UNIVERSITI PUTRA MALAYSIA

DETERMINANTS OF RENEWABLE ENERGY AND THEIR IMPACT ON ECONOMIC GROWTH

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By

TEE WU SHUN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for Degree of Doctor of Philosophy

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By

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June 2020

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Renewable Energy has gained significant popularity in recent years as a result of the concerns toward climate change and the debate over the limited supply by traditional energy resources such as coal, oil and gas. It has been argued that sustainable energy supply associated with the promotion of clean energy could serve as an important engine for growth. Intuitively, sounds protection reinforce the investment in the renewable energy sector due to the renewables investor might feel more confidence toward their efforts being recognized. The first objective of this study carried out in attempt to examine if intellectual property right is an important driver for the renewable energy production. By employing dynamic panel Generalised Method of Moments (GMM) from 1986 – 2014 which covers the sample 59 countries. The empirical results show that there is strong evidence to conclude that intellectual property rights indeed an important driver for the renewable energy electricity production. Greater protection right motivates the renewables energy firm to increase the energy production from renewable resources. Our findings further suggest that stronger protection tends to propagate the deployment of renewable energy technologies which ultimately promote the renewable energy production.

Tremendous surge in the oil price drawn the attention to the renewable energy consumption recent years due to the spike in oil price might be the stimulus engine for renewables consumption. Throughout the application of dynamic panel threshold methodology in investigating the impact of oil prices on renewable energy consumption growth by using a range of data from 1995 to 2018 that consisted of 160 countries, which were divided into; high-income, upper-middle-income, lower-middle-income and low-income groups. The empirical results, based on a nonlinear framework, indicated that there is an oil prices threshold to renewable energy consumption. The results reveal that above the threshold, oil prices are negatively and significantly related to growth in renewable energy consumption. The result of high-income group also demonstrated that oil prices have a negative and statistically significant impact on renewable energy consumption growth during times of high oil prices. Nevertheless, for the upper-middle income group, oil prices is a positive and

significant determinant of renewable energy consumption growth below the threshold level. The lower-middle-income group indicated that the impact of oil prices is insignificant during times of low and high oil prices. The low-income group showed that the impact of oil prices is weak significant, below the threshold level. Our findings further suggest that there is no substitution effect between oil prices and renewable energy, but rather, that both complemented each other. Any increase in oil prices will harm growth in renewable energy, as oil continues to be an important production input in the renewable energy sector.

Continuously targeting the renewable energy consumption raise an awareness of the environmentally friendly energy which ultimately could trigger a change in the energy trend for future generation. Financial assistance is critically important to support the renewable energy consumption particularly due to the cost of acquiring the renewable energy is relatively higher compared to conventional energy. Therefore, with respect to the concern raised on whether finance does impose any impact to the renewable energy consumption and subsequently growth, the third objective of this study aim to examine the moderating impact of finance on renewable energy to growth. By applying panel GMM methodology with a set of data for 106 countries ranging from 2006 to 201, this study found that country with well-developed financial system tends to promote the economic growth while country with least developed financial system will affect economic growth negatively. These findings imply that renewable energy consumption will spur the growth but only in the present of strictly regulated financial framework. Our findings suggest that countries with well-developed financial system might have the possibility to avoid from the problem with asymmetric information which eventually could further reduce the potentially losses of lenders, thus, they will be willing to lend more for the renewables borrowers. On the other hand, countries with least-developed financial system might conceal some information keen to be known by lenders which in turn might dampen the renewable energy industry due to the users will find it difficult to get the financial resources.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENENTU TENAGA BOLEH DIPERBAHARUI DAN KESANNYA TERHADAP PERTUMBUHAN EKONOMI

Oleh

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Tenaga Diperbaharui telah mendapat populariti yang signifikan dalam beberapa tahun kebelakangan ini sebagai hasil dari keprihatinan terhadap perubahan iklim dan perdebatan mengenai pembatasan bekalan oleh sumber tenaga tradisional seperti arang batu, minyak dan gas. Telah dikatakan bahawa bekalan tenaga lestari yang berkaitan dengan promosi tenaga bersih dapat berfungsi sebagai mesin penting untuk pertumbuhan. Secara intuitif, perlindungan suara menguatkan pelaburan dalam sektor tenaga boleh diperbaharui kerana pelabur yang boleh diperbaharui mungkin merasa lebih yakin terhadap usaha mereka yang dikenali. Objektif pertama kajian ini dilakukan dalam usaha untuk mengkaji apakah hak kekayaan intelektual adalah pemacu penting bagi pengeluaran tenaga boleh diperbaharui. Dengan menggunakan panel dinamik Generalized Method of Moments (GMM) dari tahun 1986 - 2014 yang merangkumi sampel 59 negara. Hasil empirikal menunjukkan bahawa ada bukti kuat untuk menyimpulkan bahawa hak harta intelek sememangnya menjadi pemacu penting bagi pengeluaran tenaga elektrik yang boleh diperbaharui. Hak perlindungan yang lebih besar mendorong syarikat tenaga boleh diperbaharui untuk meningkatkan pengeluaran tenaga dari sumber yang boleh diperbaharui. Penemuan kami menunjukkan bahawa perlindungan yang lebih kuat cenderung menyebarkan penggunaan teknologi tenaga boleh diperbaharui yang akhirnya mempromosikan pengeluaran tenaga boleh diperbaharui.

Kenaikan harga minyak yang luar biasa menarik perhatian kepada penggunaan tenaga yang boleh diperbaharui beberapa tahun kebelakangan ini kerana lonjakan harga minyak mungkin merupakan rangsangan bagi penggunaan bahan terbaharu. Sepanjang penerapan metodologi ambang panel dinamik dalam menyelidiki kesan harga minyak terhadap pertumbuhan penggunaan tenaga boleh diperbaharui dengan menggunakan rangkaian data dari 1995 hingga 2018 yang terdiri dari 160 negara, yang terbagi menjadi; golongan berpendapatan tinggi, berpendapatan tinggi, berpendapatan rendah, sederhana rendah dan berpendapatan rendah. Hasil empirikal, berdasarkan kerangka nonlinier, menunjukkan bahawa ada ambang harga minyak untuk penggunaan tenaga yang dapat diperbaharui. Hasil kajian menunjukkan bahawa di atas ambang harga,

harga minyak secara negatif dan signifikan berkaitan dengan pertumbuhan penggunaan tenaga boleh diperbaharui. Hasil kumpulan berpendapatan tinggi juga menunjukkan bahawa harga minyak mempunyai kesan negatif dan signifikan secara statistik terhadap pertumbuhan penggunaan tenaga boleh diperbaharui pada masa harga minyak tinggi. Walaupun begitu, bagi golongan berpendapatan menengah atas, harga minyak adalah penentu positif dan signifikan pertumbuhan penggunaan tenaga boleh diperbaharui di bawah tahap ambang. Kumpulan berpendapatan rendah dan sederhana menunjukkan bahawa kesan harga minyak tidak signifikan pada masa harga minyak rendah dan tinggi. Kumpulan berpendapatan rendah menunjukkan bahawa kesan harga minyak lemah ketara, di bawah tahap ambang. Penemuan kami selanjutnya menunjukkan bahawa tidak ada kesan penggantian antara harga minyak dan tenaga boleh diperbaharui, melainkan, kedua-duanya saling melengkapi. Sebarang kenaikan harga minyak akan membahayakan pertumbuhan tenaga boleh diperbaharui, kerana minyak terus menjadi input pengeluaran penting dalam sektor tenaga boleh diperbaharui.

Dengan terus menerus menargetkan penggunaan tenaga boleh diperbaharui meningkatkan kesadaran akan energi mesra alam yang akhirnya dapat memicu perubahan dalam aliran tenaga untuk generasi akan datang. Bantuan kewangan sangat penting untuk menyokong penggunaan tenaga boleh diperbaharui terutamanya kerana kos memperoleh tenaga boleh diperbaharui adalah lebih tinggi berbanding dengan tenaga konvensional. Oleh itu, berkenaan dengan kebimbangan yang timbul mengenai apakah kewangan memberi kesan kepada penggunaan tenaga boleh diperbaharui dan seterusnya pertumbuhan, objektif ketiga kajian ini bertujuan untuk mengkaji kesan pembiayaan yang sederhana terhadap pertumbuhan tenaga boleh diperbaharui kepada pertumbuhan. Dengan menerapkan metodologi GMM panel dengan sekumpulan data untuk 106 negara antara tahun 2006 hingga 2015 kajian ini mendapati bahawa negara dengan sistem kewangan yang maju cenderung untuk mendorong pertumbuhan ekonomi sementara negara dengan sistem kewangan yang paling kurang akan mempengaruhi pertumbuhan ekonomi secara negatif. Penemuan ini menunjukkan bahawa penggunaan tenaga boleh diperbaharui akan mendorong pertumbuhan tetapi hanya pada masa ini kerangka kewangan yang diatur dengan ketat. Penemuan kami menunjukkan bahawa negara-negara dengan sistem kewangan yang maju mungkin mempunyai kemungkinan untuk menghindari masalah dengan maklumat asimetrik yang akhirnya dapat mengurangi kemungkinan kerugian pemberi pinjaman, oleh itu, mereka akan bersedia memberi pinjaman lebih banyak untuk peminjam yang boleh diperbaharui. Sebaliknya, negara-negara dengan sistem kewangan yang kurang maju mungkin menyembunyikan beberapa maklumat yang ingin diketahui oleh pemberi pinjaman yang pada gilirannya dapat melemahkan industri tenaga boleh diperbaharui kerana pengguna akan merasa sukar mendapatkan sumber kewangan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AR	Autocorrelation
CAP	Capital Formation
CO2	Carbon Dioxide Omissions
EIA	Energy Information Administration
FDI	Foreign Direct Investment
GDP	Gross Domestic Products
GMM	Generalized Method of Moments
ICRG	International Country Risk Guide
IEA	International Energy Agency
IMF	International Monetary Fund
IPR	Intellectual Property Right
IV	Instrumental Variables
LR	Likelihood Ratio
NRE	Non-Renewable Energy
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
RE	Renewable Energy
WDI	World Development Indicators
WGI	Worldwide Governance Indicators
WIPO	World Intellectual Property Organization

CHAPTER 1

INTRODUCTION

1.1 Overview

Over the last decade, the severe pollution of the environment has remained a hot topic that has been widely discussed at the national level. Tremendous growth in energy consumption, notably in heavy industries, has created concerns from various perspectives, such as labor productivity, healthcare, social welfare, and carbon dioxide (CO2) emission. With regards to this, the reaction of policymakers to excessive CO2 emissions in the environment can no longer be ignored. Due to the overwhelming demand for energy, particularly for large scale consumption of electricity, the supply of conventional energy remains as the primary energy resource to tackle the infinite trend of demand. According to a recent report released by the Energy Information Administration (EIA) in 2019, global energy consumption is expected to increase by 50 percent by 2050, primarily driven by economic growth.

Energy is essential to sustain the development of a nation. Fossil fuel has been recognized as the most common energy used globally because of the upward trend in global economic development. However, the expansion of energy-consuming activities in developed and emerging countries, and waste in rich countries (especially Gulf countries) has led to two major concerns: (1) the depletion of the most easily accessible energy resources (mainly oil) and (2) the problem of global warming caused by the rapid increase in the emissions of greenhouse gases such as CO2 and methane. The global nature of these concerns require renewable energy resources to be appropriately managed and used.

In general, energy resources can be decomposed into two different categories, namely non-renewable and renewable. A non-renewable resource (also called a finite resource) is a resource that does not renew itself at a sufficient rate for sustainable economic extraction in meaningful human time frames and will eventually exhaust quality supplies. Fossil fuels such as oil, coal, and natural gas are formed at far slower rates than the rate of energy use for mining, manufacturing, and electricity generation. In contrast, renewable energy is commonly defined as energy generated from sources that are naturally replenishing and virtually inexhaustible over time but are limited in the amount of energy that is available per unit of time (U.S. Energy Information Administration). Examples of renewable energy sources are Biomass, Hydropower, Geothermal, Wind and Solar. Overwhelming energy demands are primarily due to consumption from four sectors, i.e. residential, commercial, industrial and transportation. Figure 1.1 indicates actual and projected energy consumption by sector, where the industrial sector is the largest contributor to world energy consumption at approximately 26.79 percent in 2018.

