

1. DEVELOPMENT OF RENEWABLE ENERGY

1.1. New Energy Landscape

1.1.1. Global landscape

Without a doubt, the world is immersed in a historical change of its energy systems. Similarly, to the 19th century, which meant the beginning of fossil energy sources, global energy markets are actually in a transitional period. The evolution of energy issues over the past decades provides a change of policies and regulations about this market. An energy market based mainly on traditional fossil energy sources, is now evaluating other alternatives sources, such as renewable energies.

Two are the main issues that are responsible of this evolution: an oil and gas import dependence and the need for diversification in electricity production and climate change by CO₂ emission.

The first issue arose in 1970s after the oil crisis which took place during this decade. In this period, oil and gas were used to produce a substantial part of electricity in the world: approximately 46% of the global electricity production and 16%, respectively. Main producers of this energy resources were OPEC's countries (Fig. 1.1). This means that prices of oils and gas are very dependent on war and conflict in these areas.

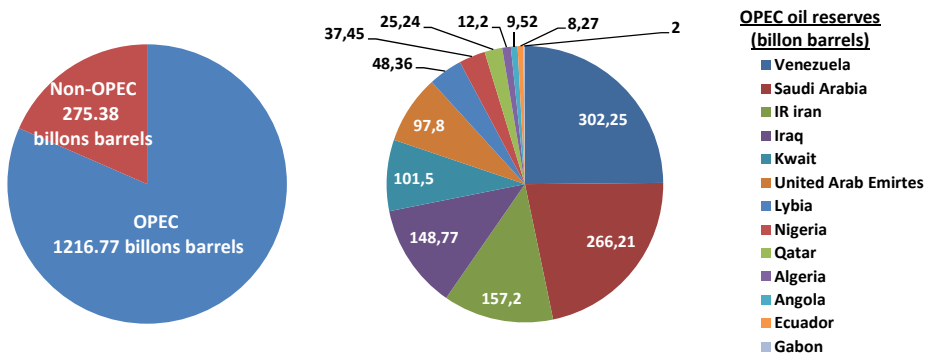


Fig. 1.1. OPEC share of world crude oils reserves (Source: own elaboration based on Fantini & Quinn, 2017)

We can find a direct relation between oil and gas prices and a conflict which occurs in OPEC areas. Fig. 1.2 shows an evolution of oil barrel prices from 1976 to 2017. Oil price fluctuation has also a direct influence on economy destabilization. So, different world debates have been established to avoid this energy dependence. New energy sources such as renewable energies or nuclear energy were promoted.

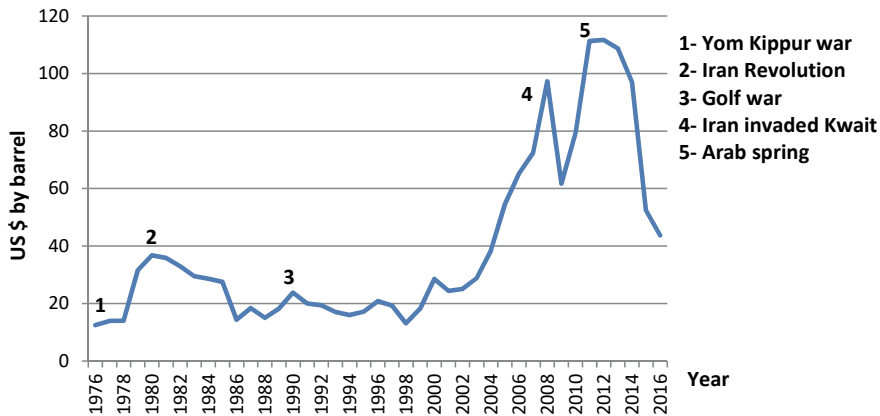


Fig. 1.2. Crude oil prices 1976-2016 (Source: own elaboration based on BP, 2017)

The second issue is an environmental problem caused by the growth of global CO₂ emissions. World Energy consumption is in continuous growing due to amelioration of the standard of living of the population of developed countries and the appearance of new developing countries. This increasing development has a direct relationship with the CO₂ production as can be seen in Fig. 1.3 where evolutions of energy consumption and CO₂ emissions during the last 50 year are shown.

Emissions of CO₂ and other greenhouse gasses are responsible for global warming and climate change. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) adopted a treaty to “stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. This treaty was extended with the famous Kyoto Protocol on December 11, 1997. Currently, 192 countries have adopted this Protocol. This reduction of CO₂ emissions means to work for changing fossil fuel combustion, main source of energy still on that date, by other alternative sources, and for the reduction of energy consumption, with more efficient technologies.

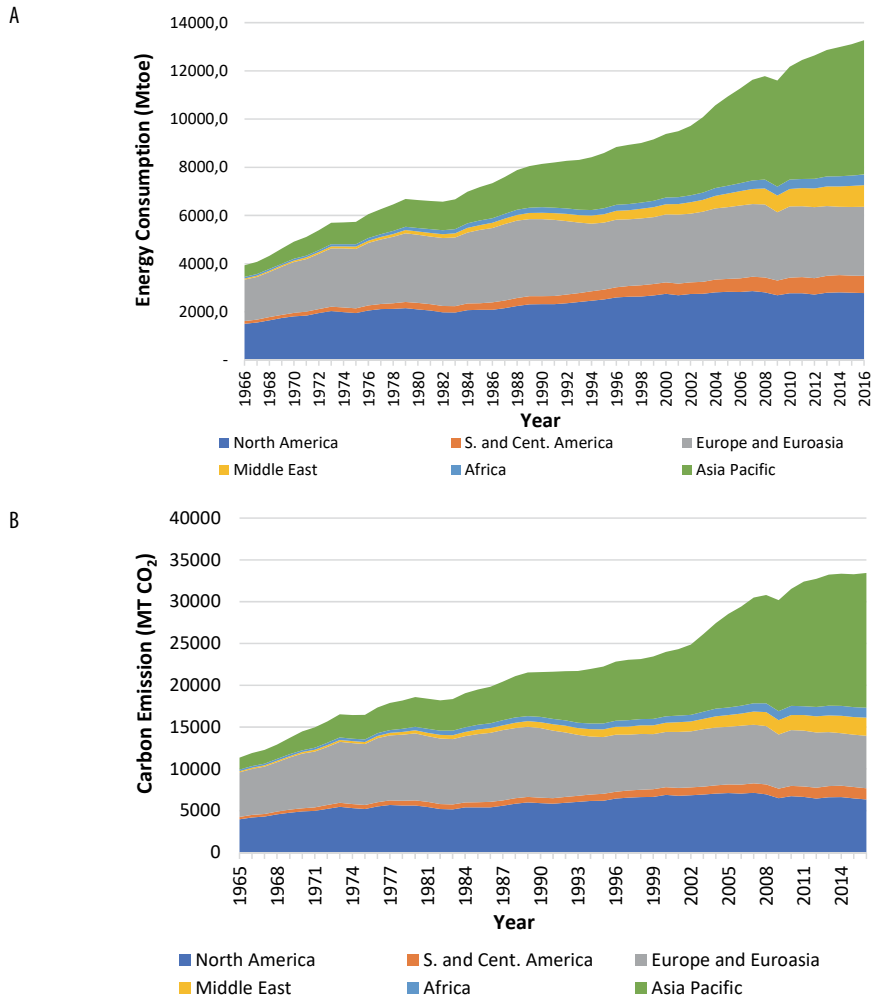


Fig. 1.3. Evolution of World Energy Consumption (A) and Carbon emissions (B) from 1966-2016 (Source: own elaboration based on BP, 2017)

The change that is taking place in the energy landscape can be highlighted by plotting the evolution of the main sources of energy in the last 50 years (Fig. 1.4). In 1966, combustion of fuels based in fossil (oil, gas and carbon) represented almost 95% of the global energy production. Hydroelectricity contribution was 5% of this production while the contribution of other renewable sources and nuclear energy was insignificant. At present, the fossil-fuel share has been reduced to 85%. Other energies, nuclear with a percentage of 5% and renewables (hydroelectricity plus other renewables) with 10%, are acquiring an increasingly important role. It is worthy to notice the development of gas fuel. The thermal gas plants replaced more polluting ones, such as carbon.

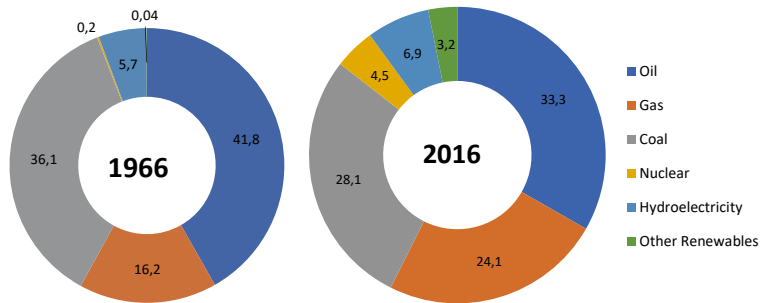


Fig. 1.4. Sources share of global primary energy consumption in years 1966 and 2016 (Source: own elaboration based on BP, 2017)

Finally, another aspect that needs to be highlighted in the new energy landscape is that the presence of new countries in global energy markets has increased dramatically in the past decade. China and other Pacific Asia countries have gone from a percentage of 12% in 1966 to 42% in 2016 of global energy consumption (Fig. 1.3), becoming the area with the highest energy consumption in the world. This is a fact that has an important effect in the current energy market and in geopolitical dynamics of world, giving rise to new energetic strategies between countries.

1.1.2. The Case of Poland, Lithuania and Spain

The aim of this chapter is to show the evolution of different renewable energies in last 50 years. The development of mains renewable energies (hydroelectricity, wind power and solar energy) in different world areas during this period will be presented, introducing also the advantages and disadvantages of each source.

Special attention will be given to three European countries: Poland, Lithuania and Spain. These countries differ significantly, both: for their climatic conditions and for their history, which has an important influence on energy consumption and on the development of renewable energies in these countries. Fig. 1.5 shows a comparison of energy consumption of these three countries from 1966 to 2016.

Poland is a traditional industrial country. Despite the social and economic problems of the period between 1966 and 1980, Poland featured an industrialization and a relative improvement in the standard of life. This corresponds with a high growth of energy consumption during this period. In 1980, Poland was shaken by an unprecedented economic and political crisis which resulted in the stabilization of energy consumption. After the fall of the socialist government in 1989, Polish industrialization continued.

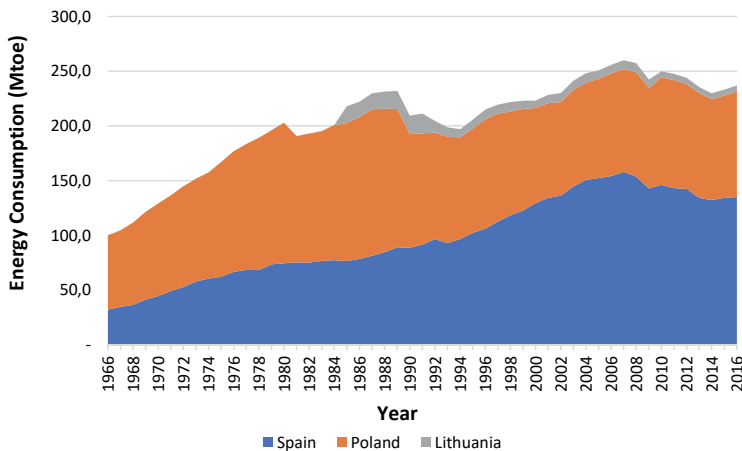


Fig. 1.5. Primary energy consumption of Poland, Lithuania and Spain from 1966 to 2016 (Source: own elaboration based on BP, 2017)

Lithuania is a smaller country (which population is less than 10% of that of the other two countries) which was part of Soviet Union since 1940, when it was occupied by USSR, until its independence in 1991. In fact, we have Lithuanian data of energy consumption only since 1985, few years before its independence. Similarly, in Poland, a growth of industrialization and energy consumption occurs after the fall of communism.

