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Editorial

Addressing Challenges of Low-Carbon Energy Transition

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Currently, national bodies and international congregations, such as that of the Stockholm, Rio, and Johannesburg conferences, jointly identified that sustainable energy development has proven to be a very challenging factor in global development. Indicative sustainability challenges facing humanity include greenhouse gas emissions (GHGs) and global climate change, with fossil fuels, led by coal, natural gas, and oil, contributing almost two thirds of global electricity generation in the year 2020.

This editorial proposes a roadmap of international strategies for sustainable energy transition and sustainable electricity generation in alignment with past and current energy-transition measures and policies. Such international strategies involve commitments such as the Paris Agreement, aimed at reducing GHGs and achieving a global average temperature rise to 1.5 °C above the pre-industrial level. The technological changes to be implemented are the following: (a) energy savings on the demand side, (b) generation efficiency at the production level and fossil fuel substitution by various renewable energy sources (RES), and (c) low nuclear carbon [1]. These technological changes require low-carbon energy transition to develop and spur new technological advancements for further exploitation of abundant but intermittent RES in a sustainable mix of limited non-renewable sources. Such a sustainable mix can support the minimization of costs and environmental impacts while maintaining high standards of quality, stability, and flexibility in an electricity supply system. The technologies needed for this low-carbon energy transition support the use of conventional mitigation (negative emissions) technologies in order to sequester carbon emissions; to alter the global atmospheric radiative energy budget; and eventually, to stabilize or even reduce the global average temperature. Such indicative sustainable electricity systems are jointly approaching technology, policy, strategies, and infrastructure—such as smart grids and models—with an appropriate mix of both renewable and low-carbon energy sources [1].

Hence, transmission systems need to be upgraded simultaneously by the integration of large-scale renewable power plants and by changing the mix of generations to ensure system reliability. Subsequently, considering carbon emission costs, carbon trading, and carbon taxes can improve renewable power systems through the large penetration of renewable power generators by adding the costs related to a sudden change in renewable generation (ramping cost) in the objective function. Since electrification is characterized as one of the major determinants of carbon dioxide emission reduction, the modelling of decarbonizing power systems can be demonstrated in real-world systems from the electricity sector to address global climate change and to mitigate the impacts of climate change over the coming decades [2].

For low-carbon energy transition, it remains technically feasible and economically beneficial to operate large-scale RES technologies to steer the global electricity transition towards sustainable energy production and supply to then improve efficiency, compared with existing non-renewable sources, and to also significantly reduce costs and to provide

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stable energy. Subsequently, a resilient grid with advanced energy-storage capacities from variable renewables should also be part of the transition strategies [1].

A critical dimension of low-carbon energy transitions is climate change mitigation. Climate change mitigation in an urban environment can be linked to households' energy consumptions, thus directly and positively impacting energy-poverty reduction due to a high reduction potential for greenhouse gas (GHG) emissions. In an urban environment, whether the renovation of residential buildings or the installation of micro-generation technologies based on renewable energy sources could possibly meet energy savings and the reduction potentials for GHG emissions remains a topic of future research [3]. In the relevant literature, climate change mitigation policies in the household sector can support energy-poverty reduction and energy justice. Subsequently, measures and policies on climate change should confront the shortcomings of existing energy-poverty reduction management measures and should implement measures of climate change mitigation linked to energy consumption in households [3].

Climate change consequences are also increasingly problematic in terms of lowering the air quality, especially in densely populated areas around the world, such as in China. Since air pollution has become an increasingly serious environmental problem in such densely populated areas, a problem that becomes even worse due to winter heating, different policies have been applied to replace coal in heating systems during winter, the so-called "coal to gas" policy [4]. In such a study, the effects of this policy reform were examined using a panel dataset of 16 districts in Beijing, focusing on the impacts of the "coal to gas" policy on air quality. Strong evidence sustained that the "coal to gas" policy significantly improved the air quality in Beijing in terms of reductions reported for the detection of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter smaller than 10 μm (PM10), particulate matter smaller than 2.5 μm (PM2.5), and carbon monoxide (CO). This "coal to gas" policy was proven to be particularly effective in areas with less energy-use efficiency, supporting central governments in continuing to alleviate air pollution locally and globally [4].

