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Review

Managing Technology Transfer Challenges in the Renewable Energy Sector within the European Union

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Abstract: The use of fossil fuels to generate energy is often associated with serious negative effects on the environment. The greenhouse gas emissions resulting from burning these fuels destroy the ozone layer and lead to global warming. As a strategic approach to the solution of this problem, calls for research and development, as well as the implementation of technologies associated with renewable energy sources within the European Union (EU), have intensified in recent years. One of the keys to a successful outcome from this intensified effort is to identify the challenges associated with the transfer of both intellectual property and technology rights in the renewable energy sector within the EU. The present paper contributes towards this direction. Firstly, data from the literature were used to identify contemporary trends within the European Union with regards to technology transfer and intellectual property within the sector of renewable energy. Then, a statistical analysis utilising an ordinary least squares (OLS) model was conducted to establish a correlation between renewable energy innovations (research and development) and the level of investment associated with renewable energy technologies. Finally, this correlation, along with the associated challenges, was then critically explored for four of the most popular renewable energy sources (namely solar energy, biomass, wind energy, and marine renewable energy), and conclusions are reported.

Keywords: renewable energy; intellectual property; technology transfer; European Union

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1. Introduction

Given the negative effects fossil fuels have on the environment, such as the destruction of the ozone layer by greenhouse gas emissions, resulting into global warming, there has been increased global attention towards renewable sources of energy wind farms with wind turbines [1]. Global warming has been blamed for rising sea levels, the increased intensity of droughts, the increased intensity of rainfalls, floods, and an increase in global temperatures [2]. As a result, calls for the research and development of technologies associated with renewable sources of energy have increased in recent times [3]. Additionally, there has been an increase in calls for global partnerships to promote high-level political cooperation in the renewable energy sector [4]. Nations within the European Union have not been left out in this noble initiative [5].

Nations within the European Union have a great potential to significantly increase global greenhouse gas emission. At the same time, they also have the ability to reduce these emissions by developing and implementing technologies associated with renewable energy [6–8]. Countries such as Germany (presently a member state of EU) and Britain (presently a former member of EU) have ranked high in the investments associated with renewable energies, as well as global leaders in clean energy investments such as China and the United States of America [9,10]. Developed nations tend to fear that the implementation of technology transfer policies may deprive innovative firms within their jurisdiction of essential intellectual assets [11]. Developing nations, on the other hand, perceive technology transfer as expensive and that it should be facilitated (funded) by their developed counter parts [12].

One of the ways through which greenhouse gas emissions can be reduced, controlled, or prevented, is by enabling the transfer of clean energy technologies. This measure was listed by the United Nations Framework Convention on Climate Change (UNFCCC) [13–15]. Parties to this convention are now leading the enhancement of investments associated with clean energy [16]. As a result, they now recognise the important role that investment in renewable sources of energy plays in the enhancement of clean energy adoption. Many European Union nations, as active members of the UNFCCC, share this approach and set aside larger portions of their budget to invest in renewable sources of energy [17].

The UNFCCC promotes the use of clean energy by encouraging its parties to implement policies that promote the transfer of clean energy technologies [18]. The convention also puts a larger responsibility on developed nations listed in Annex II (which includes European Union nations) to help facilitate the transfer of renewable sources of energy [19,20]. To successfully implement renewable energy, it is necessary to transfer advanced technologies to regions where older technologies may still be in operation [21,22]. However, this transfer of technology is subject to concerns directly related to any associated intellectual property rights. European Union nations are no exception to this reality [23]. Consequently, such concerns hinder the transfer of clean energy technologies amongst European Union nations and the world at large [24,25].

With this risk of hindrance in mind, it is of interest to explore specific research questions, such as whether concerns over intellectual property can stalemate the transfer associated with renewable energy technologies, and whether investments in renewable energy sources (which are essential in the promotion and implementation of renewable energy sources) are correlated to, and thus can be affected by, intellectual property. The present paper provides a critical overview of renewable energy technologies and attempts to answer the aforementioned research questions. Furthermore, for the first time, a statistically significant correlation between investments in renewable energy sources and intellectual property is revealed via statistical analysis conducted using the industry-standard software STATA.

The rest of the paper is structured as follows: Section 2 discusses contemporary trends in technology transfer and intellectual property within the sector of renewable energy. Furthermore, a statistical analysis is conducted, revealing a positive correlation between investments in renewable sources of energy and the number of patents in EU nations. Section 3 highlights challenges such as the integration of electricity grids associated with the implementation and promotion of renewable energy technologies. Sections 4–7 explore four of the most important and popular types of renewable energy, namely solar power and photovoltaics (Section 4), biomass and bioenergy (Section 5), wind energy (Section 6), and marine renewable energy (Section 7). For each of Sections 4–7, first a short description of state-of-the-art technology is provided, then challenges with regards to technology transfer and associated intellectual property are presented, and lastly, the ramification of these challenges on the European Union are discussed. Finally, Section 8 summarizes the conclusions of the present work.

2. The European Context

2.1. Negotiations on Climate Change and the Future of the Climate Change Issues

The European Union has played and continues to play an important role in mitigating the effects of climate change [26]. For many years the region has been a leader in negotiations and policy-making related to international climate change. It is a fact that the European Union has established itself as a protagonist in championing for the management of climate change [27]. Since negotiations regarding climate change began in 1991 through the Climate Change Convention, the European Union has been a leader in pushing for the implementation of international climate change policies aimed at protecting the environment [28,29]. It has also been pushing for international commitments towards the protection of the environment. In fact, in the past, the European Union, through the Climate Change Convention negotiations, has unsuccessfully supported the implementation of binding emission reduction targets to industrialised nations [30,31].

During the 1997 Kyoto Protocol negotiations, the EU proposed significant cuts (−8%) to greenhouse gas emissions produced by major industrialised nations [32–36]. The EU also championed for domestic actions aimed at mitigating climate change. Additionally, the European Union, through its independent commitment (which aimed at reducing greenhouse gas emissions in the region by 20% by the year 2020, compared to 1991 levels), has been a driving force behind the launch of the global post-2012 climate agreement, which was agreed to by the United Nations Framework Convention on Climate Change (UNFCCC) member states in December 2007, in Bali, Indonesia [37–40].

During climate change negations, the European Union usually puts an emphasis on strong legal binding commitments, as well as strong international institutions [27]. This emphasis reflects the region's internal legalistic and formal institutional framework which is aimed at promoting policies that help fight climate change. The EU usually champions for international co-operation, collective global efforts, a global framework that is legally binding, and multilateralism during climate change negotiations [41]. This was evident during the 2011 Durban climate summit, where the EU emphasized its desire for a well-developed roadmap and deadlines for finalising the comprehensive legally binding global frameworks for dealing with climate change for all member states [42]. This theme was retained in the 2015 Paris accord. In fact, several months before the 2015 Paris accord, one of the then most prominent commissioners, Miguel Arias Cañete (who was the European Commissioner for Energy and Climate Action), stated that an agreement that would come out of the Paris accord must be applicable to all and must be internationally legally binding [43–46]. In this way, the European Union acts as a pace setter for actions associated with saving the planet from the effects of climate change.

From the information mentioned above, it is quite clear that the role of the European Union in ensuring renewable energy technologies are adopted is significant. It is also evident that the European Union plays a major role in decisions related to the mitigation of climate change and the implementation of renewable energy sources. Therefore, future decisions related to climate change issues and the implementation of renewable sources of energy depend largely on the current and future actions taken by the European Union.

