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Is the Role of Nuclear Energy Vital in Reducing Carbon Footprint? An Examination of the Twelve Highest Nuclear Energy Consumption Countries

Nükleer Enerjinin, Karbon Ayak İzini Azlatmadaki Rolü Hayati mi? En Yüksek Nükleer Enerji Tüketen On İki Ülke İncelemesi

İrem YALKI

Abstract

The crucial problem in the last few decades is environmental degradation unquestionably. The main cause of environmental degradation is burning fossil fuels, and they dominate the energy sector. Besides, energy demand has been increasing, and this situation forces policymakers to make a decision on economic development versus climate change. Also, the Paris Agreement put pressure on the countries to reduce CO_2 emissions, so it accelerated countries' transition to clean energy resources. At this point, nuclear energy comes to the forefront as it is classified as clean energy status. On the other hand, the notion of nuclear energy is clean or not is a matter of debate. In case of a nuclear accident, it becomes the most environmentally damaging resource. Thus, this study aims at investigating the role of nuclear energy on the axis of reducing carbon footprint. For this purpose, the values and the shares of nuclear energy in the World and the top twelve nuclear energy consumption countries, and also their CO_2 emissions are examined by using descriptive analysis. The results should be interpreted as the CO_2 emissions avoided by using nuclear energy is not vital for these countries. Moreover, the emissions could be provided by renewable energy resources.

Key Words: nuclear energy, carbon footprint, clean energy, environmental degradation

Özet

Son yılların en öne çıkan sorunu, tartışmasız çevresel bozulmadır. Çevresel bozulmanın temel sebebi ise, fosil yakıtların kullanımıdır ve bu yakıtlar enerji söktörünü domine eden enerji türüdür. Bu durumun yanı sıra, gideerek artan bir enerji talebi söz konusudur ve bu durum politika karar vericileri, iklim değişikliğine karşı ekonomik kalkınma arasında karar vermeye zorlamaktadır. Ayrıca, Paris Anlaşması'nın, ülkelerin CO_2 emisyonlarını azaltmaları konusunda bir baskı oluşturması, ülkelerin temiz enerji kaynakalrına geçişini hızlandırmıştır. Bu noktada, nükleer enerji temiz enerji sınıflamasında yer aldığı için ön plana çıkmıştır. Ancak, nükleer enerjinin temiz enerji olup olmadığı da bir tartışma konusudur. Bir nükleer kaza olması durumunda, çevreye en çok zarar veren enreji türü haline gelir. Dolayısıyla bu çalışma, nükleer enerjinin karbon ayak izini azalma eksenindeki rolünü incelemeyi amaçlamaktadır. Bu sebeple, dünyada ve nükleer enerjiye en fazla sahip on iki ülke için nükleer enerjinin payı ve CO_2 emisyonları betimsel analiz ile incelenmiştir. Sonuçlar, nükleer enerji kullanılarak kaçınılan CO_2 emisyonlarının bu ülkeler için hayati olmadığı şeklinde yorumlanabilir. Ayrıca, bu emisyonlar yenilenebilir enerji kaynaklarından da sağlanabilir.

Anahtar Kelimeler: nükleer enerji, karbon ayak izi, temiz enerji, çevresel bozulma

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ARAŞTIRMA MAKALESİ

1.Introduction

Environmental degradation is a major problem that concern all countries over the last few decades. According to WEF (2023) five risks out of 10 are associated with the environment in the short term. In the long term, the number of risks increases to six, and in addition to this, their risk levels come to the front. According to IPCC (2014), energy-related carbon dioxide (CO_2) emissions are the major reason for climate change. CO_2 emissions originated from burning fossil fuels and industrial processes are 78% of the total GHG emissions increase from 1970 to 2010. As energy is the main driver of all economic activities, they are strongly related to each other. Therefore, without any differentiation developed and developing countries are facing a fateful problem, which is trying to balance economic actions and the environment. There are two sides to this situation. From the first perspective, especially for emerging countries, while positive developments are taking place such as reducing poverty, building infrastructure, and all the economic activities are targeting to achieve basic living standards, all these developments are accelerating energy consumption. On the other side, these positive developments lead to environmental degradation (Sadiq et al., 2022,p. 3672). Consequently, economic expansion and the environment are in a loop. The awareness, this situation is not sustainable, the countries agreed to limit the increasing CO_2 emissions with the level at 1.5 ^oC. The Paris Agreement (2015) puts pressure on the countries to reduce CO_2 emissions, so it accelerated countries' transition to clean energy resources. In addition to the Paris Agreement, The European Green Deal (2019) narrowed the circle of the necessity of energy transition. Thus, energy policies have become one of the most important issues of all countries. While forming new energy policies, the policymakers have to take into consideration the energy trilemma; which consists of energy security, affordable energy, and energy access (Usman & Radulescu, 2022, p.1). Considering the three major energy subjects, the main energy strategy for the countries relies on promoting renewable and nuclear energy resources (Pata & Samour, 2022,p.1). In addition, the European Commission stated in the EU Taxonomy Accelerating Sustainable Investments (2022) that gas and nuclear energy had adopted as "*transitional activities to facilitate the transition..".* Gas and nuclear energy need to meet some criteria to be counted in the taxonomy such as their technologies. Although, the EU Taxonomy is not a mandatory for the investors, but it supported gas and nuclear energy. This statement caused debate about whether these energies are evaluated as clean or not. Even if an accident is not taken into consideration, nuclear energy has very serious problems such as radioactive waste and radioactive leakage that will affect human health and the environment (Usman & Radulescu, 2022,2). Thus, nuclear energy has to be investigated from every aspect. For this purpose, this study aims at examining the role of nuclear energy in reducing CO_2 emissions. The question of the study is "Does nuclear energy irreplaceable in the energy transition?". To find the answer to this question, the general outlook of nuclear energy is investigated. The highest twelve nuclear energy consumption countries' nuclear energy values and shares are also examined. To make a comparison, the countries' CO_2 emission levels and CO_2 emissions avoided by using nuclear energy are examined as well. This study used descriptive analysis to illustrate these factors. As a result, the serious problems related to nuclear energy are vital risks. While an energy transition period is in process, instead of supporting

