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CONNECTING THE DOTS: RENEWABLE ENERGY AND NUCLEAR ENERGY – MUTUALLY SUPPORTIVE OR MUTUALLY EXCLUSIVE – A CRITICAL REVIEW

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Abstract

Nuclear energy and renewable energy are two prominent sources of power that have been under scrutiny for their environmental impact and sustainability. Nuclear energy, derived from splitting atoms to generate heat, produces large amounts of energy with minimal greenhouse gas emissions. However, it poses risks such as radioactive waste and potential accidents. On the other hand, renewable energy sources like solar, wind, and hydropower are clean, sustainable, and abundant. They have a lower environmental impact and are increasingly cost-effective. By comparing the benefits of both nuclear and renewable energy, it is evident that the right energy mix is a more viable and sustainable option for the future.

Keywords: renewable, nuclear, energy, sustainable development, cost-effective

JEL: O10, O11, O12, O13

Introduction

The energy sector plays a crucial role in the development of a country's economy. It is the backbone of industrialization, transportation, and infrastructure, and is essential for economic growth and prosperity. Throughout history, countries that have invested in developing a highly advanced energy sector have seen significant economic progress. One of the key examples of this is the USA. This country emerged as a global economic powerhouse in the 20th century largely due to its robust energy sector. The discovery and exploitation of vast oil reserves in Texas and other regions fueled the country's industrial revolution and propelled it to the forefront of innovation and development. The availability of cheap energy sources like oil and natural gas enabled the U.S. to build a thriving manufacturing industry, expand its transportation networks, and drive technological advancements.

Similarly, countries like Germany and Japan have also experienced rapid economic growth by investing in renewable energy sources and cutting-edge

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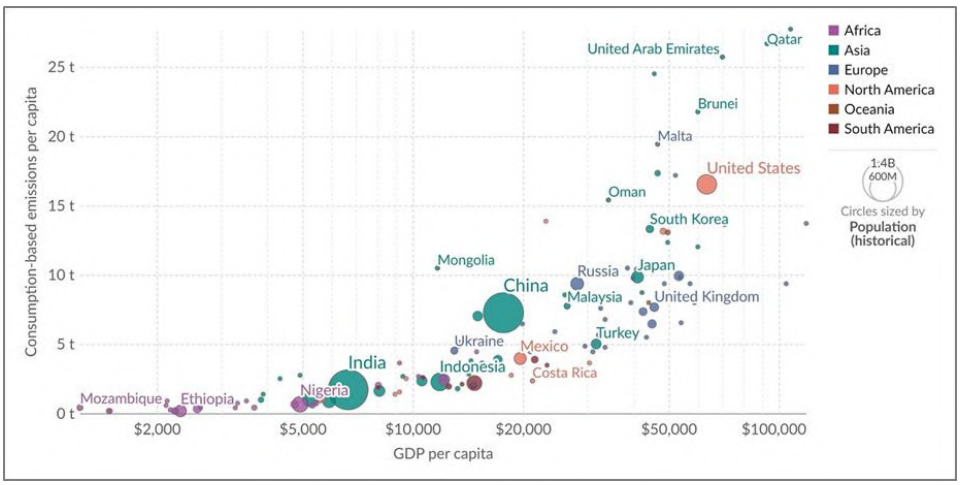
technologies. Germany is a leader in solar and wind energy production, creating thousands of jobs and reducing its dependence on fossil fuels. Japan, on the other hand, has focused on developing nuclear energy and high-tech solutions to meet its energy needs, despite setbacks like the Fukushima disaster. Developed countries like Norway and Sweden have also harnessed their natural resources, such as hydropower and biomass, to build sustainable energy systems that have become models for the rest of the world. These countries have not only achieved energy independence but have also significantly reduced their carbon footprint and contributed to global efforts to combat climate change.



Source: Our World in Data (2023a).

