Energy Information Scale and education (Technical data ($F(6,283) = 8{,}743$, $p < 0.05$) and Renewable Energy-Environment Relationship ($F(6,283) = 9{,}164$, $p < 0.05$)). According to the results of the Tukey test, which reveal which groups have a significant difference between the opinions of the participants on the Renewable Energy Information Scale (Technical Data (TD), Renewable Energy-Environment Relationship (RE-ER)) and education, there is no significant difference between the views of the education groups on the technical data under the Renewable Energy Perception Scale subtitle; Primary school (Avg. 4.14; S.S. = 0.77), secondary school (Avg. 4.38; S.S. = 0.83), high school (Avg. 4.65; S.S. = 0.56), associate degree (Avg. 4.87; S.S. = 0.92). However, the opinions of the individuals in the undergraduate, graduate, and doctoral groups (Avg. 4.19; P.S. = 0.73), (Avg. 4.63; P.S. = 0.64), (Avg. 4.12); S.S. = 0.67) and primary, secondary, high school, associate degree education groups, there is a significant difference between the opinions of the individuals. There is no significant difference between the views of high school (Avg. 3.65; S. S. = 0.67) and associate degree (Avg. 3.91; S.S. = 0.87) education groups regarding the Renewable Energy-Environment Relationship, which is included in the subtitle of Renewable Energy Perception Scale. However, there is a significant difference found between the opinions of individuals in primary, secondary, undergraduate, graduate, and doctoral groups on Renewable Energy-Environment Relationship (Avg. 3.52; S.S. = 0.47), (Avg. 3.37; P.S. = 0.51), (Avg. 3.02; S.S. = 0.88), (M. 3.37; S.S. = 0.74), and (M. 3.56; S.S. = 0.77).

It was examined whether there is a 0.05 difference between the seven subheadings (Perception of Environment Overview (PEO), Environment Education Perception (EEP), Environment Protection Perception (EPP), Environment Issues Perception (EIP), Environment Awareness Responsibility Perception (EARP), Problems of Sensory Perception (EPSP), and Environment-Friendly Activities Perception (EFAP)) in the Environmental Perception Scale and the education level variable.

According to the results of the Anova test, there is a significant difference between the views of individuals on the Environmental Perception Scale and education (Perception of Environment Overview ($F(6.283) = 5.362$, $p < 0.05$),

Environment Education Perception ($F(6.283) = 10{,}623$, $p < 0.05$), Environment Protection Perception ($F(6.283) = 7.128$, $p < 0.05$), Environment Issues Perception ($F(6.283) = 11{,}682$, $p > 0.05$). However, there is no significant difference between the subtitles Environment Awareness Responsibility Perception, Problems of Sensory Perception, and Environment-Friendly Activities Perception and Education ($F(4.519) = 1516$, $p > 0.05$), ($F(4.519) = 1.612$, $p > 0.05$), and ($F(4.519) = 1.783$, $p > 0.05$), respectively.

According to the Tukey test results, which show in which groups there is a significant difference between the participants' opinions on the Environmental Perception Scale (Perception of Environment Overview (PEO), Environment Education Perception (EEP), Environment Protection Perception (EPP), Environment Issues Perception (EIP)), and education. According to the results, there is no significant difference between the Perception of Environment Overview opinions of the participants in primary school (Avg. 3.76; S.S. = 0.81), middle school (Avg. 3.74; S.S. = 0.54), and high school (Avg. 3.64; S.S. = 0.62) education groups. However, it has been observed that there is a significant difference between the opinions of the individuals in the associate, undergraduate, graduate, and doctoral groups ((Avg. 4.57; S.S. = 0.70), (Avg. 4.18; S.S. = 0.80), (Avg. 3.98; S.S. = 0.61), and (Avg. 4.55; S.S. = 0.36)) and the individuals in the primary, secondary, and high school education groups regarding the Perception of Environment Overview subtitle of the Environmental Perception scale. There is no significant difference between the opinions of associate (Avg. 3.87; S.S. = 0.19) and undergraduate (Avg. 3.61; S.S. = 0.62) education groups on Environment Education Perception, which is under the subtitle of Environmental Perception Scale. However, it is observed that there is a significant difference between the opinions of the individuals in the primary, secondary, high school, graduate, and doctorate groups ((Avg. 4.32; S.S. = 0.08) (Avg. 4.26; S.S. = 0.41), (Avg. 4.84; S.S. = 0.27), (Avg. 4.29; S.S. = 0.63), and (Avg. 4.18; S.S. = 0.76)) and the individuals in the associate degree and undergraduate education groups. Regarding the Environment Protection Perception under the subtitle of the Environmental Perception Scale, there is no significant difference between the views of the education groups in primary school (Avg. 3.34; S.S. = 0.52), secondary school (Avg. 3.57; S.S. = 0.69), and doctorate (Avg. 3.3; P.S. = 0.63). However, there is a significant difference between the opinions of individuals in the high school, associate degree, undergraduate, and graduate groups ((Avg. 4.65; S.S. = 0.42), (Avg. 4.93; S.S. = 0.57), (Avg. 4.83; S.S. = 0.90), (Avg. 4.42; S.S. = 0.67), and (Avg. 4.62; S.S. = 0.59)) and the opinions of individuals in primary, secondary, and doctoral education groups. There is no significant difference between the opinions of primary school (Avg. 3.27; S.S. = 0.69), secondary school (Avg. 3.87; S.S. = 0.96), and doctorate (Avg. 3.84; S.S. = 0.78) education groups regarding the Environment Issues Perception, which is under the subtitle of Environmental Perception Scale. However, there is a significant difference between the opinions of individuals in high school, associate degree, undergraduate, and graduate groups ((Avg. 4.56; S.S. = 0.63), (Avg. 4.72; S.S. = 0.54), (Avg. 4.62; S.S. = 0.77), and (Avg. 4.39; S.S. = 0.51)) and the opinions of individuals in primary, secondary, and doctoral education groups.

5 Conclusion

Çanakkale is one of the cities where the most important renewable energy sources are produced in Turkey. The main reason for this research to be conducted in Çanakkale is that it ranks third in wind energy production in Turkey. The main sources of income in Çanakkale are agriculture, livestock, and tourism. Therefore, potential environmental crises may cause numerous economic problems in the region.

Giving more information or putting pressure on the public to influence public opinion on renewable energy does not guarantee social transformation (Aitken, 2010). The process of information or internalization of information takes place in the light of social experiences (Rydin, 2007). Hence, communities that experience the benefits become more willing to transform.

The research is based on education and residence variables, the opinions of the participants on renewable energy were investigated. According to the survey findings, those living in the center of Çanakkale have more technical and renewable energy information than those living in rural. Since the education level of the participants residing in the center is higher than the participants in the countryside. There is a sharp distinction between primary school, secondary school, high school, and associate degree groups, and undergraduate, graduate, and doctoral groups in terms of having information on renewable energy. In other words, education is an important factor in environmental awareness.

It was found that environmental perception, environmental education perception, environmental protection perception, and perception of environmentally friendly activities were higher in individuals living in rural areas. However, the perception of environmental issues is more prominent among the participants living in the city center. Although the Çanakkale city comes to the fore with its organic and natural products, the countryside has a more natural and environmentally friendly structure compared to the city center with its livelihoods and lifestyle, as everywhere else. Therefore, the participants living in the countryside have stronger perceptions of the environment and nature, which are closely related to their daily routines, despite their lower education level. City centers, on the other contrary, keep environmental issues on the agenda due to their education, but they have fewer practices than those living in the countryside.

References

Aitken, M. (2010). Why we still don't understand the social aspects of wind power: A critique of key assumptions within the literature. *Energy Policy*, 1834–1841.

Çakmak, M. (2020). Environment perception scale: Study on validity and reliability. *International Online Journal of Educational Sciences*, 281–303. https://doi.org/10.15345/iojes.2020.03.019

Chiles, T. H., & Mcmackin, J. (1996). Integrating variable risk preferences, trust, and transaction cost economics. *The Academy of Management Review*, 73–99.

Fornell, C., & Larcker, D. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*, 39–50.

Gürson, P., Topcu, M. K., Ülker, H. İ., & Erkan, T. E. (2014). Yenilenebilir Enerji Politikaları ve Enerji Arz Güvenliği. *International Conference on Eurasian Economies*, (pp. 1118–1123). Skopje.

Hughes, L., & Shupe, D. (2010). Creating energy security indexes with decision matrices and quantitative criteria. *World Energy Council's 2010 Montreal Conference.* Montreal.

Huijts, N., Midden, C., & Meijnders, A. L. (2007). Social acceptance of carbon dioxide storage. *Energy Policy, 35*, 2780–2789.

IEA. (2020). A sustainable recovery plan for the energy sector. Paris. Retrieved from https://www.iea.org/: https://www.iea.org/reports/sustainable-recovery.

İpekoğlu, H. Y., Üçgül, İ., & Yakut, G. (2014). Yenilenebilir Enerji Algısı Anketi: Güvenirlik ve Geçerliği. Yekarum e-Dergi (pp. 20–26).

Rousseau, D., Sitkin, S., Burt, R., & Camerer, F. C. (1998). Not so different after all: A cross-discipline view of trust. *The Academy of Management Review*, 393–405.

Rydin, Y. (2007). Re-examining the role of knowledge within planning theory. *Planning Theory, 6*, 52–68.

T.C. Kalkınma Bakanlığı. (2018). On Birinci Kalkınma Planı (2019–2023) Enerji Arz Güvenliği ve Verimliliği Özel İhtisas Komisyonu Raporu. Ankara: T.C.

TUREB. (2021a). *Rüzgar Enerjisi Santralleri Raporu*. Retrieved from https://app.powerbi.com: https://app.powerbi.com/view?r=eyJrIjoiMjRiZTk3NzktMmNiYS00OTZlLTk4ZjktNmJiYTNiYTZhM2M1IiwidCI6ImU5YzY0NjU4LWFkMWQtNDUwOS1hODk0LTE2NWZhYjU2NjEyMyIsImMiOjl9.

TUREB. (2021b). Türkiye Rüzgar Enerjisi İstatistik Raporu - Ocak 2021. Retrieved from tureb.com.tr: https://tureb.com.tr//lib/uploads/55081baf3b9a1091.pdf.

Turkish Wind Energy Association. (n.d.). *Home*. Retrieved 02 26, 2022, from https://www.tureb.com.tr/: https://www.tureb.com.tr/

Wexler, M. N. (1996). A sociological framing of the nımby (Not-In-My-Backyard) syndrome. *International Review of Modern Sociology, 26*, 91–110.

Wind Europe. (2020). *Wind energy and economic recovery in Europe.* Wind Europe. Retrieved from https://proceedings.windeurope.org/biplatform/rails/active_storage/disk/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaDdDRG9JYTJWNVNTSWhaelJ1WmpCMll6a3pZM2RwZHpWMWNXTjFNemh0ZUd4aE5IaHBZd1k2QmtWVU9oQmthWE53YjNOcGRHbHZia2tpY1dsdWJHbHVaVHNnWm1sc1pXNWhiV1U5SWxkcGJtUkZkWEp

Wind Europe. (2021a, 09 09). *Turkey reaches 10 GW wind energy milestone*. Retrieved from https://windeurope.org: https://windeurope.org/newsroom/news/turkey-reaches-10-gw-wind-energy-milestone/.

Wind Europe. (2021b). *Wind energy in Europe: 2021 Statistics and the outlook for 2022–2026.* Brussels. Retrieved from https://windeurope.org/intelligence-platform/product/wind-energy-in-europe-2021-statistics-and-the-outlook-for-2022-2026/

Wolsink, M. (2000). Wind power and the NIMBY-myth: Institutional capacity and the limited significance of public support. *Renewable Energy, 21*, 49–64.

Wüstenhagen, R., Wolsink, M., & Burer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 2683–2691.

Factors Affecting Clean Energy Investments for Zero Emissions: OECD Countries

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Abstract Clean energy production is becoming the basic need of countries day by day in order to reach the zero-emission target. In particular, energy production with the opportunities offered by nature constitutes the first energy policy of countries. Contrary to the positive effect of clean energy production on environmental factors, significant investments are needed in terms of cost. Especially the high initial setup and operating costs of clean energy-producing facilities and long installation phases are perceived as two essential factors for clean energy. This part of the book includes a statistical analysis of factors, such as country populations, economic indicators, environmental parameters, life expectancy, and rate of energy produced from clean energy, which affects clean energy investments for zero emissions. The data on these factors belong to the OECD members. Based on the results, countries will reach the minimum level in their zero-emission target by increasing the share of clean energy in the total energy produced and taking the factors considered in clean energy production.

1 Introduction

Energy is generally accepted as an indicator of economic growth and development. Globally, there is an escalating trend of energy demand to carry out daily human activities such as heating, cooking, transportation, etc. (Owusu &

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Asumadu-Sarkodie, 2016). This increase in energy requirement results from industrialization, technical improvements, and population growth in developed and developing countries (Atalan et al., 2020).

The world's total energy needs are substantially met by conventional energy sources, including coal, natural gas, and oil. However, this energy type causes global warming as mainly CO_2 and other air pollutants are emitted into the atmosphere and then increase the earth's temperature risking all the living creatures when used (Emodi et al., 2014). Greenhouse gas emissions, mainly containing CO_2, are originated from four main sectors, namely waste, industrial processes, agriculture, and energy (Liu et al., 2021; Mukhtarov et al., 2022; Xie et al., 2021; Zhou et al., 2021). Climate Watch Institution stated that the majority of the global greenhouse gas emissions arose from the energy sector with 73.3%, the underlying reason for burning fossil fuels to produce energy (Silva & del Castillo, 2021).

In addition, the escalation in the world's temperature results in glaciers melting, which in turn causes sea levels to increase and floods along with agriculture and fishery industry to be damaged. The other adverse aspect of conventional or nonrenewable energy sources is that they are depletable sources, making them unsustainable for both present and future energy requirements worldwide (Shahzad, 2015).