2.2. Current Trends in the Technology Transfer of Renewable Energy Technologies

As discussed earlier, one of the major ways in which the effects of climate change can be mitigated is through technology transfer. In recent years, several technologies associated with employing renewable sources of energy have emerged [47]. This has especially been the case in rapidly developing nations such as the United States, European Union member states (which are examples of developed or industrialised countries), and China (an example of a rapidly developing nation) [48,49]. During the 1970s, there was a surge in investments in renewable sources following an increase in oil prices during that time. However, during the 1980s, investments in renewable sources of energy significantly reduced, as a relatively stable pricing policy of oil and fuel was adopted [50]. Presently, more emphasis has been given to renewable sources of energy by the international community (and especially the European Union), as fossil-based fuels lead to global warming, as emissions associated with them destroy the ozone layer [51,52].

While most nations within the European Union have implemented renewable sources of energy technologies and are on their way towards achieving the 2020 EU renewable energy targets, the implementation of these technologies in some countries within the region has not been on par with their counterparts [53]. This may be in part due to the challenges associated with technology transfer, as most of the patents associated with renewable energies are privately owned [54]. To counter this problem, the European Union has been encouraging renewable technology transfer amongst its member states and with the rest of the world. In fact, through its JOULE programme, the European Union is on track to achieve its 2020 renewable energy targets [55]. Such areas included offshore islands and mountainous regions. It should be noted that the JOULE programme was a joint initiative, through which several nations under the European Union gave specific attention to renewable energy technologies by decentralising these technologies to regions isolated from the national and regional grids. It can, therefore, be said that the JOULE programme resulted in successful technology transfer amongst European Union member states.

Renewable energy technology transfer in the European Union can be measured by number of the disclosed innovations related to this field in this region [56]. This can also be measured by the number of disclosed innovations related to the mitigation of the effects of climate change. The number of disclosed innovations related to methods of mitigating climate change has been rising steadily since 1997 [57]. This indicates a constant rise in technology transfer related to renewable sources of energy amongst the European Union member states.

Due to the continuous increase in technology transfer among European Union member states, the European Union is on track to achieve its 2020 renewable energy goals as explained by [58]. Table 1 below shows net electric energy generation from different sources between 2011 and 2016. From the table, it is observed that net electric energy generation from renewable sources of energy has risen since 2011. Net electric energy generation from other sources, such as nuclear and fossil fuels, are on the decline. This is also shown in Figure 1, where the percentage of total generation composition for renewable sources of energy steadily increased over the period from 2011 to 2016 [58].

Table 1. Net electric energy generation from different sources between 2011 and 2016.

Electric Energy Source/Year	2011	2012	2013	2014	2015	2016
Renewable Energy Sources (TWh)	323	382	438	495	572	573
Nuclear (TWh)	887	862	857	859	836	817
Fossil Fuels (TWh)	1641	1562	1420	1344	1345	1354
Hydro (TWh)	517	567	590	613	578	583

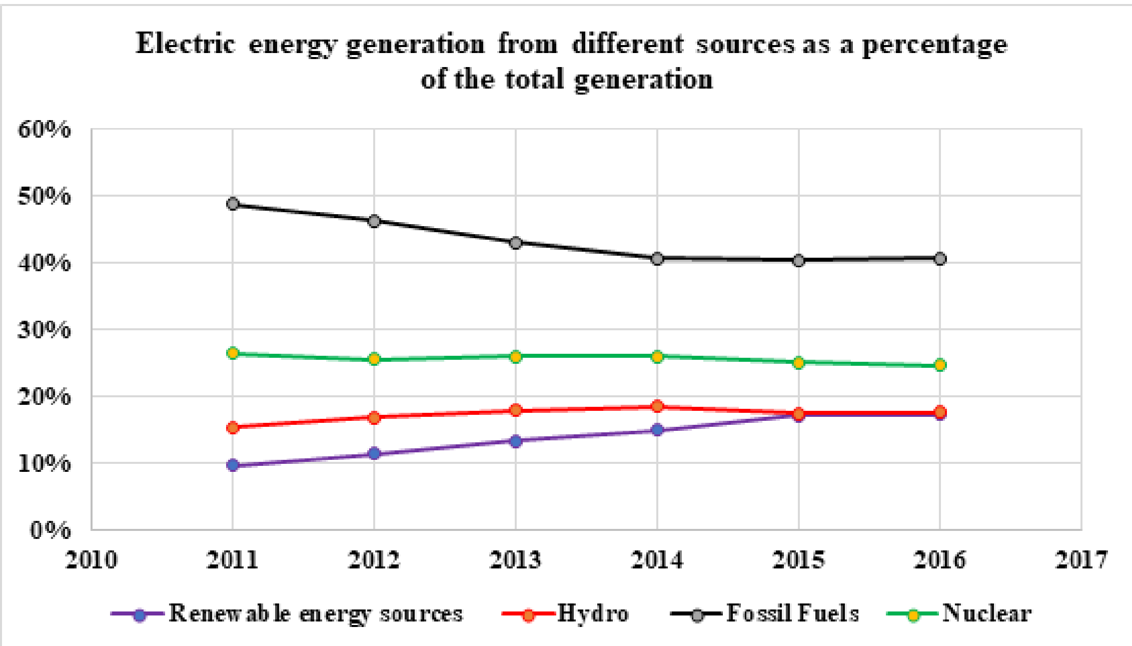

Figure 1. Electric energy generation from different sources as a percentage of the total generation (calculated from [58]) from 2011 to 2016.

In particular, electric energy production from renewable sources of energy was 11% in 2011, which then climbed up to 17% in 2015 and 2016, thus significantly approaching the goal of (at least) 20% by 2020 that was set by the European Union. During the same period, as shown in Figure 2, electric energy generation from fossil fuels has been on the decline in the European Union. Similar trends are widely recorded in the literature. For example, in Figure 2, the percentage share of renewable energy sources, such as wind and solar, has been increasing steadily from 1990 to 2019. From the same figure, it is also clear that the percentage share of fossil fuels has been increasing from 1995 to 2019, after which it began to decline, and has been on the decline ever since.

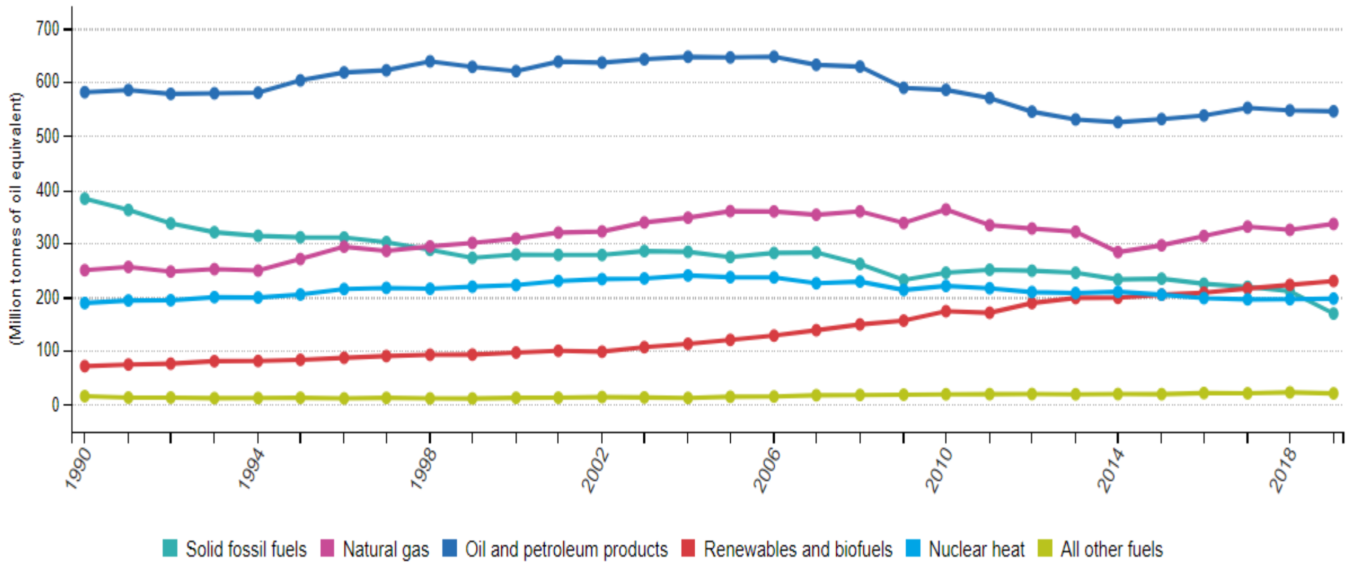

Figure 2. Gross available energy in the EU from different sources, from 1990 to 2019, in million tonnes [59].