* Consumption-based emissions are measured in tones per person. They are territorial emissions minus emissions embedded in exports, plus emissions embedded in imports. GDP per capita is adjusted for price differences between countries (PPP) and over time (inflation).

Figure 1: The world's energy problem – Consumption based CO2, emission per capita vs GDP per capita

The Figure above shows the strong interdependence between the GDP per capita and the emissions of carbon dioxide per capita. Data confirms that the higher the standard of living, measured as GDP per capita, the higher the emissions of carbon dioxide, especially for industrializing countries. There are strong and undeniable arguments in support of this correlation. Firstly, the dynamics and the absolute value of GDP depends on the volume of production of goods and services. Other things being equal, the higher the volume of production the higher the GDP. At the same time, the higher level of production supposes higher

energy consumption. In addition, it is well known that the production of energy is responsible for more than 80% of the carbon dioxide emissions. Secondly, higher GDP per capita means higher standard of living based on sufficient purchasing power allowing a high level of consumption. Households consume not only final products, but also energy products like electricity, heating energy, petrol products (gasoline, diesel, LPG), public transportation services, countries. Those products are demanded in much higher volumes in countries like Singapore, the USA, Switzerland, South Korea and Japan than in low-income countries like Malawi, Ethiopia and Tanzania in Africa.

No doubts, as shown in the same Figure, the so called „energy poverty" means difficult access to energy sources and it leads directly to a low standard of living. Therefore, if the improvement of the standard of living is a key objective for every developing or developed country, the most challenging question is how to decuple the higher standard of living from the increased emissions. The decupling is possible, and it is based on policies for sustainable development. Such policies are (a) balanced increase of renewable energy and non-renewable energy with zero or very low harmful emissions; (b) decrease of the energy intensity per unit of GDP; (c) introduction of environmentally-friendly technologies; (d) behavioral and economic stimuli for downgrading of consumerism, etc.

Methodology and approach

In this regard, the fact should be highlighted that the energy sector is a vital component of a country's economic development. A well-developed energy infrastructure can drive innovation, create jobs, and attract investment, leading to increased productivity and competitiveness in the global market. By looking at the historical examples of developed countries that have relied on advanced energy sectors for their economic growth, investing in sustainable and efficient energy sources is essential for long-term prosperity and sustainability. To achieve this objective, we included a literature review to identify the criteria involved in the process. In the second phase we included a validation from a case study review comparing how the criteria are influencing the whole process towards the opportunities and tackling the challenges with the renewables in different countries. We use the literature review and the selected case studies to support *our thesis that optimal energy mix must be different for the different countries*. The specifics are based on the number of preliminary conditions, like climate conditions and the available renewable resources like solar, wind and hydro energy. The existing or the absence of nuclear plant (s) is another reason for the differences in the energy mix. The relevance of the optimal energy mix for every country must be adequate to the structure of the respective national economy depending on the ratio between the production of goods and services as share of

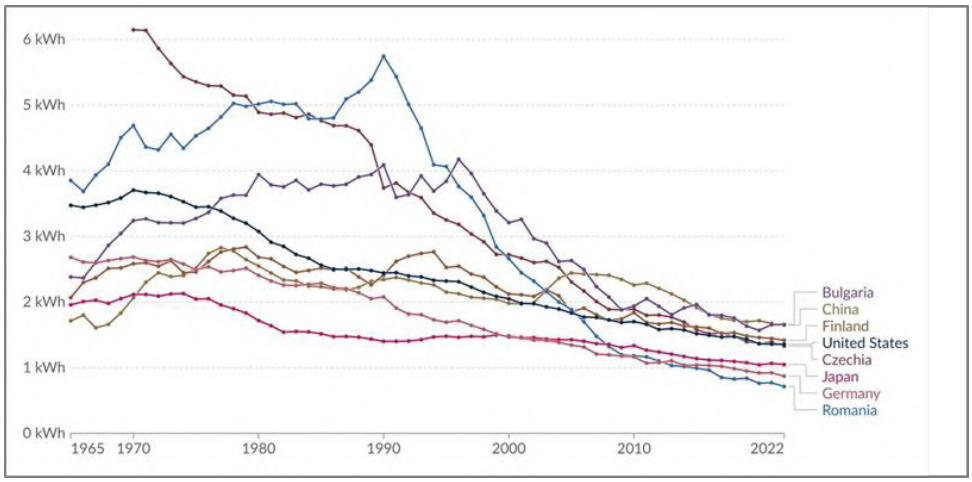
GDP, the energy efficiency level of these industries and the energy intensity per unit of GDP. In other words, we argue that it is not possible to have a „universal model of optimal energy mix" and there are „no silver bullets" for economies with different structure, a different technological level, different access and availability of renewables and non-renewables, etc.

