IMPACT OF RENEWABLE ENERGY ON ECONOMIC GROWTH

Lappeenranta–Lahti University of Technology LUT
Bachelor’s Programme in Energy Technology
2024
Author: Jiankun Su
Examiner(s): Clara Mendoza Martinez, D.Sc. (Tech.)
Jin Wang, D.Sc. (Tech.)
ABSTRACT

Lappeenranta–Lahti University of Technology LUT
LUT School of Energy Systems
Energy Technology

Jiankun Su

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Bachelor’s thesis

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45 pages, 26 figures, 1 table.
Examiner(s): Clara Mendoza Martinez, D.Sc. (Tech)
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Keywords: Renewable Energy, Economic Growth, Energy Consumption, Carbon Dioxide Emissions, Population Growth and Urbanisation.

Renewable energy as a new trend for energy consumption now has been more and more important, not only for the low carbon emissions but also the economic growth. From the preliminary investigation of contribution to the EU budget, geographical location factor, technology level factor and also, based on the resource information, this case study shows a clear overview of different renewable development situation on the basis of the selected European countries including the UK, Germany, France Italy and Spain. Analysis includes current situation, application of renewable energy and also, the discussion of which renewable energy is the most suitable for the development in the future. Based on the research found, the implications as well as suggestions are also included in the case study report.
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1 Introduction

1.1 Economic Growth

The meaning of economic growth is the increase of economic goods production and services during a specific timeframe when compared to a preceding period [1]. This is an important factor, which is utilized to test whether the country proceeds in a relatively steady process. For the Effective States and Inclusive Development (ESID) Research Centre, economic is an important factor which can promote progress in social terms, such as increasing the citizens’ well-being and equality [2]. When economies grow, the state capacity of state as well as the supply of public goods can develop significantly. Besides that, it can influence the decrease of the poverty and contribute the social equality and justice. Although, economic growth is a curial factor for the development of country, it should proceed with the assistance of the politic regulations, which is an important driver for economic growth reflected in both the initiation and sustained maintenance of the growth process.

The most common measurement method used worldwide is the real gross domestic product, which includes all the costs consumed by consumers, businesses, and government in a specific period. The formula is shown below [3]:

\[
GDP = Consumption + Investment + Government Spending + Net Exports
\]

Or more currently as:

\[
GDP = C + I + G + NX
\]

Figure 1 shown a basic overview of GDP trend for different regions: World, European Union, United Kingdom, Germany, France, Italy and Spain [4]. The trend is similar for the different regions. From 1980 to 2023, the GDP development is fluctuated with two severe decreases, which are in 2008 and 2019. This, represent the Global Financial Crisis and COVID-19. The Global Financial Crisis (2007-2008) impact was mainly due to financial market turmoil and recession and then lead the decline in economic activity. As for COVID-19, global disruptions, market volatility and losses on employment and income were some of the factors that affect heavily the world economic growth.
1.2 Energy Consumption

1.2.1 Overview of energy consumption.

Energy consumption is the whole amount of the energy that is required to fulfil the needs of the population, it is made by the certain processes and measured in the unit of kilowatt hours (kWh). Energy consumption includes the use of electricity, gas, diesel, oil, and biomass. As for the distinction of different types of energy, it will be discussed in this thesis is the renewable energy as well as the non-renewable energy. Renewable energy is the energy that is derived from sources which can be regenerated in a short period of time [5], such as wind, sunlight, hydrogen, tidal energy and nuclear energy. so on. Non-renewable energy refers to the energy sources that can’t be replaced once they have been utilized. There are four major types of non-renewable energy resources: oil, natural gas, coal and nuclear energy.

From the figure 2, it can be concluded that until 2022, the main energy consumption by sources is still oil and coal, which are non-renewable energy [6]. But the trend that the percentages of renewable energy consumption is growing over time. This is positive feedback that can be found from the figure, which means that there is ongoing trend of the development of the share of renewable energy, which can assist the less usage of non-renewable energy.
1.2.2 Renewable and non-renewable energy consumption and comparation to selected regions.

A basic overview of the renewable energy consumption for different countries from 1980 to 2022 is shown in figure 3 [6]. The figure revealed the combination of different sources, which includes hydropower, solar, wind, geothermal, wave, tidal, and modern biofuels. One can infer that the shares of renewable energy of Germany, Spain and United Kingdom are above the European Union. Among them, Germany indicates the highest percentages of primary energy derived from renewable sources by 2022. Besides that, Italy and France renewable energy consumption share is below the overall European Union consumption. As for the growth, it can be found that although France and Italy are below the overall level, the speed of growth is faster compared to other countries. There are different kinds of fluctuates for the United Kingdom, Germany and Spain, within the trend of increasing.
For non-renewable energy sources, previously mentioned and considering that they cannot be replaced when they are used, which is a major problem for humanity. The main solution for decreasing the utilization of the non-renewable energy is to develop new types of technologies which depends mainly on renewable energy. In the next section, the non-renewable energy consumption will be introduced, using fossil fuel as its representative, for an in-depth analysis in the introduction.