It has also been projected that, with the current rate of investment in renewable sources of energy in the European Union, the region may exceed its 27% share of renewable sources of energy by 2030, up from 17% in 2015. In fact, it is estimated that by 2030, the European Union's renewable energy will constitute 34% of total energy production. Figure 3 below shows the share of renewable energy in European Union member states in 2014 and 2015, and the 2020 target for each member state.

From Figure 4, we can observe that the renewable energy share for European member states ranged from 5% to 54%, between 2014 and 2015. This shows that some European nations, such as Sweden (SE), Finland (FI), Austria (AT), Latvia (LV), Croatia (HR), and others (see Figure 3) have already exceeded the 2030 target, and most nations are on their way to achieving the 2020 target. Other EU nations, such as Belgium (BE), Cyprus (CY), Luxembourg (LU), Malta, and the Netherlands, are far from achieving the 2020 target and are not expected to achieve the target. However, from Figure 4, we can see that the European Union as a region has achieved its 2020 target.

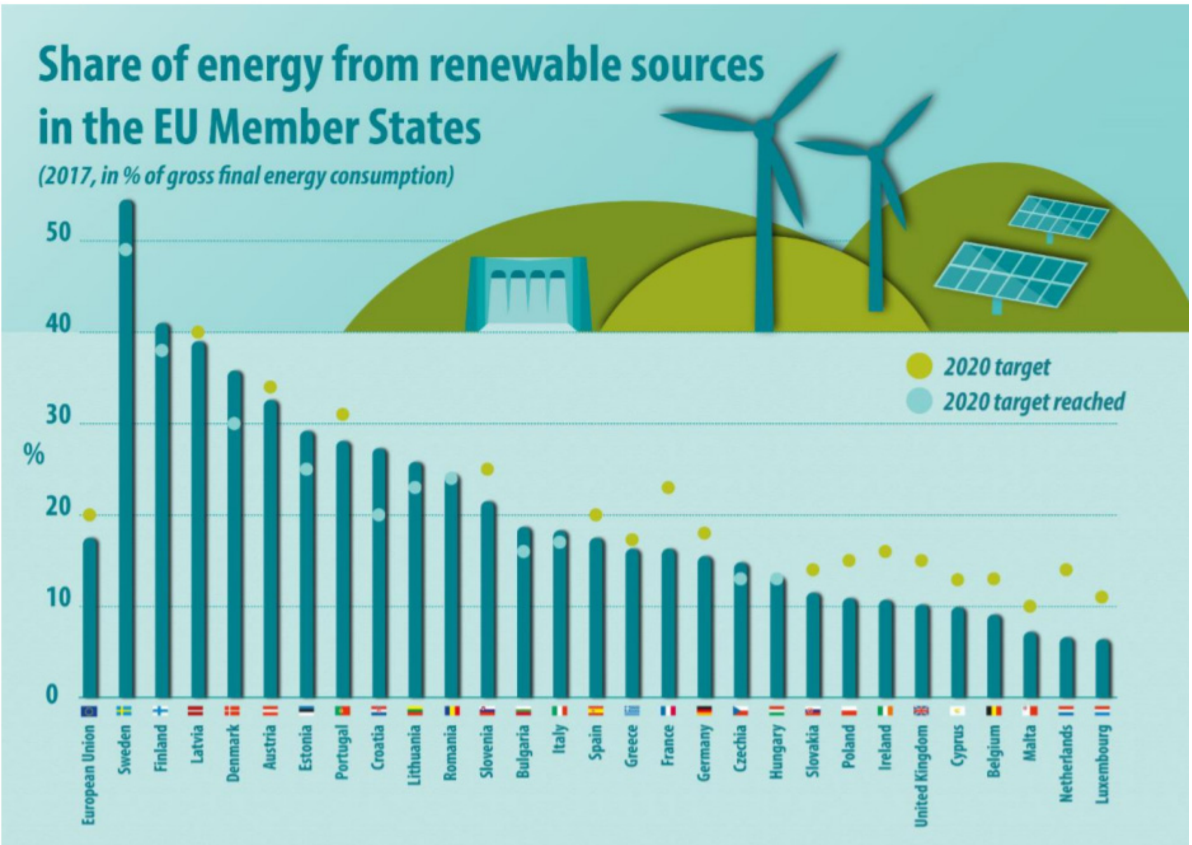

Figure 3. The share of renewable energy in European Union member states in 2014 and 2015, and the 2020 target for each member state [60].

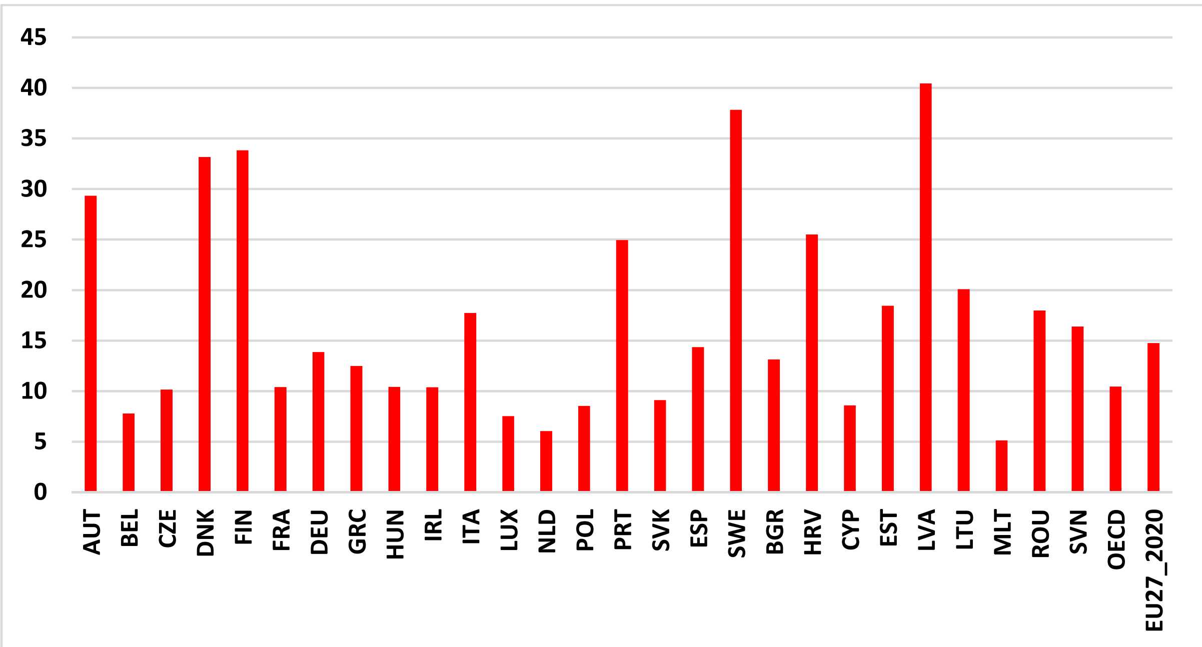

Figure 4. The 2016 share of renewable energy as a percentage of total energy production amongst European Union member states.

