Restructured Global Energy: toward a Cleaner, and Safer and More Reliable Future

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Abstract
The world's energy structure is about the rational extraction, distribution, and use of energy. The existing fossil fuel-based energy structure has caused serious environmental, safety, livelihood, and resource problems for human society. As a result, a future energy composition based on renewable and clean energy sources is emerging. This paper first focuses on the main pitfalls of the current energy structure and the clean energy options available for the future. On this basis, I make sound predictions and discuss in detail the features of the future energy composition, the obstacles, and possible solutions. By completing such a study, I hope to provide a theoretical basis for the forthcoming energy transition and to provide policy makers with a series of ideas on possible new energy uses and arrangements.

Keywords
Energy structure; Fossil fuels; Renewable energy; Environmental problems.

Introduction

The revolution and development of human society is always accompanied by the extraction, distribution, and application of energy. Energy powers almost everything in our life, from a lightbulb in the lounge to luxurious cars on the road, from machines operated in a factory to a spacecraft flying to the Moon. To secure reliable energy structure and supply has always been one of the ultimate goals of all the countries, regions, and society to sustain the stable running of our daily life, industrial production, and economy. Since the start of industrial revolution, modern energy structure has gradually shifted into a fossil fuel-based mode where the majority of energy comes from the coals, natural gases, and petroleum. While these highly thermal efficient energy sources greatly boast the technological and industrial development, their combustion, which is the way people utilize its energy, has brought enormous side effects to the environments. Moreover, their uneven distribution across the world has also caused security concerns beyond from just the energy perspective. With the increasing focus on these concerns, people around the world have devoted themselves into discovering and applying alternative energy categories such as solar, wind, hydrogen, and forming an upgraded energy structure based on them.

This dissertation summarizes the three main problems with the existing energy structure, which is dominated by chemical fuels, namely high pollution (environmental pollution), high dependency (heavy reliance on imports) and unsustainability (rapid resource depletion). In

Citation: Minyu Xia. (2023) Restructured Global Energy: toward a Cleaner, and Safer and More Reliable Future. The Journal of Young Researchers 1(7): e20231018

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Received on August 22, 2023; Accepted on August 30, 2023; Published on October 18, 2023

order to address these problems, this paper also presents the basic knowledge and principles of new clean energy sources, including solar, hydrogen and biomass energy. Not only does it cover their practical applications (solar power stations, tidal power plants, etc.) and their promising development, but it also highlights the technical, financial, and ideological obstacles that we encounter on the way to researching these sources of energy. In this regard, the article also proposes corresponding feasible solutions, such as lowering the threshold for new energy research and development, government support for small research and development enterprises and enhancing the scientific literacy of the next generation to strengthen the country's soft power. Accordingly, I believe that the future development should be based on sustainable development, supplemented by local development ideas, with clean, renewable, and green energy sources being the mainstay of energy supply.

Literature review

Current energy structure

Throughout the history of human energy development, there have been three major turning points, from the earliest days when primitive man could use a drill to obtain fire, mankind has since bid farewell to the primitive era in a real sense. Commenting on the role of fire, Engels said, "Rubbing to make fire for the first time gave man dominion over a natural force which finally separated him from the animals." Later, in the nineteenth century, Watt improved the steam engine and kicked off the first industrial revolution, with coal resources gradually replacing wood energy. However, as the Industrial Revolution gradually progressed and coal resources were used in large quantities, the environment in Britain, a major industrial country, was greatly damaged, and a second Industrial Revolution emerged, marked mainly by electricity and the internal combustion engine. This led to the arrival of one of the most important energy sources in history - oil. Today, oil is still a very important source of energy. At present, mankind is at a third important turning point: the transition to new and renewable sources of energy is accelerating. 2020, the global energy share will be about 31% for oil, 25% for natural gas, 27% for coal and 17% for new energy sources (International Energy Forum, 2021). With the energy structure in 1985: coal-fired power generation accounts for 38% of global electricity generation. Hydroelectricity accounted for 20%, nuclear for 15%; natural gas for 14%, and for comparison, it is easy to see that oil accounted for nearly 30% (Ember (Ed.) 2023), and natural gas, coal and oil together accounted for nearly 80%. It is evident that the current energy structure is extremely problematic.