It can be observed from the figure 4 shown below is that the main trend of fossil fuel for the European Union is increasing firstly and then decreasing with fluctuations, which shows that with the development of renewable energy, there is positive feedback of the utilization of fossil fuel [7]. For each country analysed, Germany is the country which consumes most fossil fuel among these countries and Spain consumes least. Besides that, the decreasing trend for each country is compiled with the whole trend of the European Union, which shows the positive feedback.

Figure 4: Fossil fuel consumption for European Union and each country [7].

1.2.3 Alternatives of renewable energy in different selected regions.

With the development of renewable energy, there are different kinds of the detailed energy sources, such as: solar, wind, hydropower and biofuels. All these energy sources are the essential part of renewable energy and will have an influence on the growth of economy. To have a better understanding of these energy sources, a detailed development trace figures of renewable energy alternatives in different regions, was discussed. Below it’s the figure which shows the development trend for different sources of renewable energy.
From figure 5 it can be concluded that, all the different renewable energy sources have different levels of enhance [8]. From the view of European Union, a great enhance of renewable energy in the development of solar and biofuel can be observed, although the development of hydropower and wind is not as outstanding as solar and biofuel energy sources. Wind power generation is the most significant renewable energy source with the highest speed of increase. For each country, there is no significant increase in the sources which includes hydropower and biofuel in United Kingdom; Germany has the most significant of the development of renewable energy, which includes solar, wind and biofuel; France has the best enhance in hydropower and good development in biofuel, although not outstanding at solar and wind; for Italy and Spain, the development is located in the middle level.

![Figure 5: Alternatives of renewable energy in different selected regions, including solar, wind, hydropower and biofuel. [8.]](image)

1.3 Greenhouse gases and CO2 emissions

1.3.1 Emissions of Greenhouse Gases and CO2 Affective Factors.

Emissions of Greenhouse Gas and CO2 is related to economic growth and energy consumption, which have a great impact to the global development as well as the protection of the environment. Global data related to the emissions of greenhouse gas
emissions in 2015 finds that there are three main factors which are needed to consider: electricity generation (29%), transportation (27%) and production (21%) [9]. Among these factors, transportation sector stands out, as is the second-largest source of greenhouse emissions in European Union. With the research conducted, was possible to find that the road transportation is the biggest contribution of the greenhouse gas emissions, which is more than 72%, followed by air, marine, rail, which are separately 13.3%, 12.8%, 0.5% share in emissions, respectively [9]. With the trend that can be more energy transported in the following years. Thus, suitable method to reduce the percentages of transportation energy in the whole energy sectors is to utilize more renewable energy instead of non-renewable energy and advanced technology need to be explored.

1.3.2 Economic Transition that Affects Emissions and economic growth.

Some kinds of economic transition can be utilized to reduce the emissions that population wish to avoid. Transition should include all the processes of the lifespan of the energy, such as production, transportation and generation. Two kinds of transition will be introduced in this section of the thesis for analysis: Clean Energy Transition and Transportation in Transition. Both kinds of transition have their own benefits as well as drawback on not only greenhouse emissions, but also economic growth. With the suitable utilization as well as arrangement, there will be a better control of the emissions with lower consumption of cost.

As for Clean Energy Transition, this means that there should be a shift from the original energy use like fossil fuels, coal and some other to renewable energy that product less greenhouse emissions. This kind of global transition was agreed in the Paris Agreement [10]. The agreement’s central aim is to limit the temperature increase around the world below 2 degrees to pre-industrial levels by encouraging low carbon emission energy sources. Besides that, the clean energy transition is also good for economic growth, it can be found from the figure 6 below.
Figure 6: Per capita GDP% difference in the accelerated transition scenario vs. the business-as-usual scenario each year. IN: India, SA: Saudi Arabia, US: United States of America, EU27: European Union countries, G7: Group of Seven, ID: Republic of Indonesia, JA: Japan, UK: United Kingdom [10].

From this figure it can be found that for the economies in the G7, the outcome shows that the overall GDP increase speed will be higher with the accelerated transition compared to the business-as-usual scenario. Set G7 as an example, where GDP will be 1.8%, 1.3% and 0.8% higher in 2025, 2030 and 2035 respectively [10]. This shows the positive trend and the suitable transition that can be utilized.

For transportation in transition, the main method that is utilized recently is to achieve decarbonization, which is essential. The detailed method that is selected is building electric vehicle (EV) infrastructure, supporting to utilize alternative fuels such as hydrogen and biofuels [11]. Although there are several ways that can be utilized also, the investment behind these processes is hard to overlook. There will be more problems concerned inside when considering the situation that the transition of transport will have an influence on the labour markets, business productivity and competitiveness [12]. Accordingly, from that, there will also be potential obstacles for environment, quality of life and overall attractiveness of towns and cities. The suitable solution for this situation is to evaluate the investment of them and then find the most suitable way to undertake the transition, so that the cost of unnecessary processes can be avoided.
1.4 Statement of national choice

There are some factors for the reason why the research contribution mainly involves these countries, including contribution to the EU budget, geographical location factor, technology level factor and so on.

