International Journal of Economy, Energy and Environment
2025, Vol. 10, No. 1, pp. 7-16
https://doi.org/10.11648/j.ijeee.20251001.12

Review Article

Prospects and Challenges of Sustainable Energy Future: Policy and Technology Perspectives

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Abstract

The world faces unprecedented pressure to develop appropriate tools and policies for a sustainable energy future. Though science suffers from a burden of proof, it has thus far proved true to different predictions on human-induced climate change impacts. The call to transition from sole dependence on fossil fuels to drive human civilization is alarming. Science, technology, and international climate policies provide some promising steps toward a practical net-zero economy path. Policies, innovations, and technologies play a critical role in supporting the energy transition agenda toward a sustainable future. The recent innovations in technology and business models that embrace the adoption of alternative energy sources are impressive, where the use of renewable and alternative energy sources such as solar and wind are gaining traction. Awareness of the importance of adopting a suitable energy future is on the rise, with private investors beginning to push companies to change; countries worldwide are adopting various measures to a just transition, essentially adopting policies to embrace a low-carbon economy. Amid all the positive indications of the global community to embrace a sustainable energy future, the challenge of replacing fossil fuels, which are thus far the cheap, versatile, and dependable energy source, is prevalent. Appropriate policies will need to be adopted so that there will be a just transition embracing the principle of leaving no one behind. To keep up with the pace of the global social economic dynamics, countries will have to embrace strategies that mix different options tailored in local conditions while keeping abreast with the global dynamics. This paper reviews the roles of appropriate policies and technological advancement to support a sustainable energy future.

Keywords

Sustainable Energy Future, Energy Transition, Renewable Energy, Technology, Policies

1. Introduction

Planet life is tied to the energy supplied in it; the energy supply has been evolving over the years, starting from the early days when energy was solely dependent on biomass to the modern energy solutions characterized by technological advancement and resource discovery. The recent innovations in technology and business models to embrace the adoption of alternative energy sources are impressive; solar and wind, for instance, have recorded a 10-35 percent cost reduction for every doubling of installations; hydrogen and biofuels seem to follow suit [1]. Despite the evolution, the world faces unprecedented challenges in energy supply and resources. There is a mismatch between supply and demand, and this is projected to grow substantially in the future as the demand grows and the resources are depleted. The future of energy will be

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Received: 18 February 2025; **Accepted:** 28 February 2025; **Published:** 13 March 2025

determined by various factors; the energy consumption patterns, which is the growth in demand, will affect the level of energy services to be provided. The future energy scenarios will depend on consumption patterns tied to economic growth [2], technological advancement, increased population, urbanization rate, geographical and geopolitical issues and increased climate change pressures.

Opportunities exist to address the challenges inherent to future energy uncertainties. The sustainable future of energy will largely depend on appropriate policies, both local and global, that support innovation and lifestyle change. While it can be argued that technological advancement can be largely market-driven and perhaps argued as a de facto, an enabling environment would be critical to determining the pace of adoption. This short review article highlights some issues, challenges, and opportunities inherent to the policy measures and technological options for addressing the future energy landscape.

2. Methodology

This article employs a systematic literature review in line with the future technology perspectives, looking at the challenges and opportunities ahead and reviewing the technological options and policy directions that can support the future of energy scenarios to meet the demand within the considerations of other sustainable development dynamics.

3. Driving Forces for Future Energy

3.1. Energy Demand Growth

The increasing world population will have a significant impact on energy supply and consumption. The global population is projected to grow to nine billion by 2040 [3]. The future of energy demand will be seen mainly in countries outside the Organization for Economic Cooperation and Development (non-OECD); these are developing countries that are still leapfrogging on economic growth. The demand for energy is projected to be as much as 515.848 Exajoules [4] in 2040 compared with the 2019 demand levels, which stand at 418 Exajoules [4]. There is also a challenge in meeting the demand while addressing Greenhouse Gas (GHG) emissions reductions. In this case, emissions must pick up first in the 2020s and then go down. Even though renewables are increasing in capacity due to reduced costs, they cannot meet future demand alone. With the advocated future of carbon-neutral development pathways, nuclear is an essential source of energy to address the situation; functionally, the replacement of nuclear sources is not matched with renewables but coal and natural gas. Electricity demand projections by 2050 can be looked at in two scenarios: *high-demand baseline* and *low-demand baseline* across residential, commercial, and industrial sectors. The *high-demand baseline* presents the business-as-usual scenario that assumes trends for the sectors as a forecast to 2030 by the International Energy Agency (IEA) in its annual Energy Outlook 2009. The low-demand scenario "reflects emerging trends in the drivers for electricity demand, such as the growing interest in green buildings and green supply chains, carbon mitigation activities, anticipated equipment standards and energy code changes, research and development in energy efficiency, shifting away from energy-intensive manufacturing, and increasing foreign competition for manufacturing [5]."

