



**Electrical energy analysis in nine countries of Europe, with focus on
wind power and other renewable energy sources**

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Abstract:

This thesis has been written for the Bachelor degree in Electrical Engineering held at Blekinge Tekniska Högskola Karlskrona, Sweden. The basis of this thesis is a statistical analysis of the electrical energy situation with emphasis on contribution of wind power and other renewable energy in electricity production in the European area and key countries.

The main parameters, which considered in this thesis are electricity production and consumption, installed capacity trends and also the operation of renewable sources, especially wind power in gross electricity generation. Meanwhile, the whole data and materials are based on real values and investigated from the latest publications of governments and energy agencies of European union and key countries.

The target of European renewable energy is that the member countries must achieve at least 20 percent of final energy consumption from renewable energy by 2020. Germany, United Kingdom, Spain and France and Portugal are members of the highest consumers of electricity in the Europe and still the main source of electrical production in these countries are fossil fuels, the main challenge is that they should start to shutting down the traditional power plant and improve the infrastructure for installing the renewable electrical capacity instead.

According to the statistics, many of the European countries such as United Kingdom, Germany, Spain, Denmark and Sweden have started up to use the renewable energy to produce the electrical energy, but their governments have special keen eye for investment in the wind energy sector. Wind power grew sharply during the past decades in Europe and becoming vital every coming day in comparison to other renewable energy, since the low cost of electricity can be granted through a small investment and relies on the wind blowing compared to the conventional electricity generation sources. The diagrams demonstrate the wind power has a main portion to producing the electrical energy and every year a considerable amount of installed capacity is added to the total electrical grid.

In addition, the expansion of renewable energy to achieve the high percent of electrical production requires the improvement of infrastructure such as ecological research and high coordination between different organizations. Also, the electrical generation cannot be constant, and in winter the overall consumption and demand for electricity increases all over Europe. The exploitation of some renewable sources such as solar and wind power for electrical production can have fluctuation due to the weather condition and wind speed, which can affect the overall generation to the electrical grid.

Therefore, the balancing of several renewable sources in different seasons, needs the unique power management for reliable electrical production. In this trend, Norway is a successful country in Europe that uses over 90 percent of renewable sources for total electrical generation. The thesis has covered these challenges and how they are overcoming these issues.

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Abbreviations:

EU.....	European Union
RE.....	Renewable energy
RES.....	Renewable energy source
WT.....	Wind turbine
DC.....	Direct current
AC.....	Alternating current
HVAC.....	High voltage alternating current
HVDC.....	High voltage direct current
TWh.....	Terawatt hour
GWh.....	Gigawatt hour
KWh.....	Kilowatt hour
GW.....	Gigawatt
MW.....	Megawatt
KW.....	Kilowatt

1. Introduction:

1.1 Electricity installed capacity:

Electricity installed capacity is the maximum electrical power output, which a generator or plant can produce under specific circumstances. The electrical capacity of a generator determined by its manufacturer and indicates the maximum output power, which a generator can produce without exceeding thermal design limits.

The main units to calculate the installed capacity are MW or GW. The world's total installed electrical capacity was about 5549.6 GW estimated at 2012. [1]

1.2 Electricity generation:

Electricity generation is the amount produced electrical energy from a generator which is produced over a period of time. A generator of 1 MW capacity produces 1 MWh electricity if it works at full capacity consistently for 1 hour, if it operates only half of capacity consistently for 1 hour it will produce 0.5MWh electricity. Normally the generators don't operate at full capacity due to different reasons.

The main units to calculate the electricity generation are MWh, GWh or TWh. The world's total generated electrical energy was 21531 TWh estimated at 2012. [1]

1.2.1 Electricity generating sectors:

In every country of the world, there are different kind of electricity generation sectors, no country in the world produces its whole electricity through one sector, generation sectors depends upon several reasons like weather condition in that country and economical condition in that country.

The main electricity generation sectors are

- Nuclear
- Fossil Fuels
 - Oil
 - Gas
 - Coal
- Renewable Energy sources
 - Hydro
 - Wind power
 - Solar
 - Biomass and waste
 - Geothermal

1.3 Electricity consumption:

The electricity consumption is actual demand, which is fulfilled by existing electricity supplied by different energy sources.

The electricity consumption is measured in watt hours and 1 watt hour is equal to 3600 joule or 589.8calorie. The other main units for measuring the consumption are MWh, GWh or TWh. The world's total net consumption of electricity was 19710 TWh estimated at 2012. [1]

1.4 Renewable Energy:

Renewable energy, also called as green energy is the form of energy which comes from those sources which are not depleted when used. The renewable energy is naturally generated over a short time scale and derived directly from the nature.

The renewable energy sources have less or no carbon CO or CO₂ emission in the nature. Renewable energy sources have contributed around 22% of total production of electricity estimated at 2013.

Renewable energy sources are naturally depended and can be differ from around the world.

The main renewable energy sources are

- Hydro Power
- Wind power
- Solar
- Geothermal

1.5 Wind Power:

Wind power is one of the main sources of electricity generation and lies in one of the sources of renewable energy. The wind power is the use of wind, which blows naturally to produce mechanical power by windmills or wind turbine which later use to generate electrical power.

Wind power is totally carbon free energy and low cost electricity can be produced. The wind power is totally depending on the wind blowing if more wind blows more energy produce and if less wind blow it vice versa. That is why the generation from the wind turbine or wind farm is random.

There are two types of wind farms

- Onshore wind farms:

Onshore wind farms are built or constructed on the land area.

- Offshore wind farms

Offshore wind farms are built or constructed in the sea.

2. Electricity in EU-28:

2.1 Electricity capacity and generation:

The installed electrical capacity increased by 33% in EU-28 over the decade 2002-2012. This shows a steady increase with an average increase of 2%-3.5% over the year (Figure 1).

In 1990 the highest share of 57% in total installed electrical capacity was accounted by combustible fuels, followed by 22 % nuclear, 21% hydro and 1% all others. [5]

In 2000 the above structure was slightly changed with a share of 58% in total installed electrical capacity accounted by combustible fuels, 20% nuclear, 20% hydro, 2% wind, and 1% all others. [5]

In 2012 the whole structure was completely changed with a share of 52% in total installed electrical capacity accounted by combustible fuels, which is decreased from 58%, 13% nuclear, 16% hydro, 11% wind which is increased from 2%, 7% solar and 1% all others. [5]

The electricity generated in EU-28 remains steady through the decade 2002-2013 with a minor gradual change over the year. In 2009 the generation was at the lowest point after 2003 due to the hit of Economic recession all over the world but later the generation retains its previous position back.

In 2012 the major share of 47% of electricity generation was from Fossil Fuels, 27% from Nuclear and 24% of Renewable energy sources.

In 2013 the major share of 44% of electricity generation was from Fossil Fuels which was decreased by 3% from the previous year, 27% from Nuclear which remain constant and 27% of Renewable energy sources which was increased by 3% from the previous year.

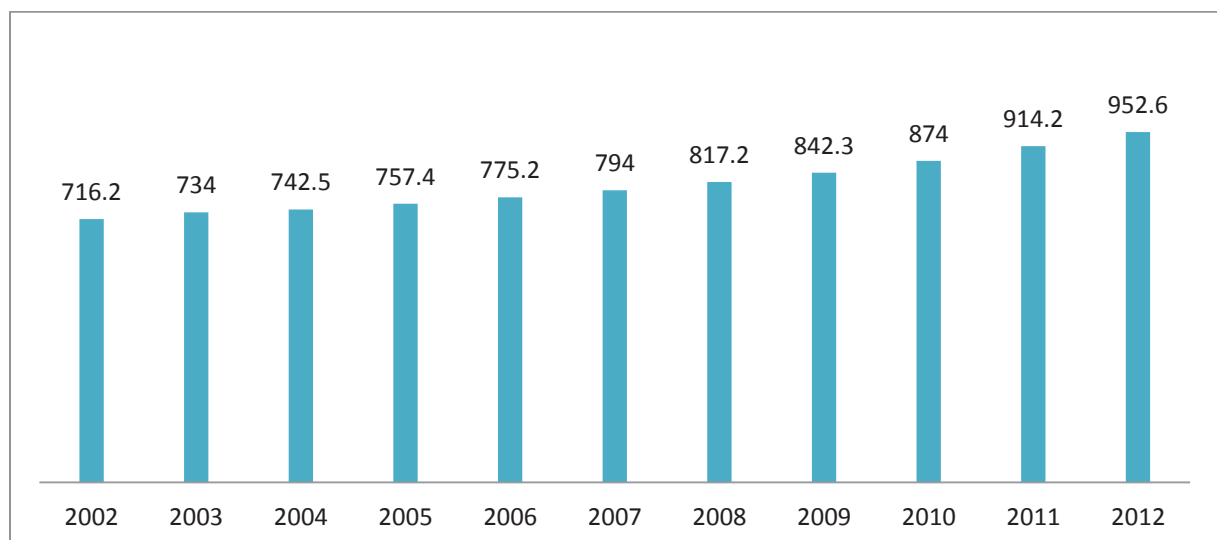


Figure 1: Installed electricity capacity (GW), EU-28 [1]

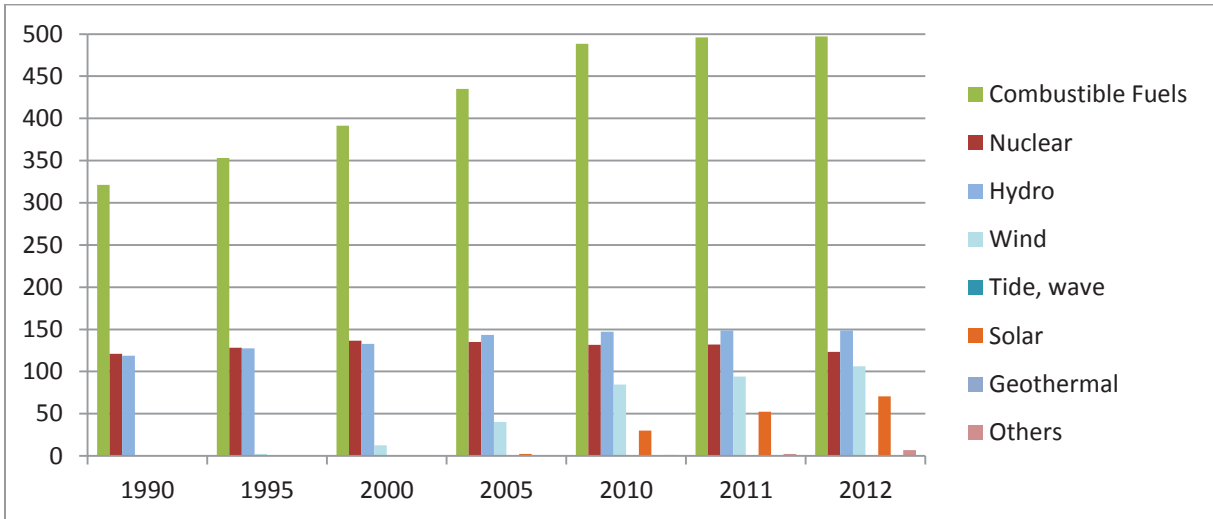


Figure 2: Installed electricity capacity (GW) by different energy sources EU-28 [5]

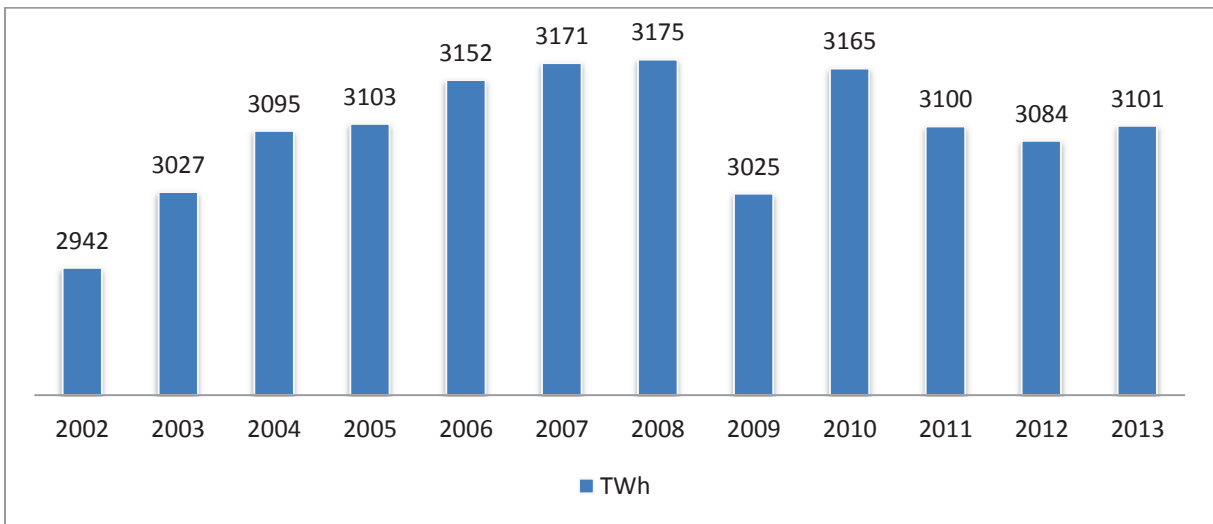


Figure 3: Electricity net generation EU-28 [1] [2]

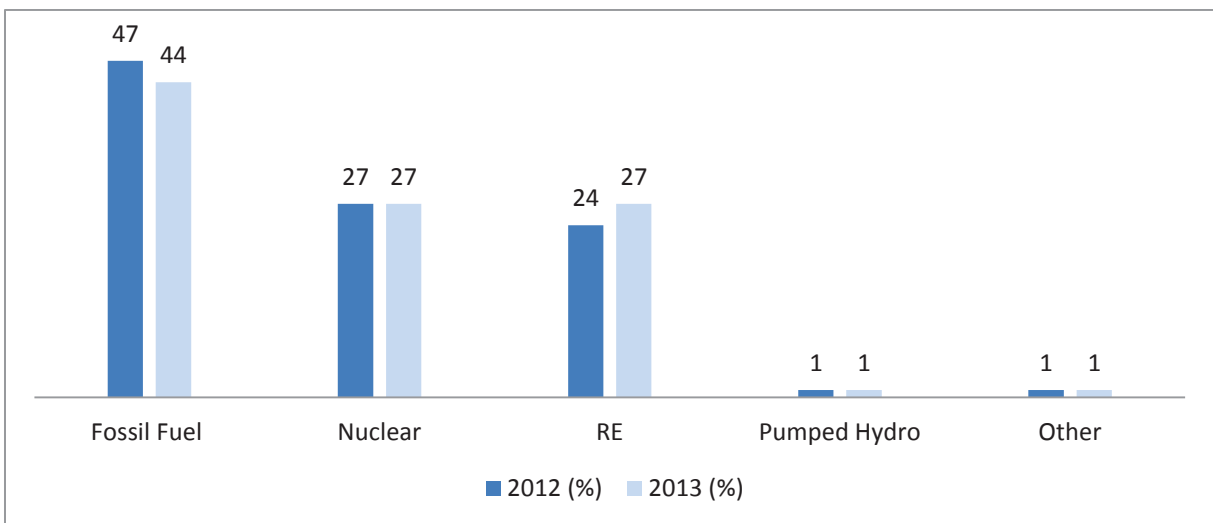


Figure 4: Share of total electricity generation by different sectors [2]

2.2 Electricity consumption:

The Electricity consumption in EU-28 has roughly remained in the same position over the decade 2003-2013, the major change was observed between the economic crisis. The final consumption decreased from 2012 to 2013. The electricity consumption 2867 TWh in 2013 was approximately same as 2871 TWh in 2004. In general the electricity consumption by industry has been decreased while on the other hand consumption by households and services is increasing steadily.

In 2012 the largest consuming sector of electricity in EU-28 was industry 36%, than households 30%, than services, 30%, and rest 4% consumed by transport and agriculture & forestry sector 2% each.

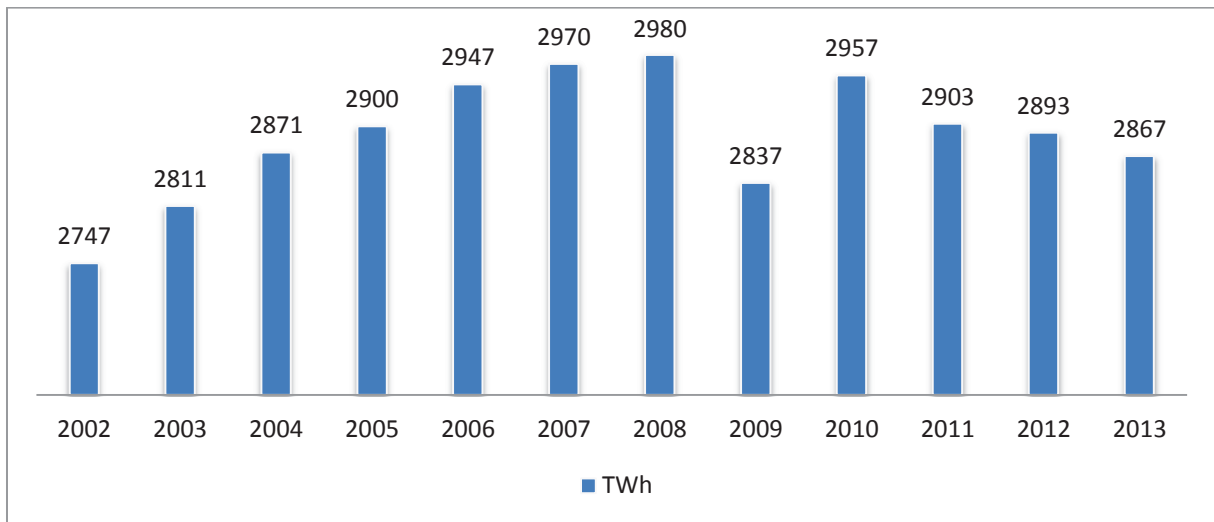


Figure 5: Net electricity consumption in EU-28 [1] [2]

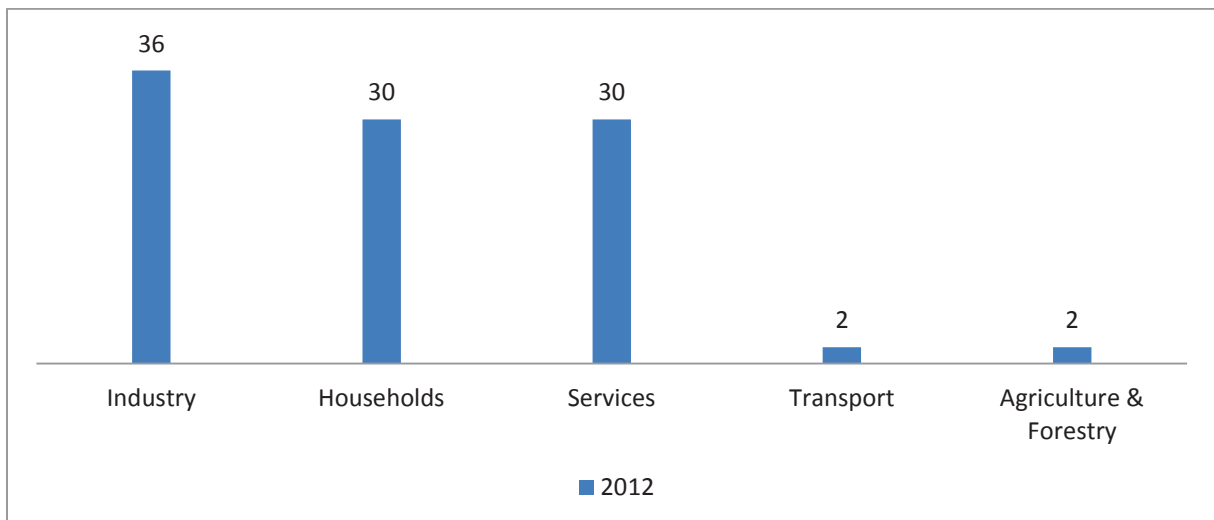


Figure 6: Electricity consumption by different sectors EU-28 [2]

2.3 Renewable Energy:

2.3.1 Renewable electricity installed capacity:

The renewable electricity installed capacity increased sufficiently over the decade 2002-2012, the capacity 319 GW in 2012 is increased by 95% with compare to the capacity 163 GW in 2005. The renewable electricity is the scope of the future, and its replacing the conventional electricity sources rapidly all over the world. The EU is planning to produce its 20% electricity demands by renewable electricity by the end of 2020.

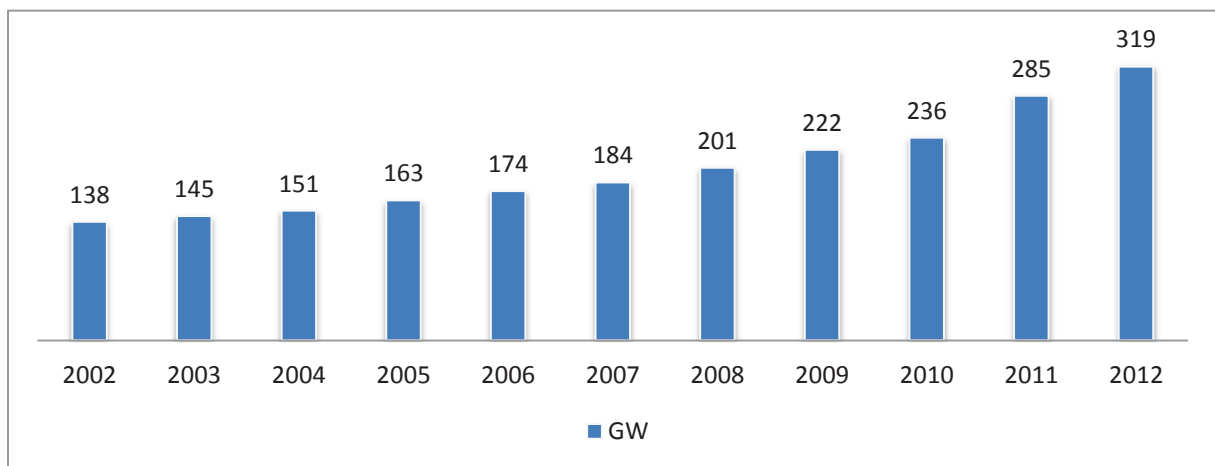


Figure 7: Installed renewable electricity capacity EU-28 [1]

2.3.2 Renewable electricity generation and consumption:

In 2013 EU-28 has fulfilled its 10% more demand of electricity through the renewable sources than in 2012, the total demand of electricity covered by renewable sources in 2013 was 27%.

The renewable energy source structure used for electricity generation had been changed significantly over the last two decades. In 1990 the major share of hydro power 94% of renewable electricity generation while the share of hydro power was 42% in 2013, the share from other sources are 29 % wind, 9 % solid biofuels, 9 % solar PV, 6 % biogas, 4 % renewable waste, 1 % geothermal energy.

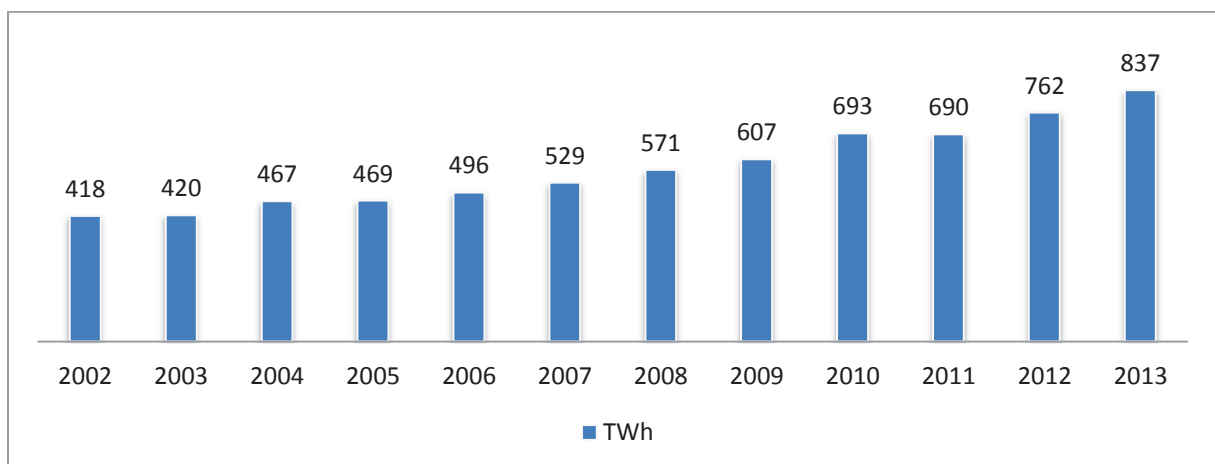


Figure 8: Renewable electricity generation and consumption EU-28 [1] [2]

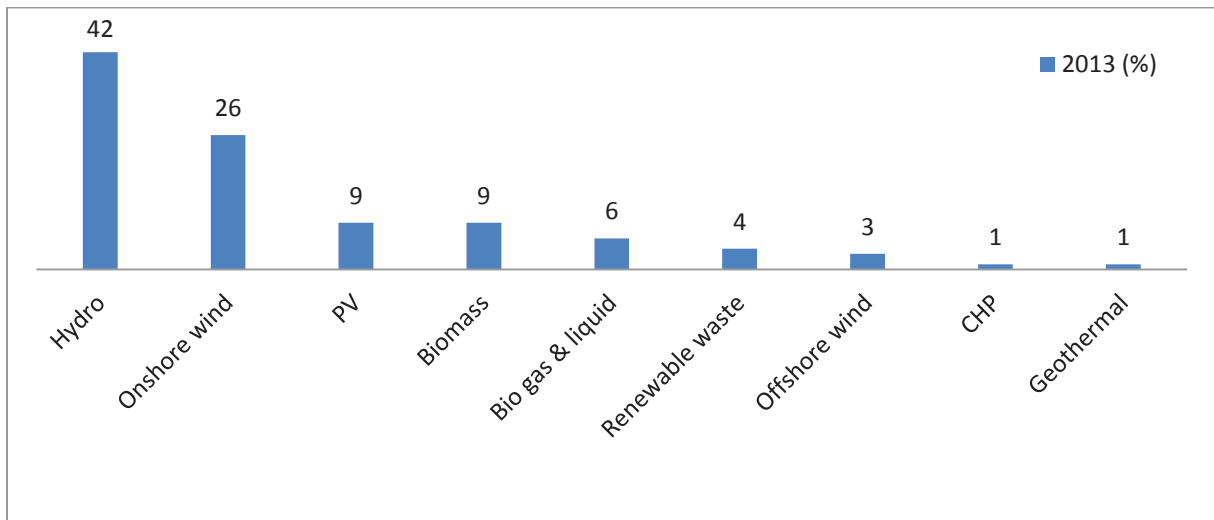


Figure 9: Share of sources in the RE Electricity generation EU-28 [2]

2.4 Wind Power:

2.4.1 Wind power installed capacity:

The wind power capacity has increased significantly over the period 2002-2014, the EU wind power industry had an annual growth rate of 10% in this period. [3]

In 2014 11.7 GW of wind power installed in EU-28, of this installed capacity 10.3 GW was onshore and 1.4 GW offshore. EU-28 overall wind power annual installations increased by 3.8% in 2014 compared to 2013. [3]

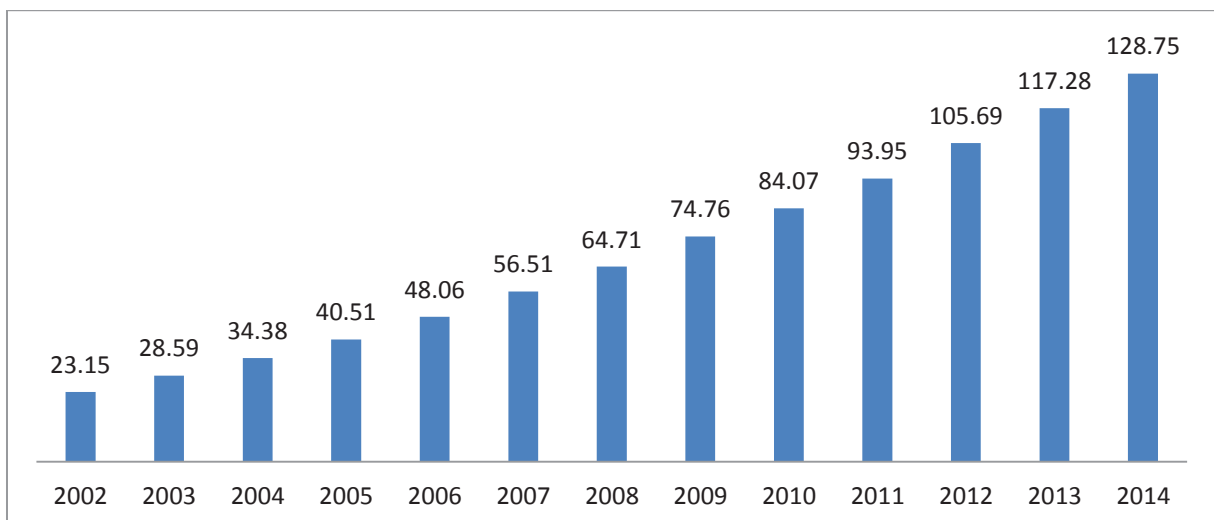


Figure 10: Installed wind power capacity (GW) EU-28 [1] [3]

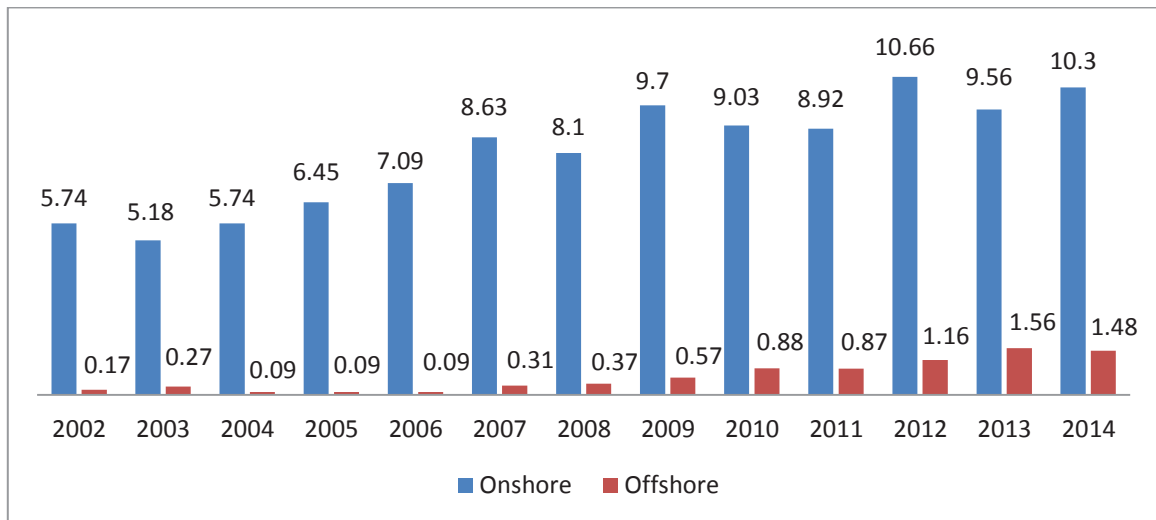


Figure 11: Annual increase of onshore and offshore wind power capacity (GW) EU-28 [3]

2.4.2 Wind Power generation and consumption:

The wind power installed capacity generated average 284TWh of electricity in whole year 2014, this generation from wind power covers the 10.3% total EU-28 electricity consumption. [3]

The EU-28 wind power generation increased by 15.5% in 2013 compared to 2012, and contributed 29% share of electricity generation from RES in 2013. [2]

Offshore wind power generation increased by 27% in 2013 and contributed 22TWh in the whole EU-28 power grid, on the other hand onshore wind power increased by 14% in 2013 and contributed 213TWh in the whole EU-28 power grid. [2]

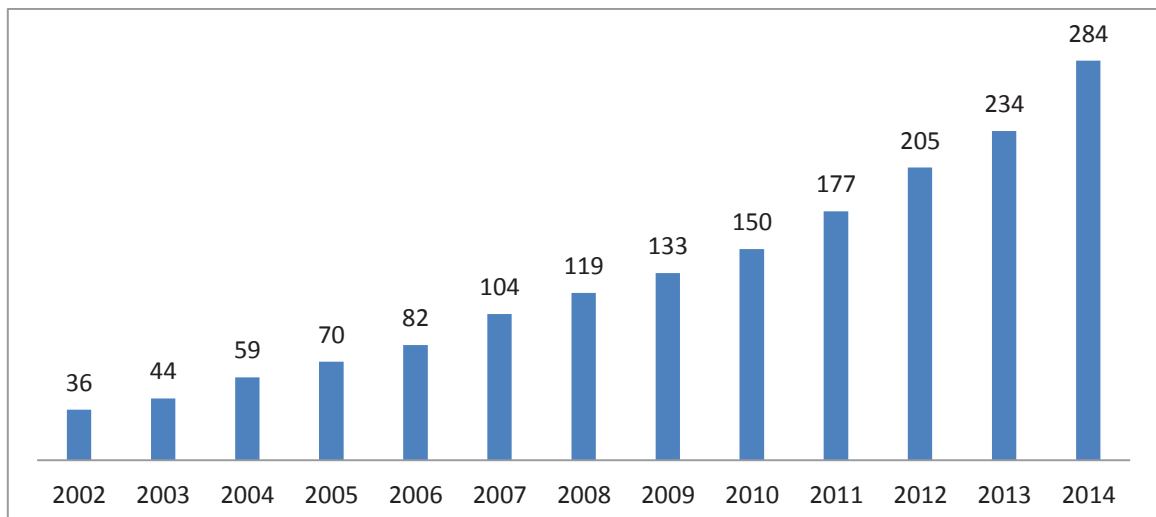


Figure 12: Wind power generation (TWh) EU-28 [1] [4]

2.4.3 Offshore wind power:

The total installed offshore wind power in EU-28 by the end of 2014 was 8000 MW or 8 GW, which generated 29.59 TWh of electricity covering the 1.1% needs of total consumption of electricity in a windy year.

The total 2488 wind turbines are installed in EU-28 which are connected to the electricity grid in 11 countries consisting 74 offshore wind farms. [6]

Farms: 74

Turbines: 2488

Capacity: 8045 MW

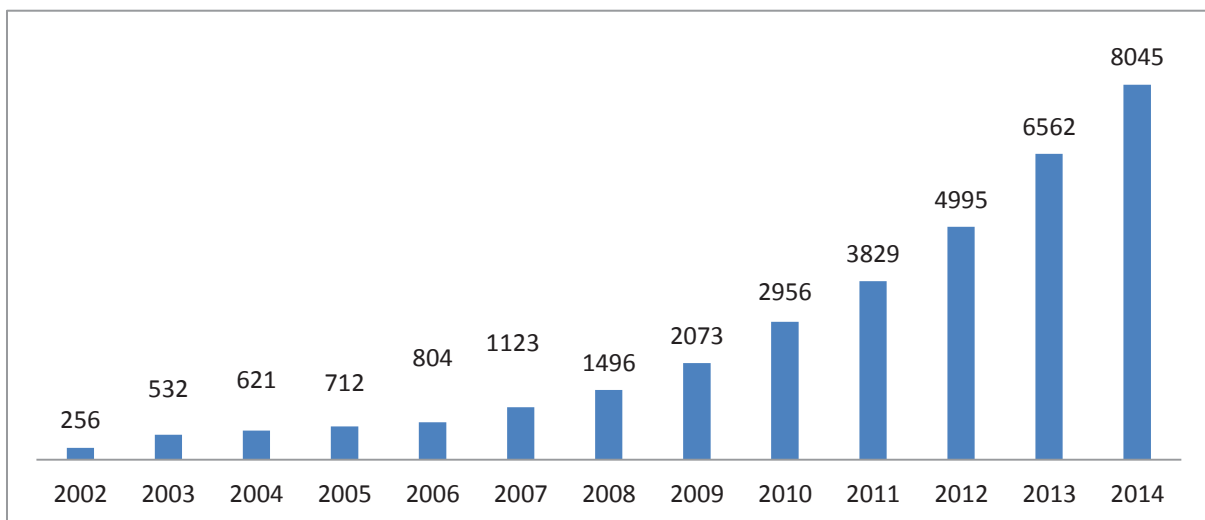


Figure 13: Offshore wind power installed capacity (MW) EU-28 [6]

3. Electricity in Germany

3.1 Electricity capacity and generation:

Germany has the highest installed power plant and one of the largest consumer of electricity in the Europe. In 2014, the total installed capacity was around 188 GW. By the gross installed capacity rating, renewable energy accounted for 43%, which mainly includes solar and wind power with capacities of 38.1 GW and 37.5 GW. The contribution of gas was 28.9 GW, coal (hard coal and brown coal) 44 GW, Biomass 8.7% and hydro power 5.9%.