Figure 1.1: Actual and Projected Global Energy Consumption by Sector, 2019
(Source: U.S. Energy Information Administration 2019)

1.2 Renewable Energy

Renewable energy has emerged as a powerful tool for future energy supply, given that conventional energy such as petroleum is limited and will be depleted someday. Therefore, the development of the renewable energy sector will ensure sustainable energy supply. Contradictory to conventional energy, renewable energy is clean, safe and inexhaustible. Therefore, it is growing fast around the world and will eventually edge out many conventional energy components to occupy a leading position in overall energy consumption. Recent developments in the renewable energy sector have heightened the need for everyone to treat climate change seriously. Global weather has changed dramatically as a result of substantial CO2 emissions associated with the rapid economic development in developing countries such as China and India, which have released an additional 1000 tones or 200 units of CO2 into the world.

It has been argued that the increased consumption of conventional energy, such as fossil fuel, produces negative externalities for the environment. For instance, large amounts of CO2 emission eventually lead to greenhouse gas (GHG) levels above the targeted level and the degradation of environmental quality. Though renewable energy is not a perfect alternative to conventional energy, as a substitute of the latter, its role has become gradually more important, particularly in the heavy industry sector. Compared to conventional energy, the cost of producing renewable energy is relatively higher, because it requires additional effort in Research and Development (R&D) and advanced technology deployment due to the limited knowledge in this industry.

Among the different types of renewable energy, wind, solar and biomass are the three emerging primary renewable energy sources. The most significant rise is in the consumption of wind power, which has grown more than energy generation from coal and nuclear power. To encourage the public or private sector to invest in renewable

energy, financial incentives serve as an important tool in driving renewables' growth. Among these incentives, the most effective measures include tax reduction, introduction of a grace period, provision of capital or discounted rates, reduced depreciation life of assets, and accelerated depreciation methods (El-Karmi & Abu-Shikhah, 2013). Apart from the incentives mentioned above, other schemes such as feed-in tariffs, investment subsidies, and green certificate trading could also be introduced by the government (Salim et al. 2014).

Recent investigations show that the contribution of renewable energy to global electricity generation is expected to increase by an average of 3.6 percent per year. Without this substitution, existing energy consumption would generate an additional 1.3 Gigatonnes of CO2 emissions, which is approximately 12 percent of the projected emission gap that needs to be filled in 2020 (Global Trends in Renewable Energy Investment, 2015). Besides that, research done by the UK Renewable Energy Association (REA) found that the funds injected into renewable energy investment have reached approximately 10.7 billion pound sterling. Such an investment has correspondingly boosted the employment rate by nine percent (UK and PWC Renewable Energy Investment, 2014). Furthermore, numerous preceding works have documented that the role of renewable resources are gradually more important.

In addition, Bloomberg's new energy research team has reported that solar energy recorded the highest growth among several types of renewable energy at 25 percent in 2014. This was followed by wind, which had an 11 percent higher investment than the former year (UNEP, Bloomberg New Energy Finance). Substantial increases in the consumption of wind energy does not only apply to the case of big nations like China but also to smaller ones like Spain. A study in Spain unveiled that the consumption of wind energy is isolated from regulatory influences and continues to experience positive growth, while the uneven growth in their renewables is not solely determined by geographical factors but also by support from independent communities within states (Montoya et al., 2014).

Figures 1.2 and 1.3 display the energy supplies generated by renewable resources. The data shows that electricity generated by renewable energy has been gradually trending upward since 1980 and achieved approximately 6000 billion Kilowatts in 2017. This demonstrates the growing reliance on renewable energy as an alternative resource to produce electricity. In terms of region, Asia and Oceania are greatest contributors to renewable energy production with around 2500 kilowatt hours of electricity generated by renewable resources. This upward trend in renewable energy usage for power supply implies that most countries have started to deploy technologies to explore renewable energy.

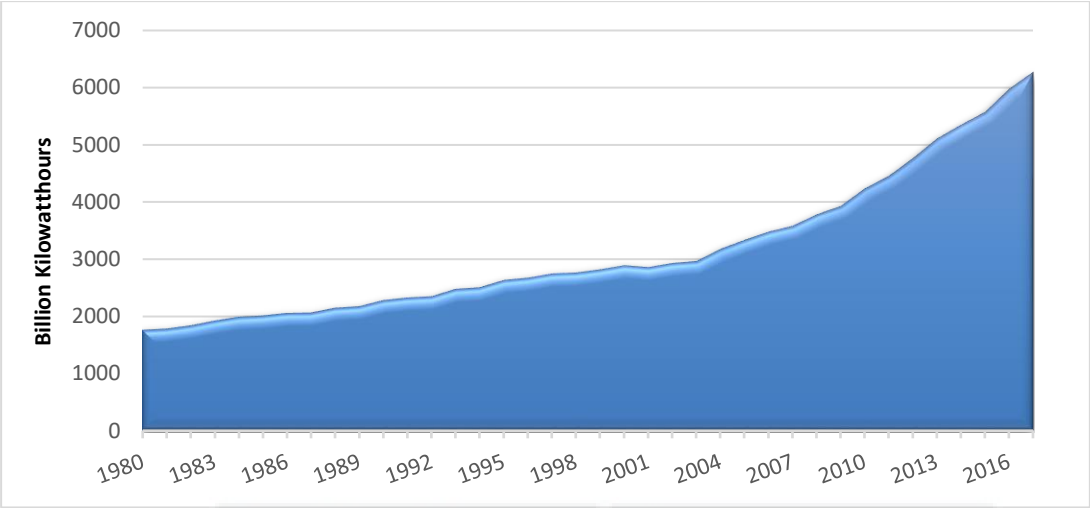
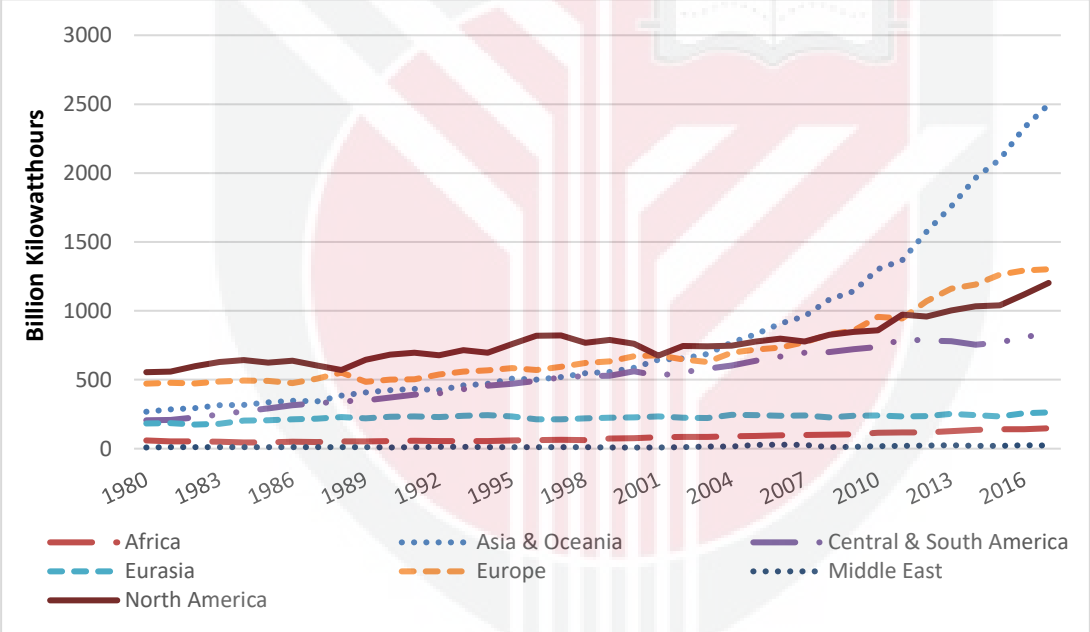


Figure 1.2: Global Renewable Electricity Net Generation (1980 – 2017)
(Source: Energy Information Administration 2019)



Figures 1.3: Total Renewable Electricity Net Generation (By Region)
(Source: Energy Information Administration 2019)

Figures 1.4 and 1.5 indicate the global total primary energy consumption and proportion of specific renewable energy, respectively. In 2018, renewable energy accounted for approximately 11 percent of primary energy consumption, out of which hydro constituted the largest proportion of renewable energy followed by wind and biomass. The contribution of solar and geothermal energy is considerably small. As such, renewable energy consumption appears to be relatively low compared to conventional energy forms. This may be due to renewable energy being considered as expensive and unaffordable by many.

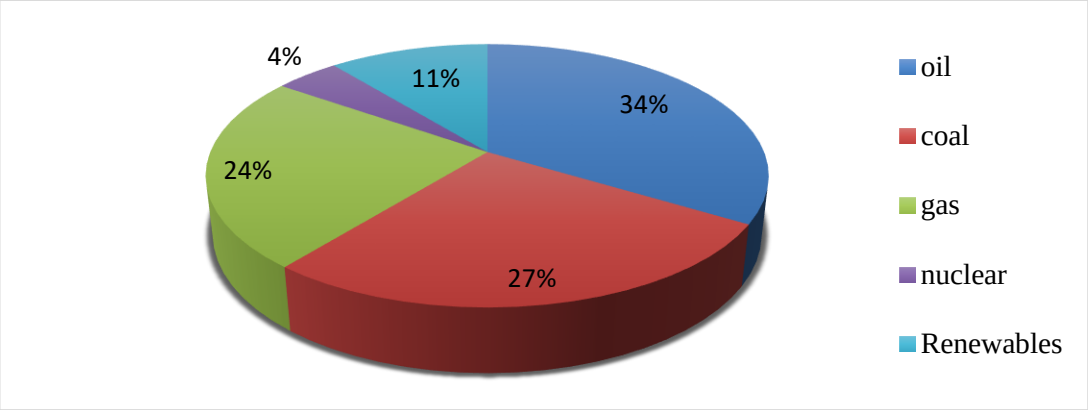


Figure 1.4: World Total Primary Energy Consumption, 2018
(Source: BP Statistical Review of World Energy 2019)

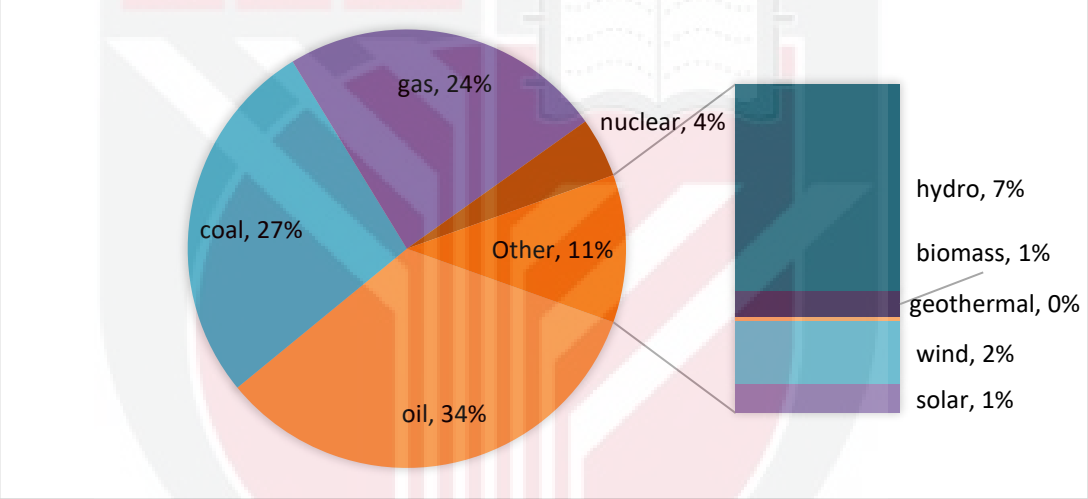


Figure 1.5: World Proportion of Specific Renewable Energy, 2018
(Source: BP Statistical Review of World Energy 2019)

1.2.1 Benefits of Renewable Energy

In less developed countries, the benefits of retrieving energy from renewable sources include improved electricity access in rural areas as well as reduced reliance on traditional energy sources and fossil fuels imports (Nepal, 2012). Since renewable energy entails benefits not only for power generation but also for emission reduction, the question raised here is "What are the key engines that have the potential to steer the growth of renewable energy?" In determining the growth of renewable energy, its demand typically holds a strong influence. Countries that experience high pressure for energy supply tend to utilize more fossil fuels due to the advantage of large scale production. Nonetheless, the high rates of electricity imposed on the industrial sector eventually lead to lower energy investments (Aguirre & Ibtikunle, 2014). In addition, renewable energy produces less emissions than non-renewable resources. Hence, deploying renewable energy technologies promotes a clean environment, which has

socio-economic benefits and retains commitment to the Kyoto Protocol[1]. Accordingly, extensive empirical works have established the linkage between renewable energy and economic growth. However, they have neglected the role of financial institutions in this link, though these institutions are intermediaries who have great potential to accelerate the development of renewable energy.