Renewable or nonconventional energy is another energy resource containing hydro, wind, solar, geothermal, tidal, and biomass energy. Renewable energy can be a reasonable solution to carbon dioxide emissions and heating the earth's surface problem (Dinçer et al., 2022; Kou et al., 2022; Meng et al., 2021; Zhe et al., 2021). In this respect, especially solar and wind energy are promoted nationally and also internationally to integrate into the electricity network to diminish the greenhouse effect (Subagyo et al., 2021).

There is an irresistible inclination toward alternative energy sources. Due to the decrease in the use of other energy sources, renewable energy sources have been increased by 3% until 2020, resulting from the 7% increase in electricity generation from renewable sources. Therefore, 29% of electricity generation in the world in 2020 came from renewable energy, which was 27% in 2019 (International Energy Agency (IEA), 2021).

Renewable energy is the energy that is permanently replenished by nature (Vakulchuk et al., 2020). Unlike fossil fuels, renewables will not run out, so they are plentiful and reliable. In addition, they are eco-friendly sources that cause the minimum amount of carbon and GHG (greenhouse gas) emissions as compared to conventional fossil energy resources. Moreover, alternative energy can improve public health as they mitigate GHG and other air-polluting particles. Renewable technologies offer new job opportunities and necessitate lower maintenance costs. Renewables also help minimize the uncertainty of energy costs that constitute countries with more independent economies (Aceleanu et al., 2017).

Hydropower, as a renewable energy type utilized for centuries, is the production of electricity by converting energy from falling or flowing water. Hydropower offers stable electricity generation after a dam is built. The lake or reservoir constituted behind the dam enables aquatic sports, fishery, etc. This sort of energy does not

cause any waste, the greenhouse gas or air pollutants. Moreover, hydropower supplies the largest portion of electricity production compared to other renewables, besides keeping 22 billion gallons of oil or 120 million tons of coal from combusting annually (Bagher et al., 2015).

Wind energy is one of the fastest developing technologies in the field of renewable energy generation with the help of wind turbines. The wind is readily accessible anywhere in the world. Wind energy is a domestic source that can be generated as long as the wind blows without requiring any fuel (Islam et al., 2013). Thus, it can help minimize energy dependency on other nations. It is a cost-effective, safe, and sustainable alternative that has a significant potential to meet the increasing demand for global energy (Ding et al., 2021; Dong et al., 2022; Haiyun et al., 2021; Kostis et al., 2022). Wind energy projects provide new jobs in the manufacturing, transportation, installation, and maintenance phases. There has been a considerable rise in electricity production from wind during the last 30 years. The declining electricity generation cost of wind in consequence of technological improvements in the wind energy sector with governmental incentives plays a significant role in wind energy production (Kaplan, 2015).

The sun is the most significant energy source providing direct and/or indirect energy to all living creatures. The energy gained in the electromagnetic radiation form emitted from the sun that is converted into thermal or electrical energy is defined as solar energy (Li et al., 2022; Serezli et al., 2021; Yüksel et al., 2021; Zhao et al., 2021). Due to its contribution to the total energy demand without causing pollution, solar power is regarded as a clean energy resource. Solar energy has several advantages in terms of low carbon emission, not necessitating fossil fuels, inexhaustible long-term solar supply, less payback period, etc. (Aman et al., 2015).

Geothermal energy is generated through the heat from the interior of the earth. It is a type of alternative energy since the heat occurs in the earth all the time. As an eco-friendly energy source, geothermal energy production is not an issue with respect to deficiency or the rising cost of fossil fuels to be discussed. Generally, the areas with active volcanoes are more suitable for this energy source (Nasruddin et al., 2016).

The rise and fall of sea levels form tides, resulting from the gravitational interaction between the earth, the sun, and the moon, which are the origins of tidal energy (O'Rourke et al., 2010). Tidal energy is an unlimited and infinite renewable energy source. Moreover, it is more resistant to climatic alterations than other energy types. Tidal energy is a pollution-free source that can be generated in the daytime and at night. In addition, the possibility of tidal currents to forecast in advance makes tidal energy a reliable resource (Shetty & Priyam, 2021).

Biomass is basically plant- or animal-based material employed as fuel in order to produce heat or electricity. Biomass energy is crucial as it is the first type of energy, except food, that human beings learn to utilize (Abbasi & Abbasi, 2010). It is conventionally employed by means of directly burning of biomass for cooking, heating, other activities, etc. The contemporary usage of biomass is its transformation to secondary energy by advanced mechanisms. Modern biomass energy is a plentiful alternative energy that can be generated no matter where. Additionally, it

offers new employment opportunities on a regional basis as well as creates additional income for the local people (Bildirici, 2013).

Overall, alternative energy technologies have gained more and more attention from investigators, political and industry leaders in recent years to overcome problems related to the economics, politics, and environment in terms of supplying increasing energy demand in a sustainable and reliable way (Sampaio & González, 2017).

This chapter of the book consists of five parts. The first part includes a literature review about clean energy and its types. In the second part, there is a detailed explanation of the clean energy policy. The third section gives information about the dependent and independent variables affecting clean energy investments for zero emissions. Statistical and computational analyzes were handled to analyze the effects of the variables in the fourth part of the study. In the last part, the importance of clean energy investments for zero emissions and possible suggestions for future studies were mentioned.

2 Clean Energy Policy

What makes renewable energy fundamentally important are the limitedness and the damage to the environment of fossil resources while producing energy. Despite the limited amount of fossil resources in the world we live in, the energy demand created by the increasing population is constantly rising. Another factor that makes renewable energy important is that the technologies used in energy production cause polluting results to the environment (Seydiogullari, 2013). However, the technological methods and equipment used in producing renewable energy sources are extremely environmentally friendly (Adalı et al., 2022; Bhuiyan et al., 2022; Fang et al., 2021; Yüksel et al., 2022). Renewable sources do not create greenhouse gases or environmental waste with air pollution, such as carbon dioxide (Harjanne & Korhonen, 2019). Renewable energy sources, which are constantly found in nature, are continually renewed wastes that will cause environmental pollution do not occur in their production process in general (Bao & Xu, 2019). In summary, the typical features of all renewable energies are that they are eco-friendly, sustainable, and obtained from domestic sources.

In the past, societies had difficulties in producing renewable energy due to the lack of the necessary technological infrastructure. However, today, with the advancement of technology, the encouragement of renewable energy investments, and society's awareness, countries can use renewable energy resources more effectively. Especially countries that are dependent on foreign energy have started to build their energy policies on renewable energy sources. Because the energy resources they import from other countries negatively affect the economic growth and welfare of the countries and so cause debts. For these countries, renewable energy sources will become a necessity, not just an alternative to fossil fuels, in the future (Harjanne & Korhonen, 2019).

The EU has been developing energy policies safe for the environment within the scope of combating climate change since 1972. Until the 2000s, these policies were formed according to the understanding of sustainable development. Since 2010, the EU has adopted the green economy model in its policies related to the environment and energy. With the approval of the Paris Climate Agreement in 2015, the EU has set two goals: Keeping the global temperature rise below 1.5 °C and adapting to the effects of climate change (Commission, 2014).

One hundred ninety-two countries signed the Kyoto Protocol against environmental pollution, global warming, and climate change caused by fossil fuels in 1997. In the decision taken, countries have committed to reducing their greenhouse gas emissions by 80% (Babiker et al., 2000; Gielen et al., 2019). The European Union Parliament approved and published the decisions on renewable energy sources to implement the Kyoto protocol. With the decision accepted by the European Parliament on 31 January 2008, the rate of energy produced by utilizing renewable energy sources has been determined to escalate to 20% by 2020 (Acaravcı & Erdoğan, 2018).

Since 2010, the green economy model as a growing concept has been started to apply by policymakers in the EU. The Green Economy is an economic model that aims to develop with low carbon emissions, protect the ecological system while providing resource efficiency, and create welfare for all. EU, within the scope of a green economy, has developed policies in energy and infrastructure systems, transportation, industry, agriculture, and many other fields (Küçük & Yüce Dural, 2022).

3 Dependent and Independent Factors

3.1 Carbon Dioxide (CO_2)

The phenomenon of global warming, the rise in temperature near the earth's surface, as the name implies, has been observed since the preindustrial era. Fossil fuel combustion is the main reason for global warming, escalating heat-trapping greenhouse gas concentrations in the atmosphere. CO_2 is the biggest contributor to the greenhouse effect of all six types of greenhouse gases (GHG) (Zhang et al., 2013).

The energy sector is the dominant source of CO_2 emissions worldwide, in which the burning of hydrocarbon-based fossil fuels is still the most widely used energy source (Köne & Büke, 2010). Therefore, renewable and clean energy utilization is vital with regard to environmental, political, and economic issues that have to be considered in electricity generation processes (Sampaio & González, 2017).

3.2 $PM_{2.5}$ (Particulate Matter)

$PM_{2.5}$ stands for particulate matter having a diameter of 2.5 μm or smaller. Particulate matter can directly be released from several origins. Alternatively, it can arise from complicated chemical reactions, such as sulfur dioxide and nitrogen oxides that are air-polluting emissions from industries, coal-fired power plants, automobiles, human activities, etc. (Pui et al., 2014).

$PM_{2.5}$ has unfavourable impacts on public health, for instance, pulmonary and cardiovascular diseases (Yang et al., 2018). Indeed, $PM_{2.5}$ was the cause of 2.9 million deaths globally in 2013 and is also predicted to decrease 8.6 months in life expectancy in Europe (Requia et al., 2017). Thus, a shift from fossil fuel to renewables is crucial in limiting particulate matter concentrations in the atmosphere to prevent adverse health effects.

3.3 Population

With the population growth and development of technology globally, the need for energy increases day by day (DeLong et al., 2010; Sorrell, 2015). This situation has revealed the need to find new energy sources. For this reason, states that want to meet their energy needs are looking for new solutions by turning to renewable energy sources, which can be an alternative to existing energy sources. In particular, population growth in developed economies creates more energy needs. For developing countries, a 1% increase in population increases energy demand by 4.16% in the long run (Nepal & Paija, 2019). With the industrial revolution, the need for workers in the factories in the city centers began to form the modern society, creating a significant population movement from rural settlements to urban centers. Urbanization has increased people's need for energy and significantly increased fossil fuel consumption (Li & Lin, 2015). Many studies show that increasing urbanization with population enhances the energy demand (Liddle & Lung, 2010; Madlener & Sunak, 2011; Zhang et al., 2013).

3.4 Gross Domestic Product (GDP) and Gross Domestic Product Per Capita (PC)

Gross domestic product (GDP) and gross domestic product per capita (PC) are the primary indicators that evaluate countries' production and growth performances. Countries that want to increase (GDP) or (PC) aim to improve their social well-being (Keskin, 2020). Increasing production continuously raises the energy demand in the same way. In other words, the most critical input to ascend GDP is energy. The need for energy, especially from the Industrial Revolution, has continued to grow

uninterruptedly until today. Since fossil fuels provide a large part of the energy need, the demand for fossil fuels has constantly increased. This situation causes the fossil fuel reserve, a nonrenewable resource, to decrease and its price to rise (Welsby et al., 2021).

Many studies have been conducted to test the relationship between a country's energy production amounts and GDP. Önder and Polat examined the effect of energy use on GDP, labor, and capital in OECD countries with panel data analysis. It has been revealed that capital and renewable energy positively affect GDP in the 1996–2014 period of these countries (Polat & Önder, 2018). Magazzino studied the relation of energy production with GDP for Italy through the cointegration analysis method (Magazzino, 2012). Shengfeng et al. investigated the correlation of electricity consumption with economic growth in their study in China. They found unidirectional causality running from electricity consumption to economic growth (Shengfeng et al., 2012).

3.5 Life Expectancy (LE)

Life expectancy (LE) is an essential tool that provides vital information about the economic development of countries and shows the health status of all nations (Zhou et al., 2012). With the increase in LE, the needs of people for life have increased. The emergence of new conditions has constantly escalated the energy demand. Energy use occurs as a result of human development. Although it has many benefits for humans, it has many adverse effects on the environment (Qu et al., 2017a, 2017b). Wang et al. found that although energy consumption has a positive effect on economic growth, it also has a negative effect on LE (Qu et al., 2017a, 2017b). Felice et al. assessed the relationship between LE and PC in Spain and Italy between 1861 and 2008. The results demonstrated that the increase in LE causes GDP growth and that economic growth causes LE to rise (Felice et al., 2016).

4 Statistical and Computational Analysis

Data on the factors affecting clean energy (CE) investments for zero emissions were obtained from two different sources. These data are for the year 2019 of 38 countries, including OECD members. In order to recognize and understand these data, descriptive statistics data were calculated and shared in Table 1 before statistical analysis. The research consists of 266 data from 38 countries, including dependent and independent variables. Mean, mean deviation (SE Mean), standard deviation (St. Dev.), variance, coefficient of variance (Coef. Var.), minimum values, quartiles (Q_1, Q_3, Median), maximum values, data interval values (Range and IQR), skewness, and kurtosis values of each dependent and independent variable were computed.