Spain is certainly a different case. In 1966, Spain began to recover from the consequences of its Civil War. So, with a population similar to that of Poland, energy consumption was 50% lower. A greater openness to abroad and a closer relationship with the USA and other Western countries produced the economic recovery of this country. At the beginning, economic growth was slow until Spain became a full member of the European Economic Community, in 1986. Then, the definite Spanish economic boom occurred, transforming Spain into one of the most prosperous countries of this Community, increasing greatly its energy consumption.

In the three countries, the Global Financial Crisis of 2008 has meant the collapse of their economies and the reduction the energy consumption.

Also, an important change in the energy sources used in these countries has occurred in the same period. Fig. 1.6 shows energy sources in Poland in the years 1966 and 2016. In 1966, coal was the main source with almost 90% of the energy production. Renewable energy contribution was negligible. At present, the renewable energy begins to develop in Poland, representing 5% of the total energy production. Also, coal contribution has been reduced, being replaced by other less polluting fossil sources, such as gas or oil.

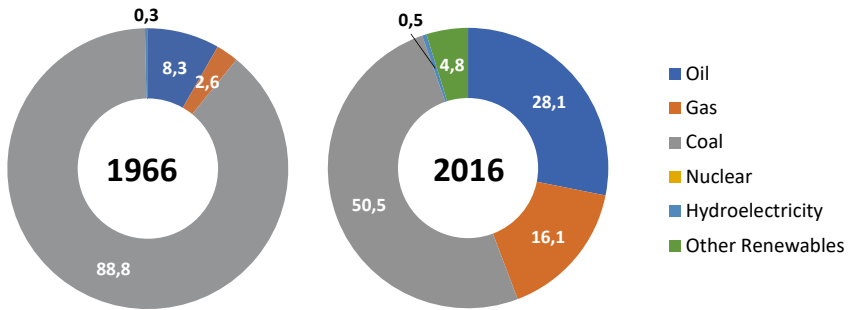


Fig. 1.6. Sources share of primary energy consumption in Poland in years 1966 and 2016 (Source: own elaboration based on BP, 2017)

The Lithuanian situation is different. Fig. 1.7 shows its main sources of energy production in 1985, the first year that data was obtained, and 2016. In 1985, fossil fuel contribution was highest, with 85% of the total energy production, mainly oil and gas. It must be pointed that nuclear energy production was 14% in this year. This high percentage is explained because two nuclear reactors began operating in Lithuania in 1983. Reactors built to export electricity to its neighbors. In 1989, Lithuanian electricity exported was 42%. In 1994, Lithuania received US\$36.8 million from the European Bank for Reconstruction and Development’s Nuclear Safety Account to close its Nuclear Power Plants (NPP) in 15-20 years. The last reactor was closed in 2009.

The closing of NPP, the source of the cheapest electricity, which provided nearly 70-80% of the country electricity supply had a special impact on the future of the energy sector in Lithuania, what has made it necessary to look for new energy sources, such as renewable one. At present, Lithuania remains highly dependent on electricity and gas imports, particularly from the Russian Federation.

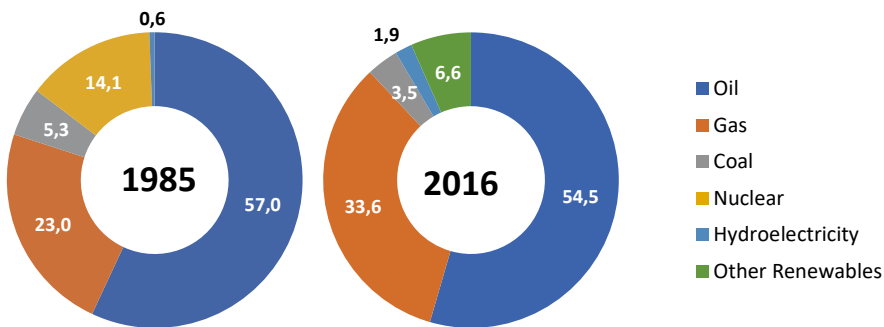


Fig. 1.7. Sources share of primary energy consumption in Lithuanian in years 1985 and 2016 (Source: own elaboration based on BP, 2017)

The Directive 2009/28/EC on promotion of the use of energy from renewable sources (RES) sets individual Lithuanian targets to reach 23% of RES in gross final energy consumption till 2020. Lithuania has reached this target in 2013, and, at the end of 2017, it has signed an agreement with Finland to export renewable energy to this country.

Spain has undergone a complete transformation in its energy landscape in the last half century (Fig. 1.8). Hydropower was traditional electricity source at the beginning of the previous century with 84% of contribution. Spanish capacity from hydroelectric dams is one of the highest proportions in Europe and the world. In the decade of the 60s, economic recovery resulted in tripled energy needs and thermal plants of traditional fossil fuel, coal and oil, were installed.

However, Spanish energy dependence (76%) is well above the average for the EU-27 (54%). The impetus of the renewable energy sector produced in the last decade has reversed this situation. The Spanish government approved the Regulation for Renewable Energies in 2007 (RD-1, 2007), assuming to reach the RES share of 12.1% of overall gross energy consumption by 2010 and 22.7% when considering only the electricity generation. At present, RES represents 17.5% of the primary energy consumption and 42.8% of the electricity demand coverage.

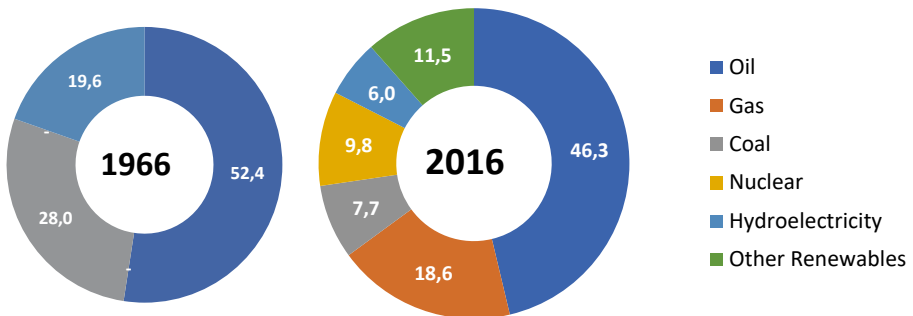


Fig. 1.8. Sources share of primary energy consumption in Spain in years 1966 and 2016 (Source: own elaboration based on BP, 2017)

1.2. Renewable Energy Sources

In the last decade, the situation of Renewable Energy Sources (RES) has shifted considerably. They have passed from being a technology which potentiality was merely known to having demonstrated their large-scale deployment. Even some countries are considering the possibility of achieving a share of 100% of their energy consumption by RES.

Technologic progress and declining costs (due to an extraordinary growth in the renewable energy markets and a number of manufactures of this technology) have done that RES are not only a tool for mitigating climate change but are dependent on economic government supports for they implantation; they are also increasingly recognised as investments that can provide direct economic profits and reduce dependence on imported fuels.

In this last decade, renewable energy has doubled its contribution to primary energy consumption (Fig. 1.9). Ten years ago, RESs were concentrated in USA, Europe and Japan. During this time, China has become the world leader in renewables manufacturing and installed capacity. Other developing countries in South America, Middle East and Africa have also increased their interest in this type of energy.

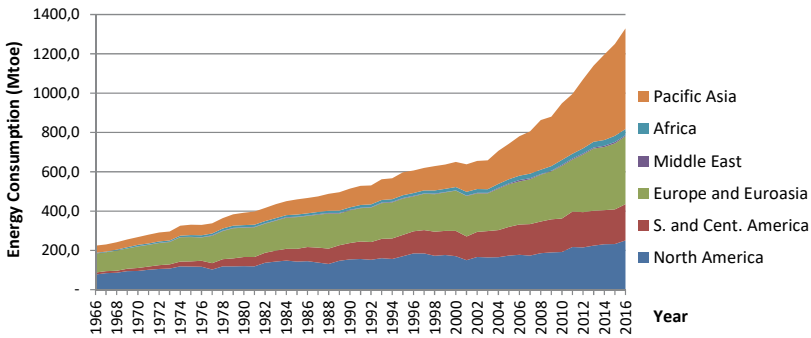


Fig. 1.9. Global renewable energy consumption from 1966 to 2016 (Source: own elaboration based on BP, 2017)

But this advance of RES, that reaches record values in 2016, has not a direct relationship with investment in this type of energies. In fact, 2016 investments were 13% lower than in 2015 (Fig. 1.10). Reduction of cost in PV and wind installations was the main cause behind this situation.

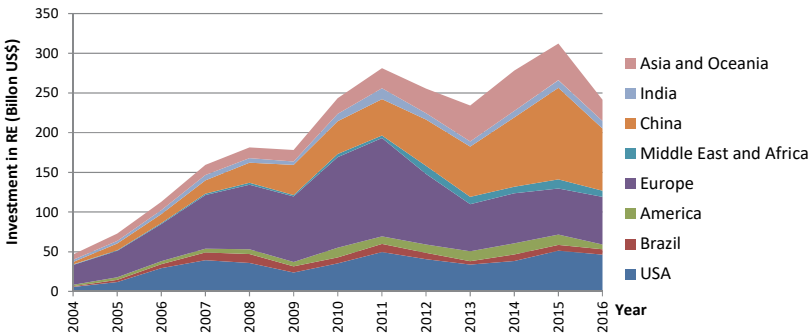


Fig. 1.10. Global new investment in Renewable Energy from 2004 to 2016 (Source: own elaboration based on REN21, 2017)

In 2011, Europe was the area with highest investments, with a share of 44%. As of this year, the European contribution was declining while China's contribution was growing. At present, the largest shares in new investments correspond to China (32%).

From the point of view of the most used renewable energy sources, as can be seen in Fig. 1.11, hydroelectric has been always the source with highest share. In 90's, other renewable sources started to be developed. Currently, hydroelectricity has a share of 68.5%, followed by wind power with 16.3% and solar energy with 5.7%.

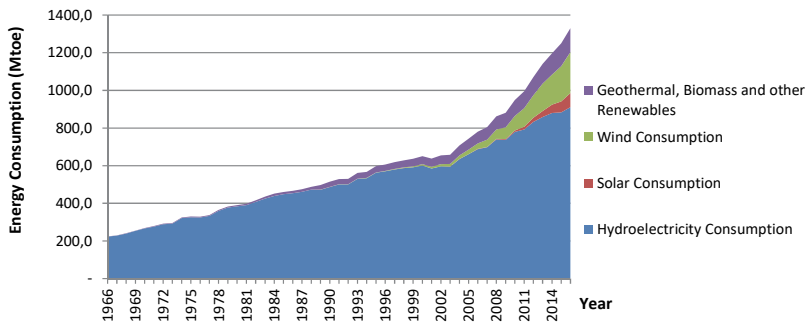


Fig. 1.11. Renewable Energy consumption by source from 1966 to 2016 (Source: own elaboration based on BP, 2017)

The largest investments among RES (excluding large-scale hydroelectricity) are dedicated to the installation of solar energy (Fig. 1.12). This investment is even greater than the wind energy that has a high contribution of energy. This is because the efficiency of this energy source is lower when compared to wind power.