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nuclear energy, transferring this support to renewable energy types such as solar and wind is considered a safer and long-term policy tool.

The remainder of the study is organized as follows. Section 2 reviews the related literature. Section 3 explains why nuclear energy matters in the context of related data of nuclear energy and CO_2. Section 4 concludes the study.

2.Literature Review

The impact of nuclear energy on reducing CO_2 emissions is a crucial topic, so in the literature number of studies have taken place. The studies vary from each other due to the investigating country or countries, and also their time length. The fact that nuclear energy does not release CO_2 emissions as fossil fuels, the studies (Hao et al., 2022; Murshed et al., 2022; Naimoğlu, 2022; Pata & Samour, 2022; Sadiq et al., 2022; Usman & Radulescu, 2022) find results that support nuclear energy has a reducing impact on CO_2. On the other hand, Bandyopadhyay et al.(2022) analyzes the top nine nuclear energy-consuming countries and find positive and negative impacts depending on the country. Ishida (2018) reveals that there is a negative impact, while Jaforullah & King (2015) results indicate no evidence found between nuclear energy and CO_2. Moreover, Price et al. (2023) specify that nuclear energy is not a cost-effective system. Due to the number of studies and different results, the most recent and empirical studies are taken place in this part of the study.

Sadiq et al. (2022) analyzed the impacts of nuclear energy, environmental technology, and globalization on ecological footprint. For this purpose, the study examined the ten largest ecological footprint countries that are China, USA, India, Russia, Japan, Brazil, Germany, Mexico, South Korea, and France in the time length from 1990 to 2017. The study used the Lagrange multiplier method, Driscoll – Kraay regression for long – run estimation, and in addition to these methods for robustness, FGLS (feasible generalized least squares) and PCSE (panel-corrected standard errors are also applied. The study added economic growth and population density as independent variables to eliminate the omitted variable bias. Moreover, for robustness checks, the study examined the impacts of independent variables on carbon footprint and carbon emissions separately. The results of the analyzes reveal that all the variables are statistically significant at a 1% level. The long – run coefficient of nuclear energy consumption, environment – related technology, and population density are negative, whereas the long – run coefficient of globalization and economic growth are positive. Based on these findings, the study recommends to evaluate nuclear energy as a type of energy that support to decrease ecological footprint if it is in conjunction with environmental technology. Thus, it expressed that the governments and policy makers should promote nuclear energy in their energy portfolio. Usman & Radulescu (2022) investigated the impact of nuclear energy, renewable energy, non-renewable energy, technological innovations, and natural resources on carbon footprint in the countries that are the highest nuclear energy producing. The countries are given in order to their nuclear energy producing levels; the US, France, China, Japan, Russia, South Korea, Canada, Ukraine, UK, and Spain. The study uses panel cointegration and panel causality methods for the years from 1990 to 2019. The panel cointegration tests results showed that nuclear energy consumption and

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renewable energy consumption were decreasing carbon footprint, while non-renewable energy consumption, technological innovations, and natural resources rents were increasing carbon footprint. Also, the panel causality tests results indicate that the unidirectional relations occurred in limited conditions. The remarkable results were seen with the nuclear energy consumption. The unidirectional causality ran from nuclear energy consumption to carbon footprint and also from nuclear energy consumption to renewable energy use. The study concluded the importance of nuclear energy as it had a role of increasing carbon footprint, but also the policy makers should take into account the risks of nuclear energy. Pata & Samour (2022) researched the effects of nuclear energy and renewable energy on ecological footprint, carbon dioxide emissions, and load capacity factor in France to test the environmental Kuznets curve (EKC). The study used cointegration and causality tests for the years from 1977 to 2017. The study also used GDP as an independent variable in each model. The findings stated that with the dependent variables carbon dioxide emissions and load capacity factor (LCF), the cointegration relationship were found. The results also figured out that nuclear energy consumption had a decreasing impact on CO_2 emissions, whereas it had an increasing impact on LCF. The findings continued with the renewable energy consumption lessening CO_2 in the short term, but in the long term no impact had been found on CO_2 and LCF as well. Another finding of the study is the EKC hypothesis in France relied on the dependent variable. For the dependent variable CO_2, it did not exist, but for LCF, it did. In addition to these findings, a rise in GDP causes a decrease in LCF in the short and also long run. The study emphasized that the energy sources in France relies on nuclear energy, and as the nuclear power plants are aged the future of the nuclear energy should be reviewed. The study also recommends France should increase the renewable energy share in the energy sources. Bandyopadhyay et al. (2022) investigated the impact of nuclear energy consumption on the ecological footprint in the nine most nuclear energy consumption countries. The countries were given as their nuclear energy share levels from starting to highest; the USA, France, Japan, Russia, Germany, South Korea, Canada, Sweden, and China. Due to the countries' ecological footprint values are different, the study aims to investigate country-specific analyzes. Thus, the study used the quantile-on-quantile regression method in the time from 1995 – 2016. The results revealed that for the countries, asymmetric impacts of nuclear energy on ecological footprint were seen. To group the countries for the impact levels and directions, the following scene was observed. For Canada, the USA, and Sweden were there was a negative and strong impact was presented in most of the quantiles. In Japan, Russia, and South Korea positive and negative impacts were seen across most of the quantiles. For Germany, also the impact was positive and negative, but in this case, the positive impact is stronger. Lastly, for China and France, across most of the quantiles, the impact was strong and positive. Based on these results, the study stated that the countries, which had a strong negative impact could implicate the nuclear energy in their energy portfolio as an ecological footprint reducing factor. For Germany, nuclear energy was not a major cause of ecological footprint. In China and France, nuclear energy consumption did not have a protective effect on the environment, also the scenario was the opposite. Ishida (2018) did research the impact of nuclear energy consumption on CO_2 emissions in Japan. To analyze the impact the study utilized the autoregressive distributed lag (ARDL) model for the period 1970 – 2010. In the study, four models are estimated. For all the models