3.2. Climate Change

Increased pressure on climate change impacts will also determine the future energy landscape. Extreme events are prevalent worldwide, ranging from droughts affecting farming activities to flooding and pest diseases, which are some of the impacts that are felt in today's world. Scientific evidence predicts that if the causes of climate change impacts are not addressed today, the future might be in jeopardy. The world is likely to witness more advocacy of global frameworks to tackle climate change, similar to the Paris objectives.

3.3. Demographic Trends and Changes in Lifestyle

Demographic trends are another factor that will affect the future of energy scenarios. Changes in populations and the need for energy use that depend on the locational situation are projected to change over time. The need for cooling in the northern hemisphere is increasingly becoming part of the energy consumption equation; this year, Europe has witnessed extremely high temperatures during summer, forcing them to use air conditioners to cool homes. For instance, the United Kingdom (UK) recorded up to 40 degrees Celsius this summer [6], and these homes will also need heating during winter periods. Conversely, changes in weather patterns in tropical regions will also affect the need for energy for various services.

The change in lifestyle will also affect energy in the future. As more people are increasingly becoming wealthier, their energy use also goes up. This is to say that a reduction in poverty, in general, will also result in a decrease in energy poverty, thus increasing energy demand. More people will be able to afford to use cars, cook with electricity, heat, and cool homes.

3.4. Urbanization and Megacities

Urbanization is also on the rise; currently, 55 percent of the world's population lives in cities. It is projected that by 2050, 68 percent of the population will be living in cities [7]. Megacities, for instance, are projected to grow at a faster rate. According to the World Energy Outlook report, a process of urbanization adds a city the size of Shanghai every four months [8]. Developing countries are characterized by rapid urbanization (28%), resulting in increased energy supply pressure. At the moment, the urban population consumes 78 percent of the global energy [9]. The *Hot Cities: battle-ground for climate change* publication by UN-Habitat portrays that urban areas account for around three-quarters of the GHG emissions causing global warming, most of which is contributed by energy consumption [10].

3.5. Global Energy Resources

The energy resource base is also a factor in determining how the energy future will unfold. According to the IEA's Key World Energy Statistics report of 2021, the global energy supply is depicted to be dependent on fossil fuels: 30.9 percent oil, 26.8 percent coal, and 23.2 percent natural gas [4]. These resources are projected to reduce substantially by the end of the century.[11] In this case, the world is projected to lean more towards alternative sources, including renewables and nuclear. Renewables are projected to constitute two-thirds of the total energy supply [12]. The BP analysis [13] on the future of energy supply articulates three scenarios for fossil fuels and renewables: new momentum, accelerated momentum, and net zero. The analysis shows the declining role of hydrocarbons compared to renewables. The analysis further argues that "in Net Zero, worldwide installed wind and solar capacity surges to over 6,500 gigawatts (GW) by 2030, quintupling relative to 2019. Conversely, in New Momentum, it totals about 3,300 GW, corresponding to a "mere" three-fold increase [14]."

3.6. Political and Policy Landscape

The future of the energy scenario will be affected by the geopolitical landscape; the on-going war in Ukraine by Russia has shifted the focus on energy resources. Analysts predict that it is likely that the efforts to shift away from fossil fuels will be slowed down as countries in Europe are faced with a shortage of supply, making them resort to any possible solution at their disposal [15]. This presents a dilemma between energy security and energy transition. In this situation, investments in fossil fuels are likely to increase, at least in a medium-term perspective. This has also set some form of precedence as countries will now be mindful of deploying energy security measures, and the use of local and decentralized energy options may gain traction.

Environmental and health concerns are increasingly becoming central to deciding investments in the energy future we want. The local population will affect the local policies and investment decisions; under the same auspice, global pollution will also dictate the global energy markets, especially on resources prone to international policies and markets, especially oil and coal. The analysis by the IEA is that there will be a decline in the importance of fossil fuels due to the global climate agenda but also improved technologies – by 2050, global fossil use will be at 50 percent of that of 2020; between 2020 and 2050 the demand for coal falls by 90 percent, oil by 75 percent, and natural gas by 55 percent [12].