As the world faces the challenges of climate change, resource depletion, and environmental degradation, transitioning to cleaner and more sustainable energy sources has become a pressing necessity. Nuclear and renewable energy offer viable solutions to these challenges, providing low-carbon alternatives to fossil fuels and promoting a more sustainable energy future. In this case, the deductive approach allows to highlight the most important industries in different countries, and the value added of each to benefit the wellbeing and competitiveness in different countries.

The energy intensity of GDP is one of the most crucial indicators for sustainable development (Khan, Hou, Zakari and Tawiah, 2021). Data shown on Figure 2 clearly indicates the basic trends in this development in the period 1966 – 2022 or for a period of nearly six decades. The most extensive changes are taking place after 1990. There are two main factors for accelerated decrease of the energy intensity. First, substantial increase in the volume of investments in research, development and large-scale implementation of new, energy saving technologies. Second, collapse of the industrial sector of Eastern Europe, especially in the heavy industry sector that is the one with the highest energy intensity per unit of production. Certainly, the trends for the specific countries are in the same direction but with very different dynamics.

The importance of nuclear and renewable energy for sustainable development

The importance of nuclear and renewable energy for a sustainable future cannot be overstated. As the world faces the challenges of climate change, resource depletion, and environmental degradation, transitioning to cleaner and more sustainable energy sources has become a pressing necessity. Nuclear and renewable energy offer viable solutions to these challenges, providing low-carbon alternatives to fossil fuels and promoting a more sustainable energy future.



Source: Our World in Data (2023b).

Note: *GDP* is measured in international dollars at 2011 prices.

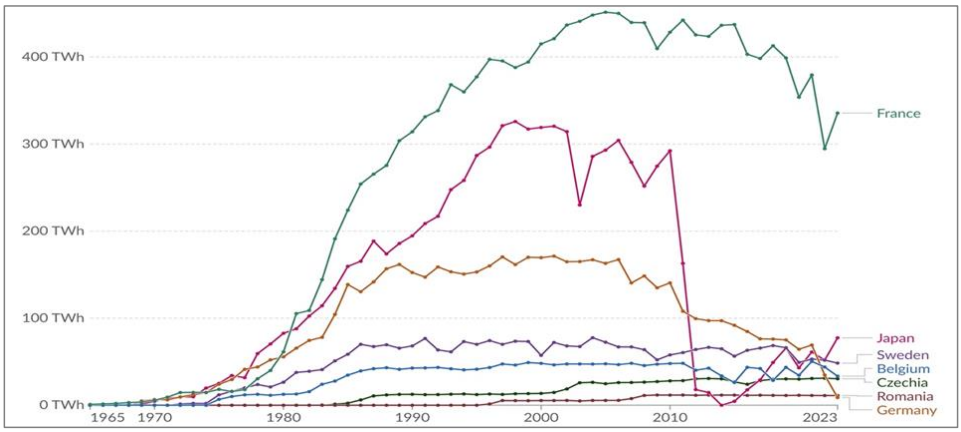
* Energy intensity is measured as primary energy consumption per unit of gross domestic product (GDP), in kilowatt-hours per dollar. GDP is adjusted for inflation and differences in the cost of living between countries.