1.4.1 Contribution to the EU budget

From the research of share of member states in EU GDP, it is shown that in 2016, as an example before the left of the UK, the gross domestic product of the EU amounted to 14800 billion euros. Germany, the UK and France take over a half of the total gross domestic production [13]. There is huge percentage of these countries in the leading of economic growth among the European countries. Compared to other European countries, from the aspect of economic growth, which is an essential factor for measurement index, these five countries have the most potential motivation for analysing the renewable energy.

![Figure 7: Share in EU GDP total, 2016](image)

Based on the recent data, in 2022, the EU is comprised of 27 member states with economies of varying sizes. It is shown that in 2022, Germany, France and Italy made up of over a half of the total European countries’ economy [14]. This shows that there is huge potential economic growth in the nearly future and also in the development of renewable energy. As for now, all of these countries are developing different kinds of renewable
energy which can promote green energy transition, which is beneficial to the global situation.

Figure 8: Percentage share of European Union GDP 2022, by member state [14].

1.4.2 Geographical location factor

For different countries, the geographical location situation is also different, accordingly, suitable renewable energy in those countries is also different. National choice is made by different geographical factors from different countries. For example, wind energy should fulfil the following requirements, such as, wind speeds and direction, elevation, terrain, humidity and air pressure [15]. With these requirements, the UK has the world’s largest offshore wind farms. As for solar energy, this should fulfil the requirements of solar irradiance, latitude, cloud cover, pollution and land quality. That is why Germany takes more attention on the development of solar energy. In this studying of case, it will analyse different situations based on different countries, which can show a diversified overview of renewable energy development.

1.4.3 Technology level factor

Similarly, for different countries, the development of different types of renewable energy is also different based on each country’s situation as well as the economic demand. It will be analysed later in the following parts of analysis.
1.5 Research questions.

From the information previously described. This thesis aims to overview the impact of renewable energy on economic growth and consequently develop an analysis on current situation. Five countries would be chosen as main scenarios: United Kingdom, Germany, France, Italy and Spain. Based on the database as well as information there will be suitable solution to these questions.

- What is the current situation for each country’s renewable energy development and how the renewable energy can contribute to the economic growth?
- What are the current applications for each country's renewable energy usage and are there possible ways for them to utilize for the better efficiency?
- What is the most suitable renewable energy for each country to enhance based on the different situations for each country?
2 Literature review

2.1 United Kingdom

2.1.1 Current situation

Nowadays, there are four main renewable energy sources utilized in the UK: wind, solar, hydroelectric and bioenergy [16]. 2020 is a significant year for the UK because at that year, electricity is mainly powered by renewable energy, which takes about 43% of energy consumption. In 2023, individual renewables contribution following: the percentage of wind power in the UK’s total electricity generation is 29.4%, and accordingly, for other renewable mix, biomass energy is 5%, solar power is 4.9% and hydropower is 1.8% [16]. This chart below shows renewables’ share of electricity generation for 2022 as well as 2023:

![Figure 9: renewables’ share of electricity generation][17]

As for the change in renewable generation and capacity, there are different trends for different types of sources. Here is the chart for the change during the period of Q3 2022 to Q3 2023.
From the chart it is shown that generation growth in onshore and offshore wind increases compared to last year, which is derived from higher speed of the wind. As for solar PV, although there is higher capacity compared to last year, lower sun hours affect the generation and finally resulting in a small decrease. Bioenergy capacity isn’t changed so much, and generation is decreased due to continuing outages at one major plant and a new outage at another, which is about 39%.

The UK has made some kinds of targets in transition to renewable energy, for example, reaching net zero emissions by 2050, which includes transitioning to clean power, reducing on imported fossil fuels and leveraging up to 90 billion pounds of private investment by 2030 [18].

### 2.1.2 Applications

- **Wind energy:**

  The main utilization location of wind energy is on land and at sea [19]. In 2020, the electricity that made from offshore as well as onshore wind in the UK is 75610 GWh [20], the percentage of wind energy in total electricity is about 24%, within in wind energy, percentage of offshore wind is 13% and onshore wind is 11%. Geographic advantages as well as advanced technology of wind turbine are the main reason for it, also commitment of government for carbon emissions reduction and sustainable transition included [21]. From 2018 to 2022, based on Statista and IEA, the total installed capacity, onshore wind power, offshore wind power capacity and wind power generation all have enhanced.
Besides that, employment in the wind industry is also increasing with time goes by, which shows positive trend not only in energy needs, but also economic benefits in the UK.

The UK already has a lot of well-installed projects of wind energy, for example, in the coast of Yorkshire, there is the world’s largest offshore wind farm located in [21]. By 2023, the UK already has general installed capacity of 30 GW representing in over 11 thousand wind turbines, which includes 15 GW for onshore wind farm and 15 GW for offshore. It shows that there is positive future for the development of wind energy in the UK. There is already a commitment depending on the advanced development of technologies and good geological location, which is part of the UK’s broader strategy to achieve net-zero emission by 2050. The wind energy market is predicted to register a Compound Annual Growth Rate of more than 6% during the period of 2022-2027 [21].