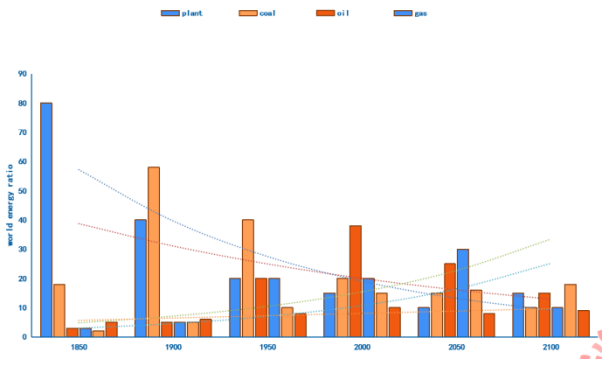

Figure 1 World Energy Structure Composition

As the graph below shows, there have been three waves of energy development in the last 150 years: firstly biomass (wood), then coal and finally oil as the main source of energy. In the future, the share of natural gas and nuclear energy in the overall energy composition will increase and the share of carbon in energy will gradually decrease. Then again, the share of fossil fuels in the world's energy will decline very slowly over the next 50 years and will still account for around 70% of the total in 2050. The historical trend in the energy composition shows that: (i) the relative share of biomass fuels declined gradually from the second half of the 19th century to the end of the 20th century, and then began to rise again in the 21st century. In the first 50 years, around 1910, the proportion of coal used rose sharply by about 8 per cent per decade; thereafter, the trend has been towards a decline of about 3 to 4 per cent per decade. (3) The relative proportion of oil use increased from the beginning of the 20th century to around 1980; from 1980 onwards, the proportion of use began to decline. (4) The relative share of natural gas

use will continue to increase from the beginning of the 20th century to the middle of the 21st century. (5) The proportion of hydro energy applications remains relatively constant throughout the 20th century and into the 21st century. (6) Since the mid-20th century, the proportion of nuclear and solar energy applications has been increasing, while the proportion of solar energy has been increasing more rapidly than that of nuclear energy. The world's energy structure has begun to diversify. However, even in the second half of the 21st century it is expected that fossil fuels will still account for the majority of energy(Zhao et al., 2000).

Problem for current structure

Highly pollutive

The high pollutive nature of the current energy composition is mainly due to the large amounts of carbon dioxide, sulphur oxides, nitrogen oxides, respirable particles and many toxic organic pollutants released during the combustion of fossil fuels such as coal, oil and natural gas. These combustion products enter and remain in the natural environment for a long time, causing haze in the atmosphere and acid rain, which pollutes water bodies and causes serious environmental pollution in the soil, such as soil acidification and heavy metal enrichment. (Environmental Protection Agency, n.d.). These pollutants in turn cause respiratory, digestive, and cardiovascular health risks for humans and organisms. What's more, emissions of carbon dioxide and other greenhouse gases have also been shown to contribute to the greenhouse effect, bringing about extreme weather and sea level rise.

Serious environmental problems are commonplace as a result of the heavy use of the dominant chemical fuels. As a major city of the first industrial revolution, London in the 1950s (nicknamed the 'Fog City') used coal as its main domestic fuel, producing carbon monoxide, carbon dioxide, dust and sulphur dioxide that built up over the city to form a haze. According to one source, in a four-day period between 5 and 8 December 1952, as many as 4,000 people died in urban London as a result of air quality problems (Wikipedia, n.d.). Seventy years later, the enormous side effects of chemical fuels seem to be even more pronounced. As a result of greenhouse gas emissions, the global average temperature is expected to rise from 14.5 degrees in the 19th century to 17.5 degrees in 2024. (National Oceanic and Atmospheric Administration, 2021).This will lead to an accelerated melting of glaciers and a rise in sea levels, triggering the loss of coastal mudflats, mangroves and corals, as well as flooding countries and cities at low altitudes, leaving tens of millions of people homeless. According to the Coastal DEM project, 190 million people worldwide currently live below sea level. As sea levels continue to rise, this number will reach 340 million by 2050 and 630 million by 2100. (Hausfather et al., 2019). Therefore, the continuation of the current highly polluting energy structure will have a significant impact on ecological stability and the quality of human life.

Highly Dependent

Highly Dependent is a phenomenon where a country or region is dependent on large amounts of imports due to its own lack of energy, especially fossil energy. This phenomenon is widespread because the global distribution of geological energy is so uneven that only a few countries have the capacity to export fossil energy, while most countries have no choice but to import energy. This high dependency can expose a country or region's energy security and energy prices to uncontrollable risks, such as extraction and transportation accidents, international political situations, and geopolitical conflicts.