Figure 2: Energy intensity in the world

Bulgaria, for example, shows an impressive decrease of the energy intensity in the period 1990 – 2022. It is a multiple times faster decline than the same process in Japan or the United States. Unfortunately, the dominant factor for such development in our economy is rather the collapse of the heavy industry during the 90s than the technological innovations. At the same time, as shown in the Figure 2, the decrease of the energy intensity per unit of Japanese GDP is relatively smaller. However, this small percentage of change is measured at an already low initial level in 1990. Unfortunately, Bulgaria continues to be the EU member-state with the highest energy intensity per unit of production and in the 58th place for competitiveness as of 2024. It is understandable, that it has a strong impact on the cost of production and further on the market competitiveness. In contrast, China for instance (14th place in the 2024 competitiveness index), still has relatively high-energy intensity of its GDP. But we must take into consideration the structure of the Chinese GDP by sectors. The share of industry in the GDP of China is nearly doubled in comparison with Bulgaria, where more than 70% of GDP is generated by the service sector. We know that there is a strong relationship between energy intensity and the volume of harmful emissions

(Shahbaz, Jam, Bibi and Loganathan, 2015). At the same time, it is even more important to further analyze the dependence between every kind of consumed energy (renewable, nonrenewable, solar, wind, nuclear, geothermal, etc.) and the kind of emissions. Nuclear energy, for example, has the potential to generate large amounts of power with minimal greenhouse gas emissions (Sovacool, 2008). Despite concerns about safety and nuclear waste disposal, nuclear power plants have proven to be reliable and efficient sources of electricity, particularly in countries like France and the United States (Jasper, 2014; Adamantiades and Kessides, 2009). By investing in advanced reactor technologies and stringent safety measures, nuclear energy can play a significant role in reducing carbon emissions and meeting the growing global energy demand (Prăvălie and Bandoc, 2018). On the other hand, renewable energy sources such as solar, wind, hydro, and geothermal power offer clean, sustainable, and abundant alternatives to fossil fuels (Rahman et. al., 2022). These sources are inexhaustible and have a minimal environmental impact, making them ideal solutions for a sustainable energy future. Countries like Germany, Denmark, and Iceland have made significant strides in harnessing renewable energy, investing in infrastructure and technology to transition to a more sustainable energy system (Lund et. al., 2019; Kamminker and Steward, 2012). We are witnessing now substantial reshape of these models aiming at gradual increase of the share of nuclear energy production, which obviously enters a new period of „renaissance".

As shown on Figure 3, France continues to be a clear leader in the EU both as nominal volume of nuclear energy production in 2023 (more than 320 terawatt hours) and its share in the total energy (electricity) generation (more than 70%). Japan shows dramatic turns in the trends of these indicators shortly after the disaster in the Fukushima Daiichi nuclear power plant. This disaster had a strong impact on the rest of the World and led to strengthening of the anti-nuclear nuclear voices in Europe and elsewhere in the World. Currently, because of numerous new socio-economic, environmental and geopolitical factors, the European Commission declared that the nuclear energy is a „green energy" (Euro active, 2022) and therefore the installation of new nuclear reactors will be directly or indirectly supported by the Union with financial resources and with technical, technological and political support. That is why, countries like the Czech Republic, Belgium, Hungary, Romania and Poland are taking steps towards enlargement of the existing capacity or the construction of new ones.