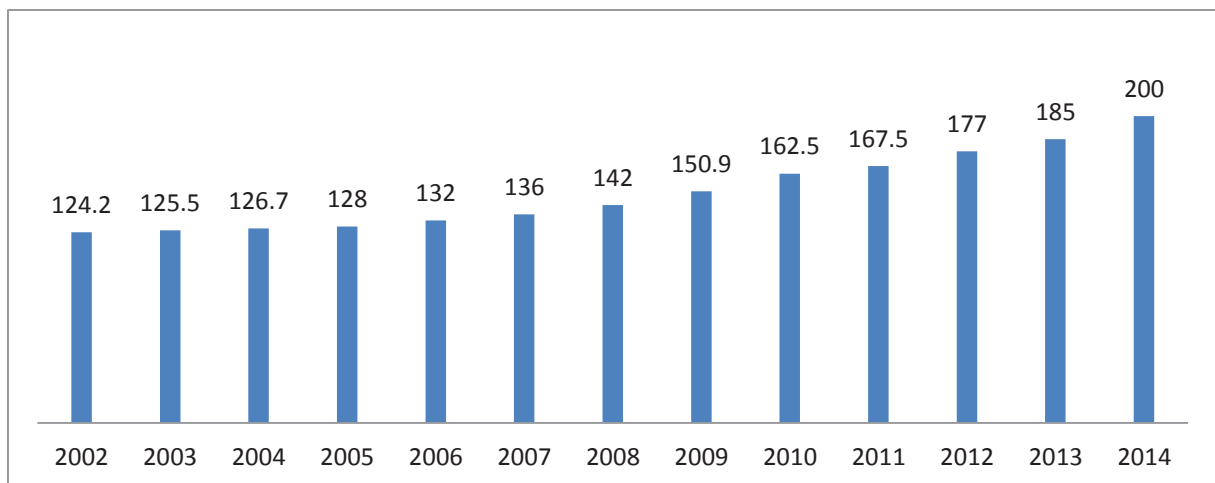


Figure 14: Installed capacity in (GW) in Germany [29] [30]

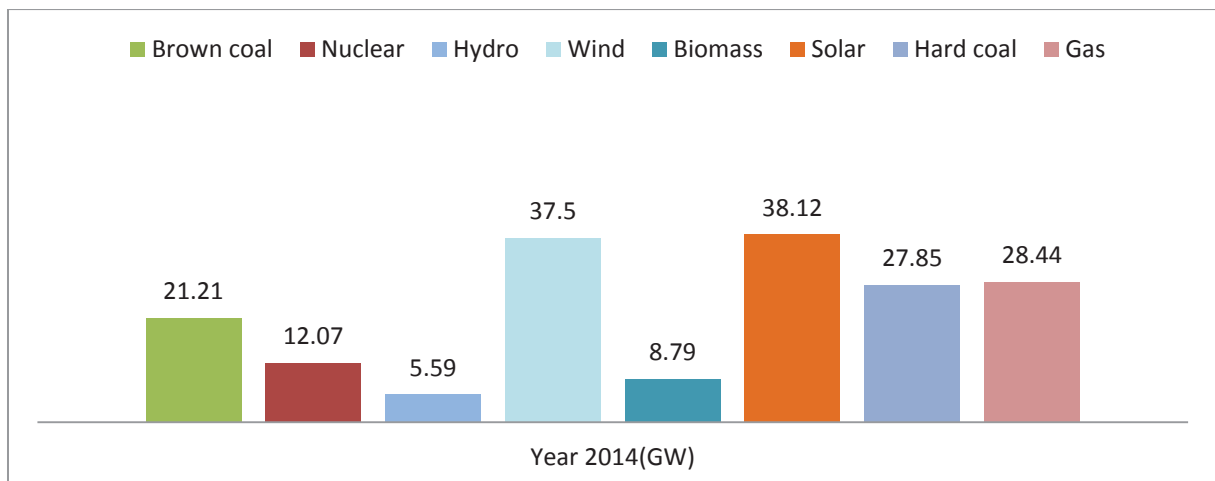


Figure 15: Installed capacity (GW) by different energy sources Germany

In Germany around 632.1 TWh electricity produced in 2013 and in 2014, the gross electricity production was 614 TWh. Renewable energy, lignite and coal plants are three fundamental resources to generate the electricity production. The highest electricity is generated from renewable energy with a contribution of 166 TWh, the of lignite power plant as a second largest power producer was 155.8 TWh, furthermore, the contribution of coal for production was 109 TWh.

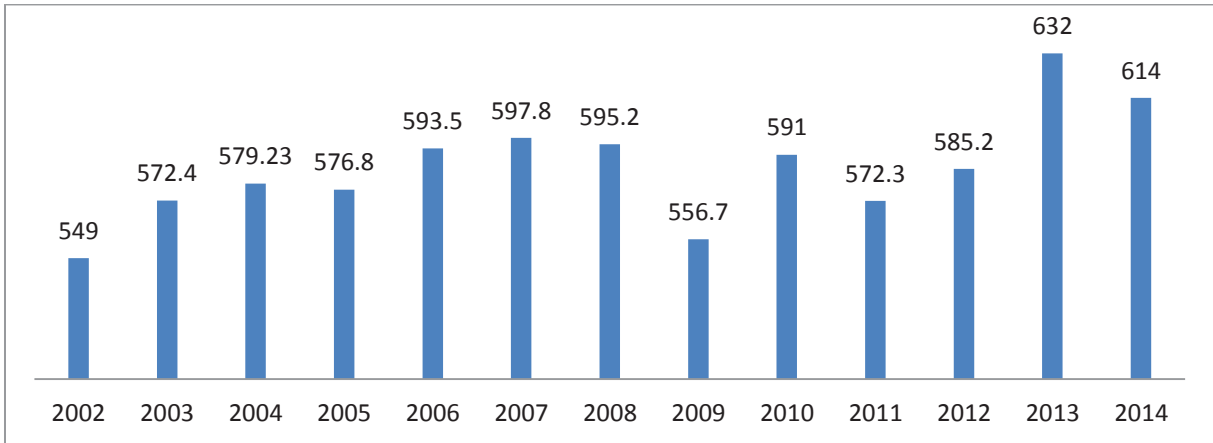


Figure 16: Electricity net generation (TWh) Germany [31]

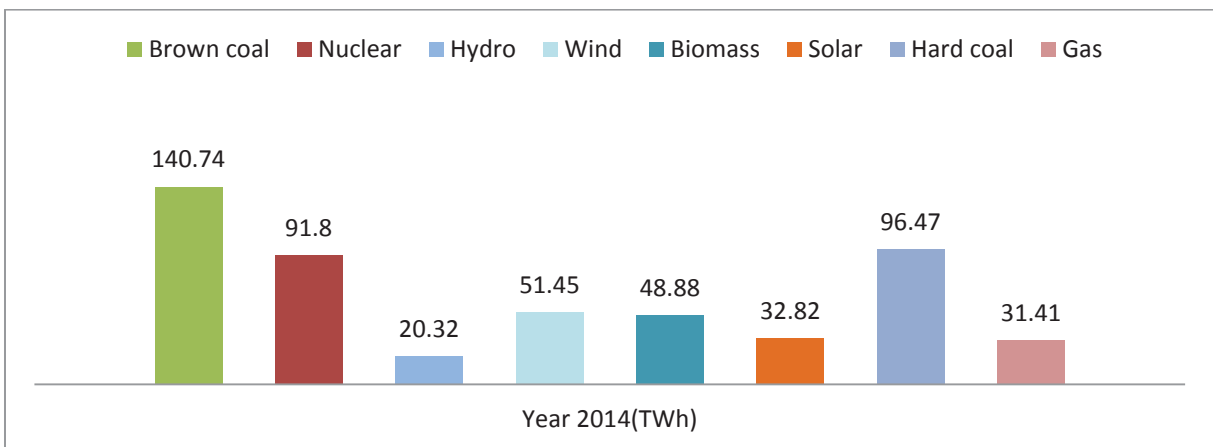


Figure 17: Share of total electricity generation by different sectors (TWh). Germany

3.2 Electricity consumption:

In 2013, gross domestic power consumption was 598.3 TWh and also in 2014, the total consumption was 576 TWh. The mining and processing industry are the greatest consumer of electricity with consumption of 245 TWh and households as a second consumer had used around 136 TWh, the portion of commerce and trade was 76.3 TWh and also the contribution of public facilities and transportation were 51 TWh and 12 TWh.

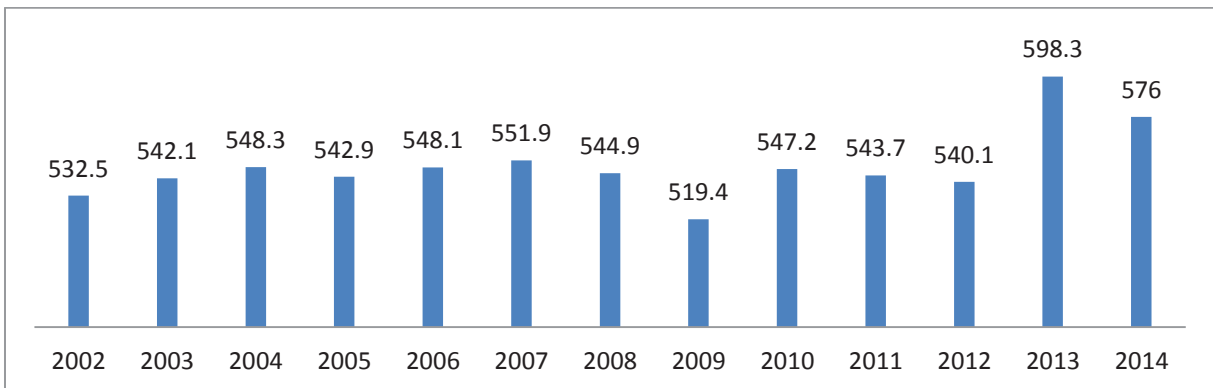


Figure 18: Net electricity consumption (TWh) Germany [30]

3.3 Renewable energy:

3.3.1 Renewable electricity installed capacity:

The development of renewable energy and shut down the nuclear powers are the fundamental goal of Germany's energy sector. Solar energy and wind power are the main energy sources. Additionally, biomass, hydro power and geothermal play the key role to achieve the renewable energy supply. In 2014, the share of installed capacity of solar energy was 38 GW, wind power 39 GW, biomass 8.5 GW and hydro power 5.5 GW.

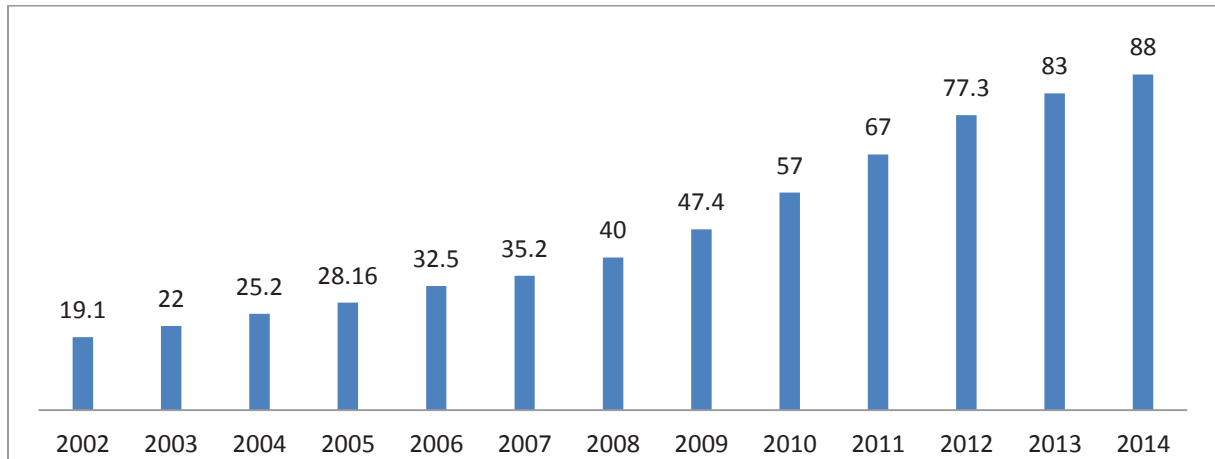


Figure 19: Install renewable electricity capacity (GW). Germany [33]

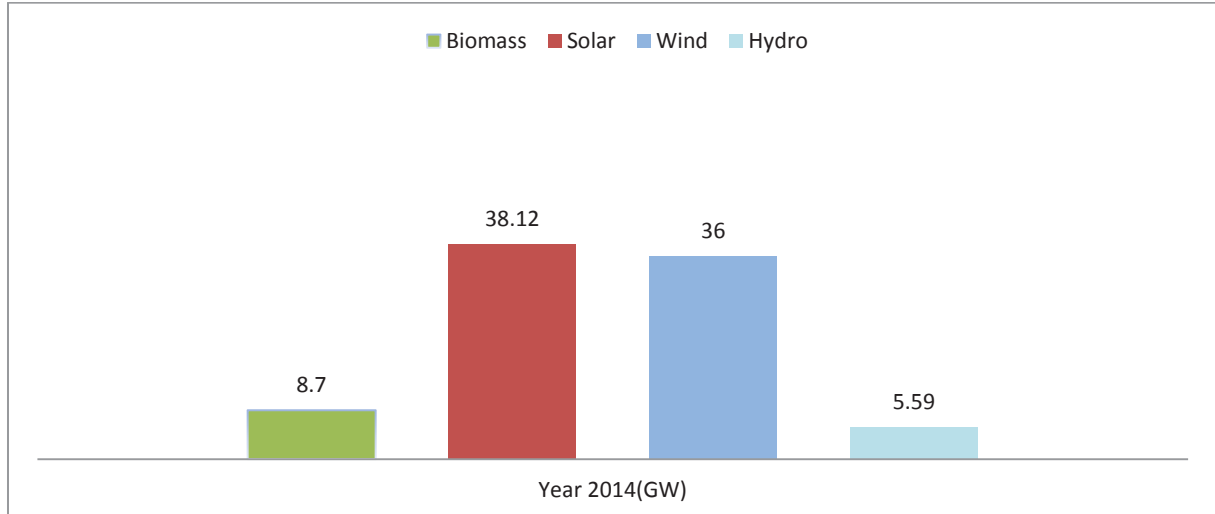


Figure 20: Installed capacity from different sources (GW).Germany

3.3.2 Renewable electricity generation and consumption:

In 2014, the gross electricity production from renewable energy was 160 TWh and this amount covers 27% of total electricity generation. In 2014, the more electricity produced from wind energy with the share of 56 TWh and also biomass produced 43 TWh. The third sector was photovoltaic with the amount of 35 TWh. The water power and household waste are the fourth and fifth valuable renewable energies the generated 20 TWh and 6TWh respectively.

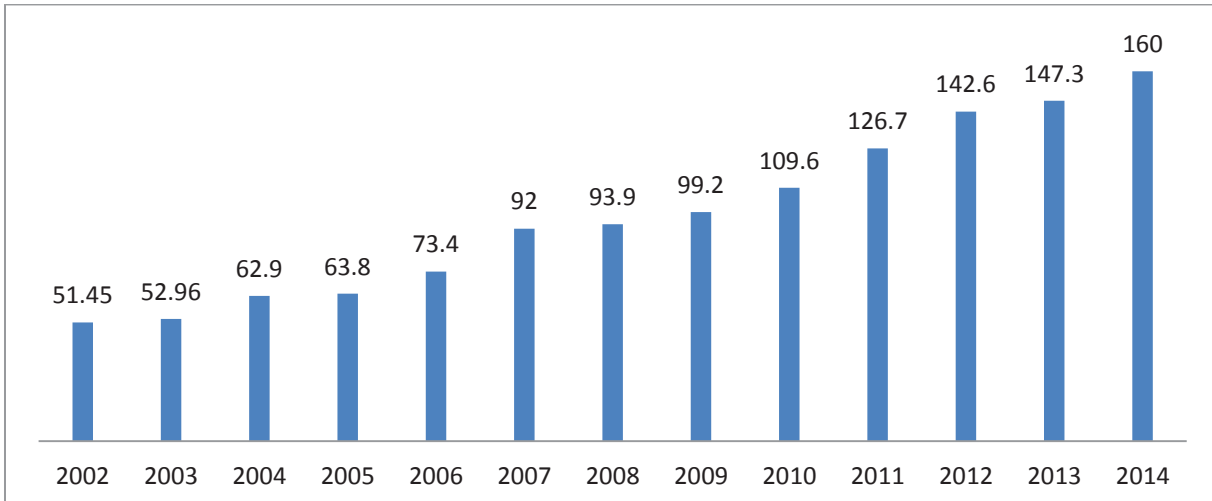


Figure 21: Renewable electricity generation and consumption (TWh). Germany [32]

Today, in Germany, despite the consumption of renewable energy production use in the transport market, even they use in the heating and cooling market and in the new construction the combined heat and power must equip.

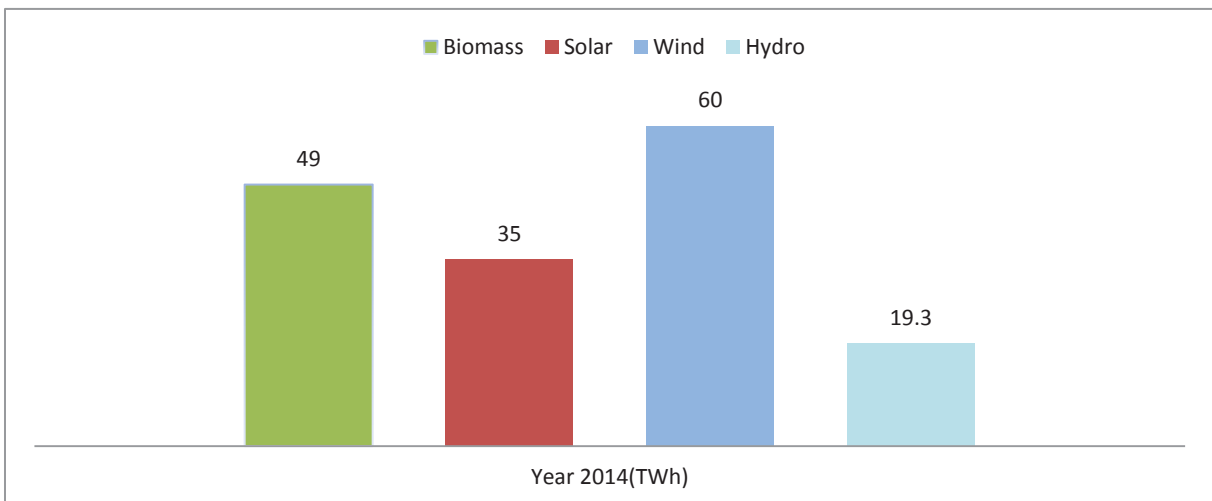


Figure 22: Share of sources in renewable electricity generation (TWh). Germany [32] [33]

3.4 Wind power:

3.4.1 Wind power installed capacity:

Wind power is the most important renewable energy and will make worth portions of the sustainable energy supply. The main purpose of the energy policy in Germany is the energy transition to a future without dependency on nuclear power and fossil fuels with the formation and development of rural locations and expansion of smaller and more powerful turbines, which are known as repowering Turbines. In 2014, Germany with 39.2 GW is one of the greatest installed capacity wind power sources in the Europe. Now around 24867 wind turbines were installed in Germany federal and they planned to add more turbines. The contributions of onshore wind turbines with 38155 MW are still more than offshore wind turbines. [34] [35]

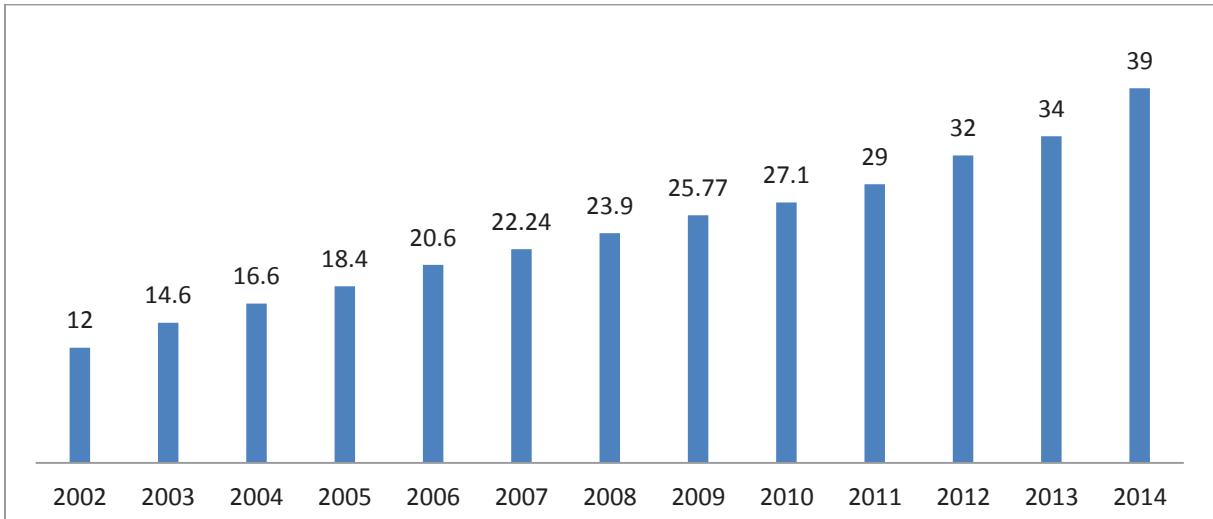


Figure 23: Installed wind power capacity (GW) . Germany

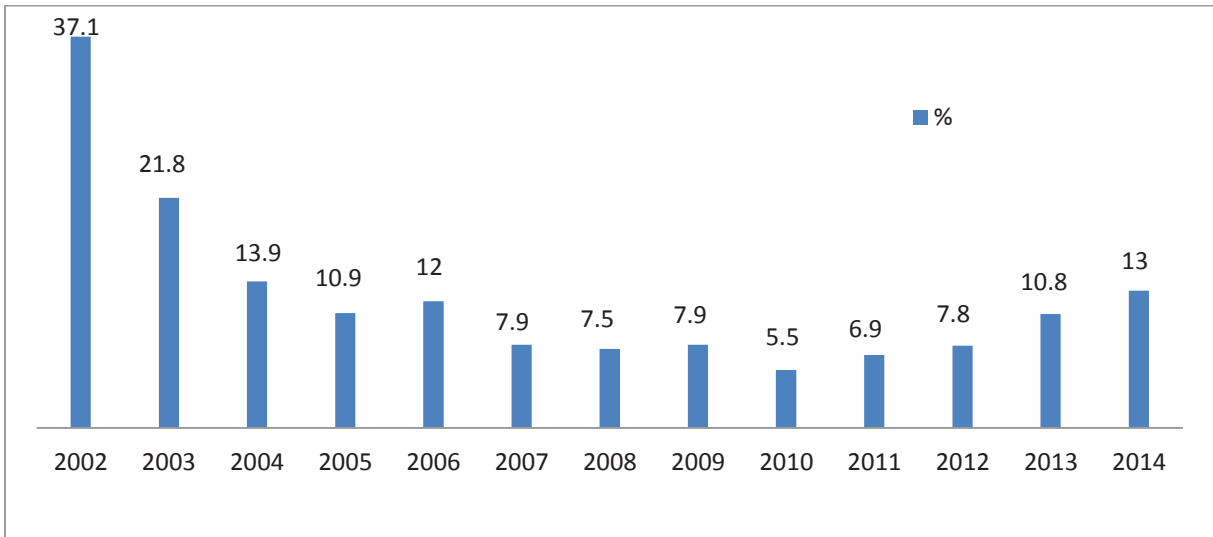


Figure 24: Annual increase of installed wind power capacity Germany

3.4.2 Wind power generation and consumption:

The electricity production in 2013 was 52 TWh and in 2014, the gross electricity production from wind power was 56 TWh and this rate include 9% of the total electricity production and the German government has plans to increase the wind power production up to 40%. The diagram below, shows the promotion of the wind power production by 47% from 2002 to 2014.

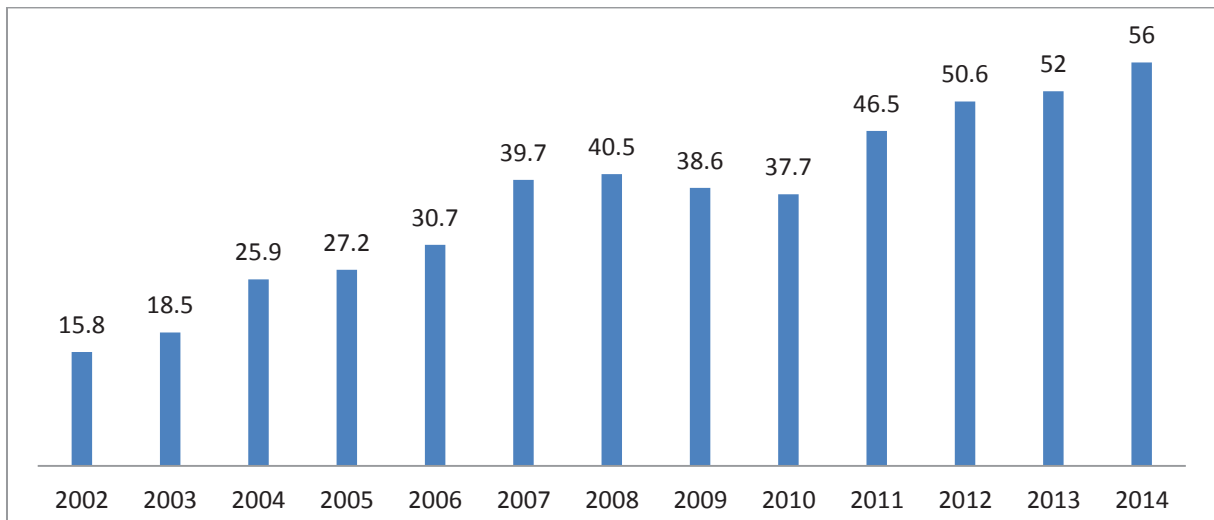


Figure 25: Wind power generation (TWh). Germany [32] [35]

3.4.3 Offshore wind power:

In 2014, Germany's government has a particular focus on offshore wind farms and the significant challenge has increased the capacities for transmitting the power generated in the North sea and conduction to the southern parts. Around 60% of 2998 MW of newly installed capacity was built in central and south of the country, but the north part remains more stability in onshore wind turbines with 40% of the total market. Regard to the 2014 report, the portion of the offshore wind energy capacity was around 1048 MW and the number of offshore turbines was 258. The development target of government is achieved 6500 MW installed capacity by 2020. The figure below shows the history of offshore installed capacity. [36]

Farms:	16
Turbines:	258
Capacity:	1048 MW

4. Electricity in France:

4.1 Electricity capacity and generation:

The current installed electricity capacity in France is around 130 GW, which is 10% increased with comparing to 2002.

The electricity sector in France depends upon Nuclear energy so about half of installed electricity capacity consist of Nuclear power.

The second sector, which has the highest installed electricity capacity is Fossil Fuels with the capacity of 26 GW recorded in 2012, after that is Hydroelectricity with the installed capacity of 18GW.

The electrical capacity remains unchanged until 2009, but the major difference can be seen after the economic recession in 2009 and capacity has increased steadily.

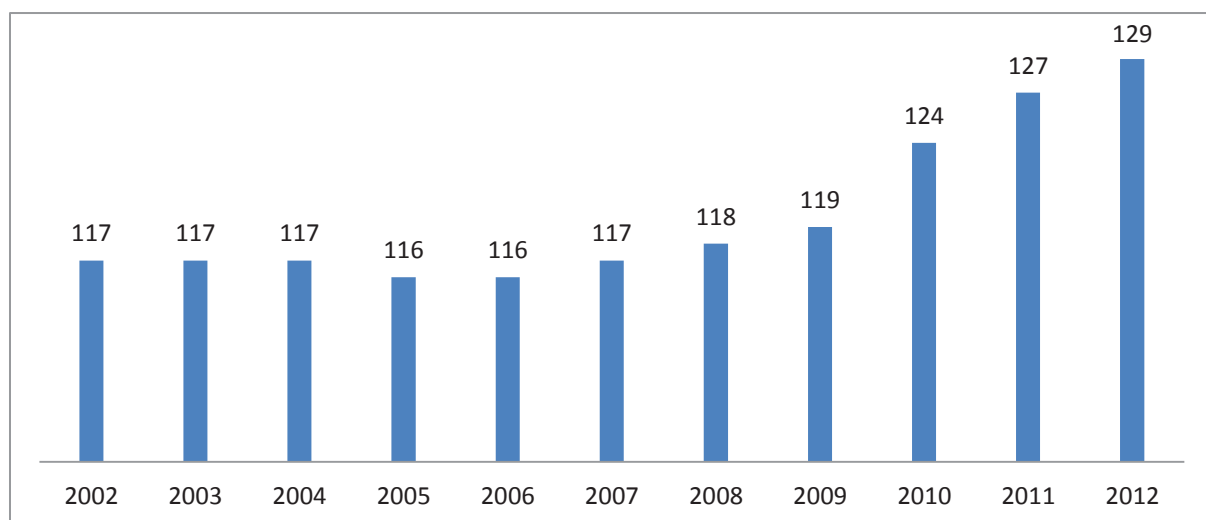


Figure 26: Installed electricity capacity (GW) France [1]

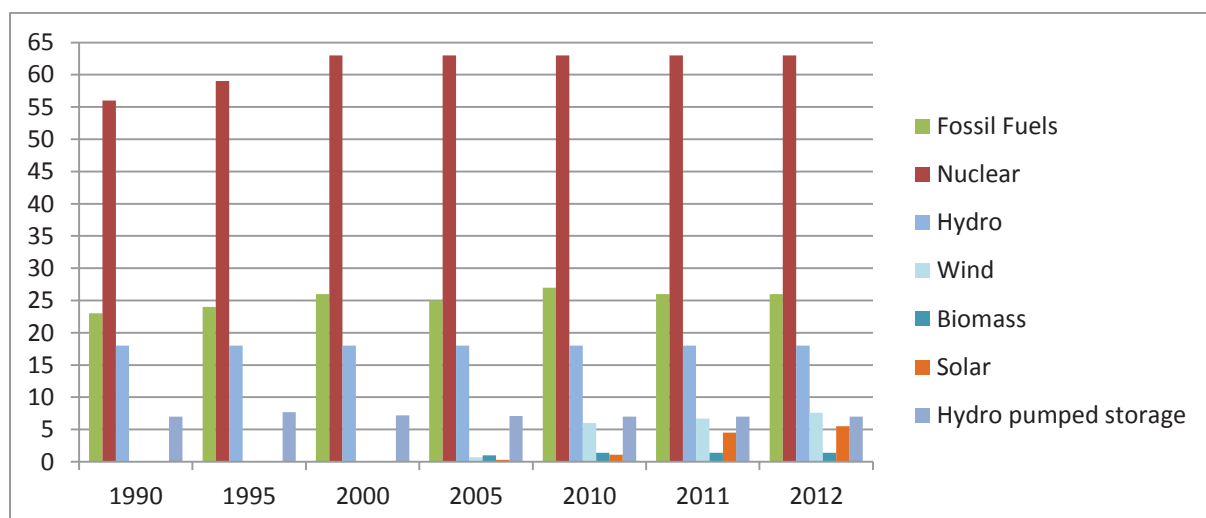


Figure 27: Installed electricity capacity (GW) by different energy sources France [1]

France was the world's 8th country in term of electricity generation by generating 568.3 TWh annually by the end of 2013. [5] The annual generation of electricity recorded in France in 2014 was 540.6 TWh, which was 1.8% less than with compare to the last year, the decline in demand due to change in export balance. [7]

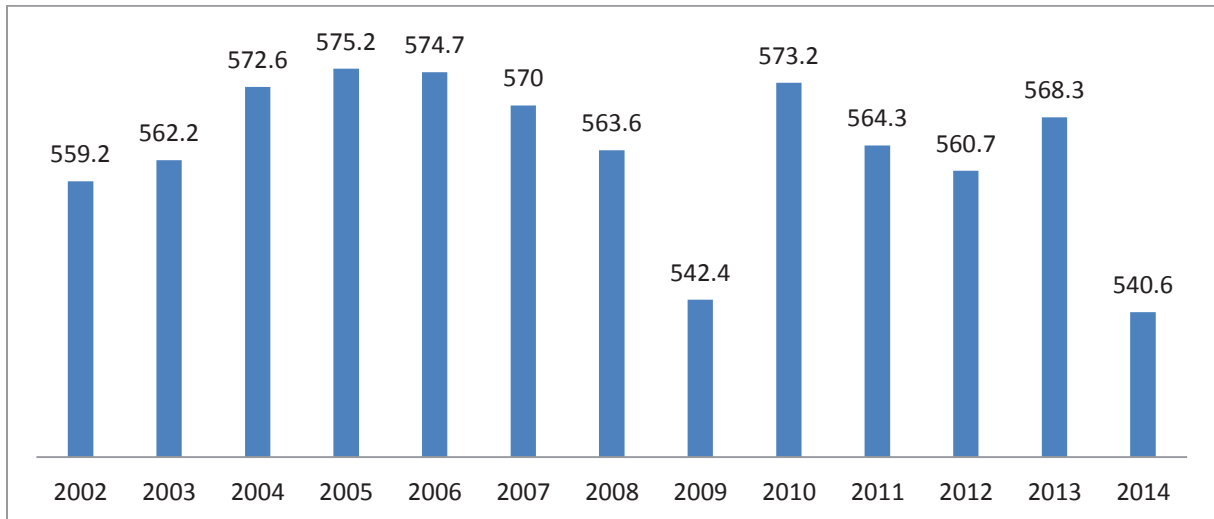


Figure 28: Electricity net generation (TWh) France [5] [7]

France has generated its 75% electricity demand by nuclear power which was 407 TWh out 541 TWh electricity need in the country by the end of 2013, this percentage is the highest percentage in the world. [8]

The share of sources other than Nuclear power which accounted for the net generation in 2014 are 12.6% hydro, 3.1% wind, 5% fossil fuels, 1.1% solar and 1.2% from other sources.