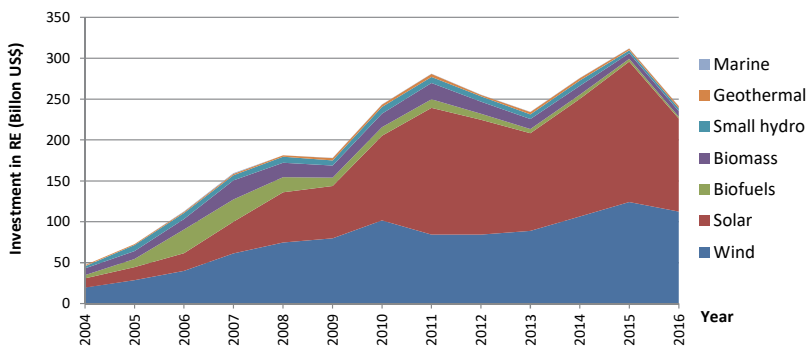


Fig. 1.12. Global new investment in Renewable Energy by source from 2004 to 2016 (Source: own elaboration based on BP, 2017)

1.2.1. Hydroelectricity

Hydropower is the largest source of renewable energy in the world, with a share of 68% of overall RES (368.1 Mtoe of primary energy consumption). It is considered as one of the cheapest energy sources to generate electricity and it is predicted that it will continue leading this sector at least until 2022.



Fig. 1.13. Photo of Hydropower Plant (Source: WEB-1)

There are three main technologies of hydroelectric power plants:

- **Run-of-river hydropower plants:** where energy is obtained directly from the water flow of a river. No energy storage exists in this technology, depending of seasonal and yearly variations.
- **Storage hydropower plants:** water is stored in a dam of a river. Water released from dam flows through a turbine, which generates electricity when it is necessary.
- **Pumped storage plant:** a electrical generator pumps water from a river or lower reservoir to the upper reservoir, where energy is stored. Water is released also through a turbine to produce electricity when it is necessary. The source of electricity for pumping water can be other source of renewable energy, such as wind or solar. So, this plant works as a storage support for another system.

When talking about hydroelectricity as a source of renewable energy, we must distinguish between hydropower plants of large and small scale. The first type corresponds to plants with a capacity higher to 30 MW (10W in some regulations) and the second one to plants with lower capacity. Small hydropower plants are less environmentally aggressive because no very large dams are required. In some national legislation, only this type of hydropower plants receives renewable energy aids.

Fig. 1.14 shows the evolution of energy consumption of hydropower plants during the last 50 years. A continuous growth is observed at the beginning of the 21st century. In this time, the largest hydroelectricity production corresponded to Europe with a share of 31%. In the last decade, China has substantially increased its production. Since 2006, China is leading this sector over other areas.

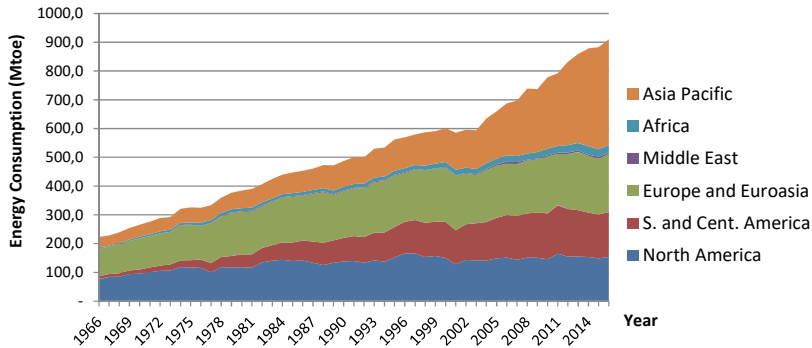


Fig. 1.14. Global hydroelectric energy consumption from 1966 to 2016 (Source: own elaboration based on BP, 2017)

Top 10 hydropower producing countries are listed in Table 1.1 for the years 1966 and 2016. In 1966, these countries produced 76% of the Global Hydroelectric consumption. The leading countries were USA, Canada, USSR, Japan and six Europe countries. In 2016, the share of hydroelectricity produced by 10 top countries was similar, 72%. But in this case, China share was almost 30% of all energy consumption.

Table 1.1. Top Hydroelectric Consumption (Mtoe), 1966 and 2016 (Source: own elaboration based on BP, 2017)

1966		2016	
Country	Energy Consumption	Country	Energy Consumption
USA	45.2	China	263.1
Canada	29.1	Canada	87.8
USSR	21.8	Brazil	86.9
Japan	18.1	USA	59.2
Francia	11.8	Russian Federation	42.2
Norway	11	Norway	32.4
Sweden	10.3	India	29.1
Italy	9.9	Indonesia	19.1
Spain	6.3	Japan	18.1
Switzerland	6.2	Turkey	15.2
Total	169.7		653.1
Global Hydroelectricity	223.2		910.3

The case of Poland, Lithuania and Spain

Poland is a flatland country with few mountains, a fact which limits the capacity of hydropower plants installation. According to the World Energy Council (2014), gross theoretical capacity of this country is 23 TWh/year, and technically exploitable capability of 12 TWh/year. The actual installed capacity is 955 MW. Moderate values for size of this country: 312,500 km² surface area.

The majority of Hydropower plants are located in the south-west area, which is more mountainous. Rivers Lusatian Neisse and Bobr concentrate largest hydroelectricity. Except from few pumped storage plants of high capacity, they are mainly small capacity. In fact, no large-scale hydropower plants have been installed in Poland in the last 40 years.

Polish hydroelectricity consumption is displayed in Fig. 1.15. This consumption is stabilized in about 0.5 Mtoe in the last years, which means a share of 0.5% of total energy consumption of the country and 10% of renewable sources.

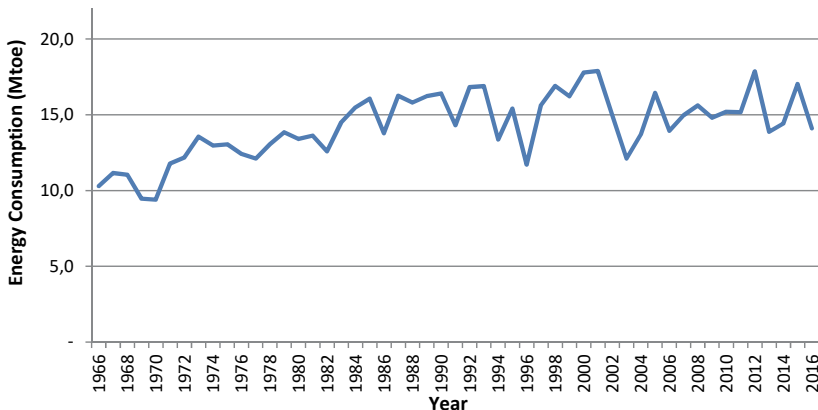


Fig. 1.15. Hydroelectric energy consumption in Poland from 1966 to 2016 (Source: own elaboration based on BP, 2017)

Lithuania, similar to the Polish case, has limitations to develop hydropower plants due to its topographical situation. The gross theoretical capacity of this country is only 2.2 TWh/year. Major number of hydropower plants are in rivers Nemunas and Neris. According to the Ministry of Energy of the Republic of Lithuania, the installed capacity in 2017 is 874 MW. The two most important hydropower plants in Lithuania are:

- Kaunas hydropower plant, with a capacity of 101 MW and 90 MW net.
- Kruonis pumped-storage hydropower plant, with a capacity of 900 MW and 760 MW net. Another unit in this plant, with an additional power of 224 MW, is planned.

Small hydropower plants contribute about 0.25% of hydropower mix.

The hydroelectricity consumption from 1985 to 2016 is showed in Fig. 1.16. An average of 0.10 Mtoe was consumed in this period. This represents 1.8% of overall energy consumption and 20% of renewable sources.

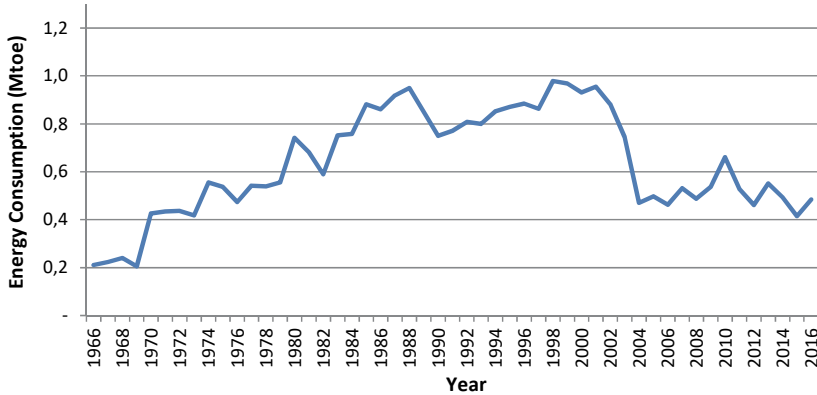


Fig. 1.16. Hydroelectric consumption in Lithuania from 1985 to 2016 (Source: own elaboration based on BP, 2017)

Hydropower has a long history in Spain. With a history of more than a century, this technology is one of the most developed and consolidated ones, with a high level of efficiency. In terms of hydroelectric capacity, Spain is in the middle rank of West European countries, with a gross theoretical capability of 162 TWh/yr. At present, the installed hydropower capacity is 20.1 GW. This source occupied the third position in electricity market behind the combined cycle plants with 27.2 GW and wind power with 23 GW.

In Spain, there are more than 800 hydroelectric plants. 75% of them are small scale plants with an output power of less than 5 MW, but the 20 largest plants produce more than 200 MW and represent 50% of the total installed hydroelectric power. These plants are mainly found in the regions of Catalonia, Galicia and Castilla y León in rivers Ebro, Duero and other rivers from northern Spain.

Some of largest Spanish hydropower plants are listed in Table 1.2.

Table 1.2. Top Hydropower Plants in Spain (Source: own elaboration based on Ministerio de Industria, Energía y Turismo, 2015)

Hydropower Plant	Capacity (MW)	Region	River
CENTRAL DE ALDEADÁVILA	1.243	Castilla y León	Duero
JOSÉ MARÍA DE ORIOL	957	Extremadura	Tajo
VILLARINO	857	Castilla y León	Tormes
CORTÉS-LA MUELA	630	Valencia	Júcar
SAUCELLE	520	Castilla y León	Duero
CEDILLO	500	Extremadura	Tajo

The hydroelectric energy consumption in Spain during the last 50 years is shown in Fig. 1.17. This consumption grew in the first 20 years, subsequently stabilizing at a value of approximately 15 Mtoe. This value represents a 14.5% share of overall energy consumption and 34% of RES.

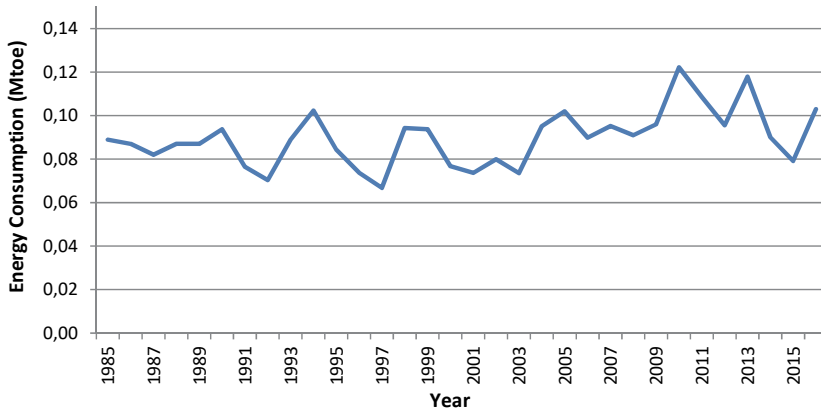


Fig. 1.17. Hydroelectric consumption in Spain from 1966 to 2016 (Source: own elaboration based on BP, 2017)

1.2.2. Wind Power



Fig. 1.18. Photo of Wind Turbines (Source: photo by A. Rodero)

Wind power transforms the kinetic energy of air flowing in electricity, using a wind turbine. This is yet a well-established technology that allows to obtain a cheap electricity, in a competitive way with fossil fuels and other traditional sources. As a result, this source has become the second renewable source in power generation, at the same time it is the source with a more significant grown rate in recent years (Fig. 1.19).