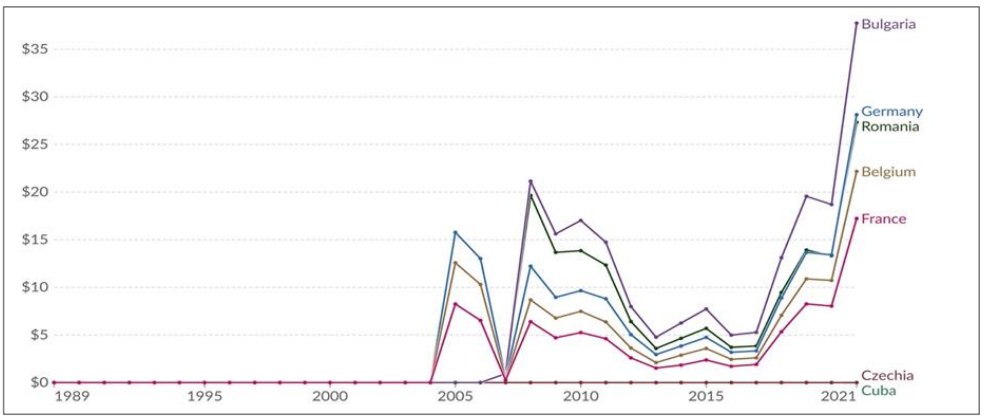
Source: Our World in Data (2023c).

Figure 3: Nuclear power generation (Measured in terawatt – hours)

Bulgaria is one of the EU countries with still a relatively high share of the use of nuclear energy for electricity production (more than 30%). However, the country lost more than twenty years in unfruitful debates over the future of for example one of the largest nuclear projects in the country, the „Belene" nuclear project, where more than 3 billion leva (approximately 1.5 billion euros) were invested in buying two reactors and initial construction work. The possible switch of the project towards enlargement of the existing nuclear plant in Kozluduy may take more than fifteen years in licensing, project development and construction. Yet, there is no solution on the financing model and the assumptions for this enlargement. During the last 10 years the Bulgarian governments argue that both „Belene" and „Kozloduy" must be completely private projects. In my view, such a position is a matter of reassessment and building a sustainable long-run energy project in the country. Most probably the Bulgarian government must become co-investor and/or must give some guarantees on the electricity price for a certain period. The Government and the potential investors must reach an agreement securing low risk and sufficient investment return for all participants in such a huge, long-term oriented project. This is the approach taken by the Polish Government in the recently announced (August 2024) decision for building of the country's first nuclear plant.

Competitiveness and the energy independent component – Connecting the dots within the limitations of energy models for sustainable development

The positive expectations for the large-scale use of nuclear energy are based on the new energy policy models of the EU (Bertoldi and Mosconi, 2020). The combination of nuclear and renewable energy can provide a balanced and diversified energy portfolio that ensures reliability, affordability, and environmental sustainability. As of 2024, the most competitive countries in the world have heavily developed energy sectors that prioritize both renewable (Gielen et al., 2019) and nuclear energy sources (Kartal et al., 2023). First, a well-developed energy sector is crucial for ensuring energy security and reliability.



Source: Our World in Data (2023d).

Note: *Yearly* prices, expressed in constant 2019 US$ per ton of carbon dioxide-equivalents, are either averages of daily allowances, allowance-weighted averages of clearing prices in all auctions held within that year.

Figure 4: Emissions-weighted carbon price in emissions trading systems, 1989 to 2021

Furthermore, investing in renewable and nuclear energy is essential for meeting climate goals and reducing carbon emissions. As the world grapples with the urgent threat of climate change, countries that prioritize clean energy sources are better positioned to transition to a low-carbon economy and fulfill their commitments under international agreements like the Paris Agreement. By reducing their carbon footprint, these countries not only contribute to global efforts to combat climate change but also create a cleaner and healthier environment for their citizens. Data shown on Figure 4 indicates rather alarming for our country trends. The emissions-weighted carbon price in Bulgaria is much higher than

the one in the developed EU economies but also much higher than in former socialist countries like the Czech Republic and Romania. I share the forecasts and expectations based on the current developments of the market for tradable permits pointing at unavoidable price increase both in the short and in the long term. It means that such developments may become an unbearable burden on the Bulgarian producers. The pressure from the competitive Chinese export on the world market is increasing and it will be difficult for us to sustain competitiveness if we must face a further price increase of those permits. Therefore, Bulgaria must take active measures for the gradual decrease of energy production based on fossil fuels and its substitution with „green" renewables and „green" nuclear energy, moving upward in the world competitiveness index.