Policies are also determinants for the future energy landscape. The IEA categorizes the policy landscape in two: The stated Policies Scenario, which incorporates existing energy policies as well as an assessment of the results likely to stem from the implementation of announced policy intentions, and the Sustainable Development Scenario, which outlines an integrated approach to achieving internationally agreed objectives on climate change, air quality and universal access to modern energy. Under the stated policies scenario, the total global energy consumption by 2040 is projected to reach 515,848 Penta Joules (PJ), while under the latter scenario, the demand will be 390,390 PJ [4].

3.7. Technology Evolution

Technology innovations will also affect the energy supply landscape in the future. The use of fossil fuels is likely to remain in the mix as the discovery and resource exploitation from advanced technology is achieved, as well as the means to curb the emissions are advanced, such as the deployment of carbon capture, utilization, and storage (CCUS) technologies. The rise of alternative fuel options, such as the advancement of biofuels, will also affect the future dependence on fossil fuels. Increasing energy efficiency capabilities will reduce the demand for energy for the same levels of services and qualities. Innovations in fossil-based and renewable energy technologies are likely to change the face of the energy supply scenario. The hydraulic fracturing or fracking technology of oil and gas extraction, advancement in superconductivity, energy storage and smart solutions will affect the supply mix of energy in the future.

4. Energy Sources and Technology: Prospects and Challenges

4.1. Energy Sources

4.1.1. Fossil Fuels

A complete phasing out of fossil fuels is not something that is anticipated anytime soon. Even for the 2050 forecast, fossil fuels will still be part of the energy supply mix. The main reason is that fossil sources have the advantage of dispatchability as opposed to alternative technologies. Again, most of the assets are still young and have many years ahead of a useful lifetime; it is uneconomical to abandon these assets. China, which has 1,110 operational coal-fired power plants; is leading the world in coal utilization [16]; given that the fleets are as young as two- to three- years, and the average lifetime is 30 to 50 years, several of those will have to be operational for many more years to come [17]. The net-zero pathways call for the phasing out of hydrocarbons due to their GHG emissions in the atmosphere. Technology trends show promising signs of keeping fossil sources within the energy mix while reducing GHG emissions.

Coal, being the global primary source of energy for electricity and heat, has the potential to clean up using the CCUS technology. While the technology is technically feasible, its economics are yet to be competitive in today's energy markets. The current Levellized Cost of Energy (LCOE) for coal ranges between USD 65/MWh to USD159/MWh (with no externality costs) [18]; adding the technology to clean them up will result in a range of USD86/MWh to USD 165/MWh [18]. The phasing out of the coal industry will also have a rebound effect as the industry employs many people who will lose their jobs; this conflicts with the notion of a just transition [19]. Consequently, this brings a dilemma in implementing stringent policies for the clean energy transition.

Technological advancements in oil and gas extraction are also making sources cheaper; the application of shale oil and gas extraction has been revolutionary and has resulted in efficiency and low cost. This innovation has benefited the United States of America (USA) and, consequently, has increased the appetite for many other countries to follow suit. Increased focus on Liquefied Natural Gas (LNG) is also seen as a revolution in the gas industry as it has made it possible for the fuel to be stored and transported beyond the traditional pipelines. The economics of fossil fuels supported by advanced technology conflicts with climate policies as some of these innovations make fossil fuel sources cheaper and encourage more investments.

4.1.2. Renewable Energy

Renewables are the most preferred sources of energy in the sustainable development pathways; they are clean and abundant. Renewable sources include solar, wind, geothermal, and wave, among others. There is on-going research on identifying possible renewable sources to be utilized at scale; however, most of them are still on the laboratory scale, and their economics are yet to justify their deployment to scale. This section highlights a few renewable energy sources, namely solar, wind, and hydropower, that seem more promising for future use in addressing both demand and environmental concerns. Analysts project that renewable energy will dominate the energy mix primarily due to sustainable development policies and their cost reduction. The EIA projects that "solar becomes the largest source [of energy], accounting for one‐fifth of energy supplies. Solar PV capacity increases 20‐fold between now [2020] and 2050, and wind power 11‐fold [12]."