Researches in wind technology have helped to increase capacity factor (a measure of efficiency of wind turbine) from an average of 22% in 1998 to 30% today. This has allowed to reduce the costs of wind energy. Kilowatt-hour (kWh) in 1980 cost 55 cents of dollars. This prize has been reduced to 5 cents at present (WEB-2).

Also, the average turbine generating capacity of new installed wind turbines is higher. This capacity depends on the size of the turbine, and increasingly larger wind turbines are being built.

There are two technologies of wind turbines, according to the location of turbines:

- **Onshore wind turbine:** it refers to turbine located on land. At present, this technology represents the higher share in wind power. It has the advantage of being one of the most affordable renewable energy sources. The price of this technology is half of offshore wind power. Its main disadvantage is its impact in the environment; which has led to criticism among environmental movements.
- **Offshore wind turbine:** it refers to turbine located in sea. The first turbines installed in sea were similar to the onshore ones. By the characteristic of winds in this environment, specific technologies have been developed. Wind speed in water is higher in sea than land for same height. Then, shorter towers can be installed so that smaller fatigue damage will be caused. Additionally, the possibility of use more area allows to build larger and more powerful wind turbine (Colmenar-Santos et al., 2016b).

The global installed wind capacity rises continuously, as can be seen in Fig. 1.19, where cumulative wind capacity is plotted from 2001 to 2017. Similar growing behaviour is found for offshore wind power (Fig. 1.20).

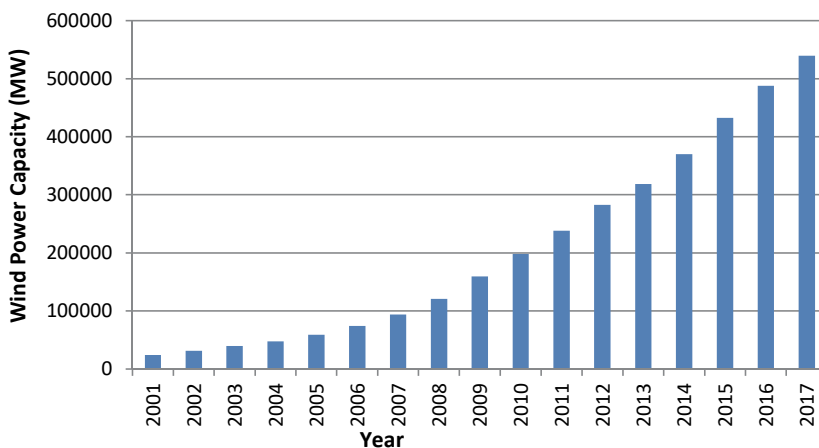


Fig. 1.19. Global cumulative installed wind capacity from 2001 to 2017 (Source: own elaboration based on GWEC, 2016)

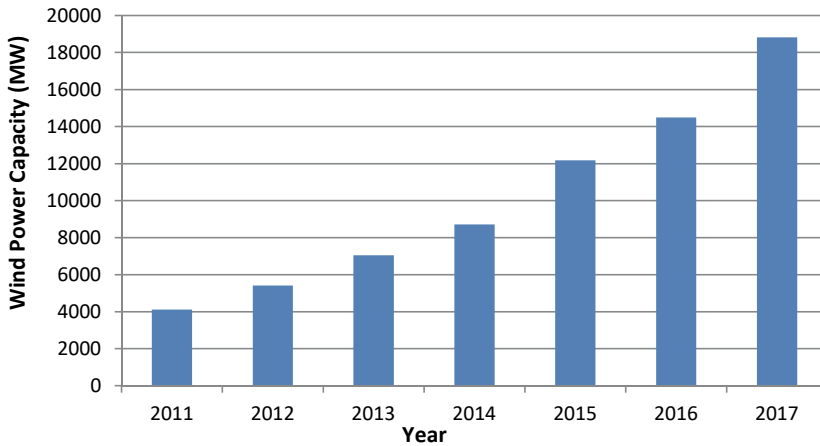


Fig. 1.20. Global cumulative installed offshore wind capacity from 2011 to 2017 (Source: own elaboration based on GWEC, 2016)

By world area, Fig. 1.21 shows wind energy consumption from 1996 to 2016. In 1996 the global wind energy consumption was only 2.1 Mtoe, but this consumption has reached 217.2 Mtoe in 2016. Europe has lead wind power technologies during this period, whereas China has loomed recently. In fact, 2017 has been first year that China has already sped ahead of the rest of the world.

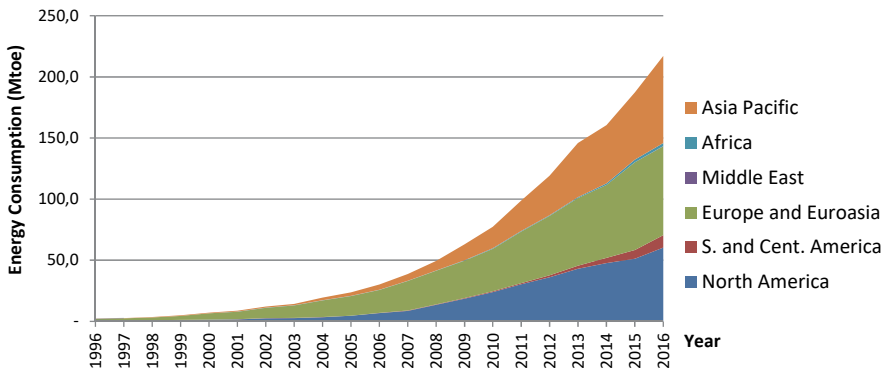


Fig. 1.21. Global wind energy consumption from 1996 to 2016 (Source: own elaboration based on BP, 2017)

Top countries with highest wind production in 2017 are listed in Table 1.3. China is the first producer with a share of 35%. USA and Germany are second and third respectively.

Table 1.3. Top Countries of installed wind capacity (Source: own elaboration based on GWEC, 2016)

Country	Capacity (GW)
China	188.23
USA	89.08
Germany	57.13
India	32.85
Spain	23.17
United Kingdom	18.87
France	13.76
Brazil	12.76
Canada	12.24
Italy	9.48

Top countries of offshore wind energy are listed in Table 1.4. In this case, United Kingdom is the first producer, with more wind turbines in its coast.

Table 1.4. Top Countries of installed wind capacity (Source: own elaboration based on GWEC, 2016)

Country	Capacity (GW)
United Kingdom	6.84
Germany	5.36
China	2.79
Denmark	1.27
Netherland	1.12
Belgium	0.88
Sweden	0.20
Vietnam	0.099
Finland	0.092
Japan	0.064

The cases of Poland, Lithuania and Spain

Wind power generation is the most dynamically developing branch of the renewable energy sector in Poland. The installed wind power capacity of 5.87 GW in 2016 puts Poland in 7th place in the European Union (Gnatowska & Wąs, 2017). The operating wind farms are mainly located the northern and central parts of the country, benefitting from the Baltic Sea winds.

Table 1.5 shows installed capacity by Polish province. Five first provinces have 68% of all capacity of country.

Table 1.5. Installed wind power capacity by Polish province (Source: own elaboration based on Energy Regulatory Office, 2017)

Province	Capacity (MW)	Province	Capacity MW)
zachodniopomorskie	1477.2	lubuskie	192.0
Wielkopolskie	686.8	dolnoslaskie	176.4
Pomorskie	684.9	podkarpackie	152.9
kujawsko-pomorskie	592.6	opolskie	138.2
Lódzkie	579.8	lubelskie	134.9
Mazowieckie	378.8	slaskie	33.1
warminsko-mazurskie	353.6	swietokrzyskie	22.3
Podlaskie	197.3	malopolskie	6.7

Fig. 1.22 shows the evolution of wind power capacity installed in Poland from 2005 to 2016. This high growing is due to investment incentive policy regulated by old Green Certificate system. A new Wind Farm Act was signed in 2016. This Act prohibits building turbines within 1.5-2 km of other buildings or forests, which means 99% of Polish land and quadruples; also, the tax rate on existing turbines. These changes are important restrictions in the development of wind energy that will have to see what future effect will have on this source (PWEA, 2016). A solution could be to resort offshore wind turbines, for instance a 1.2 GW installation is planned in the Baltic Sea.

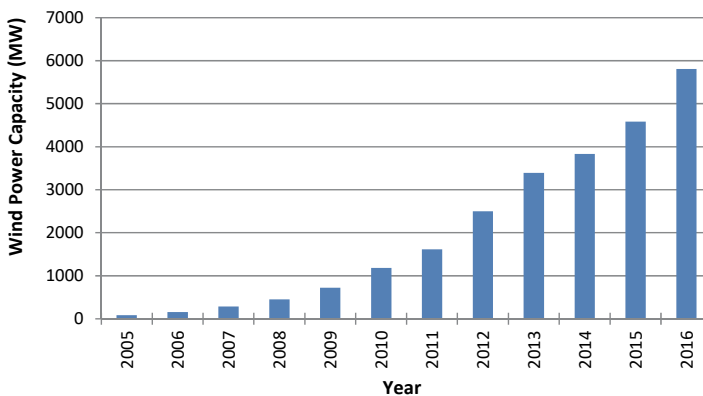


Fig. 1.22. Installed wind power capacity in Poland from 2005 to 2016 (Source: own elaboration based on PWEA, 2016)

Wind energy consumption of Poland is shown in Fig. 1.23. In 2016, this consumption has been 2.8 Mtoe, a share of 55% of all renewable energy sources and 2.9% of total energy consumption of country.

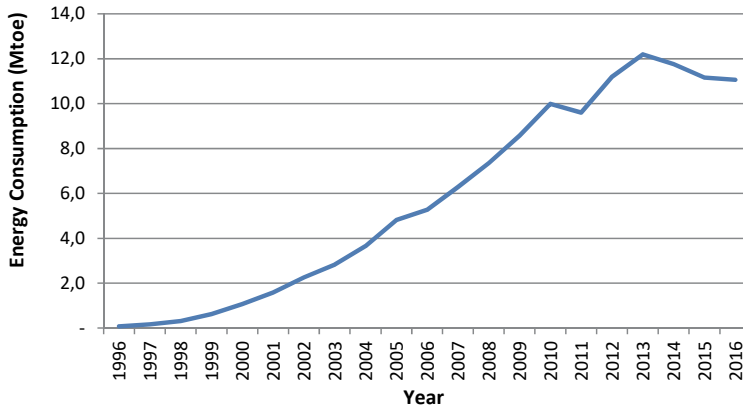


Fig. 1.23. Wind energy consumption in Poland from 1996 to 2016 (Source: own elaboration based on BP, 2017)

Lithuania has reached a capacity of 509 MW in 2016. It is the European country with most installations relative to its power consumption (EWEA, 2016). This is a result of promotion policy to reach the 23% of EU Directive, where Government has set wind energy as a priority area. The National Control Commission for Prices and Energy took measures to make more attractive this source with special high purchase prices for electricity produced by wind (6.4 eurocents per kWh in 2010) (Marciukaitis et al., 2008).