Conclusion and Recommendations

A strong emphasis on renewable and nuclear energy can drive innovation, spur economic growth, and create new opportunities for job creation and investment. The renewable energy sector has emerged as a hotbed of technological advancements, attracting talent, capital, and research and development initiatives. By fostering a culture of innovation and entrepreneurship in the energy sector, competitive countries can position themselves as leaders in the global clean energy transition and reap the economic benefits that come with it. We must stress the fact that the most competitive countries as of 2024 have heavily developed energy sectors that prioritize renewable and nuclear energy for a multitude of reasons. As other countries look to emulate their example, the transition to a more sustainable energy future is not just a matter of choice but a necessity for long-term prosperity and sustainability, for the new agenda in terms of competitiveness, both at a national and corporate level (Gechev**,** 2011)**.**

We are proposing a few key recommendations about the achievement of an optimal energy mix in correspondence with the specifics of Bulgaria:

- The development of any kind of energy mix is useless and inappropriate if the country does not have a system of national priorities with short, mid-term and long-term quantitative and qualitative criteria and indicators. Unfortunately, Bulgaria does not have such national priorities yet, approved by the national parliament, especially in the energy sector.
- The restructuring of the Bulgarian economy is a precondition for the achievement of an efficient and adequate energy mix between renewable and nuclear energy production. It will be wrong to seek such optimization based on the economic status quo or business as usual.
- The transition from industries with high energy intensity to industries with low energy intensity is a must due to two main reasons: Firstly, our energy

intensity is more than three times higher than the similar indicator of the EU. Therefore, for us it will be cheaper and faster if such a transition is combined with movement to industries with low energy intensity. Secondly, we do not have sufficient capacity for renewables capable of substituting the rising deficit and respectively rising prices of non-renewables on the international markets. The geopolitical developments in Europe and the Middle East will further complicate this situation.

- Further, Bulgaria must accelerate the project development and the building of new nuclear energy facilities. As shown in our case studies, the renovation and the introduction of new nuclear facilities are taking place in an increasing number of developed and developing countries. Unfortunately, in contradiction with its own interests, Bulgaria does not follow this clear trend in the EU and beyond.
- Bulgaria has the necessary potential for further enlargement of its nuclear capacity, including vast reserves of uranium ore. Therefore, it is in our interest to better utilize this potential and to make it a substantial component of our energy mix.
- We recommend the implementation of a stronger dependence between the economic growth and the full cost of unit additional GDP. It does not make sense if we are programming high growth based on environmentally-unfriendly technologies with high energy intensity and therefore with a high economic and social cost. Therefore, not just the nominal value of the growth is important, but rather the degree of the energy mix optimization.

Discussion

The energy sector is a crucial component of modern society, powering our homes, businesses, and transportation systems. As the world grapples with the dual challenges of climate change and energy security, the discussion of the balance between renewable and non-renewable energy sources has become increasingly important. The discussion of balancing renewable and non-renewable energy sources is one of the most important issues facing the energy sector today. By transitioning towards a cleaner, more sustainable energy mix, we can reduce our carbon emissions, mitigate climate change, and ensure a reliable and secure energy supply for future generations. Through a combination of policy measures, technological innovation, and public engagement, we can build a more sustainable energy future. As prof. Mazzucatto argues *„A mission-oriented approach to transform capitalism is the only way to make progress towards sustainable development*“ (Mazzucatto, 2022), so we need a model that benefits both people

and the planet, supporting the most competitive countries in the world and the best mutually supportive business energy models.