CO2 emissions were the dependent variable and nuclear energy consumption was the independent variable. The first model involved these two variables. In the second model, real GDP is added as an independent variable. In the third model, the real price of electricity was the other independent variable. And the fourth and last model involved all three independent variables. The estimations of the study indicate that there was no long-run relationship between the variables. For the third model, the electricity price variable was significant and the coefficient was negative, that infers if electricity prices increase, CO_2 emissions decrease. On the other hand, the nuclear energy consumption variable was significant and the coefficient of the variable was positive. The outcomes mean that if there is an increase in nuclear energy consumption, it increases CO_2 emissions. In the fourth model, the electricity prices were significantly negative as in the third model. The coefficient of real GDP was significant and positive that infers if the real GDP increases, it leads to an increase in the CO_2 emissions. The coefficient of nuclear energy consumption was negative in contrast to the third model, but in this model the coefficient was insignificant. Thus, the study results reveal that nuclear energy consumption does not have an impact on reducing CO_2 emissions, furthermore, it could lead to an increase. Jaforullah & King (2015) analyzed the impact of renewable and nuclear energy consumption on CO_2 emissions in the US for the years from 1965 to 2012. The study used cointegration and causality test, and also the real GDP and real price of energy were involved in the model. Three model specifications were evaluated in the study. The first one was the standard log-linear function, whereas the second one was formed as the linear function. The third model specification was formed except for nuclear energy consumption, all the other variables were logged. In the first model, there was no cointegration relationships were observed. The other model results indicated that renewable energy consumption had a significant and negative impact on CO_2 emissions, while nuclear energy consumption had a positive impact but it was insignificant. Thus, the study concluded that nuclear energy consumption did not support the CO_2 mitigation in the US.

The re-emergence of nuclear energy, especially due to climate change, has increased the number of studies in this field. As can be seen from the studies mentioned above and their results, it is important to add new information to the literature on this subject in every aspect. Therefore, this study aims to contribute to the related literature by trying to express why nuclear energy is supported by the EU Taxonomy and including the lifetime CO_2 avoided indicator.

3.Why Nuclear Energy Matters?

In this section of the study, the general framework of nuclear energy is taken place. The first part of this section gives a general view of nuclear energy in the world and in the highest nuclear energy consumption countries. In the next part, the CO_2 emissions of these twelve countries and also their lifetime CO_2 avoided values are given.

3.1.Share of Nuclear Energy in the Electricity Generation

Since nuclear energy produces electricity, in order to be able to compare it with other types of energy, the electricity generation data is examined.

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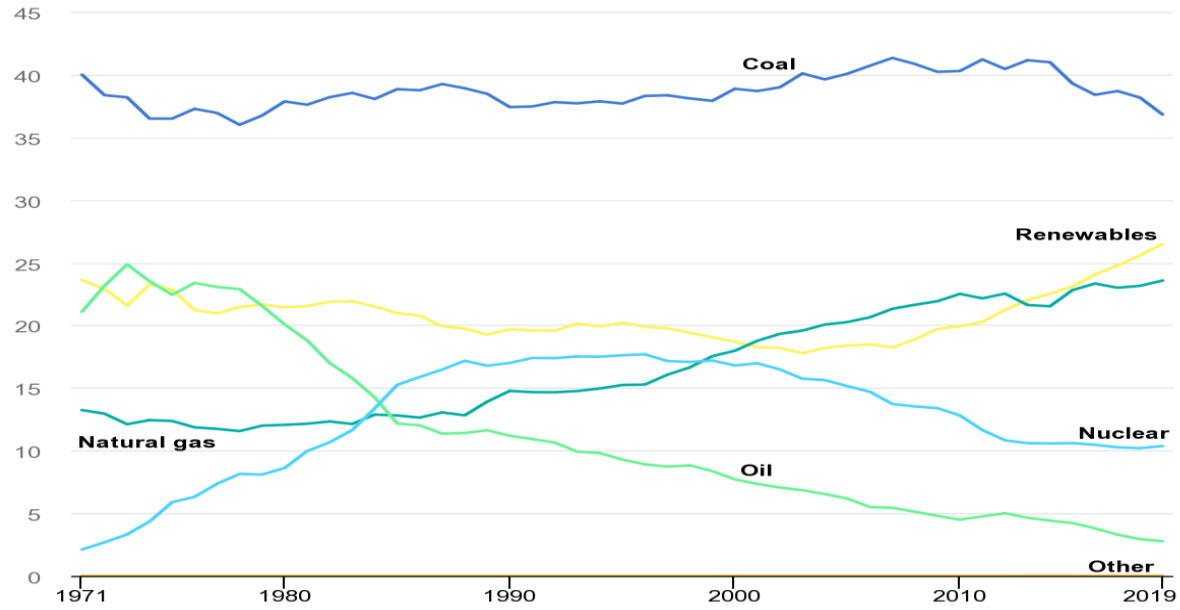