In the case of natural gas, for example, Russia accounts for 20% of global production, while Europe is fossil energy poor and therefore exports 80% of its gas to the continent, resulting in a huge energy dependence on Russia. This dependency evolved into an energy crisis for Europe with the outbreak of the Russo-Ukrainian war in 2022. As a result of the EU's ban on Russia and the inexplicable attack on the Nord Stream II gas pipeline, the shortage of gas supplies in Europe has caused the price of gas to skyrocket from around €70/MWh before the war

to around €350/MWh, nearly quintupling (Schuetze & Buckley, 2023). High energy prices have increased production costs in the manufacturing sector and pushed up the cost of electricity to heat homes in extreme weather conditions. In addition, the energy crisis in Europe, the world's leading economy, has even affected global economic development and industrial production. Thus, the high dependency on fossil-based energy sources can become a real crisis at any time when there is a potential problem.

Highly Unsustainable

Highly unsustainable energy sources are the result of the extremely slow rate of regeneration of existing fossil energy sources and their increasingly rapid consumption by human society. Fossil energy sources are formed by the transformation of plant and animal remains over centuries, none of which can be replenished in time for the time scale of human existence and are therefore non-renewable. The infinite future development of humanity cannot therefore be sustained by finite fossil energy sources. Based on current proven reserves and consumption levels, oil will last between 30 and 50 years, natural gas between 60 and 80 years, and coal for a longer period of time, around 100 to 200 years. In total, fossil energy will last for about 100 years (Met Group, n.d.).

With the growing demand for energy, the point at which fossil energy will be depleted in the real world is even earlier than these already pessimistic estimates. China's former coal mining capital, Fushun, once had the largest coal mine in Asia, with estimated reserves of nearly 1.4 Gt, and could be mined for a full 200 years. However, along with China's rapid economic growth and high demand for resource supply in the first two decades of the 21st century, this mine has already experienced significant resource depletion after only 106 years of mining, turning the Fushun coalfield into a wasteland (Leung et al., 2019). The depletion of such large energy extraction sites is also occurring around the world, and humanity has realized that a shift to new green and renewable energy sources is imminent.

Promising Alternative Energy

In response to these threats, the energy transition has become a social consensus and a national strategic objective, and since 2017 all major economies around the world have begun to support the transition to a new energy composition. One of the most important of these measures is the significant development and integration of renewable energy sources into the energy structure of the region, with solar, wind, geothermal, ocean, biomass and hydrogen energy entering the public eye. Global investment in the transformation of these sources of energy will reach a record level of $755 billion by 2021 Bloomberg (2022, January 27). Here we present only a few of these promising new energy sources.

Solar Energy

Solar energy is the energy produced by solar fusion and transmitted by light radiation to the earth's surface where it is absorbed. In essence, solar energy is the fundamental source of most of the Earth's energy and is sustainable, non-polluting, and highly energy intensive. The sun's radiant energy reaches the Earth's surface every year and is equivalent to 130 trillion tonnes of coal, making it the largest source of energy available in the world today (Wan et al., 2021).

As one of the developed countries, Germany leads the world in the use of solar energy, which accounts for 49.6% of the country's electricity generation（PV Tech, 2023）. In 2022, a very sensitive year for energy, the German government is trying to find a way out through new energy sources, as industries and households in the country are being hit hard. According to the German Solar Energy Industry Association (BSW), the average growth rate of photovoltaics will be around 28% nationwide in 2022. Three quarters of all private homeowners with a roof that can be fitted with solar energy are considering solar systems, and this growth trend is likely to continue in the future（Clean Energy Wire, 2023）The energy transition can therefore be accelerated if we make good use of solar energy.

Biomass Energy

Biomass energy is a form of energy in which solar energy is stored in biomass in the form of chemical energy, i.e., energy in the form of biomass. It is derived directly or indirectly from the photosynthesis of green plants and can be converted into conventional solid, liquid and gaseous fuels. It is estimated that plants store approximately 10 times as much energy per year as the world's main fuel consumption（Biofuels Research Institute of Jiangsu University, 2023）. Biomass comes from a wide range of sources, including wood, straw, and even biological excreta, and is therefore highly substitutable, reducing dependence on external energy sources and increasing energy security. In particular, they can be converted into solid fuels, ethanol, or biogas to replace coal, oil and natural gas, respectively, in fossil energy sources and can be used directly in modern industrial combustion plants such as boilers and furnaces.