Renewable energy can improve human wealth, mitigate greenhouse gas, reduce outdoor air pollution, and decrease dependency on imported fossil fuels. However, the benefits of renewable energy usage take time to realize. Nevertheless, renewable energy can assure sustainable economic prosperity and future jobs while supporting technical innovation. Over time, energy demand will increase significantly due to continuous country development. As a result, countries that have less energy resources will expand their import of energy (Blazejczak et al., 2011). All in all, renewable energy could assure more energy security, effective environmental and climate protection, and an economically viable energy supply, which are necessary for a country to have a competitive industrial base in the long term.

1.2.2 Challenges Encountered by Renewable Energy

Despite renewable energy's proven advantages, it remains less favored than non-renewable resources. One of the reasons is that investment in renewables competes with fossil fuel projects, which have a longer track record, relatively lower up-front costs, shorter lead time, and often more favorable political treatment. When pit against renewable energy, rational investors will still select conventional energy for their primary investment portfolio as it offers lucrative profitability. Apart from political influences, market imperfections are another potential threat to the development of renewable energy, due to factors such as financial market deficiencies and regulatory and institutional frameworks (Lindlein and Mostert, 2005). Additionally, certain industries have highly specific heating supply requirements which renewable energy may not be able to support (Blazejczak et al., 2011).

The greatest challenge for renewable energy that has been widely reported is the lack of adequate financing support. Mathews et al. (2010) argue that the private sector plays a relatively marginal role in this industry, possibly due to low anticipated returns from renewable energy. However, the view of finance as the core mechanism to support the development of renewable energy contradicts the finding of Zyadin et al. (2014), who concluded that instead of financial aids, the primary factor that prohibits the growth of renewable energy is the lack of supportive governmental policies on alternative energy.

Notably, economic influences such as high cost of capital and lack of financial support significantly deteriorate the development of renewable energy. Typically, an investment plan relies heavily on support from government or financial institutions. If financial institutions are reluctant to lend due to factors such as delayed returns on investment or limited information on a project, the development of the project would

[1]It was implemented under the United Nations Framework Convention (UNFCCC) on Climate Change, and its main objective is to control greenhouse gas emission levels in the atmosphere.

be restricted despite its potential for a high profit margin. This is what renewable energy project investors have experienced, as high up-front costs for renewable energy projects, a small market size, and market imperfections eventually affect their financial accessibility and cause the failure of their investment plan.

Moreover, there is a need for public infrastructure to facilitate the deployment of renewable energy. For instance, to prevent wind turbine breakdown and ensure adequate electricity generation, the surface of roads should be well-maintained to reduce transportation time in delivering equipment to worksites. Political instability can also threaten the benefits granted to the renewable energy industry, as a change in the predominant party may cause the revision of subsidies. This would have severe negative impacts on an investment project because the expenditures would become relatively higher without these additional aids. As such, public support schemes are deemed necessary to support the deployment of various renewable energy technologies.

The development of renewable energy faces additional challenges in the form of public or private sectors' lack of knowledge about the technological development and potential of renewable resources. Despite clear economic and financial incentives, the renewable energy industry requires greater cooperation from public and private sectors (Cancino-Solorzano et al., 2016). Renewable energy projects have even faced public resistance from people living in neighborhoods that are directly affected. For instance, in the case of onshore wind projects, the re-powering of older wind farms by replacing small turbines with large-scale turbines may cause increased truck traffic (Blazejczak et al., 2011). Figure 1.6 summarizes all the possible barriers[2] that impede the development of renewable energy.

[2] The barriers were divided into five different categories comprising market, political, economic, technical and social-cultural factors.

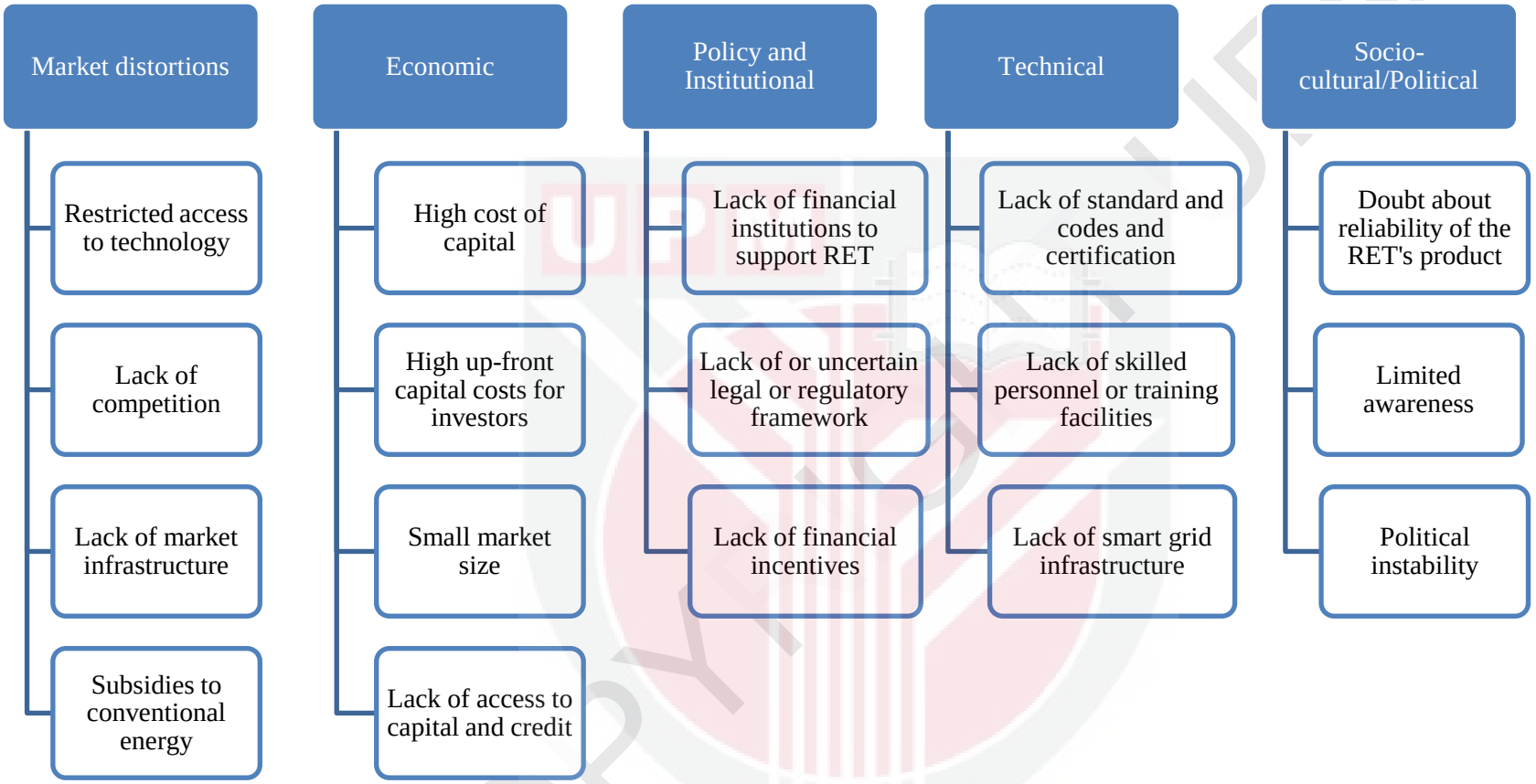


Figure 1.6: Barriers to Renewable Energy

Source: Dulal et al. (2013)

Note: RET = Renewable energy technology

1.2.3 Development of Renewable Energy

Energy security, climate change, and environmental issues such as CO2 emissions have encouraged the renewable energy sector to grow rapidly and successfully in the 20th century. Several big nations like China, the United States, Germany, Brazil, and Denmark have made significant investments in renewable energy. China recorded the biggest renewable energy investment in 2014 worth $83.3 billion, which was 39 percent higher than in 2013. The United States was ranked second highest, but its investment in renewable energy was only $38.3 billion, less than half of China's. The next ranked country was Japan, which contributed $35.7 billion to its renewable energy development in 2014, growing by about 10 percent from 2013 (Global Trends in Renewable Energy Investment, 2015).

The People's Republic of China, the world's most populous country with the highest energy demand, recently committed to phasing out coal and cleaning up its polluted air (The Climate Reality Project, 2016). The remarkable rise of China's[3] clean energy sector reflects a strong and growing commitment by the government to diversify its energy economy, reduce environmental problems, and stave off massive increases in energy imports. Figure 1.7 presents the countries with the largest renewable energy consumption in the world, where China remains the leader, followed by the United States. The amount of renewable energy consumed by China in 2018 was approximately equal to 140 million tonnes of oil, showing that China has greatly adhered to the pledges made in climate change conferences.

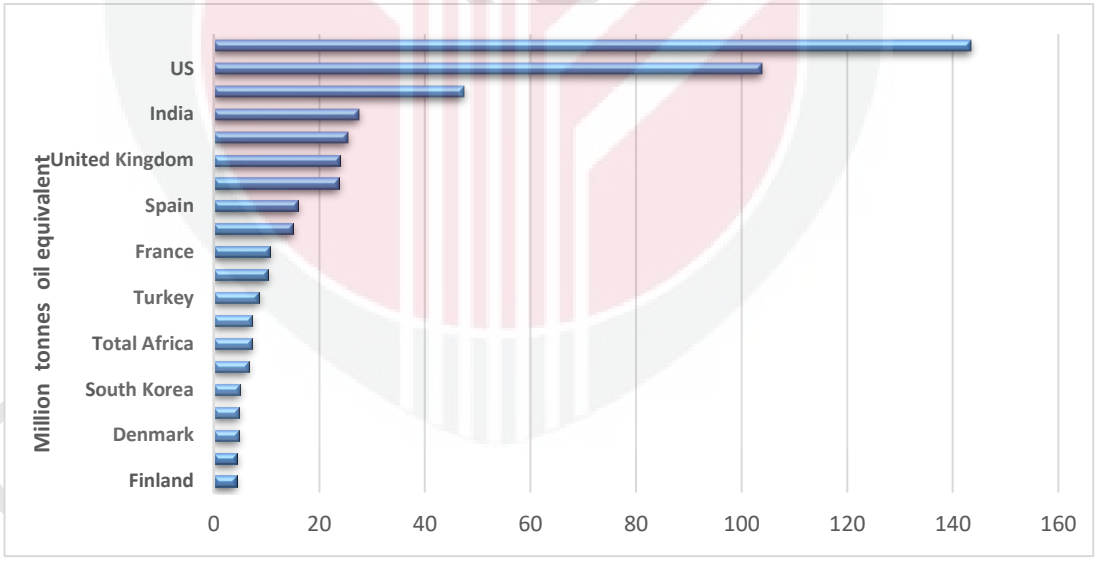


Figure 1.7: Top 20 Renewable Energy Consumption Countries, 2018
(Source: BP Statistical Review of World Energy 2019)

[3]According to the Energy Information Agency (EIA), in 2004, China accounted for 17 percent of global carbon dioxide emissions. It is expected to increase to 40 percent between 2005 and 2030 if current energy continues to behave in a similar trend.