Figure 1. The World Electricity Generation Mix by Fuel from 1971 to 2019.

Source: IEA (2023).

In Figure 1, it is clearly seen that coal has been the dominant energy source since 1971. The share has been usually around %35-40. The lowest proportion was 35.99% in 1978, and the highest proportion was 41.32% in 2007. After 2007, it did not come below 40% till 2015 with a percentage of 39.28%. Then it continued to decrease with only an exception in 2017, and in 2019 the share was counted at 36.81%. Renewable energy sources have been following coal. Renewables share has been observed between 15-25% till 2018. In 2007, the renewables energy trend started increasing, and in 2018, it stepped up to %25, and reached 25.57%, and then hit 26.49% in 2019. As seen in Figure 2, renewable energy sources had dominated by hydropower with a percentage of 16% in 2019. Therefore, renewable energy sources have occurred mainly hydropower, so the other renewable energy sources remain at lower rates. The natural gas trend is also striking. In 1971 it was 13.23%, then it became its lowest share, which was 11.55% in 1978. It displayed a smooth trend till 1988, and then it started increasing and followed the increasing trend till 2010. In this year, the share was observed at 22.50%. In the following few years, it decreased but then continued to increase again, and ended up at 23.56% in 2019. Nuclear energy and oil have particular importance. After the oil crises in the 1970s, the share of oil started to decrease and it shifted to nuclear energy. Due to the oil shocks, countries' energy security policies gained prominence, thus they started to make priority national energy resources. At this point, nuclear energy came to the forefront. Beginning with investigating the share of oil, the share was 21.08% in 1971 and hit its highest level, which was 24.85% in 1973. After 1978, it exhibited a sharp decrease, with a few years' exception, it dropped to a value of 2.77% in 2019. Nuclear energy had the lowest share among all the other energy resources until 1983. In 1971, the share was 2.11% and started to increase and became at the same level as natural gas in 1983, and with oil in 1984 as well. It continued to increase with mainly an upward slope till 1988. In this year the share was 17.16%, then it sowed a smooth trend for around ten years. In 1996, the share became

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17.68% and it started to fall down. It reached 10.82% in 2012, and it remained at approximately this level, and as the latest year, it was observed at 10.36% in 2019.

Figure 2 represents the share of electricity production by source in the World. The figure provides to observe the latest situation of the electricity production shares.

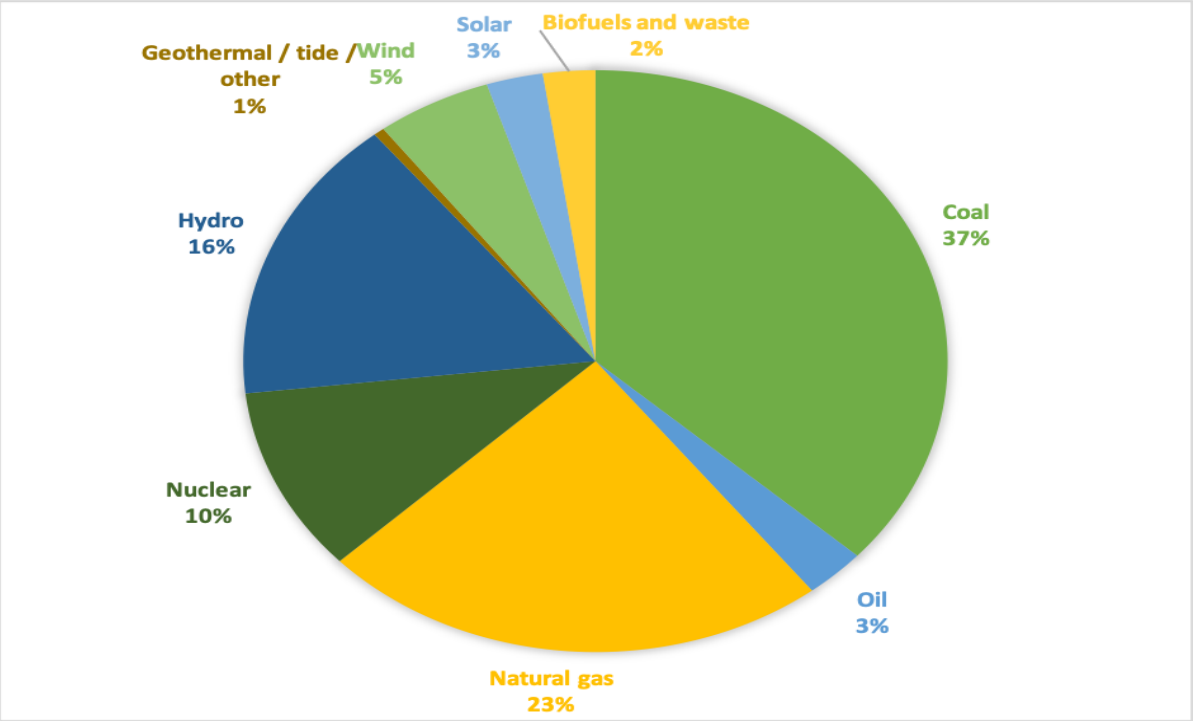

Figure 2. World Gross Electricity Production by Source, 2019.