2.3. Current Trends in Intellectual Property in Renewable Energy Technologies

As previously discussed, the overall share of renewable energy as a percentage of total energy consumption in the European Union has been growing over time, from less than 9% in 2005 to approximately 17% in 2016 [61]. Additionally, the technologies associated with renewable sources of energy have also been increasing rapidly when compared to other technologies. The number of patent applications related to renewable sources of energy filed at the European Patent Office have increased by more than 20% each year in recent times. The patent applications associated with other technologies have increased by approximately 6% per annum in recent years [62].

Despite the increasing number of patents associated with the implementation of renewable energy technologies in European Union, the renewable energy outcomes associated with individual member nations tend to be divergent (heterogenous) [63]. In fact, some countries within the region have a substantial renewable energy capacity, and patents associated with renewable energies in these countries have also increased. In some nations, investment and research (patents) associated with renewable sources of energy technologies have been modest [64]. For instance, as shown in Figure 4 below and Figure 4 above, countries such as Austria, Denmark, Finland, Portugal, Sweden, Croatia, and Latvia have significant portions of their energy accounted for by renewable sources of energy. On the other hand, countries such as Belgium, the Czech Republic, France, Hungary, Ireland, Poland, the Netherlands, and Malta had small portions of total energy accounted for by renewable energy in 2016 [65]. This shows a clear divergent path amongst the European Union member states when it comes to the implementation of renewable sources of energy [66]. This is a clear indication that not all EU member states demonstrate the same level of commitment towards the implementation of renewable sources of energy.

Comparing Figures 4 and 5 yields that, in 2016, the proportion of renewable energy as a percentage of total energy generation was not consistent with the number of patent applications across the European Union. For instance, Germany and France had the highest number of patent applications in 2016. As such, it was expected that these nations would have the highest proportion of renewable energy as a percentage of total energy generation. This was never the case. In fact, countries with the lowest number of patent applications, such as Latvia and Austria, had the highest proportion of renewable energy investments. Another very interesting observation emerges from Figure 6. Figure 6 shows that, historically, Germany has always had the highest number of patent applications within the European Union. However, in recent times, the number of patent applications associated with renewable sources has significantly reduced. Figure 6 also shows that, from 2008 onwards and within the European Union, it is only a few member states, namely Germany, France, and Denmark, that have the highest number of patents related to renewable energy technologies. This may be attributed to the fact that these nations have larger GDPs and hence have the capability of allocating more funds towards the research and development of renewable energy technologies, compared to other EU member states.

From this, it seems that EU member states have taken divergent paths towards investing in renewable sources of energy technologies. This may result in unfair burden sharing among European Union member states. In turn, this may lead to conflict amongst member states, and that could derail the EU's efforts to achieve its overall renewable energy and climate change targets.

Correlation between Investments in Renewable Sources of Energy and the Number of Patents in EU Nations.

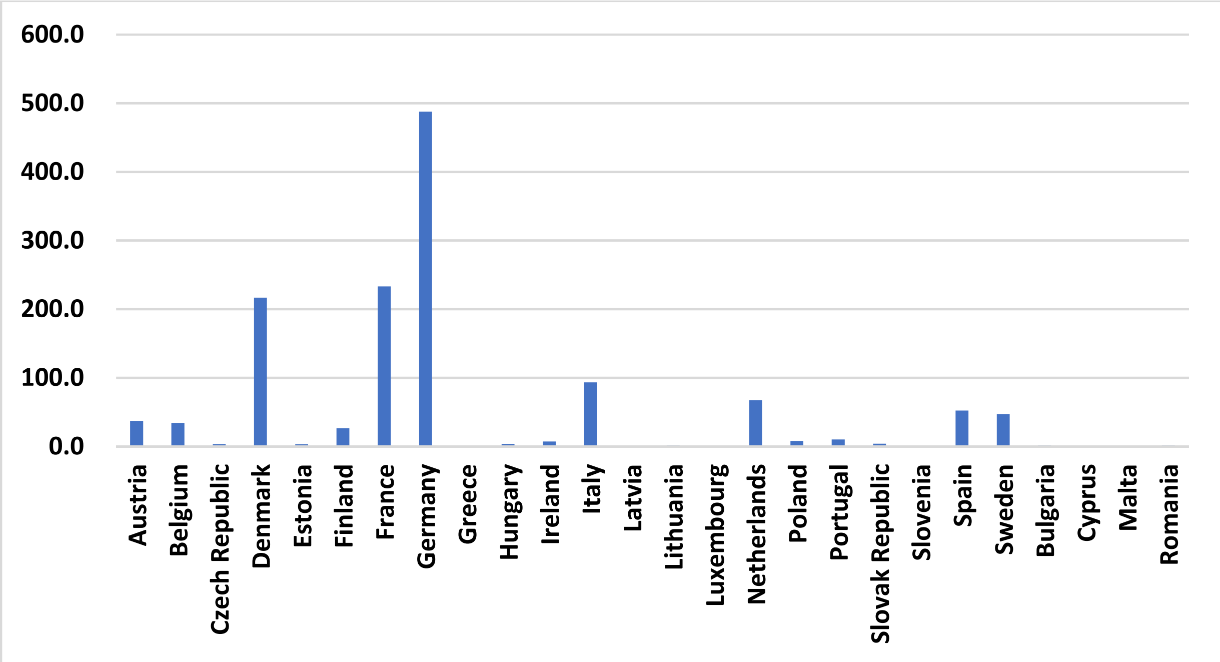

Figure 5. The number of patent applications related to renewable sources of energy in 2016.