Table 1.1 summarizes the different types of renewable energy sources used by countries. China has successfully established itself as the top consumer for all three common types of renewable energy, i.e. wind, biomass, and solar. It recorded 82.82 MTON consumption for wind energy, 20.50 MTON for biomass, and 40.16 MTON for the solar energy. The country that ranked second for these energy types was the United States, though their solar energy consumption was only about half of China's. Out of all the countries that contributed significantly to renewable energy, Germany, Brazil, the United Kingdom, India, and several European countries appeared in the top 30 list.

Table 1.1: Top 30 Renewable Energy Consumption Countries by Source, 2018

Countries	Wind	Countries	Biomass	Countries	Solar
China	82.82	China	20.50	China	40.16
US	62.84	US	14.95	US	21.98
Germany	25.25	Brazil	11.97	Japan	16.22
India	13.65	Germany	11.60	Germany	10.45
United Kingdom	12.92	United Kingdom	8.05	India	6.95
Spain	11.50	Japan	7.09	Italy	5.26
Brazil	10.97	India	6.89	United Kingdom	2.92
Canada	7.28	Italy	4.35	Spain	2.83
France	6.37	Finland	2.91	Australia	2.73
Turkey	4.49	Thailand	2.79	France	2.30
Italy	3.95	Sweden	2.68	South Korea	2.12
Sweden	3.80	South Korea	2.30	Turkey	1.79
Australia	3.68	Canada	2.17	Chile	1.16
Denmark	3.14	France	1.93	South Africa	1.12
Poland	2.91	Spain	1.67	Thailand	1.07
Portugal	2.86	Chile	1.48	Belgium	0.90
Mexico	2.86	Poland	1.43	Greece	0.86
Netherlands	2.39	Denmark	1.38	Canada	0.80
Ireland	1.90	Belgium	1.23	Netherlands	0.72
Belgium	1.69	Netherlands	1.10	Brazil	0.71
South Africa	1.56	Austria	1.08	Taiwan	0.62
Japan	1.54	Czech Republic	1.07	Czech Republic	0.53
Romania	1.47	Australia	0.80	Mexico	0.51
Greece	1.43	Portugal	0.73	Pakistan	0.48
Austria	1.34	Hungary	0.54	Switzerland	0.44
Finland	1.33	Argentina	0.52	Israel	0.41
Norway	0.88	Turkey	0.50	Romania	0.38
Morocco	0.87	Colombia	0.47	Austria	0.36
Chile	0.83	Taiwan	0.46	Ukraine	0.29
Egypt	0.55	Switzerland	0.45	Philippines	0.28

(Source: BP Statistical Review of World Energy 2019)

As has been highlighted in extensive environmental studies, the CO2 emissions released by fossil fuels are relatively higher than bio-fuels. Since CO2 emission has negative impacts on the environment, the development of renewable energy should be concentrated on. First, increasing the production or consumption of renewable energy ideally reduces the dependency on fossil fuels; this is the outcome that every

policymaker desires to achieve. Second, productivity would be higher if the labor force is not harmed by pollution and is physically healthier. Third, employing renewable sources to generate electricity decreases the level of waste while simultaneously reducing CO2 emissions and protecting against infectious diseases. Lastly, promoting the development of renewable energy would ensure sustainable energy supply when conventional resources are depleted one day in the future. Therefore, the multiple potential benefits of renewable energy provide a clear picture on its importance for the current as well as future generation.

1.2.4 Factors Affecting the Development of Renewable Energy

Generally, the core factor that significantly drives the development of renewable energy is concern about the limited supply of conventional energy such as oil and coal. Limited supplies of these traditional energies remind the rest of the world to embark on renewable energy projects as substitutions for conventional resources. Therefore, renewable energy sources such as wind, hydro, and solar have become the best alternatives to ensure sustainable energy supply. Though the issue of finite supply is the foremost discussion around the world, it has been shown that institutional factors have considerable impacts in the matter, particularly in the strategic decision-making on energy policies (Évariste et al., 2016). Nevertheless, various forums held by the United Nations (UN) continue to emphasize the issue of climate change, whereby the development of renewable energy remains a priority to UN members to mitigate the consequences of climate change.

Moreover, political stability should not be neglected, as stable institutions indirectly imply the credibility of central governance. It strengthens the confidence of foreign investors, which then encourages further technology transfer and dissemination among countries. Through this, less developed nations will have the chance to obtain the knowledge shared by developed nations; such progress would certainly assure the unanimous growth of renewable energy. Therefore, it is imperative to consider the role of political influences in the deployment of renewable energy. A stronger governance framework with the implementation of protection rights such as Intellectual Property Rights (IPR) would extend support to the renewable energy industry by protecting the creativity and invention of investors. Such protection may confine the imitation level of technology and prevent the 'free rider' issue.

Similar to conventional energy, renewable energy also faces challenges in paving the way for future growth. One of the notable factors that carries a pivotal role in the development of renewable energy is financial aid. Asymmetric information and moral hazards are common obstacles that prohibit the mobilization of funds to productive sectors, whereby the lender or financial institution has doubts about the borrower's ability to pay. When financial institutions are reluctant to provide financial assistance, pioneer investors may revoke their investment plans. Hence, accessibility to funds is important as extended borrowing would directly grant additional support for capital funding. As a result, firms would be able to build a strong foundation for their business without worrying about financial difficulties. Consistent support from financial institutions could also ensure that firms have sufficient funds to engage in R&D and

thereby reveal the potential opportunity in the renewable energy industry. The ultimate goal of this would be to promote efficiency while avoiding negative externalities.

1.2.5 Institutions and Renewable Energy

The barriers encountered by the renewable energy sector can be divided into two categories, i.e. economic and non-economic. One of the most prominent non-economic factors is institutional barriers, which encompass the low influence and dedication of institutions, lack of efficiency and transparency in institutional bodies, and the absence of strict governance. The combination of all these factors hinders renewable energy from growing rapidly and smoothly. The quality of institutions thus plays a central role in renewable energy governance and affects policy outcomes. Three common dimensions have been employed to measure the institutional quality of a country, namely economic, political, and social. Institutional factors that may impede the implementation of renewable energy strategies consist of entrepreneurial and household traditions as well as traditional legislation and rules (Apergis & Eleftheriou, 2015).

Institutional factors can be regarded as the core factor to ensure the success of renewable energy development. Carlsson and Lundstrom (2003) pointed out that price stability and the quality of the legal system influences the quality of the environment. Though the energy sector has a role in facilitating the development of renewable energy, it heavily relies on the laws and policies established in the executive and legislative branches of government (Berg, 2013).

1.2.6 Intellectual Property Rights (IPR) and Renewable Energy

Intellectual property rights (IPR)[4] can be defined an intangible asset which embodies the creations of the mind, such as inventions, literary and artistic works, designs and symbols, as well as names and images used in commerce (World Intellectual Property Organization). IPR provides its owners with legal means to prevent abuse of their rights, thereby enabling them to better capitalize on their innovations (Lippoldt, 2008). Generally, intellectual property is protected by law, which enables people to earn recognition or financial benefit from what they have invented. Appropriate and robust protection of intellectual property plays a pivotal role in promoting market competitiveness, and serves as a remuneration tool to reciprocate the effort of innovators. The protection and enforcement of intellectual property rights should contribute to the promotion of technological innovation and the transfer of technology, to the mutual advantage of producers and users of technological knowledge, in a manner conducive to social and economic welfare with a balance of rights and obligations[5].

[4] Pattern right, copy right, design right and trademark right are the examples of intellectual property right.
[5] It is an acknowledgement of Trade-Related Aspects of Intellectual Property Rights (TRIPS)

Furthermore, being part of the institutional factor, intellectual property rights (IPR) embody the characteristics to ensure sustainable renewable energy growth. Not only do patent rights have the ability to influence economic efficiency through trademark protection, they also allow consumers to search for the symbol or name of a product to distinguish their quality. This in turn reduces their implicit cost in selecting the best product. Failing to link investments and products to trademarks, however, would discourage inventors and diminish their tendency to invest in quality-enhancing investment (Park, 2006). However, while IPR theoretically affects various industries positively by recognizing developers' efforts, Awokuse and Yin (2010) claimed that strictly adhering to IPR protection may affect the trade of knowledge transfer.

As shown in Figure 1.8, the recent trend in patents, an IPR, indicates that its applications in energy-related technologies have grown significantly since 2002. Likewise, Figure 1.9 provides an overview of the renewable energy patents published by IRENA, which has been trending upward since 2005. IRENA uses data from the European Patent Office's (EPO's) PATSTAT and climate change technologies classification to provide comprehensive information on patents filled for renewable technology worldwide. The substantial growth in patent application in the respective technology fields is likely a response to market conditions such as increased R&D investment, shifts in policy incentives like feed-in-tariffs, and technological advances like cost reductions in manufacturing (Global Challenges Report, 2014).

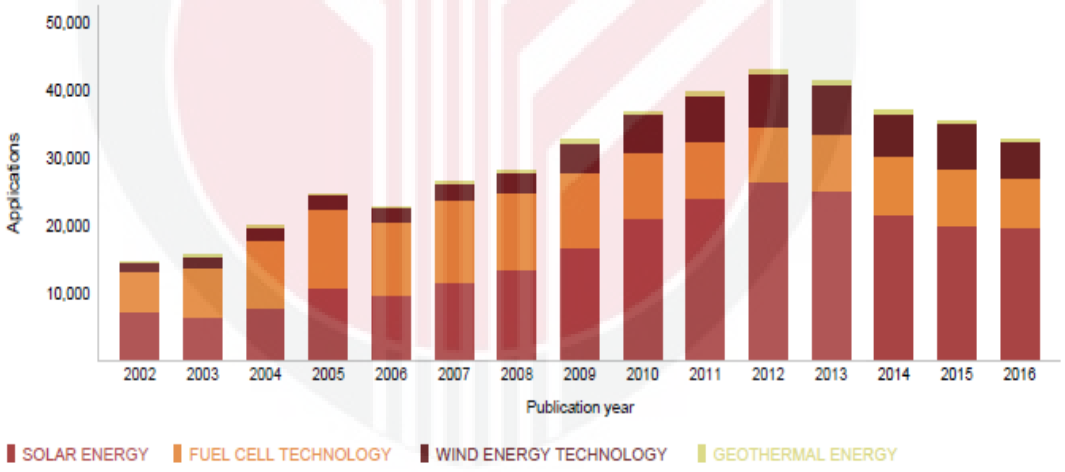


Figure 1.8: Trend in Patent Applications in Energy-Related Technologies, 2002–2016
(Source: WIPO Statistics Database and EPO PATSTAT database 2018)