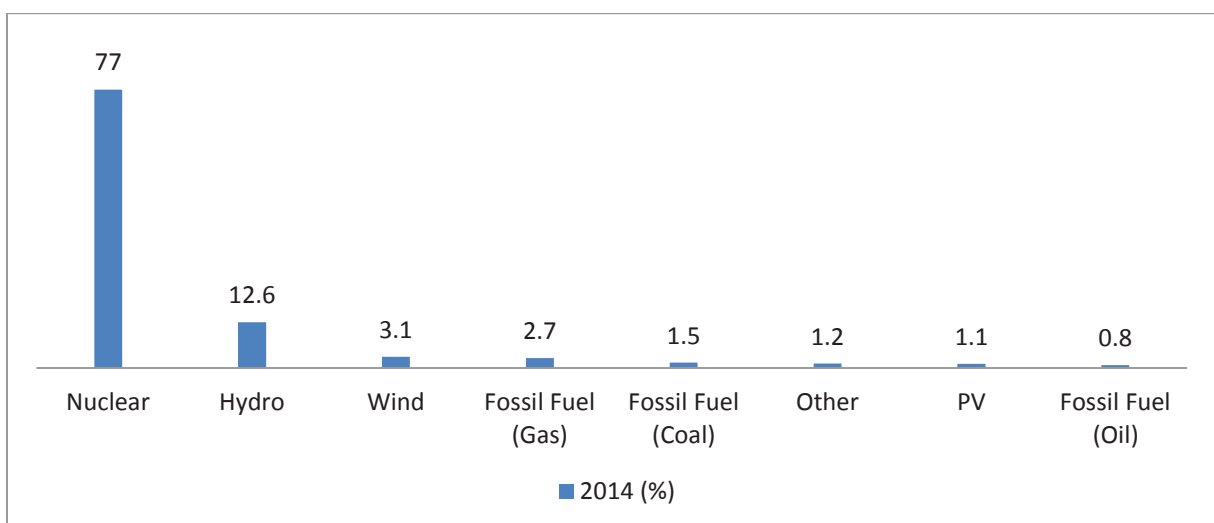


Figure 29: Share of total electricity generation by different sectors [7]

4.2 Electricity consumption:

The consumption of electricity in France is less than the production, which is because France exports its extra produced electricity to the neighboring countries, France exports around 10% of its electricity to the other countries.

The consumption of electricity in France is not constant the electricity consumption in 2012 is at the same position as it was in 2005, the electricity consumption observed at the lowest points in 2009 and 2011 otherwise it was same with a minor \pm change.

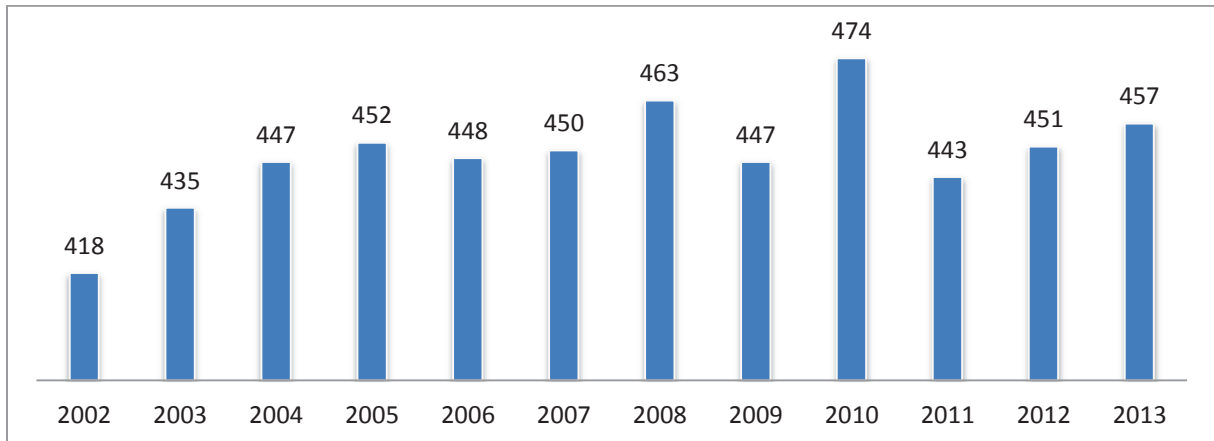


Figure 30: Net electricity consumption (TWh) France [1] [2]

4.3 Renewable Energy:

4.3.1 Renewable electricity installed capacity:

The renewable electricity capacity has increased around 70% until 2012 to compare to 2002. The renewable electricity capacity remains unchanged almost until 2007 but then there is a slight increase after the rapid development of other renewable sources other than the wind power.

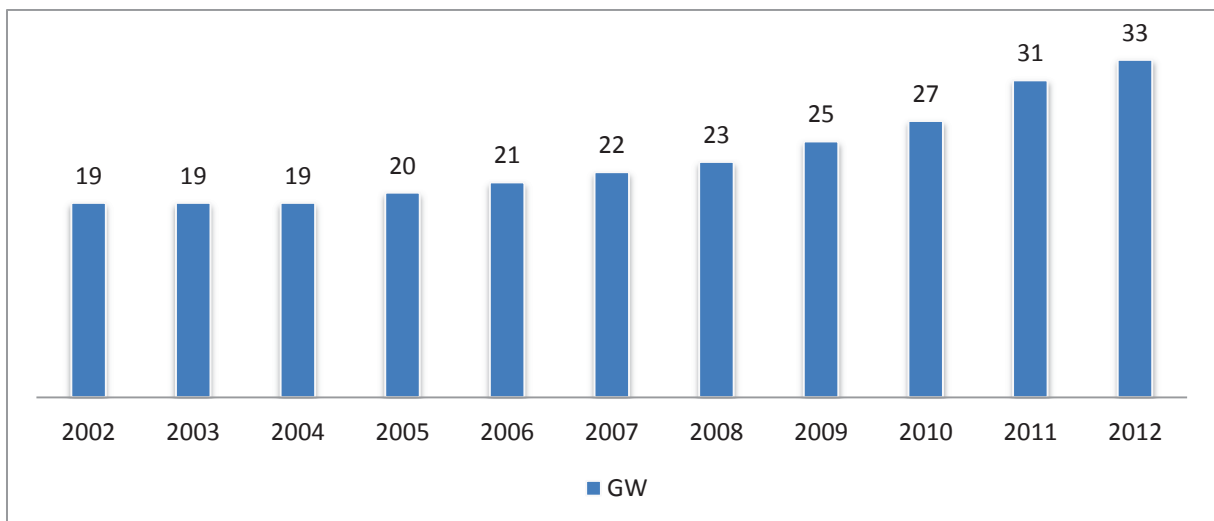


Figure 31: Installed renewable electricity capacity France [1]

4.3.2 Renewable electricity generation and consumption:

In 2014 96 TWh of electricity produced from the renewable electricity sector, which is around 45% increased compared to 2002.

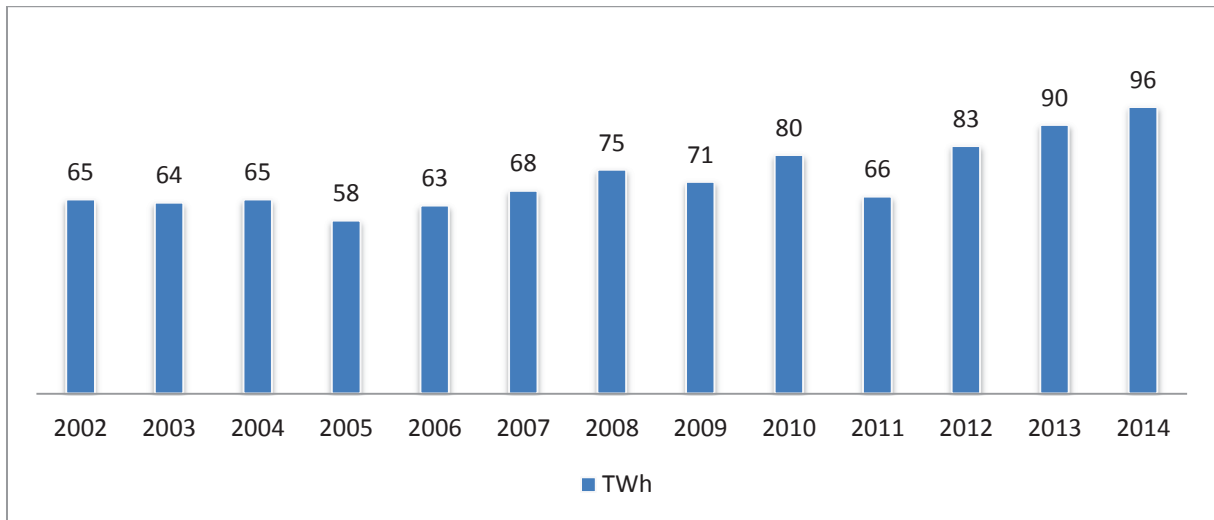


Figure 32: Renewable electricity generation and consumption France [1] [7]

In 2014 the share of electricity generation through renewable sources in whole generation net is around 20%, which is the same as it was in 2013.

In 2007 the share from renewable sources was around 13%, but later more renewable sources came into market the share has increased rapidly.



Figure 33: Share of renewable generation in total annual electricity generation France [7]

The major share of renewable electricity is Hydro power around 70% recorded in 2014, in this structure the share from other sources are 18% wind, 6% solar and 5 other renewable sources.

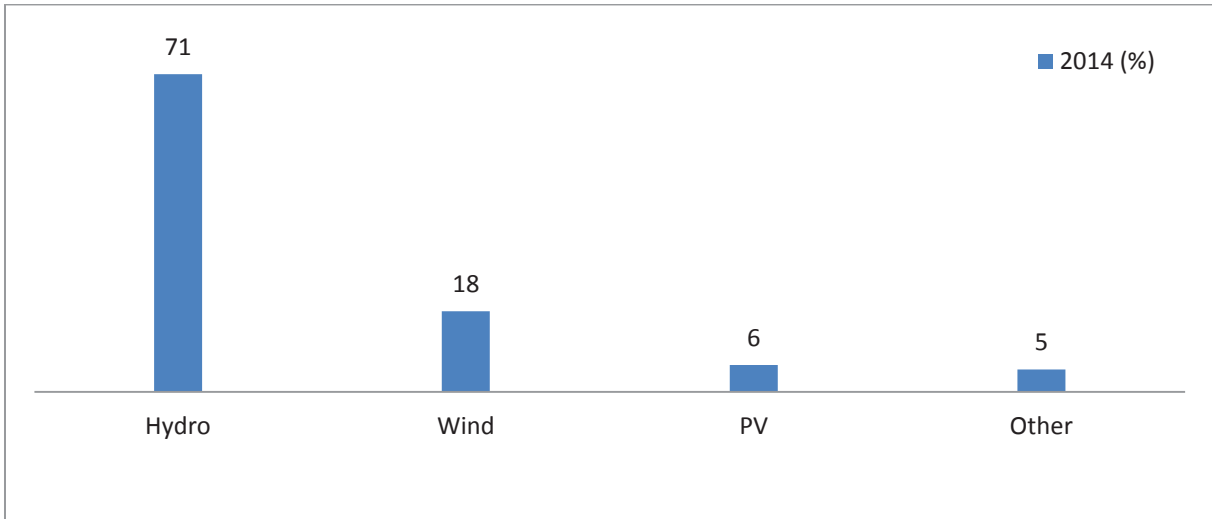


Figure 34: Share of sources in renewable electricity generation France [2]

4.4 Wind Power:

4.4.1 Wind Power installed capacity:

The wind power installed capacity in France has increased very much to drastically change over the last decade. The capacity was only 148 MW in 2002, which later on by the end of 2014 reached up to 9285 MW.

The French wind market has an addition of 1035 MW by the end of 2014 with a 12.5 % increase with compare to 2013.

The French wind market sustained a growth rate of around 10-12% annually after 2010.

The French government has set targets to achieve 25 GW of wind power by the end of 2020. [10]

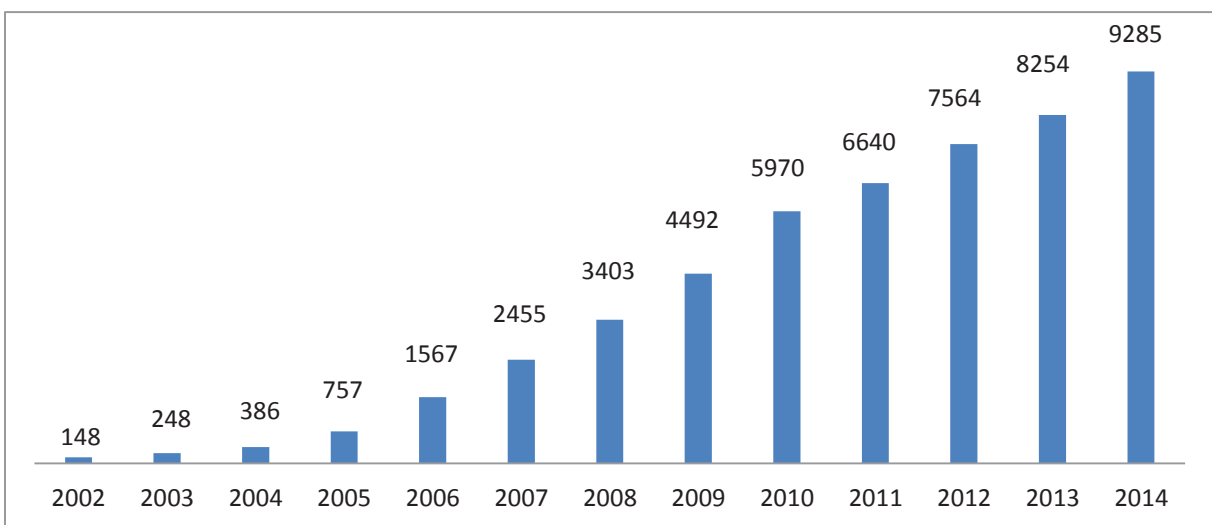


Figure 35: Installed wind power capacity (MW) France [1] [9]

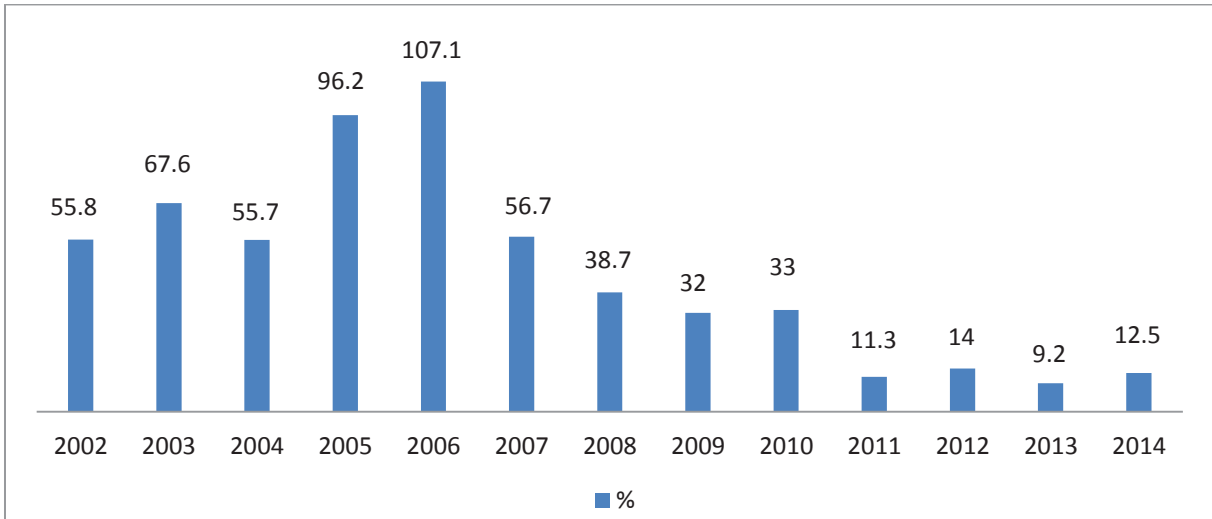


Figure 36: Annual increase of installed wind power capacity France [9]

4.4.2 Wind Power generation and consumption:

Wind power in France is accounted 4% of total national consumption of electricity. The renewable energy sources, shares around 20% demand of electricity generation from which wind power has 18% shares in renewable electricity by the end of 2014. France is the world's 8th largest country in the term of wind power electricity production. [10] [11] [20]

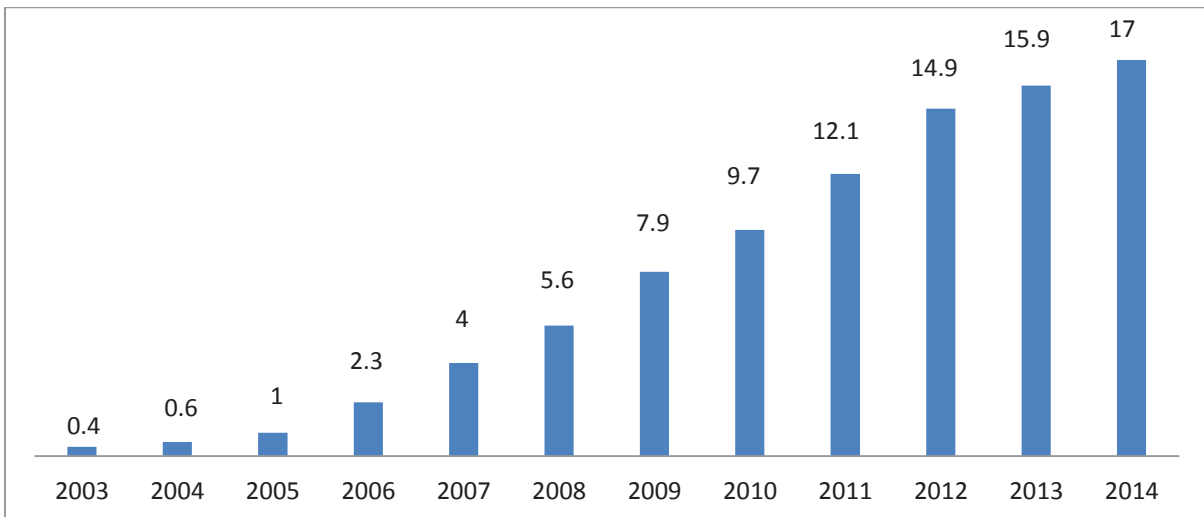


Figure 37: Wind power generation (TWh) France [7]

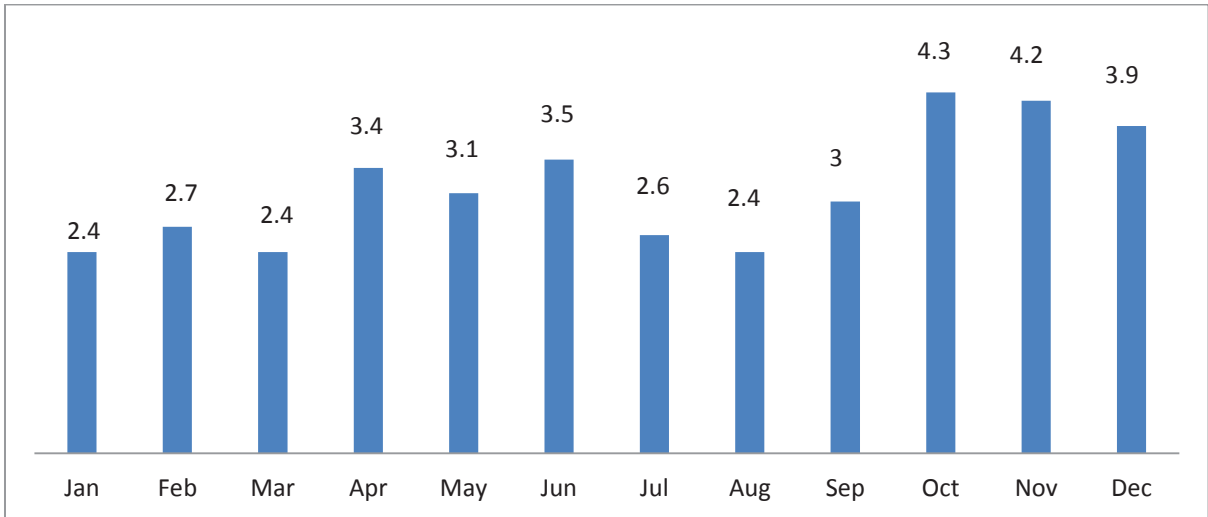


Figure 38: Demand (in%) covered by wind power in 2013 France [12]

4.4.3 Offshore wind power:

France has no installed offshore wind power capacity, the French government has recently signed some agreements and some work is in process on offshore wind power.

5. Electricity in UK:

5.1 Electricity capacity and generation:

In the United Kingdom, the electricity produced by different sources of energy such as fossil fuels, nuclear, renewable energy and imports. In 2013, the total installed capacity was 78 GW, and in 2014 was around 75 GW. The main share of installed capacity comes from combined cycle plants (CCGT) with a capacity of 31 GW, coal with a capacity of 21.5 GW, nuclear power with 10.5 GW.

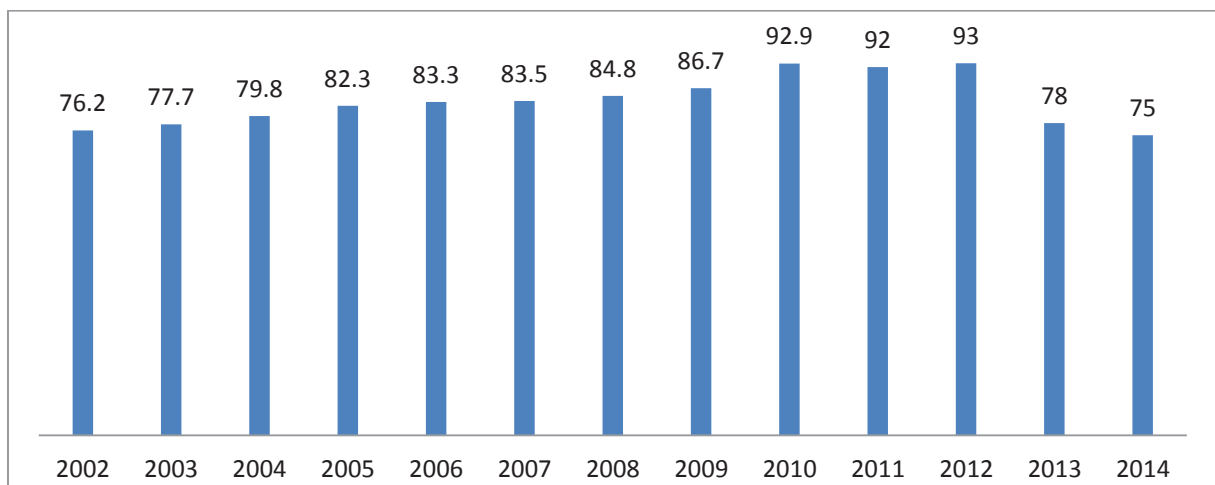


Figure 39: Installed electricity capacity (GW). UK [37]

In 2014, around 335 TWh electricity generated and the main source of energy for power supply was fossil fuels which include natural gas with 30.2% and coal with 29.1%. The amount of electricity changes every year, with shifting between the coal and gas due to the fuel prices. Around 19.2% of electricity generated from renewable energies and the contribution of wind power and solar energy in this section was 35.5 TWh.

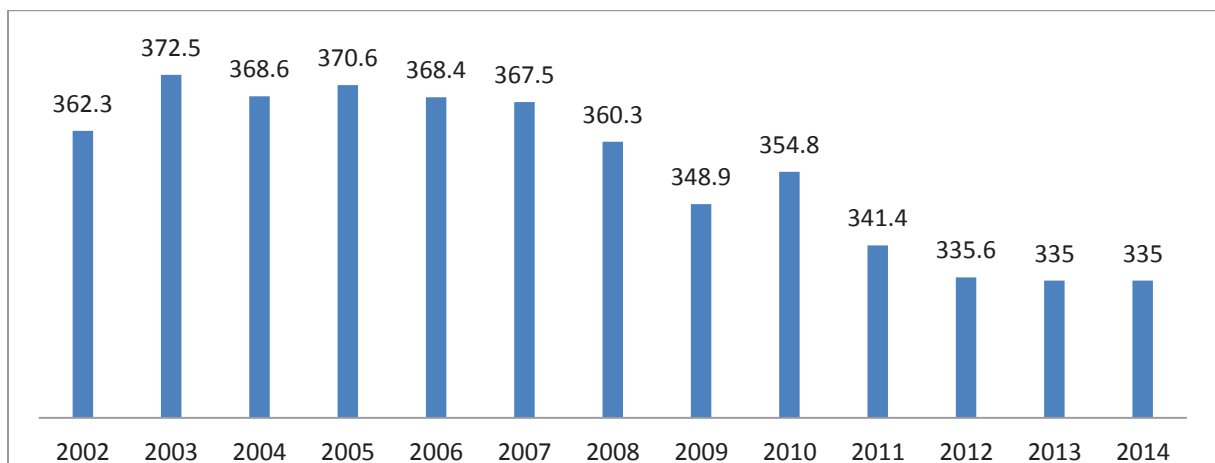


Figure 40: Electricity net generation (TWh). UK [38]

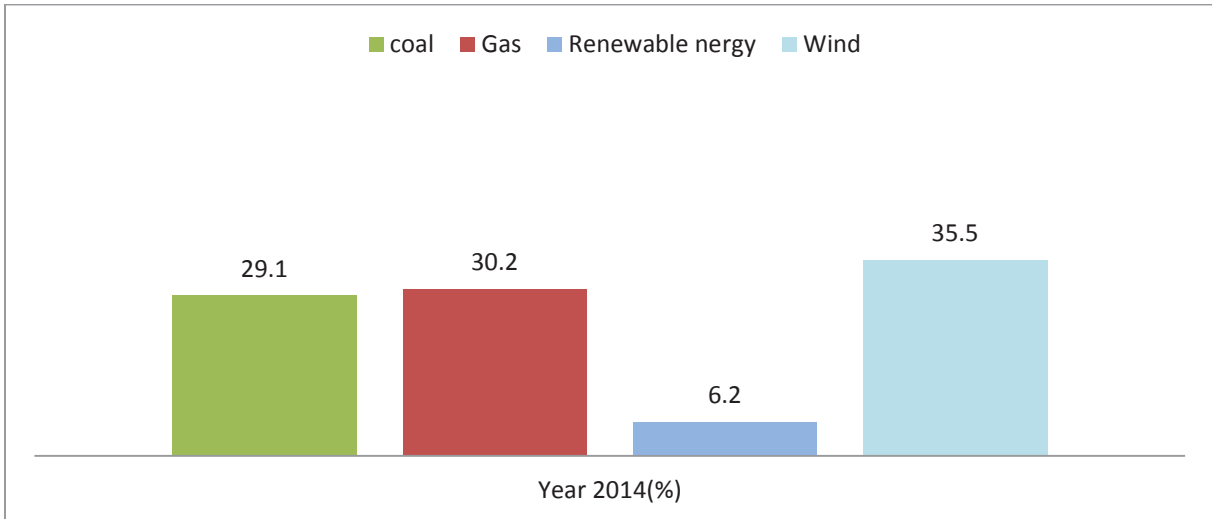


Figure 41: Share of electricity from different sources (TWh). UK

5.2 Electricity consumption:

According to the table below, the gross consumption of electricity decreased 4.3% in 2014, from 317.3 TWh to 303.8 TWh in 2013. In 2014, UK was a net importer from France and the Netherlands with the capacity of 15 TWh and also exported electricity to Ireland with a rate of 2.4 TWh. In the UK, the largest consumer of electricity was the domestic sector by 107 TWh, industry was 98 TWh, while consumption by commercial and other users was 104.8 TWh.

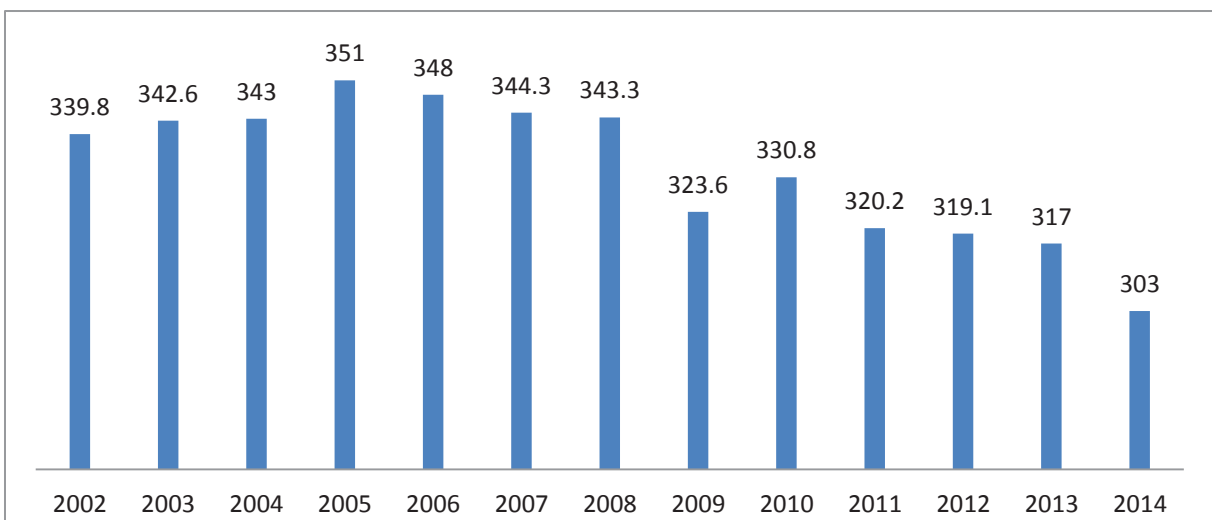


Figure 42: Net electricity consumption (TWh) . UK [38]

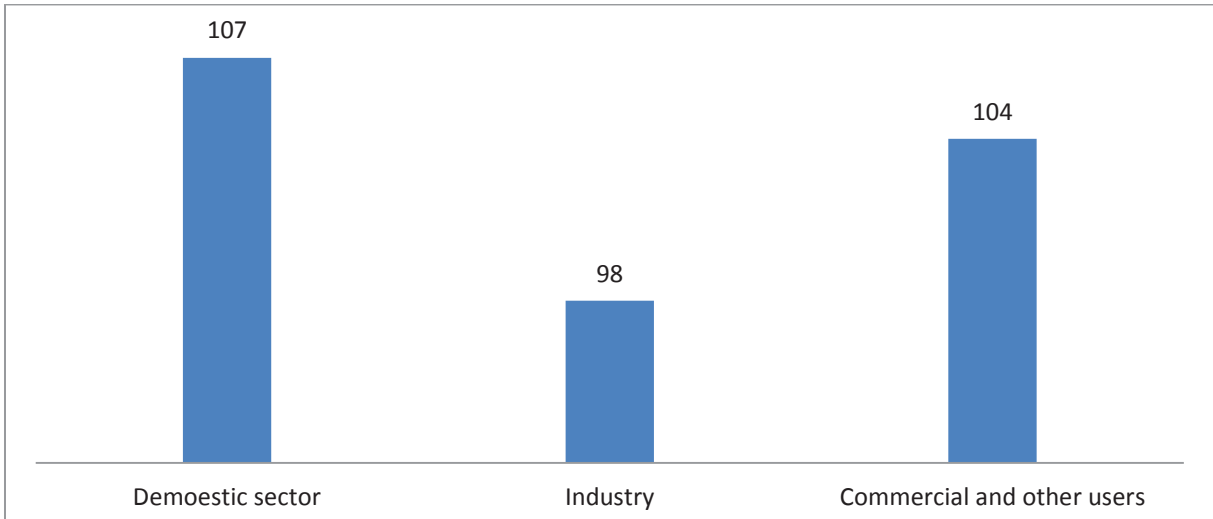


Figure 43: Consumption by different sector (TWh). UK

5.3 Renewable energy:

5.3.1 Renewable electricity installed capacity:

The total renewable installed capacity in 2014 was around 20 GW, and covers 22% of electricity production. Meantime the wind power had a huge contribution to the capacity of 12 GW and capacity of biomass and waste was around 3GW, further, solar energy and hydro power were 1.8 GW and 2.2 GW respectively. The diagram below demonstrates the history of installed capacity from 2002 to 2014.

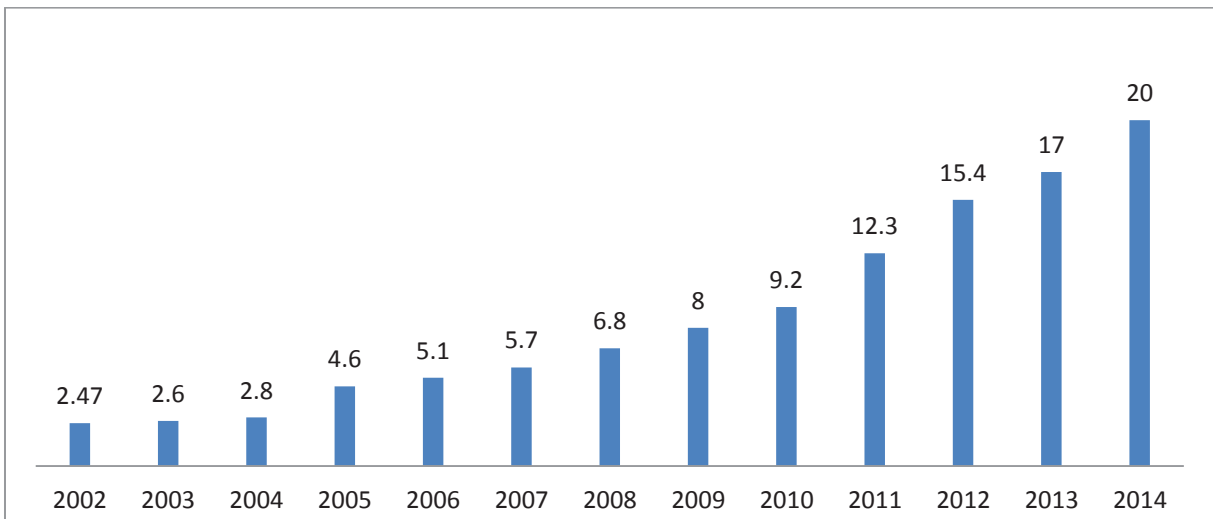


Figure 44: Installed renewable capacity (GW). UK [38] [39]

5.3.2 Renewable electricity generation and consumption:

In 2013 the total production of renewable energy was 70 TWh and in 2014, this amount changed to 80 TWh. The contribution of wind power production was around 30 TWh and the production from solar was 11 TWh and also the power generation from hydro power and bio energy were 6 TWh and 23 TWh respectively. The diagram illustrates the history of electricity production in turn of 2002 to 2014.