- **Solar energy:**

  Till 2023, solar capacity of the UK has reached 15 GW. Besides that, between 2022 to 2023, sun’s influence on energy landscape continues to grow, with 0.952 GW of solar PV capacity [22]. Recently, solar power’s share in the UK’s total energy generation remains relatively modest, in 2023, solar power contributes about 2.3% of the total energy production. Across the whole UK, there are about 1.3 million solar panel installations already, these are distributed into not only for domestic places, but also for commercial places as well as farms, which can prove that solar energy system in the UK is decentralized.

  Besides the energy perspective, there are also job creation and investment opportunities from solar energy. The UK solar industry has employed more than 6500 people, this can be increased to more than 42000 people if the UK set 40 GW of solar power by 2030 [23]. Solar energy UK calls on the government to increase the capacity of solar energy in the UK, to the targets which is 40 GW as mentioned before and accordingly, 54 GW by 2035 and 100 GW in 2050. If these targets can be achieved, this can assist to decarbonize the UK’s power needs.

- **Hydropower:**

  Hydropower, as a renewable energy resource, helps to decarbonize the country’s power system. This has saved about 300 TWh energy for electricity generation from other sources,
equally 160 million tons of carbon dioxide emissions over that period [24]. However, although land in west and north of the UK is kind of high and there is plenty of rain, the low lying and less rainfall result in the situation that, main hydropower is generated in the north of Scotland. Even in that kind of places, average elevation is still low and the potential for economic growth is small, compared to Norway and Switzerland, which are 95% and 56% [25]. But the UK could also have advance in tidal and wave energy resources if it can overcome different aspects of challenges, such as: technology, economy and environmental.

In the future, for the target of net-zero of the UK, there is a report produced by The Energy Informatics Group said that there will be estimation of 217.5 MW of hydropower could be built by 2030 under the suitable environment of policy and even 1 GW of additional capacity that would generate about 1.5% of the net-zero demand by 2050 [24].

- **Bioenergy:**

As for now, bioenergy is the second largest source of renewable energy in the UK, which generates 12.9% of the total UK supply in 2021 [26]. With the development of biomass, demand for it is expected to rise in the UK to supply BECCS, transport fuels and chemicals and so on. Source that utilized recently is forest residues, but perennial energy crops have also been identified as a future source of domestic biomass, which is because its good properties: fast-growing and energy dense. However, there are some kinds of different challenges also for biomass utilization expansion, such as social economic and technical and so on. This situation should be solved by the production of land-use policy to support schemes across multiple sectors to address.

As already mentioned, the UK has set target to achieve net zero GHG emissions by 2050, which gives insight for the bioenergy in short, medium and long-term views for transport, heat and electricity [27]. Carbon capture and storage plays an essential role for the UK carbon capture, usage and storage sector. At the aspect of economy, it includes electricity, biomethane and greening the gas grid, heating, combined heat and power and transport. So that the appropriate approach to utilize well within the situation of decarbonization is needed.
2.2 Germany

2.2.1 Current situation

Renewable energy that is utilized in Germany is mainly based on wind and biomass, plus solar and hydro [28]. Germany renewables share was 46 percents in 2022. From the chart below, which shows renewables’ share in gross power consumption in Germany, it can be seen that overall trend of renewables’ share is increasing, although there is decrease in 2020. At the same time, recently, there are different trends, including overall electricity consumption decline and absolute renewables production enhance, which is about six percents increase [29]. The development of renewable energy is significant.

Based on data from the Centre for Solar Energy and Hydrogen Research Baden - Württemberg (ZSW) and utility association BDEW, peak share of utilization of renewable is mainly located in summer as well as winter [29]. In June, there is a significant data record for the contribution of solar energy in electricity generation, which is 9.8 TWh. Take whole year as example, there is 113.5 TWh from onshore wind energy for generating electricity [29]. It can be concluded that there is around 75 percents renewable electricity that is made by solar as well as wind energy, as for others including biomass, hydropower, and small share of geothermal plants.
As for targets, Germany has set to construct an electricity supply system based completely on renewable energies by 2050 is technically as well as ecologically feasible, and also, the switch to renewable energies increases energy security, economically beneficial renewable energy on electricity supply system and decisive political support [30]. Based on the targets, it is essential to define accordingly goals and then depending on goals, set up decisive actions and then tackle the upcoming challenges technological and societal adaptation.

2.2.2 Applications

- Solar energy

Solar energy stands out as one of the leading technologies. By the end of 2022, Germany has installed photovoltaic capacity of 67GW with an additional installed capacity of 7.5GW in the first half 2023 [31]. Growth of solar energy can be seen in many sectors, such as home solutions, plants on commercial real estate and larger ground mounted plants and so on.

As for 2021, employment number for solar energy industry is around 58500, based on the data by Germany’s Federal Environmental Agency [32]. The cost for solar PV has been decreasing in the recent years and what is significant is that according to Internation Energy Agency, electricity would be the cheapest product. It is shown that, cost for solar PV has fallen by 87 percent between 2013 to 2023, and accordingly for battery storage is
Besides that, falling panel prices are also a big driver in solar power expansion, which means there will be other factors, such as efficiency of production of solar energy, more flexibility for different utilization for different levels of person, sustainable awareness for the public and effort from researchers and companies.