Another critical dimension of low-carbon energy transition is electrification. Indeed, electrification plays a determining role in improving quality of life, especially among rural communities, where anthropocentric energy policies can challenge sustainable development among local communities. In this context, it can be noted how electrification affects sustainable development at the grassroots level with experimental indicators, such as economic, technical, social, and environmental ones [5]. In such a study, the varying electrification levels and the extent of local electrification towards communities' sustainable development were determined by an exploratory factor analysis for two islands in the Philippines with less than 500 households. It is noteworthy that, where communities experienced less than 24 h electricity access, there were rarely productive uses of electricity and the local communities still made use of conventional fuels for lighting. Contrarily, in communities with 24 h electricity access, there were improvements in almost all aspects, although they were slightly burdened by the unaffordability of tariffs. This means that a longer duration of electrification enables local communities to experience strikingly positive impacts on their socioeconomic development; thus, decision- and policy-makers can assess electrification in rural off-grid communities, streamlining efforts to support underprivileged communities in achieving sustainable development [5].

Based on the relevant literature, there is a strong relationship between sustainable development and low-carbon energy transition through the utilization of renewable energy, as well as a shift towards other types of fuel and upgrades to conventional units. In such a way, the low-carbon energy transition can, first, set goals for emission peaks and carbon neutrality and, second, provide a variety of energy products and flexible adjustment functions for power systems with high penetration of RES. Such energy-transition planning refers to modulation/manufacturing principles and advantages, optimal configuration schemes based on equipment capacity, as well as the operational flexibility of a power system [6].

In a similar study, the authors utilized indicators relevant to energy policies and to energy transition, containing five critical social equity impacts—environmental improvement, health, employment, participation, and energy cost—from the viewpoint of an "equitable" energy transition [7]. Therefore, it is apparently challenging to investigate the correlation between quantitative social equity impacts and the shift toward new electricity-oriented RES (mainly wind, photovoltaic, geothermal, tidal, and biomass) with varied timescales; geographical coverages; and differing developmental levels, energy resources, and policies applied [7]. Social equity improvement is promising through the increased utility of new RESs, especially among developing nations, where it is critical to enjoy short-term social equity benefits at the risk of long-term negative social equity outcomes. In such a way, the holistic evaluation of low-carbon energy transition and social equity can proactively realize a more equitable energy transition [7].

In densely populated and fast developing countries, such as in China, the equitable energy transition, and swift expansion of wind and solar energy investments go beyond the notion of a state-led model, implying that, due to a series of internal power struggles and external shocks, the current regulatory system is undergoing significant restructuring. Such a technological shift is linked to new policies that are largely differentiated from the policies from previous decades that were concentrated on capacity expansion and instrumental interests for RES development. By presenting the institutional arrangements of nations' (such as China's) regulatory systems from the RES technological sectors, existing institutions and vested interests can face tremendous challenges while inspiring the development of ideologies that can help RES technological sectors truly compete with energy incumbents in order to bring about meaningful low-carbon energy transitions locally and globally [8].

The combined effect of increasing energy efficiency and controlling the mitigation of global warming is apparently pronounced in energy-intensive sectors, such as that of the energy-intensive pulp and paper industry (PPI), suggesting an imperative need for transforming energy-use practices, energy security, and industrial competitiveness. Among the leading forerunners of energy-efficient operations and decarbonization of the PPI are Finland and Sweden [9]. Changes in energy production and consumption using a decomposition analysis of companies' investments into energy technologies and an energy efficiency index targeted the following: (a) a decrease in energy consumption per unit produced and (b) a decrease in the share of fossil fuels through partial replacement with bio-based alternatives; then, energy efficiency and self-generated green electricity can be further improved, especially at the operational level for kraft pulp mills [9].