References

Adamantiades, A., Kessides, I. (2009). Nuclear power for sustainable development: Current status and future prospects, Energy Policy, Volume 37, Issue 12, pp. 5149-5166.

Bertoldi, P., Mosconi, R. (2020). Do energy efficiency policies save energy? A new approach based on energy policy indicators (in the EU Member States), Energy Policy, Volume 139, 111320.

Euroactive. (2024). The official website of Euroactiv.com (28.07.2022), available at: https://www.euractiv.com/section/energy/opinion/eu-decision-to-label-nuclear-green-is-key-to-energy-transition-and-autonomy/

Gechev, R. (2011). Natural resources and economic growth, Journal Ikonomika 21, Issue 1- Eng.

Gielen, D., Boshell, F., Saygin, D., Bazilian, M., Wagner, N., Gorini, R. (2019). The role of renewable energy in the global energy transformation, Energy Strategy Reviews, Volume 24, pp. 38-50.

Jasper, J. (2014). The Nuclear Politics – Energy and the State in the United States, Sweden and France, Princeton Legacy Library, Princeton University Press

International Institute for Management Development. World Competitiveness Center. (2024). The official website of IMDB on the competitiveness ranking as of 2024 (20.07.2024), available at: https://www.imd.org/centers/wcc/world-competitiveness-center/rankings/world-competitiveness-ranking/rankings/wcr-rankings/#_tab_Rank

Kartal, M., Samour, A., Adebayo, T., Depren, S. (2023). Do nuclear energy and renewable energy surge environmental quality in the United States? New insights from novel bootstrap Fourier Granger causality in quantiles approach, Progress in Nuclear Energy, Volume 155, 104509.

Khan, I., Hou, F., Zakari, A., & Tawiah, K.V. (2021). The dynamic links among energy transitions, energy consumption, and sustainable economic growth: A novel framework for IEA countries, Energy, Volume 222, 119935.

Lund, P.D., Skytte, K., Bolwig, S., Folsland Bolkesjö, T., Bergaentzlé, C., Gunkel, Ph., Kirkerud, J., Klitkou, A., Koduvere, H., Gravelsins, A. (2019). Pathway Analysis of a Zero-Emission Transition in the Nordic-Baltic Region, *Energies* 12, no. 17: 3337.

Mazzucatto, M. (2022). Financing the Green New Deal, Nature Sustainability 5, pp. 93-94.

Our World in Data. (2023a). Consumption-based CO2, emissions per capita vs. vs GDP per capita, available at: https://ourworldindata.org/grapher/consumption-co2-per-capita-vs-gdppc

Our World in Data. (2023b). Energy use per person, 2023, available at: https://ourworldindata.org/energy

Our World in Data. (2023c). Nuclear power generation, available at: https://ourworldindata.org/nuclear-energy

Our World in Data. (2023d). CO_2 and Greenhouse Gas Emissions, available at: https://ourworldindata.org/co2-and-greenhouse-gas-emissions

Prăvălie, R., Bandoc, G. (2018). Nuclear energy: Between global electricity demand, worldwide decarbonization imperativeness, and planetary environmental implications, Journal of Environmental Management, Volume 209, pp. 81-92.

Rahman, A., Farrok, O., Haque, M. (2022). Environmental impact of renewable energy source based electrical power plants: Solar, wind, hydroelectric, biomass, geothermal, tidal, ocean, and osmotic, Renewable and Sustainable Energy Reviews, Volume 161, 112279.

Shahbaz, M., Jam, F., Bibi, S., and Loganathan, N. (2015). Multivariate Granger causality between CO2 emissions, energy intensity and economic growth in Portugal: evidence from cointegration and causality analysis, Technological and Economic Development of Economy, 22 (1), pp. 47-74.

Sovacool, B. (2008). Valuing the greenhouse gas emissions from nuclear power: A critical survey, Energy Policy, Volume 36, Issue 8, 2008, pp. 2950-2963.