- **Wind energy.**

As for wind energy in Germany, the installed generation capacity is 66.2GW at the end of 2022, including both onshore as well as offshore wind farms. Onshore wind farms have been slowing down because of planning restrictions, length of permitting procedures and other factors. However, the gas crisis in 2022, which caused problems of increased electricity prices and legislative changes aimed at expediting permitting procedures, assist development of onshore wind farms again [31]. In the first half of 2023, growth of wind energy is 1.5GW, with the total growth of 2.1GW in 2023.

![Figure 13: Development of Germany’s onshore wind power capacity [33].](image)

As for economic development, from positive view, in 2017, there is total installed capacity of 63.1 MW, which assists economic growth in 50.8 million euros and equally, reduction of 132770 tons of carbon dioxide emissions [34]. Turbine manufacturers and wind power project developers from Germany early on in their development started to operate in markets abroad. From the period from 2010 to 2018, there are around 60 percents revenue that was generated abord among total manufactures. But the service providers in project development, installation, maintenance depends mainly on domestic sales, because of that,
there is huge challenge for the manufactures due to market of the country is not positive and finally, production chains may be disrupted or even lost if the cost is too high to afford [35]. Besides that, small profit and stiff competition also make it harder for companies, representing in the competition with international companies. From data shown, only two German companies remained in top ten wind turbine producers. It can be seen that the finical benefit of wind energy is still challenging and hard to promote.

- **Biomass energy**

The share of biomass energy and hydro power is smaller compared to renewable energy mentioned before, which contribute less than 10% of the total installed capacity of renewable energy generation plants [31]. Biomass in solid, liquid and gaseous form is used for electricity and heat generation, biofuel production and also transport sector [36].

Based on the data, there is a huge economic benefit from renewable energy plants, which is 14.7 billion euros. Biomass energy, as an example, had contributed around 9.9 billion euros benefits, representing in different parts of utilization. Among the benefits, there was 4.5 billion derived from generation of electricity and 2.9 billion derived from generation of heat and 2.5 billion derived from biofuels. Besides that, CO2 saving from bioenergy is also significant, also take 2015 as an example, with the assistance of bioenergy, there is 61.3 million tons of CO2 emission avoided [37].

2.3 France

2.3.1 Current situation

In France, hydropower, wind and solar are the primary sources of renewable energy that are utilizing. According to the data from 2022, it is shown that there was over 65GW enhance of renewable energy capacity growth during the past years [38]. There is huge increase for wind and solar photovoltaic, representing in the generation of electricity from 14% in 2010 to 23.4% in 2020. [39]. Although there is increase in the development of renewable energy, according to targets that already made before, outcome is still not as wished as targets expected. In 2023, France passed the Renewable Energy Acceleration law to assist renewable energy growth, including measurement of the current situation,
plan for deeper development in the following years and detailed procedures for the construction of new renewable energy projects.

From the chart that is shown below, it can be shown that hydropower takes the most percentage of renewable power capacity in France this represents half of renewable electricity generation, following are wind power, solar and others.

![Figure 14: Installed renewable power capacity in France in 2022, by energy source [38].](image)

France has already made some framework for promoting renewable energy, for example, two successive five-year energy investment plans, target of it is to invest more in the clean energy transition [39]. Besides that, French government is currently reviewing scenarios made for 2050 decarbonisation and making detailed decision for long-term electricity mix beyond 2035. Besides that, France is the fourth Europe’s electric mobility market after Norway, Sweden, the Netherland and Germany.

2.3.2 Applications

- Hydropower

Hydropower is the primary source of renewable energy electricity in France and the second most significant electricity generation technology after nuclear [40]. According to the data that measured, in 2023, installed capacity of hydropower was 25.7GW, which fulfilled target that already made before. As predicted in scenarios, installed hydropower capacity is 26.5GW by 2030, 28.2GW by 2040 and 30.1GW by 2050.
Nowadays, hydropower accounts for 24% of total electricity generation, this is an opportunity to redistribute hydropower profits [41]. France’s hydropower infrastructure includes more than 2500 plants, among them Auvergne-Rhone-Alpes region is France’s leading producer of hydroelectricity [42]. Besides that, because of flexibility as well as responsiveness, hydropower can be utilized with other renewable sources, such as: solar and wind. In this situation, this can provide massive, efficient energy storage to provide more continuous energy than single one source. In France, there will be increase trend for the renewable energy market in the following years, the reasons for this situation including renewable technologies falling costs, demand for cleaner energy is increasing, policies and regulations made for the targets [43]. So that it can be seen that the whole trend for renewable energy is positive, and the role of hydropower will be still increasing in the future.