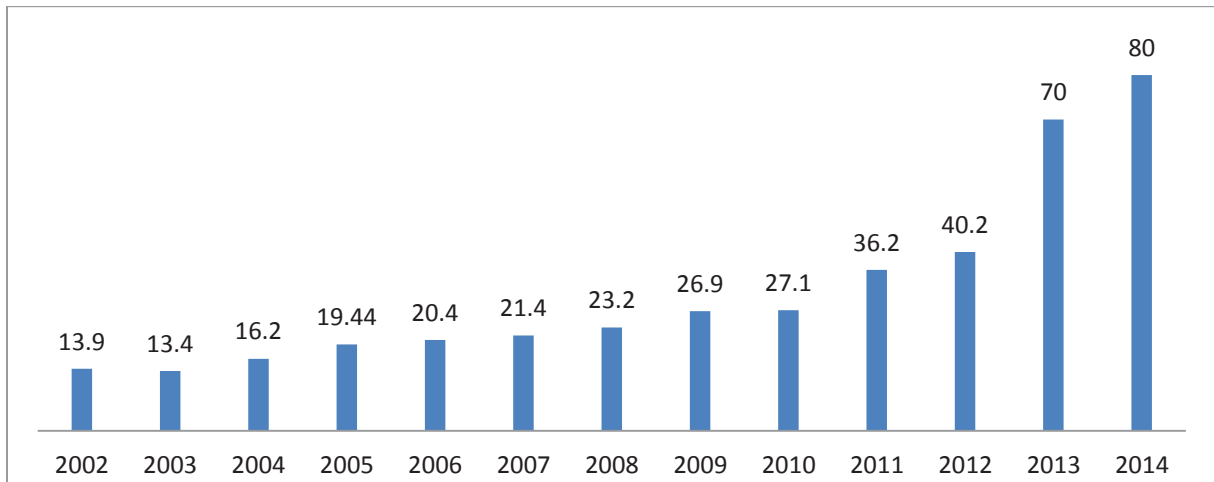


Figure 45: Total renewable electricity production (TWh). UK [38] [39]

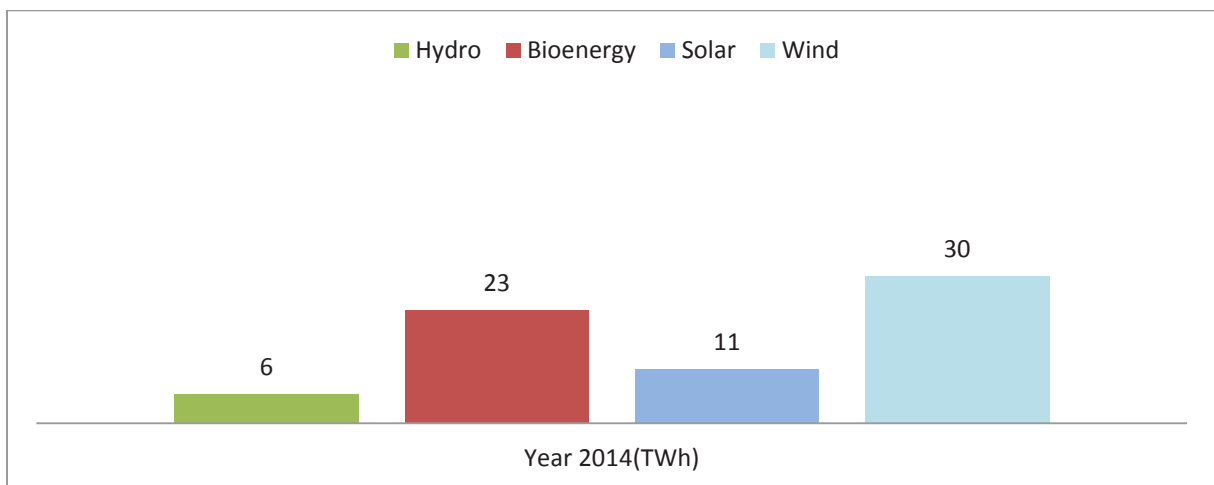


Figure 46: Share of renewable electricity production by different sources (TWh). UK

5.4 Wind power:

5.4.1 Wind power installed capacity:

The England is one the best places for growing wind energy and the world's sixth greatest contractor of wind energy. According to the industry reports, in the last three years more wind energy has been connected to the UK electricity network instead of gas capacity. During the last years the capacity of wind power rose by 15%, which are concluded on and offshore with total capacity of 12 GW and the purpose is reaching 14 GW by 2020. However around 1.4 GW is under construction and they will add to grid in early 2015. [40]

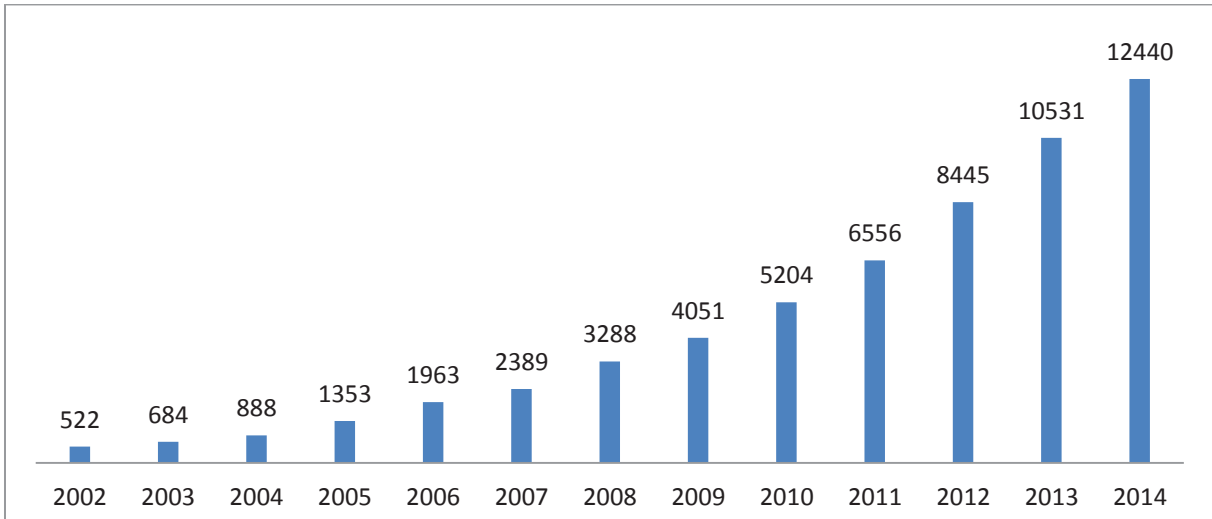


Figure 47: Wind power installed capacity (MW) . UK

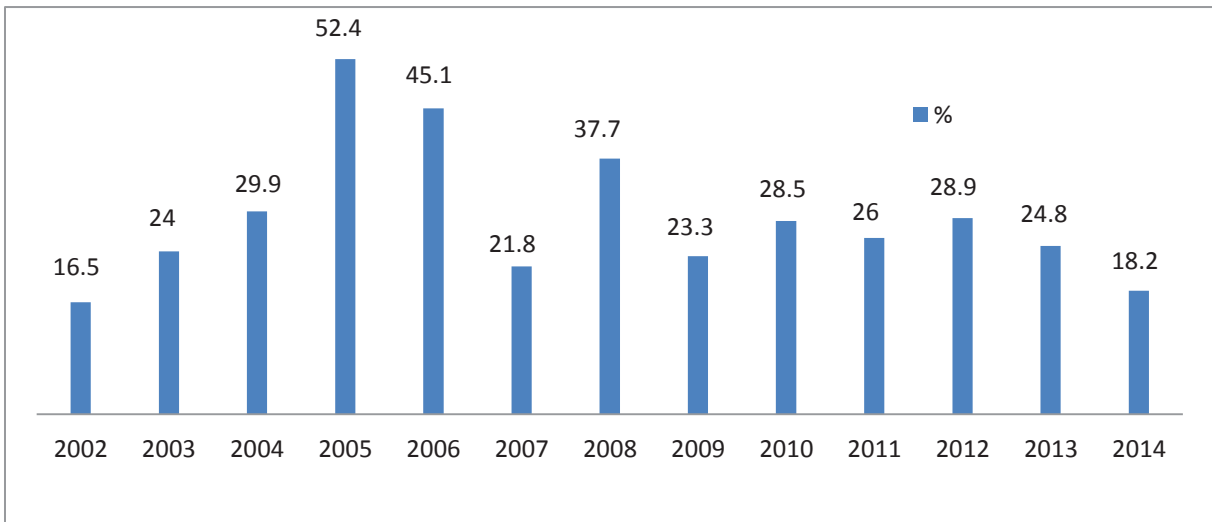


Figure 48: Annual increase of installed wind power capacity UK

5.4.2 Wind power generation and consumption :

At the end of 2014, the onshore section generated 17 TWh and this amount will supply 10% of the UK's gross electricity annually, which is approximately equal to consumption of four million homes. The latest reports show that today 750 projects are under construction and 4853 turbines have been fully installed with the capacity of 8071 MW. On the other hand, the UK government has special planning to expand the wind farms and commonly wind farm will take about 2 years of local usage with approval amount of 40%. The diagram below shows the history of wind power electricity production.

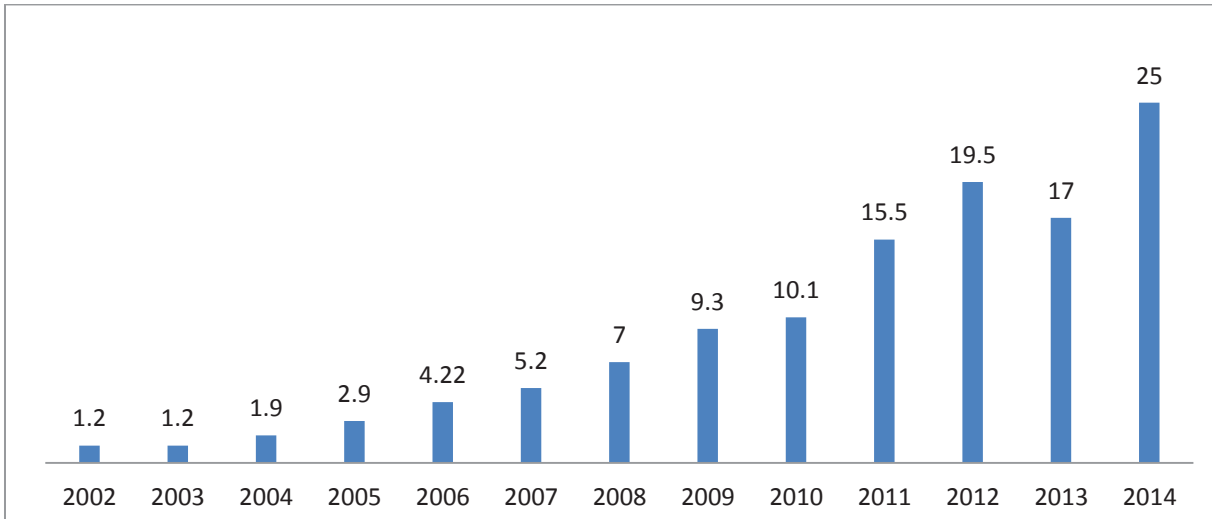


Figure 49: Wind power electricity net generation (TWh). UK [40] [41]

5.4.3 Offshore wind power :

The UK is one of the world leader in offshore wind energy with 1184 offshore turbines with the capacity of 4049 MW and 24 projects under construction. Gross capacity in UK water supplies 8TWh which is estimated to provide two million homes. In addition to the capacity already installed a further 11.9GW is either in construction or has planning approval, and a further 5.2GW is in the planning system. Industry projections see a total of around 6GW of capacity installed by 2016 and around 10GW installed by 2020, by which point offshore wind will supply between 8 and 10 per cent of the UK's electricity annually.

Farms:	24
Turbines:	1301
Capacity:	4494 MW

6. Electricity in Spain:

6.1 Electricity capacity and generation:

In Spain, Electrical generation, distributed into two sections which is covered peninsular and non-peninsular systems. In 2014, total installed capacity (peninsular and non-peninsular) was 108 MW and about 0.1% less than 2013 and the largest considerable conversion was decreased the contribution of coal by 159 MW. The major contribution in installed capacity was belong to combined cycle with 27 MW, the second was wind power with the capacity of 23 MW, the third was the coal plant with the capacity of 11.5 MW, further, installed capacity of nuclear power was 7.8 GW and solar power was 6.9 GW as well. The diagram below shows the history of installed capacity from 2002 to 2014.

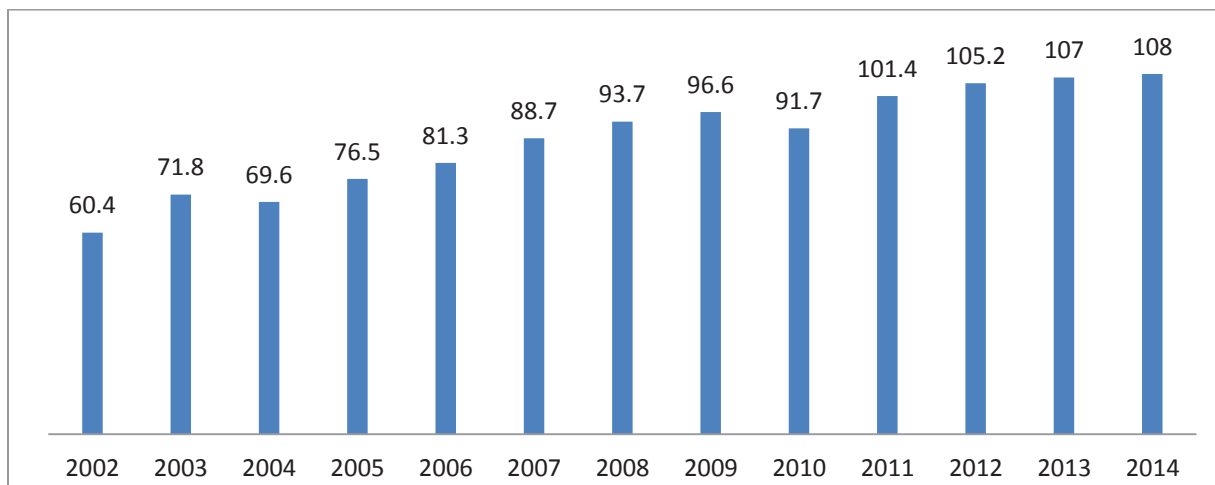


Figure 50: Total installed capacity (GW). Spain [42]

The total production in 2014 was 273 TWh, the main contributions in electricity production belong to nuclear and wind power with capacities of 57 TWh and 51.5 TWh respectively. The share of production of coal was 46.5 TWh and hydro power was 35.6 TWh, in addition the proportion of cogeneration plant 26.1 TWh and solar energy was 13 TWh as well. The table below shows the rate of electricity production at the turn of 2002 to 2014. The diagram below represents the share of electricity generation by different sector.

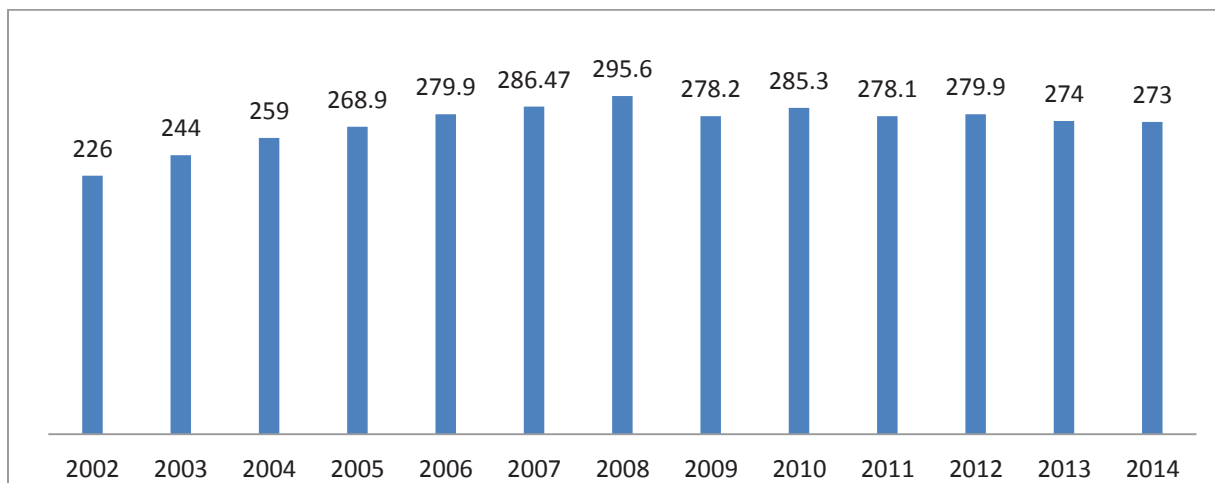


Figure 51: Total net generation (TWh). Spain [42]

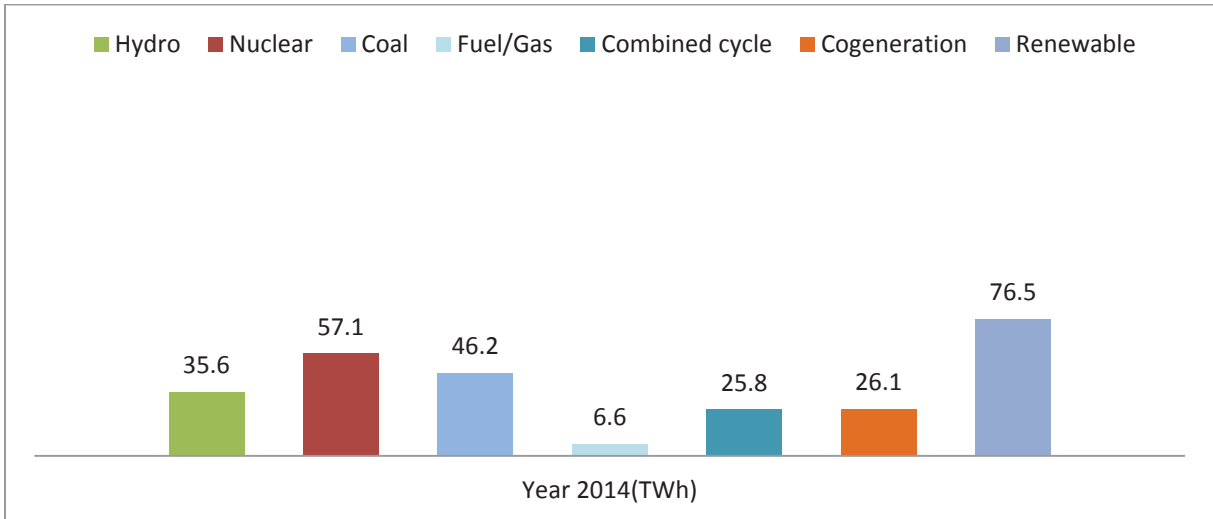


Figure 52: Total net generation by different sources (TWh). Spain

6.2 Electricity consumption:

In accordance with the annual report 2014 that is shown in the table below, in the Spain electricity system, the demand was close to 243.5 TWh, around 1.2 lower in comparison to 2013. The most demand was belonged to the nuclear by 21.9% and wind power by 20.4% and coal with 16.4%. The diagrams below show the history of consumption and contribution of sources in total electricity consumption.

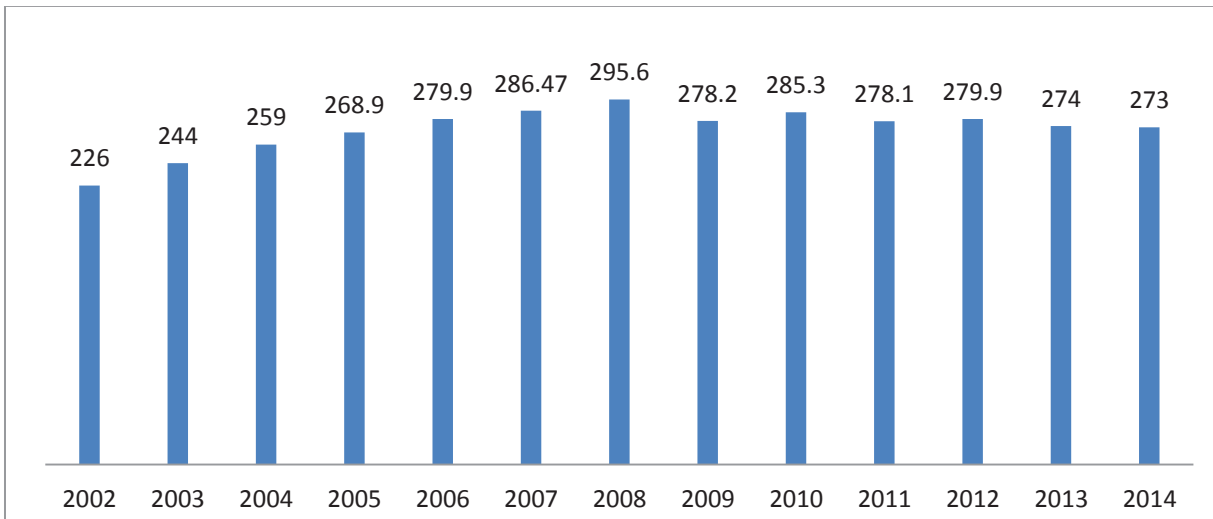


Figure 53: Total net consumption (TWh). Spain [42]

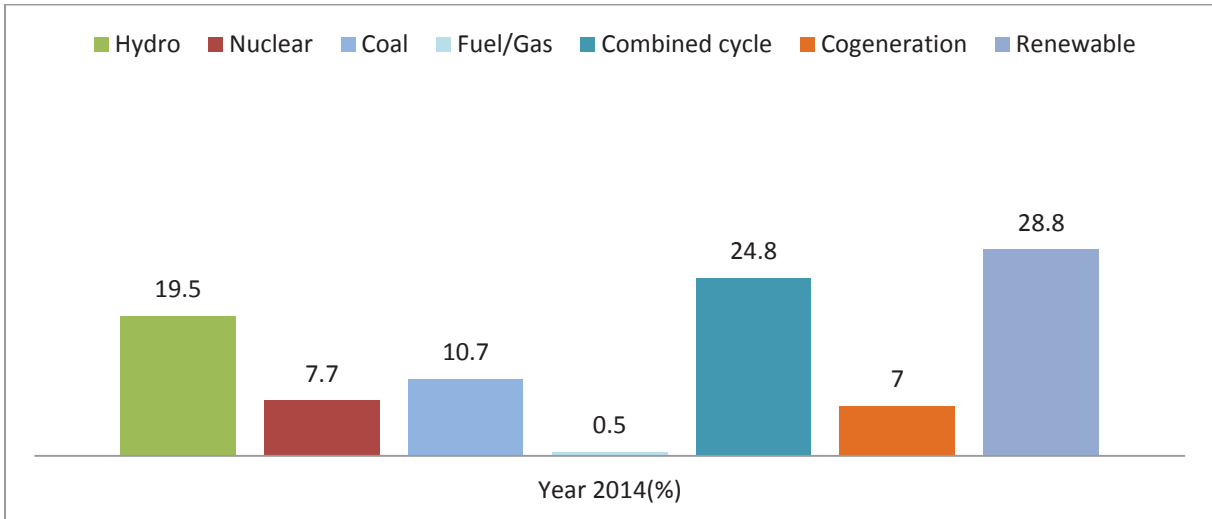


Figure 54: Total net consumption by different sources (TWh). Spain

6.3 Renewable energy:

6.3.1 Renewable electricity installed capacity:

Renewable energy has significant promotion in total energy production. In 2014, the total renewable installed capacity was around 49 GW with covering around 42.8%, the largest contribution belongs to Wind energy with the capacity of 23 GW and hydro power was 18 GW, solar 6.9 GW and renewable thermal was 1 GW. Two diagrams below illustrate the history of installed capacity from 2002 to 2014 and contribution of renewable sources.

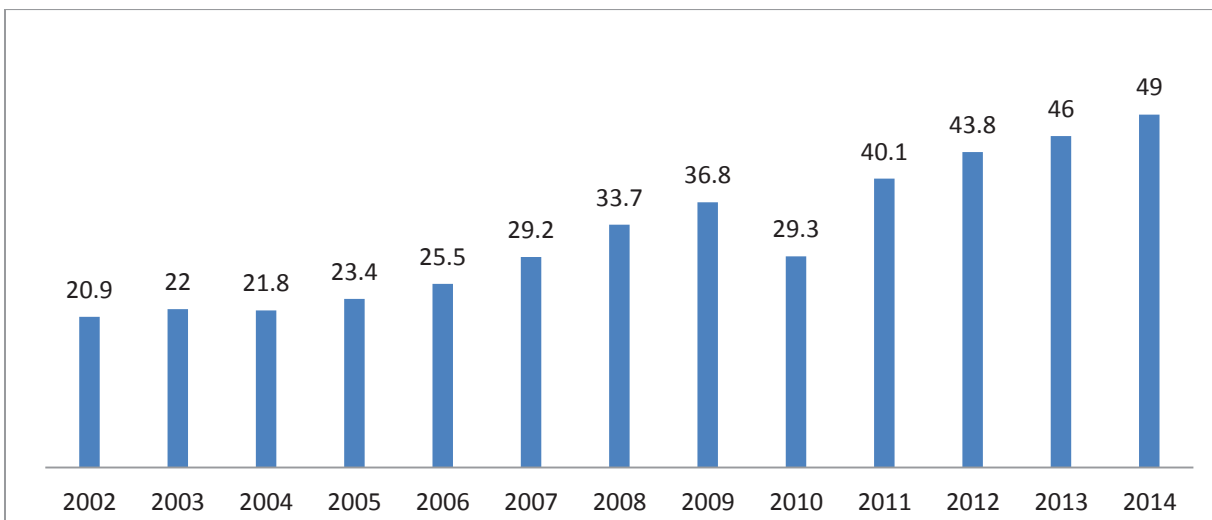


Figure 55: Total renewable installed capacity (GW). Spain [42]

6.3.2 Renewable electricity generation and consumption:

The total production of renewable energy was 102 TWh, meantime the total production from wind power was 51.5 TWh, and cogeneration power 26.1. The Hydro power was 7.1 TWh and also share of solar energy which is conclude solar photovoltaic and solar thermal was 13 TWh, in addition, renewable thermal was 26.1 The diagram below shows the promotion of renewable energy for total electricity production.

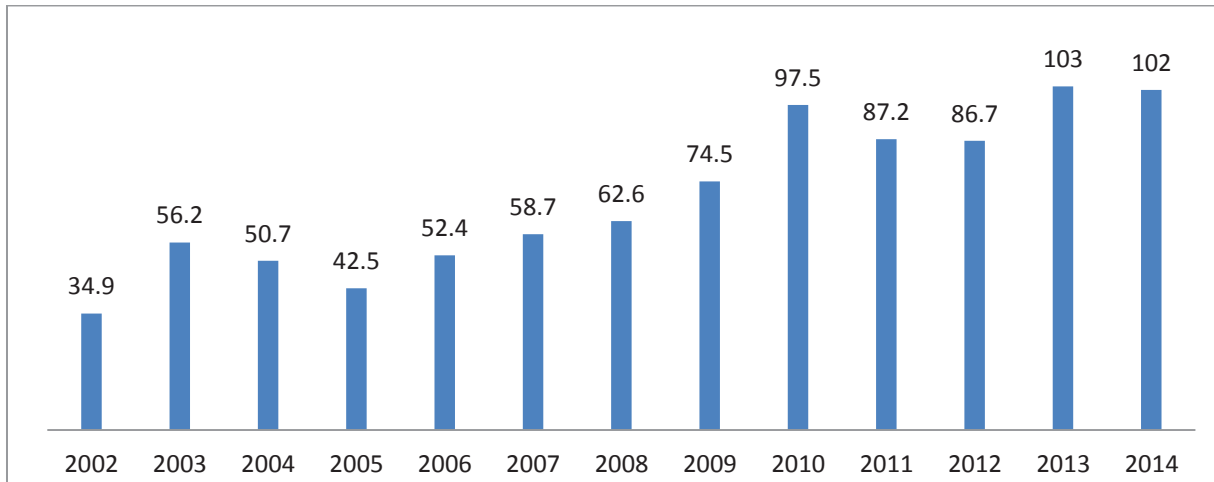


Figure 56: Renewable electricity production (TWh). Spain

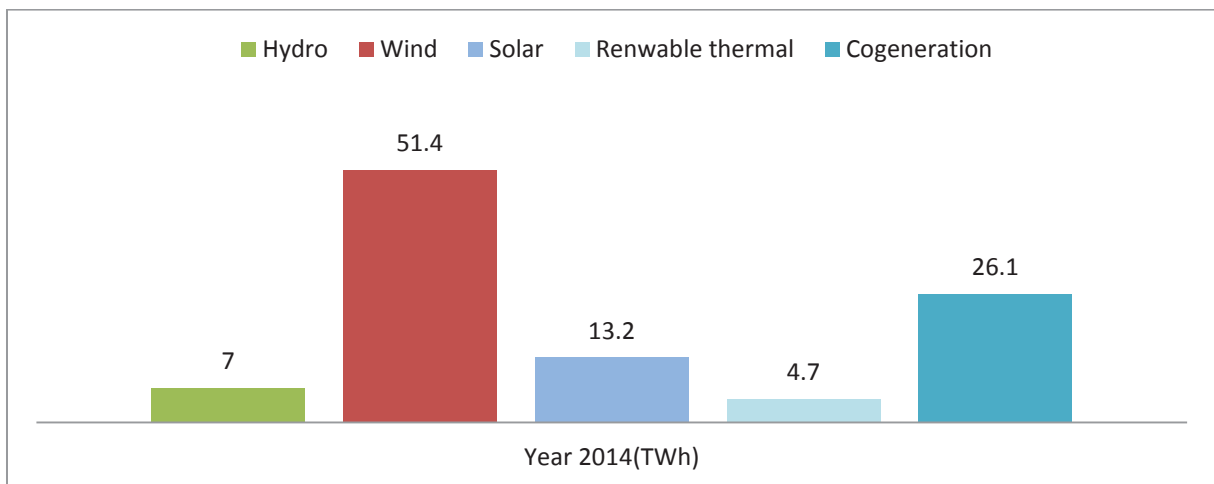


Figure 57: Renewable electricity production from different sources (TWh). Spain

6.4 Wind power:

6.4.1 Wind power installed capacity:

The wind energy is a crucial role in electricity production and Spain is the fourth largest producer of wind power in the world. By December 2014, installed wind capacity was around 22986 MW and more than 2000 turbines installed, by this index the wind energy has been a second producer of electricity production in 2014.

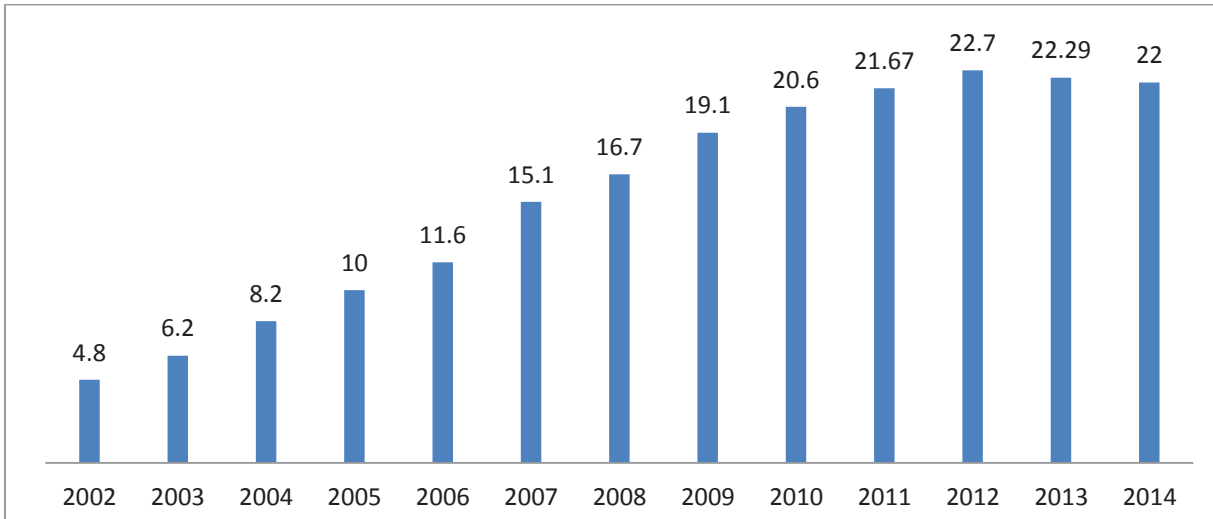


Figure 58: Wind power installed capacity (GW). Spain

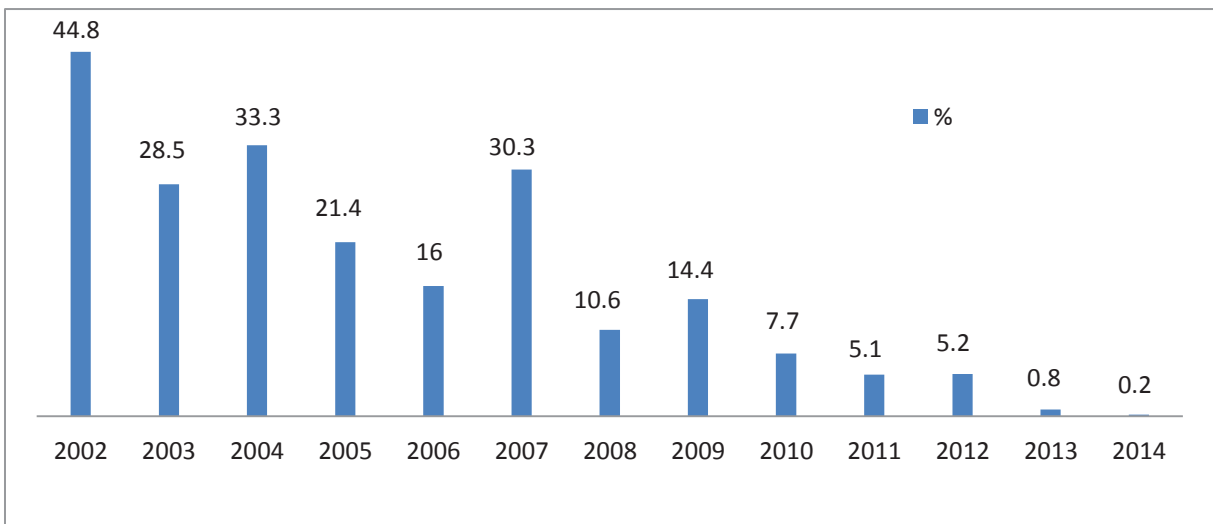


Figure 59: Annual increase of installed wind power capacity Spain

6.4.2 Wind power generation and consumption:

Due to the low activity in the wind power section during in 2013 and 2014, only 400 MW added to the grid. The total production from wind power in 2014 was 54.1 TWh, which is mainly produced by onshore sector because Spain has just 5 MW installed capacity in offshore production. The diagram below shows the improvement of wind power during the year of 2002 to 2014.

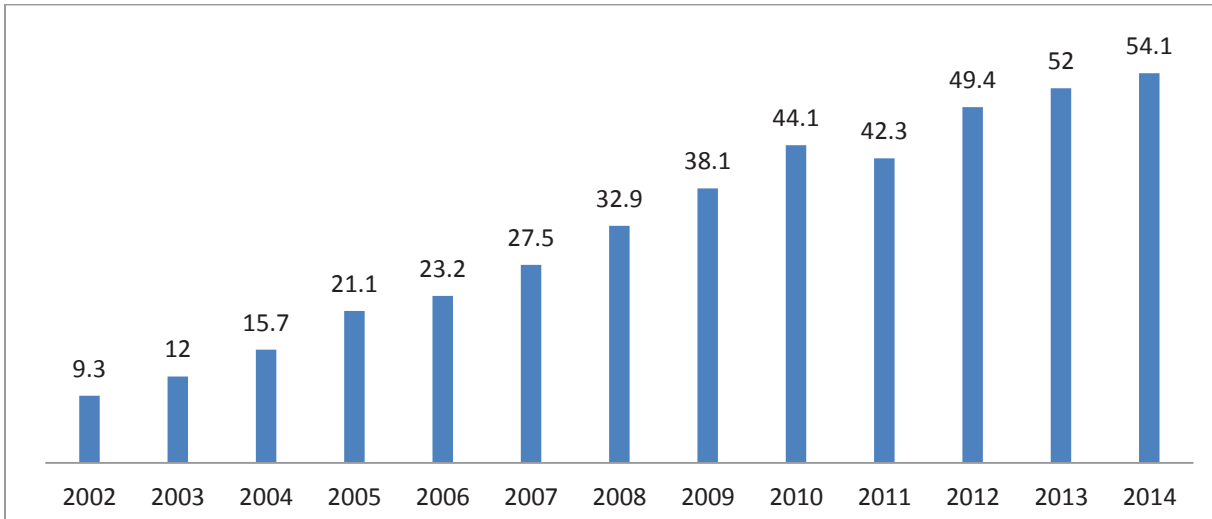


Figure 60: Wind power generation (TWh). Spain

6.4.3 Offshore wind power:

The total installed offshore wind power in Spain by the end of 2014 was 5 MW with only 1 farm which has only 1 turbine of 5 MW..