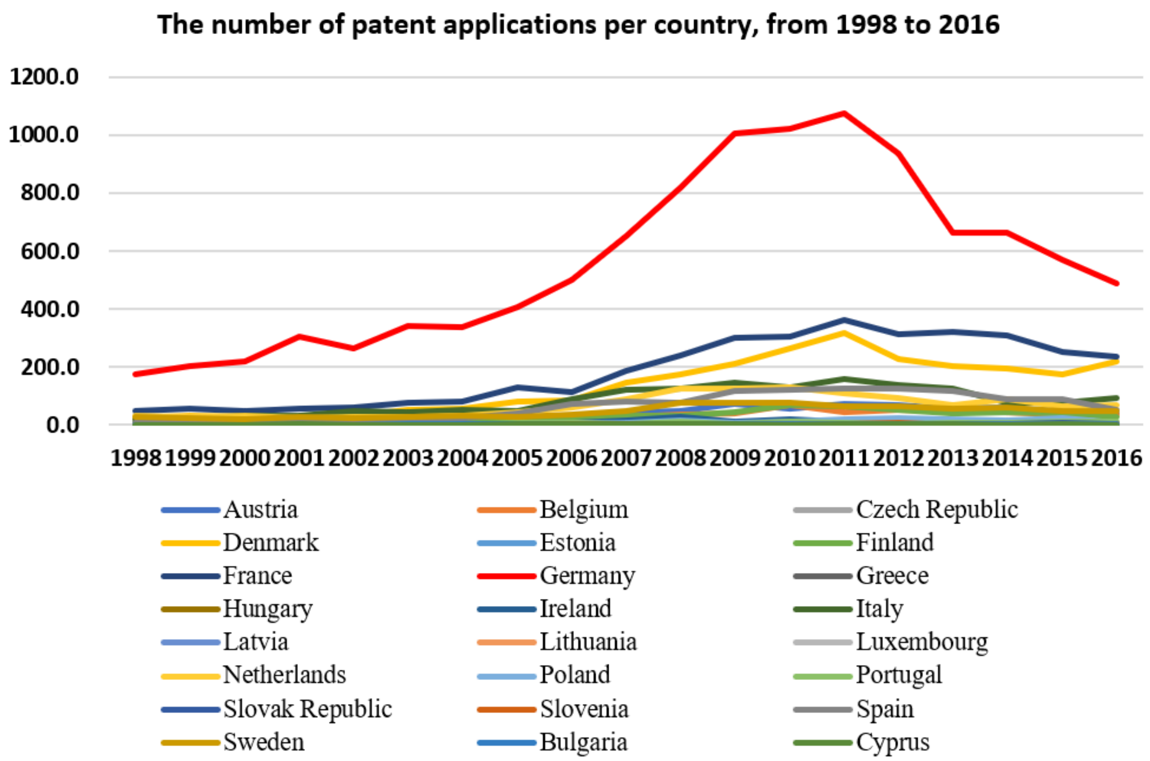

Figure 6. The number of patent applications per country, from 1998 to 2016.

To better understand if the number of patents for renewable energy amongst EU member states is related to the amount invested in renewable energy for that nation, regression analysis was carried out between renewable energy and the number of patents per country. The study was conducted using patent application panel data for 28 European member countries from 1998 to 2016. For this regression analysis, data was downloaded from the Organisation for Economic Co-operation and Development (OECD) database, for the years 1998 to 2016, and included Gross Domestic Product (GDP), the number of patents for renewable energy per year, and renewable energy as a percentage of total energy generation. To control for the effect of size of GDP on research and development (measured by the number of patent applications), the number of patent applications for each nation was divided by the country's GDP. This was implemented because countries with higher GDPs are likely to invest more in research and development, and as a result, have a higher number of patent applications when compared to countries with lower GDPs. The dependent variable was the proportion of renewable energy as a percentage of total energy generation. This proxy was used to measure investments in renewable energy, since the higher the proportion of renewable energy as a percentage of total energy generation, the higher the investment in the renewable energy sector. The regression model used in this exercise is shown below.

$$\text{PropRen} = \beta + \beta_2(\text{IP/GDP}) + \beta_4(\text{InGDP}) + \text{E} \tag{1}$$

In the above regression model, PropRen is the proportion of renewable energy as a percentage of total energy generation, (IP/GDP) is patent applications per GDP (i.e., the ratio of patent applications to Gross Domestic Product), lnGDP is the natural logarithm of Gross Domestic Product, and E is the base which is ≈2.72. The above regression analysis using an ordinary least squares (OLS) model was carried out using STATA, a statistical software for data science, and the results are shown in Table 2 below. The results are also discussed after the table.

Table 2. The regression results for the relationship between investments in renewable energy and the research and development of renewable energy.

Variables	Renewable
Natural log of GDP	7.474 *** [0.350]
Patents per GDP	9409.304 *** [1362.909]
Constant	−80.148 *** [4.232]
Observations	494
Number of Countries	26
R-squared	0.577

Standard errors in brackets. *** $p < 0.01$.

From the results shown in Table 2, it observed that the correlation between the proportion of renewable energy as a percentage of total energy generation was positively related to the number of patent applications for renewable energy amongst EU member states. The *p* value for this relationship was less than 0.01. Therefore, it can be concluded that amongst EU member states, the research and development of renewable energy determines the amount being invested into renewable energy. Other than research and development, another factor that determines investment in renewable energy (measured by the proportion of renewable energy as a percentage of total energy generation) in the EU is GDP. The results in Table 2 show a statistically significant positive correlation between the proportion of renewable energy as a percentage of total energy generation and GDP [67]. This means that the higher the GDP, the higher investments are in research and development.

The above results are consistent with studies conducted in China [68,69]. These studies found a positive correlation between innovations in renewable energy (measured by patent applications) and renewable energy investments (measured by the proportion of renewable energy as a percentage of total energy generation).

3. Economic Background of Energy Implementation and Promotion of Renewable Energies

3.1. Challenges Linked with Electricity Grids

One of the major enablers of the implementation of renewable energy across the European Union member states is electricity grids [70,71]. However, these grids have been associated with several challenges, preventing or delaying the evacuation of renewable energy from production sites to consumption sites. The major challenges associated with the European Union electricity grid, especially the smart grid, are system integration, technology maturity, consumer engagement (especially in grid projects), and regulatory barriers [72–74].

3.1.1. System Integration

For electricity grids to be successful in their operations, all multidisciplinary stakeholders with divergent opinions, regulations, businesses, interest, and technologies need to be integrated and ensure that grid systems (including smart grid systems) are interoperative [75]. This is, however, not the case. Regardless of significant investments made in grid systems (especially the smart grid system), challenges still exist in integrating new technologies into the existing grid. One of these challenges is the failure to integrate ICT systems due to incompatibilities between various IT components and protocols.

3.1.2. Regulatory BARRIER

Governments often play important roles in the implementation and management of grids within the European Union. A government is often the policy maker and, through its regulatory institutions, supervises the implementation of grid projects to ensure that the interests of the stakeholders are taken care of, abusing the market is prevented, and benefits associated with the project are protected. However, the existing policies and legal frameworks were designed to manage traditional (standard) electricity grids. No regulations are specifically designed for the implementation and management of emerging technologies in EU grid systems, such as the smart grid system.

Additionally, despite heavy investments in improving the EU's electricity network, the current regulations and policies only encourage member states to reduce operation costs by employing cost-efficient technologies rather than upgrading to newer, smarter systems. In 2012 alone, the EU invested more than EUR 6.8 billion into the innovation, research, development, and implementation of over 300 smart grid projects across its member states.

3.1.3. Maturity and Security of Technology and Supply Quality

Newer grid technologies, such as smart grid systems, are often designed to incorporate ICT, power electronics, and storage technologies to ensure that the production, consumption, and transmission of electricity is balanced at all levels. Integrating these systems with old systems will require changing the network control and design. Additionally, the elimination of power factor problems and the synchronisation of new technologies with old technology is needed. For this to be successful, newer technologies must be mature and understood by the operators.

3.1.4. Grids Operating at Full Capacity

Another major challenge facing the electricity grid in the EU is that most grids are operating either beyond or close to their full capacity [76]. Furthermore, several cross-border transmission lines in EU member states are near full capacity, and hence may not sufficiently evacuate power to neighbouring nations [58]. If these transmission lines are used to evacuate additional power, then the chance of congestion on the grid increases, which makes the cross-border flow of power vulnerable [77]. This means that any additional power, especially from renewable sources of energy, needs new transmission lines to be built, which is not cheap [78].

3.1.5. The Remote Location of Renewable Power Plants

Resources associated with wind energy are often found in remote regions where the current grids (transmission networks) are not available. Therefore, to effectively evacuate power produced by renewable sources of energy, new transmission networks will have to be built. This not only costly but also comes with its challenges [79]. The construction of new transmission networks within European Union member states is often very difficult [58]. This is because of opposition from politicians and environmentalists who are against the construction of overhead power transmission lines. It is also extremely difficult to obtain the rights of way for building long-distance transmission lines across European Union member states. In some jurisdictions, approvals for rights of way may take more than 10 years [80].