### Solar PV

For solar PV, according to data and statistical studies of the Ministry of Ecological Transition, installed photovoltaic capacity in France at the end of the third quarter of 2023 amounts to 18.26GW [40]. But it doesn’t fulfil the target that already made for between 2020 to 2023. And with this trend goes by, it cannot also fulfil the target that made for 2023 to 2028. It needs stronger acceleration to achieve the according goals. In the future, France has made targets for better utilization of solar energy, such as, capacity of 100GW by 2050, connecting an additional 740MW every quarter.
In France, solar energy provided nearly 5% of the electricity consumed in 2022, development of solar energy is one of the methods that assist to accelerate the energy transition and finally, achieve carbon neutrality by 2050 [44]. As for the material of solar energy, solar panel can work not only in ambient light situation, but also in grey situation. Besides that, 94% of a solar panel is recyclable. In France, an eco-contribution is paid for each purchase of panel. There is relative organization named SOREN, which is responsible for collecting as well as recycling the panels.

- Wind energy.

For wind energy, onshore in the first, in the third quarter of 2023, installed onshore wind power capacity was 21.86GW and growth of it is predicted to continue as a linear progression [40]. And also, onshore wind development in France has recently picked up speed and the according targets set for the coming years will be fulfilled as wished. However, for offshore wind power, in the end third quarter of 2023, the installed offshore wind power is 1.49GW, it can be shown that offshore wind power in France is still lagging badly behind in this area, even cannot fulfil the targets set in the PPE.
As for financial benefit, in 2023, onshore wind power production has amounted to about 24600MW, which represents almost 9 percent of national electrical consumption. What is remarkable is that, in December 2020, France had the fourth European wind farm, behind Germany, Spain and the United Kingdom. In the aspect of offshore wind power, which is under construction, it will have 80 wind turbines, providing equivalent of the annual electricity consumption of 700000 people.

2.4 Italy

2.4.1 Current situation

Main renewable energy sources that Italy have are hydropower, photovoltaics, wind power and biomass. In 2023, electricity generated from renewables fell from 35.3% to 30.6% and accounted for nearly 19% of total energy consumption. The detailed separate data compared to the same period between 2023 and 2022, 17.3 more hydropower was generated, 4.3% increase of photovoltaics and 2.6% decrease of wind power, stable for biomass as well as geothermal energy.
Under the National Recovery and Resilience Plan (NRRP), Italy allocated €59 billion to assist the “green revolution and ecological transition” in the period of 2021-2026 period. In this investment, there is €23.78 billion which is utilized into renewable energy, including hydrogen and sustainable mobility and networks. This construction can be completed by 2026 as planned. After completing project, the power as well as gas grids can be strengthened and there will be greener economy as predicted.

2.4.2 Applications

- Hydropower

According to Global Data, hydropower accounted for 19% of Italy’s total installed power generation capacity and 15% of total power generation in 2021 [47]. The total number of hydropower facilities in Italy at the end of 2018 was 4331 according to detailed reports. With expectation, installed capacity of hydropower is about to continue to increase from 2022 to 2035, at which point hydropower is expected to account for 12% of total installed generation capacity. With measurement, large hydropower capacity rose during the period of 2010 to 2021 at a CAGR of 0.47%. With expectation, the growth of it will be within the range of 0.13% during 2021-2035 [47].
Figure 19: Projections on net generation capacity of hydropower in Italy from 2015 to 2050 [45].

According to data presented in 2019, based on a variety of different studies, more than 15000 people in Italy are employed in green jobs which are directly connected to hydropower. It can be shown that potential financial benefits derived from hydropower is huge.

- Solar energy

The average power that made by solar energy is 20TWh recently. There is the greatest number of plants in the northern part of Italy and main per capita energy production is located in central as well as southern part of Italy [48]. In 2023, there is about 5.8GW increase for installed renewable capacity, which is 2.7GW higher than the figure for green activations shown in the previous year [49]. But compared to the target that already made for 2030, which is 9GW per year growth, it is still not enough. The share of share energy in total green energy production is 20% and as for the nation’s requirements of energy is around 8%. With the development of companies which operate within the chain of photovoltaic, there will be decline trend for the price of installation of solar photovoltaic systems. For Italy, it can be represented in price of different levels of PV systems, located in different part of society.
As for economic impact of Italy’s PV sector, there are several KPIs, such as primary market value, investments and value-added reveal that photovoltaics is a cornerstone of the Italian energy strategy. PV technology has great potential in terms of economic and environmental impact. Nevertheless, consumer behaviour is affected by external factors in energy source of the future and energy choice, besides that, there is an important factor that made by the governmental institutions representing the decision-making of the incentives and procedures which can promote the utilization of solar energy [49].

- Wind power:

The main location for wind power industries in Italy is in the southern part, which generates nearly one sixth of the total green energy of Italy. 20TWh of energy are produced each year. With expectation, this figure will be double by 2030 [50]. Based on Global Data, the percentage for wind power is about 10% of the total installed power generation and 7% in 2021 [51]. Onshore wind power capacity rose during the period of 2010 to 2021 at a CAGR of 6% and with expectation, from the period of 2021-2035, onshore wind power will grow at a CAGR of 6%.

Figure 20: Number of photovoltaic systems in Italy from 2010 to 2022 [49].
The future of wind power in Italy is set to develop along at least three courses of action. First is the installation of more new wind turbines of the country and in the coming years those regions could be able to contribute at least 2GW of installed capacity more; second one is about upgrading and modernizing existing plants; finally, construction of offshore wind power. With expectation, green jobs linked to wind power could cover over 67000 according to ANEV’s forecasts from the period of now till 2030.