Fig. 1.24 shows installed wind power capacity in Lithuania from 2004 to 2016. This capacity has passed from 6 MW in 2004 to 509 MW in 2016.

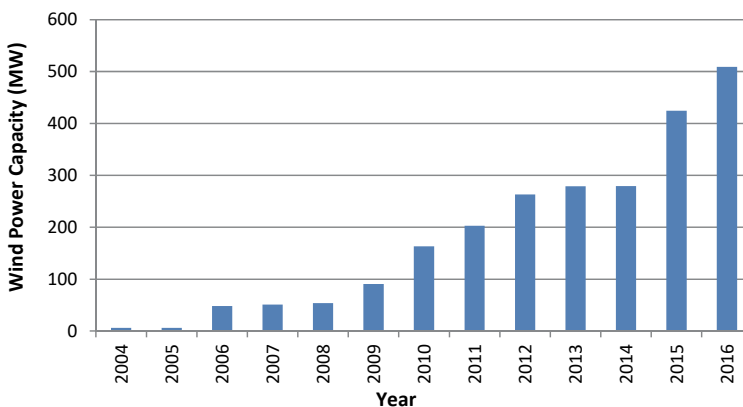


Fig. 1.24. Installed wind capacity in Lithuania from 2004 to 2016 (Source: own elaboration based on WEB-3 and EWEA, 2016)

There are about 193 wind farms in Lithuania, the majority of them with power lower 2 MW. But ten top Lithuanian wind farms, located in the North-West border of country, produce 70% of all wind capacity (Table 1.6). First one is Pagėgiai 13 that with a capacity of 73.5 MW is a biggest farm of Baltic countries.

At present, all farms are onshore. Lithuania and other Baltic countries are developing projects to install offshore wind farms in their coast. In the case of Lithuania, the current regulation on seabed exploration licensing crippled progress of this technology.

Table 1.6. Top Wind Farms of Lithuania (Source: own elaboration based on WEB-4)

Country	Capacity (GW)
Pagėgiai 13	73.5
4Energy vėjo elektrinių parkas	60
IKEA Group vėjo elektrinių parkas	45
Čiūtelių vėjo jėgainių parkas	39.1
Benaičių-1 vėjo elektrinių parkas	34
Vydmantų vėjo parkas	30
Rotulių II VE parkas	24
Kreivėnų vėjo elektrinių parkas	20
Laukžemės VE	16
Didžiųjų VEP (L-591)	16

Fig. 1.25 shows wind energy consumption in Lithuania from 2000 to 2016. The energy consumption was 0.24 Mtoe in 2016. A share of 4.5% of total energy consumption and 50% of renewable energy consumption.

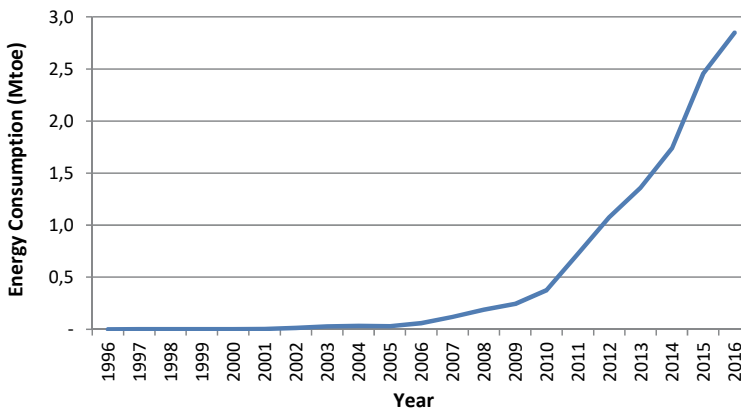


Fig. 1.25. Wind energy consumption in Lithuania from 2000 to 2016 (Source: own elaboration based on BP, 2017)

Spain is the fifth producer of wind energy in the world, with a capacity of 23026 MW. It was the second in wind capacity and the first in annual growth for some years, but the uncertainty due to the change of the Spanish regulation of incentive to renewable energies in 2013 results in stopping of new wind farm installations.

Evolution of Spanish wind capacity from 1998 to 2016 is displayed in Fig. 1.26. Blockage of wind system in last years is clearly observed in Fig.1.26.

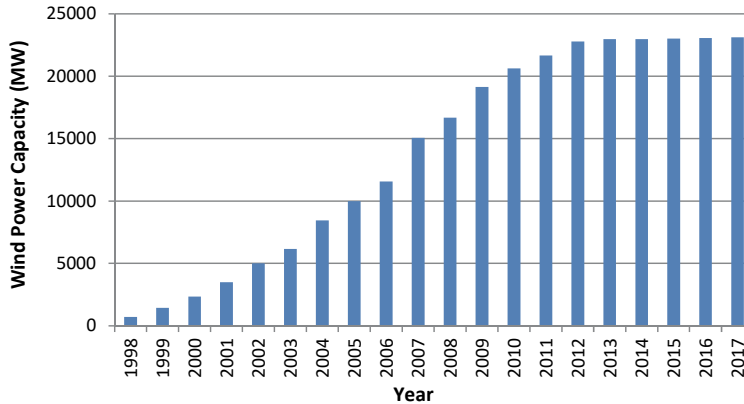


Fig. 1.26. Installed wind capacity in Spain from 1998 to 2016 (Source: own elaboration based on AEE, 2016)

1077 wind farms are distributed by the different Spanish regions (Table 1.7). The five first regions produce 78% of overall wind power. The leader is region Castilla y León that produces 95% of total energy consumed in this region and 24% of Spanish wind capacity. Castilla y León is in the second position; it produces 75% of its energy consumption.

Table 1.7. Wind capacity and number of wind farms in Spanish regions (Source: own elaboration based on AEE, 2016)

Spanish Region	Capacity (MW)	Number of wind farms
Castilla y León	5.561	241
Castilla-La Mancha	3.807	139
Andalucía	3.338	153
Galicia	3.328	161
Aragón	1.893	87
Cataluña	1.269	47
Comunidad Valenciana	1.189	38
Navarra	1.004	49
Asturias	518	21

Spanish Region	Capacity (MW)	Number of wind farms
La Rioja	447	14
Murcia	262	14
Canarias	177	56
País Vasco	153	7
Cantabria	38	4
Baleares	4	46

Evolution of wind energy consumption in Spain from 1996 to 2016 is shown in Fig. 1.27. Similar to the wind capacity, a stagnation of consumption growth can be observed in last years, which is due to the fall in consumption by crisis and the decline in installations of new wind turbines. In 2016, wind energy consumption was 11.1 Mtoe, a percentage of 8.2% of total Spanish energy consumption and 47% of renewable energy.

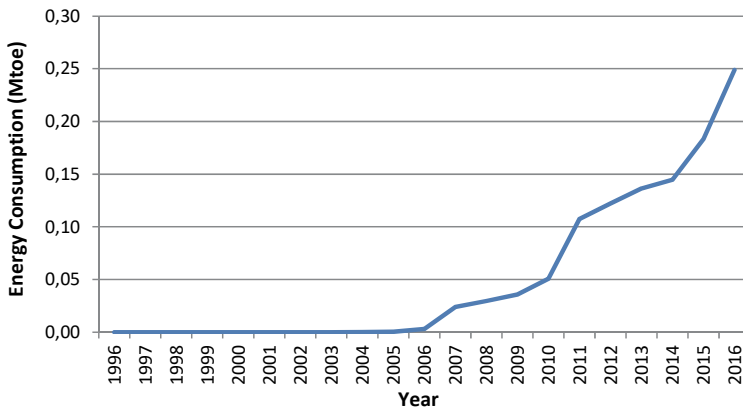


Fig. 1.27. Wind energy consumption in Spain from 1996 to 2016 (Source: own elaboration based on BP, 2017)

1.2.3. Solar Energy

Solar power technologies are considered to be one of many key solutions toward fulfilling the global increasing demand for energy and reduction of CO₂ emissions. The sun is the most important source of free and inexhaustible energy. Installed sun electricity capacity of the world was more 305 GW at the end of 2016, but the potentiality of this source is higher and development of new technologies will contribute to its future growth.



Fig. 1.28. Photo of CSP Plant (Source: photo by A. Rodero)

Fig. 1.29 shows the solar energy consumption in the world. In 2016, this consumption reach amount of 331 Mtoe, a share of 2.3% of global energy consumption. Europe have led this sector still 2016. Important investment of China in this technology has made its contribution exceed that of Europe for the first time this year.

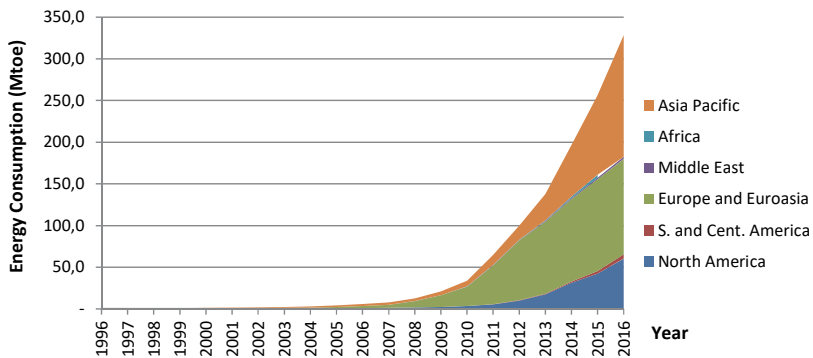


Fig. 1.29. Global solar energy consumption from 1996 to 2016 (Source: own elaboration based on BP, 2017)

There are three main types of solar technologies:

- **Photovoltaic (PV) collectors:** transform solar radiation directly into electricity by photovoltaic effect. It is the most developed technology for solar energy with a capacity of 303.1 MW at the end of 2016 and a continuous exponential growth as shown in Fig. 1.30. Solar PV installation can be isolate (off-grid) or grid-connected. Demand of off-grip is expanding, but the capacity of grid-connected systems is rising more quickly and continues to account for majority of global solar PV installations.

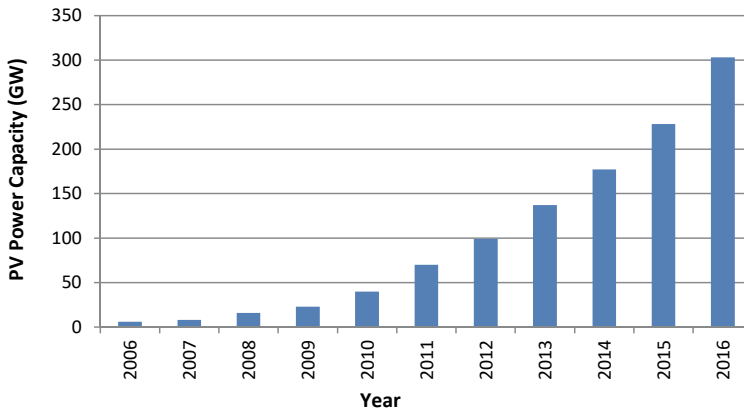


Fig. 1.30. Global Solar Energy Capacity from 2006 to 2016 (Source: own elaboration based on REN21, 2017)

China and Japan are leaders in PV technology. In fact, Asia accounts for 48% of all world production of photovoltaic energy (Table 1.8).