Farms: 1
 Turbines: 1
 Capacity: 5 MW

7. Electricity in Sweden:

7.1 Electricity capacity and generation:

In 2013, the total generation capacity in Sweden was 38.27 GW, The hydro power with the capacity of 16.15 GW was the main installed capacity, the second was nuclear power with the capacity of 9.53 GW and also thermal power and wind power were other sectors with capacities of 8.07 GW and 3.74 GW respectively.

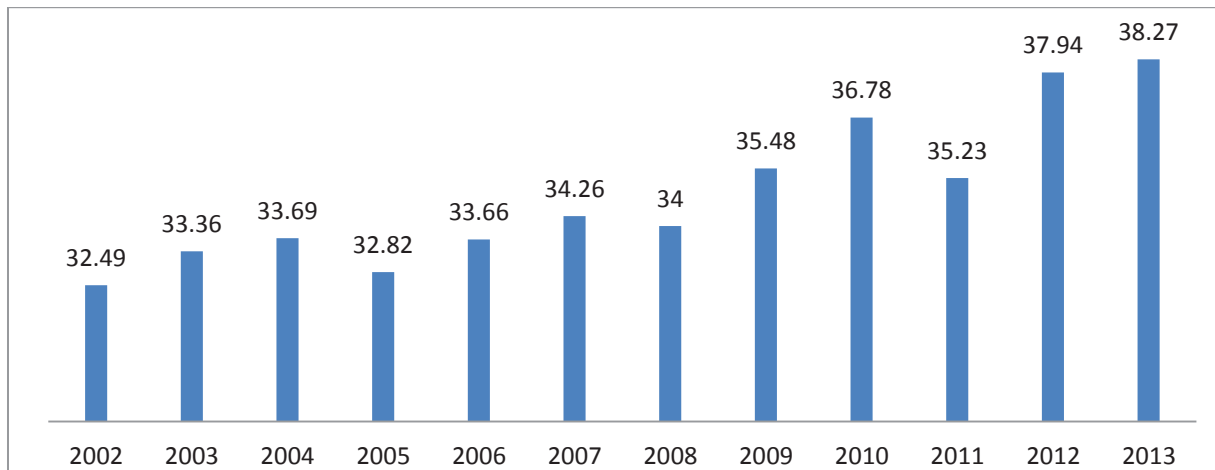


Figure 61: Total installed capacity (GW). Sweden [56]

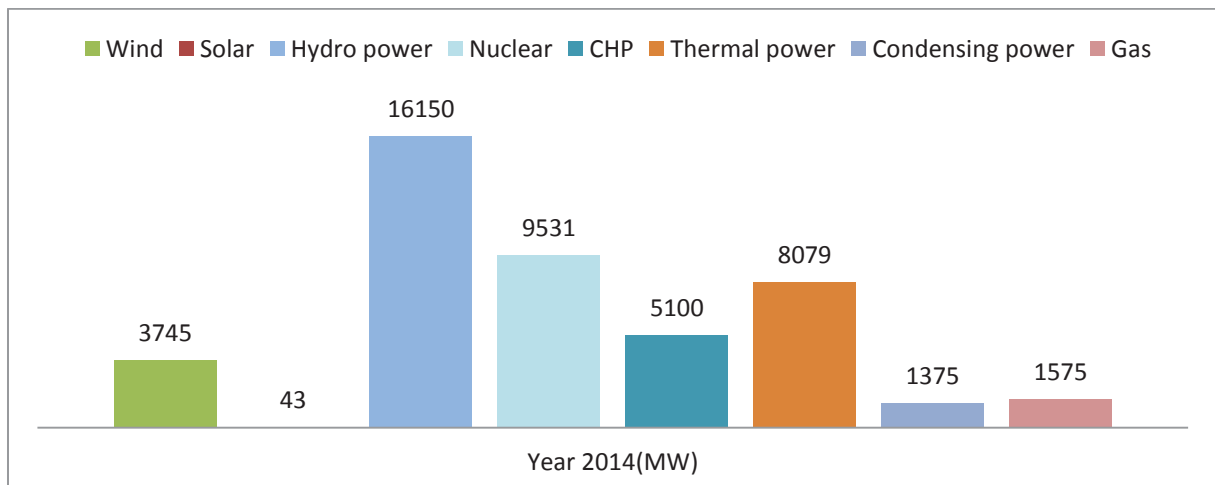


Figure 62: Total share of installed capacity by different sectors (MW). Sweden [56]

In 2014, Sweden produced 151 TWh and in 2013 the total electricity production was 150 TWh. The contribution of hydro power was almost 61 TWh and the wind power production was 10 TWh compared with 7 TWh the year before. Nuclear power had an increase during the year 2013 to nearly 64 TWh and other thermal power decreased slightly to just over 15 TWh.

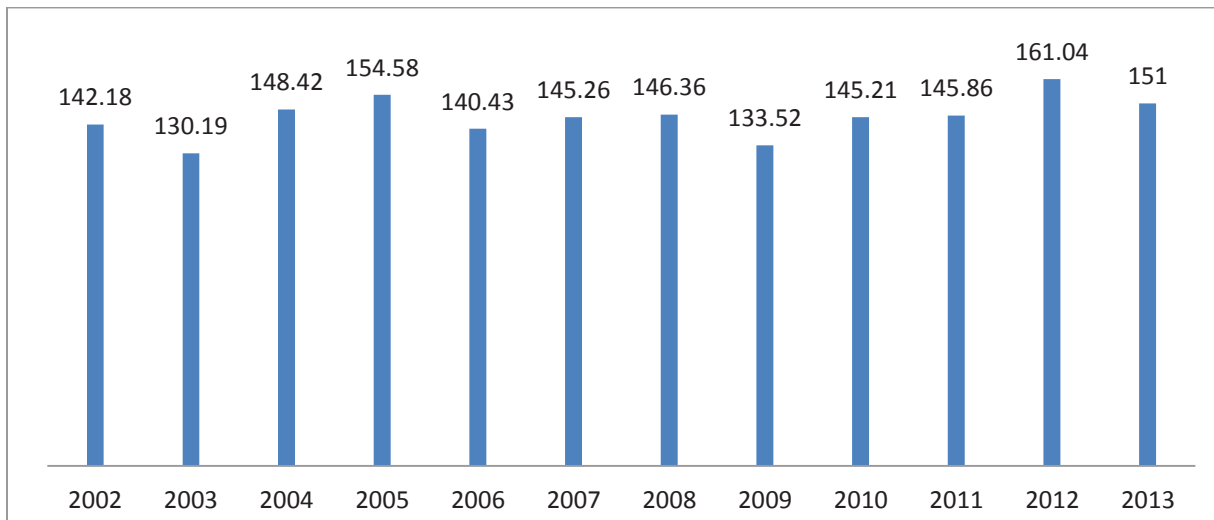


Figure 63: Total net generation (TWh). Sweden [57]

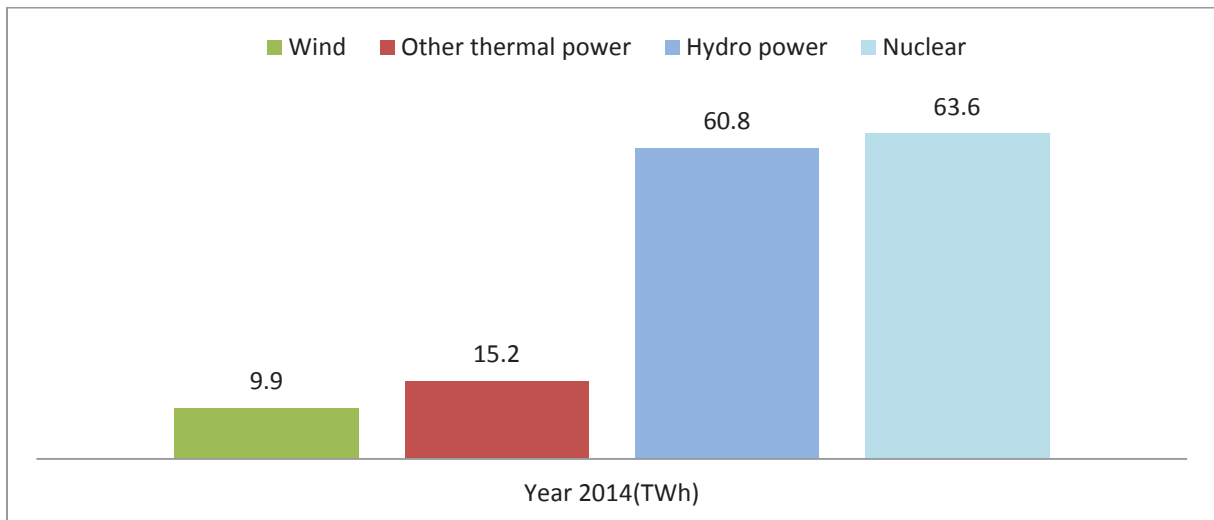


Figure 64: Total share of electricity production by different sources (TWh). Sweden

7.2 Electricity consumption:

In 2013 the total electricity consumption was 139.5 TWh and about 2.4% decreased from 2012. The main consumer in Sweden were households and services with the consumption of 71 TWh and the second largest was belongs to distribution losses with 11 TWh. The industry consumption was 51 TWh and refineries and district heating was 10.5 TWh. Transportation was the lowest consumer which accounted for 3 TWh. [58] [59]

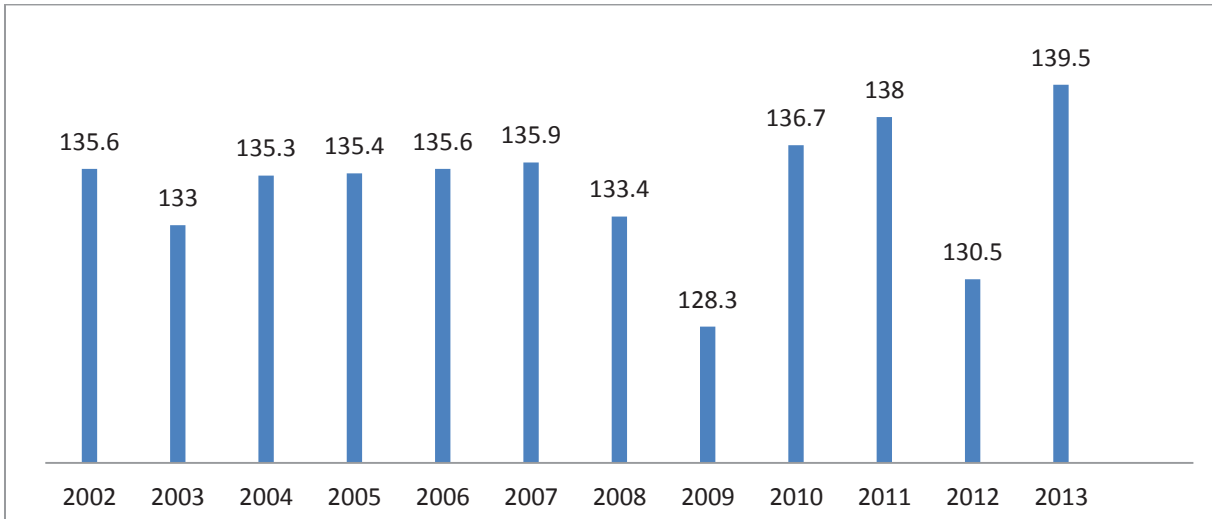


Figure 65: Total electricity net consumption (TWh). Sweden

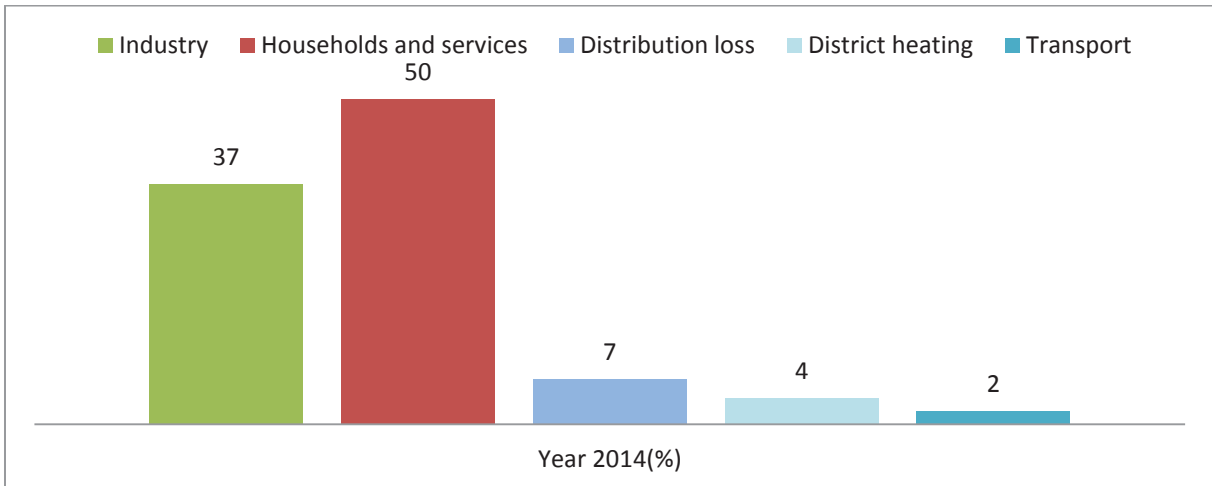


Figure 66: Total net consumption by different sectors (%). Sweden

7.3 Renewable energy:

7.3.1 Renewable electricity installed capacity:

Sweden is one of the leading country in production of renewable energy. In 2013, around 52% of the gross electricity generation was produced from renewable energy. The most significant sources are hydro power and bio energy and wind power as well. The Sweden energy agency has plans for expansion of wind power by 64 %, bio energy 27% and hydro power by 8%, further sun and peat will increase less than 0.1%. The diagram below shows the history of installed capacity process. [57][60][61]

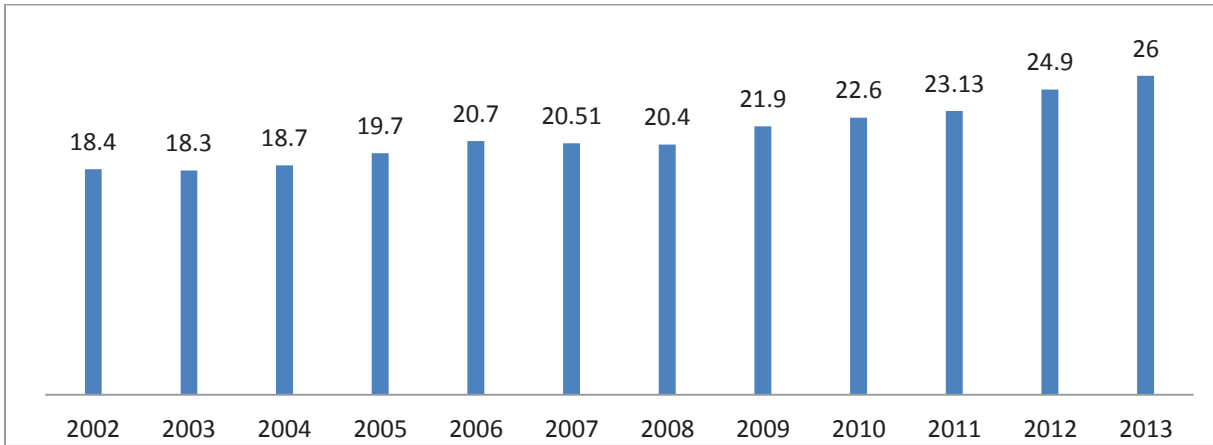


Figure 67: Total renewable installed capacity (GW). Sweden

7.3.2 Renewable electricity generation and consumption:

Total electricity production from renewable energy in 2013 was around 99 TWh, which is mainly produced by hydro power, wind power and bio energy. [57]

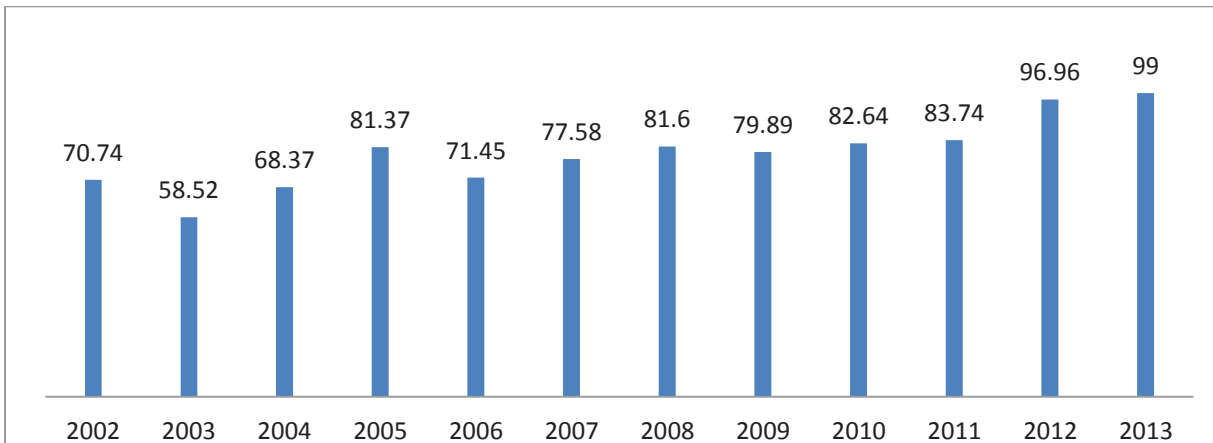


Figure 68: Total renewable production (TWh). Sweden

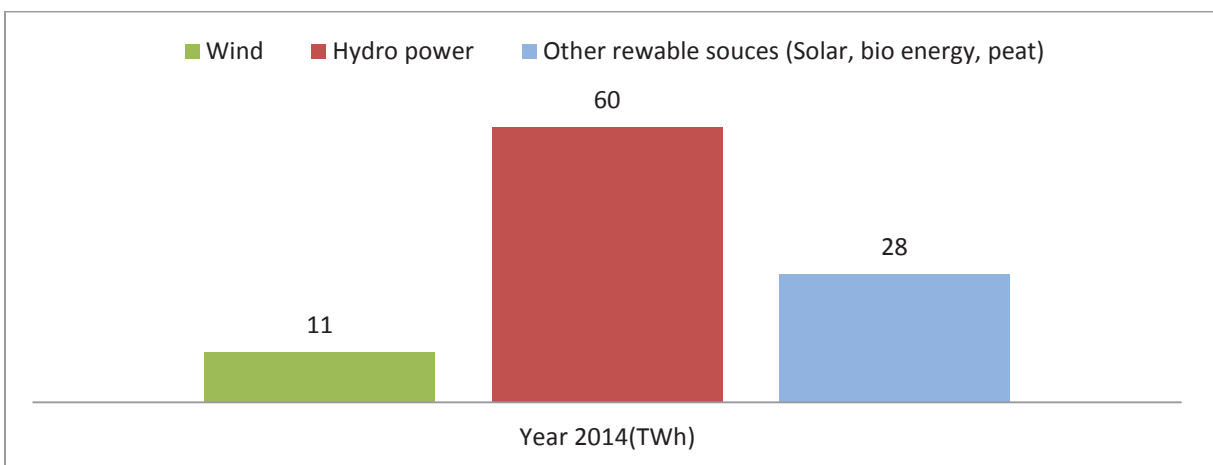


Figure 69: Share of renewable energy from different sources (TWh). Sweden

7.4 Wind power:

7.4.1 Wind power installed capacity:

In 2013, 724 MW onshore wind power was installed, the total wind power installed capacity was 4470 MW and in 2014 was 5425 MW and covered 6% Swedish power grid. The Swedish national agency has plans to expand the capacity about 700 to 800 MW per year, which is equal to 1.8 TWh electricity generation and if the adequate adjustments prepare, around 20 TWh electricity production could be achieved by 2020. [62] [63] [64]

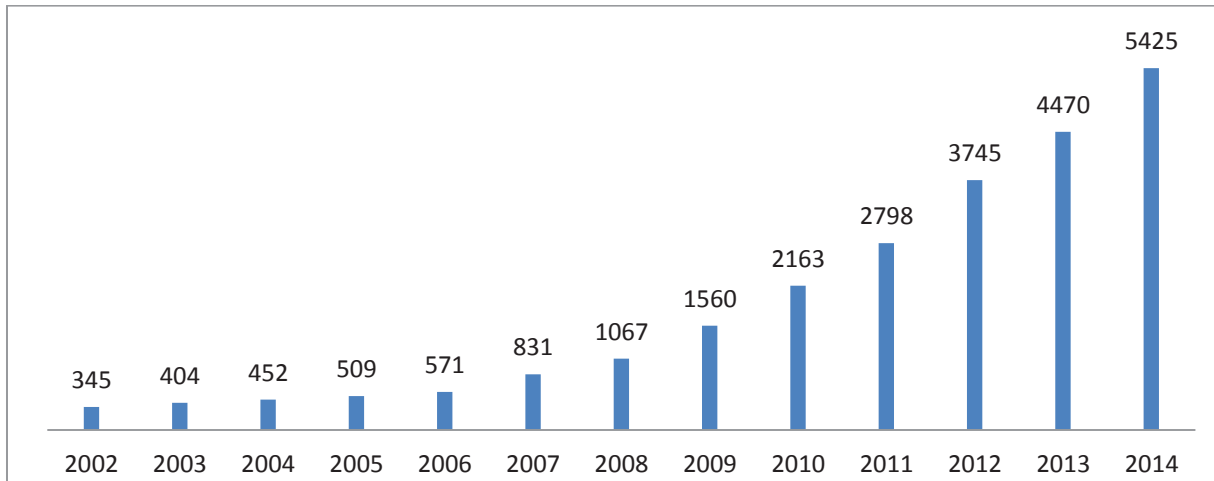


Figure 70: Total installed capacity (MW). Sweden

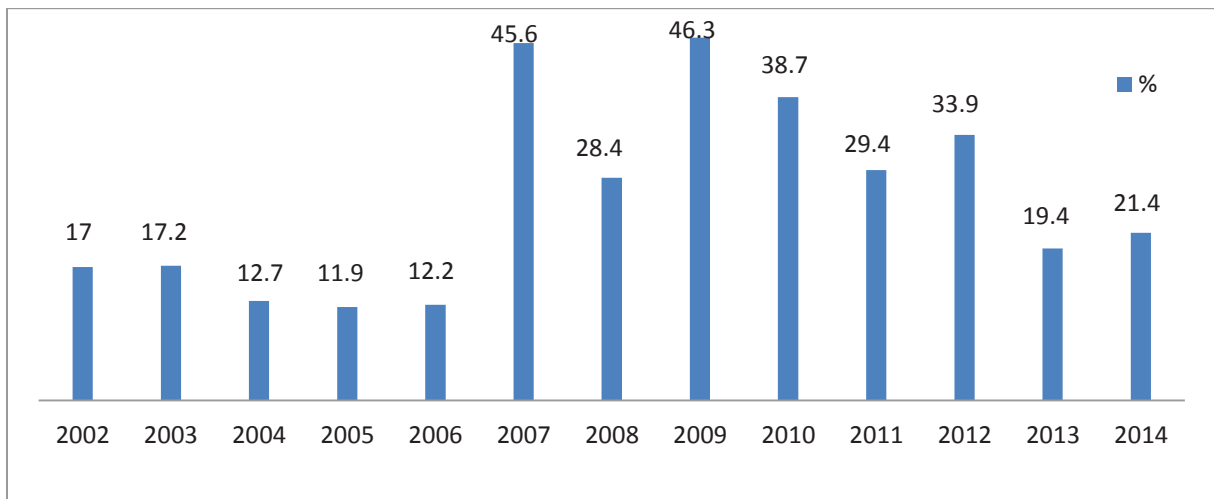


Figure 71: Annual increase of installed wind power capacity Sweden

7.4.2 Wind power generation and consumption:

The total production from wind power was 9.9 TWh in 2013, with around 841 wind farms. The graphs below represent the history of wind power installed capacity and generation in turn of 2002 to 2013. [62] [63] [64]

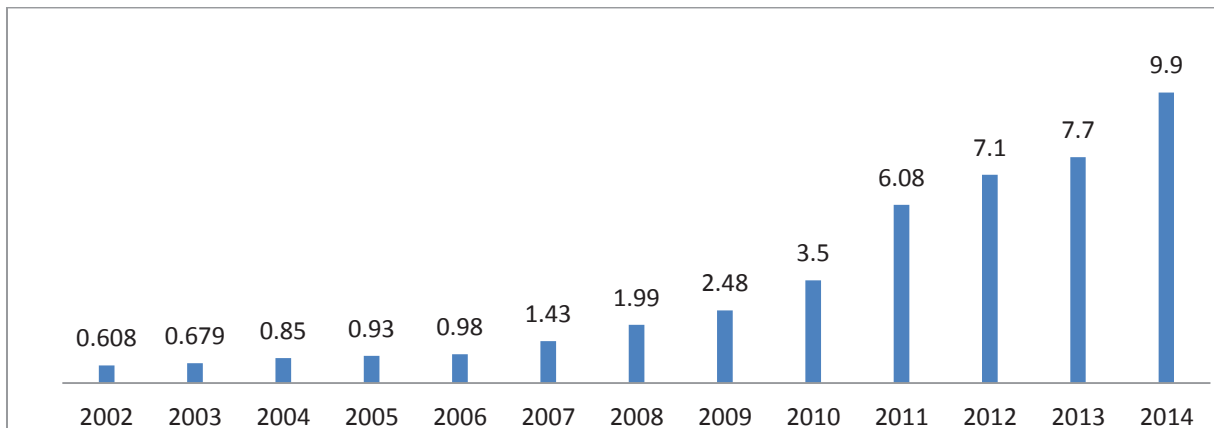


Figure 72: Total wind power generation (TWh). Sweden

7.4.3 Offshore wind power:

Sweden has 6 offshore wind power farms by the end of 2014, which have 91 turbines in total and installed capacity is 212 MW.

Farms:	6
Turbines:	91
Capacity:	212 MW

8. Electricity in Norway:

8.1 Electricity installed capacity:

In Norway the total installed capacity was 32 GW at the turn of 2013-2014 and have increased 367 MW from the previous year. Around 95% of installed capacity is based on hydro power and thermal capacity is close to shut down due to the CHP (composition of heat and power) capacity by 68MW. Also Norway has just two reserve gas power with the capacity of 300MW in addition the total installed capacity of wind power is 811 MW. The diagram below introduced the history of installed capacity in Norway during the 2002 to 2014.

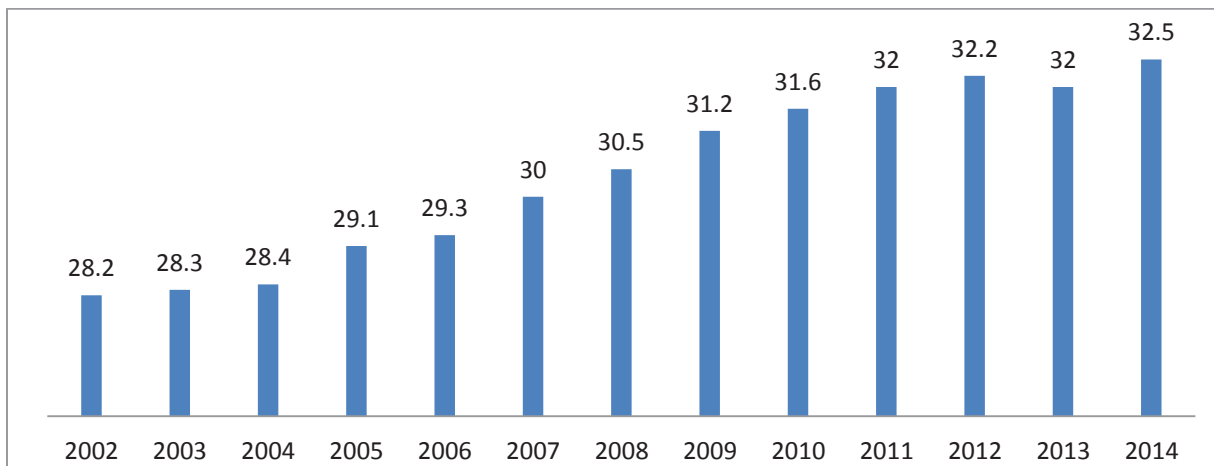


Figure 73: Total installed capacity (GW). Norway [43] [44]

In 2014, the total electricity production was around 141 TWh and Norway is leader country in the Europe to produce the electrical energy through hydro power plant with generation of 130 TWh, which covers 96% whole of electrical energy production. In addition the contribution of thermal power production is 6.2 TWh approximately 2.2% and wind power is around 2.2 TWh relatively 1.8%, supplied total electrical production. Further, no nuclear power plant and solar have established in Norway. [43] [44] [45]

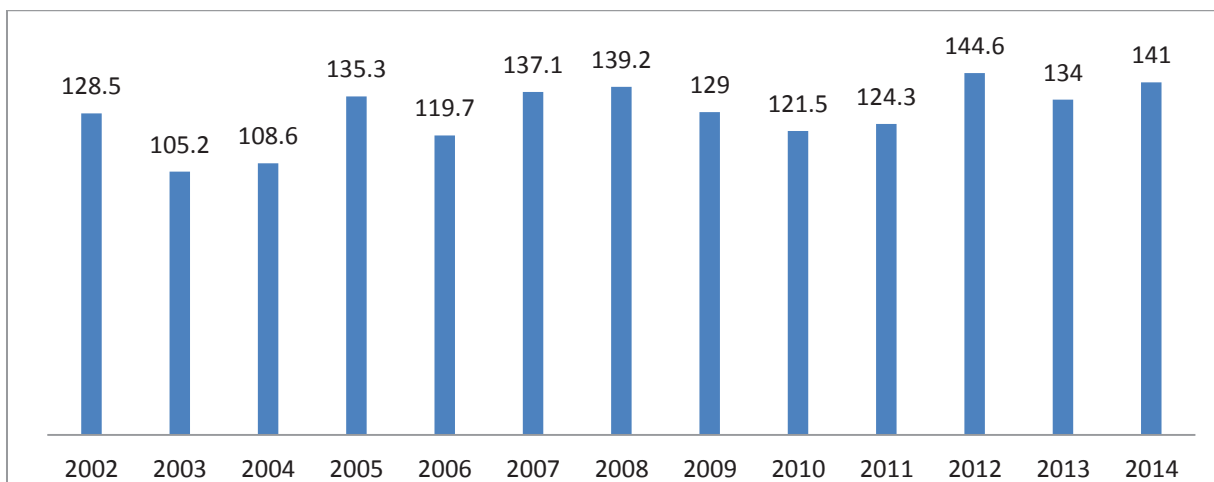


Figure 74: Total electricity net generation (TWh). Norway

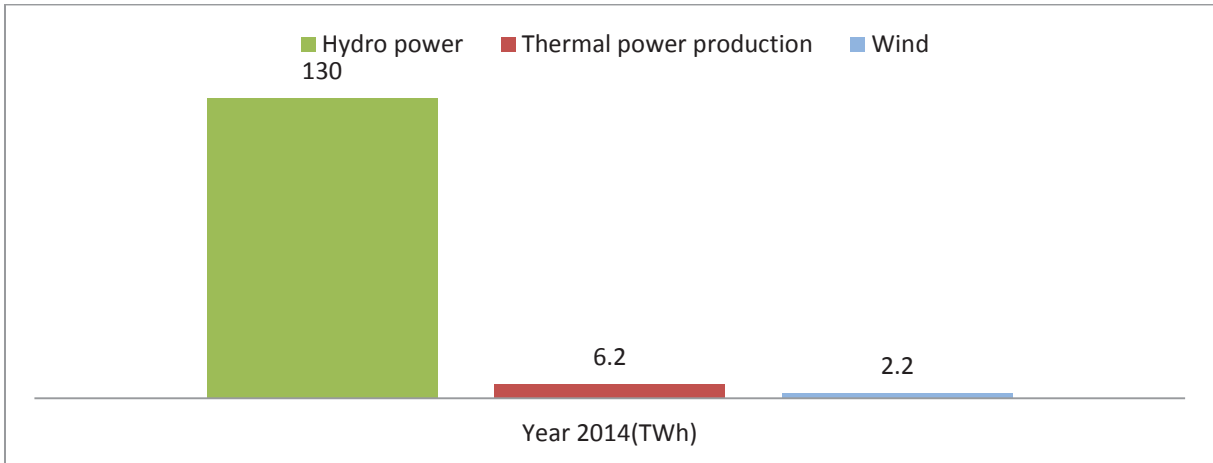


Figure 75: Total electricity production by different sector

8.2 Electricity consumption:

In 2014, the gross electricity consumption was about 126 TWh meanwhile in 2013 the consumption was around 128 TWh. In 2013 the net consumption rate includes pump storage with 1406 GWh and loss with 8024 GWh. On the other hand the gross consumption amount was mining and manufacturing 51928 GWh, Services such as transportation 26647 GWh also private households and agriculture 40965 GWh. [44] [45]

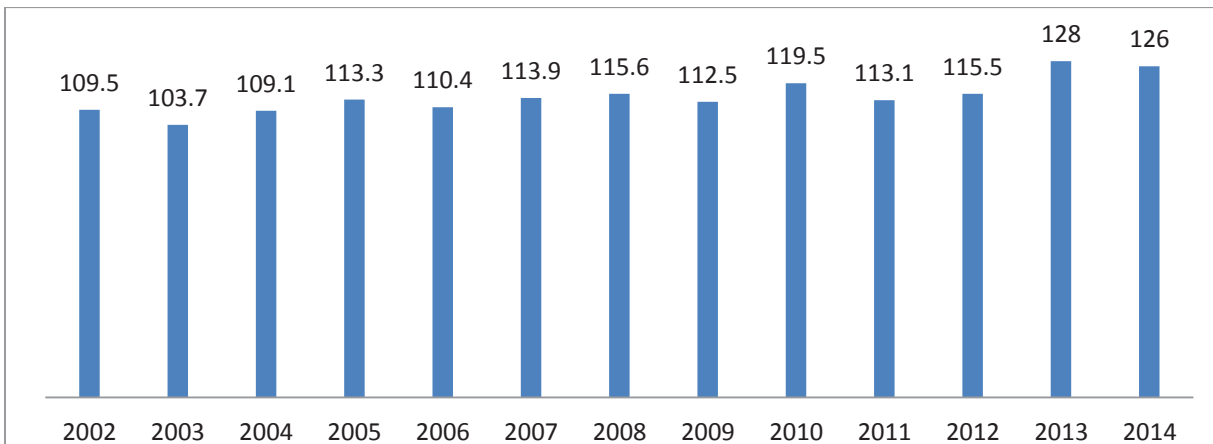


Figure 76: Total electricity net consumption (TWh). Norway

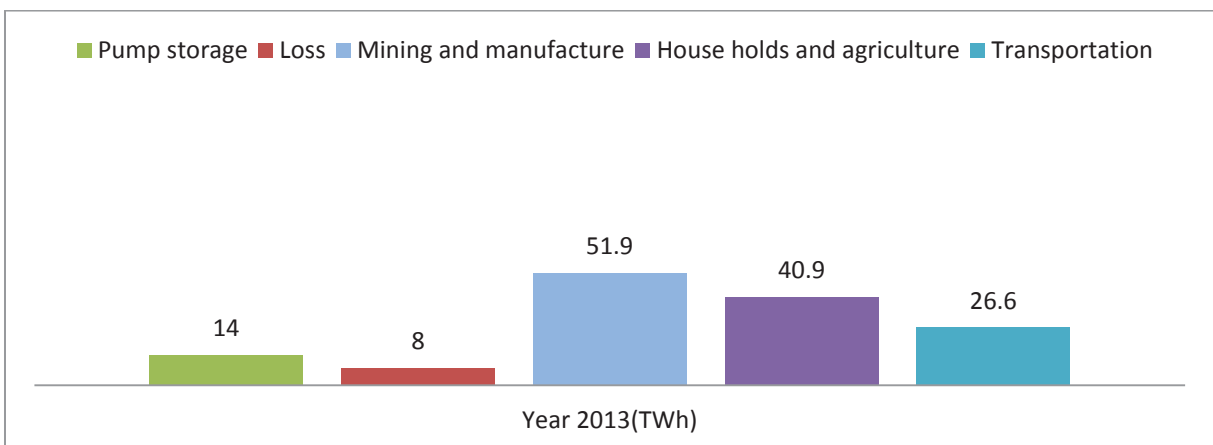


Figure 77: Electricity consumption by different sectors (TWh). Norway

8.3 Renewable energy:

8.3.1 Renewable electricity installed capacity:

Norway has 29.5 GW installed renewable electricity capacity by the end of 2012, which has increased by 10% with compare to 2002. Norway has a positive trend toward the renewable electricity in the last decade.