At a similar geographical area, it was argued that the five Nordic countries have aggressive climate and energy policies and are among the leaders of RES technologies and energy efficiency achievers. Denmark is a pioneering country of wind energy, Finland and Sweden are pioneering countries of bioenergy, Norway is a pioneering country of hydroelectricity, and Iceland is a pioneering country of geothermal energy. Thus, these countries show promise in meeting the "fossil free" target by 2050. Low-carbon energy transition among the Nordic countries implies (a) promoting decentralized and renewable forms of electricity supply, (b) shifting to more sustainable forms of transport, (c) improving the energy efficiency of residential and commercial buildings, and (d) adopting carbon capture and storage technologies for the industrial sector [10]. Empirical barriers that the Nordic transition must confront are those of political contestation, technological contingency, as well as social justice and recognition concerns. Such an integrated framework should shape future transition pathways for both energy researchers and energy planners [10]. Similar renewable-energy efficiency policies for the demand sides include the decarbonization of the following sectors: transport, mining, and other industries; their aim is to reduce emissions from the demand side, while reaching more than 80% renewable electricity generation by 2030, including mainly wind, solar, and hydropower plants. Such cleaner production portfolios can support fewer emissions and more source diversification, thus contributing to national sustainable development goals, even though emissions reduction by 2030 from the demand side is not clearly noticed for some scenarios [11].

Climate change is also relevant to energy poverty, which is an important target of the sustainable development goals and a frequent vulnerability due to socioeconomic conflicts and governance failures (to meet such SDGs). In this respect, research on energy poverty and energy security are linked to sustainability transitions in alignment with (indeed, little attention to) security threats as factors influencing transitions or security policy as part of policy mixes [12]. Policy coherence and integration analyses of energy poverty and energy security should be linked to strategy documents with research on sustainability transitions, considering how landscape pressures and energy niches are presented locally and globally. In such a governmental documentation pertaining to Estonia, Finland, and Scotland during 2006–2020, it was shown that energy policies on security and poverty functionally overlap. However, policy integration and coherence have yet to be sufficiently addressed, focusing on conflicts created by coexisting low-carbon and hydrocarbon-based security considerations. While the accelerating energy transition, the energy poverty affection, and the energy security implications of energy niches have received too little attention, an increasingly multifaceted landscape is offered to create a complicated policy environment where pursuing policy coherence becomes solidified [12].

In a similar geographical context, the main challenges of the low-carbon transition in the Baltic States were studied, providing a discussion of energy and climate policies and ranking these countries based on achievements regarding the low-carbon transition under the criteria of energy-poverty issues, which are key issues during the transition towards a low-carbon future [13]. The methodology applied, MCDM tool-COPRAS, enabled the adoption of indicators to rank the Baltic States in terms of the most important climate change mitigation and energy poverty reported. The selection of these indicators was based on a literature review, while the ranking of countries was based on results from scenarios showing how low-carbon energy transition can be accomplished [13,14]. In this respect, the repercussions of a low-carbon energy transition policy should be discussed during ongoing debates on policies about accelerating the phase-out of coal to meet climate change targets, such as in the case of exploring the impacts of such destabilization policies—most prominently, in the case of Germany's nuclear phase-out policy—on technological change in RES technologies [15].

However, the commitments to climate change mitigation and the plan of "greening" energy systems may not make themselves any fairer, inclusive, or just. Therefore, for energy fairness, it remains crucial to investigate how the diffusion of low-carbon technologies can impact gender and social equity. In this context, RES projects alone cannot achieve gender and social equity, as energy interventions do not automatically tackle the structural dynamics embedded within sociocultural and socioeconomic contexts. Contrarily, existing power asymmetries that are related to access and resource distribution, if not addressed early on lead to the same structural inequalities simply being replicated and transferred over into new energy regimes [16]. Subsequently, the primary driver of a low-carbon energy transition is governmental responsibility in the early stages of an transformation from centralized to decentralized energy, while concerning the experience accumulated from existing (small-scaled) regional and municipalities' experience [17]. Therefore, a contemporary energy plan should examine the dynamic and complex processes derived from ongoing decision making from (local-leveled) energy transition to RES technologies [17]. Therefore, it remains challenging to determine how methodologies should define the drivers, barriers, and policy recommendations that are case-specific to the geographical areas studied [13].