Table 1.8. Top countries with Solar PV installations (Source: own elaboration based on WEB-5)

Country	Capacity (GW)
China	78.1
Japan	42.8
Germany	41.2
USA	40.3
Italy	19.3
UK	11.6
India	9
France	7.1
Australia	5.9
Spain	5.3

- Concentrated solar power (CSP) plants** (Fig. 1.28) are systems that collect and concentrate light from the sun to produce the high temperature needed to generate electricity by a power block, similar to these used in traditional fossil fuel thermal plants. CSP technologies are currently in medium to large-scale operation with a production of about 4.8 GW in 2016 and mostly located in Spain and the USA (Fig. 1.31). China has projected to build 20 pilot plants to produce 9.6 GW for 2020.

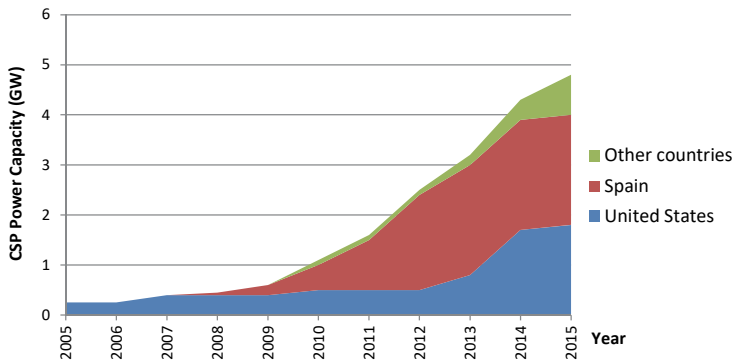


Fig. 1.31. Global CSP Capacity from 2006 to 2016 (Source: own elaboration based on BP, 2017)

The main problem with this technology is its high cost. Current reduction of cost in photovoltaic technologies makes CSP uncompetitive and needs research to improve its efficiency and reduce costs. This type of research is necessary for development of CSP to large-scale.

There are four main type of CSP (see Chapter 2):

1. Parabolic Trough Reflector (PTR),
2. Solar Tower,
3. Parabolic Dish,
4. Linear Concentretor Fresnel.

Parabolic trough reflector (PTR) technology is responsible for 96.3% of total world thermal energy production and Solar Tower is in the second place with 3%.

- **Solar heating system.** This technology is used extensively in all regions of the world to provide hot water and to heat and cool space. It is mostly low temperature system that uses flat plate or vacuum solar collectors. Evolution of capacity of this technology in the last decade is shown in Fig. 1.32. In 2015, capacity reaches 450 GW-thermal.

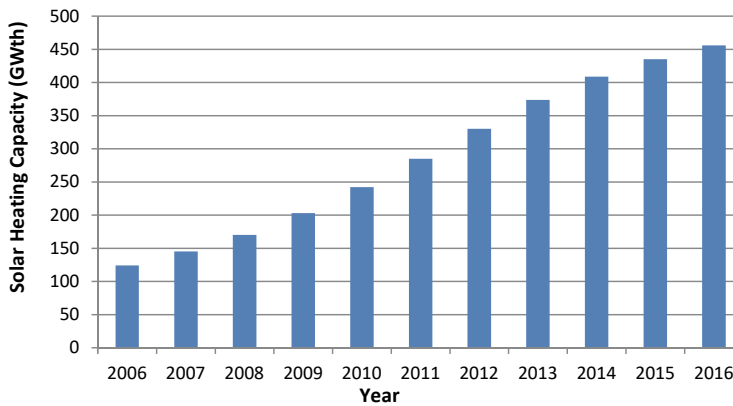


Fig. 1.32. Global Solar Heating Capacity from 2006 to 2016 (Source: own elaboration based on REN21, 2017)

The leader country of this technology was China with a share of 71%, followed by United States (10%), Turkey (3%) and Germany (3%) (Table 1.9).

Table 1.9. Top countries with Solar Heating Capacity (Source: own elaboration based on REN21, 2017)

Country	Capacity (GWth)
China	323.8
United States	45
Turkey	13.5
Germany	13.5
Brazil	9
India	6.3
Australia	6.3
Austria	3.6

The main application of solar thermal technology is water heating in single-family houses with a share of 63% in 2015, but markets have been transitioning to large-scale systems for building, public sector and district-heating (REN21, 2017).

The case of Poland, Lithuania and Spain

Poland is relatively new in the solar energy sector. Although, solar capacity in the country will reach to 15.83 GW in 2050 according to the Polish Energy Policy 2050. Growth is still slow for this propose. Fig. 1.33 shows the evolution of Solar Energy Consumption in Poland in the last decade. Significant consumption begins in 2013

and has a continuous growth. In 2016, solar energy consumption is 0.028 Mtoe, what is only 0.03% of the overall energy consumption of the country.

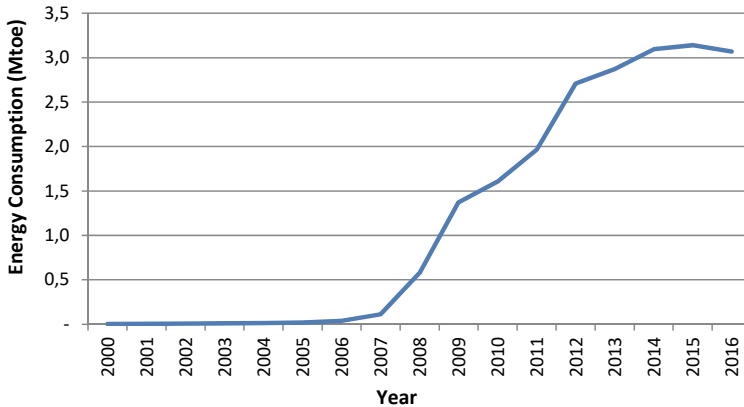


Fig. 1.33. Solar energy consumption in Poland from 2006 to 2016 (Source: own elaboration based on BP, 2017)

All RES experts agree that Poland has a big potential in PV electricity, but instability of regulations and uncertainty of subsidies has stopped development of this technology. Despite this fact, the PV facilities have grown in Poland in recent years, especially from year 2013 (Fig. 1.34). In 2016, the Solar PV capacity in Poland reach to 195.7 MW, majority by on-grid system (98%).

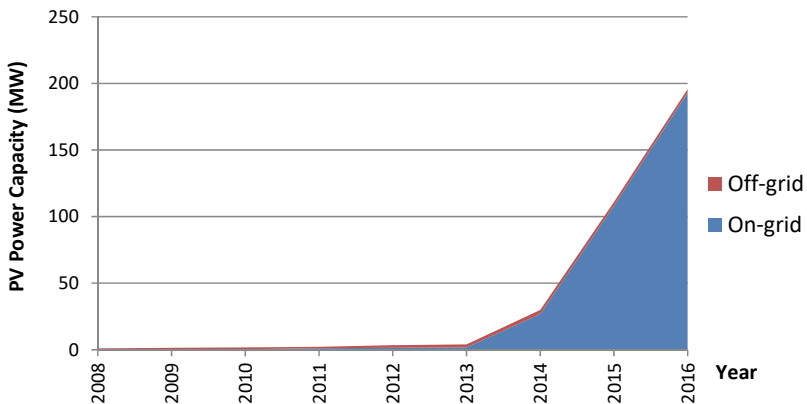


Fig. 1.34. Solar PV capacity in Poland from 2008 to 2016 (Source: own elaboration based on WEB-6)

Sector of solar thermal collector is the biggest microgeneration RES market in Poland, bigger than biomass, heat pumps, photovoltaics etc. Subsidies from the National

Fund for Environmental Protection and Water Management (NFOSiGW) have had a great influence in the development of this technology. During 5 year of programme duration, NFOSiGW contributed up to 35% of solar collector installations. In 2012, Poland was second European country in collector investment and annual collector surface installation.

Fig. 1.35 shows the accumulative collector surface in Poland from 2008 to 2016. In this year, the surface of overall solar collector reaches to $2.13 \cdot 10^6 \text{ m}^2$ that it is equivalent to an energy production of 1.5 GWh.

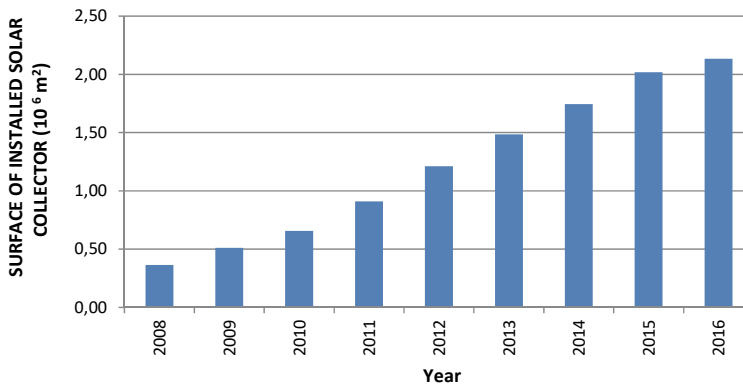


Fig. 1.35. Accumulative surface of solar thermal collectors in Poland from 2008 to 2016 (Source: own elaboration based on WEB-6)

Lithuania, like Poland, does not have important solar contribution to its energy market, with an annual potential of solar energy of approximately $1,000 \text{ kWh/m}^2$, similar to other countries from the same latitude. Current solar consumption is only 0.015 Mtoe, a share of 0.27% of overall energy consumption (Fig. 1.36). The most favourable place for solar energy development is in the western part of the country, where the number of sunny days is the largest (Valančius et al., 2015). Solar energy is used for heating of water or building with passive system but also for produce electricity by PV plants.

PV electric generation reached 80 MW in 2016, far of the Government aim of 200 MW for 2020. Fig. 1.37 shows the evolution of PV electricity generation from 2008 to 2016. The biggest growth was between 2011-2013, due to generous feed-in tariff (FIT) scheme was put in place for plant up to 30 MW. The scheme ensured a 12-year FIT for the project and facilitated access to simplified authorization and network connection procedures. Currently, with an 80% of commercial installation, a new scheme has been approved by Government for development of small-scale net metering plants of capacity up to 10 MW for homeowners and up to 50MW in public building. The owners could receive from 30% to 100% of the investment support.