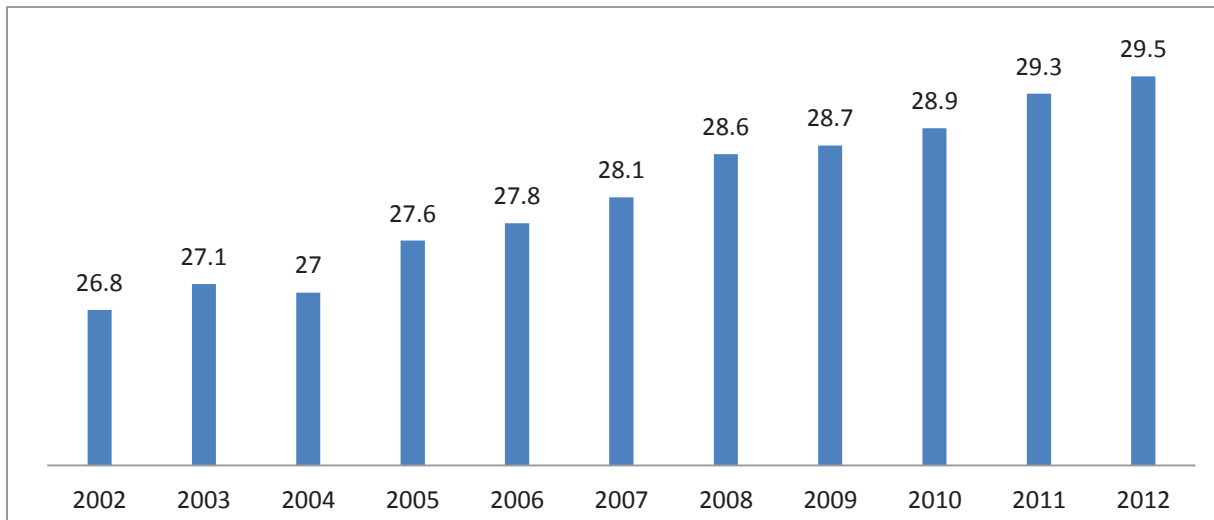


Figure 78: Total renewable electricity installed capacity (GW) Norway [1]

8.3.2 Renewable electricity generation and consumption:

In Norway 56% of the energy requirements is generated by the renewable energy and the government target is scrimp the emission of greenhouse gases by 30% by expanding the renewable energy to 67%. In Norway, the hydroelectric power covers the majority of total electricity production with a contribution of 96%, meanwhile no solar power has been established, but Norway is the global leader in producing of solar grade silicon. [46] [47]

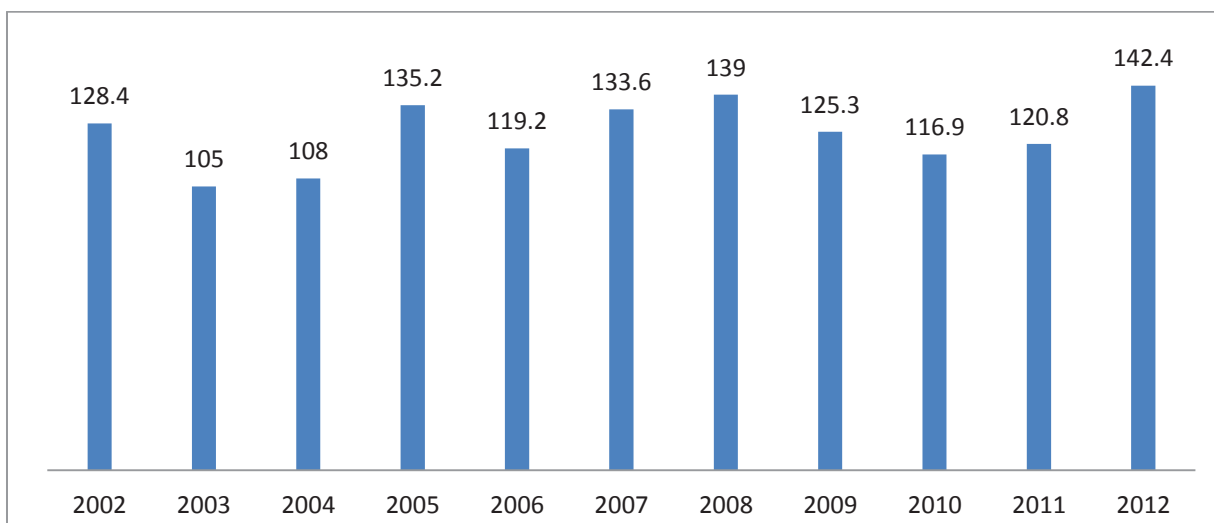


Figure 79: Total renewable electricity production (TWh) Norway

8.4 Wind power:

8.4.1 Wind power installed capacity:

Norway is one the best place for developing the wind energy, but expanding of this market has not considerably grown in comparison to other European countries. By the end of 2013 the installed capacity was around 771MW and by the end of 2014 the installed capacity steps up to 819MW.

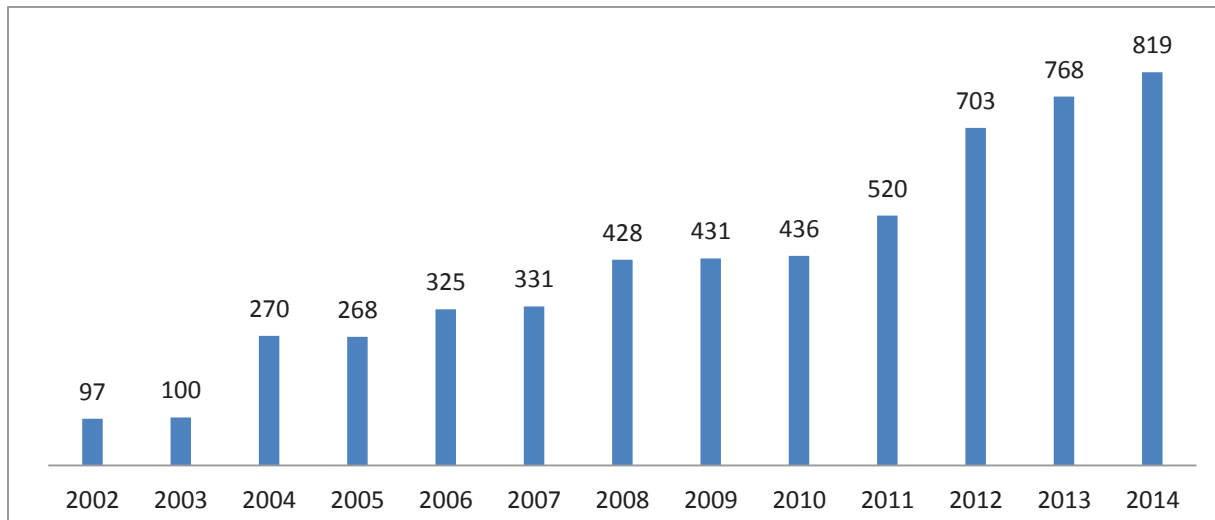


Figure 80: Total wind power installed capacity (MW). Norway

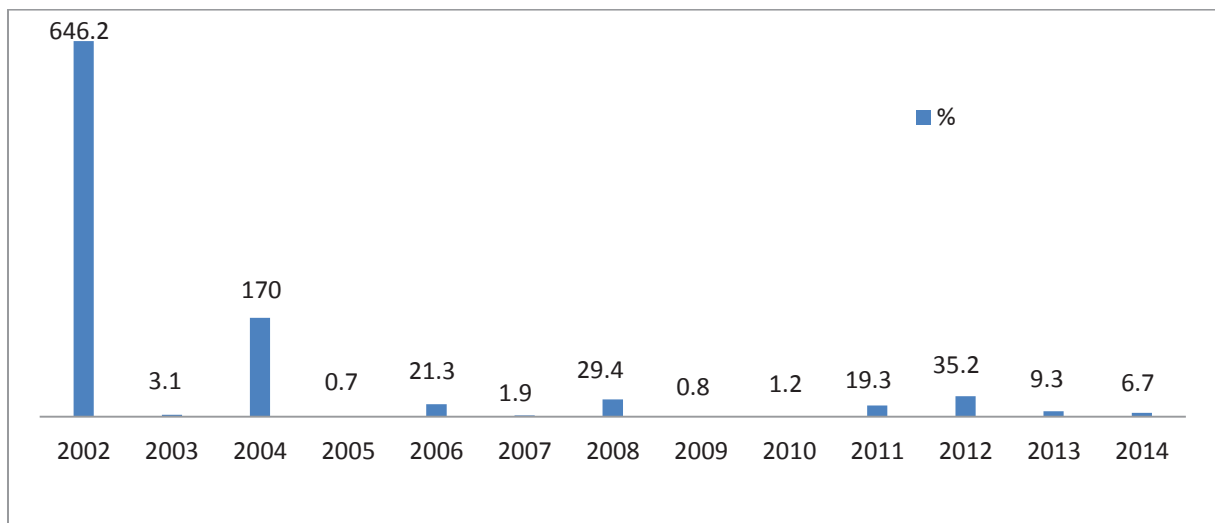


Figure 81: Annual increase of installed wind power capacity Norway

8.4.2 Wind power generation and consumption:

The distribution of electricity from wind power is around 2.2 to 2.4 TWh. This rate corresponds to 1.8% of the electricity produced in total. The government expected to provide 3000-3500 MW capacity by 2020 that estimated to produce 6 to 8 TWh. Further, the majority of wind power projects is located on the land base. According to the latest report, around 398 wind turbines with the capacity of 856 MW installed and they produce electricity around 2.2 TWh.. [46] [47] [48]

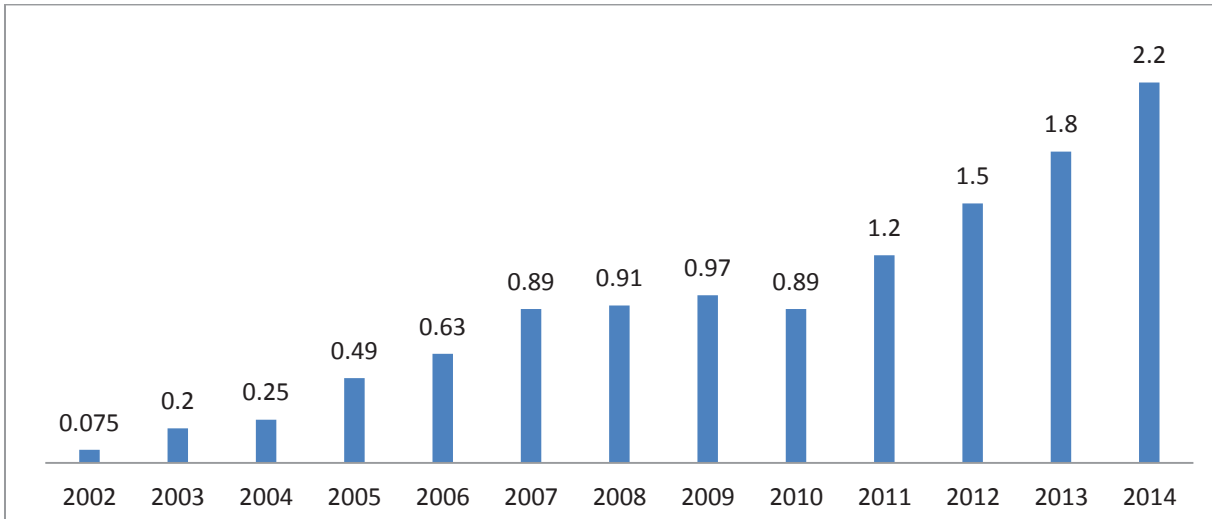


Figure 81: Total wind power electricity production (TWh). Norway

8.4.3 Offshore wind power:

Norway has just one offshore wind turbine that this turbine is the world's first floating turbine with the capacity of 2 MW. [6]

Farms: 1
 Turbines: 1
 Capacity: 2 MW

9. Electricity in Finland:

9.1 Electricity capacity and generation:

The Finland's electricity installed capacity remains almost constant from last decade, and currently the installed electricity capacity is around 17-18 GW.

The major share in installed capacity comes from the different kind of fossil fuels after that the major share is Nuclear power and after that hydro comes.

In the recent years wind and solar had played their role and emerge as new sources of electricity.

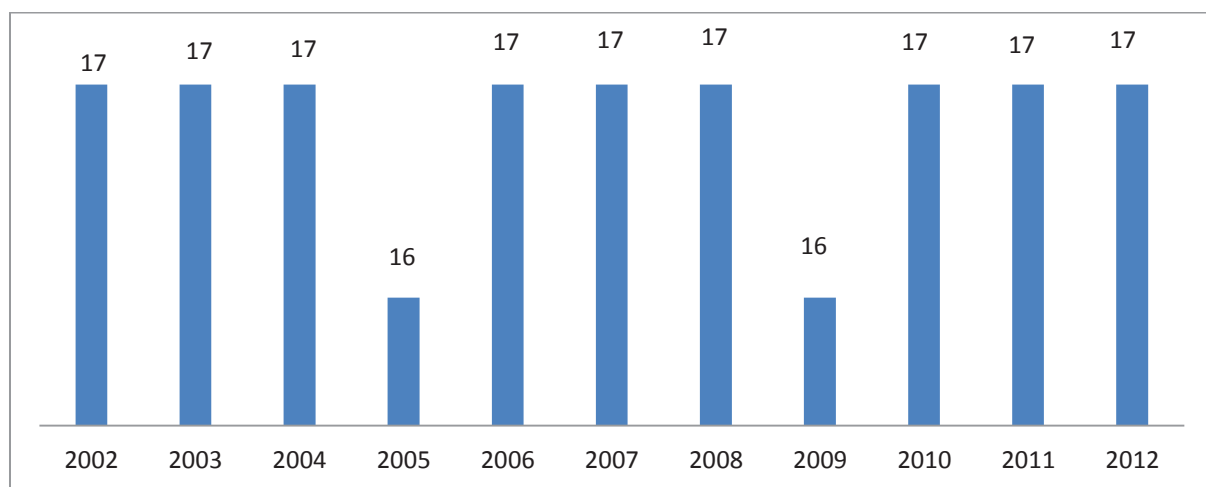


Figure 82: Installed electricity capacity (GW) Finland [1]

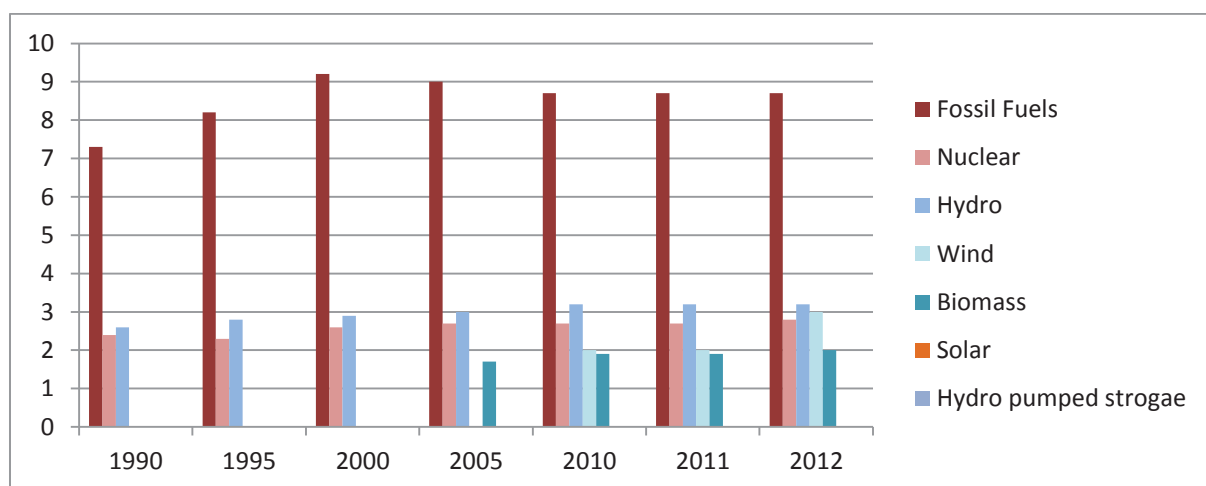


Figure 83: Installed electricity capacity (GW) by different energy sources Finland [1]

Finland was on 41st position in term of electricity production with 71,200 GWh or 71.2 TWh by the end of 2013. [5] The whole electricity sector in Finland depends upon the nuclear power, wood consumption and forest industry black liquor, electricity import from neighboring countries and cogeneration. The import of electricity from neighboring countries is 20%.

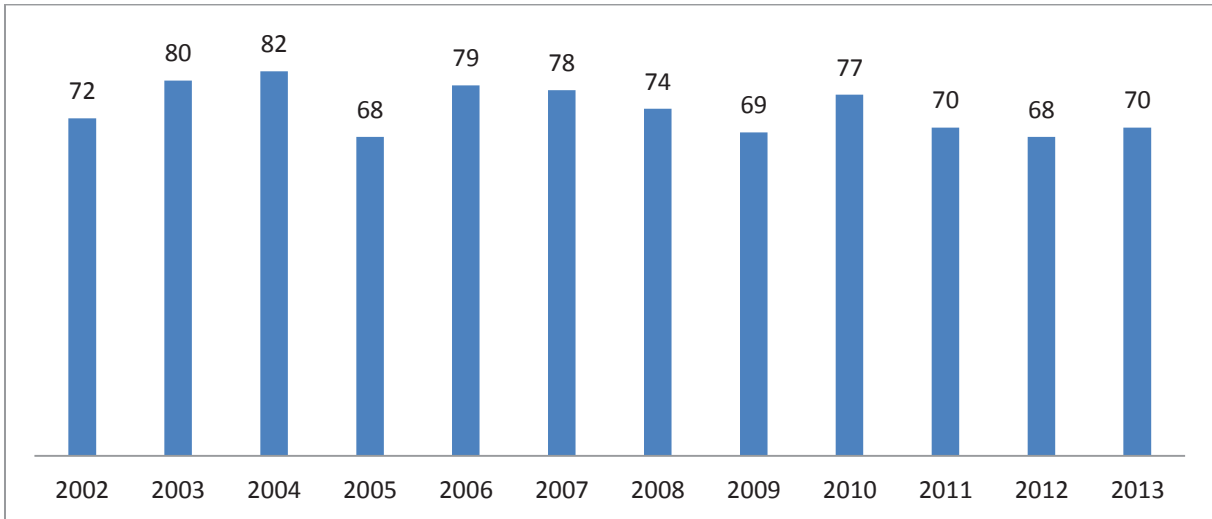


Figure 84: Electricity net generation (TWh) Finland [1] [5]

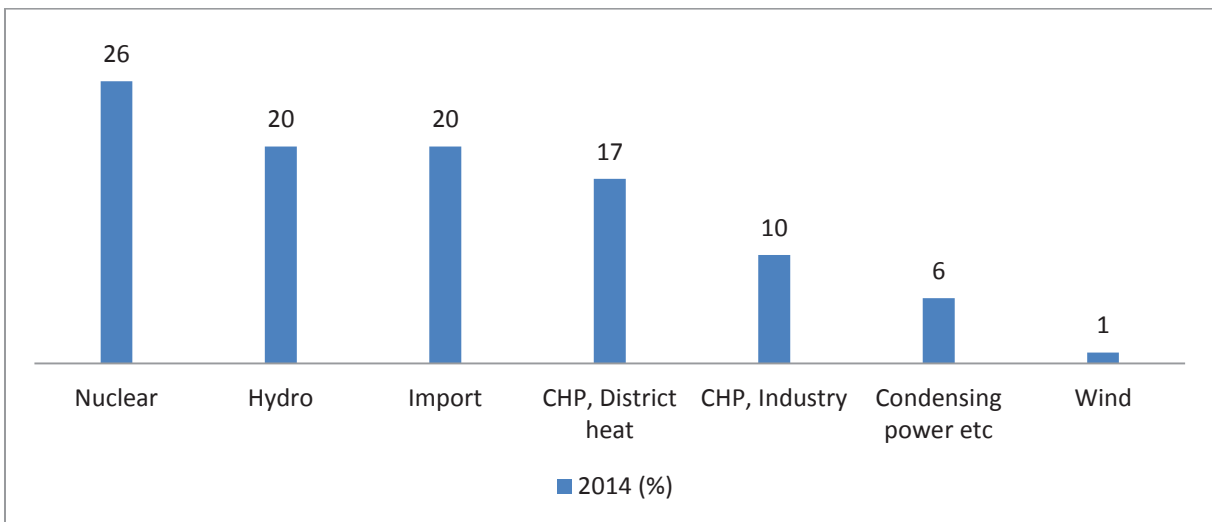


Figure 85: Share of total electricity generation by different sectors Finland [13]

9.2 Electricity consumption:

The electricity consumption recorded almost constantly since last decade except the year 2009 where the electricity consumption was at its lowest point.

Industry is the main consumer of electricity in Finland with more than 50% of the total consumption. The forest industry alone consumed around 25%. In 2013 total electricity consumption was 83.9 TWh or 5.4 MW per capita, and in 2012 was 85.1 TWh or 15.7 MW per capita. [6]

The whole Industry sector is the main consumer of electricity in Finland with consuming half of the consumption of electricity, after that the second households and public services share the equal amount of electricity consumption.

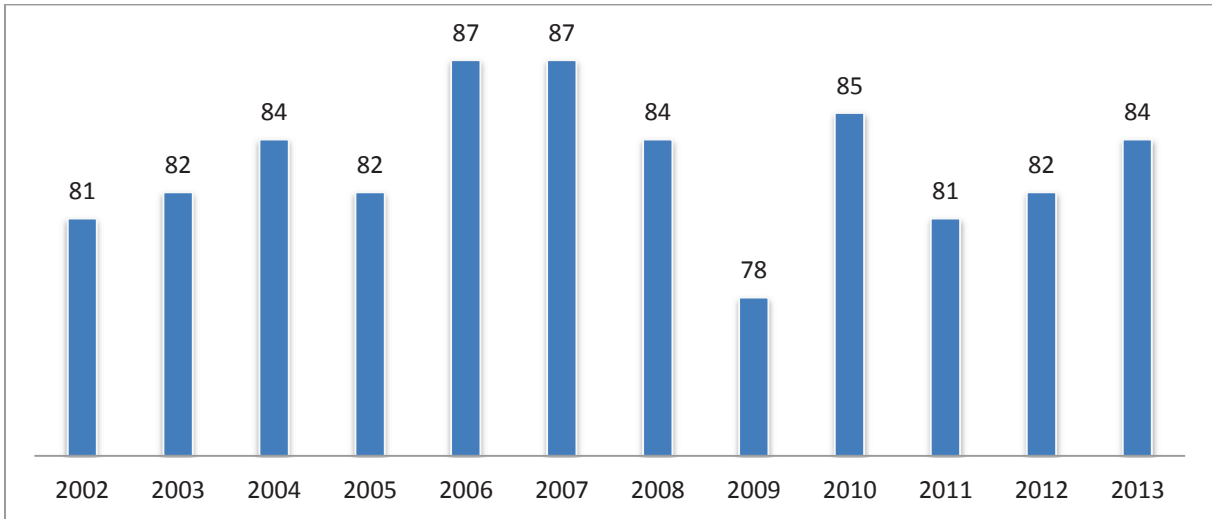


Figure 86: Net electricity consumption (TWh) Finland [1] [13]

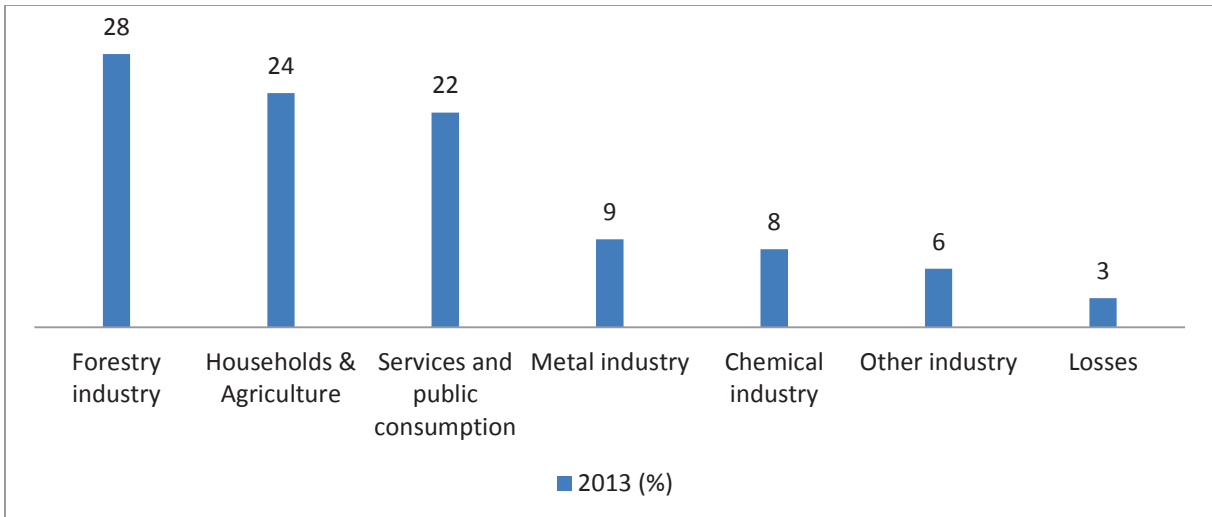


Figure 87: Electricity consumption by different sectors Finland [13]

9.3 Renewable Energy:

9.3.1 Renewable electricity installed capacity:

The renewable electricity capacity has upward trended in Finland since last decade, the capacity has increased by 15% by 2012 to compare to the installed capacity in 2002.

The major reason in increase of renewable electricity capacity is that new sources like wind and solar had come into the market and new plants from these sources are installed in the country.

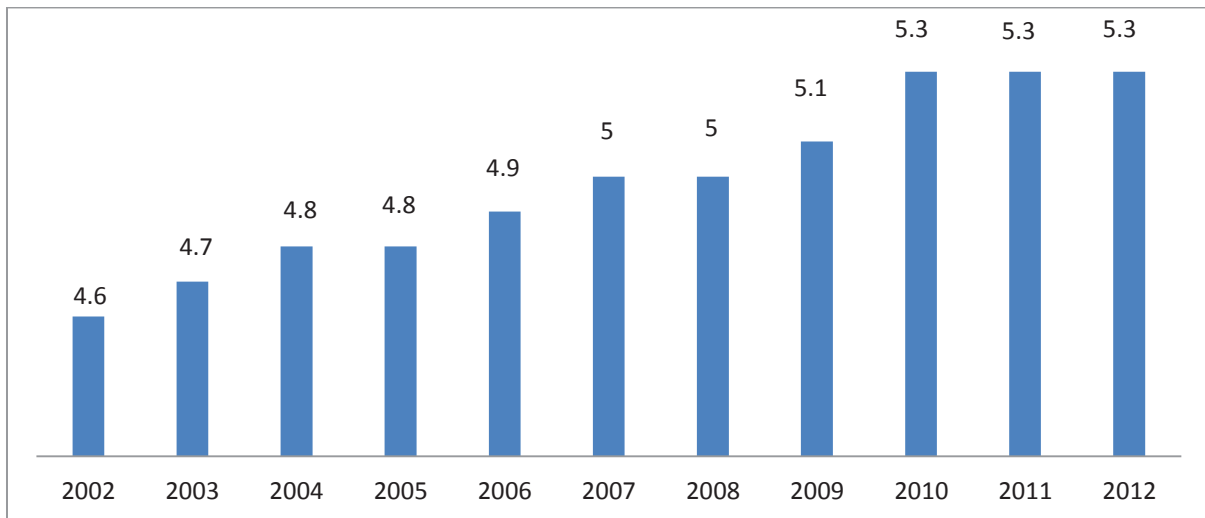


Figure 88: Installed renewable electricity capacity (GW) Finland [1]

9.3.2 Renewable electricity generation and consumption:

The renewable electricity has a reasonable share in the whole net generation of electricity, account 25 TWh or 36% by the end of 2013.

The input from the renewable energy sources in the whole grid of electricity is almost on the constant level over the last decade contributing 24% on an average in the electricity grid.

The major cause of fluctuation in in the generation from the renewable electricity is because of it depends most of on hydro power and due the variable generation from hydro power these variations occur in the generation cycle. Renewable electricity in Finland most of depends on hydro power which is accounted for more than half of RES share.

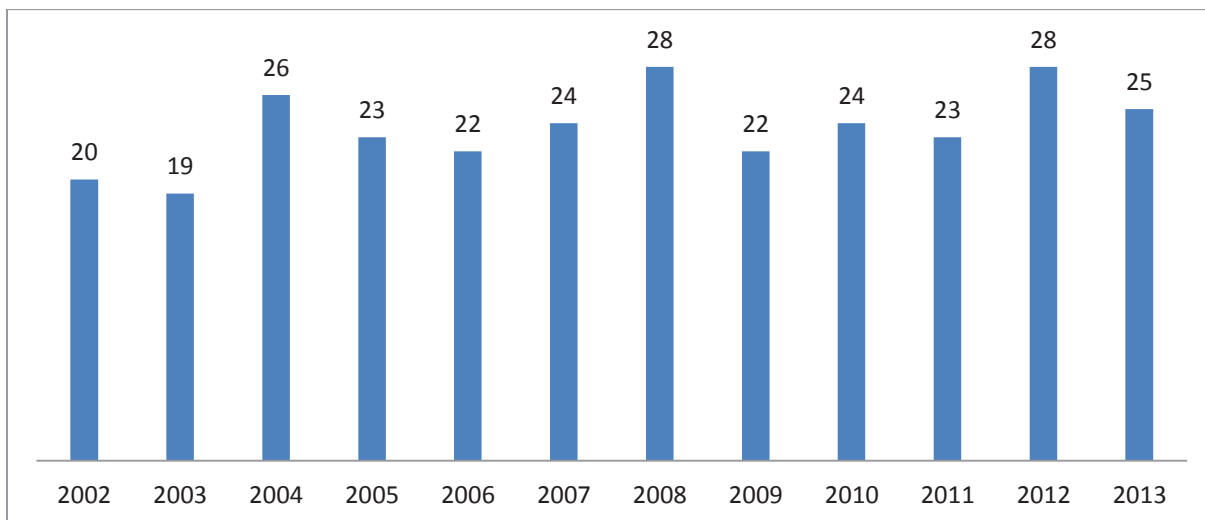


Figure 89: Renewable electricity net generation (TWh) Finland [1] [14] [15]

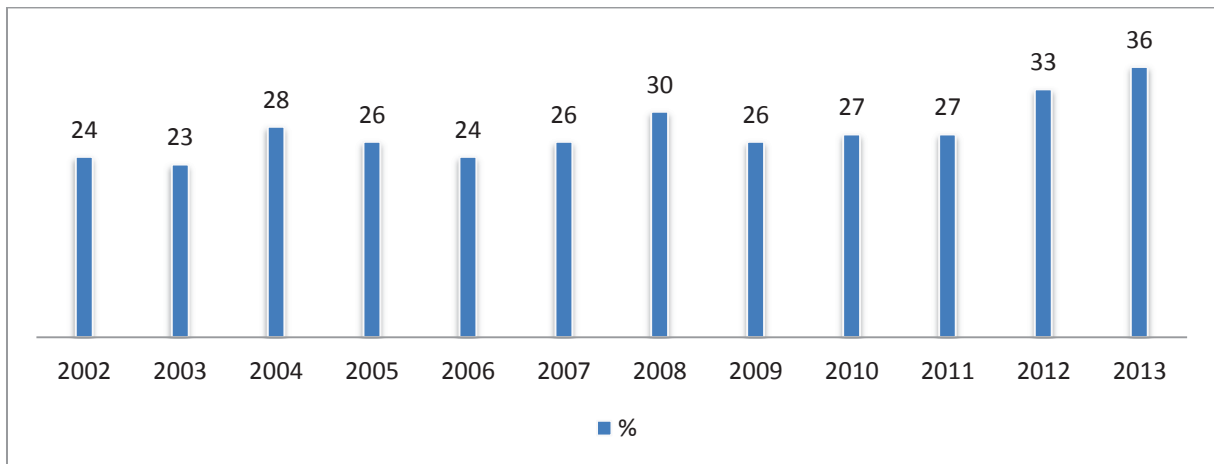


Figure 90: Share of renewable generation in total annual electricity generation Finland [14] [15]

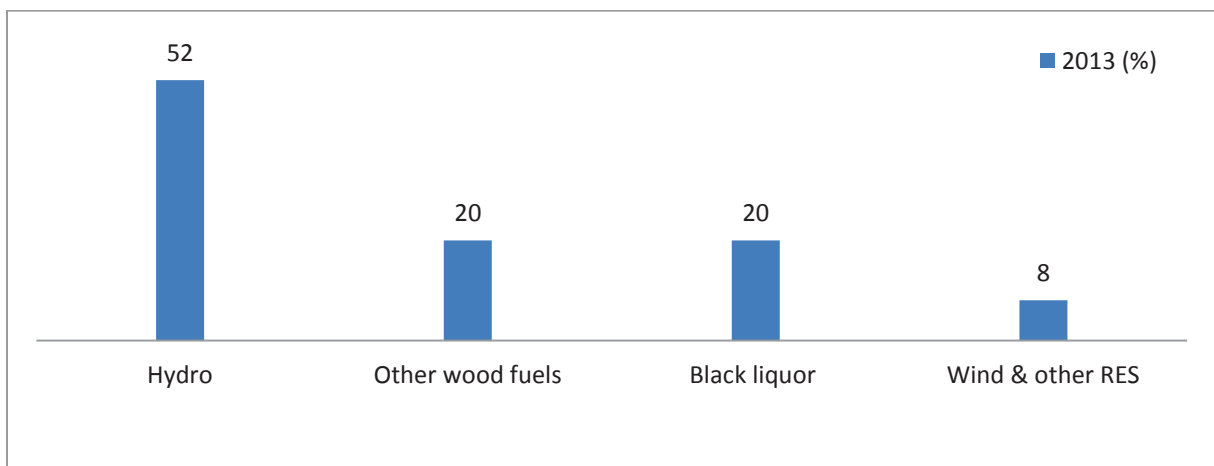


Figure 91: Share of sources in renewable electricity generation Finland [15]

9.4 Wind Power:

9.4.1 Wind Power installed capacity:

Wind Power capacity in Finland developed rapidly over the last decade to compare to other countries in the world. In coming years the Wind Power construction and production statistics will break the records from previous years. The Wind Power has now a good start in Finland.