3.2. Challenges Linked with Fuel Transportation

Fuel transportation in the EU mainly takes place in three ways: pipeline transportation, road transportation, and railway transportation [81]. The major challenge associated with the transportation of fuel is associated with road transportation. Road transportation is expensive, it is associated with greenhouse gas emissions (emissions come from the trucks transporting the fuel), and it contributes to the accelerated destruction of road infrastructure [82].

3.3. The Role of Tax-Payers Money in the R&D of Renewable Energy

Even though the private sector has played an important role in the research and development of renewable energy, EU governments also play their role by providing research funds to government research institutions for the enhancement of research and development related to renewable sources of technology [83,84].

Studies have shown that government subsidies, which often come in various forms such as tax cuts and exemptions, cash grants, low interest loans, and rent rebates, have a positive effect on the research, development, and investment in renewable energy [85,86]. That is, taxpayers' money, which may appear in the form of tax incentives and monetary subsidies, often helps to promote investment in renewable sources of energy (research and development included). Even though both tax incentives and monetary subsidies are in use, tax incentives are more important for promoting innovations and the development of renewable sources of energy [87]. Through subsidies, taxpayers' money can support small, medium, and macro enterprises (private enterprises) in research and development related to renewable energy [88].

As result, European Union member states, through taxpayers' money, develop and implement policies that encourage subsidies and tax incentives, and are geared towards encouraging research and development related to renewable energy technologies in the private sector. Governments should also increase their funding and support to public institutions [89].

4. Solar and Photo-Voltaics

4.1. The Technology

Solar energy mainly involves using the sun's energy to generate electricity through solar photovoltaic cells and CSP (concentrating solar power) systems, or to heat water via thermal systems [90]. Figure 7 below shows how solar energy can be used to heat water for domestic use. Photovoltaic systems convert solar energy into electricity directly via a photovoltaic (PV) cell. PV cells are semiconductors that directly convert solar radiation into direct electric current [91–93].

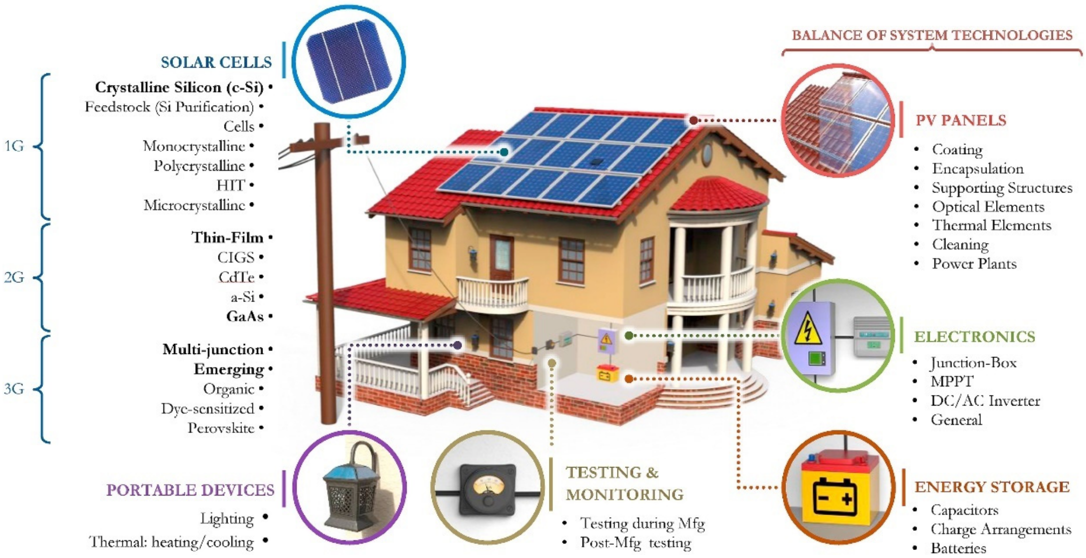

Figure 7. An example of a solar photovoltaic technological system for domestic use [94].

By 2015, the installed solar power capacity in Europe was 97.14 GW, with countries such as Germany, the United Kingdom, Belgium, Spain, Italy, France, and Greece accounting for over 85.7% of this capacity [95]. With current campaigns to increase the share of renewable energy in total energy production, the installed capacity is expected to increase to even higher percentages [96]. In fact, there is a commitment by European Union nations to increase the proportion contributed by renewable energy by 27% by the year 2030 [97].

4.2. Technology Transfer and IPR Challenges

The major issue (barriers) facing the implementation of solar and photovoltaic energy is intellectual property rights [98]. While negotiations surrounding other aspects associated with global climate change have progressed, negotiations regarding intellectual property rights associated with solar and photovoltaic technologies (and other renewable sources of energy) have not made significant progress [99]. No agreement has been reached regarding the transfer of intellectual property rights associated with either green energies or technologies associated with mitigating the effects of climate change. There are those who argue that intellectual property rights are the barrier to the transfer of clean energy (climate change) technologies [100,101]. There is also another group of scientists who argue that intellectual property rights are very important incentives for research and development, and innovations. In particular, the main argument is that industrialised nations which bear the largest number of patent applications for renewable energy sources fear that the implementation of technology transfer policies may deprive innovative firms within their jurisdiction of essential intellectual assets [102]. Developing nations, on the other hand, perceive technology transfer as expensive and should, thus, be facilitated by developed counterparts [103].

As a result of this, there have been debates about who should fund (support) technology transfer, the role of intellectual property rights, and capacity buildings associated with renewable sources of energy, of which solar energy is part of. Therefore, some nations view intellectual property rights transfer as a barrier to the diffusion (transfer) of technology.

4.3. Discussion on the Ramifications for the European Union

This stalemate has resulted in the intermittent implementation of renewable energy technologies among European Union member states. Additionally, the aforementioned stalemate has resulted in fewer renewable energy investments in developing nations. A good example of this ramification is the huge disparity between investment in renewable energy and the number of intellectual property rights. From a statistical analysis of EU intellectual property rights and renewable energy panel data, it was found that nations with larger GDPs tended to have higher number of patent applications and investment in renewable energy when compared to smaller nations. This is evidence of a lack of technology transfer amongst the EU member states.

As a result of these difficulties, technology transfer has been one of the major functions of UNFCCC since it was formed. To enhance technology transfer, the convention (via article 4.5) requires developed nations, to all practicable steps, to facilitate, finance, and promote the transfer of clean energy technologies and intellectual property rights to other nations, especially to developing nations.

5. Biomass and Bioenergy

5.1. The Technology (Including 1st, 2nd, and 3rd Generation)

Biomass includes all organic matter, such as trees, crops, and plants, that collect and store solar radiation via photosynthesis [104]. Bioenergy or biomass energy essentially comes from the conversion of biomass into energy such as heat, liquid fuel, and electricity [105,106]. Biomass can be burnt directly to produce heat energy, or it can also be converted into biofuels which can be transported and stored [107,108]. Since this type of energy can be transported and stored, its energy supply is highly dependable. This is unlike solar and wind energy, which are often intermittent. Bioenergy can be ategorized into three generations, namely the first, second, and third generation [109]. First generation biofuels are made from food crops that are often grown in arable (cultivatable) land [110]. Consequently, they compete with food and thus are a food security threat. Second generation bioenergy comes from non-food biomass, but this biomass is also often grown in arable land. This means that they compete with food crops for space [111,112]. Figure 8 below shows a comparison between petroleum fuel sources and the first two generations of bioenergy. Third generation bioenergy does not compete with food and is produced from non-food biomass. Additionally, this biomass is not cultivated in arable land. They are often cultured [113].