Solar energy, for instance, is the most abundant resource on Earth. However, making it usable entails a process that makes the resource not a replacement for others. The intensity of solar energy depends on geographical locations and other factors. Various technologies are implemented in solar energy: solar photovoltaics (PV), Solar Concentrated Solar PV (CPV), Concentrated Solar Power (CSP), and Stirling, among others [20]. For solar PV systems, the economics are not competitive to achieve grid parity. Solar power requires a large area to install panels for the PVs or mirrors, or the case of CSP. The advantage of solar is that it has a diurnal curve that goes with parity to the energy demand of human beings. In this case, it can supply power during the day when human activities are taking place.

Wind is perhaps one of the renewable energy sources that is seen to be widely adopted and will have a notable footprint in the future. Offshore wind is the most reliable technology as the wind patterns are more regular than the onshore wind. However, with the LCOE averaging 84/MWh, the cost of the offshore wind, for the time being, is still on the higher side [21]. Wind is projected to make up to half of the global energy supply by 2050 [22].

Intermittent technologies, notably solar and wind, are faced with storage issues, which are necessary to smooth the power and provide power when needed when the resource is not available. The cost of technology is still high to be economical. The prospects for dealing with solar and wind energy lie in implementing smart-grid and efficient storage systems and implementing appropriate forecasting methods that will help dispatch planning. This is the solar resource math with diurnal energy demand. With abundant energy from solar and wind, there is an opportunity to generate renewable hydrogen energy with surplus energy. These will be helpful in complementing the use of fossil fuels, especially for the transportation sector.

Hydropower is the most mature technology which has been implemented since ancient times. Hydropower has the advantage over others, being a dispatchable source. Recently, climate change, which has resulted in increased drought, has affected the hydro resources adversely; even those existing power plants have seen a reduction in water resources, which has resulted in a decrease in firm power generation. Large hydropower is considered not renewable due to its adverse environmental effects on biodiversity and aquatic life. A few opportunities still exist to invest in small-scale hydropower, which is regarded as not having negative environmental impacts and, thus, categorized as renewable.

4.1.3. Nuclear Energy: The Controversial but Promising Source

Nuclear energy has many faces when it comes to future energy; while it is not renewable and is replenishable, it is a clean source of energy that, if taped, will substantially support the Paris climate objectives of limiting the temperature rise by 1.5 degrees Celsius at least by the middle of the century [23]. However, nuclear energy is the most controversial energy source due to its proliferation. There is a global threat of misusing nuclear energy as weapons of war rather than for useful energy, which threatens global security. Radioactive waste management is also a big challenge threatening people's health near these sources. This makes it face resistance from the communities. Nuclear power plants, as they are to date, are bulk (typically 1,000 MW or higher) and entail high investment costs. The overnight construction cost of nuclear is high, accounting for more than 50 percent of its total investment. Nuclear power also presents safety concerns, as the capacity to manage plants when harmful incidents such as that of Hiroshima occur is yet to be fully addressed, as it entails multiple levels of issues, from personnel skills to technology capabilities [8].

In support of the projected rising energy demand and the urgency to address climate change impacts and shift to clean energy sources, nuclear seems to have a significant role to play; for this to happen, regulations guiding this resource will have to be revisited so that nuclear proliferation challenges are somewhat taken care of. Innovations for the next generation of nuclear energy which include small modular reactors (SMR) with installed capacity below 30MW [8], also referred to as Pocket Nuclear Reactors,[24] as well as the possibility of having floating nuclear plants [25] to have movable plants generating power where and when needed will be paramount. Several countries have nuclear resources that they use as a source of energy; France, for instance, generates around 85 percent of its electricity from nuclear sources [26], and on a global scale, nuclear energy generates more than 11 percent of electricity [8]. Amid all the controversy, the world is witnessing an increasing interest in investing in Nuclear energy as a dependable energy source in many economies; China is leading in having the most significant share of nuclear energy in the pipeline [26]. Increasing investments in nuclear energy are also found in emerging markets, including in African countries such as Kenya [27].

4.1.4. Biofuels and Modern Agriculture

Biofuels have been gaining traction as renewable fuels for transportation. Countries that are at the forefront of biofuels are the USA, with half of the market share, and Brazil, with a third of the global biofuel market share [17]. They both account for 84% of global biofuels [28]. These countries have instituted a blending policy in conventional fuels with ethanol. The current widely used technology is referred to as the first generation of biofuels, which mainly use food sources such as vegetable oil, maize corn, starch and palm oil to produce ethanol and biodiesel. These present a food-energy crisis.