Table 1 The descriptive statistical values of variables

	Independent variables					Dependent variables	
Terms	Population (million)	GDP ($)	PC ($)	LE (year)	CE[a] (%)	CO_2 (tons/capita)	$PM_{2.5}$ (μg/m^3)
Total count	38.0000	38.0000	38.0000	38.000	38.000	38.000	38.000
Mean	35.8800	1,420,609	39,759.0	78.332	20.900	6.4970	13.166
SE mean	9.61000	571,699	3918.00	0.5150	2.7600	0.5890	0.9970
St. Dev.	59.2300	3,524,189	24,154.0	3.1780	17.010	3.6280	6.1430
Variance	3508.74	1.2E+13	5.8E+08	10.097	289.46	13.162	37.741
Coef. var.	165.070	248.080	60.75000	4.0600	81.390	55.840	46.660
Minimum	0.40000	24858.0	6425.000	70.900	2.0000	0.0000	5.6000
Q1	5.25000	194,740	19,261.00	76.200	9.2000	4.3500	7.7750
Median	10.5000	402,032	40,678.00	79.550	15.470	5.3500	11.950
Q3	50.7200	1,392,226	52,074.00	80.825	28.010	7.8000	17.175
Maximum	328.300	2,143,323	113,219.0	82.100	88.920	15.200	27.400
Range	327.900	2,140,837	106,794.0	11.200	86.920	15.200	21.800
IQR	45.4700	1,197,486	32,813.00	4.6250	18.820	3.4500	9.4000
Skewness	3.59000	5.24000	0.930000	−0.9800	2.0400	1.0400	0.7400
Kurtosis	16.0500	29.8600	0.930000	−0.2500	5.7400	1.0100	−0.3100

[a]% of clean energy in total energy production

μg micrograms

The average values of population, GDP, PC, LE, CE, CO_2, and $PM_{2.5}$ of OECD members were calculated as 35.88 million, $142 billion, $39,759, 78.32 years, 6.497, 13.1166, and 20.9 (% of the total energy produced), respectively. While the USA has the highest population of 328.3 million among OECD members, Iceland has the least population with 400 thousand. Likewise, the US country has the largest share among the country's economies, with $21.4 billion. When the PC value is examined, approximately $32.8 thousand is calculated between the highest and the lowest value. Although the LE of people differs according to the countries, they have values close to each other. LE is analyzed as 11.2 years on average between the longest LE and the shortest LE. The average LE of OECD members is computed as 78.33 years. Another essential factor on zero emissions is the renewable or clean energy units included in the total electricity consumption of the countries. Countries allocate budgets from their economies for clean energy. If the budget amounts are compared with the amount of energy obtained from clean energy, Iceland has the highest rate with 88.92%. The smallest ratio belongs to Korea, which produces 2% of the total energy consumed from clean energy. On average, 20.9% of OECD members' energy consumption is provided by clean energy.

CO_2 and $PM_{2.5}$ variables, which are defined as independent variables, are also among the indicators of zero emissions. Only these two parameters, which represent zero emissions, were considered for this study. The most critical factor in defining zero emissions with only two parameters is the completeness of the data for OECD members and the fact that the data for other parameters are estimation or incomplete. Average CO_2 and $PM_{2.5}$ values of OECD members were analyzed as 6.497 and 13.166, respectively.

The preferred method for this book chapter is general regression analysis, one of the statistical analysis methods. Generally, regression analysis is used for data identification, parameter estimation, estimation and control purposes (Barbur et al., 1994). The general principle of this method is to determine the type and values of the variables to be handled in the analysis. There are generally three types of variables in regression analysis. These variables are defined as input and output variables, and the error parameter is thought to affect the regression of external factors (Ayaz Atalan & Atalan, 2021). The source of the value of the error parameter in the equation can be expressed as measurement errors, device failures or other undefined errors that occur in an experiment. The main equation, which includes these variables and forms the basis of the regression equation, is given below:

$$y_i = \beta_0 + \beta_1 x + \in \tag{1}$$

The above equation is created as an example of linear regression analysis. In the traditional regression equation, there are two different parameters apart from the variables. These parameters are defined as the regression constant β_0 and the variable coefficient β_1. In Eq. (1), there is only one independent variable, and only one dependent variable is affected. In Eq. (2), more than one variable affects only one dependent variable.

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots + \beta_n x_n + \in \tag{2}$$

In order to know the estimations of the obtained data, it is necessary to know the regression constant and coefficient values. Therefore, the regression analysis is formulated as the least-squares criterion as follows (Montgomery et al., 2012):

$$S(\beta_0, \beta_1) = \sum_{i=1}^{n} (y_i - \beta_0 + \beta_1 x_i)^2 \tag{3}$$

Since β_0 and β_1 are the estimators of the least squares' method, Eq. (3) must satisfy the following condition. In that case (Khuri, 2013):

$$\left.\frac{\partial S}{\partial \beta_0}\right|_{\widehat{\beta}_0, \widehat{\beta}_1} = -2 \sum_{i=1}^{n} (y_i - \beta_0 + \beta_1 x_i) = 0, \text{and } \left.\frac{\partial S}{\partial \beta_0}\right|_{\widehat{\beta}_0, \widehat{\beta}_1}$$
$$= -2 \sum_{i=1}^{n} (y_i - \beta_0 + \beta_1 x_i) x_i = 0 \tag{4}$$

If Eq. (4) is simplified, the following equations arise (Montgomery et al., 2012):

$$n\widehat{\beta}_0 + \widehat{\beta}_1 \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i, \text{ and } \widehat{\beta}_0 \sum_{i=1}^{n} x_i + \widehat{\beta}_1 \sum_{i=1}^{n} {x_i}^2 = \sum_{i=1}^{n} y_i x_i \tag{5}$$

For this study, the error coefficient was taken into account as zero since it did not include any experiments and the data obtained were accessible. In this section, there are five common independent variables that affect two separate dependent variables. The variables to be used in the statistical analysis for this study are defined in the above section. Before the regression analysis, spearman rho correlation analysis was performed to measure the correlation values between dependent and independent variables. Correlation values vary between −1 and 1 (Atalan, 2020). Values approaching two opposite values show a strong correlation between two variables, while values approaching zero show a weak correlation between variables.

The correlation technique was utilized to calculate the correlation value between five independent and two dependent variables. Correlation values for data set of seven variables are computed using Eq. (6) as below (Atalan, 2021):

$$r = \frac{\sum_{i=1}^{n} (y_i - \overline{y})(x_i - \overline{x})}{\sqrt{\sum_{i=1}^{n} (y_i - \overline{y})^2} \sqrt{\sum_{i=1}^{n} (x_i - \overline{x})^2}} \tag{6}$$

Table 2 The statistical values of dependent and independent variables

	Term	Coefficient	SE coef.	*T*-value	*P*-value	VIF
CO_2	Regression 1	7.700000	14.50000	0.53	0.597	–
	Population	−0.018100	0.024100	−0.75	0.457	9.46
	GDP	0.000001	0.000000	1.30	0.202	9.44
	PC	0.000067	0.000028	2.43	0.021	2.10
	LE	−0.029000	0.192000	−0.15	0.882	1.73
	CE	−0.084000	0.029300	−2.87	0.007	1.15
PM 2.5	Regression 2	18.00000	23.70000	0.76	0.454	–
	Population	0.080500	0.039500	2.04	0.050	9.46
	GDP	−1E-06000	0.000001	−2.21	0.035	9.44
	PC	−0.000110	0.000046	−2.29	0.029	2.10
	LE	0.005000	0.315000	0.02	0.988	1.73
	CE	−0.088700	0.048100	−1.85	0.074	1.15

–, no data available
SE coef. the coefficient of standard error, *VIF* measures how much the variance of an estimated regression coefficient changes (increases or decreases) if the variables are correlated

where the correlation coefficient is symbolized by r. The number of observation data in the sample data set are defined as x_i. In this equation, dependent and independent variables are expressed with the symbols y_i and x_i, respectively. The mean values of the data in the x and y data sets are shown as $\overline{x}$ and $\overline{y}$. When the correlation values are compared with the linear regression method, correlation coefficients and regression models tend to converge. Therefore, the equation r is actually given as:

$$r = \sqrt{\beta_1 \left(\frac{S_{xx}}{SS_T} \right)} \tag{7}$$

The correlation values between the variables show both positive and negative relationships. It is seen that there is a positive and strong correlation between the national income of the countries and the population values. However, we can say that there is both a weak and negative correlation between the population and the PC variable. This relationship is also experienced with the LE variable. However, it is revealed as a result of the analysis that there is both a strong and positive correlation between the population and the GDP variable. The correlation value between these two variables was calculated as 0.925. There is a strong correlation between GDP and CE and $PM_{2.5}$ variables. It is understood that PC variable has a strong and positive relationship with other variables except for the $PM_{2.5}$ variable. It can be said that there is a negative correlation between the LE variable and only the $PM_{2.5}$ variable. The CO_2-dependent variable has a negative relationship with both $PM_{2.5}$ and CE variables.

As a result of correlation analysis of dependent and independent variables, general regression analysis was performed, and the data are shown in Table 2. According to the regression analysis, it is revealed as a result of the coefficients

obtained that the independent variables have negative and positive effects on the dependent variables. Independent variables are analyzed according to three statistical significance values on dependent variables. These values are taken into account as 10.0%, 1.0%, and 0.1%. However, in general, it is possible for an independent variable to have too much effect on a dependent variable if the p-value is less than 0.05. It can be tested whether the variables with a value greater than this affect the dependent variable according to the other significance level.

The effects of independent factors affecting clean energy investments for zero emissions on two dependent factors were statistically analyzed. CO_2 and $PM_{2.5}$ indicators, which represent zero emissions, are dependent variables, and analysis results were obtained for each variable. First of all, it has been determined that PC and clean energy variables are effective on CO_2 with a significance level of 0.01. The populations of the countries, according to the 10% significance level, emerge as a result of the analysis in which the GDP and LE variables are effective.

In the statistical analysis, it is obvious that three of the five independent variables are effective for the dependent variable of $PM_{2.5}$. Population, GDP, and PC variables from the influential variables were calculated as 0.050, 0.035, and 0.029, respectively. The effectiveness of these variables is based on a statistical significance value of 0.5, provided that the statistical significance level is 0.1, CE is effective on $PM_{2.5}$ of the independent variable. The statistical significance value of CE was calculated as 0.07. We can argue that it is effective on $PM_{2.5}$, provided that the LE independent variable belonging to OECD members is taken as a 10% significance level.

There are some limitations in this section of the book. At the beginning of these limits, it is related to the number of independent variables selected. Considering the data obtained, variables with complete data were taken into account in order to obtain more reliable results from the statistical analysis. Due to the missing data of many independent variables such as education rates, the amount of energy consumed, and the number of vehicles running on electricity could not be included in this study. In addition, transportation vehicles are not taken into account in this study. The main reason why this variable is not considered is that the number of electric vehicles currently operating in the countries are not available. Another limitation is the lack of encouraging numerical data on the opportunities that countries provide to investors for clean energy. However, these countries enact clean energy laws for zero emissions, especially to reduce CO_2 emissions.

As a result, the importance of clean energy for zero emissions emerges with the statistical analysis result in this section. With clean energy having a significant percentage of the energy used, it is evident that countries will reach the minimum level of net-zero emissions. In order to obtain clean energy, countries need to allocate a significant part of their budgets. The main reason for this situation is that the facilities created for clean energy are more costly and require a longer time than traditional energy. Therefore, policymakers should put more emphasis on research and support technical developments to improve renewable energy technologies. In particular, it encourages OECD members for clean energy in order to both meet a large part of their needs and consider environmental factors. In order to reduce carbon emissions of OECD members, clean energy laws are established for

the purpose of meeting the demand for alternative or green energy. These countries also have policies that largely support investors and enterprisers for clean energy investments.

5 Discussion and Conclusion

In this section, statistical analysis has been carried out by considering the factors affecting clean energy investments for zero emissions. The factors impact the investments for green energy to reach the goal of net-zero emissions that include the economic and demographic parameters of the countries. These parameters were defined as dependent and independent variables for statistical analysis. Both general regression analysis and correlation values of dependent and independent variables were calculated. Although there are both negative and positive relationships between the dependent and independent factors, there are weak and strong correlations between the variables.

According to the general regression analysis, it has been determined that some independent variables have negative coefficients, and some have positive coefficients on the dependent variables. But all the independent variables turned out to have a statistical effect on the CO_2 and $PM_{2.5}$ variables (based on 10%, 1%, and 0.1% statistically significant), which represent zero emissions. It can be emphasized that OECD members should allocate more budget to clean energy facilities, especially with the fact that clean energy is effective on CO_2 and $PM_{2.5}$. In other words, these members need to invest heavily in renewable energy facilities that represent clean energy, which is a large part of the total energy they use. In addition, other parameters that affect zero emissions are the economic indicators of the countries. Therefore, we can conclude a profound connection between the clean energy investment rate and the country's economic indicators.

References

Abbasi, T., & Abbasi, S. A. (2010). Biomass energy and the environmental impacts associated with its production and utilization. *Renewable and Sustainable Energy Reviews, 14*(3), 919–937. https://doi.org/10.1016/j.rser.2009.11.006

Acaravcı, A., & Erdoğan, S. (2018). Yenilenebilir Enerji, Çevre ve Ekonomik Büyüme İlişkisi: Seçilmiş Ülkeler için Ampirik Bir Analiz. *Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi, 13*(1), 53–64. https://doi.org/10.17153/oguiibf.359419

Aceleanu, M. I., Şerban, A. C., Pociovălişteanu, D. M., & Dimian, G. C. (2017). Renewable energy: A way for a sustainable development in Romania. *Energy Sources, Part B: Economics, Planning, and Policy, 12*(11), 958–963. https://doi.org/10.1080/15567249.2017.1328621

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Aman, M. M., Solangi, K. H., Hossain, M. S., Badarudin, A., Jasmon, G. B., Mokhlis, H., Bakar, A. H. A., & Kazi, S. (2015). A review of Safety, Health and Environmental (SHE) issues of solar energy system. *Renewable and Sustainable Energy Reviews, 41*, 1190–1204. https://doi.org/10.1016/j.rser.2014.08.086

Atalan, A. (2020). Forecasting for healthcare expenditure of turkey covering the years of 2018-2050. *Gümüşhane Üniversitesi Sağlık Bilimleri Dergisi, 9*(1), 8–16. https://doi.org/10.37989/gumussagbil.538111

Atalan, A. (2021). Effect of healthcare expenditure on the correlation between the number of nurses and doctors employed. *International Journal of Health Management and Tourism, 6*(2), 515–525. https://doi.org/10.31201/ijhmt.949500

Atalan, Y. A., Tayanç, M., Erkan, K., & Atalan, A. (2020). Development of nonlinear optimization models for wind power plants using box-Behnken design of experiment: A case study for Turkey. *Sustainability (Switzerland).* https://doi.org/10.3390/su12156017

Ayaz Atalan, Y., & Atalan, A. (2021). Development of design of experiment optimization to obtain high-quality sugar. *İstatistik ve Uygulamalı Bilimler Dergisi, 2*(1), 1–7. https://doi.org/10.52693/jsas.908537

Babiker, M., Reilly, J. M., & Jacoby, H. D. (2000). The Kyoto Protocol and developing countries. *Energy Policy, 28*(8), 525–536. https://doi.org/10.1016/S0301-4215(00)00033-1

Bagher, A. M., Vahid, M., Mohsen, M., & Parvin, D. (2015). Hydroelectric energy advantages and disadvantages. *American Journal of Energy Science, 2*(2), 17–20.