Finland was having 211 wind turbines with a total capacity of 448 MW by the end of 2013. The 2013 was a record year in term of construction and production of wind power. [16] In 2014 184 MW was capacity added into the system with 59 new plants.[17] Finland was having 260 wind turbines with the total capacity of 627 MW by the end of 2014. [16]

Finland will add more wind power plants by the end of 2015 which will increase the production capacity more than 300 MW, the main wind power plants are Honkajoki, Lappeenranta, Pori, Raahe and Simo. [16]

The goals set by the Finnish government in the wind energy industry are to achieve 2500 MW or 6 terawatt-hours per year electricity generation by the end of 2020. The wind power will cover the 7% electricity demand by 2020.[18] [3]

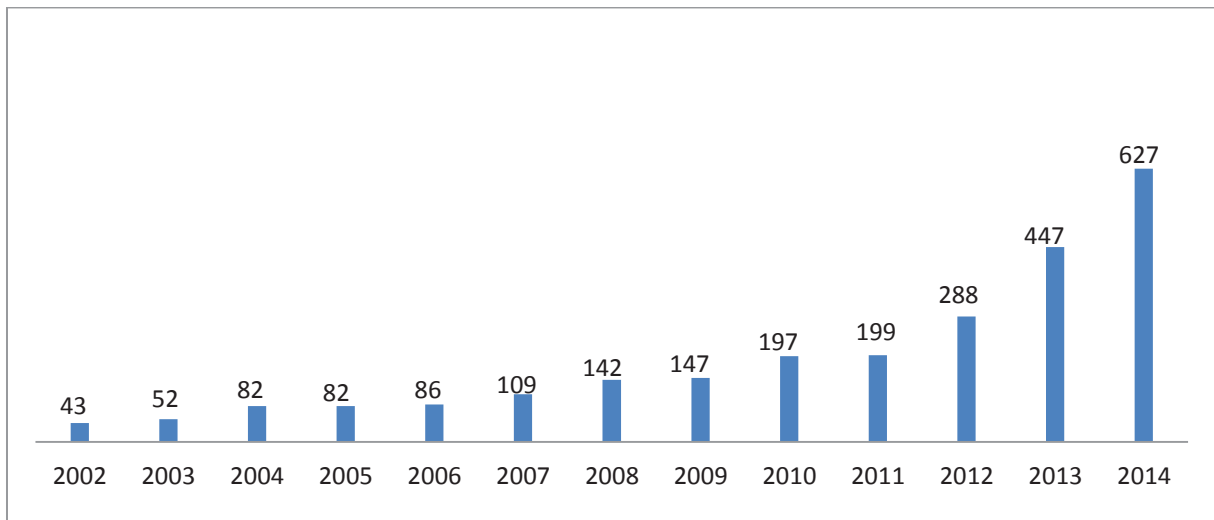


Figure 92: Installed wind power capacity (MW) Finland [16] [19]

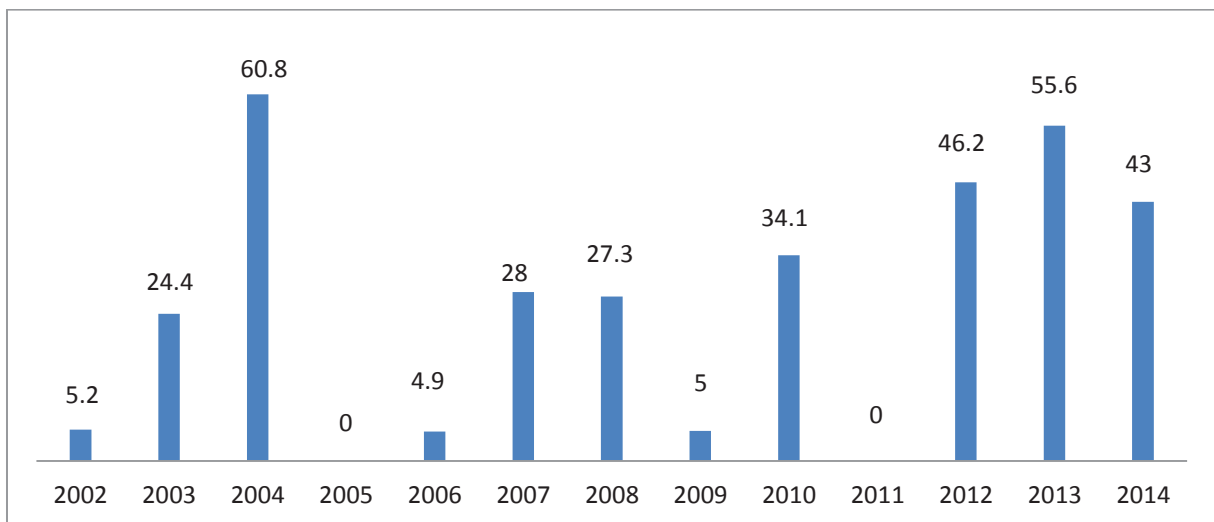


Figure 93: Annual increase of installed wind power capacity Finland [19]

9.4.2 Wind Power generation and consumption:

Wind power in Finland has relatively less production with compare to other Nordic countries. In 2014 1.3% electricity produced with wind power. [16]

In 2013 total production of electricity from wind power was 771 GWh, which was the 0.9% of total consumption of electricity, with compare to 2012 wind power generation was increased by 56%. [16]

In 2014 total production of electricity from wind power was 1.1 TWh, which was the 1.3% of total consumption of electricity, with compare to 2013 wind power generation was increased 43% in 2014. The wind power which was generated in 2014 was equivalent to the electricity consummated by annually by 500 000 2-room apartments. [16]

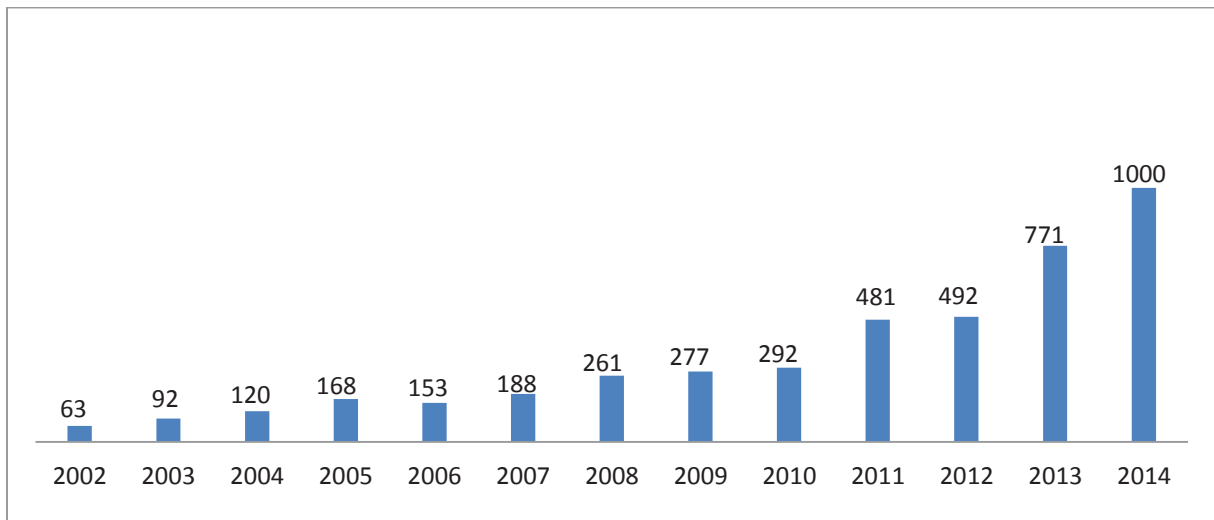


Figure 94: Wind power generation (GWh) Finland [16]

9.4.3 Offshore wind power:

Finland has 26 MW offshore wind power capacity by the end of 2013, the power capacity comes from the 2 offshore wind farm consisting 9 turbines. [6]

Farms: 2
 Turbines: 9
 Capacity: 26 MW

10. Electricity in Portugal:

10.1 Electricity capacity and generation:

The electricity installed capacity in Portugal increased by 80% accounted by the end of 2012 with compare to 2002. The electrical capacity has a constant increase in Portugal over the last decade.

The Portugal has no electricity capacity for Nuclear power the whole electricity mix depends upon hydro, wind and thermal power.

Portugal has the highest share in the electricity mix of fossil fuels, which is accounted 8.7 GW by the end of 2012, other sectors are wind and hydro with the share of 4.5 GW and 4.5 GW installed capacity respectively.

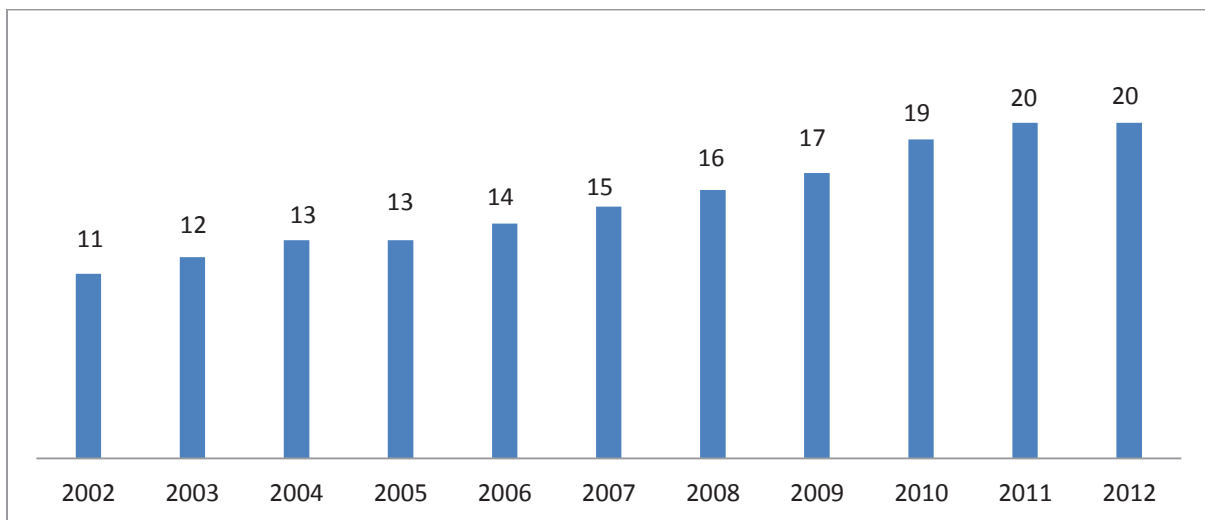


Figure 95: Installed electricity capacity (GW) Portugal [1]

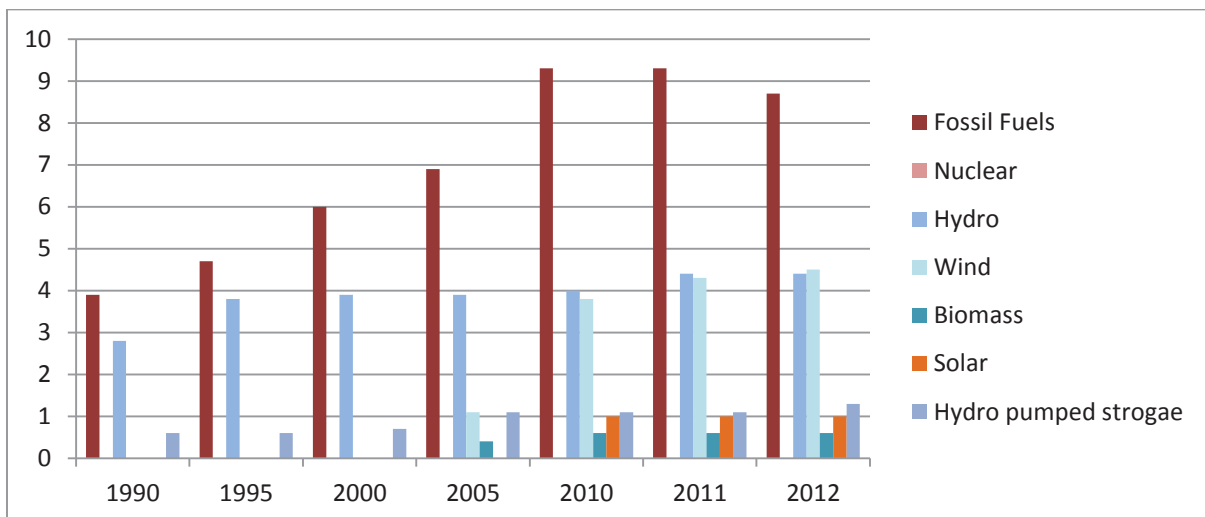


Figure 96: Installed electricity capacity (GW) by different energy sources Portugal [1]

Portugal was the 51st country in the world in term of electricity production by the end of 2013 for producing 52,700 GWh. [5]

Portugal had achieved a constant level over the last decade in term of electricity generation, the electricity generation has a constant behavior with minor \pm changes.

The main sectors in electricity generation are hydro power which has contributed 29.7% share in the net generation of electricity, and the wind power with a contribution of 23.8%.

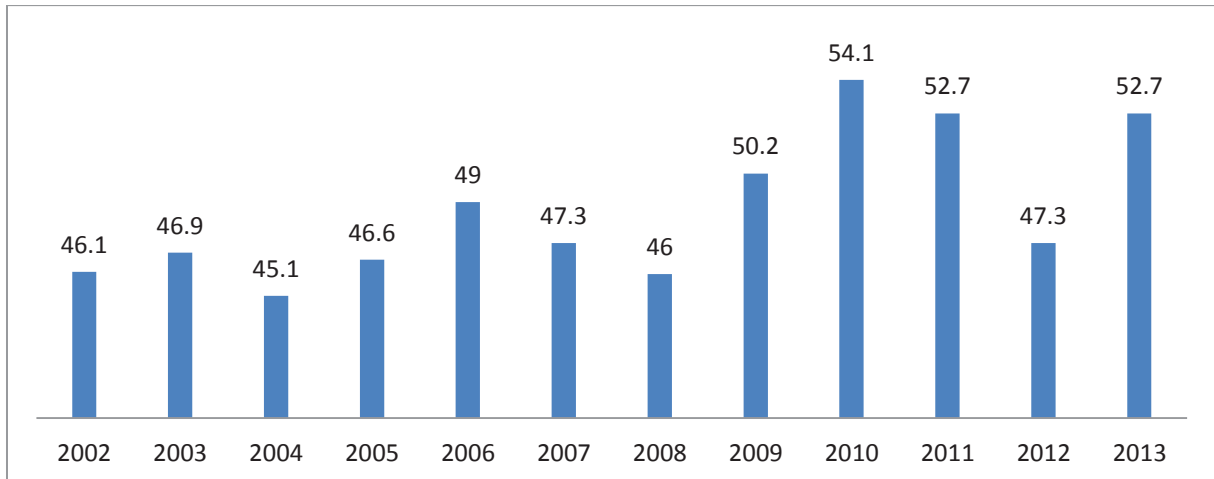


Figure 97: Electricity net generation (TWh) Portugal [1] [5]

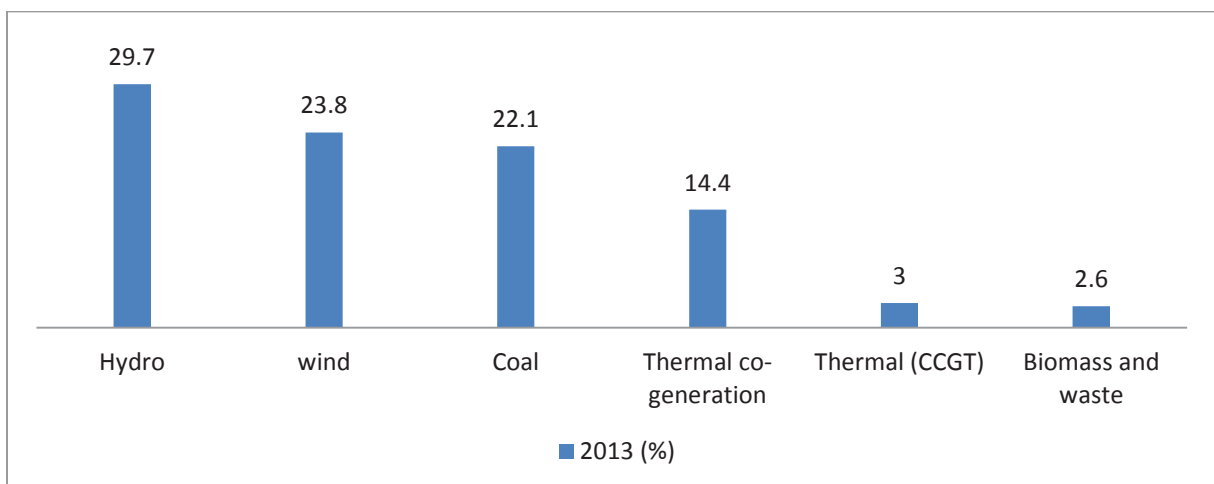


Figure 98: Share of total electricity generation by different sectors Portugal [21]

10.2 Electricity consumption:

Portugal has generated 58.3% of electricity demands from renewable energy sources which are 20% increased with compare to 2012. [10] In 2014 the share of renewable energy in the generation of electricity was 63%. [8]

The main consumption sectors in Portugal are in industry, commercial and public services and residential.

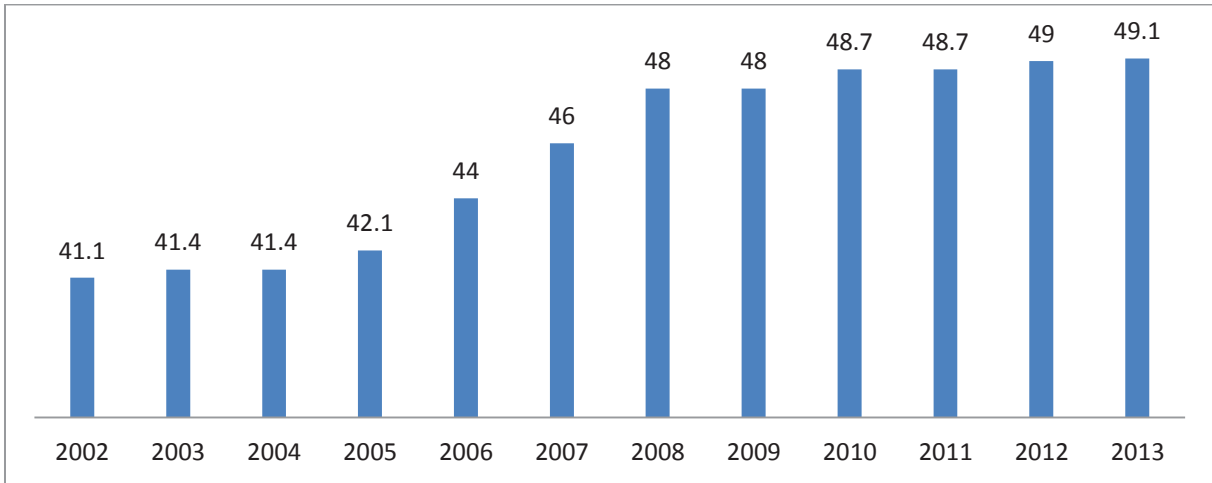


Figure 99: Net electricity consumption (TWh) Portugal [20] [21]

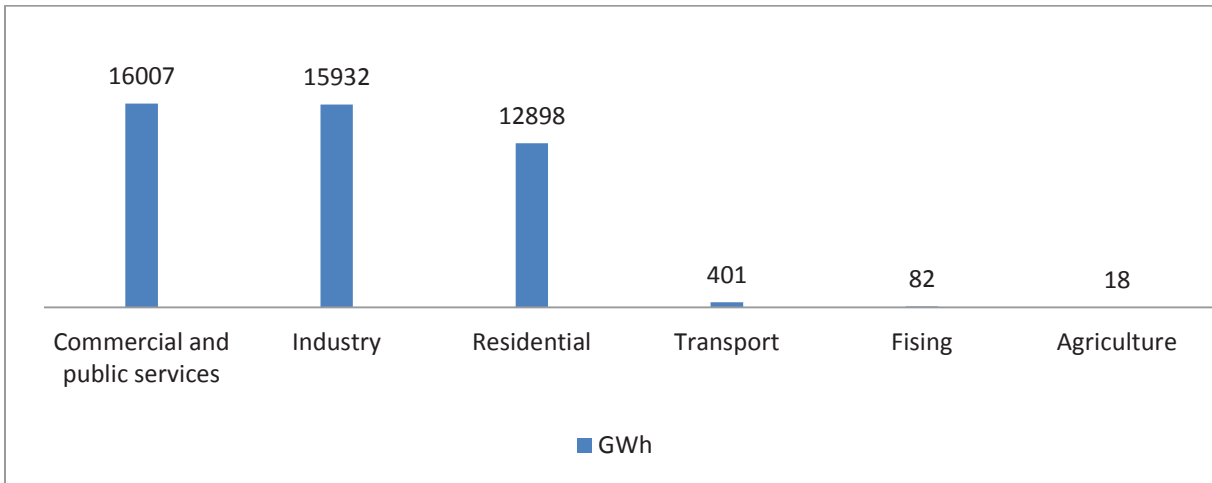


Figure 100: Electricity consumption by different sectors Portugal

10.3 Renewable Energy:

10.3.1 Renewable electricity installed capacity:

The currently installed renewable electricity capacity in Portugal is around 11 GW by the end of 2013, which is 76% increased with comparing to 2005.

The renewable electricity capacity has increased t an average growth rate of 8% since 2005.

The 55% of installed capacity of electricity in Portugal comes from renewable electricity, which rank it at the top of list among other countries in the world in term of the renewable electricity capacity, share in the whole electricity grid.

The major share of installed renewable electricity comes from Hydro power and wind power with the share of 50% and 41% respectively by the end of 2013.

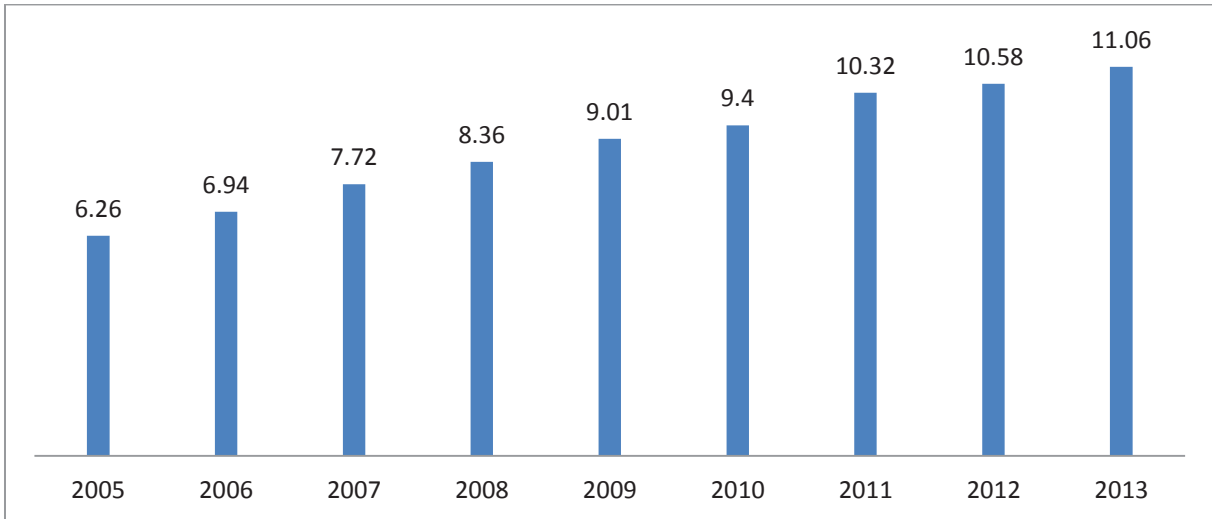


Figure 101: Installed renewable electricity capacity (GW) Portugal [22]

10.3.2 Renewable electricity generation and consumption:

The current generation of electricity through renewable sources is around 30 TWh, which has the contribution of 60% of whole net electricity generation.

The generation of electricity through renewable sources has a variable graph over the last decade, the reason renewable electricity depends upon two major sources, which are hydro and wind and the electricity generated through these sources depends upon whether situation and cannot be predicted.

The renewable electricity sources have a vital role in electricity generation in Portugal, which are fulfilling the half of the electricity needs of the country.

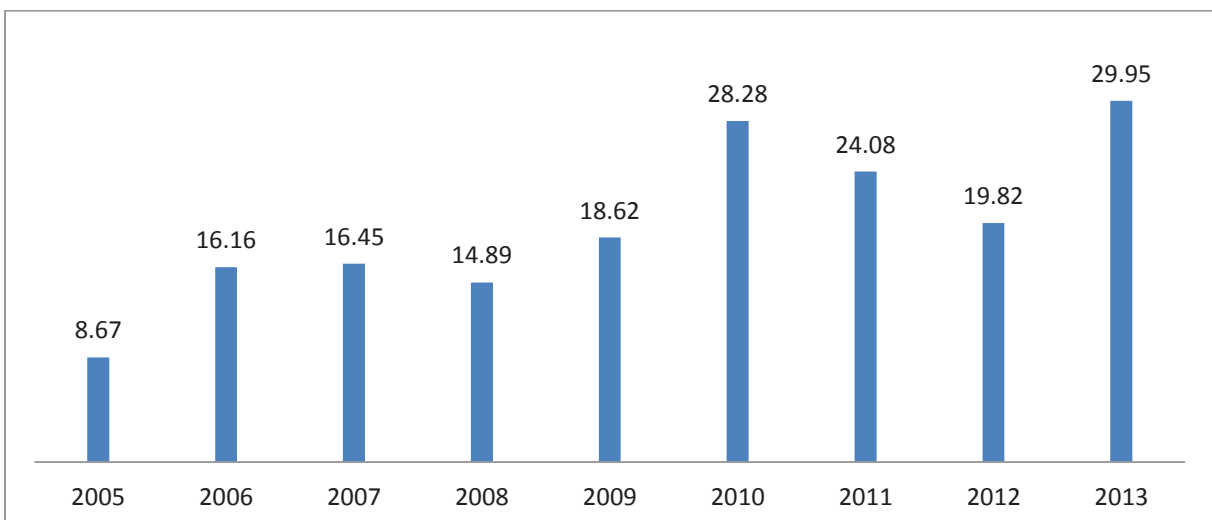


Figure 102: Renewable electricity net generation (TWh) Portugal [22]

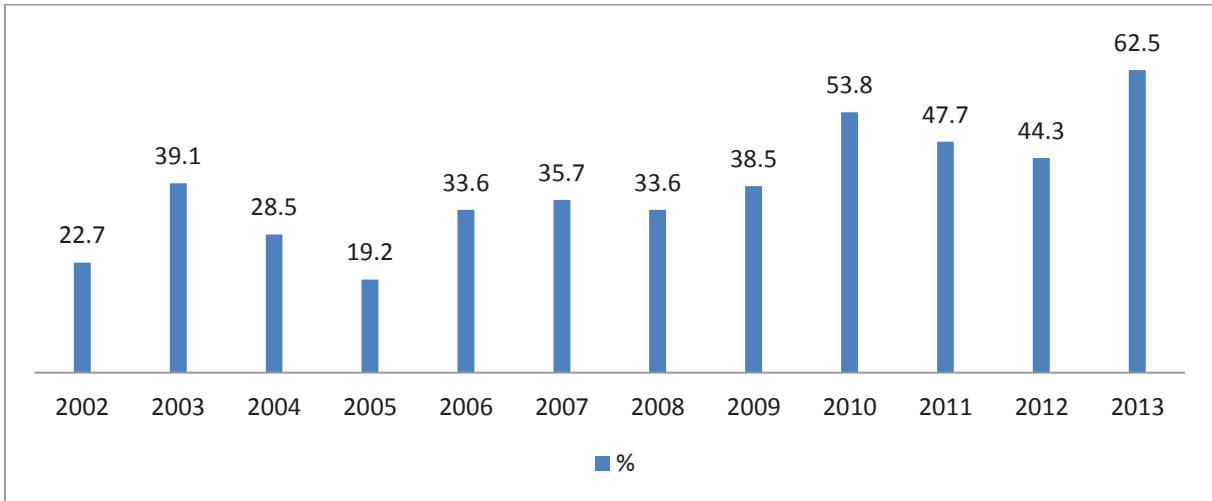


Figure 103: Share of renewable generation in total annual electricity generation Portugal [14]

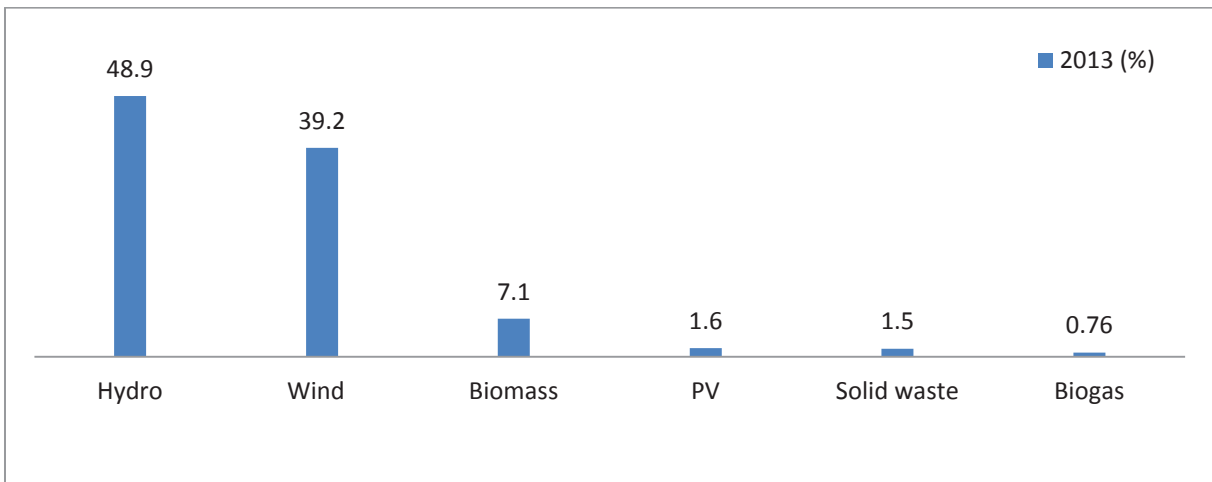


Figure 104: Share of sources in renewable electricity generation Portugal [22]

10.4 Wind Power:

10.4.1 Wind Power installed capacity:

The wind power capacity in Portugal has increased drastically over the last decade which started from just 194 MW in 2002 and reached up to 4914 MW by the end of 2014.

The wind power capacity installation has highest increase during the period 2002 to 2008, after that has not so much higher increase but still maintaining a constant increase over the year.

Portugal has installed 192 MW wind power in 2013 which was 4.4% increased with compare to 2012 by the end of 2013 the total installed capacity was 4,709 MW. Wind power supplies 11.9 TWh electricity demand during the 2013. [24] [25]

The new National Renewable Energy Action Plan (NREAP) by Portuguese government in 2013 approved reduces the wind power targets to 5,300 MW by 2020 from 6,875 observed previously. [26]

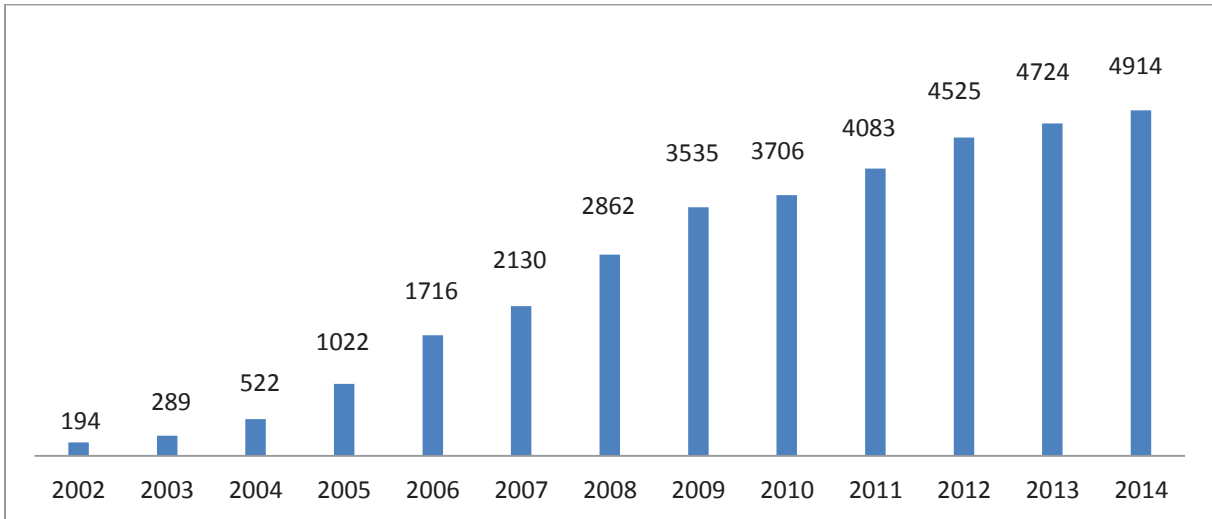


Figure 105: Installed wind power capacity (MW) Portugal [23]

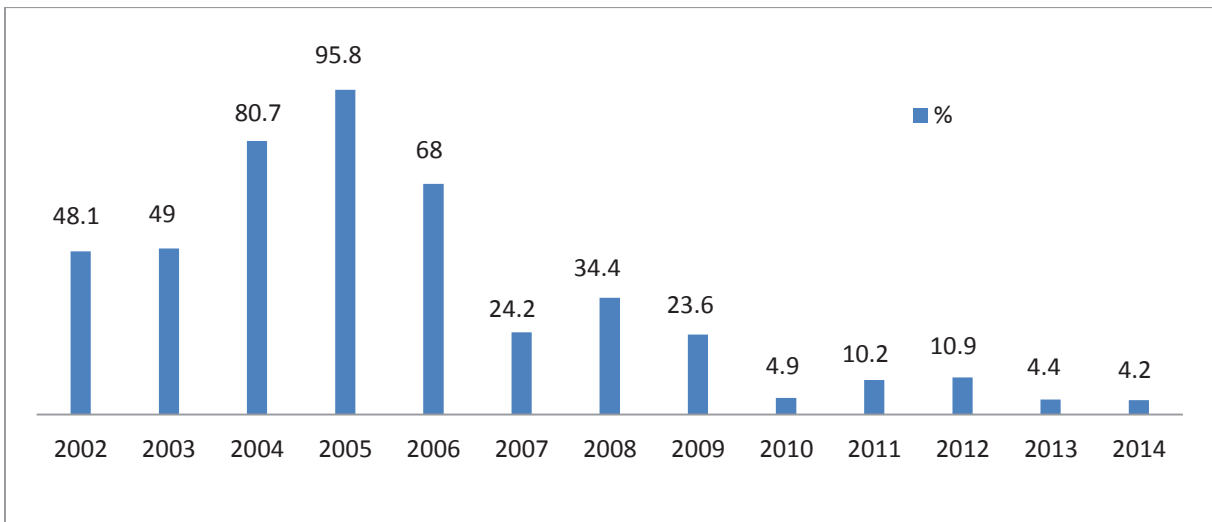


Figure 106: Annual increase of installed wind power capacity Portugal [23]

10.4.2 Wind Power generation and consumption:

Wind power in Portugal is a major source electricity generation with fulfilling the 23% demands of electricity consumption in the country. In 2013 Portugal continues its progress towards to generate the electricity through the renewable energy sources especially with wind power. [24][25]

The wind power consumption, which was 24% of total consumption achieved in 2013 was the second highest in the world. [27]

In Portugal wind shares the 39% of total electricity generation through renewable sources which has decreased in 2013 by 12% with compared to 2012. The reason is a 17% increase of hydro power generation with compare to 2012. [25]

The wind power increase in Portugal in 2013 is the result of favorable wind conditions noticed in the hilly areas in the country where most of wind power capacity is concentrated.