In such a case-specific analysis committed to climate change, transmission investment was proposed as an instrument for low-carbon energy transition. Investing in the transmission capacity implies the occurrence of a physically connected market and inter-regional trade of effective fuel shifting; thus, a transmission investment strategy can optimally integrate the following: (a) geopolitical parameters among geographically close countries but under different political jurisdictions judged as stable and receptive to firm trading arrangements; (b) economic parameters related to the fuel mix, where the differences in nations' supply and demand characteristics are important for achieving mutual benefits through cost reduction; (c) environmental parameters linking nations' carbon intensities, which could benefit from the resources of a neighboring jurisdiction with lower intensities; and (d) financial parameters for each country, which are able to attract investment capital. This integrated approach to a low-carbon energy transition/energy economy is apt in the economic and environmental dimensions [18].

While the benefits in the economic and environmental dimensions are apparent, that in the technological dimension is more subtle. Indeed, with the discontinuation of the established technological regime and the technological change, they have to be redirected and accelerated in the direction of zero-carbon solutions [15]. Given the utmost priority and significance of climate change, the following can simultaneously support phase-out emerging policy mixes:

- The development and diffusion of low-carbon technologies and low-carbon solutions [15];
- Policy mixes and sustainability transitions regarding the "flip sides" to innovation [15]; and
- The crucial importance of destabilization policies for unleashing "destructive creation" [15].

Moreover, among the main challenges of a low-carbon energy transition in rural areas is electrification in rural areas or islands, where it is technically impossible for remote island communities to make land available for a centralized solar PV system. In such cases, the transition towards higher-tier electricity access has been materialized through a multi-tier framework (MTF) of electricity access from tier 0, where access is very limited, to tier 5, where access is of a grid quality. The critical point of this transitioning of households from lower to higher tiers can unlock the potential in meeting more of their energy needs. The move from lower to higher tier levels in all MTF attributes was proven successful for households, except for affordability, since the cost of a standard electricity consumption package of 1 kWh/day was dropped from 18% of the average household income to 6%. Again, high levels of electrification are feasible through a microgrid using rooftop solar PV. In such a context, affordability remains a challenging issue worthy of more intensive investigation [19].

The low-carbon energy transition in a global context of interest cannot be feasible without attempting to commit industrial decarbonation in the energy-intensive industrial sector. This sector is among the first and one of the most important (and in many cases traditional) employers of industrial activity and national revenue sources in developing and developed economies worldwide [20]. In this respect, it is noteworthy to examine the energy, economic, and environmental fallout, as well as production evaluation and to control the investment and the carbon dioxide emissions reported. Similar to the industrial sector, the energy sector is certainly characterized by a strong dependence on fossil imports that increase the energy factor and price. In this regard, several geographical sites and factories should be studied under a variety of climatic regional conditions in order to determine the optimal sustainable configurations for each location, both at a modelling scale and in real-world conditions for local and global energy and environment gains and investments [20].

Besides the prospects of low-carbon energy transition in the industrial sector thanks to RES technologies discussed in the relevant literature, a wide spectrum of key aspects—mainly barriers, challenges, and opportunities—in the context of agro-biomass and agro-industrial waste valorization that can accelerate a low-carbon economy was explored. Such an analysis is primarily important especially in countries such as Greece, where agricultural production and agro-industrial business are the most prevailing economic sectors [21]. In such a low-carbon economy transition, the Circular Waste Bioeconomy (CWBE) principles were introduced and integrated into the economic, social, and environmental characteristics in a local-level analysis, offering insights into how to leverage (regional-driven) emerging low carbon circular economy in the future. The research constraints reported were inefficient management in the region, suffering from a lack of synergies and collaborations between different stakeholders. To this end, a low-carbon CWBE adoption for regional development should (a) comply with local community cohesion and symbiosis; (b) offer financial market opportunities to implement critical small-local leveled projects; and (c) call young scientists and citizens to instill their awareness, build up their knowledge and skills as well as nurture citizens' personal responsibility towards public-owned schemes of circularity interest [21].