Bao, C., & Xu, M. (2019). Cause and effect of renewable energy consumption on urbanization and economic growth in China's provinces and regions. *Journal of Cleaner Production, 231*, 483–493. https://doi.org/10.1016/j.jclepro.2019.05.191

Barbur, V. A., Montgomery, D. C., & Peck, E. A. (1994). Introduction to linear regression analysis. *The Statistician, 43*(2), 339. https://doi.org/10.2307/2348362

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., et al. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Bildirici, M. E. (2013). Economic growth and biomass energy. *Biomass and Bioenergy, 50*, 19–24. https://doi.org/10.1016/j.biombioe.2012.09.055

Commission, E. (2014). Living well, within the limits of our planet. In COM(2012) 710 final. https://doi.org/10.2779/57220.

DeLong, J. P., Burger, O., & Hamilton, M. J. (2010). Current demographics suggest future energy supplies will be inadequate to slow human population growth. *PLoS One, 5*(10), e13206. https://doi.org/10.1371/journal.pone.0013206

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Ding, Z., Yüksel, S., & Dincer, H. (2021). An Integrated Pythagorean fuzzy soft computing approach to environmental management systems for sustainable energy pricing. *Energy Reports, 7*, 5575–5588.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision-making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Emodi, V. N., Yusuf, S. D., & Boo, K.-J. (2014). The necessity of the development of standards for renewable energy technologies in nigeria. *Smart Grid and Renewable Energy, 05*(11), 259–274. https://doi.org/10.4236/sgre.2014.511024

Fang, S., Zhou, P., Dinçer, H., & Yüksel, S. (2021). Assessment of safety management system on energy investment risk using house of quality based on hybrid stochastic interval-valued intuitionistic fuzzy decision-making approach. *Safety Science, 141*, 105333.

Felice, E., Pujol Andreu, J., & D'Ippoliti, C. (2016). GDP and life expectancy in Italy and Spain over the long run: A time-series approach. *Demographic Research, 35*, 813–866. https://doi.org/10.4054/DemRes.2016.35.28

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews, 24*, 38–50. https://doi.org/10.1016/j.esr.2019.01.006

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Harjanne, A., & Korhonen, J. M. (2019). Abandoning the concept of renewable energy. *Energy Policy, 127*, 330–340. https://doi.org/10.1016/j.enpol.2018.12.029

International Energy Agency (IEA). (2021). Global Energy Review 2021. https://www.iea.org/reports/global-energy-review-2021/renewables

Islam, M. R., Mekhilef, S., & Saidur, R. (2013). Progress and recent trends of wind energy technology. *Renewable and Sustainable Energy Reviews, 21*, 456–468. https://doi.org/10.1016/j.rser.2013.01.007

Kaplan, Y. A. (2015). Overview of wind energy in the world and assessment of current wind energy policies in Turkey. *Renewable and Sustainable Energy Reviews, 43*, 562–568. https://doi.org/10.1016/j.rser.2014.11.027

Keskin, A. (2020). G20 Ülkelerinin CO2 Emisyonları Ve Kişi başına Düşen Milli gelirin 1960-2012 Dönemi Arasındaki Amprik Analizi. *Journal of Civilization Studies, 5*(1), 25–38.

Khuri, A. I. (2013). Introduction to Linear Regression Analysis, Fifth Edition by Douglas C. Montgomery, Elizabeth A. Peck, G. Geoffrey Vining. International Statistical Review. https://doi.org/10.1111/insr.12020_10.

Köne, A. Ç., & Büke, T. (2010). Forecasting of CO2 emissions from fuel combustion using trend analysis. *Renewable and Sustainable Energy Reviews, 14*(9), 2906–2915. https://doi.org/10.1016/j.rser.2010.06.006

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of european economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Küçük, G., & Yüce Dural, B. (2022). Avrupa Yeşil Mutabakatı ve Yeşil Ekonomiye Geçiş: Enerji Senaryoları Üzerinden Bir Değerlendirme. *Anadolu Üniversitesi Sosyal Bilimler Dergisi, 22*(1), 137–156. https://doi.org/10.18037/ausbd.1095137

Li, K., & Lin, B. (2015). Impacts of urbanization and industrialization on energy consumption/CO2 emissions: Does the level of development matter? *Renewable and Sustainable Energy Reviews, 52*, 1107–1122. https://doi.org/10.1016/j.rser.2015.07.185

Li, J., Yüksel, S., Dınçer, H., Mikhaylov, A., & Barykin, S. E. (2022). Bipolar q-ROF hybrid decision making model with golden cut for analyzing the levelized cost of renewable energy alternatives. *IEEE Access, 10*, 42507–42517.

Liddle, B., & Lung, S. (2010). Age-structure, urbanization, and climate change in developed countries: revisiting STIRPAT for disaggregated population and consumption-related environmental impacts. *Population and Environment, 31*(5), 317–343. https://doi.org/10.1007/s11111-010-0101-5

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*(5), 3687–3701.

Madlener, R., & Sunak, Y. (2011). Impacts of urbanization on urban structures and energy demand: What can we learn for urban energy planning and urbanization management? *Sustainable Cities and Society, 1*(1), 45–53. https://doi.org/10.1016/j.scs.2010.08.006

Magazzino, C. (2012). On the relationship between disaggregated energy production and GDP in Italy. *23*(8), 1191–1207. https://doi.org/10.1260/0958-305X.23.8.1191.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., & Yüksel, S. (2021). A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financial Innovation, 7*(1), 1–34.

Montgomery, D. C., Peck, E. A., & Vining, G. G. (2012). *Introduction to linear regression analysis* (5th ed.). John Wiley & Sons.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy, 187*, 169–176.

Nasruddin, Idrus Alhamid, M., Daud, Y., Surachman, A., Sugiyono, A., Aditya, H. B., & Mahlia, T. M. I. (2016). Potential of geothermal energy for electricity generation in Indonesia: A review. *Renewable and Sustainable Energy Reviews, 53*, 733–740. https://doi.org/10.1016/j.rser.2015.09.032

Nepal, R., & Paija, N. (2019). Energy security, electricity, population and economic growth: The case of a developing South Asian resource-rich economy. *Energy Policy, 132*, 771–781. https://doi.org/10.1016/j.enpol.2019.05.054

O'Rourke, F., Boyle, F., & Reynolds, A. (2010). Tidal energy update 2009. *Applied Energy, 87*(2), 398–409. https://doi.org/10.1016/j.apenergy.2009.08.014

Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering, 3*(1), 1167990. https://doi.org/10.1080/23311916.2016.1167990

Polat, A., & Önder, H. (2018). Enerji Tüketiminin GSYİH ile İlişkisi: OECD Ülkeleri Panel Veri Analizi. *Journal of Research in Economics*. https://doi.org/10.24954/mjecon.2018.18

Pui, D. Y. H., Chen, S.-C., & Zuo, Z. (2014). PM 2.5 in China: Measurements, sources, visibility and health effects, and mitigation. *Particuology, 13*, 1–26. https://doi.org/10.1016/j.partic.2013.11.001

Qu, W. H., Xu, L., Qu, G. H., Yan, Z. J., & Wang, J. X. (2017a). The impact of energy consumption on environment and public health in China. *Natural Hazards, 87*(2), 675–697. https://doi.org/10.1007/S11069-017-2787-5/FIGURES/5

Qu, W.-H., Xu, L., Qu, G.-H., Yan, Z.-J., & Wang, J.-X. (2017b). The impact of energy consumption on environment and public health in China. *Natural Hazards, 87*(2), 675–697. https://doi.org/10.1007/s11069-017-2787-5

Requia, W. J., Adams, M. D., & Koutrakis, P. (2017). Association of PM2.5 with diabetes, asthma, and high blood pressure incidence in Canada: A spatiotemporal analysis of the impacts of the energy generation and fuel sales. *Science of the Total Environment, 584–585*, 1077–1083. https://doi.org/10.1016/j.scitotenv.2017.01.166

Sampaio, P. G. V., & González, M. O. A. (2017). Photovoltaic solar energy: Conceptual framework. *Renewable and Sustainable Energy Reviews, 74*, 590–601. https://doi.org/10.1016/j.rser.2017.02.081

Serezli, E., Yüksel, S., Tamer, İ., & Dinçer, H. (2021). The role of innovative renewable energy investment strategies on macroeconomic stability. In *Financial strategies in competitive markets* (pp. 165–178). Springer.

Seydiogullari, H. S. (2013). Renewable energy for sustainable development. *Journal of Planning, 23*(1), 19–25. https://doi.org/10.5505/planlama.2013.14633

Shahzad, U. (2015). The need for renewable energy sources. *International Journal of Information Technology and Electrical Engineering, 2*, 16–18.

Shengfeng, X., Sheng, X. M., Tianxing, Z., & Xuelli, Z. (2012). The relationship between electricity consumption and economic growth in China. *Physics Procedia, 24*, 56–62. https://doi.org/10.1016/j.phpro.2012.02.010

Shetty, C., & Priyam, A. (2021). A review on tidal energy technologies. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2021.10.020.

Silva, S. N., & del Castillo, J. Á. (2021). An approach of the hydropower: advantages and impacts. A review. *Journal of Energy Research and Reviews*, 10–20. https://doi.org/10.9734/jenrr/2021/v8i130201

Sorrell, S. (2015). Reducing energy demand: A review of issues, challenges and approaches. *Renewable and Sustainable Energy Reviews, 47*, 74–82. https://doi.org/10.1016/j.rser.2015.03.002

Subagyo, S., Moh Yanuar, J. P., Bambang, P. N., & Saleh, A. (2021). Substitution of energy needs with renewable energy sources. *IOP Conference Series: Earth and Environmental Science, 927*(1), 012032. https://doi.org/10.1088/1755-1315/927/1/012032

Vakulchuk, R., Overland, I., & Scholten, D. (2020). Renewable energy and geopolitics: A review. *Renewable and Sustainable Energy Reviews, 122*, 109547. https://doi.org/10.1016/j.rser.2019.109547

Welsby, D., Price, J., Pye, S., & Ekins, P. (2021). Unextractable fossil fuels in a 1.5 °C world. *Nature, 597*(7875), 230–234. https://doi.org/10.1038/s41586-021-03821-8

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Yang, B., Guo, J., & Xiao, C. (2018). Effect of PM2.5 environmental pollution on rat lung. *Environmental Science and Pollution Research, 25*(36), 36136–36146. https://doi.org/10.1007/s11356-018-3492-y

Yüksel, S., Dinçer, H., Çağlayan, Ç., Uluer, G. S., & Lisin, A. (2022). Bitcoin mining with nuclear energy. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Yüksel, S., Mikhaylov, A., Ubay, G. G., & Uyeh, D. D. (2021). The role of hydrogen in the Black Sea for the future energy supply security of Turkey. In *Handbook of research on strategic management for current energy investments* (pp. 1–15). IGI Global.

Zhang, M., Liu, X., Wang, W., & Zhou, M. (2013). Decomposition analysis of CO2 emissions from electricity generation in China. *Energy Policy, 52*, 159–165. https://doi.org/10.1016/j.enpol.2012.10.013

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 21582440211040133.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

Zhou, W., Zhu, B., Chen, D., Griffy-Brown, C., Ma, Y., & Fei, W. (2012). Energy consumption patterns in the process of China's urbanization. *Population and Environment, 33*(2–3), 202–220. https://doi.org/10.1007/s11111-011-0133-5

The Impact of Economic Growth on Carbon Emission

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Abstract In this study, we investigate the dynamic relationship between carbon emission and economic growth for Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, and Turkey, which are named Newly Industrialized Countries (NICs). A one-way Granger causality relationship was determined between GDP and carbon in NICs. It is concluded that economic growth causes of carbon emissions in NICs. On the other hand, Granger causality relationship from carbon emission to growth could not be determined. While considering these results, it is understood that countries focus on economic development without focusing on the environmental issues. Hence, it is strongly recommended that necessary regulations should be conducted to minimize carbon emission problems in the industrial development process. Within this framework, clean energy investments should be improved. In addition to this issue, technologic developments should be increased for the purpose of improving carbon capture system. These actions can be very helpful to minimize carbon emission problem.

1 Introduction

Carbon emissions have become a serious problem all over the world. The biggest negativity created by this problem is the emerging global warming problem. Due to the global warming problem, the average temperature is increasing all over the world. This situation causes an increase in forest fires. As a result, agricultural production decreases. This problem in the agricultural sector causes countries to suffer from food shortages (Li et al., 2022; Zhao et al., 2021; Yüksel et al., 2021). Therefore, to reduce such problems, the carbon emission problem should be eliminated.

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To reduce the carbon emission problem, first, the causes of this problem should be determined. One of the most important problems that cause carbon emissions is the preference of fossil fuels in energy production. In this process, carbon gas is released into the atmosphere because of the burning of fossil fuels such as oil and coal. This situation causes significant air and environmental pollution (Adalı et al., 2022; Bhuiyan et al., 2022; Serezli et al., 2021). Therefore, alternative energy types should be preferred instead of fossil fuels. In this context, the use of renewable energy sources will contribute significantly to reducing the carbon emission problem.

It is the use of fossil fuel-based energy that has the most impact on the carbon emission problem. These types of energy are mainly used in industrial production. In this context, it is considered as one of the most important raw materials of the energy industry (Du et al., 2020; Li et al., 2020; Qiu et al., 2020). In summary, it is obvious that if economic growth is carried out unconsciously, this will increase the carbon emission problem. Therefore, especially in recent years, the term sustainable growth has emerged (Fang et al., 2021; Yüksel et al., 2022). In this process, while developing the economy, it is essential not to harm the environment. In order to achieve this goal, it is essential to make the necessary legal arrangements in countries.

In this chapter, an econometric analysis is performed for the purpose of evaluating the relationship between carbon emission and economic growth. In this framework, a group of countries are taken into consideration. This analysis can be very helpful to understand whether these countries focus on environmental issues while improving their economies. With the help of the findings, appropriate strategies can be generated for the countries to provide sustainability in economic development. In other words, the results of this study can lead the policy makers to focus on effective implementations.