The second generation of biofuels that produce cellulosic ethanol relates to using non-food products or biomass to produce fuels. This presents some sources like algae, diatoms, and Jatropha. Algae, in particular, is considered the scientific solution for green and sustainable energy due to its ecological and economic features [29]. However, to be able to be adapted to scale, more scientific advancement is needed to increase productivity, harvestability and protection against pests. Some biofuel sources, such as Jatropha, grow in marginal land, making them more attractive. The advantage of these includes less competition with food products, they are abundant, and they have a significant potential for replacement of petroleum products. They also present a good source of carbon emission reductions through sequestration capability and replacement of the use of fossil fuels.

The biggest challenge with these sources is the low efficiency; more applied research needs to be carried out to make the technology commercially proven viable and accepted. Some of these crops depend on specific geographical conditions; Jatropha, for example, grows well in the equatorial belt, which does not have much fuel market. In this case, they are faced with logistical challenges in transporting them to where the market is [17]. Water use is also one of the issues linked to negative impacts on biofuel production processes. Sustainable agriculture to produce the volume of fuel needed globally will require substantial water use.

The other challenge with biofuel crops is increasing productivity; this will entail using fertilizers for which their production lines are energy intensive and contribute to GHG emissions. Improvement in agriculture will be essential in addressing these challenges to improve crop productivity with less carbon intensity in the process. Modern agriculture, which increases crop productivity, resistance to pests, and diversification, coupled with genetic engineering techniques, seems to answer these challenges. However, it is still far from being a reality. There are many issues ranging from technical, political, and acceptance issues that will need to be looked at so that biofuel can be a replacement for petroleum fuels [30].

To be fully integrated into the use of transportation, more advancements in technology will be required so that engines can be compatible with ethanol and biodiesel, just as it is with gasoline and diesel. There are many parameters that need to be addressed in this space: energy content, flash point, oxidation stability, water content, and viscosity. It is also paramount for the technology to make biofuel free from elements such as sodium, potassium, manganese, calcium, phosphorus, and sulfur, which affect engine performance and life [17].

4.2. Energy Sector Transformation

4.2.1. Decarbonization

Energy transformation is made up and will be supported by such policies as decarbonization, decentralization and digitization [17]. Decarbonization of the energy sector will be essential to support the shift from dependence on fossil fuel sources to renewable energy and the associated technologies. As stipulated in the earlier chapters of this review article, governments are forced with a challenge to find alternative ways to adhere to the global climate policies, the Paris objectives of limiting the temperate rise by 1.5 degrees come 2030 compared to the pre-industrial era, as well as sustainable development goals policies that aim at achieving a net-zero carbon development path by the mid-century, come 2050. Decarbonization will see a change in energy sources, energy efficiency measures, and technology shifts. Decarbonization will need to be approached in a just fashion to allow for minimum negative impacts on the societal socio-economic space.

4.2.2. Decentralization

Decentralization looks to be one of the options that most countries will opt for, especially to curb the threat to energy security. The on-going geopolitical tension has brought about a new dimension in the global energy supply landscape. Investment in energy systems within geopolitical boundaries will be one of the high political agendas in countries; this will be seen mainly in the OECD countries that have suffered the consequences of the on-going war in Ukraine. European Union (EU) bloc, which historically has been dependent on the Russian energy supply, 40 percent of gas, is now forced to figure out alternative energy supply options for their household and industrial applications. Replacing the energy embargo from Russia as part of the sanction package over its invasion of Ukraine will not see an appropriate replacement anytime soon. The downside is that this catastrophic situation may derail the sector's decarbonization efforts as countries might resort to quick fixes and turn to fossil-based energy supply, mainly from coal [31].

4.2.3. Digitization

Digital technology will be important in the energy supply chain. This ranges from switching devices at power generation facilities to transmission infrastructure for end uses. The future outlook comprises integrated technologies of energy sources, including intermittent sources, solar and wind. The diversity of energy sources will need to be integrated by smart technology (microgrids). Smart grid implementation is a bit complicated in the developed world where the infrastructure already exists. It is a bit easier for developing countries where the transmission infrastructure does not exist to leapfrog to innovative grid technologies [32]. At the same time, much as digitization is paramount in the future energy landscape, it presents threats to the energy infrastructure, such as the potential of cyber-attacks.