2.5 Spain

2.5.1 Current situation

As for renewable energy sources in Spain, including bioenergy, wind, solar and hydro, account for 50.8% of the energy utilized in electricity generation in 2023 [53]. There is a speedy energy transition currently in Spain for fulfilling the demand of achieving 2050 climate neutrality [54], for example, Spanish government has planned that till 2026, there will be auctions of renewable energy with the amount at least 2.9GW and with more than 120GW renewable capacity.

Electricity generation is the main utilization for renewable energy in Spain, although the share utilized into heating and cooling sectors is small. As mentioned before, renewable
energy utilized into electricity generation is significant. The remarkable standpoint is that, in 2019, there is a new record for renewable energy representing that the installed capacity of renewable exceeds non-renewable energy for the first time.

The current Spain energy framework is based on the objectives that made for 2050 for national climate neutrality, the percentage of renewable energy in electricity mix is 100% and the share of renewable energy in total energy is about 97% [56]. Renewable energy is an opportunity for the country to not only for promoting the economic growth and by creating jobs through the modernization of industry, but also support vulnerable populations, improve energy security and then, support RD&D and innovation.

2.5.2 Applications

- Wind energy.

Spain is one of the leading wind energy markets worldwide. In 2022, it was the fifth largest wind energy capacity, after China, the United States, Germany and India [57]. There are about 1300 wind farms and more than 22000 wind turbines, which are mostly all onshore. Offshore wind farms are hard to construct due to challenges for bottom-fixed technology, however, the utilization of floating structures is a key for Spain to develop its offshore capacity.
As for the detailed targets for wind energy, it is set to reach 40.6GW of wind power capacity by 2025 and surpass 50GW by 2030, which means the capacity of wind energy will be double than current situation. As for offshore wind energy, Spanish government has approved an Offshore Wind Roadmap, which aims for one to three GW of offshore wind installed by 2030 [57].

Figure 23: Contribution of wind energy sector to GDP in Spain from 2016 to 2022 [58].

From the chart, contribution of wind energy sector to GDP in Spain from 2016 to 2022, it can be shown that the trend of contribution is continuously increasing, although there is short drawback in 2020 due to COVID-19. The future of wind energy in Spain is positive.

- Solar energy

As one of the first countries to promote large-scale solar photovoltaics and the leader in production of concentrated solar power [59], in 2022, Spain’s solar power energy sector achieved a significant milestone, with the annual installation of around 8.4GW in capacity, including both ground-mounted systems as well as self-consumed units [60]. The contribution of photovoltaic energy to the energy mix has been a substantial increase. In 2023, there is increase for photovoltaic energy to the energy mix, which is 10.6%, reaching 38.3%, it is a significant increase from 27.7% in the same period of 2022. From national level, the share of PV within Spain’s energy mix also enhanced from 10.1% in 2022 to 14.6% in 2023 [60].
As for financial benefit derived from solar energy, from 2009 to 2019, the price of electricity from solar generation declined by 89%. The sharp fall in the cost of solar generation, meaning this is the cheapest electricity as for now, derived from a virtuous cycle [61]. Utility scale solar PV dominated the installed capacity in 2018 accounting for 75% of the total in Spain although some sources would not define smaller sized as utilization scale. The government projects an increase in solar PV capacity by approximately 30GW, rising from 9GW in 2020 to 21.7GW by 2025 or even 39.2GW by 2030 [59].

<table>
<thead>
<tr>
<th>Installed PV capacity in Spain by class size in 2017</th>
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<tbody>
<tr>
<td>&lt;10 kW</td>
</tr>
<tr>
<td>10-100 kW</td>
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<tr>
<td>100-500 kW</td>
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<tr>
<td>&gt;500 kW</td>
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</table>
Hydropower

According to Global Data, hydropower accounted for 17% of total installed power generation capacity and also, 11% of total power generation in 2021. With expectation, installed capacity will increase during period of 2022 to 2035 [62].

There are already more than 120 hydroelectric plants in operation and almost 10826 of installed capacity. The benefit of clean and renewable hydroelectric energy will fulfill the demand of 7.6 million homes in the country [63]. Hydropower is a key role in Spain’s energy transition to a more sustainable and resilient system, with this assistance, the dependence on fossil fuels and accordingly, greenhouse gas emissions will reduce also. To this is added the energy storage capacity thanks to pumped hydro plants, making it high-impact technology.
3 Discussions and implications

- Analysis for most suitable renewable energy sources for national choice and implications.

Base on the research that found from the resources that found before, the discussion as well as implication is shown as below, including the most suitable renewable energy sources that can be utilize for each country and what challenges and solutions can be in process. Detailed discussion is shown below:

- **United Kingdom**

  From the database as well as the information that searched from resources, wind energy is the most suitable energy source for developing in the UK. Compared to other sources, wind energy has more advantages, including the existing huge proportion of share in electricity generation, well geographical positions for wind energy generating, potential employment foe economy growth and a variety of successful energy projects. All of these factors contribute to the promotion of wind energy development. For the implication of promotion of wind energy, more installed capacity can be constructed to fulfil the economic growth of the UK and in this situation, wind energy can also assist the development of other sources of renewable energy as an example.