2 Data and Descriptive Statistics

In this study, we investigate the dynamic relationship between CO_2 emission and economic growth for Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, and Turkey, which are named Newly Industrialized Countries (NICs). A sample of the study has a balanced panel data set and covers the years 1960–2020. The explanatory variable is CO_2 emissions (CO_2) and the explained variable is GDP per capita (GDPP). The variable of carbon emission is taken as metric tons and real GDP per capita (2015 US$) is used as an indicator of economic growth. All variables were converted to logarithmic form and included in the analysis. The variables CO_2 and GDPP data are taken from respectively the Global Carbon Atlas database and World Bank database.

According to the CO_2 emission data, the country with the highest average carbon emission is China. After China, India, South Africa, Mexico, Brazil, Indonesia, Turkey, Thailand, Malaysia, and the Philippines follow, respectively. Based on GDP data, the country with the highest average per capita income is Mexico. Mexico

is followed by Turkey, South Africa, Malaysia, Thailand, Philippines, China, Brazil, Indonesia, and India. When the standard deviation value, which is an indicator of volatility, is analyzed over CO_2 emissions and GDPP statistics, it is seen that the country with the highest standard deviation for both variables is Thailand, and the country with the lowest standard deviation is South Africa. The skewness coefficient, which expresses the asymmetry in the probability distribution, shows that the series for India for the CO_2 variable is skewed to the left, while the series for the other nine countries are skewed to the right.

When the situation in question is examined over the GDP variable, it has been determined that the variables of the economies of Brazil, Indonesia, Malaysia, Mexico, South Africa, and Thailand are skewed to the right, while the other variables are skewed to the left. According to the kurtosis coefficient showing the tail structure of the distribution curve, it was determined that the CO_2 and GDPP variables were flattened for all individual series. The results of the Jarque-Bera test statistics for the CO_2 variable show that the Mexican and South African series are not normally distributed at the 5% significance level. When the results of the Jarque-Bera test statistics for the GDPP variable were examined, it was concluded that the series belonging to Brazil, India, and Mexico were not normally distributed at the 5% significance level. Finally, when the descriptive statistics are evaluated for the whole panel, it is seen that the GDPP average is greater than the CO_2 for the whole panel. The standard deviation value is higher in the CO_2 variable than in the GDPP. The skewness coefficient shows CO_2 is skewed to the left and GDPP is skewed to the right. The results of the kurtosis coefficient show the CO_2 is flat, and the GDPP is vertical. According to the Jarque-Bera test statistics, the variables do not show normal distribution at the 1% significance level.

3 Empirical Model

In the study, the relationship between carbon emissions and economic growth was investigated by panel cointegration and panel causality tests. The first step of the study, which examines the relationship between CO_2 and GDP, is to test the cross-section dependence. Although different approaches are presented in the literature for testing cross-sectional dependence, the most commonly used tests are Breusch-Pagan Lagrange multiplier (LM), Pesaran scale Lagrangian multiplier (LM), and Pesaran cross-section dependence (CD) tests. With the help of these tests, the cross-sectional dependence of the individual data of the countries and the panel cointegration equation were examined. Cross-sectional dependency is important in determining the unit root test and cointegration model to be applied. In this context, first generation unit root tests should be applied if there is no cross-sectional dependence between the variables, and if there is, second generation unit root tests should be applied. The stationarity of the series was investigated by using Levin-Lin-Chu, Breitung (2000), Im-Pesaran-Shin, and Pesaran CIPS (2007) unit root tests. After the cross-section dependency test, the second step is to test the homogeneity.

According to Pesaran and Yamagata (2008), many empirical studies assume that the slope coefficients in the panel data models are homogeneously distributed among the units. However, in panel data models, the standardization of slope homogeneity according to the cross-section size and time dimension is lost. In the study, the homogeneity of panel sampling was investigated via delta and delta-adj developed by Pesaran and Yamagata (2008). After testing the cross-sectional dependence and homogeneity of the panel sample, the appropriate cointegration method was decided. Augmented mean group (AMG) and correlated effects mean group (CCE) are models that work well under cross-sectional dependence and homogeneity. For this reason, AMG and CCE estimators were used to estimate the long-term coefficients based on countries and panels. Finally, the causality relationship between carbon emissions and economic growth was examined by Granger and Dumitrescu Hurlin panel causality tests. Details on the methods applied in the study are presented in the following section.

4 Empirical Results

Before investigating the cointegration relationship between the variables, it is necessary to investigate whether there is a cross-sectional dependence between the series forming the panel sample. Cross-sectional dependence expresses the dependency relationship between error terms. If the error terms show dependency with each other, the results from conventional F and t tests using variance-covariance estimators will be biased and inconsistent (Breusch & Pagan, 1980; Pesaran, 2004; Sarafidis & Wansbeek, 2010; Baltagi et al., 2012). In order to overcome this problem, cross-section dependency should be tested before starting the panel data analysis. Panel cross-section dependence was investigated by Breusch-Pagan LM (1980), Pesaran CD (2004), and Pesaran et al. (2008) bias adjusted CD tests. Pesaran CD (2004) and Breusch-Pagan LM (1980) tests are based on the comparison of time dimension (T) with the cross-sectional dimension (N). Cross-section dependence is determined according to the Breusch-Pagan LM (1980) test when T>N and according to the Pesaran CD (2004) test when N>T and T>N. Unlike traditional CD and LM tests, the bias-adjusted CD test considers that the group mean is biased. The test statistic developed by Pesaran et al. (2008) is based on adding the variance and mean to the test statistic and correcting the said deviation by removing it.

Pesaran (2004), unlike the Breusch–Pagan test, argues that the criterion for showing an asymptotic distribution is valid when N (0,1), provided that $T \rightarrow \infty$ and $n \rightarrow \infty$ assumptions are met. However, where the sample set is large and the time dimension is finite, the LM test may cause dimensional distortions. This is due to the fact that the LM test is not properly centered on the finite T time dimension (Peseran, 2021). To overcome this situation, Pesaran-Ullah and Yamagato developed a scaled cross-section dependency test for large N and finite T (Pesaran et al., 2008; De Hoyos & Sarafidis, 2006).

The null hypothesis stating that there is no cross-sectional dependence in the individual and cointegration equations for all three tests was rejected at the 1%

significance level. In other words, it has been concluded that there is a cross-sectional dependence between the countries that make up the panel. According to this result, in the sample that defines the newly industrialized country group, a shock that occurs in one country or a change in the policy implemented affects other countries as well.

Another important step in panel data analysis is the determination of homogeneity. According to Pesaran and Yamagata (2008), many empirical studies assume that the slope coefficients in the panel data models are homogeneously distributed among the units. However, in panel data models, the standardization of slope homogeneity with regarding cross-section size and time dimension is lost. Therefore, Pesaran and Yamagata (2008) generalize the test procedure based on Swamy's (1970) test for slope homogeneity, making use of the cross-sectional distribution of individual slopes for panels with a large time dimension.

After the cross-section dependence and homogeneity tests, it is necessary to determine the stationarity and integration degrees of the variables. In the literature, the potential of analysis with nonstationary time series to reveal spurious regression results is often emphasized. For this reason, first, the integration degrees of the series should be examined. There are many unit root tests in the literature. However, the detection of cross-section dependence in the previous section shows that second-generation unit root tests, which consider the cross-section dependence rather than traditional unit root tests, should be applied. In this context, Levin-Lin-Chu, Im-Pesaran-Shin, Breitung (2000), and Pesaran CIPS unit root tests, which are the second-generation unit root tests, were used to examine the integration degrees of the variables.

LLC test recommends a three-step procedure. The first step is to generate orthogonal residuals over the individual ADF regression equations for all samples in the panel. In the second stage, long- and short-term standard deviation values are estimated for individual observations. In the last stage, the t-statistics values are calculated over the pooled sample. The results obtained because of the analysis are compared with the results of the null hypothesis that the series does not contain a unit root and the alternative hypothesis that the series contain a unit root. According to the results of the test statistics, the rejection of the null hypothesis means the panel is stationary (Levin et al., 2002). Contrary to the basic hypothesis of the LLC test, IPS is designed as an alternative to heterogeneous panels and offers panel unit root testing based on the average of two groups (Hlouskova & Wagner, 2005; Breitung & Samarjit, 2005).

Another model in which the stationarity of the series is investigated by the Breitung test. The Breitung test is a pooled panel unit root test that does not require bias correction factors and is obtained by appropriate variable transformation. Because of its unified nature, the Breitung test allows the detection of more heterogeneous alternatives for autoregressive parameters around a mean (Breitung, 2000; Hlouskova & Wagner, 2005; Breitung & Samarjit, 2005; Moon et al., 2006).

After determining the stationarities of the variables, the cointegration relationship between the CO_2 and GDPP variables was examined by the augmented mean group (AMG) and common correlated effect (CCE) methods operating under cross-section

dependence and homogeneity. The AMG method developed by Eberhardt and Bond (2009) adds the common dynamic effect factor to the panel regression equation, allowing the cointegration relationship to be examined under cross-sectional dependence. In the AMG method, the equivalent mean development of unobserved common factors for all countries is calculated by taking the difference from the year dummy values of the regression pooled over the first differences.

The estimation results for the individual and the panel reveal that, the change in GDPP in NICs increases CO_2 emissions. According to the results of the individual AMG estimator, a 1% increase in GDPP will increase CO_2 emissions by 70% in Brazil, 52% in China, 1.01% in Indonesia, 1.09% in India, 1.27% in Malaysia, 1.2% in Mexico, 0.99% in Philippines, 0.58% in Thailand, and 0.78% in Turkey. Similarly, when the CCE estimation results are interpreted, a 1% increase in GDPP will increase CO_2 emissions by 0.07% in Brazil, 15% in Indonesia, 15% in India, 28% in Malaysia, 15% in Mexico, 19% in Philippines, 14% in Thailand, and 12% in Turkey. In both the AMG and CCE estimators, the effect of the increase in GDPP on CO_2 in South Africa was found to be statistically insignificant. When the Panel AMG and Panel CCE results are interpreted, it is seen that the results got with both estimators are consistent with the whole panel. According to the panel AMG result, a 1% increase in GDPP increases CO_2 emissions by 83% in NICs. Although the panel CCE results show that the impact is less, the 1% increase in GDPP shows that the CO_2 emissions in NICs will increase by 78%.

In the Dumitrescu Hurlin causality analysis, the coefficients do not change over time, but differ between individual samples. The Dumitrescu Hurlin panel causality test, which is assumed to be the same for all individual observations, operates under balanced panel models. The Dumitrescu Hurlin causality test tests the effects of the past values of x on the present value of y, just like Granger. While the null hypothesis in the Dumitrescu Hurlin test is established in the same way as Granger, the alternative hypothesis assumes that causality may exist for some individual observations, but not necessarily for the entire panel sample. Therefore, while the null hypothesis is set as $H_0 : \gamma_1 = \ldots = \gamma_K = 0$, the alternative hypothesis defined as $H_1 : \gamma_{i1} = \ldots = \gamma_{iK} = 0$ includes assumptions $\gamma_{i1} \neq 0$ or. . .or $\gamma_{iK} \neq 0$. In the Dumitrescu Hurlin panel causality analysis, the variables must satisfy the stationarity condition. Therefore, the variables that are stationary in their first difference are included in the analysis after the difference process (Hurlin & Dumitrescu, 2012; Lopez & Sylvain, 2017).

Following the above theoretical framework, the findings regarding the panel Granger causality analysis and Dumitrescu Hurlin panel causality analysis are presented in Table 1.

When the Granger panel causality results are examined through Table 1, a one-way Granger causality relationship was determined between GDP and CO_2 in NICs. According to the results of the analysis, the null hypothesis that the GPP is not the Granger cause of CO_2 in NICs was rejected for all three lags. Considering that GDP defines economic growth, it is concluded that economic growth causes of CO_2 emissions in NICs. On the other hand, the null hypothesis that CO_2 is not the Granger cause of GDPP was accepted for all three lags. In other words, Granger

Table 1 Granger panel causality and Dumitrescu Hurlin panel causality test results

Null hypothesis	Prob(lag=1)	Prob(lag=2)	Prob(lag=3)
(a) Granger panel causality tests			
GDPP does not Granger cause CO_2	0.0000	0.0011	0.0018
CO_2 does not Granger cause GDPP	0.7871	0.8834	0.9136
(b) Pairwise Dumitrescu and Hurlin panel causality tests			
GDPP does not homogeneously cause CO_2	0.4835	0.0127	0.0322
CO_2 does not homogeneously cause GDPP	0.5665	0.8689	0.5182

Note: The prob. values got from the Granger panel causality and Dumitrescu Hurlin panel causality results were compared with the significance levels of 1%, 5%, and 10%

causality relationship from CO_2 to growth could not be determined. When Dumitrescu Hurlin causality results are examined, it is seen that the findings are largely consistent with the Granger panel causality results. As shown by the results in panel b of the table, it is seen that the null hypothesis of "GDPP does not homogeneously cause CO_2" was accepted at the first lag. This shows that there is no causal relationship between GDP and CO_2 variables at the first lag. Considering the second and third lags, it is seen that the null hypothesis that GDPP is not the cause of CO_2 was rejected at the 0.05 significance level. According to this result, when the second and third lag levels are considered, it is concluded that economic growth causes of CO_2 emissions. When it is questioned whether CO_2 causes of growth, the findings show that there is no causal relationship for all three lags, just like the Granger results.

5 Discussion and Conclusion

Carbon emissions is accepted as the main cause of global warming problem. Because of the global warming problem, there will be a significant increase in forest fires. As a result, agricultural production decreases (Kou et al., 2022; Liu et al., 2021; Mukhtarov et al., 2022; Xie et al., 2021). This problem in the agricultural sector causes countries to suffer from food shortages. Therefore, to reduce such problems, the carbon emission problem should be eliminated. For the aim of reducing the carbon emission problem, first, the causes of this problem should be determined. One of the most important problems that cause carbon emissions is the preference of fossil fuels in energy production (Dinçer et al., 2022; Meng et al., 2021; Zhe et al., 2021; Zhou et al., 2021). In this process, carbon gas is released into the atmosphere because of the burning of fossil fuels such as oil and coal. This situation causes significant air and environmental pollution. Therefore, alternative energy types should be preferred instead of fossil fuels. In this context, the use of renewable energy sources will contribute significantly to reducing the carbon emission problem.