5. Options to Meet Future Energy Demand

The future energy demand will have to be met by the combination of both technology and policy. The right policies will largely encourage innovations and the advancement of technology. The future demand will be looked at from short- to medium- and long-term perspectives.

Within a short to medium period, energy efficiency plays a critical role. Energy efficiency is a cost-effective means that can be achieved in the short term. Due to increasing energy demand stress, the world will strive to institute energy efficiency measures to curb energy consumption in electricity and fuels. Electrical-powered appliances and equipment will increasingly become efficient in providing the same quality of service with less electrical consumption; such technologies are like efficient lighting systems. In the transportation sector, vehicles are increasingly becoming efficient, increasing the mileage covered with less fuel.

In the short- to medium-term, there will be a gradual replacement of fossil fuels to clean energy sources. This is primarily anticipated in terms of both electricity and fuels for transport. Renewable energy penetration is projected to grow in the medium term; to achieve climate objectives, the share of renewables in total final energy consumption should be 65% by 2050 [33] compared to that of 2019, which is 17.7% [34].

There will also be a transformation in the fuels for transport. Biofuels are gaining traction. Many countries are expected to institute policies to increasingly adopt biofuels. The USA adopted biofuel standard policies and regulations in the early 2000s; the government established the Energy Policy Act of 2005, which mandated requirements for a minimum amount of ethanol to be blended with transportation fuel [35].

The European Union bloc is also likely to follow suit if they are able to change the incentives directed to diesel towards clean energy options. Hydrogen technology is also on the rise; several countries have developed national hydrogen strategies championed by Japan and Korea in 2019 [36]. The current sources used to generate hydrogen are from fossil-based sources. The European Union bloc is projected to be at the forefront of scaling up hydrogen fuels due to its electrolyzer capacity [36]. As renewable energy sources, namely solar and wind are becoming affordable, it will be possible to generate more hydrogen with surplus power. The focus on electric mobility will also reduce the demand for fossil fuels for transportation. Countries like the United Kingdom (UK) committed to going electric by 100% by 2030. However, achieving this target is challenging as there are many issues that will have to be looked at when phasing out internal combustion engines [37]. In any case, we see automobile companies shifting their focus toward manufacturing electric cars to prepare for the future market shift [38]; this is especially true due to increased policies in favor of the transformation, like the new commitments announced by the EU bloc to phase out manufacturing and sale of new petrol and diesel cars by 2035 [39]. The future of biofuels will also be affected by new techniques for extracting the fuels; such technologies include artificial photosynthesis to increase the productivity of biofuels, which is necessary for energy storage from biofuels, support energy efficiency, robustness, and speed. The trick is finding suitable molecules for these characteristics.

Other prospects for future energy generation will be affected by the technological advancement in nuclear energy and other emerging technologies, such as a tidal wave. The superconductivity will also affect the future energy generation supply chain to meet the demand; the technology traditionally used in the telecoms is now gaining traction in wide use in energy infrastructure; improvements of this technology will be essential to support the smart, intelligent systems such as smart grids.

6. Policy Dimensions and Attributes

With the current challenges of climate change, meeting energy demand, and embracing economic growth and geopolitical spheres, countries are in the midst of choosing between a rock and a hard space. Meeting energy demand as a result of population and economic growth will most likely require local policies, as this scenario will be pertinent in developing countries with local energy resources that are still untapped. The developed world will continue to lean on embracing transboundary and global policies to meet their demand due to the fact that they lack sufficient resources at a local level.

The policies will have to be structured around three key attributes as stipulated by the World Energy Council (WEC) analysis; the policies will have to embrace the 3A's: accessibility, availability, and acceptability [40].

The policies will have to be structured to address the issue of energy accessibility. Currently, almost two billion people do not have access to commercial forms of energy and another billion have only periodic unreliable access. Despite on-going efforts to promote energy access, the population having no access to energy is still alarming; globally, nearly 759 million people are without access to electricity today [41]; this is not expected to change much by 2030 when around 650 million people are projected to still lack access to electricity [42], of these 600 million are in sub-Saharan Africa. The number in clean cooking is more alarming, with 2.6 billion people without access today globally [41]; again, this is projected not to change much by 2030, where 2.2 billion are projected to still lack clean cooking energy, and of these, 853 million are in sub-Saharan Africa. With the global Sustainable Development Goals (SDGs), namely SDG 7 (*Affordable and Clean Energy for All*), policies will have to be developed to address the energy access challenge and make access to all possible. The challenge is that meeting the growing demand may conflict with other global policies, such as the goal of limiting global temperature rise, since countries might find themselves in a situation that compels investing more in polluting sources to meet the growing demand, especially for industrial applications.