Source: IEA (2021).

In Figure 2, the shares of renewable energy sources are represented separately Thus, it gives more detail about the percentages. In 2019, the highest share was 37% belonging to coal. Natural gas followed coal with a value of 23%. Then the highest third one was hydro at a level of 16%. The share of nuclear energy was 10%. These four energy sources are the main sources of electricity production. The other forms of energy levels remained between 1-5%.

In Figures 1 and 2, solely the percentages are given, so the real values of electricity generation should be evaluated. As shown in Figure 1, the share of nuclear energy in electricity generation started to increase and then followed a decreasing path. The main reason for the decrease is the amount of electricity generation did not display a significant change over the years, but its share decreased depending on the growing energy supply (*Nükleer Enerji ve Türkiye, 2022*, p.4). Table 1 shows the number of reactors, the nuclear energy share in electricity generation, and total capacity to represent the specific situation of nuclear energy.

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Table 1. The Number of Operating Reactors and Their Share of Electricity Generation (%), and Total Capacity in the World

	The number of reactors	Nuclear energy share (%) in electricity generation	Total capacity (GW)
1996	437	17,6	345
2010	441	12,8	375
2015	441	10,6	382
2022	441	10,06	393

Source: Nükleer Enerji ve Türkiye (2022).

As seen in Table 1, despite the number of reactors and total capacity have not shown a notable change, the nuclear energy share has declined. The situation has occurred due to the increasing energy supply. The nuclear plants' total capacity merely increased from 345GW to 393GW in 27 years. However; in some countries, nuclear energy is one of the main energy sources. They give priority to nuclear energy in their energy policies (Wang et al., 2023, p.2). Besides, nuclear energy had a significant share in electricity production, the countries, which give place to nuclear energy in their energy portfolio should be investigated. Therefore, the highest twelve nuclear energy electrical capacity countries are given in order of their capacity. The countries are listed as follows: the USA, France, China, Russia, the Korea Republic of, Canada, Ukraine, Japan, Spain, India, and the UK. The reason for taking twelve countries is that these countries' net capacities are higher than 5 GW(e). For the purpose of simplicity, the other countries are not taken into account in this study. The total capacity of the World is 368610 MW. Thus, the main countries are taken place in the study.

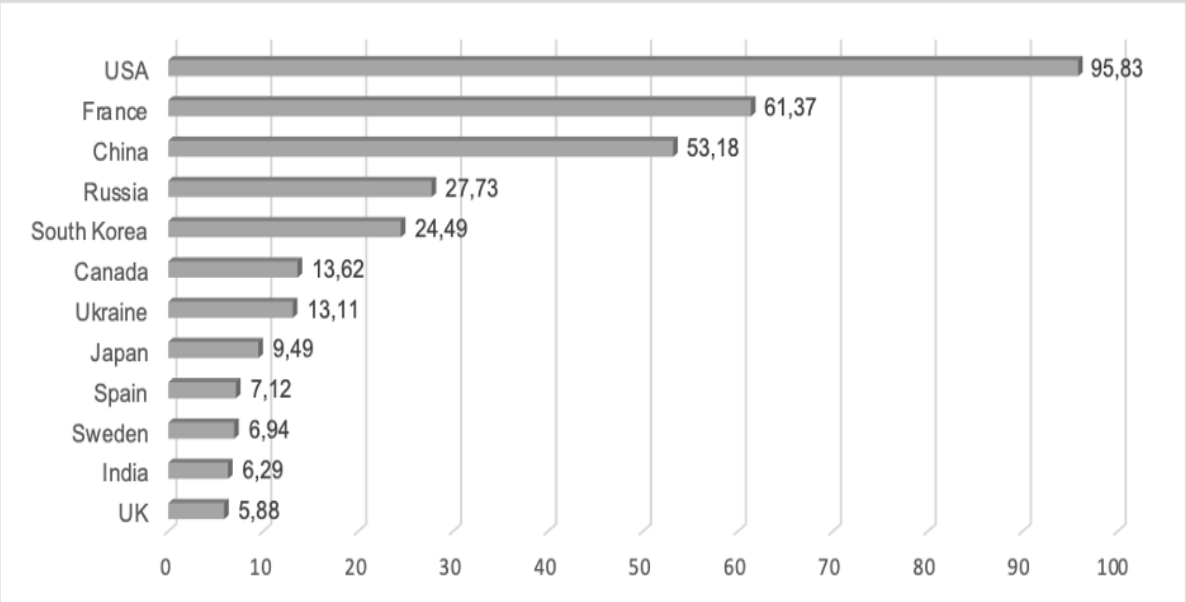

Figure 3. The Net Nuclear Electrical Capacity, GW(e) in Operation for the Highest Twelve Countries

Source: It is compiled by the author using the PRIS / IAEA (2023) dataset.