It is the use of fossil fuel-based energy that has the most impact on the carbon emission problem. These types of energy are mainly used in industrial production. In this context, it is considered as one of the most important raw materials of the energy industry. In summary, it is obvious that if economic growth is carried out unconsciously, this will increase the carbon emission problem (Dinçer et al., 2020). Therefore, especially in recent years, the term sustainable growth has emerged. In this process, while developing the economy, it is essential not to harm the environment. In order to achieve this goal, it is essential to make the necessary legal arrangements in countries.

In this study, it is aimed to investigate the dynamic relationship between carbon emission and economic growth for Brazil, China, India, Indonesia, Malaysia, Mexico, Philippines, South Africa, Thailand, and Turkey, which are named Newly Industrialized Countries (NICs). A one-way Granger causality relationship was determined between GDP and carbon in NICs. It is concluded that economic growth causes of carbon emissions in NICs. On the other hand, Granger causality relationship from carbon emission to growth could not be determined. While considering these results, it is understood that countries focus on economic development without focusing on the environmental issues.

While considering the results of this analysis, it is strongly recommended that necessary regulations should be conducted to minimize carbon emission problems in the industrial development process. In this context, clean energy investments should be improved. In addition to this issue, technologic developments should be increased for the purpose of improving carbon capture system (Ding et al., 2021; Dong et al., 2022; Haiyun et al., 2021; Kostis et al., 2022). These actions can be very helpful to minimize carbon emission problem. In this context, first of all, states should provide the necessary incentives for clean energy investments. These incentives may have an impact on the cost advantage of investments. In this way, renewable energy projects will be preferred over fossil fuels in countries (Cheng et al., 2020; Mikayilov et al., 2020; Yuan et al., 2020). On the other hand, companies need to adapt to carbon capture technology in order to reduce the carbon emission problem. In this context, priority should be given to making the necessary technological investments.

References

Adalı, Z., Dinçer, H., Eti, S., Mikhaylov, A., & Yüksel, S. (2022). Identifying new perspectives on geothermal energy investments. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Baltagi, B. H., Feng, Q., & Chihwa, K. (2012). A lagrange multiplier test for cross-sectional dependence in a fixed panel data model. *Journal of Econometrics, 170*(1), 164–177.

Bhuiyan, M. A., Dinçer, H., Yüksel, S., Mikhaylov, A., Danish, M. S. S., Pinter, G., Uyeh, D. D., & Stepanova, D. (2022). Economic indicators and bioenergy supply in developed economies: QROF-DEMATEL and random forest models. *Energy Reports, 8*, 561–570.

Breitung, J. (2000). The local power of some unit root tests for panel data. *Advances in Econometrics, 15*, 161–177.

Breitung, J., & Samarjit, D. (2005). Panel unit root tests under cross-sectional dependence. *Statistica Neerlandica, 59*(4), 414–433.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies, 47*(1, Econometrics Issue), 239–253.

Cheng, F., Lin, M., Yüksel, S., Dinçer, H., & Kalkavan, H. (2020). A hybrid hesitant 2-tuple IVSF decision making approach to analyze PERT-based critical paths of new service development process for renewable energy investment projects. *IEEE Access, 9*, 3947–3969.

De Hoyos, R. E., & Sarafidis, V. (2006). Testing for cross-sectional dependence in panel-data models. *The Stata Journal, 6*, 482–496.

Dinçer, H., Yüksel, S., & Martínez, L. (2022). Collaboration enhanced hybrid fuzzy decision-making approach to analyze the renewable energy investment projects. *Energy Reports, 8*, 377–389.

Dinçer, H., Yüksel, S., Ubay, G. G., & Karakuş, H. (2020). BSC-based evaluation for the factors affecting the performance of wind energy companies. In *Strategic priorities in competitive environments* (pp. 1–15). Springer.

Ding, Z., Yüksel, S., & Dincer, H. (2021). An Integrated Pythagorean fuzzy soft computing approach to environmental management systems for sustainable energy pricing. *Energy Reports, 7*, 5575–5588.

Dong, W., Zhao, G., Yüksel, S., Dinçer, H., & Ubay, G. G. (2022). A novel hybrid decision-making approach for the strategic selection of wind energy projects. *Renewable Energy, 185*, 321–337.

Du, L., Dinçer, H., Ersin, İ., & Yüksel, S. (2020). IT2 fuzzy-based multidimensional evaluation of coal energy for sustainable economic development. *Energies, 13*(10), 2453.

Eberhardt, M., & Bond, S. (2009). Cross-Section Dependence in Nonstationary Panel Models: A Novel Estimator, University Library of Munich, Germany, MPRA Paper.

Fang, S., Zhou, P., Dinçer, H., & Yüksel, S. (2021). Assessment of safety management system on energy investment risk using house of quality based on hybrid stochastic interval-valued intuitionistic fuzzy decision-making approach. *Safety Science, 141*, 105333.

Haiyun, C., Zhixiong, H., Yüksel, S., & Dinçer, H. (2021). Analysis of the innovation strategies for green supply chain management in the energy industry using the QFD-based hybrid interval valued intuitionistic fuzzy decision approach. *Renewable and Sustainable Energy Reviews, 143*, 110844.

Hlouskova, J., & Wagner, M. (2005). The performance of panel unit root and stationarity tests: Results from a large-scale simulation study. *Econometric Reviews., 25*, 85–116.

Hurlin, C., & Dumitrescu, E. (2012). *Testing for granger non-causality in heterogeneous panels*. HAL Open Science.

Kostis, P., Dinçer, H., & Yüksel, S. (2022). Knowledge-based energy investments of European economies and policy recommendations for sustainable development. *Journal of the Knowledge Economy*, 1–33. https://doi.org/10.1007/s13132-022-00972-5

Kou, G., Yüksel, S., & Dinçer, H. (2022). Inventive problem-solving map of innovative carbon emission strategies for solar energy-based transportation investment projects. *Applied Energy, 311*, 118680.

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics, 108*, 1–24.

Li, J., Yüksel, S., Dınçer, H., Mikhaylov, A., & Barykin, S. E. (2022). Bipolar q-ROF hybrid decision making model with golden cut for analyzing the levelized cost of renewable energy alternatives. *IEEE Access, 10*, 42507–42517.

Li, X., Zhu, S., Yüksel, S., Dinçer, H., & Ubay, G. G. (2020). Kano-based mapping of innovation strategies for renewable energy alternatives using hybrid interval type-2 fuzzy decision-making approach. *Energy, 211*, 118679.

Liu, J., Lv, J., Dinçer, H., Yüksel, S., & Karakuş, H. (2021). Selection of renewable energy alternatives for green blockchain investments: A hybrid IT2-based fuzzy modelling. *Archives of Computational Methods in Engineering, 28*(5), 3687–3701.

Lopez, L., & Sylvain, W. (2017). Testing for Granger Causality in Panel Data, University of Neuchatel, Institute of Economic Research, IRENE Working Paper 17-03.

Meng, Y., Wu, H., Zhao, W., Chen, W., Dinçer, H., & Yüksel, S. (2021). A hybrid heterogeneous Pythagorean fuzzy group decision modelling for crowdfunding development process pathways of fintech-based clean energy investment projects. *Financial Innovation, 7*(1), 1–34.

Mikayilov, J. I., Mukhtarov, S., Dinçer, H., Yüksel, S., & Aydın, R. (2020). Elasticity analysis of fossil energy sources for sustainable economies: A case of gasoline consumption in Turkey. *Energies, 13*(3), 731.

Moon, H.-R., Perron, B., & Phillips, P. C. B. (2006). On the breitung test for panel unit roots and local asymptotic power. *Econometric Theory, 22*(6), 1179–1190.

Mukhtarov, S., Yüksel, S., & Dinçer, H. (2022). The impact of financial development on renewable energy consumption: Evidence from Turkey. *Renewable Energy, 187*, 169–176.

Pesaran, M. H. (2004). General diagnostic tests for cross-section dependence in panels, IZA DP, Discussion Paper No. 1240.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, 22*(2), 256–312. Heterogeneity and Cross Section Dependence in Panel Data Models: Theory and Applications.

Pesaran, M. H. (2021). General diagnostic test for cross-sectional dependence in panels. *Empirical Economics*, Springer, *60*(1), 13–50.

Pesaran, M. H., Ullah, A., & Yamagata, T. (2008). A bias-adjusted LM test of error cross section independence. *The Econometrics Journal, 11*(1), 105–127.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics, 142*(1), 50–93.

Qiu, D., Dinçer, H., Yüksel, S., & Ubay, G. G. (2020). Multi-faceted analysis of systematic risk-based wind energy investment decisions in E7 economies using modified hybrid modeling with IT2 fuzzy sets. *Energies, 13*(6), 1423.

Sarafidis, V., & Wansbeek, T. (2010). Cross-sectional dependence in panel data analysis, 401 MPRA, No. 20367.

Serezli, E., Yüksel, S., Tamer, İ., & Dinçer, H. (2021). The role of innovative renewable energy investment strategies on macroeconomic stability. In *Financial strategies in competitive markets* (pp. 165–178). Springer.

Xie, Y., Zhou, Y., Peng, Y., Dinçer, H., Yüksel, S., & an Xiang, P. (2021). An extended pythagorean fuzzy approach to group decision-making with incomplete preferences for analyzing balanced scorecard-based renewable energy investments. *IEEE Access, 9*, 43020–43035.

Yuan, J., Zhang, Z. M., Yüksel, S., & Dinçer, H. (2020). Evaluating recognitive balanced scorecard-based quality improvement strategies of energy investments with the integrated hesitant 2-tuple interval-valued Pythagorean fuzzy decision-making approach to QFD. *IEEE Access, 8*, 171112–171128.

Yüksel, S., Dinçer, H., Çağlayan, Ç., Uluer, G. S., & Lisin, A. (2022). Bitcoin mining with nuclear energy. In *Multidimensional strategic outlook on global competitive energy economics and finance*. Emerald Publishing Limited.

Yüksel, S., Mikhaylov, A., Ubay, G. G., & Uyeh, D. D. (2021). The role of hydrogen in the Black Sea for the future energy supply security of Turkey. In *Handbook of research on strategic management for current energy investments* (pp. 1–15). IGI Global.

Zhao, Y., Xu, Y., Yüksel, S., Dinçer, H., & Ubay, G. G. (2021). Hybrid IT2 fuzzy modelling with alpha cuts for hydrogen energy investments. *International Journal of Hydrogen Energy, 46*(13), 8835–8851.

Zhe, L., Yüksel, S., Dinçer, H., Mukhtarov, S., & Azizov, M. (2021). The positive influences of renewable energy consumption on financial development and economic growth. *SAGE Open, 11*(3), 21582440211040133.

Zhou, P., Luo, J., Cheng, F., Yüksel, S., & Dinçer, H. (2021). Analysis of risk priorities for renewable energy investment projects using a hybrid IT2 hesitant fuzzy decision-making approach with alpha cuts. *Energy, 224*, 120184.

Examining the Nexus Between Cost Overrun of Central Projects and N_2O Emissions: An Analysis for India

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Abstract It is a well-known fact that infrastructural projects have long-run impacts on the income and employment of the countries. Besides, it is also the fact that these projects badly impact the environment in terms of pollution through emissions of different greenhouse gases and particulate matters. Further, if the projects get delayed due to some reasons there arises the additional emissions burden upon the environment. Under the backdrop, the present study aims to examine whether cost overruns in different infrastructural projects have any sort of co-movements with the emissions of nitrous oxide (N_2O), which is the prime pollutant in infrastructural projects, in case of India for the period 1995–2018. Employing Engle-Granger cointegration test technique, the study finds a significant persistent relationship between the cost overrun of delayed central sector projects and nitrous oxide in India. The study also finds negative but insignificant coefficient of the error correction term in the ECM. Finally, the Granger causality test demonstrates that cost overrun has had no effect on or influences environmental degradation in India due to N_2O emissions in the short term. The government of the country should apply good governance tools to control the problems of cost overruns.

1 Introduction

Infrastructural development is essential for increasing economic progress and reducing poverty. There is no doubt that high-quality public infrastructure promotes economic growth, job creation, and citizens' well-being. Land plays an important part in that case for the selection of a construction site. The construction and disposal of infrastructure thus impact the condition of the soil structure through the use of vehicles and heavy machinery during the transport of materials to the construction site and the transport of waste materials during the demolition of infrastructure. This transportation of staff and raw materials to and from construction sites results in

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greenhouse gas (GHG) emissions into the environment, and these emissions contribute to climate change, which results in both human health and environmental hazards.

Infrastructure construction also consumes a significant amount of materials derived from natural resources. Many materials used in the operation of infrastructure, like coal, steel, or nuclear power stations, damage the environment and create pollution during their extraction. The sourcing, processing, manufacture, distribution, use, and disposal of construction materials have significant local and global environmental impacts.

Thus, maintenance or modernization of existing infrastructure may also impact the ecology and biodiversity on the chosen site and in surrounding areas; water resources are also affected due to growing pressure on the quantity and quality of water supplies during construction; and it also affects the physical, cultural, social, and economic factors in an area.

The most distinct part of India's physical infrastructure development in recent years is the development of road networks across the country. Majority of infrastructure projects in India are affected by time overruns. These overruns vary from a few months to as high as five or more years, placing the project viability at risk. As many as 470 central sector projects have witnessed a combined cost overrun of ₹4.37 trillion and 560 projects have an average time overrun of 46.94 months, according to the Ministry of Statistics and Programme Implementation (MoSPI). MoSPI monitors infrastructure projects of ₹150 crores and above. The August 2021 report shows that of the 1718 central infrastructure projects, 560 projects reported a delay in the original deadline, while 86 projects, of which 36 are mega projects worth more than ₹1000 crore, have reported further delays. The sector-wise break-up reflects that road transport and highways, railways, petroleum, coal, and power have approximately 1522 projects being monitored. The delay is likely to result in cost overruns of ₹4.37 trillion, or 19.9% of the original cost against 8.59% in the quarterly project status.