- **Germany**

  Solar energy has great potential benefits for developing based on the research so that in Germany, it could be the most suitable alternative of renewable energy for developing. The reasons are not only because the technology of solar energy in Germany is advanced, but also the convenience derived from instructions of solar energy, it can be utilized for home, plants on commercial estate as well as larger ground mounted plants. The employment of solar energy in Germany is also an essential factor for why it is important. Besides that, great productivity, sustainability and flexibility are also important factors which contribute it to the most suitable renewable energy for Germany.

- **France**
From the research based on the resources, hydropower is the most suitable renewable energy for developing in France. There are several explanations for the reasons, such as: huge installed capacity which well fulfilled the targets that made before, modified scenarios which based on the according situations, great share of total electricity generation, a variety of energy plants and advanced policies as well as regulations. Besides that, the role of hydropower will be increasing also in the future. For the implication of promotion of hydropower, there should be more installed capacity be constructed and more specific policies as well as regulations should be published by the government.

- **Italy**

Hydropower should be the most suitable renewable energy source for developing in the recent as well as the following years. This is not only because the history of hydropower has been proceeding since late 1800s, which shows a long period of time, but also, portions of it is also a main factor of it. Besides that, physical features of Italy and existing large hydropower plants are also essential for developing. But the main challenge of hydropower in Italy is that hydropower plants should be in upgrade, which limit efficiency of hydropower production and if this challenge can be solved, amount of energy generated each year will increase nearly 10% in the future.

- **Spain**

Wind energy is already one of the leading energy markets around the world, which shows its significance for Spain. It is derived from its huge amount of wind farms as well as advanced wind turbines which are located onshore. The contribution of wind energy to economy growth is also an essential factor for Spain representing in Spain is the third biggest exporter of wind turbine blades [61]. But accordingly, the challenges as well as implications for better development also cannot be ignored, such as, recyclability of the materials, highly defined and precise manufacturing processes and also, potential damage of the environment animals. All of these challenges should be overcome to have a further way for development of wind energy in Spain.

- **Population growth and urbanization**

Population growth and urbanisation have a huge impact on renewable energy. With the increase of population growth and urbanisation, energy consumption as well as greenhouse gas emissions increase accordingly. Rapid population growth has contributed degradation
of the environment and renewable energy sources. However, there is some positive effect derived from population growth, for example, economy. Population growth can promote the technological and management changes, which assist utilization and supply of sources more effectively [65]. Urbanisation would also have the impact of utilization of energy, representing in more energy requirement, which includes buildings, transportation systems and industries running [66]. However, there are also advantages for urbanisation, including that, electricity utilization for citizens is lower than person living in the suburbs and rural areas; urbanization promotes land use more efficiently compared to the other types of living conditions; public transportation instead of private transportation would also reduce the environmental effects, which contributes carbon neutral society [67].

Here are the figures about the recent population growth from 1903 to 2024 and share of the population living in urban areas from 1960 to 2023 of selected European countries. It can be seen that the whole trend for different selected countries is the same, which is increasing. At the same time, challenges as well as opportunities are compiled with it. There should be suitable actions to adopt population growth’s good aspects and avoid its shortcomings.

![Figure 26: Population growth in the UK, Germany, France, Italy and Spain from 1903 to 2024](image)

The modification of population growth as well as urbanisation requires government and civil society capacity, aligned incentives among different stakeholders and sufficient planning foresight and humility. There are already good development partners, like the World Bank and research organizations like Urban, which can assist for the solution of the current problems and then apply a framework for projecting growth and weighing options and inform data-driven planning [70].
4 Conclusion

The purpose of this Impact of Renewable Energy on Economic Growth is to answer the three following research questions: What is the current situation for each country’s renewable energy development, which gives examples as overview of the global economic growth, and how the renewable energy can contribute to the economic growth; what are the current applications for each country’s renewable energy usage and are there possible ways for them to utilize for the better efficiency; what is the most suitable renewable energy for each country to enhance based on the different situations for each country. The research provides a clear overview of the current development situation for the selected countries, including measurement data, affective factors for development and what kind of future is predicted based on the current situation of renewable energy in each country.

Based on the research, it is shown that for each country, based on the different situations, there is different kinds of renewable energy which is suggested to enhance to promote growth of economy for each country. And also, implication is included in the discussion part for each country, including what kind of challenges each country is facing and what kind of actions can be taken into utilization in the nearly future.

In the current global economy, renewable energy development is indeed to develop and enhance, not only for the economic growth, but also for sustainable global environment. Despite for some renewable energy cannot be promoted for the current in some countries, the findings of this case study remain valid as well as valuable, and also the discussion as well as implications remain as key factors and competitive. Future developments should take into account of the results of the research and based on the results, provide more suitable development policies as well as regulations to promote the renewable energy development in a long period of time.
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