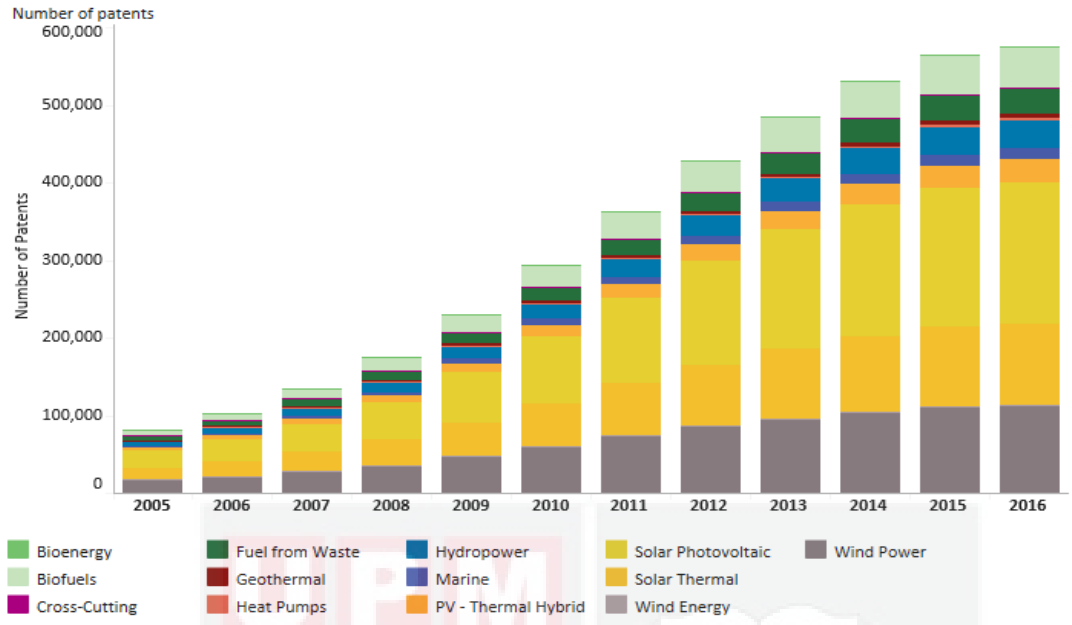


Figure 1.9: Renewable Energy Patents Evolution, 2005 – 2016
(Source: IRENA INSPIRE 2019, www.irena.org/inspire)

By striking the balance between the interests of innovators and wider public, intellectual property system aims to foster an environment in which creativity and innovation can flourish. Hence, sharing the best practices associated with policy design could be the most effective approach to facilitate renewable energy investment (G20 Deployment of Renewable Energy, 2015). It is well-accepted that businesses drive innovation, and a good portion of intellectual property is produced as a result of financial investment. Intellectual property laws provide a guarantee to technology developers that their investment will result in rights to exploit their technology exclusively and rights to prevent others from using their technology without authority. The World Intellectual Property Organization (WIPO) was established to facilitate the adaption, adoption and deployment of green technologies, particularly in developing and emerging nations. This international exchange forum helps in facilitating the diffusion of renewable energy technologies.

It has conclusively been shown that intellectual property is a valuable tool to promote the development and diffusion of green technology (Thomson & Webster, 2010). IPRs are often justified on moral grounds to credit one's effort in production (Dibble, 1994). It plays an important role in the proprietary right of technology which is transferrable, licensable, and subject to trespass in the form of infringement (Chu, 2012). Gattari (2013) highlighted that intensive patent protection ensures the profitability of green projects and subsequently leads to more green energy related private investment and new jobs associated with the progress of green energy technology.

Within the context of renewable energy technology projects, protection rights over technology exert pressure on investors. Evidently, one of the first considerations before commencing a project is the acquisition of a license from a government

institution, which is typically the hardest stage. The decision of whether to release the license is subject to several criteria such as conflict of interest, environmental impact, and social welfare. Consequently, the applicants of these technology copyrights tend to abandon their investment in technology-related projects. The pressure of licensing is especially greater for newly established renewable energy projects compared to traditional energy projects, as the latter may possess a higher chance of being approved due to a longer historical record. IPR as an incentive to those who contribute to the creation or innovation of technology will certainly motivate investors to develop unique and practical technologies in the renewable energy industry.

In addition, the reinforcement of patent protection for renewable energy technology will lead to an increase in private investment and therefore more jobs in the green energy sector (Gattari, 2013). This again demonstrates that renewable energy and growth are closely related, given the higher employment rate resulting from job creations in the renewable energy industry. Moreover, IPR protection provides new technology solutions and assets through which expertise can be exchanged. It also gives innovators and companies the confidence they need to invest in, trade, and share their technological know-how with business partners, customers, and other stakeholders (World Energy Council, 2011). As a result, there would be more room for improvement in renewable energy technology. Lorenczik and Newiak (2012) further pointed out that emphasizing IPRs promotes R&D efficiency, spurs innovation, improves social welfare, and reduces income inequality.

On one hand, IPR is likely to be an essential instrument to stimulate the investment of renewable energy. On the other hand, it may create a barrier to the development of renewable energy if the cost of acquiring IPR is deemed high. Higher investment costs in technology-related projects might be affordable for certain big investors, but not for majority of them. Hence, the reinforcement of IPRs ostensibly denotes a protective source of knowledge while creating a barrier to access (Newiak, 2011). It is nevertheless good to have such protection as a reward scheme to recognize developers' contributions and encourage their involvement in similar transitions. Therefore, it is plausible that rigorous IPR boosts green energy investment. Consistent with this, Dechezleprêtre et al. (2013) suggested that strict IPR paves the way for the transfer of climate change mitigation technologies as without the protection of IPR, innovators would have to rely on secrecy to prevent their inventions being disclosed.

Figure 1.10 indicates the relationship between intellectual property (IP) protection and the production of renewable energy. The scatter plot demonstrates that stronger intellectual property protection boosts renewable energy growth. This implies that when IP protection is rigorous, firms or developers are more willing to disseminate knowledge on renewable energy, thereby encouraging technology transfer in the renewable energy industry. The existence of such protection reflects that innovation via R&D is regarded as an important pillar to stimulate investment in the renewable energy sector.

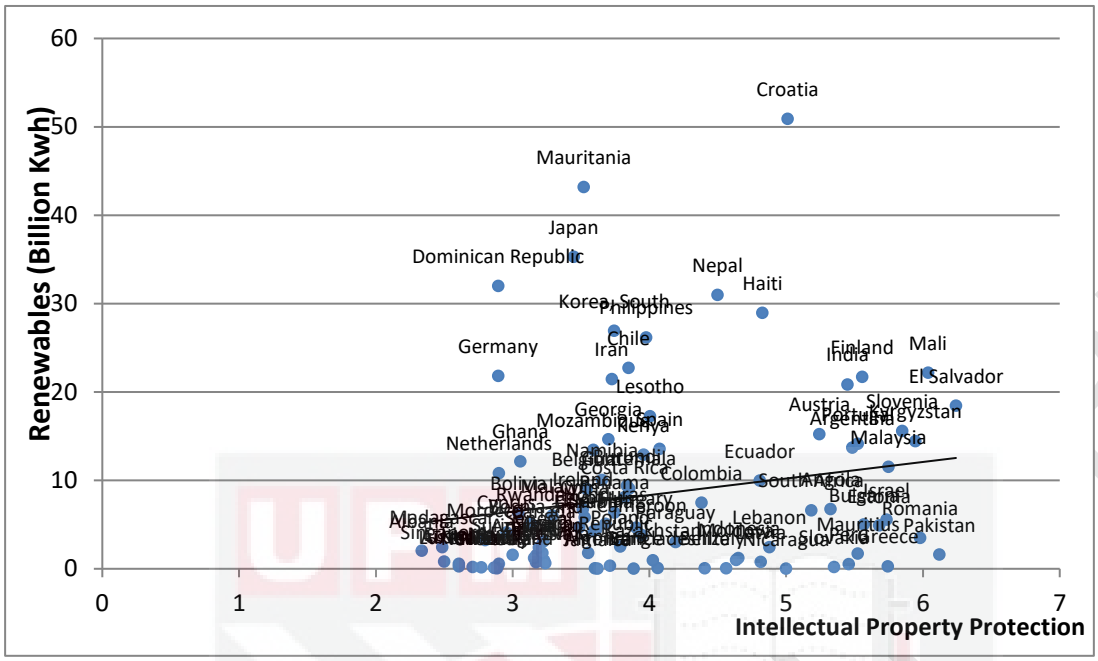


Figure 1.10: Intellectual Property Protection and Renewable Energy
(Source: World Development Indicator and Global Competitiveness Index 2018, IMD World Competitiveness Centre)[6]

Without policies to govern IPR, technology developers may possibly be reluctant to share their information, causing further delays in investment and technology transfer. When no party is willing to move first and would rather wait for benefits or imitations, the problem of delays in investment would worsen due to the existence of such 'free riders' (Wait, 2010). While the conferment of patents could be an incentive for firms to invest in innovation-oriented energy projects, granting patent assets may also lead to monopolistic advantages. As such, patent right holders can manipulate the charges of technology diffusion when given such protection, making the capital incurred relatively higher for other firms. Overall, there seems to be some evidence that the incentives provided by intellectual property laws could ensure fair competition among developers. Specifically, innovators would try to design cost-efficient green technology that maximizes output to achieve better performance than other green energy technology designers.

1.2.7 Financial Sector Development and Renewable Energy

Public and private financial support are an important channel to promote high technology investment in energy-related projects. Generally, renewable energy requires substantial capital to embark on R&D activities, which may cause investors to withdraw initial investments in renewable energy projects. A good investment prospect always offers the greatest return at the lowest cost. In contrast, renewable energy investment takes a longer time to realize profits, while its returns are less

[6] The measurement of Intellectual Property Protection ranges from '1' to '7'.

competitive than conventional energy investments. As such, renewable energy is relatively less attractive to investors.

Up to now, far too little attention has been paid to the development of renewable energy compared to conventional energy. One of the plausible reasons for this is the unwillingness of financial institutions to extend loans to the industry as it does not have proven historical achievements. Although renewable energy is strongly encouraged by governments and large organizations such as G20, existing financial support is still lacking. To strengthen the development of renewable energy, financial support through credit, equity, or bonds is a fundamental requirement. Regardless of the channel, a platform to raise capital is much needed for the development of renewable energy.

Figure 1.11 illustrates the relationship between financial sector development and the production of renewable energy from 1960 to 2014. The proxy used to measure financial depth is bank credit, which tends to move in the same direction as renewable energy. This suggests that high bank credit encourages more production of renewable energy. Thus, finance does play a pivotal role in the development of renewable energy, whereby financial institutions serve as one of the capital funding channels for participants in the renewable energy sector.

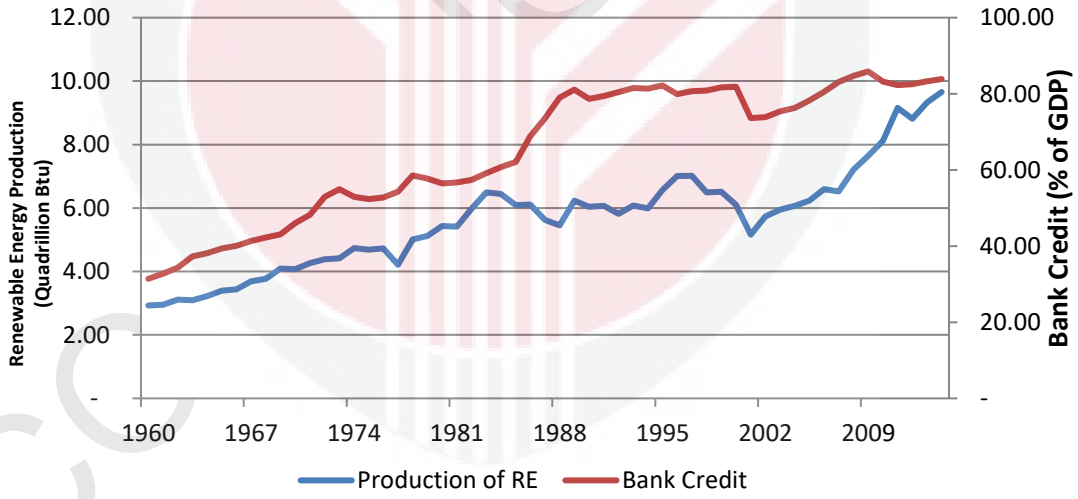


Figure 1.11: Finance Sector Development and Renewable Energy
(Source: World Development Indicator and Energy International Agency 2018)

The pressure exerted by conventional resources, especially the downward price pressure from crude oil that has increased since 2015, has impacted the growth of renewable energy. Low oil prices lead to the selection of alternative energy resources to generate electricity, which involves substituting solar or wind with petroleum in the electricity generation process. If that happens, there is a possibility that the development of renewable energy will move progressively backward. Therefore, financial assistance via credit or equity support is indispensable during turbulent

periods. With financial inflow into investment projects, the renewable energy industry would be able to sustain their operations and compete against oil drilling projects. Besides, the establishment of green credit guarantee schemes (GCGs) and the reduction of tax would potentially reduce the risk and increase the return rates from renewable energy investments (Farhad & Naoyuki, 2019).