One major factor that has been identified as the reason for cost overruns in most projects get delayed (i.e., when there is a delay, the total overhead costs rise) is a delay in tie-up for project financing, delay in finalization of detailed engineering, change in scope, delay in tendering, ordering and equipment supply, and law and order problems are among the other reasons.

While localized interruptions hindered all projects, project implementers blamed factors like a lack of infrastructure support and connections, land acquisition delays due to political intervention in relocation; land scarcity with greater land transaction costs; poor planning institutions; and substantial legal delays in rehabilitation, forest and environmental clearances, inadequate workforce, and changes in the scope of the project for the delays.

As per a recent report submitted in Rajya Sabha, the Upper House of the Indian Parliament, by the Union Minister of Coal in November 2021, a total of 15 coal mine projects of Coal India Ltd. (CIL) are held up due to delays in environmental clearance, land acquisition and Rehabilitation and Resettlement (R&R). A total of 5 out of 15 delayed Coal India projects are awaiting forest or environmental

clearance. So, the project gets delayed beyond its expected completion time due to certain difficulties, i.e., more time is required to finish the project than initially planned for which the client/contractor has to spend more money for the completion of the project than originally estimated, i.e., the project goes over budget.

Infrastructure development is critical to economic growth. Land is a state matter; hence the Centre and states must collaborate to make land acquisition a simple and painless process for investors. Environmental approvals must be granted in a more efficient and open manner. Everybody must follow time-bound clearances and implementation guidelines.

Infrastructure projects in India are infamous for delays and cost overruns. In India, the total original cost of implementation of the 1565 projects was Rs. 21,86,542.05 crores and their anticipated completion cost is likely to be Rs. 26,59,914.61 crores, which reflects overall cost overruns of Rs. 4,73,352.56 crores, i.e., 21.65% of original cost (MoSPI report, 2022). The problem of cost overrun of central sector project, especially in the construction industry, is a worldwide phenomenon. A project in the construction is considered successful if it is completed on time, within budget, and to specification or quality standards. However, in the recent past, it is seen that most projects get delayed, leading to cost and time overruns.

More time delay in Infrastructure construction leads to more consumption of materials derived from natural resources. Many materials used in the operation of infrastructure, like coal, steel, or nuclear power stations, damage the environment and create pollution during their extraction. The sourcing, processing, manufacture, distribution, use, and disposal of construction materials have significant environmental impacts. Land plays an important part in that case for the selection of a construction site. The construction and disposal of infrastructure thus impact the condition of the soil structure through the use of vehicles and heavy machinery during the transport of materials to the construction site and the transport of waste materials during the demolition of infrastructure. This transportation of staff and raw materials to and from construction sites results in GHGs emissions into the environment and thus global warming.

Nitrous oxide (N_2O) which is equivalent to CO_2 is a major contributor to global warming, with a 114-year atmospheric persistence compared to 12 years for methane. Within 100 years, nitrous oxide's global warming potential per kg is roughly 310 times that of carbon dioxide. N_2O can live in the atmosphere for up to 125 years. Most N_2O emissions have come from emerging countries like India, China, and Brazil. The growth has been the quickest in the past five decades; the research was conducted through an international collaboration between the International Nitrogen Initiative (INI) and the Global Carbon Project of Future Earth, a partner of the World Climate Research Programme.

Elevated levels of nitrous oxide (N_2O) can cause damage to the human respiratory tract and increase a person's vulnerability to, and the severity of, respiratory infections and asthma. Long-term exposure to high levels of nitrous oxide can cause chronic lung disease. Globally, about 40% of total N_2O emissions come from human

activities, such as agriculture, fuel combustion, wastewater management, and industrial processes are increasing the amount of N_2O in the atmosphere. In 2019, nitrous oxide (N_2O) accounted for about 7% of all US greenhouse gas emissions from human activities. Also, nitrous oxide is emitted from agriculture, land use, transportation, industry, and other activities. Nitrous oxide is generated as a byproduct during the production of chemicals such as nitric acid, which is used to make synthetic commercial fertilizer, and in the production of atopic acid, which is used to make fibers, like nylon, and other synthetic products.

It is thus derived theoretically that infrastructure projects in different heads like cement production, coal production, atomic energy production, fertilizers, and railway projects have positive connections with N_2O emission. Further, there is an increasing possibility that delayed projects will lead to huge economic and environmental costs. Under this backdrop, the present study examines the relationship between Cost Overrun in Central Projects (COCP) and Nitrous Oxide (N_2O) as the environmental degradation in India over the period from 1995 to 2018 by employing time series econometric techniques.

2 Literature Review

Nitrous oxide (N_2O) is a byproduct of fuel combustion in mobile and stationary sources. Nitrous oxide emissions from stationary combustion sources result predominantly from the burning of coal at electric power plants. Nitrous oxide is emitted from wastewater that contains nitrogen-based organic materials, such as those found in human or animal waste. Factors that influence the amount of nitrous oxide generated from wastewater include temperature, acidity, biochemical oxygen demand, and nitrogen concentration.

The Kyoto Protocol aims to reduce the emissions of six GHGs, which have a global warming potential higher than CO_2 (Gielen and Kram, 1998). The most important source of N_2O emissions is the agricultural sector, where 30–50% of the total emissions happen due to the use of nitrogen fertilizers making fertilizer projects the key source of N_2O emissions.

The majority of nitrous oxide comes from agriculture, including microbes in fertilized soils and animal manure. It is a potent greenhouse gas with about 300 times the heat-trapping power of carbon dioxide. Two additional important factors driving soil N_2O emissions are labile soil organic C and inorganic N. Manure stabilized soil improved mine soil N status, increased heterotrophic activity, and introduced the potential for denitrification. N_2O emission from manure treatments was up to 3–5 times greater than those from no manure controls (Dutta et al., 2015).

Since road construction seems to have the potential to drastically impact environmental quality and may be responsible for enormous GHG emissions, quantifying its effects becomes an important concern. Pilger et al. (2020) investigates the environmental impacts, associated with the input and output flows, as well as the

cost overruns of the construction of a road and also shows using of life cycle assessment (LCA) to quantify the environmental impacts.

Some studies, on the other hand, discover that transportation infrastructure has either a positive or a negative impact on environmental air quality. Some suggest that increasing transportation infrastructure investment is conducive to improving air quality. Guo et al. (2020) from their analysis based in China found that increasing road construction will be in favor of reducing air pollution in the future, as increases in road width can help mitigate congestion, improve fuel efficiency, and thus reduce emissions.

As half of annual greenhouse gas (GHG) emissions are associated with infrastructure, the Scottish government developed a new infrastructure assessment framework and methodology to enable comprehensive infrastructure investment decision to achieve an inclusive net-zero carbon economy (Brander and Jackson 2021). They used some methods such as taxonomies, input–output modeling, and integrated assessment modeling.

In Turkey, Dalkic et al. (2017) discovered that high-speed rail systems have a relatively low level of emissions impact, despite the fact that the transportation sector is one of the major emitters of GHGs due to the high consumption of fossil fuels.

By 2030, the expected growth in industry, residential, transportation, power generation, and construction will increase pollution-related health impacts for most cities in India (Guttikunda et al. 2014). The available information on urban air pollution, its sources, and the potential of various interventions to control pollution, should support a cleaner path to 2030.

The steel industry is the third largest contributor to air pollution and one of the largest contributors to emissions of GHGs. Every ton of steel produced in 2018 emitted on average 1.85 tons of carbon dioxide, equating to about 8% of global carbon dioxide emissions (World Steel Association). Steel is used in every important industry energy, construction, automotive and transportation, infrastructure, packaging, and machinery.

Despite the fact that aviation provides just around 3% of total global NO_2 from all human sources, some researchers found that aircraft contributes a significant percentage of NO_2 concentrations in the upper troposphere, also causes a strong impact on ozone layer for as it accumulates in the atmosphere over a long period of time.

An increasing rate of greenhouse gas (GHG) emissions from infrastructural advancement create a climatic burden on the atmosphere. Without careful environmental analysis and a risk response strategy, infrastructural projects are bound to fail and may cause direct financial loss due to cost overruns.

The growing demand for food in India coupled with the growing population will further increase global nitrous oxide emissions. As we have already discussed earlier, a major proportion of the N_2O emissions in the last four decades have come from the agricultural sector, mainly because of the use of nitrogen-based fertilizers.

There are a number of case studies that show the scope and severity of infrastructure project delays and cost overruns. Delays and cost overruns in public sector

projects can increase the capital-output ratio in the sector and elsewhere, limiting investment efficacy.

Morris investigates the opportunity cost of an extra unit of capital for the extra time it takes to complete a project. Internal issues in the public sector and government, as per the study, are mostly to blame for delays and expense overruns. The most common cause of cost and time overruns is poor project preparation, which leads to scope modifications during execution.

Based on a large dataset of 894 projects in India, Singh (2010) shows that time overrun is one of the important factors behind cost overruns and the longer the implementation phase, the higher the cost overruns. The study also reveals that some delays and cost overruns are unavoidable due to flawed methodologies and contractual incompleteness, implying that poor planning and contractual failures are mostly to blame for cost overruns and, as a result, for a waste of public resources.

Also another investigation is done based on a combined set of projects from 17 infrastructural sectors, Singh (2011) discovered that civil construction projects have experienced higher cost overruns and longer delays than other projects; the National Highways Authority of India (NHAI) has a significantly superior project delivery system than the Indian Railways; and compared to other road projects and PPP projects in India. The reason behind this delay is incompleteness of project designs and contracts which further implies that a better initial design may help reduce delays and cost overruns.

According to Ganiyu (2015), the construction industry's responsiveness to the preservation of natural resources for the benefit of future generations (sustainability) has been very poor in developing countries. Eliminating material wastage and complexities in housing processes are the core factors that, if achieved, will reduce construction costs to a minimum, reduce the negative impact of construction on the environment while maintaining high-quality housing.

Excavators, forklifts, and loaders all have their own power train mechanisms, according to Doo-Yearn (2011). The economic and environmental impacts are larger than that of the vehicle sector because of the enormous labor load and extended daily operative hours. Energy saving technologies, such as hybrid power trains, have prospects in the sector. Hybrid forklifts and loaders will be available soon. Delays in decision-making, according to Bhatia (2016), are the key determinants and explanations for schedule and expense overruns in residential construction projects. Unforeseen occurrences, internal conflicts within the project team, poor work organization and planning, and no proactive action done by any of the parties involved.

Herrera et al. (2020), focusing on road infrastructure, observe that cost overruns occur on roadways in many countries, owing to design flaws and revisions. The occurrence of cost overruns in road projects is strongly influenced by design and planning considerations.

In their study, Dlamini and Cumberlege (2021) aim to determine the impact of cost overruns and delays in construction projects, and the findings suggest that they have a negative influence on the construction sector. Financial control, planning, and control, application of project budget procedures, cash flow management, and strategy execution were determined to be critical competencies for preventing cost

overruns, according to the study. Planning and scheduling, time management, application of construction processes, decision-making, and risk management were the essential abilities for time overruns.

3 Significance of the Study

In this research, we set out to identify and review the existing literature of the last decade quantifying the embodied GHG emissions in a case study, the Cost Overrun of Central Projects in India. We have taken nitrous oxide (N_2O) as a major environmental pollutant that affects the atmosphere more than 300 times in comparison with CO_2. A number of studies have been done based on other related GHGs based on individual construction project works, like railways, transportation, mining, and power plants, but few works consider N_2O as a major pollutant in the atmosphere, and no works consider all major infrastructural central projects' environmental impacts from the point of project delay and cost overruns.

4 Objective of the Study

In this study, we tried to find out whether there is a long-run relationship between central projects' cost overruns and N_2O emissions due to these projects and to show which infrastructural projects emitted N_2O more than others.

5 Selected Variables and Source of Data

The data regarding Cost Overrun Central Projects (COCP), measured in INR crore, is collected from the Ministry of Statistics and Programme Implementation (MoSPI, https://www.mospi.gov.in) and the data of Nitrous oxide (N_2O) (measured in thousand metric tons of CO_2 equivalent) as proxied for environmental degradation is collected from the World Bank Open Data (https://data.worldbank.org). Cost overrun is taken from fourteen selected sector central projects which are responsible for N_2O emissions—Atomic energy, Civil aviation, Coal, Finance, Fertilizers, Mines, Steel, Petrochemicals, Petroleum, Power, Railways, Surface transport, Telecommunication, and others (Heavy Industry + Defence Production + Health and family welfare + Urban Development).

6 Research Methodology, Results, and Discussions

Firstly, the Karl Pearson's correlation coefficient is estimated to show the degree of association between COCP and N_2O then appropriate time series econometric tools are applied to examine the significant persistence relation between them. For this, unit root test (ADF and PP) has been carried out to verify the stationarity of data series, then the Engle-Granger cointegration test is conducted to show the long-run equilibrium relationship between COCP and N_2O, then Error Correction Mechanism (ECM) has been applied for short-run dynamics between these two variables and finally Granger causality test is applied to identify the direction of causality between them.

6.1 Correlation Coefficient

The Karl Pearson's correlation coefficient is used to determine the degree of linear relation between COCP and N_2O. It is also called as Cross correlation coefficient as it predicts the relationship between two quantities. Since the present study deals with these two variables of discussion, the correlation coefficient between them is calculated using the formula:

$$r = \frac{T(\sum(\mathrm{N_2O})(\mathrm{COCP}) - \sum(\mathrm{N_2O})\sum(\mathrm{COCP})}{\left[T\sum(\mathrm{N_2O})^2 - (\sum \mathrm{N_2O})^2\right]\left[T\sum(\mathrm{COCP})^2 - (\sum \mathrm{COCP})^2\right]}.$$

where, T is the total time point.