In general, based on this editorial, the consideration of geographical implications in research cannot be undermined, since a prosperous low-carbon energy transition cannot be conceptualized without valuing the following six determinants: location, landscape, territoriality, spatial differentiation, scaling, and spatial embeddedness [22]. In this study, it was illustrated that the geographies of a future low-carbon economy are not yet fully determined and that a range of divergent—and contending—potential geographical futures have to be determined. The research focus was placed on spaces and places that a transition to a low-carbon economy will produce, enhancing our understanding of what living in a low-carbon economy will be like. To this end, methods of evaluating the choices and the pathways available are also crucial [22].

Linking the past with the future, future research studies should be resolutely committed to the green transition of national economies by opting for industry decarbonation and energy efficiency, which now impose themselves as essential access criteria to foreign markets, taking into consideration the integration synergies developed (especially synergies that jointly provide carbon dioxide emissions savings and advantageous payback times) among RES technologies, such as solar energy opportunities and protagonist actors for thrifty, sustainable, and low-carbon industries of the future. This energy efficiency prospect based on RES utilization is especially challenging among energy-intensive industrial sectors, such as that of the textile sector [20].

Closing this editorial, it is noteworthy that research recommendations should stress the effectiveness with which policymakers, researchers, and practitioners are able to research, develop, demonstrate, and deploy culturally appropriate technologies and policies for a low-carbon energy transition [23]. Theoretically, the "low-carbon energy transition" and the "green transition" can be clearly distinguished, while a framework with relevant dimensions for an energy-transition analysis can be introduced. Practically, the effectiveness of different incentives for given periods can be clearly explained from the perspectives of direction, intensity, and timeliness, which provide valuable reference for governments' decision-making [24].

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References

1. Kabeyi, M.J.B.; Olanrewaju, O.A. Sustainable Energy Transition for Renewable and Low Carbon Grid Electricity Generation and Supply. *Front. Energy Res.* **2022**, *9*, 743114. [CrossRef]
2. Shen, W.; Qiu, J.; Dong, Z. Electricity network planning targeting Low-Carbon energy transition. *Glob. Energy Interconnect.* **2018**, *1*, 487–499. [CrossRef]
3. Streimikiene, D.; Lekavičius, V.; Baležentis, T.; Kyriakopoulos, G.; Abrhám, J. Climate Change Mitigation Policies Targeting Households and Addressing Energy Poverty in European Union. *Energies* **2020**, *13*, 3389. [CrossRef]
4. Liu, Z.; Chen, X.; Cai, J.; Baležentis, T.; Li, Y. The Impact of "Coal to Gas" Policy on Air Quality: Evidence from Beijing, China. *Energies* **2020**, *13*, 3876. [CrossRef]
5. Lozano, L.; Taboada, E. The Power of Electricity: How Effective Is It in Promoting Sustainable Development in Rural Off-Grid Islands in the Philippines? *Energies* **2021**, *14*, 2705. [CrossRef]
6. Zhou, X.; Zhao, Q.; Zhang, Y.; Sun, L. Integrated energy production unit: An innovative concept and design for energy transition toward low-carbon development. *CSEE J. Power Energy Syst.* **2021**, *7*, 1133–1139. [CrossRef]
7. Chapman, A.; Shigetomi, Y.; Ohno, H.; McLellan, B.; Shinozaki, A. Evaluating the global impact of low-carbon energy transitions on social equity. *Environ. Innov. Soc. Transit.* **2021**, *40*, 332–347. [CrossRef]
8. Shen, W.; Xie, L. The Political Economy for Low-carbon Energy Transition in China: Towards a New Policy Paradigm? *New Political Econ.* **2018**, *23*, 407–421. [CrossRef]