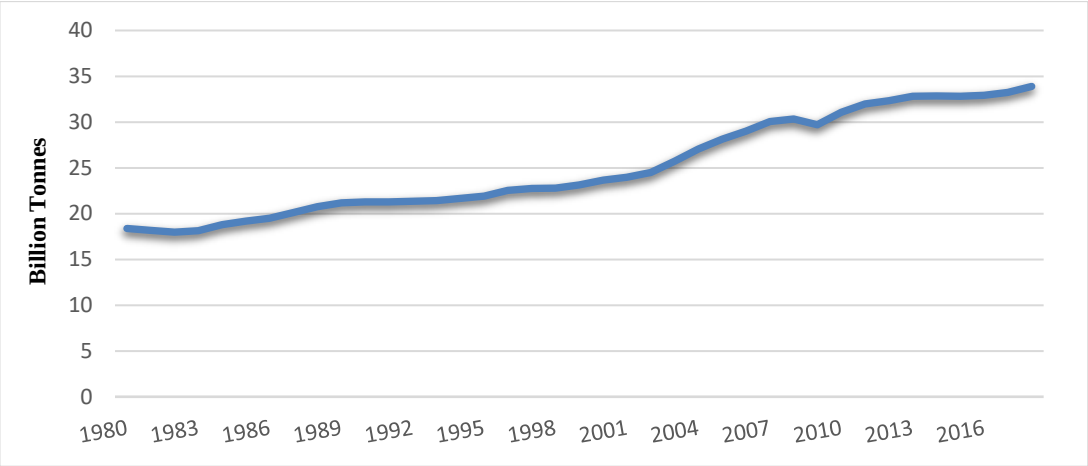
1.3 Energy and Environmental Issues

Recently, research produced by the World Economic Forum in 2019 has shown that global temperature has increased by an average of 1.5 percent annually. This has highlighted the concern on climate change, an issue that receives substantial attention from many countries in the world. It is expected that failing to confine the rapid growth of greenhouse gas emissions will cause global temperature to increase by 2.7 degrees Celsius by the year 2100 and 3.5 degrees Celsius after the year 2200 (WEO, 2015)[7]. There is thus an urgent need to address the problems caused by climate change. In extreme events, climate change may severely increase rainfall and wind events associated with tropical cyclones in some Asian countries. The consequences of intense rainfall also include floods and longer heat waves, while unstable weather also causes the deterioration of crop yield and food security. Apart from that, unusual climate undermines the ecosystem and creates new diseases which are harmful to human health[8]. The degradation of environmental quality associated with the negative externalities caused by pollutant emissions ultimately affect human health via health violations, subsequently causing reduction in labor productivity (Tiba et al., 2016).

Figure 1.12 presents the total CO2 emissions released globally. The evidence is alarming as the volume of CO2 emissions rose approximately 10 million tons in 12 years from 2001 to 2013, which is a fast pace compared to the increase of CO2 emissions over the 20 year period from 1986 to 2006 by 10 million tons as well. This graphical illustration implies that the acceleration in economic development and the significant population growth led to the upward consumption of traditional energy resources such as fossil fuels and coal, resulting in higher pollutant levels.

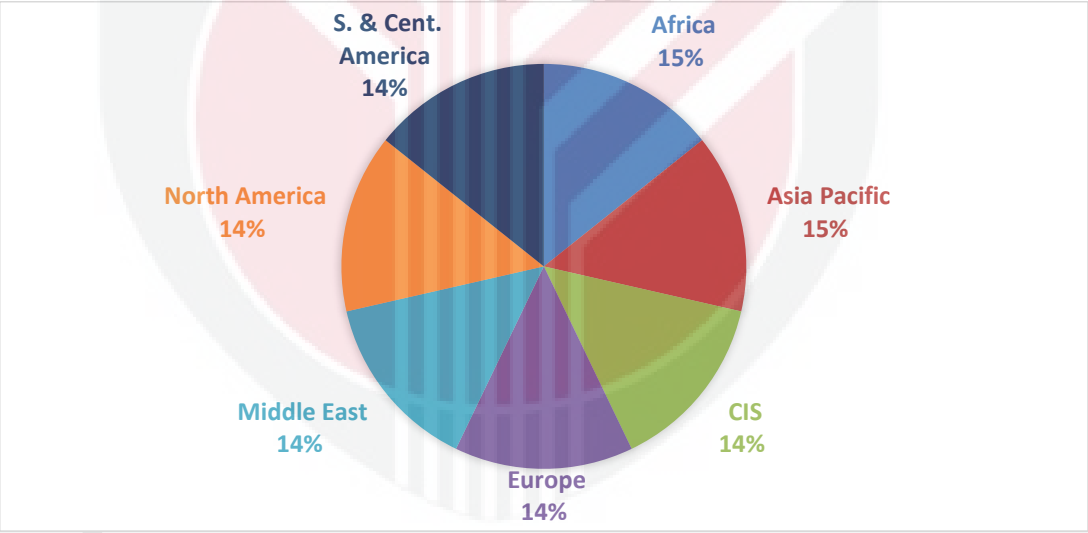
[7]The analysis from WEO further concludes that current actions taken are insufficient to ensure the world's two degrees Celsius temperature increase goal is achievable.

[8] Climate change: impacts, vulnerabilities and adaptation in developing countries: united nations framework convention on climate change



Figures 1.12: World Total Carbon Dioxide (CO2) Emissions, 1980 – 2018
(Source: BP Statistics of World Energy 2019)

According to Figure 1.13, annual statistical records indicate that Asia Pacific remains the top contributor of CO2 emission, recording 16,374 million tons in 2013, which is almost half of total global CO2 emission. Therefore, Asia Pacific must bear the key responsibility in tackling the issue of climate change.



Figures 1.13: World Carbon Dioxide Emissions, 2018
(Source: BP Statistics of World Energy 2019)

Several factors underscore a greater focus on renewable energy. First and foremost, due to the finite supply of conventional energy resources, a better substitute is needed to fulfil energy demands. Second, climate change's severe destructive impacts need to be addressed rapidly, as humankind would not be able prevent the consequences of massive changes in weather such as flood, drought, and the rise in sea level. Every nation has reached a consensus on the significance of renewable energy for various future prospects; hence, numerous efforts have to be made to facilitate the growth of

the renewable energy industry. For instance, minimizing restrictions on cross-border trading, removing barriers to technology transfer, providing incentives or subsidies to renewable energy investors, and reducing tax rates are some measures that can be considered. Most importantly, such efforts require the collaboration of every member in the United Nations.

1.4 The Impacts of Renewable Energy

Renewable energy is emerging not only as a solution to meet growing energy demand while reducing carbon emissions but also as a potential engine for economic growth and diversification. Renewable energy utilization has direct impacts on economic growth through investment channels. Sectors that would greatly benefit from renewable energy development are construction, manufacturing and engineering. These are the sectors that have close links with renewable energy projects and play major roles in providing the equipment, infrastructure and essential support to renewable energy usage. Global GDP is expected to grow by 1.1 percent or USD 1.3 trillion by 2030 if the share of renewable energy in global energy output is doubled. Figure 1.14 shows the projected GDP growth rate by 2030 for countries that have substantial investments in the renewable energy sector.

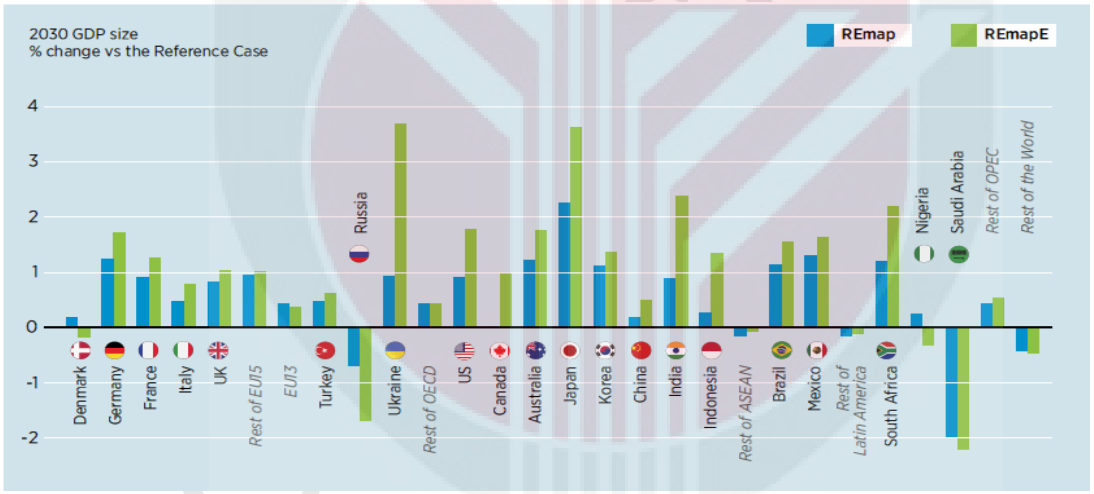


Figure 1.14: Renewable Energy Deployment[9] Impact on GDP
(Source: IRENA 2016)

As renewable energy deployment has slowly become the priority some nations, concerns about health and education are more prevalent. In fact, there is a close relationship between pollution and human well-being (Hunter, 2011; Mabahwi et al., 2014), since renewable energy investment reduces the reliance on non-renewable energy, which mitigates pollution and protects health. Consequently, welfare, as one of the intangible measures of human well-being, would be improved through the reduction of greenhouse gas emissions and the subsequent improvement in human

[9]Note: Remap refers to global share of renewable energy while REmapE refers to renewable energy with an emphasis on power generation usage.

wealth associated with education. Further to this discussion, natural disasters such as pestilence or earthquakes due to climate change have devastating impacts on human well-being. Society should therefore not treat undermine the negative externalities of climate change, which could be distressing CO2 emissions are neglected.

The creation of employment opportunities is instrumental in ensuring sustainable GDP growth and better welfare. If the renewable energy sector continues expand, millions of jobs would be created from renewable energy investment, specifically through the of launch of renewable energy power plants which require a large labor force. This not only generates more jobs but also discovers and trains potential talent to extract their contribution to renewable energy technology innovation. As a result of employment creation, workers gain the chance to acquire new skills while earning a stable income. Eventually, job security from the sector would be the catalyst to eradicate poverty and alleviate income inequality. The increase in the number of skilled laborers in this sector would improve productivity and cost efficiency, subsequently decreasing the cost of technology. As manufacturers compete to gain cost benefits, the geographical relocation of jobs in the renewable energy sector to Asian markets would occur (IRENA, 2016). Eventually, these changes contribute to the increase in income per capita of a country.

Despite renewable energy's significant positive impact to the economy, it is not without a trade-off. It is possible that renewable energy investments draw funds out of other economic sectors, giving way to the 'crowding out'[10] effect. Crowding out happens when projected returns from the renewable energy industry are lower than other industries despite full funding from bank loans. In other words, it means the former industry is less productive than the latter. Consequently, renewable energy may not bring positive impacts to GDP growth due to the existence of economic inefficiency.