The estimated value of correlation coefficient between COCP and N_2O, i.e., $r = 0.7668$ and the respective t-value is 5.6037 which is significant at less than 1%. This positive and significant correlation implies that both the central project cost overrun/time delay and nitrous oxide emissions as environmental degradation increased simultaneously during the period 1995–2018 in India. Following the result, the present study used some required econometric time series methods to justify the long-run significant relationship between these two variables as follows-

6.2 Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Unit Root Test

Time series variables included in regression models need to be stationary because regression of a nonstationary variable to another nonstationary variable leads to a situation of spurious regression. Thus, in this section, at first, unit root test result is shown by applying Augmented Dickey-Fuller (ADF, 1979) and Phillips and Perron

test. To tackle the problem of Autocorrelation problem, Dickey and Fuller have developed a test called the ADF test. They augmented by including lags of the dependent variable to correct any serial correlation in the disturbance term. The equations are:

For COCP:

$$\Delta(\mathrm{COCP}) = \alpha + \beta t + \delta(\mathrm{COCP})_{t-1} + \sum_{i=1}^{m} \gamma_{\square} \Delta(\mathrm{COCP})_{t-i} + u_t \tag{1}$$

For N_2O:

$$\Delta(\mathrm{N_2O})_t = \alpha + \beta t + \delta(\mathrm{N_2O})_{t-1} + \sum_{i=1}^{m} \gamma_{\square} \Delta(\mathrm{N_2O}) + u_t \tag{2}$$

where, u_t is a white noise error term. α and β can be set to zero if required. The equation incorporates different terms $\Delta(\mathrm{N_2O})_{t-1} = (\mathrm{N_2O}_{t-1} - \mathrm{N_2O}_{t-2})$, $\Delta(\text{-}\Delta(\mathrm{N_2O})_{t-1} = (\mathrm{N_2O}_{t-1} - \mathrm{N_2O}_{t-2}), \Delta(\mathrm{N_2O})_{t-2} = (\mathrm{N_2O}_{t-2} - \mathrm{N_2O}_{t-3})$, etc. If the computed absolute value of the tau statistics (τ) exceeds the ADF or Mackinnon critical values, we reject the null hypothesis that H_0: $\delta = 0$, in which case the time series is stationary. The augmented Dickey-Fuller test is based on the assumption that the errors are not statistically dependent and have a constant variance. While relaxing these assumptions we can use an alternative test namely the Phillips-Perron test. Phillips and Perron developed a generalization of the ADF test procedure that allows for less restrictive assumptions about the distribution of error terms. The test regressions are:

For COCP:

$$\Delta(\mathrm{COCP})_t = \delta(\mathrm{COCP})_{t-1} + u_t \tag{3}$$

For N_2O:

$$\Delta(\mathrm{N_2O})_t = \delta(\mathrm{N_2O})_{t-1} + u_t \tag{4}$$

The asymptotic distribution of the PP τ-statistic is the same as the distribution of ADF τ-statistic. So, the ADF critical values are still applicable here.

The result is shown in Table 1.

From the ADF and PP test results, the present research study makes out that both the series belonging to N_2O and COCP are not stationary in their level values. It becomes stationary when first difference is taken. It is found that the hypotheses of unit root for both the series are rejected under first difference at less than 1% level of significance. Thus, the result reinforces to conclude that the series is in first difference form and so they do not have a unit root and are stationary, i.e., the series are I (1).

Table 1 Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test results

Unit root test	Level	
	N_2O	COCP
ADF	−0.977535	1.016440
PP	−0.929537	0.848312
	First difference	
ADF	−3.47589***	−3.990225***
PP	−3.511432***	−4.012985***

Note: '***' implies significant at 1% level
Source: Authors' own calculations

Table 2 ADF test results for residuals $(\widehat{\varepsilon}_t)$ in level

	Without drift and trend	Probability	Remark
ADF	−2.178625	0.0310	Stationary at level
PP	−2.124792	0.0349	Stationary at level

Source: Authors' own calculations

6.3 *Engle-Granger (EG) Cointegration Test and Error Correction Mechanism (ECM)*

In this section, the study conducts a cointegration test to show the existence of long-run or equilibrium relation and ECM to show the short-run dynamics between COCP and N_2O. Engle and Granger (1987) provided a two-step test to examine the presence of cointegrating relationship (i.e., long-run relationship) between the variables. Since both COCP and N_2O are I(1) series then according to this method, the estimated residuals series $\widehat{\varepsilon}_t \left[= (\text{COCP})_t - \widehat{a} - \widehat{b}(\text{N}_2\text{O})_t\right]$ should be I(0) to have a long-run association between them. Thus, check stationarity of $\widehat{\varepsilon}_t$ to determine if the variables were actually cointegrated. The form of the ADF test equation of the estimated residual is:

$$\Delta\widehat{\varepsilon}_t = \delta\widehat{\varepsilon}_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta\widehat{\varepsilon}_{t-1} + v_t \tag{5}$$

The results is shown in Table 2.

In Table 2, both the ADF and the PP test results show that the residual series $(\widehat{\varepsilon}_t)$ is stationary in level. Thus the residual series is I(0). This implies that both the variables N_2O and COCP are cointegrated, i.e., nitrous oxide and cost overrun of delayed central sector projects have a long lasting relationship between them. More time spent on infrastructure construction means more materials produced from natural resources are consumed. The reason behind is that many infrastructural materials, such as coal, steel, and nuclear power plants, pollute the environment and cause pollution throughout their extraction. Construction materials have major environmental implications during their sourcing, processing, manufacture,

distribution, usage, and disposal. Despite this, infrastructure construction and disposal have an impact on the soil structure due to the usage of vehicles and heavy machinery to bring materials to the construction site and to transfer waste materials during infrastructure destruction. Staff and raw materials are transported to and from building sites, resulting in N_2O emissions into the atmosphere and therefore contributing to the global warming.

Since the co-integration is confirmed to exist between N_2O and COCP, then the next step entails the construction of Error Correction Mechanism (ECM) to model dynamic relationship between the two. The purpose of the ECM is to indicate the speed of adjustment from the short-run disequilibrium to the long-run equilibrium state. We can write the ECM as:

$$\Delta(N_2O)_t = \phi + \gamma\Delta(COCP)_t + \lambda\widehat{\varepsilon}_{t\text{-}1} + W_t \tag{6}$$

where, γ is the short-run coefficient which measures the immediate impact of a change in COCP will have on a change in N_2O. This gives the marginal contribution of cost overrun of delayed central sector projects to nitrous oxide in the environments. λ is the adjustment effect (or, error correction coefficient and shows how much of the disequilibrium is being corrected) and $\widehat{\varepsilon}_{t-1}$ is error correction term. When $\widehat{\varepsilon}_{t-1}$ is non-zero (positive or negative), there is disequilibrium in the short run. However, equilibrium will be restored in the long run if and only if $\lambda < 0$.

6.4 The Estimated ECM

$$\begin{array}{lcccccc} \Delta\left(\widehat{N_2O}\right) & = & 4434.51 & - & 0.111057\Delta(COR) & - & 0.0242\widehat{\varepsilon}_{t-1} \\ p & : & [0.0002] & & [0.3458] & & [0.6512] \end{array}$$

The coefficient of $\widehat{\varepsilon}_{t-1}$ is negative but insignificant. The negative coefficient of $(res)_{t\text{-}1}$ implies that if there were any short-term disturbance from the long-run stable relationship, such disturbance would be corrected over time and the long-run stable relationship would be restored. The coefficient of Δ(COCP) is also negative and insignificant.

6.5 Granger Causality Test

In this section, the study conducts Granger causality test to examine the direction of causality from independent variable to dependent variable. Granger (1969) was the first econometrician to offer a formal test of the direction of causality between the

Table 3 Granger causality test results

Null hypothesis	F- Stat	Prob.
Δ COCP does not Granger cause Δ N_2O	0.32321	0.7284
Δ N_2O does not Granger cause Δ COCP	0.84615	0.4474

Note: Δ = First order difference; Lags is 2
Source: Authors' calculations

variables. It is basically a statistical test. The Granger test involves estimating the following pairs of equations:

$$(\Delta N_2O)_t = a_1 + \sum_{i=1}^{n} \alpha_{\square}(\Delta COCP)_{t-i} + \sum_{j=1}^{m} \beta_j(\Delta N_2O)_{t-j} + \varepsilon_{1t} \tag{7}$$

$$(\Delta COCP)_t = a_2 + \sum_{i=1}^{n} \gamma_{\square}(\Delta COCP)_{t-i} + \sum_{j=1}^{m} \delta_j(\Delta N_2O)Y_{t-j} + \varepsilon_{2t} \tag{8}$$

Here, the null hypotheses are:

H_0: $\alpha_{\square} = 0$ ($i = 1, 2, \ldots, n$) [For Eq. (7)].
H_0: $\delta_j = 0$ ($j = 1, 2, \ldots, m$) [For Eq. (8)].

The *F*-statistics is:

$$F^* = \frac{(RSS_R - RSS_{UR})/m}{RSS_{UR}/(n-k)} \tag{9}$$

where, RSS_R is restricted residual sum square, RSS_{UR} is unrestricted residual sum square, m is number of lagged COCP terms (for Eq. (7)) or number of lagged N_2O terms (for Eq. (8)). We reject the H_0 if $F^* > F_\lambda$ (m, $n-k$)] and conclude that "COCP Granger causes N_2O" (for Eq. (7)) or "N_2O Granger causes COCP" (for Eq. (8)). The results are given in Table 3.

The *F*-statistics are insignificant for both the null hypotheses shown in Table 3. Thus, the Granger causality test result shows that there is no short-run causal interplay between nitrous oxide and cost overrun of the central projects in India. However, there exists a long-run association between them but in the short period, cost overrun neither affected nor affect the environmental degradation via N_2O emissions during 1995–2018.

6.6 Discussion

Infrastructural development is a key to long-term growth of output and employment of any economy. Further, delay in completion of the projects also puts additional financial burden upon the economy and its citizens. On the other hand, the

infrastructure project developments make the emissions of major GHGs such as nitrous oxide making damage to the nature's capacity in one hand and health hazards on the other. Therefore, the relation between the cost overruns and emission of nitrous oxide is a justifiable task for highly growing economies like India. The present study has intercepted in this area and found long-run relationships between the cost overruns and emission of nitrous oxide, although no causal interplays in the short run are found in them. Hence, infrastructure development is required for the economy but delayed infrastructural investments are not accepted by any economy so far as its low income generating and high pollution making activities are concerned. The government of the country should maintain good governance to overcome cost overruns.

7 Conclusion

In India, like any other country, infrastructure project delays and their associated cost overruns have significant implications from an economic as well as environmental point of view. Cost overruns in the central government's projects not only create a burden upon the economy, but also lead to reducing the environmental quality to a greater extent. N_2O, one of the major components of GHGs, has significantly increased in India after the New Economic Policy, 1991. The study thus has aimed to examine the significant relationship between N_2O and COCP in India during the period from 1995 to 2018. The correlation coefficient is found to be positive and significant. Further, the Engle-Granger cointegration test result shows that there exists a long-run association between them during this period. Since the estimated coefficient of the error correction term in the ECM is negative but insignificant. Finally, the Granger causality test result shows that in the short period, cost overrun neither gets affected nor affects the environmental degradation via N_2O emissions in India. The Government of India should maintain good governance to overcome the problems of delayed projects and their associated cost overruns.

References

Bhatia, D. (2016). Schedule overrun and cost overrun in the construction of private residential construction project: Case study of Pune, India. *International Journal of Technical Research and Applica, 4*(2), 174–177.

Brander, M., & Jackson, D. (2021). Greenhouse gas emissions and infrastructure investment decisions. *September 2020*, 1–35.

Dalkic, G., Balaban, O., Tuydes-yaman, H., & Celikkol-kocak, T. (2017). An assessment of the CO_2 emissions reduction in high speed rail lines: Two case studies from Turkey. *Journal of Cleaner Production.* https://doi.org/10.1016/j.jclepro.2017.07.045

Dickey, D., & Fuller, W. (1979). Distribution of the estimator for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*, 427–431. https://doi.org/10.2307/2286348

Dlamini, M., & Cumberlege, R. (2021). The impact of cost overruns and delays in the construction business. *IOP Conference Series: Earth and Environmental Science, 654*(1). https://doi.org/10.1088/1755-1315/654/1/012029

Doo-Yearn. (2011). Development of fuel –efficient construction equipment, ECCE, May 30-jun 3 2011, pp: 31–36.

Dutta, T., Dell, C. J., & Stehouwer, R. C. (2015). Nitrous oxide emissions from a coal mine land reclaimed with stabilized manure. *Land Degradation & Development, 27*(2), 427–437. https://doi.org/10.1002/ldr.2408

Engle, R., & Granger, C. (1987). Co-integration and error correction: Representation, estimation, and testing. *Econometrica, 55*(2), 251–276.

Ganiyu, B. O. (2015). Construction approaches to enhance sustainability in affordable housing in developing countries. *World Congress on Sustainable Technologies.*

Gielen, D., &Kram, T. (1998). The Role of Non-CO_2 Greenhouse Gases in Meeting Kyoto Targets 1 Western European emissions. 17–18.

Granger, C. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica, 37*(3), 424–438. https://doi.org/10.2307/1912791

Guo, Y., Zhang, Q., Lai, K. K., Zhang, Y., Wang, S., & Zhang, W. (2020). The impact of urban transportation infrastructure on air quality. *Sustainability (Switzerland), 12*(14), 1–23. https://doi.org/10.3390/su12145626

Guttikunda, S. K., Goel, R., & Pant, P. (2014). Nature of air pollution , emission sources , and management in the Indian cities. Atmospheric Environment, 95, 501–510. https://doi.org/10.1016/j.atmosenv.2014.07.006.

Herrera, R. F., Sánchez, O., Castañeda, K., & Porras, H. (2020). Cost overrun causative factors in road infrastructure projects: A frequency and importance analysis. *Applied Sciences (Switzerland), 10*(16). https://doi.org/10.3390/app10165506

Pilger, J. D., Machado, L., Lawisch-Rodriguez, A. D. A., Zappe, A. L., & Rodriguez-Lopez, D. A. (2020). Environmental impacts and cost overrun derived from adjustments of a road construction project setting. *Journal of Cleaner Production, 256*, 120731. https://doi.org/10.1016/j.jclepro.2020.120731

Singh, R. (2010). Delays and cost overruns in infrastructure projects: Extent, causes and remedies. *Economic and Political Weekly, 45*(21), 43–54.

Singh, R. (2011). Determinants of cost overruns in public procurement of infrastructure: Roads and railways. *Indian Policy Forum, 7*, 97–158.