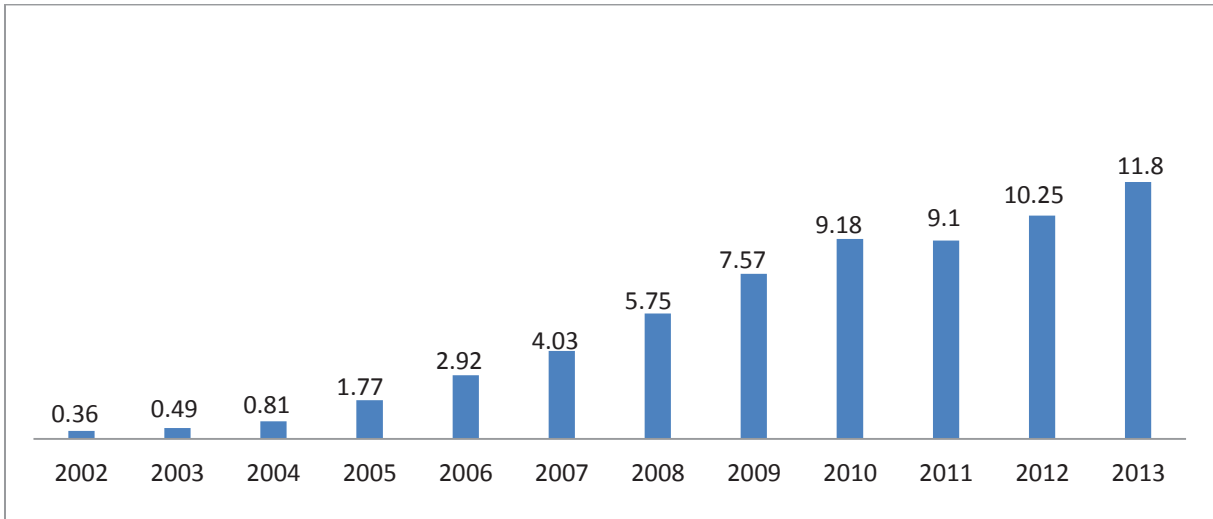


Figure 107: Wind power generation (TWh) Portugal [1] [23]

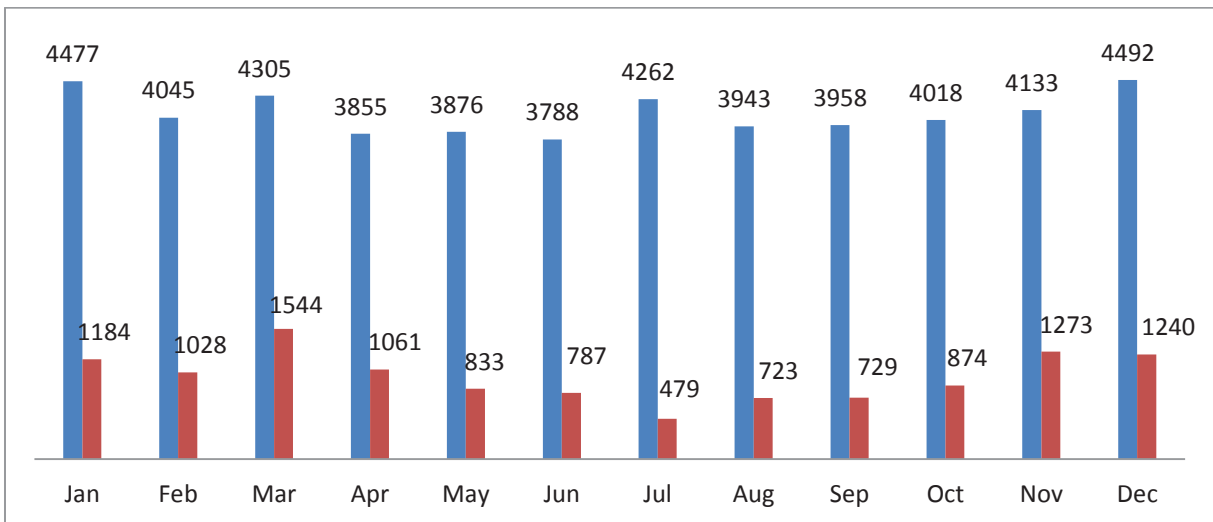


Figure 108: Wind power generation (GWh) in electricity sector in year 2013 [23]

10.4.3 Offshore wind power:

Portugal has 2 MW total capacity of offshore wind power with 1 turbine. The wind turbine is installed in Atlantic Ocean 6 KM away from the Lisnave port in Norte region. [6] [28]

Farms: 1
 Turbines: 1
 Capacity: 2 MW

11. Electricity in Denmark:

11.1 Electricity capacity and generation:

In 2014, the installed capacity in Denmark was 14 GW and in 2013 the total installed capacity was around 13 GW. Approximately half of the electricity produced in Denmark has generated from renewable energy and also the government has special plans to reduce the dependency on fossil fuels such as coal, gas and oil. The main capacity installation in Denmark is on waste, wind power and large scale CHP (combine heat and power) that one of the environmentally friendly way to produce both power and heat. The diagram below shows the installed electricity capacity from 2002 to 2014.

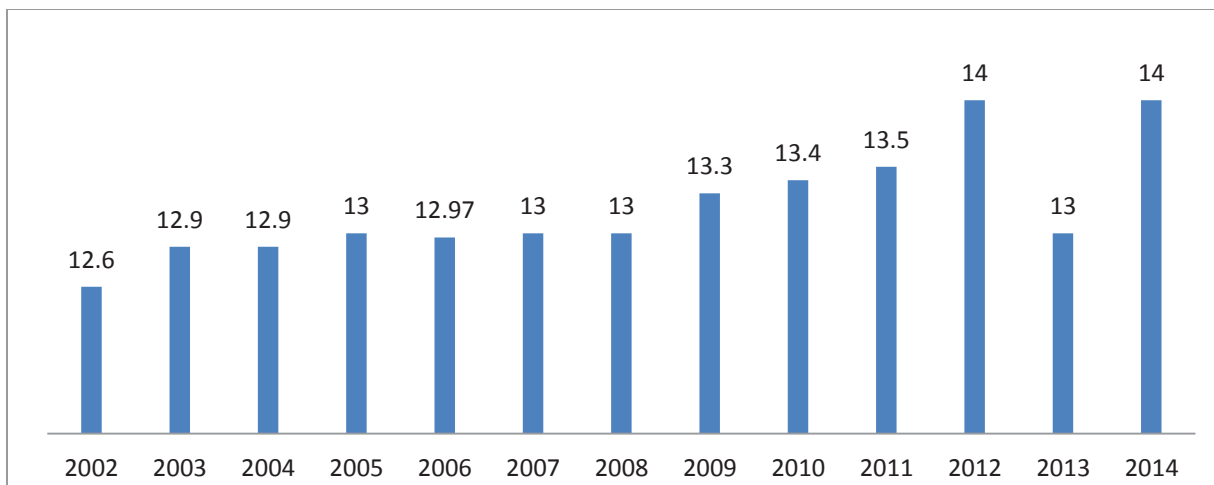


Figure 109: Total electricity installed capacity (GW). Denmark [50] [51]

In Denmark, the electricity production, mostly generates with a variety of individual plants and different fuels depends on the environmental condition and electricity production divided into thermal power and renewable energies such as photovoltaic cells, hydro power, waste and the wind energy which has considerable contribution to produce the electricity. However, still the fossil fuels have contributed for supply thermal powers. In 2013, around 33 TWh electricity generated and in 2014, the gross electricity production was 31 TWh. [50] [51]

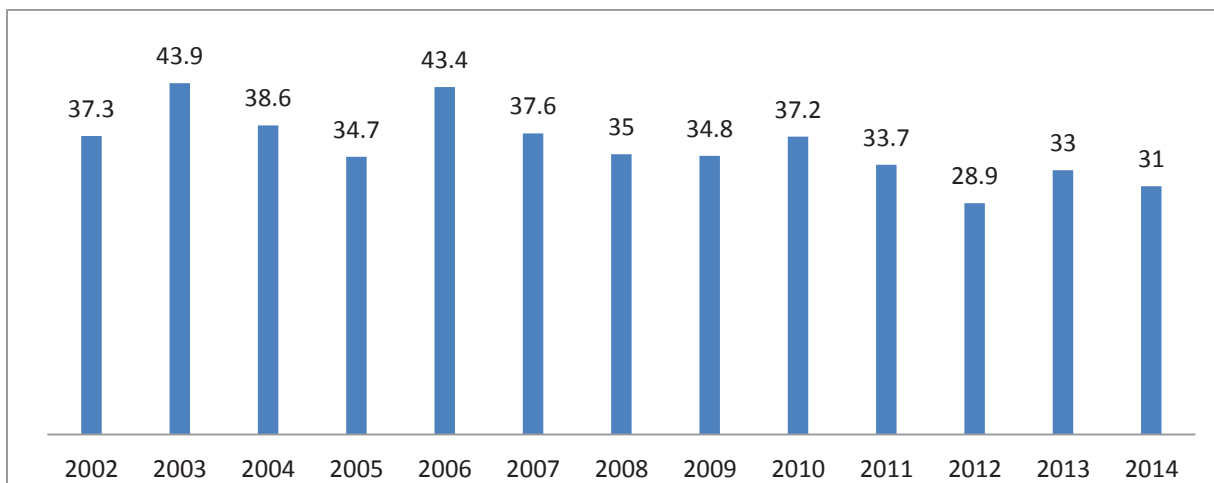


Figure 110: Total net electricity generation (TWh). Denmark

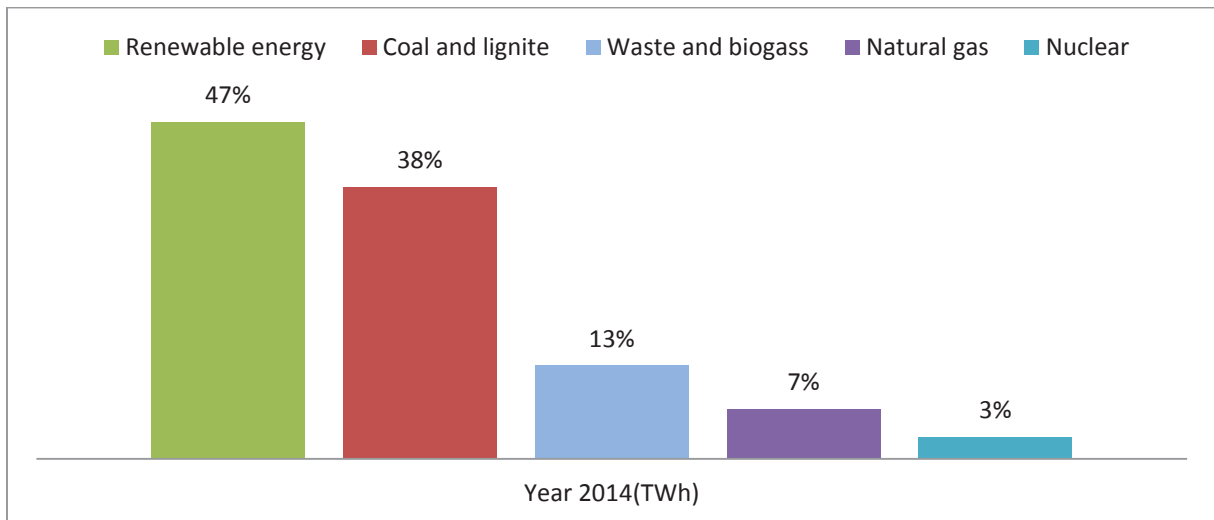


Figure 111: Total net production from different sources (TWh). Denmark

11.2 Electricity consumption:

In 2014, the gross consumption includes transmission loss was 33.5 TWh and in comparison with 2013, decreased by 1.7%. The statistical statement shows that the electricity consumption will increase by 3.7 TWh from 2015 to 2024. The consumption of fossil fuels such as coal, natural gas and oil has reduced by 35%, 69%, and 75% subsequently during the period 2010 to 2014. The main consumers in Denmark are transportation, agriculture and industry, commercial and public service and also households. [50] [52]

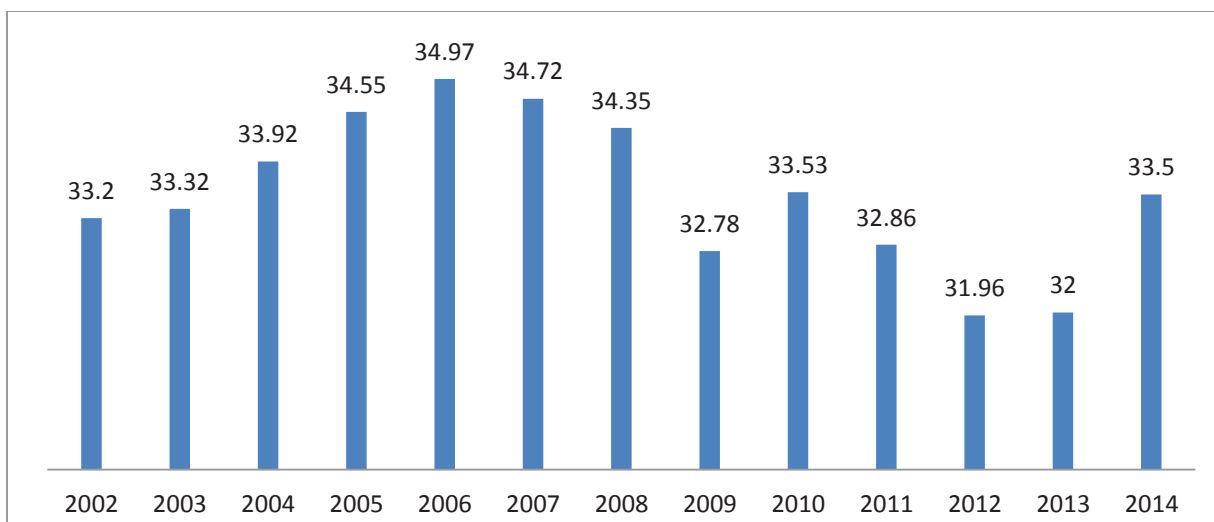


Figure 112: Total electricity consumption (TWh). Denmark

11.3 Renewable energy:

11.3.1 Renewable electricity installed capacity:

In 2014, the total electricity production has extracted from renewable energy was around 17.5 TWh and in 2013, the total electricity generation was 15.7 TWh and the government expected to develop the generation to approximately 87% for the next decade. The graph below shows the development of installed capacity of renewable energy from 2002 to 2012. [50] [53]

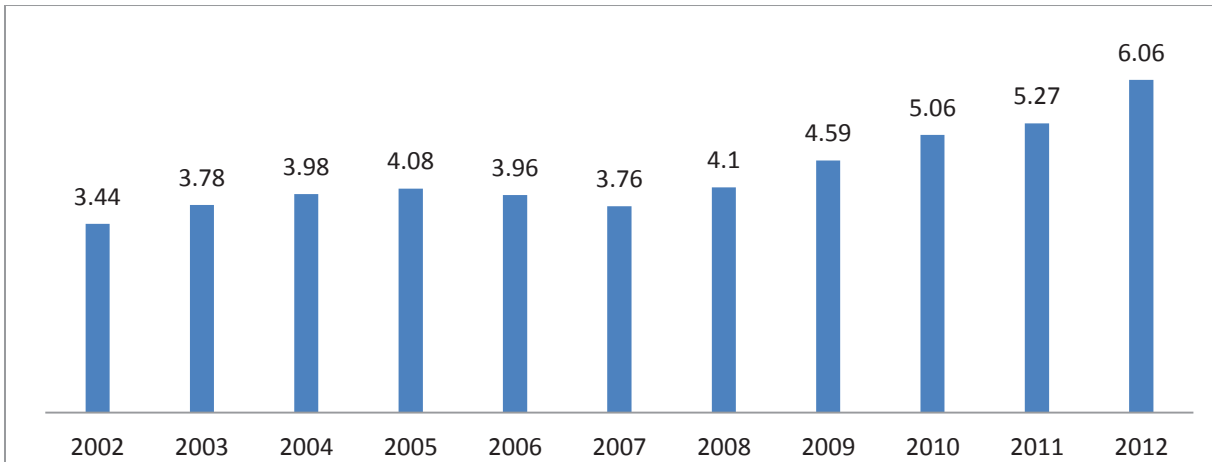


Figure 113: Total renewable electricity installed capacity (GW). Denmark

11.3.2 Renewable electricity generation and consumption:

The renewable energy supplied 19 TWh of gross electricity generation in 2014, meanwhile in 2013, this rate was 16.5 TWh, which showing the growth of 10% in the usage of renewable energy in the total electricity production. The renewable energy in Denmark contains hydro power, solar, biogas and biomass (straw and wood) and wind power. The renewable energy in Denmark overcomes by wind power to the share of 74.5% and according to the government forecast to increase the contribution of wind power by 57% by end of 2020. The diagram below shows the composition of electricity generation from renewable energy in 2014. [50] [53]

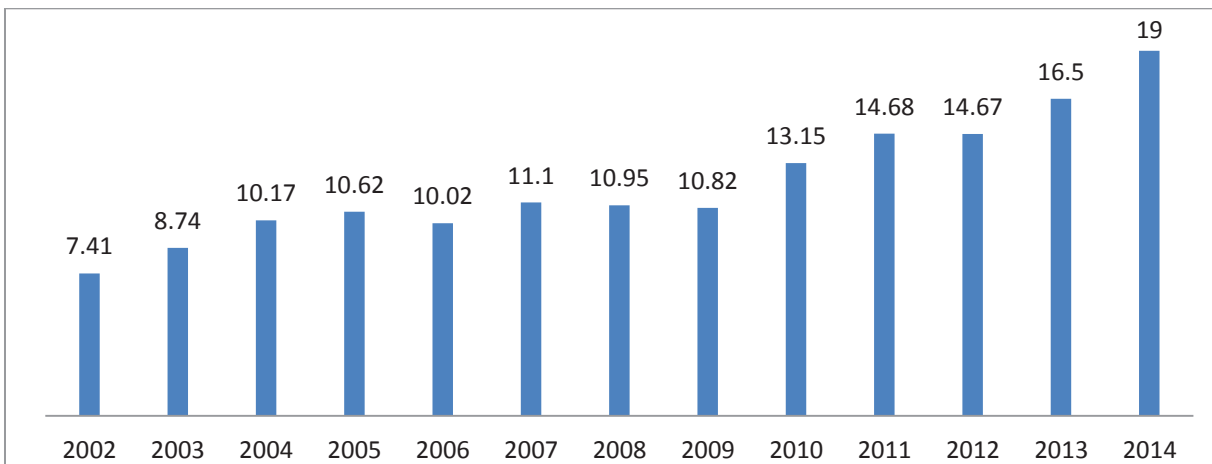


Figure 114: Total renewable net electricity generation (TWh). Denmark

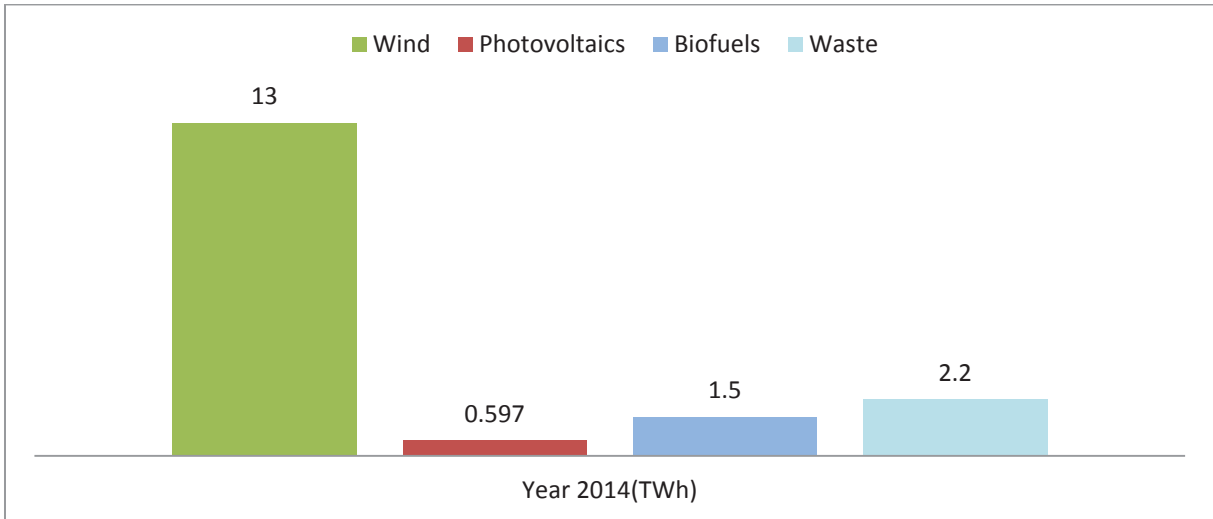


Figure 115: Total renewable electricity production from different sources (TWh). Denmark

11.4 Wind power:

11.4.1 Wind power installed capacity:

Wind power plays the essential role in the Danish electricity generation and the development of wind energy started from 1980's and grows with sharp promotion until now and become the Denmark to the one of experienced country in the wind power supply which has the highest ration of wind power in the world. In 2013, with 6772 turbines the installed capacity was 4818 MW and the contribution of onshore capacity was 3547MW. In 2014 there were 7913 wind turbines and the installed wind capacity was 4855 MW and the share of onshore wind capacity was 3622 MW. The diagram below shows the huge expansion of wind power from 2002 to 2014 and expected to rise up the capacity up to 2100 MW by the end of 2024. [50][54] [55]

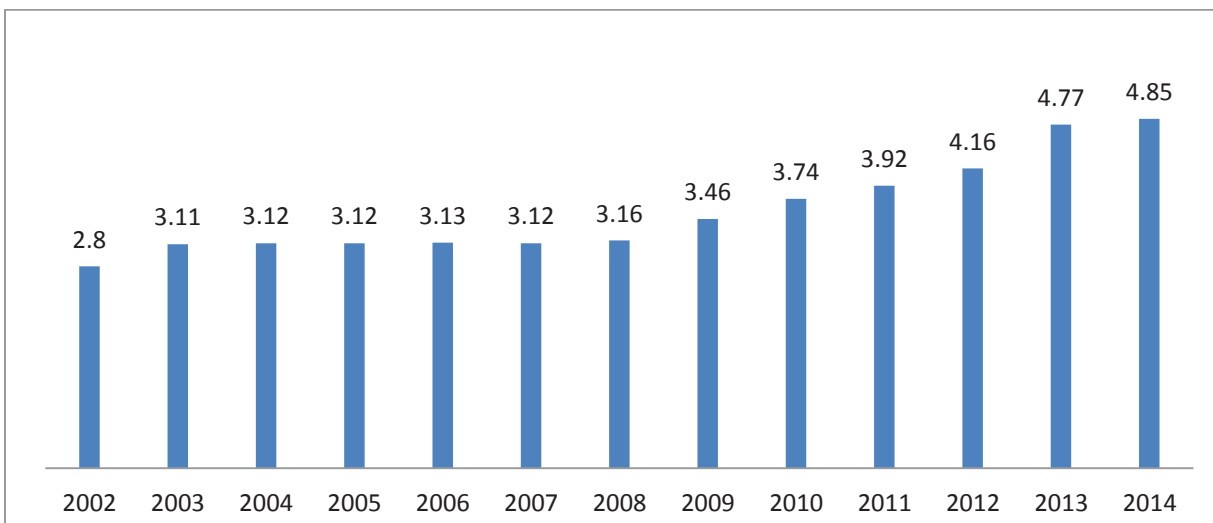


Figure 116: Total wind power installed capacity (GW). Denmark

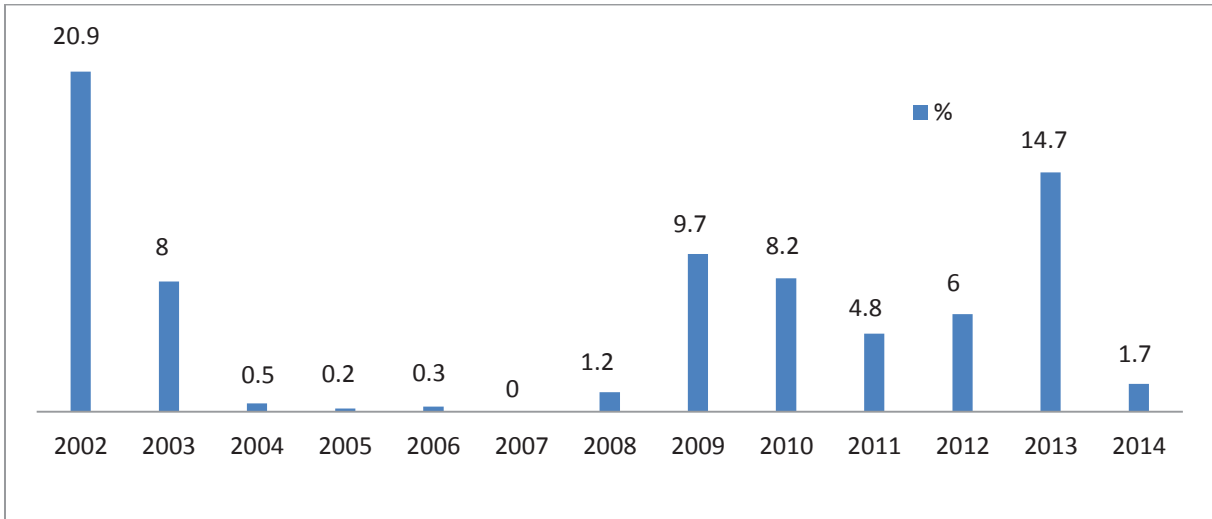


Figure 117: Annual increase of installed wind power capacity Denmark

11.4.2 Wind power generation and consumption:

In 2014, the contribution of wind energy for production was 42.7% and the consumption was 39.1%, around 1955 TWh added to the total electricity generation from wind energy that totally produced 13.7 TWh and also, the share of land base wind power was 7.9 TWh and also. In addition, in 2013, share of wind production was 33.8% and also the consumption was 32.7% and the production amount was 11.1 TWh, the contribution of onshore wind power was 6.7 TWh. The analysis of the past two years presented the growth of 9% in the electricity production in 2014. As a consequence of the development, the Danish energy sector has expected to append from 13.7 TWh in 2014 to 23.3 TWh in 2024. The diagram below, presented the development of the wind energy production from 2002 to 2014. [50] [54] [55]

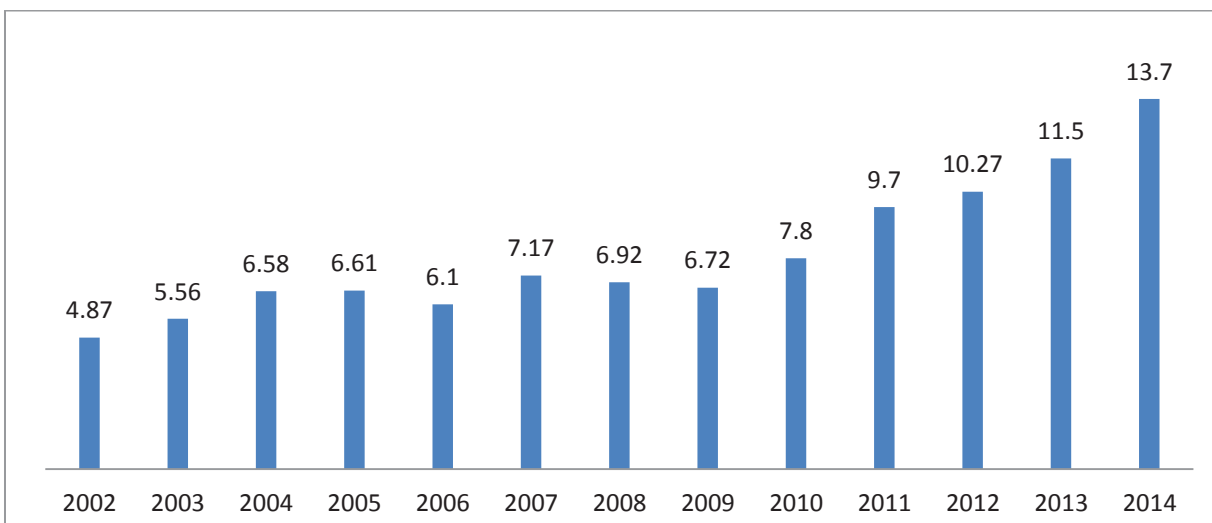


Figure 118: Total wind power generation (TWh). Denmark

11.4.3 Offshore wind power:

In 2014, the offshore sector had 19% growth in comparison with 2013 and the contribution of offshore wind power for electricity production was 5.1 TWh and also the total number of offshore turbines was 513 with the installed capacity of 1271 GW which this rate covers 15.8% of total electricity production.

On the other hand, in 2013, the total wind electricity production was 4.3 TWh, and the installed capacity of 1271 GWh, which has the same amount like 2014. The Danish energy sector expected to increase the capacity of offshore wind turbines approximately to 49% by 2014. [50][54][55]

Farms:	12
Turbines:	513
Capacity:	1271 MW

12. Conclusion:

In this report a large number of statistical data from the last decade are studied which consist of nine European countries and as well as in the total whole European Union area. The topics for which the data are studied are general electricity (capacity, generation and consumption), renewable energy and wind power in those countries and in whole European Union.

The electrical capacity has increased with a significant change in every country, especially in the European Union, the main reason is RES (wind, solar, biomass) other than hydro has come into the market and RES produces low cost electricity and also the carbon emission is low from these sources. These RES are taking the place of old conventional electricity sources which produces a lot of carbon emission and electricity cost is much higher with compare to RES. The electrical capacity in the European Union has increased by 33% by the end of 2012 with compare to 2002, on the other hand, RES capacity has increased by 131% by the end of 2012 with compare to 2002, this show a great trend towards the RES. The highest growth in electricity installed capacity observed in Portugal with 80% increased by the end of 2012 with compare to 2002, the major growth from other countries are from Germany and Spain, with 58% and 55% respectively during the period of 2004-2014. The growth in other European countries is around 10-15% during the last decade.

The electricity consumption and generation are related to each other and both have a variable curve during the last decade in whole European Union as well as the countries mentioned here. The rapid decrease in electricity consumption observed during the period 2009-2011 when Europe hit by the economic crisis so in this period the consumption and generation gone to levels of 2002-2004, the reason of this factor is that the power demand in Europe is correlated with GDP curve. In 2013, after recovering the economic crisis, the generation and consumption level observed in the level of 2005 overall. In recent years the electricity consumption increased due to new sector coming into electricity consumption, which is hybrid automobiles, which are getting very much popular and environmentally friendly. The generation of electricity from fossil fuels is decreasing and the generation from the RES is increasing over the years. In 2013, the half of electricity produced by the low carbon facilities in Europe, which is around 53% and in 2010 it was around 47% and it include the nuclear power and RES. The generation of the nuclear is observed constant throughout the last decade.

The power consumption in overall Europe is observed slightly decreased from 2012 to 2013. Electricity consumption in 3 biggest economies (UK, Germany and France) of Europe remained almost on constant level with range of +/-1%, Spain has observed the decrease of 3%.

The RES has observed a higher growth rate all over the Europe, the higher growth is observed in Germany, where renewable electricity installed capacity has increased by 250% by the end of 2014 with compare to 2004, which is 44% of total installed electrical capacity and generated 26% from total electricity generation. The United Kingdom has also observed a higher growth rate of 334% increased of installed renewable electricity capacity by end 2014 with compare to 2004, which share the 16% in total installed capacity and generated 23% in whole electricity net generation. Portugal has 60% share of renewable installed capacity in whole electricity capacity, which is one of the highest ratio in the world, so the Portugal dependency on renewable is much higher and reached 40% of renewable electricity capacity from wind power. On the other hand Sweden and Norway have 67% and 90% shares of renewable electricity installed capacity in total installed electricity capacity respectively, but in both countries the main source of renewable electricity is hydro power.

The growth of wind power has increased in all over the Europe observed in the last decade, 11791.4 MW of wind power capacity installed in the European Union in the year 2014 to increase of 3.8% with compare to 2013 which has a worth of around and €18.7bn. The current wind power capacity of the EU is 128 GW, of which 120 GW comes from onshore and 8 GW comes from offshore. The compound annual growth rate of wind power in the EU is around 10%. In 2014, 60% of new wind power installations comes from only 2 European countries of Germany and UK, which shows 14% growth in comparison to their share of 46% in 2013. The top four countries in term of new wind power installations are Germany, UK, Sweden and France sharing 77.2% of total wind power installations. Denmark and Spain, which were previously large markets in term of wind power faced a decrease of 91% and 85% respectively in wind power installations.

The Denmark has the highest ratio of installed wind power capacity in its electrical grid among the EU countries discussed here, which is around 35% and produced 45% electricity through wind power in 2014. The second country is Portugal which has a wind power share of 22% in installed electricity capacity and produced 23% electricity through wind power. The third country with the highest share of wind power is Spain, which has the share of 20% in installed electricity capacity and produced 37% its electricity through wind power in 2014. Germany has also a significant share of wind power in an installed electricity capacity, which is around 20%, but only produced 10% electricity through wind power in 2014.

As a consequence, it seems that the expansion of wind power in Europe is the fastest growing way to attain the clean energy for electrical production,. The European wind energy association (EWEA) is a fundamental organization to expand the wind power, then the growing of the similar organization can make the infrastructure to expand the wind power and helps to progress the projects for investment and lead the member countries to share the latest information and technologies.

Meanwhile, the most concerns about the expansion of wind power is the power management in different weather conditions, especially the wind speed. The speed has the direct effect on the operation of wind turbines. The European countries have good condition related to the wind speed and many companies trying to improve the wind power technology that produces the electric power of lower wind speed. Therefore, investment on this aspect can reduce the time to achieve the highest electrical production and wind power can be used as the main electrical power source. The conventional power plant can be used as reserved power plants in crucial condition. On the other hand, growing the green electricity like wind energy, needed the reduction of consumption of gross electricity and this target occurs when the consumption tends to use the smart technology and by expansion of large storage systems.

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Appendix A:

List of top 52 countries by electricity production: [5] Highlighted countries are covered in the report.

Country	Production (TWh)
1. China	5649.5
2. US	4260.4
3. India	1111.7
4. Japan	1088.1
5. Russia	1069.3
6. Germany	633.6
7. Canada	626.8
8. France	568.3
9. Brazil	557.4
10. South Korea	534.7
11. UK	356.8
12. Mexico	293.6
13. Saudi Arabia	292.2
14. Italy	288.4
15. Spain	285.3
16. Iran	263.4
17. South Africa	256.1
18. Taiwan	252
19. Australia	244.8
20. Turkey	239.3
21. Indonesia	216.2
22. Ukraine	193.8
23. Thailand	164.8
24. Poland	164.4
25. Sweden	160.4
26. Egypt	148.5
27. Argentina	138.8
28. Norway	134.2
29. Venezuela	131.7
30. Malaysia	131.6
31. Vietnam	130.1
32. UAE	111.3
33. Netherlands	95.1
34. Pakistan	93.2
35. Kazakhstan	91.9
36. Czech Republic	87.1
37. Belgium	85.1
38. Philippines	76
39. Switzerland	73.4
40. Chile	72.4
41. Finland	71.2
42. Austria	67.7
43. Israel	63
44. Kuwait	62.9
45. Colombia	62.2
46. Romania	59.4
47. Algeria	59
48. Greece	58.3
49. Paraguay	57
50. Uzbekistan	54.2
51. Portugal	52.7
52. Iraq	51.1
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62. Denmark	31

Appendix B:

List of European Union countries by their population:

1. Germany
2. UK
3. France
4. Italy
5. Spain
6. Poland
7. Romania
8. Netherlands
9. Belgium
10. Greece
11. Czech Republic
12. Portugal
13. Hungary
14. Sweden
15. Austria
16. Bulgaria
17. Denmark
18. Finland
19. Slovakia
20. Ireland
21. Croatia
22. Lithuania
23. Slovenia
24. Latvia
25. Estonia
26. Cyprus
27. Luxemburg
28. Malta