Massive growth in renewable energy deployment provides additional opportunities for all economies to meet growing demands for associated goods and services, including energy equipment. It also presents challenges, particularly for economies heavily reliant on fossil fuel exports. Therefore, a transition towards a greater share of renewable energy in the global energy mix will bring about a shift in trade and energy linkages that carry global and national impacts. Additionally, renewable energy utilization could reduce imports, which is a significant economic benefit, specifically for countries with large trade balance deficits. On the contrary, diversifying energy-related investments in oil-exporting countries may affect their GDP negatively. If fossil fuels account for a significant portion of a country's exports, increased renewable energy and decreased fossil fuel trade would dampen the economy of these countries. The trade-off between renewable energy and conventional energy provides an insight into this trade pattern, whereby a country that relies heavily on fuel exports will undoubtedly benefit from renewable energy investment by reducing its trade deficit and improving its trade balance. On the other hand, a country that has

[10]"Crowding out" of capital refers to the possibility that the investments needed for increased renewable energy deployment compete with and displace investments elsewhere in the economy. This can have a negative effect on GDP. (IRENA, 2016)

substantial fossil fuel exports will encounter great barriers if the demand for renewable energy increases.

Promoting the deployment of renewable energy could have direct impacts on the environment as well. The reduction of pollutants from conventional energy use is a good example, whereby substituting these traditional resources with renewable energy decreases domestic fossil fuel consumption and eventually emission levels. With the improvement of renewable energy technologies, the world can expect to enjoy lower electricity costs compared to conventional energy, which may lead to the decline in electricity prices by 2030[11]. There are indeed pros and cons in evaluating renewable energy development[12]; however, the positive impacts of renewable energy are generally far greater than its negative impact. Some positive effects include job creation, mitigation of climate change and welfare improvement. To embrace the transformation of the energy system, a country needs to reinforce its regulatory framework so as to achieve embedded climate change milestones.

1.5 Non-Renewable and Renewable Energy

Energy transformation is the focus of many countries such as the United States, China, Germany, and Japan, as mitigating the consequences of climate change remains the core mission of these developed nations, primarily due to their commitment to United Nations Climate Change conferences. Many industries, particularly in power generation sectors, are still heavily dependent on traditional energy resources to generate electricity output. Hence, converting energy supply through renewable resources is certainly difficult to accomplish in a short period of time. One of the prominent factors is the lack of cost competitiveness. Non-renewable energy or conventional energy is well-established in terms of technologies and infrastructure, while renewable energy may not have such favorable support tools. As a result, the cost of electricity generation for the latter is relatively higher.

Downward pressure on oil prices has caused overall fossil fuel prices to decline sharply. Figure 1.15 depicts the relationship between oil price[13], fossil fuels and renewable energy consumption. It shows that renewable energy consumption has increased sharply between 2003 and 2015 while fossil fuel consumption slowed down during the same period. Historical data demonstrates that higher oil prices encourage the consumption of renewable energy sources. When oil price is hit by supply glut issues, the production of petroleum is discouraged as some producers may find it non-profitable to continue production. This creates the opportunity for renewable energy firms to strengthen their position in the energy market and indirectly paves the way for the development of renewable energy. When the price of crude oil moves closer to the cost of acquiring renewable resources, firms will have the option of choosing

[11] Lower electricity prices might slow down inflation, increase real incomes, stimulate household consumption, and boost economic activity in electricity-intensive sectors. (IRENA, 2016)

[12] When the policy decisions on renewable energy are influenced by corruption, the development of renewable energy resources may lead to more intense illegal activities, the consequences of which are termed 'renewable energy resource curse' (Gennaioli & Tavoni, 2016).

[13] Two common prices are widely used to represent the oil price in the economy: WTI and Brent.

renewable energy as an alternative or sticking to the consumption of traditional crude oil. Furthermore, if the price to be paid for these two different resources are almost the same regardless of other characteristics, such as productivity or efficiency, the energy industry may eventually opt for renewable energy as their preference.

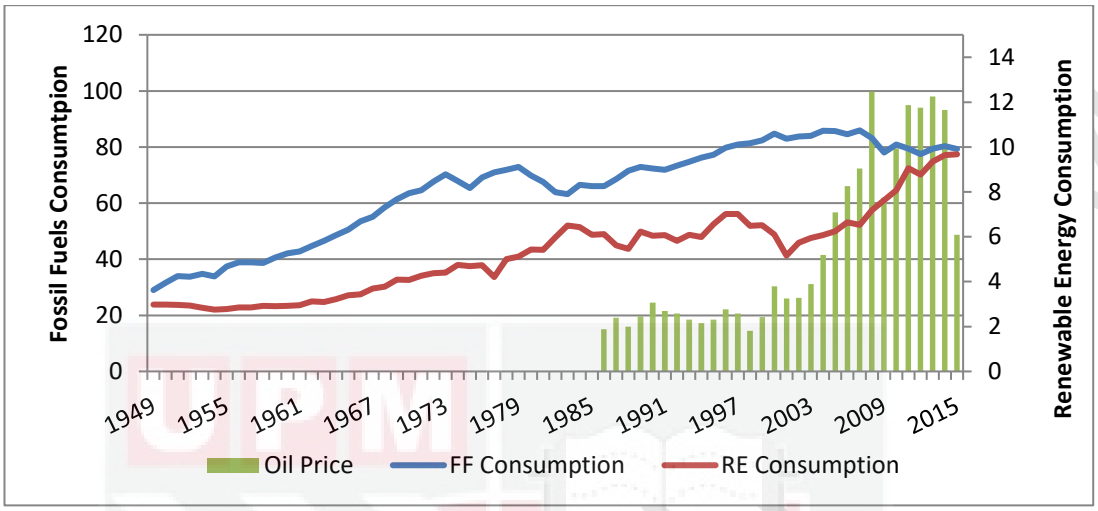


Figure 1.15: Oil Price, Fossil Fuel and Renewable Energy Consumption
(Source: U.S Energy Information Administration 2018)

From the producer perspective, the reduction in crude oil prices discourages the production of non-renewable energy due to concerns over profitability. This may not be the case from the consumer perspective given the impact of low crude oil prices. When crude oil prices hit ground level, it steers demand, particularly among manufacturers with high consumption levels. This is a direct benefit to them as the cost of production would decrease due to unforeseen circumstances.

A comparative analysis conducted by Marques et al. (2016) revealed that the substitution effect between renewable energy and non-renewable energy exists, albeit at a minuscule level. This is because the consumption of fossil fuel sources decreases when the production of renewable energy electricity rises. They further concluded that due to the intermittent characteristic of renewable energy, its development would be affected without the support of fossil fuels to meet unexpected demand. Knowledge stock plays an important role in spurring energy transition, such that employing renewable energy to achieve more output with fewer emissions could be realized provided that knowledge stock in the renewable energy sector increases with the decline in the non-renewable sector (Silva et al., 2013). Figure 1.16 depicts that the oil price showed an enormous surge after the Asian Financial Crisis in 1997. The upward trend in oil price caused the cost of fossil fuel consumption to rise drastically, but it plunged to its lowest point at $43.19 per barrel in 2017.

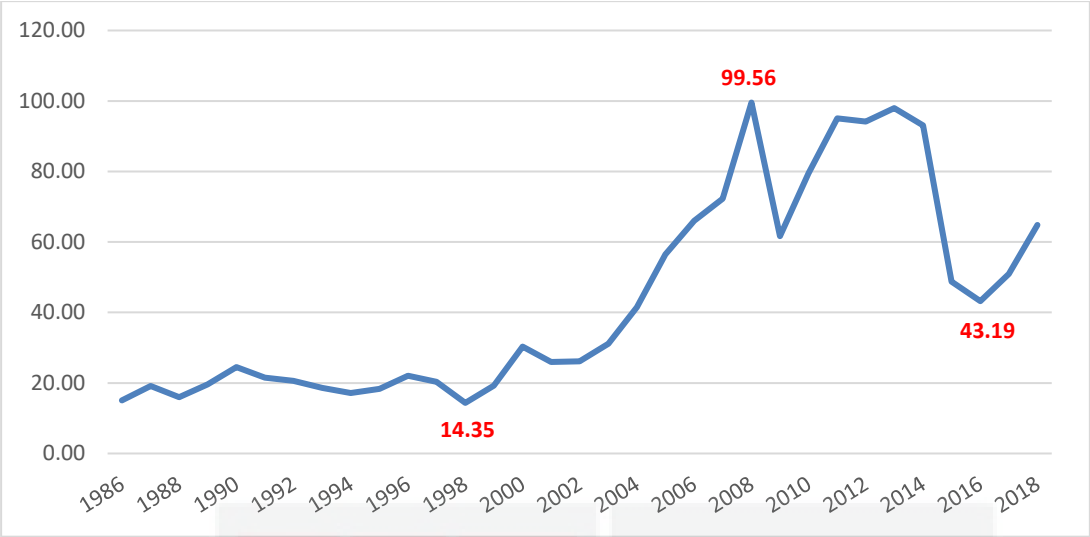


Figure 1.16: Time plots of WTI Crude Oil Price
(Sources: World Bank 2020)

1.6 Renewable Energy and Economic Growth

There is no consensus on whether renewable energy is a threat or benefit to economic growth. Moreover, as has been proven by conventional energy development, renewable energy will theoretically create employment opportunities, facilitate technological innovation, create additional energy access, and stimulate industry development (Mbarek et al., 2016). However, the wide propagation of renewable energy does not necessarily mean it is favorable to national development. Arguments may arise from the view of job security, economies of scale, and productivity. Promoting renewable energy may adversely affect labor market conditions via the substitution effect. Specifically, workers in the conventional energy sector may lose their jobs if there is an enforcement to employ renewable energy.

Figures 1.17 and 1.18 are scatter plots that depict the relationship between renewable energy and growth in financially developed and underdeveloped countries, respectively. The increase in the production of renewable energy promotes growth in financially developed nations. However, the inverse relationship exists in less financially developed countries, where the production of renewable energy lowers economic growth. These findings highlight the vital role of financial development, as a country with better financial accessibility appears to have greater investment in renewable energy production and therefore higher growth. This is in agreement with Gonenc and Yurukova (2014), who found that the growth of the renewable energy sector largely depends on private external financing. In financially underdeveloped countries, labor productivity in renewable energy is low due to financial difficulties. This hinders firms from offering training to their workers, thus decreasing their output. As such, in these countries, higher renewable energy investment may lower economic growth.

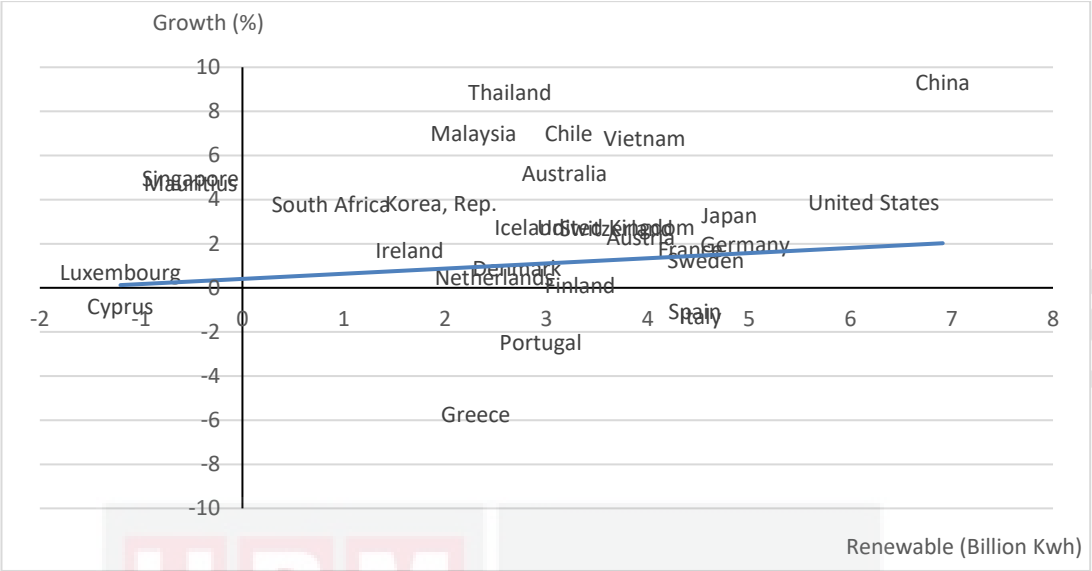


Figure 1.17: Relationship between Renewable Energy and Growth (Financially Developed Countries)[14]
(Data sources: EIA and World Bank 2018)