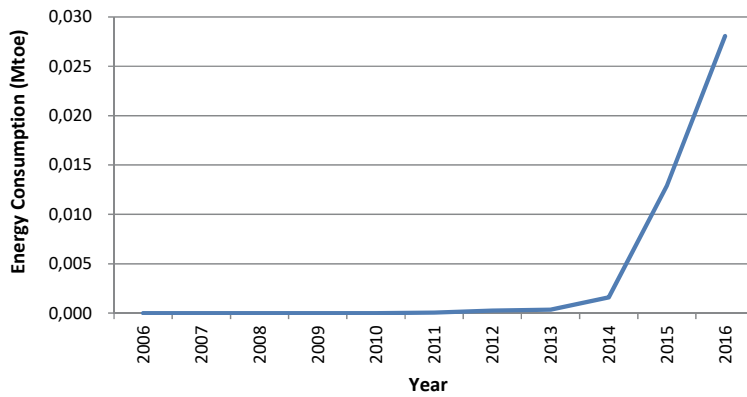


Fig. 1.36. Solar energy consumption in Lithuania from 2006 to 2016 (Source: own elaboration based on BP, 2017)

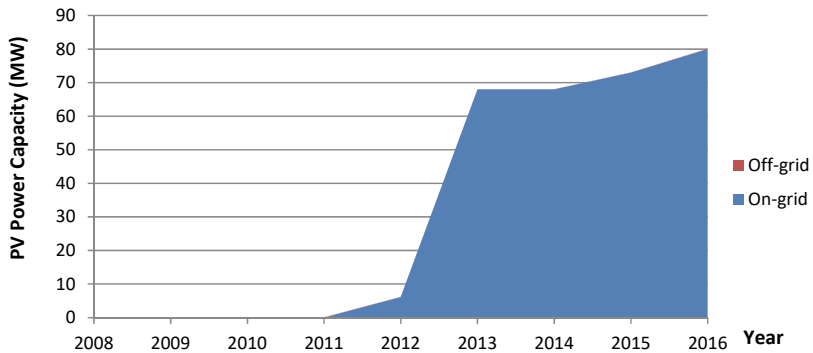


Fig. 1.37. Solar PV capacity in Lithuania from 2008 to 2016 (Source: own elaboration based on WEB-6)

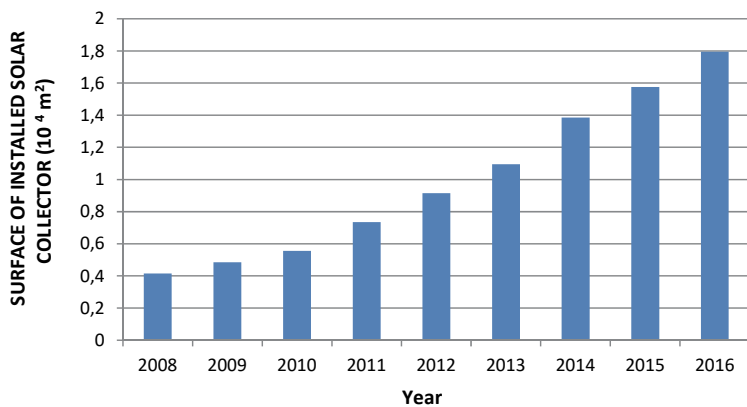


Fig. 1.38. Accumulative surface of solar thermal collectors in Lithuania from 2008 to 2016 (Source: own elaboration based on WEB-7)

Heating system has been also promoted by Renewable Energy Law, with economic support and prioritizing building projects that use heating with RES. Evolution of accumulative surface of installed solar collectors is shown in Fig. 1.38. In 2016, this surface was 17950 m², equivalent to 13 MW.

Neither Poland nor Lithuania have working CSP installations.

Spain shows a completely different case in the development of Solar Energy. Spain has been leader in solar sector, result of its climatic conditions and of a subsidies policy. Spain is one of the countries with the longest amount of sun hours in Europe (potential of solar energy of approximately 2,000 kWh/m²) and it was one of first European country to introduce a “feed-in tariff” program in 2002. However, the new renewable energy law of 2012 cancelled the feed-in tariff system and resulted in the reduction of the number of solar installations.

Fig. 1.39 shows solar energy consumption in Spain from 2000-2016. It can be seen the increase in consumption what started in 2007, when the new Spanish law was approved (RD-1, 2007). This Law improved amount of the “feed-in tariff” system. The maximum consumption was in 2016 when it reached 3.1 Mtoe, corresponding to a share of 2.3% on overall energy consumption of the country and 13.1% on renewable energy sources.

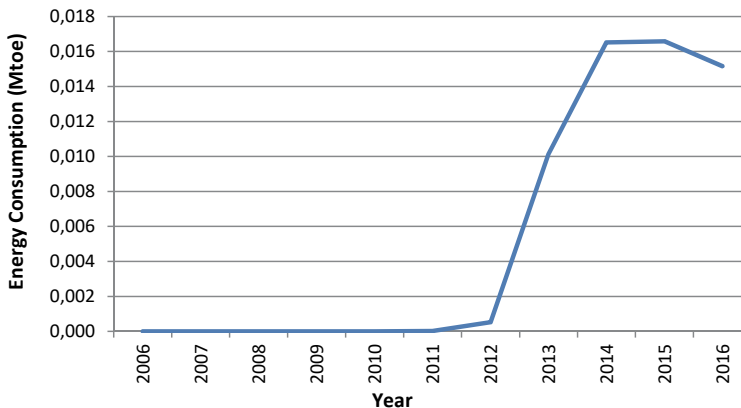


Fig. 1.39. Solar energy consumption in Spain from 2000 to 2016 (Source: own elaboration based on BP, 2017)

PV capacity grew rapidly in Spain from 2007 to 2008 result of law of Renewable Energy of 2007 (Fig. 1.40), rising from accumulative capacity 267 to 3600 MW. In 2013, new installations were stopped by change of law (Mir-Artigues et al., 2015).

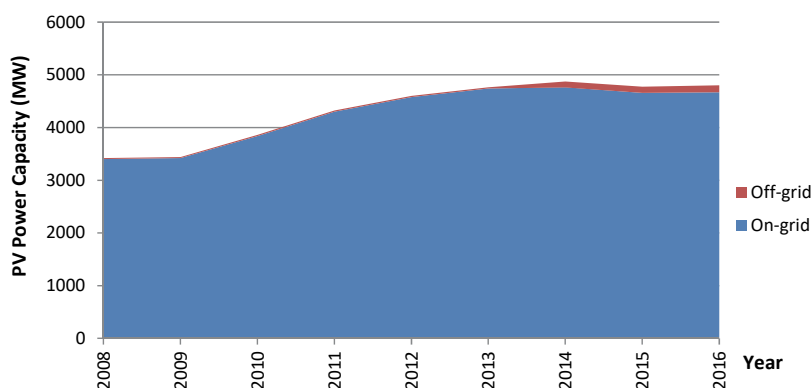


Fig. 1.40. Accumulative solar PV capacity in Spain from 2000 to 2016 (Source: own elaboration based on BP, 2017)

The most part of generation was in southern Spain, with a share of 72%, central part of the country 20% and the north only 8%. Table 1.10 shows distribution of PV electricity generation in different regions.

Table 1.10. PV electricity generation in Spanish regions in 2017 (Source: own elaboration based on WEB-8)

Spanish Region	Electricity Generation (MWh)
Castilla-La Mancha	1743029.8
Andalucía	1580768.7
Extremadura	1119171
Castilla y León	897004.3
Región de Murcia	774324.9
Comunidad Valenciana	543521.1
Cataluña	420557.2
Comunidad Foral de Navarra	315736.2
Aragón	311344.2
La Rioja	139487.4
Comunidad de Madrid	91855.5
País Vasco	31249.6
Galicia	20808
Cantabria	1944.5
Principado de Asturias	605.9
Total	7991408.3

The majority of this production is on-grid. Only 27% of PV electricity production is off-grid. In this regard, it should be noted that the Spanish government approved a new national law on self-consumption of energy that taxes solar installations in 2015. Owners of a solar installation that just produces for their own use and does not feed into the grid must pay the same grid fees as any other electricity consumer. This has further made the situation worse of the PV sector in Spain (López-Prol & Steininger, 2017).

Development of solar heating systems in Spain is closely related to the regulation of construction in building included in the Spanish Technical Building Code (RD-2, 2006). This regulation requires the use of a renewable energy source to cover a minimum percentage of energy for water heating in new construction building. This requirement is also mandatory for expansion of existent buildings with increasing of water consumption of 5000 l/day. The minimum percentage depends on Spanish area, being more restrictive in the South where share can reach 60%.

According to this regulation, every new building in Spain from 2009 has a solar or biomass heating system. Fig. 1.41 shows development of solar collectors' surface in Spain during that time. Growth was very high in the first years. As of 2011, the slope decreased due to the building stop by the economic crisis. In 2016, the area of installed solar collectors reached 3,910,600 m², equivalent to 2.7 GWth.

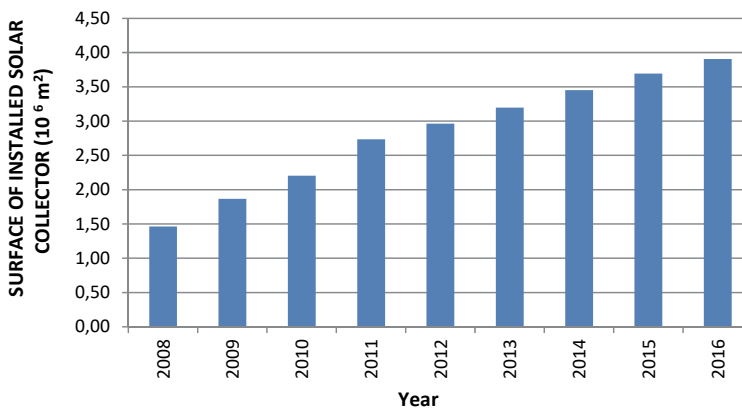


Fig. 1.41. Accumulative surface of solar thermal collectors in Spain from 2008 to 2016 (Source: own elaboration based on WEB-7)

Finally, we will present the development of CSP technology in Spain, which is a world leader. Within the framework of the Feed-in-Tariff program of 2007, the first CSP plant was built in Seville in 2007, a Solar tower of 10MW. In the end of 2009, 8 CSP plants more were built with a capacity of 283 MW and Government approved still a total of 50 plants with a capacity of 2304 MW.

In 2012, new Law of Energy cancelled the Feed-in-Tariff program and no more CSP plants have been built since then, keeping the CSP capacity of the country constant (Fig. 1.42).

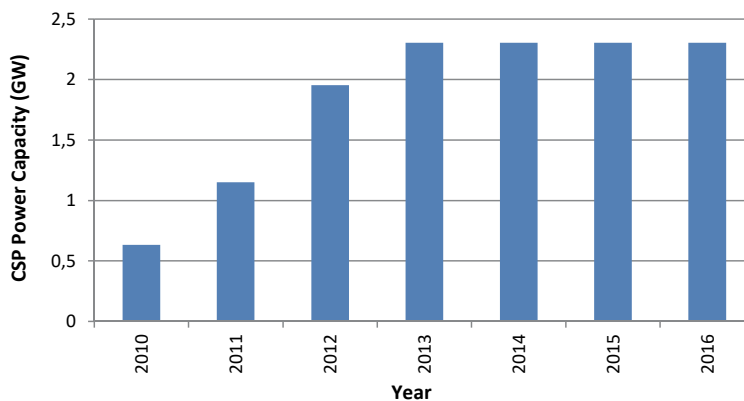


Fig. 1.42. CSP capacity in Spain from 2008 to 2016 (Source: own elaboration based on WEB-7)

The 50 Spanish plants are located mainly in the southwest part of country, in provinces listed in Table 1.11. They are plants with a capacity lower 50MW, which is the maximum capacity to take advantage of FIT program.

Table 1.11. Provinces with CSP plants in Spain (Source: own elaboration based on WEB-8)

Province	Electricity Generation (MWh)
Badajoz	1573159
Sevilla	918797.7
Ciudad Real	742678
Córdoba	631755.3
Cáceres	483228.5
Granada	454797.5
Cádiz	314407.3
Alicante	98825
Lleida	87196.2
Murcia	43106.3
Total	7991408.3

Currently, the Feed-in Tariff has been replaced by a complement payment to pool price of electricity to provide to the investor a “reasonable profitability” of 7.5%. We will see how this system works and if there is a resurgence of renewable energy boom in Spain or, at least, a partial recovery (in case these levels are not reached).

1.2.4. Geothermal Energy

Geothermal energy is considered as heat energy generated and stored in the Earth, that comes in two main variants: vapour-dominated or liquid-dominated forms. The most desirable are high-temperature geothermal systems (over 150°C) whereas most often in Europe we have a brush with low-temperature systems, that could be used for heat generation, usage in balneological and recreational purposes etc. (Fig. 1.43).