At the same time, biomass is perhaps one of the very few forms of energy that has the potential to be carbon neutral or even carbon absorbing during its use. This is because the carbon dioxide produced by the combustion of the original biomass is equal to, or a small amount of rain replaces, the carbon dioxide absorbed by plants from the atmosphere during their growth, which fits well with the human quest for sustainable and green development. It is worth mentioning that the concept of biomass power generation in the world originated in the 1970s and began with the vigorous implementation of straw power generation in Denmark at that time after the oil crisis（Denmark.dk, 2023）. Since 1990, biomass power generation has been vigorously pursued in many countries in Europe and the USA, yet to date its share of the world's energy composition is only 1.9%. If the significant potential of biomass can be exploited in depth in the near future, it could very well fill the gap of fossil fuels and provide a lasting energy supply for human society.

Hydrogen Energy

Hydrogen energy is the energy released during reactions or changes in the state of hydrogen and its isotopes. Unlike fossil fuels such as oil and coal, which produce CO2, CO, NOx, SO2, greenhouses or corrosive gases, hydrogen is theoretically the most environmentally friendly secondary energy source as the only product of combustion is H2O (water). In addition, hydrogen has the highest energy density of all, reaching 141 MJ/kg in liquid form, more than three times that of petrol. The efficiency of the devices used is high, with fuel cells being twice as efficient in energy conversion as conventional internal combustion engines.

Because of the many advantages of hydrogen energy, Japan has invested heavily in hydrogen energy over the past few years, from the government down to companies. According to the Wall Street Journal, the Japanese government has more than doubled its budget for hydrogen-related research and development to $300 million in the two years to 2019(The Wall Street Journal, 2021). The range of Toyota's new Mirai model has been increased by 30% thanks to a redesign and upgrade of the fuel cell system (Toyota UK, 2021). All in all, hydrogen energy has a bright future, not only because it is relatively safer than other fuels (the hazards caused by hydrocarbon fuels are easier to control than those caused by them), but also because its outstanding efficiency of use can be a good solution to the problem of fuel substitution for transport. Once mankind has made a breakthrough in the acquisition and storage of hydrogen energy, it is likely that hydrogen will occupy a large proportion of the future energy structure.

Apparently, the above literature review implies that sustainable energy categories, if well developed and applied, can profoundly address the urgent threats imposed by fossil fuels, and reshape the energy structure around the world in the near future. As two major questions concerning this future structure, including “what will it look like” and “what are the main difficulties” are worth answering for everyone working on this topic. In this dissertation, I provide my own understanding on them in the following discussion section.

Discussion

Future Energy Structural Features

Considering the inherent disadvantages of the existing energy structure and the future development needs of human society, I believe that the future energy structure will be characterized by a green and sustainable energy structure, with a cleaner and more diversified global energy structure.

Clean

Due to the imminent threat to the environment, ecology and human life posed by existing fossil energy sources, I believe that the primary characteristic of the future energy structure will be an increasingly clean one. This means that clean, green energy (energy that does not emit pollutants and can be used directly in production and living) will gradually replace highly polluting energy sources and increase its overall share. This means that non-polluting energy sources such as solar energy and hydrogen will be stored and used more often by society. By replacing them, we expect to be able to significantly reduce emissions of wastewater and air as soon as possible, improving air and water quality and soil quality. It will also reduce or even stop the emission of greenhouse gases into the atmosphere.

In fact, this is what major economies around the world have agreed to work towards. Each country has set its own agenda for energy saving and emission reduction. For example, China is striving to reach peak CO2 emissions by 2030 and working towards carbon neutrality by 2060; similarly, France, a major country in the EU, will rely on renewable energy and nuclear power to achieve net zero emissions by 2050, while Germany will achieve carbon neutrality by 2045, five years earlier than originally planned; and reduce greenhouse gas emissions by 65% in 2030 compared to 1990, exceeding the EU The US will achieve net zero emissions from the power sector by 2035 and net zero greenhouse gas emissions by 2050（Wind Europe, 2021）（Visual Capitalist, 2021）.This shows that cleanup will be an important focus of the energy system transition.