9. Lipiäinen, S.; Kuparinen, K.; Sermyagina, E.; Vakkilainen, E. Pulp and paper industry in energy transition: Towards energy-efficient and low carbon operation in Finland and Sweden. *Sustain. Prod. Consum.* **2022**, *29*, 421–431. [CrossRef]
10. Sovacool, B.K. Contestation, contingency, and justice in the Nordic low-carbon energy transition. *Energy Policy* **2017**, *102*, 569–582. [CrossRef]
11. Simsek, Y.; Sahin, H.; Lorca, Á.; Santika, W.G.; Urmee, T.; Escobar, R. Comparison of energy scenario alternatives for Chile: Towards low-carbon energy transition by 2030. *Energy* **2020**, *206*, 118021. [CrossRef]
12. Kivimaa, P.; Sivonen, M.H. Interplay between low-carbon energy transitions and national security: An analysis of policy integration and coherence in Estonia, Finland and Scotland. *Energy Res. Soc. Sci.* **2021**, *75*, 102024. [CrossRef]
13. Streimikiene, D. Low carbon energy transition of baltic states. *Montenegrin J. Econ.* **2021**, *17*, 219–230. [CrossRef]
14. Streimikiene, D.; Kyriakopoulos, G.L.; Lekavicius, V.; Siksnelyte-Butkiene, I. Energy Poverty and Low Carbon Just Energy Transition: Comparative Study in Lithuania and Greece. *Soc. Indic. Res.* **2021**, *158*, 319–371. [CrossRef]
15. Rogge, K.S.; Johnstone, P. Exploring the role of phase-out policies for low-carbon energy transitions: The case of the German Energiewende. *Energy Res. Soc. Sci.* **2017**, *33*, 128–137. [CrossRef]
16. Johnson, O.W.; Han, J.Y.-C.; Knight, A.-L.; Mortensen, S.; Aung, M.T.; Boyland, M.; Resurrección, B.P. Intersectionality and energy transitions: A review of gender, social equity and low-carbon energy. *Energy Res. Soc. Sci.* **2020**, *70*, 101774. [CrossRef]
17. Takao, Y. Low-carbon leadership: Harnessing policy studies to analyse local mayors and renewable energy transitions in three Japanese cities. *Energy Res. Soc. Sci.* **2020**, *69*, 101708. [CrossRef]
18. Guler, B.; Çelebi, E.; Nathwani, J. A 'Regional Energy Hub' for achieving a low-carbon energy transition. *Energy Policy* **2018**, *113*, 376–385. [CrossRef]
19. Rabuya, I.; Libres, M.; Abundo, M.; Taboada, E. Moving Up the Electrification Ladder in Off-Grid Settlements with Rooftop Solar Microgrids. *Energies* **2021**, *14*, 3467. [CrossRef]
20. Smouh, S.; Gargab, F.Z.; Ouhammou, B.; Mana, A.A.; Saadani, R.; Jamil, A. A New Approach to Energy Transition in Morocco for Low Carbon and Sustainable Industry (Case of Textile Sector). *Energies* **2022**, *15*, 3693. [CrossRef]
21. Fytili, D.; Zabaniotou, A. Organizational, societal, knowledge and skills capacity for a low carbon energy transition in a Circular Waste Bioeconomy (CWBE): Observational evidence of the Thessaly region in Greece. *Sci. Total Environ.* **2022**, *813*, 151870. [CrossRef]
22. Bridge, G.; Bouzarovski, S.; Bradshaw, M.; Eyre, N. Geographies of energy transition: Space, place and the low-carbon economy. *Energy Policy* **2013**, *53*, 331–340. [CrossRef]
23. Sovacool, B.K.; Griffiths, S. The cultural barriers to a low-carbon future: A review of six mobility and energy transitions across 28 countries. *Renew. Sustain. Energy Rev.* **2020**, *119*, 109569. [CrossRef]
24. Pingkuo, L.; Huan, P. What drives the green and low-carbon energy transition in China?: An empirical analysis based on a novel framework. *Energy* **2022**, *239*, 122450. [CrossRef]