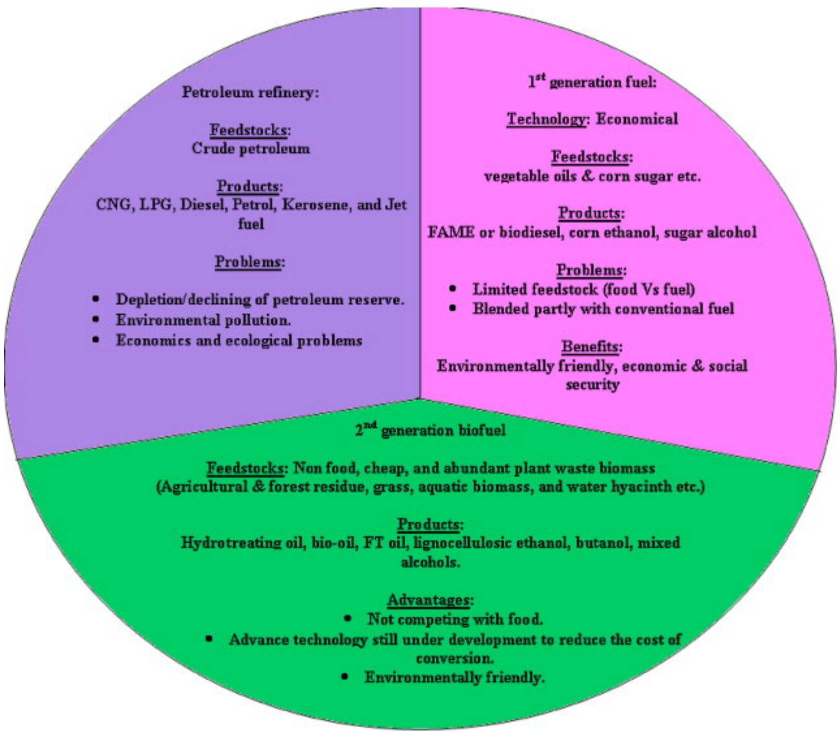

Figure 8. A comparison of the 1st and 2nd generation biofuel and petroleum fuel sources [114].

5.2. Technology Transfer and IPR Challenges

One of the challenges affecting the transfer of bioenergy amongst European Union member states is the disagreement about how the various resources associated with biomass and bioenergy should be used. Some member states feel that the EU was never transparent on several issues. For instance, it is argued that the EU was never specific about the land use, change of land use, and forestry agreement (also known as LULUCF agreement), which specifically affected the transfer of biomass and bioenergy technology [115,116]. This agreement covers the use of forestry in developed nations that had pledged to reduce greenhouse gas emissions in accordance with the Kyoto protocol [117]. Since a few European Union nations, such as Sweden, Finland, and Austria, have large timber industries and wanted to protect them, the Environment Council of Ministers was not able to agree on the rules and policies associated with forestry in developed nations [69].

As is the case with solar energy technology, the transfer of biomass technology as a renewable source of energy is hindered by intellectual property rights [118]. It is argued that the issue of intellectual property rights cannot be resolved, so long as the sharing of renewable energy technologies amongst EU member states cannot be agreed upon. Member states holding advanced bioenergy technologies are not willing to share their know-how, nor bear the cost of sharing their know-how [119]. Other developed member states are also unwilling to increase costs associated with sharing such technologies [120]. On the other hand, EU member states that spend a lot less money on the research and development of renewable energy sources argue that the cost associated with intellectual property rights should be shared amongst all member states [121].

5.3. Discussion on the Ramifications for the European Union

The use of biomass to produce energy has negative implications. For instance, first generation biomass can also be used as source of food and is cultivated in arable land [122]. This means that embracing this type of energy may result in food insecurity, as crops that should be used as source of food would now be used to produce energy [123]. Second generation biomass is cultivated in arable land (land used to grow food crops). This means that embracing this type of technology would result in food insecurity, as land that should be used in cultivation of food crops would now be used to produce second generation biomass [124]. As a result, it is recommended that when implementing biomass as a source of energy, only third generation biomass should be considered, as that type of biomass does not compete with food crops in any way, and it is cultured instead of being cultivated [125].

Additionally, the regulated use of trees and other biomass as a source of fuel as a way of reducing carbon emissions (as trees act as carbon sinks), as suggested by the LULUCF agreement, would mean that amount of biomass that would be available for processing bioenergy would be limited [126].

6. Wind Energy

6.1. The Technology

Wind energy mainly involves the conversion of wind energy into a useful form of energy, such as electricity by wind turbines, mechanical energy by wind wills, pumping water by wind pumps, and propelling ships by sails [127–129]. Figure 9 below shows an example of a wind farm with wind turbines for the production of electric energy.

As of 2016, the installed capacity of wind energy in the European Union was 209.6 GW, of which 165.9 GW were from onshore installations and 43.9 GW were from offshore installations [130]. The current installed capacity of onshore wind energy in the European Union is approximately 169 GW [131]. It is estimated that by 2050, the installed capacity of wind energy and other renewable sources of energy will contribute to the highest proportion of energy mix amongst European Union member states [132,133].

Figure 9. An example of a wind farm with wind turbines for the production of electric energy [134].

6.2. Technology Transfer and IPR Challenges

For many decades, developed nations among the European Union member states have been the custodians of wind energy technologies [135]. On the other hand, developing nations inside and outside the EU, such as China, India, and Brazil, have been the recipients of these technologies [136–138]. Nevertheless, their participation in the research and development of such technologies has been minimal [139]. After the Kyoto protocol, there has been successful wind energy technology co-operation amongst EU member states, and among EU and Asian countries (such as the co-operation between Germany and China). A good example is the co-operation between the EU and India [140]. However, not all technology co-operations have been successful [141].

From the discussion above, the main issue hindering wind energy technology transfer amongst EU member states, and from EU members to other nations outside the EU, is intellectual property transfer with a focus on who should bear the cost associated with sharing the technology [142,143]. Developed nations are unwilling to share their wind energy technologies because they feel that it is not in their best interest with regards to innovation. Furthermore, they feel that if they must share, then it is the developing nations requiring the technology that should bear the associated costs [144]. Developing nations, on the other hand, argue exactly the opposite [145]. As a result, no agreement has been reached regarding the transfer of intellectual property rights associated with wind energy [146,147]. This lack of agreement has hindered the successful transfer of wind energy amongst EU member states [148].

6.3. Discussion on the Ramifications for the European Union

The ramification of this challenge is that there has been no successful wind energy technology transfer between Germany (i.e., a developed European Union nation) and India, thereby depriving the European Union of the benefits of technology sharing and transfer [149]. The main reason for this unsuccessful co-operation was that Indian technologies were being marked as completely different technologies in Germany [150].

Undoubtedly, there is a stalemate with regards to the transfer of wind energy amongst EU member states. This stalemate has hindered the full implementation of renewable energy technologies amongst European member states [151]. Developed nations are not willing to enhance the transfer of wind technologies (which most of them hold) to the less-developed nations in the EU [152]. It is because of this reason that the correlation between renewable energy intellectual property rights and the implementation of renewable energy among EU member states is divergent [153]. Nations with larger GDPs tend to have a larger number of renewable energy patent applications and larger investments in renewable energy, while the opposite is true for smaller nations (nations with smaller GDP per capita). This is evidence of a lack of technology transfer amongst EU member states [154].

It is therefore recommended that, to enhance technology transfer, the UNFCC Article 4.5 be applied, according to which developed nations, to all practicable steps, should facilitate, finance, and promote the transfer of clean energy technologies and intellectual property rights to other nations, especially to developing nations.