Diverse

Diversification refers to the shift from a single to a diverse energy structure. Diversification of the energy structure is, by definition, a shift from the current relatively homogeneous share of energy sources to a diverse share of new energy sources in the energy composition. If polluting is the drawback of the current energy system, I believe that the huge share of individual energy sources is the fatal flaw of the current energy system. I think that diversification is the basis of energy security. Looking back at the problems of European energy sources mentioned above, the uncertainty and risks faced by a country whose energy lifeline is in the hands of other countries because of its over-reliance on fossil fuels are extremely high. The unstable state of the national energy structure eventually led to the outbreak of the European energy crisis. I believe that after this energy crisis, many European countries will consider diversifying their energy composition in the future. Diversification means that the energy structure is broken down as much as possible, so that more different types of energy are involved in the country's energy supply. In this way, even in times of international instability or geopolitical crises, the country's energy function cannot be seriously affected and the impact on energy supply can be minimized because of the smaller share of the energy structure. A diversified system will underpin future energy development and ensure that we are well on the way to the energy transition.

Locally Tailored

As mentioned in the section 2.2.2, one focus of future energy structure is energy security, the core of which is to ensure stable supply of certain energy with abundant reserve. Therefore, in the process of gradually replacing traditional fossil fuels with new clean energy sources, the choice of the right type and share of energy for each country and region according to its own conditions is a crucial consideration. Rather than blindly pursuing popular energy sources, I believe that a locally adapted energy composition based on the geography and distribution of resources is a reasonable solution. In this way, the reliability, security, and economic aspects of the energy transition will be addressed to the greatest extent possible.

For example, areas with long coastlines generally enjoy vast ocean energy resources, so countries with marine resources such as the UK, Canada, Russia, India, and South Korea can take advantage of tidal, wave and even coastal wind energy. In fact, the above five countries are already planning and designing more than a dozen tidal power plants (all large plants in the 100-1million kilowatt range, with some planning plants with a total installed capacity of 10 million kilowatts or more). (Wikipedia, n.d.) Similarly, dry areas at higher altitudes usually have good light conditions and can therefore be sites for solar energy collection and use. I understand that China's Shanxi province, located inland at mid-latitudes, is rich in light, with an average of up to 2,800 hours of sunshine per year, and could provide 3.2 billion kWh of green electricity over 25 years, saving up to 1,056,000 tonnes of coal and carbon（World Economic Forum, 2017）. Therefore, in my view, local adaptation of energy sources not only meets the above-mentioned need for a cleaner and more sustainable energy structure, but also, and most importantly, allows access to energy to be tailored to the local context and to the local natural and economic situation.

Future Obstacles and Solutions

The energy transition and zero-carbon development are complex systemic projects, and a successful energy transition requires a balance between economic and technological development, security of energy supply and the achievement of carbon neutrality targets. This means that there are a range of technical, economic, and perceptual issues associated with this process. In this section, I aim to analyse the possible obstacles and solutions from these three perspectives.

Technological Barriers and Solutions

Unlike the straightforward extraction and combustion of traditional fossil fuels, the collection and utilization of new energy sources are often designed to involve research in a variety of cutting-edge technologies, many of which are still in their early stages. Obviously, the immaturity of the technology can hinder the diffusion and use of the corresponding energy source. Here we discuss the examples of hydrogen energy and biomass energy mentioned in the previous sections.

Although the promise of hydrogen as a high-quality energy source was recognized a century ago, its widespread use today is still hampered by a number of technical difficulties, one of which is its storage and transport. In order to transport and use hydrogen efficiently and safely, it generally needs to be converted from a gaseous to a liquid form. In addition to the significant operational costs, existing high pressure or cryogenic liquefaction methods consume as much as 13-15 kW h/kg, which is already half the calorific value of hydrogen combustion of 33.3 kW h/kg, resulting in a significant waste of heat. To significantly reduce costs and increase efficiency, the development of solid room temperature hydrogen storage materials will be required. At present, such materials are limited by controlled adsorption/desorption and limited surface area.