Another attribute to be considered for future energy scenarios is availability. Energy will need to be available at and when needed to provide services. Availability looks at the various aspects of the energy delivery value chain: reliability, energy quality, affordability, infrastructure, conservation, energy security, regulations, and technology. In recent years, there have been significant disturbances in getting energy resources from where they are to where they are needed and converting them to sustainable stationery, electricity, and transport services. Sustainable means linking the availability targets of governments and industry within the accessibility and acceptability targets set out.

There has been a challenge to the acceptability of some of the energy policy interventions. The local and international public concerns on safety, climate change, and air pollution resulting from some energy sources bring challenges to policy choices. There is also an issue of public attitude toward particular energy sources. Environmental concerns are among the most important factors shaping the future of the energy industry around the world. For instance, nuclear energy is a clean source that does not emit GHG emissions. It provides sufficient power for both industrial and domestic applications; however, the concerns on this source/technology are that nuclear energy presents a threat locally and globally, the issue of handling waste, and that of possible proliferation. To adopt nuclear as one of the future energy sources, governments will have to strike a balance between developing and adopting policies that are mindful of these concerns.

The governments will also have to think about how best to strike a balance between carrot and stick policies. Both direct regulations and market-based policies will have a role to play depending on geographical location and the technology targeted.

7. Conclusions

Energy demand will grow due to population and economic growth, especially in non-OECD countries. Policies to address these challenges will be necessary.

Climate change is also at the heart of future energy; the international community is striving to urge countries to institute policies and measures to curb the threatened future by climate change impacts. To abide with international sustainable development and the climate frameworks, hard choices will need to be made to allow for economic growth at the same time, address climate change concerns brought about by the energy sources. The transition and transformation to climate-friendly energy investments will need to be directed to alternative options to fossil fuels. To embrace a just transition, developed countries will have to provide the necessary support to developing countries in terms of support to investments in new and climate-friendly energy options and technologies.

The on-going geopolitical tension has brought about new dynamics for the energy pathways. Investment in energy security may see more renewable energy added to the global mix. The use of local renewable energy resources will not only bring about energy security but may also reduce the need for energy transportation, which, in a way, contributes to the reduction of global GHG emissions.

Biofuels have a promising future in replacing dependence on fossil fuels; however, their entire life cycle assessment needs to be considered to ensure that biofuels will cater to depleting resources and curb climate impacts. Technology will play a key role in cleaning the biofuel value chain, making the source clean and secure.

For a sustainable future, it will be necessary for countries to embrace a shared vision such that countries rationally share the burden to make the future planet secure, as some will be losers and others will gain in the transformation process. One thing that I may conclude is that the policy debate for future energy will be dominated by issues that include affordability, flexibility, reliability, resilience, and security. The discussion of the energy future will also be centered on geographical differentiations and disparities; the solutions will have to consider these aspects.

Increasingly, energy access and use links to human rights [43], and in this case, the aspects of inclusivity come into play. Future plans for energy will be affected by the on-going and potentially future geographical tensions that will likely be a cause of a more displaced population whose energy provisions dynamics are complex and are yet to be fully integrated into the global sustainable energy debate.

Abbreviations

CCUS	Carbon Capture, Utilization and Storage
CPV	Solar Concentrated Solar PV
CSP	Concentrated Solar Power
EU	European Union
GHG	Greenhouse Gas
IEA	International Energy Agency
LCOE	Levelized Cost of Energy
LNG	Liquefied Natural Gas
OECD	Organization for Economic Cooperation and Development
PV	Photovoltaic
SDGs	Sustainable Development Goals
SMR	Small Modular Reactors
WEC	World Energy Council

Acknowledgments

I would like to acknowledge the review provided by Prof. Laurent Cleenewerck, the international faculty coordinator at Euclid University.

Author Contributions

Emmanuel Gabriel Michael Biririza is the sole author. The author read and approved the final manuscript.

Funding

No funding was received for this study.

Conflicts of Interest

The author declares no conflicts of interest.

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Biography

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