It is clearly seen in Figure 3, the USA nuclear plants' capacity is at the highest level by far and away. The nuclear energy capacity is 95.83 GW in the USA, the proximate country, which is France, the value is 61.37 GW. Then China follows France with 53.18 GW. After these three countries, the values get lower. Russia and South Korea have similar values, which are 27.73 GW and 24.49 GW respectively. Leaving these countries behind, the gap is getting closer within the other countries. The nuclear capacity of Canada and Ukraine are 13.62 GW and 13.11 GW respectively. After Ukraine, the level decreases below 10 GW. Japan's nuclear energy capacity is 9.49. For Japan, a special occasion is on the matter. In Japan, 22193 MW has suspended operation. Fukushima nuclear accident in 2011 affected the place of nuclear energy in the country's energy policies (WNA, 2023). Spain, Sweden, India, and UK have the capacity respectively 7.12 GW, 6.94 GW, 6.29 GW, and 5.88 GW.

The net nuclear electrical capacity in total data directly points out the top countries precisely. However, interpreting this data solely is not sufficient for country comparisons. Since the electricity usage of the countries is different, the share of nuclear energy in electricity production will also be different. In addition to this data, it is necessary to look at the percentages. Therefore, the nuclear share of generation data for these countries is given in Figure 4. When these two data sets are examined, it is noteworthy that the order of countries majorly differs.

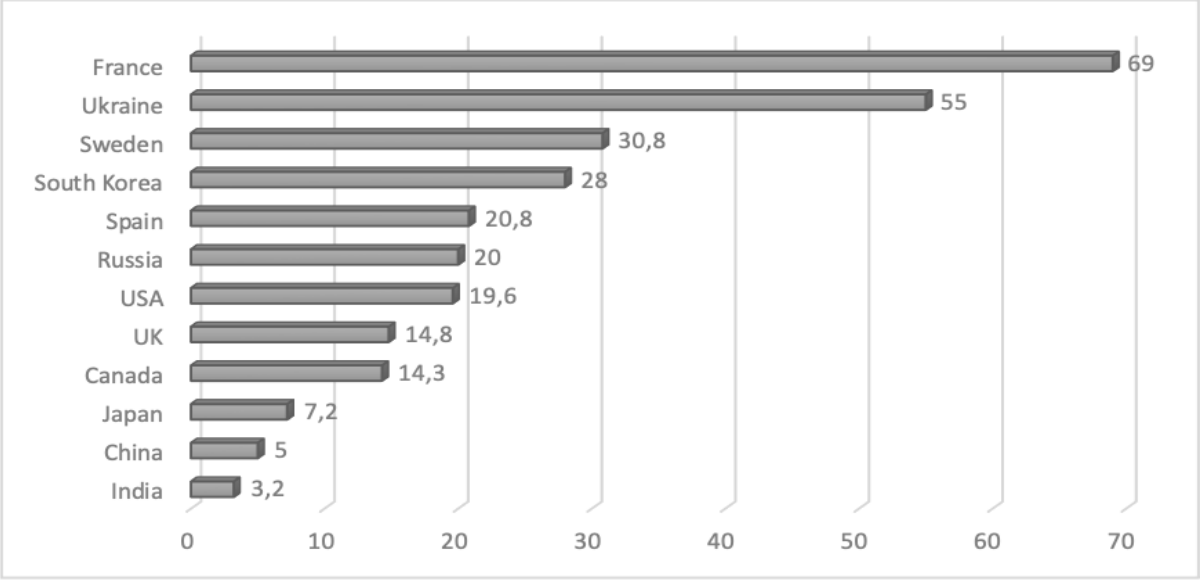

Figure 4. The Nuclear Share of Generation for the Highest Twelve Countries (%)

Source: It is compiled by the author using the PRIS / IAEA (2023) dataset.

At this point, the country that stands out is the USA. Among all the countries, the USA has the highest capacity in the World, but when the share of generation is analyzed, it is seen that the order is regressed to seventh place, with a percentage of 14.8%. As the energy consumption of the USA is at the top values, the situation occurs. The same scenario presents in China as well. When the net nuclear electrical capacity of China is the matter, the country takes the third place. On the other hand, the nuclear share of generation is just 5%, and the order falls to the tenth among the twelve countries. Conversely, for Ukraine and Sweden, the opposite of this situation occurs. While Ukraine is in the

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seventh order in the net nuclear capacity, the country's nuclear share takes place in the second order with a percentage of 55%. The order of Sweden for the net nuclear capacity is the tenth, but the percentage of the nuclear share is 30,8% and the order of the share is the third. Additionally, another striking point that draws attention belongs to France. The orders are consistent, for the net nuclear capacity, it is the second country and for the share, it is the first one. However, the nuclear share of the country is very high, with a value of 69%. The high percentage means that France's electrical capacity is dependent on nuclear energy. This situation also remarks on the energy security problem for the country in case of a problem occurs related to the nuclear plants. Thus, the share of nuclear energy in the countries comes with energy dependency questions. In Figure 5, the countries that have nuclear energy shares above 25% are given.