The principle of biomass energy generation is based on the principle of harvesting the energy released by burning the material to drive a motor to generate electricity. Currently, we encounter the main problems (1). it is not easy to select the right combustion material among the many organisms (2). the complex structure of organisms, many common biomass materials become less combustible due to their relatively high water content and part of the combustion capacity is used for water evaporation, reducing combustion efficiency, lower density such as woody materials take up more space, which makes handling them more difficult in the face of piles of materials and the cost of transporting and storing large amounts of material is also increased. (3). Current technological bottlenecks present application limitations, and in many countries, there are bottlenecks in direct biomass-fired power generation technology that prevent the high efficiency of biomass-fired boilers. Inefficient equipment and high consumption of material handling can even turn biomass resources into sources of pollution.

To solve the above problems, greater investment in scientific research is needed. I believe that the solution can be found from three specific perspectives. (1) Government guidance. This means the government should focus its research on the most urgent and critical technologies so that institutions and companies can follow. Meanwhile, it also has to lower the threshold of participation in the development of relevant advanced technologies, so that more enterprises can join the competition, creating a healthy market atmosphere and thus reducing the research costs. (2) Funding for small enterprises. To encourage more small and even micro enterprises to engage in the above research activities, sufficient and continuous financial support should be provided to these enterprises. This is because research & development (R&D) always costs a considerable amount of money and lacking continuous cash flow will cause those companies to give up on further research. (3) Education input. It is important that younger generations can receive high quality educations on their scientific literary, critical thinking and logic reasoning. By this way, a larger portion of the population can be turned into talent resources, which is the core part of future research and a country's soft power.

Cost Barriers and Solutions

As an essential consumable, energy has incalculable market and economic benefits, and whoever has control over energy has control over wealth. But energy research and development, like financial investment, requires a large amount of capital to start, and as research in science and technology is both money and time consuming, a project that is in a long-term profit and loss situation loses its value. This is why so much research is abandoned halfway through. And the ultimate goal of making a profit in the marketplace can only be achieved if expensive energy research results are transformed into affordable products that are universally accepted. This is why the financial drain is a major obstacle to energy development. Fossil fuels are currently less expensive than new energy sources because they are less technologically developed and therefore more widely accepted in the market, after all, the question of livelihoods will always be at the forefront of people's minds.

The consumer barrier is not only a question of funding for research, but also a question of livelihoods for those who depend on energy to survive and make a living in society. Moreover, the only way to make a profit in the marketplace is to eventually turn expensive energy research into affordable products that are universally accepted. However, scientific research is a drain on both money and time, and a project that is in a permanent state of profit and loss loses its R&D value. This is why the financial drain is a major obstacle to energy development. The biggest advantage of fossil fuels over new energy sources is that they are cheaper. I think that when research into new energy sources is mature enough and fossil fuels lose their price advantage, people will abandon fossil fuels on their own, and the question of livelihood will always be at the forefront of their minds.

The impediment to consumption is not only a question of funding for research, but also a question of livelihoods for those who depend on energy to survive and make a living in society.

Ideological Barriers and Solutions

As we move forward with the times, our ideology should change with the times, yet we still find that many people's ideologies are not in line with the times and are still old-fashioned when you think about it. Not only are there fuel car enthusiasts who resist new energy vehicles, but there are also those who are concerned about the economic impact of new energy research and development and even social security issues. Those who know that fuel cars are no match for new cars in terms of environmental friendliness are turning their attention to the traffic accidents that occur with new cars and are therefore making a big deal out of them, trying to dissuade consumers of new cars from switching to 'safer', exhaust-emitting cars in terms of their safety. Those who fear that the government's help in the development of new energy will affect their lives will be overly anxious and shift their anxieties, believing that the development of new energy will cut into their quality of life. I believe that if

the basic direction of new energy and development policies are not known or misunderstood by the public, this will have a significant impact on the cause of new energy development in some way.

The government can guide the society in the context of the actual environment, focus on moral education, implement new energy development policies, and make positive adjustments in the mindset for the new energy era.

Conclusion

This article provides personal solutions and future projections for the current energy transformation through the development of energy structures and the rise of new energy sources as a gradual alternative to fossil fuels. As the world's energy sources are in an unstable state, countries are more inclined to rely on themselves, so I have proposed in this essay the idea of localised development. In the face of increasing environmental problems, the article provides a detailed account of clean energy. As you can see, the article covers a broad spectrum of energy sources, with the intention of bringing what is learned and the insights summarised to help humanity in its energy transformation.

Conflict of Interests: the author has claimed that no conflict of interests exists.

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