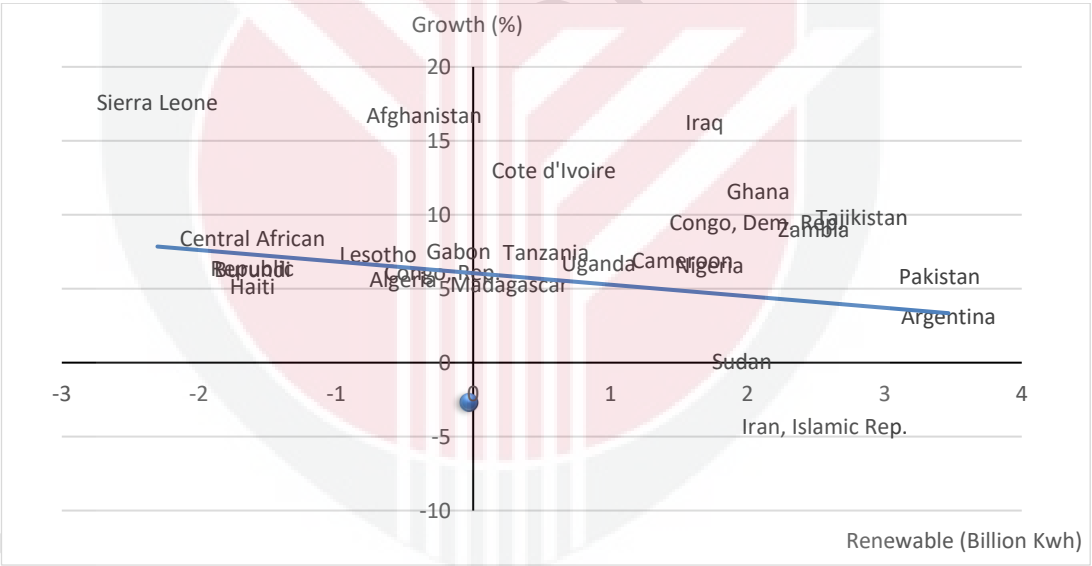


Figure 1.18: Relationships between Renewable Energy and Growth (Financially Underdeveloped Countries)
(Data sources: EIA and World Bank 2018)

Deployment of renewable energy positively effects growth by reducing the negative impacts of fossil fuels, particularly emissions. However, the comparative costs of sacrificing traditional resources for renewable energy sources must be noted (Awerbuch & Sauter, 2006). This corroborates the idea of Chien and Hu (2007), who

[14] The classification of high and low financial development countries is done based on the credit to private sector indicator.

believe that increasing the use of renewable energy improves the macroeconomic efficiency of economies through capital formation while simultaneously mitigating CO2 emissions. Tiba et al. (2016) further highlighted the importance of energy policies given the interdependence between renewable energy consumption and economic growth. Çoban and Topcu (2013) also pointed out that financial development facilitates accessibility to advanced technology. Similarly, Fangmin and Jun (2011) found that financial intermediation has a positive correlation with the total electricity output of renewable energy projects in a study based on 55 countries.

Renewable energy offers clean resources to the environment, which seems favorable for economic growth. However, it largely depends on how policy makers design energy policies to address the substitution effect and its consequences. Indeed, there are pros and cons in renewable energy development, the primary advantage being climate change mitigation and pollutant reduction. The biggest threat from renewable energy is the loss of employment for thousands of people if such change is implemented. Hence, a smooth transition would require cooperation between a country's central government and labor market authorities to assure job security for those involved.

1.7 Problem Statement

The sustainable growth in energy demand from developing and transitional economies reflects the increasing importance of energy supply (Brunnschweiler, 2009). Greater energy demand implies higher energy consumption in the world today, particularly the consumption of fossil fuels such as coal, oil, and natural gas. However, these energies will be depleted due to their finite supply and their CO2 emissions. Therefore, the intervention of renewable energy is imperative.

1.7.1 Intellectual Property Rights (IPR) and Renewable Energy

The establishment of a strong renewable energy sector in less developed countries can be accomplished by acquiring and adapting renewable energy technology from developed nations (Downey, 2012). Arguably, strong IPR protection encourages research and innovation, which then attracts private investment from fund holders. Conversely, weak IPR hinders private investment as developers would not be willing to share their knowledge. This implies that IPR is critical for the creation and innovation of new technologies.

There is uncertainty about whether the enforcement of IPR will prohibit or facilitate the development of renewable energy. The 'free rider' problem would worsen without policies to shelter IPR. On the other hand, strictly adhering to IPR protection for the sake of monetary benefits would limit the diffusion of renewable energy. Consequently, technology transfer may be delayed and slow down renewable energy technology. Complying with IPR should therefore not be for financial incentives, as technology sharing through knowledge transfer plays a crucial role in fostering economic growth.

Limited research exists with respect to IPR's effects on the development of renewable energy. In developing countries, IPR may prevent access to critical technologies. However, one empirical work by Downey (2012) argued that IPR is not a significant barrier to the transfer of renewable energy technology in the case of China. As with any other technology industry, clean energy technologies are subject to a variety of IP protections. Without IP protections, innovation would be severely limited and new clean energy technologies would not be developed. Although there have been attempts to study the issue, there is no conclusive evidence that IPRs present or do not present a barrier to renewable energy development.

1.7.2 Oil Price and Renewable Energy

Recent declines in the prices of various conventional energies such as coal, petroleum and natural gas, along with climate change campaigns, have gradually stimulated renewable energy consumption. As the renewable energy sector can potentially achieve sustainable energy development for the future, many countries have begun to leverage renewable energy resources to demonstrate their commitment to the United Nations (UN) Climate Change conferences. However, two conflicting issues emerge with high oil prices. Typically, a high oil price offers crude oil producers the chance to boost their production. On the other hand, a high oil price could promote renewable energy consumption due to the cost of traditional energy being relatively more expensive.

A weak oil price is likely to slow or reverse the growth of renewable energy in favor of conventional energy. Thus, the question remains whether and how high oil prices drive growth in renewable energy. Though the prices of conventional energy have been declining in recent years, it might not favor renewable energy if the cost of renewable energy remains uncompetitive. Decreases in oil prices exact pressure on the non-renewable energy sector, severely impacting its profitability and in extreme cases, forcing operators to shut down production. Such a situation renders support to the renewable energy sector to allow it to compete with well-established energy firms. Hence, can be rationalized that cheap oil prices support the energy transformation plan, especially when oil prices are cheap enough, by altering the energy consumption pattern and rejuvenating the affected oil and gas sector.

Nevertheless, whether higher or lower oil prices favor the renewable energy industry remains ambiguous in the literature. Plausibly, a sustained increase in oil prices has a good outcome for the renewable energy industry, as the cost of consuming conventional energy is becoming more expensive. However, lower oil prices can also threaten[15] the renewable energy industry. If oil prices and renewable energy are complementary, then a lower oil price will benefit the renewable energy sector due to the reduced cost of acquiring renewable energy. Conversely, if crude oil prices are low enough to crowd out renewable energy consumption, then low oil prices would be

[15]If the issue of low oil prices persists in the long term, it may impede the growth of the renewable energy sector because of the competitive force from fossil fuel energy (Khan et al., 2017).

classified as a threat rather than an opportunity to the renewable energy industry. Therefore, when the cost of acquiring renewable energy is far higher than fossil fuels, cost-considerate firms will switch to fossil fuels.

1.7.3 Renewable Energy and Growth

Investment in renewable energy projects require huge capital and incur higher costs than expected returns, as funds might need to be allocated to R&D. Moreover, the absence of well-developed financial intermediaries and consequent financing difficulties is another obstacle in the realization of renewable energy projects in developing nations. For instance, firms involved in the renewable energy sector might experience limited access to financing because the sector needs to compete against well-established traditional resources with relatively lower up-front costs and shorter lead times.

It is difficult to neglect the issue of market perfection, as limited information in the renewable energy market creates concerns among lenders about projects' lack of credibility. As such, the possibility of renewable energy users receiving financial support becomes lower. With respect to such barriers arising from asymmetric information, there is a need for a credible and reliable support system with sound designated financial sector policies to ensure the stable performance of the renewable energy sector. Most energy developers require high up-front costs when acquiring competitive renewable technologies and face higher cost of production. Hence, funding agents are hesitant to finance this high-risk low-return sector. Apart from that, high capital costs associated with long return time frames (compared to conventional energy options with lower capital costs and quick returns) engender further difficulties for renewable energy investors. When the rate of acquiring financial assistance is unprecedentedly high, particularly in financially underdeveloped nations, rational investors will give up the idea of investing in renewable energy.

Renewable energy's promotion of growth highly depends on the level of financial development of a country, whereby greater financial development encourages renewable energy consumption and subsequently fosters growth. If financial institutions do not place confidence in the renewable energy sector, countries with less established financial systems are far more affected. Investors in these countries are eager for financial support from institutions, without which renewable energy would fail to constitute a strong framework that addresses climate change and promotes economic growth.

1.8 Objectives of the Study

Empirical findings generally conclude that the role of renewable energy is critical in fostering a nation's growth. Hence, this study attempted to examine the relationships between financial development, renewable energy, and growth. The study further expanded the area of focus to the determinants of renewable energy production, i.e. IPR. The study also aimed to reveal the relationship between renewable and non-renewable energy, which has been a prominent issue in recent years. The specific objectives of this study were:

1. To investigate the effect of Intellectual Property Rights (IPR) on renewable energy production
2. To examine the impact of effective oil price levels on renewable energy consumption
3. To identify whether financial development plays an important role in moderating the impact of renewable energy consumption on growth

1.9 Significance of the Study

Though extensive research has been conducted to reveal the potential factors that determine renewable energy growth, there has been limited literature on the role of institutions in renewable energy development. In particular, scarce empirical work exists on the influence of IPR on the development of renewable energy. Generally, this area has received less attention as countries lack ready theoretical frameworks and consistent measurements of intellectual property. To the author's knowledge, only one study in China examined the impact of IPR on renewable energy industry, finding that IPR was not significant in facilitating renewable energy technology transfer (Downey, 2012).To evaluate whether IPR is a driving force of renewable energy development, this study explored the relationship between various IPR measures and renewable energy development. By doing so, it acts as a benchmark for energy policy makers in identifying the core elements for renewable energy development.

The second objective of this study contributes to the existing non-renewable and renewable energy literature via the threshold analysis of the relationship between oil price and renewable energy consumption. Due to limited conventional energy sources, policy makers have started to focus on renewable energy development. The concern over the depletion of traditional energy resources implies the importance of sustainable energy development and indicates that energy security could be a major promoter of renewable energy development (Chien & Hu, 2008; Gan, Eskeland, & Kolshus, 2007). One study demonstrated that the plunge in oil prices in 2014 did not produce a major impact on the renewable energy sector (Khan et al., 2017). Hence, this study contributes by focusing on how to address the potential issues arising from the fluctuation of crude oil prices.

The inclusion of finance as an interaction term in the study of renewable energy and growth is a novel contribution to extant research. It adds value by combining the impact of both variables on economic growth, which is unprecedented in existing

works. Considering the depletion of conventional energy as well as growing energy demand, renewable energy is important, especially as an alternative to traditional energy supplies. The ultimate objective of these energy efforts is to ensure sustainable economic growth. Hence, climate change mitigation plans associated with economic growth will not be accomplished if renewable energy remains weak in its competitiveness.

1.10 Organization of the Study

The remainder of the study is organized as follows. Chapter Two reviews the existing theoretical and empirical works. Chapter Three focuses on the methodology and empirical model. Chapter Four covers the discussion of results obtained from the analysis. Chapter Five consists of the conclusion and policy recommendations.

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