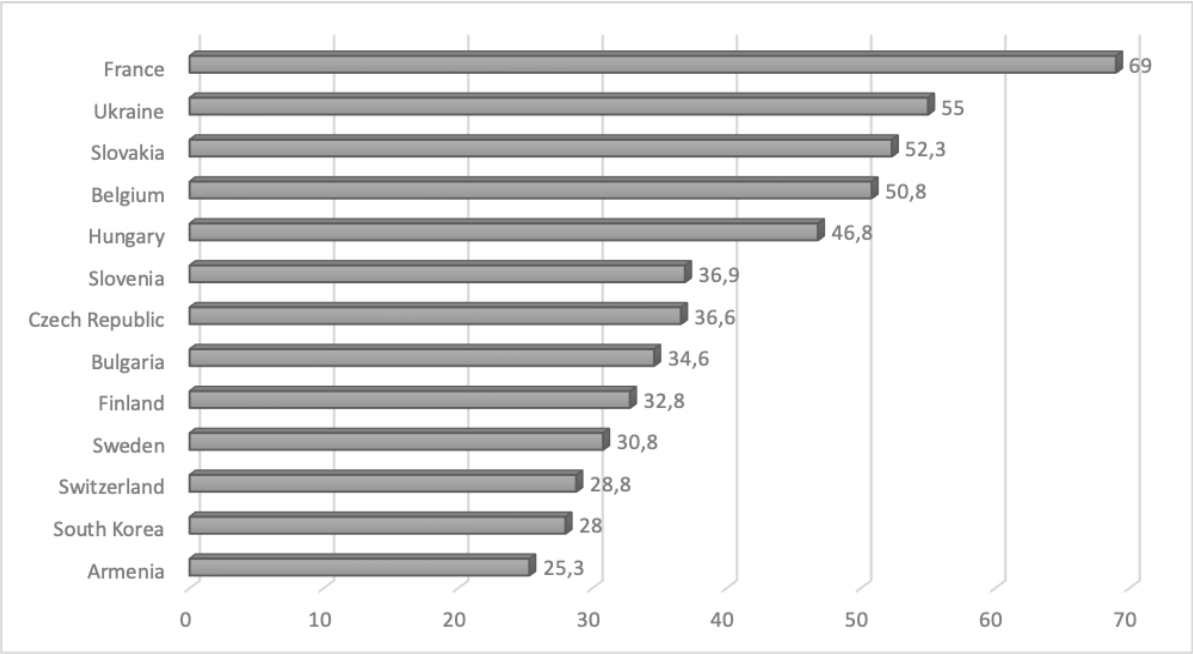

Figure 5. The Highest Nuclear Energy Shares (%) for Thirteen Countries

Source: It is compiled by the author using the PRIS / IAEA (2023) dataset.

For energy shares 25% is a significant value when the subject is energy dependency. When the highest nuclear shares are ordered thirteen countries' shares are above the 25%, and they are given in Figure 5. The striking matter in this situation is that when we compare the nuclear energy shares of the 12 countries with the highest nuclear energy capacity and the countries with the highest nuclear energy share above 25%, only 4 of these 12 countries take place in this classification. Moreover, 9 of the 13 countries that have a nuclear share above 25% are the EU countries. This scene makes essential the necessity of questioning the EU Taxonomy to classify and support nuclear energy as clean energy.

3.2.The Carbon Emissions of the Twelve Highest Nuclear Energy Consumption Countries

In this part of the study, CO_2 emissions of the Highest twelve nuclear energy consumption countries are Taken place. Actually, the ecological footprint indicator represents environmental degradation

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more accurately, but for nuclear energy, as it avoids CO_2 it is more suitable to use CO_2 emissions. In addition to this, the World Nuclear Performance Report (2022) presents crucial information about the countries. The report estimates a factor stated as “lifetime CO_2 avoided”. It quantifies if coal-fired plants were taken place instead of nuclear plants, the total CO_2 emissions that would have been revealed to the atmosphere. This data is vital, hence it gives the policy-makers the chance to make an evaluation based on the actual data. In Table 2, the two mentioned datasets are given together.

Table 2. The CO_2 emissions and the Lifetime CO_2 Avoided in the Top Twelve Nuclear Energy Consumption Countries ($MtCO_2$)

	CO2 emissions (MtCO2)	The Lifetime CO2 Avoided (MtCO2 cf. coal)
USA	5007	22764
France	306	11320
China	11472	2051
Russia	1756	4324
South Korea	616	2966
Canada	546	2747
Ukraine	202	2191
Japan	1067	6102
Spain	234	1649
Sweden	36	2075
India	2710	519,7
UK	347	2300

Source: It is compiled by the author using the World Nuclear Performance Report (2022) and the Global Carbon Atlas (2023) datasets.

The data for the CO_2 emissions are gained from the Global Carbon Atlas and the year for this indicator is 2021. The data for the lifetime CO_2 avoided is collected from the World Nuclear Performance Report. While interpreting these datasets together, there is a vital part to be considered. The CO_2 emissions data represents only one year, which is 2021. On the other hand, the lifetime CO_2 avoided data consists of all the years that a nuclear plant operates. So, while comparing the datasets the nuclear reactors operation time has to be known. For the simplicity of the study, the details are not evaluated in this study. However, from Table 2 alone, it is possible to mention that, as most of the nuclear reactors are old-aging, nuclear energy is not a vital source to reduce CO_2 emissions. At this point, since the energy structure of each country is different, it is necessary to analyze it on a country basis.

In Figure 6, the lifetime CO_2 avoided data is given for the highest twelve nuclear energy electrical capacity countries in $MTCO_2$ cf.coal. It is also crucial to illustrate the order of the countries and compare them with the net nuclear electrical capacity in operation data.