7. Marine Renewable Energy

7.1. The Technology

Marine renewable energy often comes from six sources, namely: tidal currents, ocean currents, waves, salinity gradients, tidal ranges, and ocean thermal energy conversion [155]. These marine energy sources are often research and development intensive, and most are in the demonstration or prototype stage [156].

Currently, the global installed capacity of ocean renewable energy is approximately 77 million MW. Countries like Australia, the United Kingdom, Germany, France, South Korea, the Netherlands, China, Canada, and others have already installed varying amounts of marine renewable energy technologies [157,158]. With the current campaigns towards adopting renewable sources, it is expected that the installed capacity of these renewable sources of energy will increase in the future [159]. Figure 10 depicts an artist illustration of the futuristic OpenHydro marine current turbine [160].

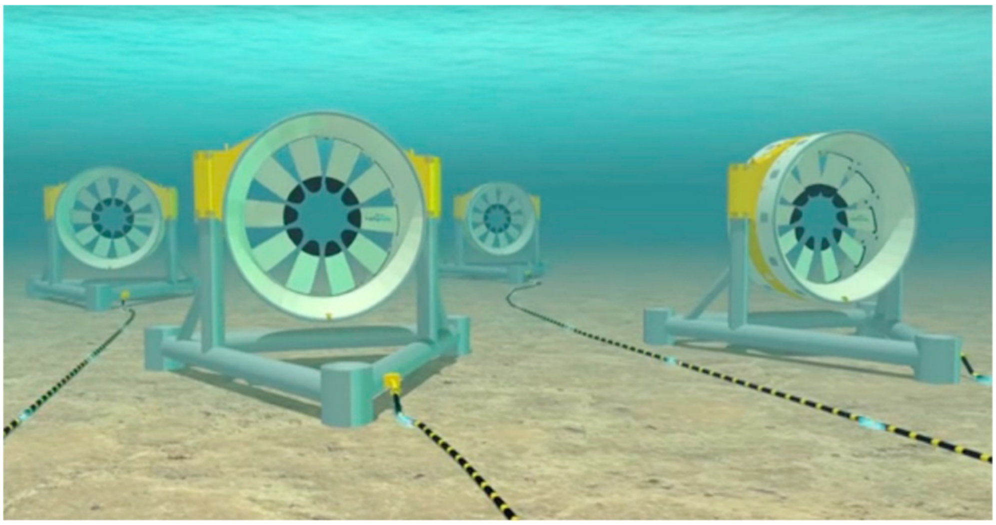

Figure 10. An artist illustration of the futuristic OpenHydro marine current turbine [160].

7.2. Technology Transfer and IPR Challenges

One of the major challenges affecting the technology transfer of marine renewable sources of energy is that these technologies are still young and most of them are yet to be refined. This means that they are still in the prototyping and developing stage [161], and thus are not ready for use by the masses. As a result, the custodians of these technologies are unwilling to share their technologies with the masses, regardless of the amount of cash being offered. They feel that sharing the intellectual property rights of non-refined technology may lead to them losing control of the technology and any benefits that may be associated with it [162].

Another major barrier associated with technology transfer in marine renewable sources of energy is the disagreement regarding who should bear the costs associated with sharing intellectual property rights [163]. On one hand, nations that have already developed and are implementing marine energy technologies (most of which are developed EU member states and have invested heavily in research and development) feel that sharing the technology without proper cash involved will hurt their research and development industry [164]. That is, their scientists will be unwilling to invest their time in developing new technologies. On the other hand, nations in need of these technologies (most of which are developing EU member states) feel that it is their developed counterparts who should bear any costs associated with the transfer of marine energy technologies [165]. This stalemate that hinders the transfer and mass implementation of renewable sources of energy amongst EU member states has already been discussed.

7.3. Discussion on the Ramifications for the European Union

From the discussion above, it is observed that there is a stalemate amongst European Union member states regarding who should be responsible for the transfer of intellectual property rights associated with marine energy technologies [166]. This disagreement has resulted in the slow implementation of marine energy renewable sources among EU member states, and fewer investments in marine-based renewable sources across the European Union [167]. To deal with this challenge, an amicable agreement amongst the EU member states needs be reached on how to safely release this technology [168].

It is also observed that most of the technologies associated with marine energy are not fully refined as they are still being developed. This means that, as already mentioned in Section 7.2, the technology is not yet ready for the market and use by the masses [169]. As a result of this, the implementation of marine renewable energy technologies amongst EU member states is not widespread.

8. Conclusions and Overall Implications

Using fossil fuels to generate energy results into the emission of greenhouse gases into the atmosphere, which damages the ozone layer and leads to global warming. As such, there has been an increased intensity in the research, development, and implementation of renewable energy technologies within the European Union (EU) in recent years. To successfully implement renewable energy technologies amongst EU member states, these technologies need to be transferred to regions that have not yet fully integrated these technologies into their energy mix. However, there are certain challenges associated with this transfer.

The major challenge is that, as is the case with any technology development and transfer, there is a high associated cost, including both the cost of infrastructure and the cost of intellectual property rights. However, available financial resources are not limitless. As not all EU member states have a similar GPD, they do not fully share the same priorities, and thus demonstrate a different commitment towards investing in research and the development of new technologies related to renewable energy sources. In turn, this leads into a strong divergence in opinion with regards to the way the associated technology should be transferred, and how the respective cost should be spread, across EU member states. Developed nations tend to fear that the implementation of technology transfer policies may deprive innovative firms within their jurisdiction of essential intellectual assets. Developing countries, on the other hand, perceive that technology transfer is expensive and should be facilitated (funded) by their developed counterparts. As a result, an additional point of friction is developed between EU members, and between northern-tier and southern-tier EU members, which leads to a further north-south rift being developed.

Another important parameter on the development and transfer of new technology related to renewable energy sources is commercialisation. The number of patent applications may be a good indication of technology development, but there is a long way to go before a proposed idea is fully developed, scaled up, and becomes suitable for commercialisation and widespread utilisation. This challenge is particularly true with the latest trend in electrification and the introduction of electric vehicles in future smart cities. Evidently, additional support must be provided to all stakeholders, so that promising new technologies with low technological readiness may be converted rapidly into a commercial product.

A serious concern related to the development and transfer of technology related to renewable energy sources is their dependence on weather conditions; dependency that makes these energy sources "unreliable". Unfavourable weather conditions, in combination with this "unreliability", may cause a serious impact on both local economies and the global economy. A typical example is the "perfect storm" reported for the summer of 2021. In more detail, the European energy market significantly relies on wind energy, and a very strong indication for that is the exponential growth of offshore wind farms, which are installed and operating in the North Sea. In the summer of 2021, a very high demand for energy was observed: a large proportion of this demand was due to the intensified economic recovery of business activity after the lockdowns due to COVID-19, while another large proportion of this demand was due to very high temperatures, which led people towards an intensified use of air conditioning and cooling systems. Unfortunately, the summer of 2021 was "windless" as the recorded wind speeds were the lowest of this century. Consequently, the energy production at the aforemetioned North Sea wind farms was severely decreased, and regional energy markets were forced to urgently find other ways to provide power to their consumers. That, in combination with other factors, sent electricity prices skyrocketing and created a massive knock-on effect on regional economies.

To conclude, based on the analysis presented in the present paper, it becomes clear that the level of renewable energy technology investments amongst EU member states is significantly affected by the level of research and development. The latter is directly associated with the management of cost and intellectual property rights related to renewable energy technologies. At the same time, existing renewable energy technologies seem to be weather-dependent. Unless an agreed management across EU member states is reached and weather-dependency is reduced, it seems that there will be a significant delay in the transfer of renewable energy technologies across EU member states, and thus a significant delay in achieving the EU's renewable energy targets for the near and distant future.

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