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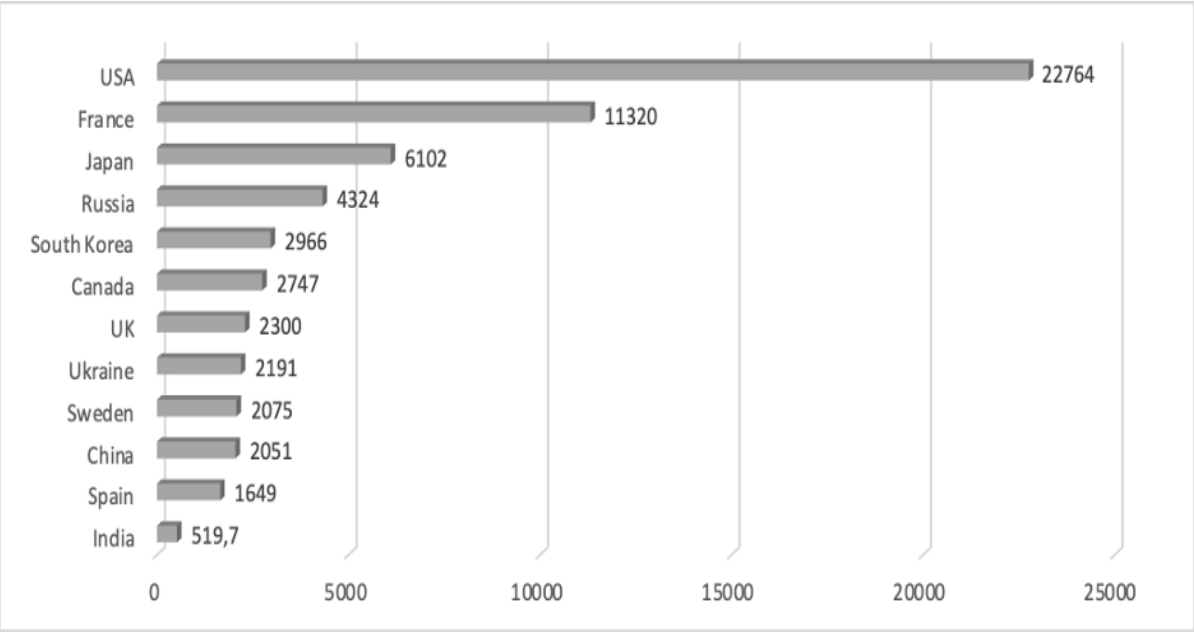

Figure 6. The lifetime CO_2 Avoided for the Highest Twelve Nuclear Energy Electrical Capacity Countries ($MtCO_2$ cf.coal.)

Source: It is compiled by the author using the World Nuclear Performance Report (2022) data.

When the places of the countries are compared based on the lifetime CO_2 avoided and the net nuclear electrical capacity in operation data, it is seen that five of the twelve countries are in the same order. They are the USA, France, Russia, South Korea, and Canada. In the lifetime CO_2 avoided dataset, Japan comes after the USA and France. As their nuclear capacities are so high and also these countries have taken place nuclear energy as their energy source for a long time. Therefore, it is expected to remain in their places as the first and second countries. As mentioned above, Japan has suspended operations, also with the USA and France, Japan has been using nuclear energy for so long, even though some reactors have been suspended, they avoided CO_2 emissions. Unsurprisingly, the place of Russia, South Korea, and Canada are the same. The other remaining countries, as their nuclear energy levels are lower and very close to each other, depending on the capacity of the nuclear plants and their operation time, it varies.

4.Conclusion

The study aims to examine the impact of nuclear energy on decreasing CO_2 emissions. For this purpose, the related data of nuclear energy and CO_2 emissions are analyzed by using descriptive analysis. The results show that nuclear energy is not a vital energy. On the contrary, the serious problems related to nuclear energy should be counted as vital risks. One of the main risks that could occur at any time is that nuclear energy could cause radioactive leakage. It directly affects human health, also the environment, and the extent of this problem may be unpredictable. The other problem that has no definite answer is nuclear waste. The nuclear plants are old-aging and the radioactive waste seems to be a serious threat to the environment. In addition to these serious problems, building a nuclear plant is not a low-cost investment. Besides, in the construction process, unexpected

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problems occur and they often fail to start operating at the end of the planned period. These unexpected problems lead the cost increases as well. Another cost-related problem is if an accident occurs, it is difficult to generate electricity in a short time so, it needs an alternative energy source to meet the deficit. Moreover, the repairing process and costs could be also unpredictable. Comparing the costs with the renewable energy sources, even though any of these mentioned cost scenarios occurs, it is not favorable. As the renewable energy sources are on the rise, nuclear energy lost its cost-effectiveness. While all the risks are taken into consideration, it is clearly seen that nuclear energy is not an efficient energy source. The decision of including nuclear energy in the countries' energy mix is more of a policy decision. The EU Taxonomy proves this. Most of the EU countries' nuclear energy shares are at high levels. On the other hand, Germany, which has been using nuclear energy for a long time, has decided to close its nuclear power plants. Therefore, denuclearization is entirely dependent on policy decisions. The policymakers have to evaluate nuclear energy from every aspect, and seek to find the answer of "Does nuclear energy clean or is it a danger of explosion?". In light of this information, this study recommends, while an energy transition period is on the matter, instead of supporting nuclear energy, transferring this support to renewable energy types such as solar and wind is considered a safer and long-term policy tool.

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