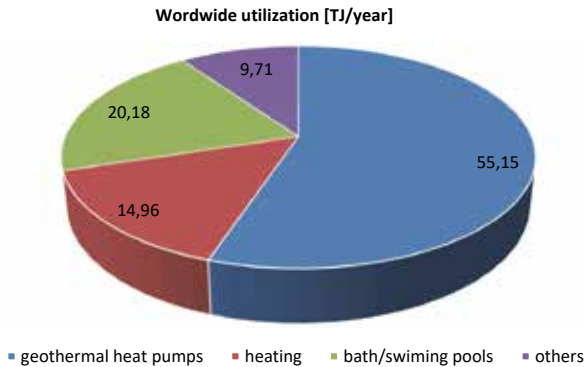


Fig. 1.43. Worldwide total energy use in 2015 (TJ/year) (Source: own elaboration based on Lund & Boyd, 2016)

The total installed capacity from geothermal sources amounts to 750 GWth worldwide and about one third of this (20 GWth) in Europe. At the end of 2015 leaders in generating capacity were USA, Philippines and Indonesia (World Energy Council, 2016). In 2016 European leaders in geothermal energy production were Italy (5570.6 TOE), Germany (269.3 TOE), France (243.3 TOE), Portugal (157.7 TOE) and Hungary (119.9 TOE).

Highest utilization of direct geothermal heat was noted in China, Turkey and Iceland. As showed by Lund & Boyd (2016), the worldwide leaders in direct utilization of geothermal energy in terms of population are Iceland (0.082 TJ/year person), Sweden (0.053 TJ/year person) and Finland (0.0329 TJ/year person). Taking into account country area the leaders are Switzerland, Iceland and The Netherlands with 0.2867-0.1941 TJ/km² year.

On the other hand, the largest increase in geothermal energy utilization since 2010 was observed in Thailand, Egypt and Philippines. The biggest annual energy use in MWt (not taking into account heat pumps) was noted in China, Turkey, Japan, Iceland and India. Installations in these countries are estimated as about 68% of the world capacity. Also, in case of geothermal energy used for heat pumps work China is one of leaders, however USA is the first one (Lund & Boyd, 2016).

Geothermal energy is used by applying various technologies for instance:

- power generation,
- steam field technology (fluid supply system: production wells, separation vessels, conveyance pipe-work, conditioning vessels, control elements and reinjection systems: fluid conveyance pipe-work, pumps, mineral scale inhibitors, injection wells, and associated controls),
- direct use applications,
- ground heat pumps.

The case of Poland, Lithuania and Spain

Considering these three countries, the greatest geothermal production takes place in Poland. In 2016 it was estimated for 22.2 TOE. In Spain it was slightly smaller (18.8 TOE) whereas in Lithuania this kind of energy was significantly lower (2.0 TOE). Development of energy production over the years was presented in Fig. 1.44, while inland consumption was shown in Fig. 1.45.

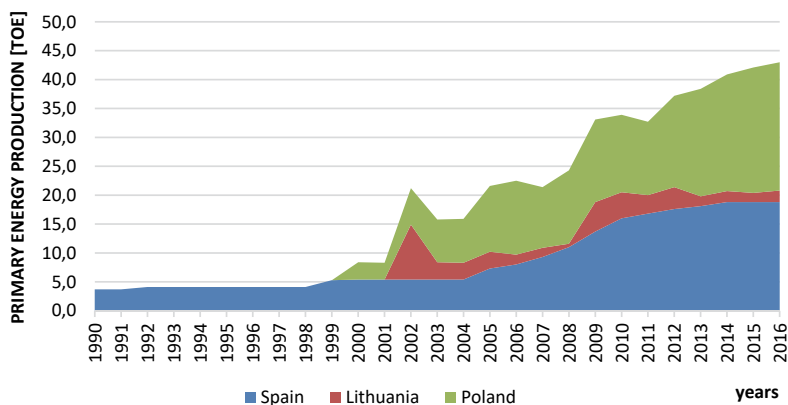


Fig. 1.44. Development of geothermal energy production in Poland, Spain and Lithuania (Source: own elaboration based on WEB-9)

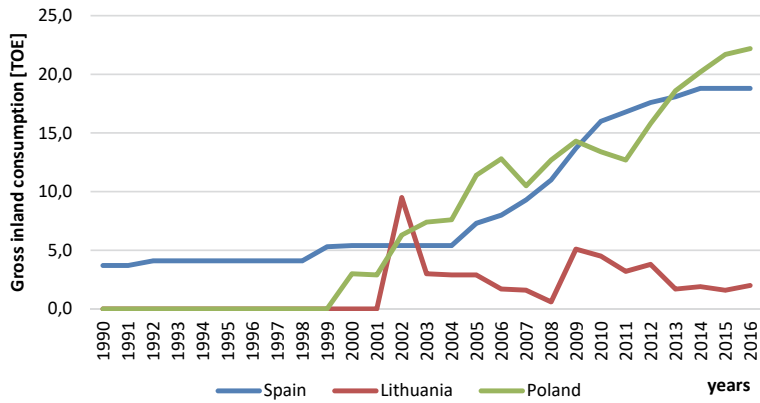


Fig. 1.45. Changes in gross inland consumption in Poland, Spain and Lithuania (Source: own elaboration based on WEB-9)

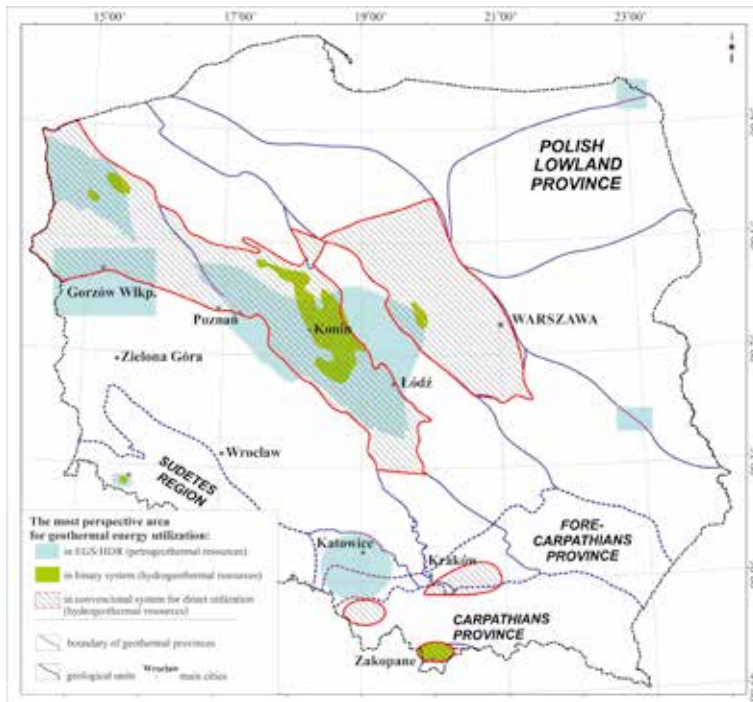


Fig. 1.46. Location of the most prospective area for geothermal energy utilization in Poland (Source: Sowizdzka, 2018)

In Poland, geothermal direct-use installed capacity in 2014 was estimated for 488.84 MWt whereas direct use energy utilization – 761.89 GWh (World Energy Council, 2016).

Development of geothermal resources in Poland is slow, mainly due to economic reasons. However, recently the financial support of geothermal investments in Poland was provided by the Central Fund for Water Management and Environment Protection, so development in this kind of systems is predicted. Fig. 1.46 shows the geothermal energy resources (Sowizdzał, 2018). According to Sowizdzał (2018) the most perspective province is the Polish Lowlands (especially Warsaw Trough, Mogilno-Łódź Trough and Szczecin Trough), which resources of geothermal waters are located in the Mesozoic groundwater horizons. Moreover, the Podhale area, located in the Carpathian Geothermal Province shows good possibilities for development. Also, the Sudetic Geothermal Region is expected to be developed, mostly in usage of its water for balneotherapy. Main geothermal installations were shown in Fig. 1.47. The oldest ones are Podhale, Pyrzyce and Mszczonów (Fig. 1.48 A-B) that have worked for several years.



Fig. 1.47. Main Polish geothermal installations (Source: Sowizdzał, 2018)

A



B



Fig. 1.48. Mszczonów Geothermal Plant A) Outside view B) Indoor equipment (Source: photos by M. Słowek Geotermia Mazowiecka S.A.)



Fig. 1.49. Geothermal potential in Spain (Source: IGME, 2018)

The Spanish potential for geothermal generation is estimated to be of 610 GWt. Potential of geothermal resources is shown in Fig. 1.49. Medium-high enthalpy resources (EGS), with temperature in a range 170-300°C are located only in Canary

Islands, while in the continental part medium at lower temperature up to 160°C are possible to obtain. As noted by Colmenar-Santos et al. (2016a) development of geothermal sector has stopped in 2011. In 2014 geothermal direct-use installed capacity in 2014 was estimated for 64.13 MWt, whereas direct use energy utilization –95.80GWh (World Energy Council, 2016).

In Lithuania we can find some resorts located along the Baltic Sea shore (Fig. 1.50), from Middle Cambrian, Lower Devonian and Middle Devonian, where it is possible to obtain water at temperature 30–80°C, whereas the temperature close to 100°C was also registered in southwest Lithuania. The first geothermal plant started to work in 2000 in Klaipeda. The plant geothermal capacity is estimated to be 13.6 MWt. The number of small-scale ground source heat pump systems is close to 5,500 systems with total installed capacity above 70 MWt (Zinevicius et al., 2015). Geothermal direct-use installed capacity in 2014 was about 94.60 MWt and direct use energy utilization was recorded as 198.04 GWh (World Energy Council, 2016).

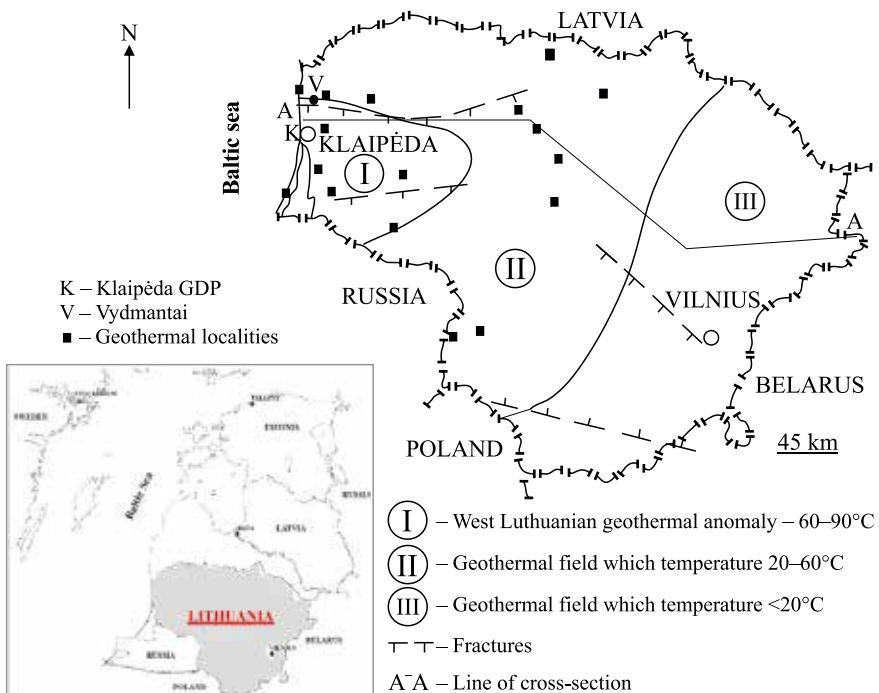


Fig. 1.50. Geothermal potential in Lithuania (Source: own elaboration)

References

- AEE (2016) *Eólica 2016*. Asociación Empresarial Eólica.
- BP (2017) *BP Statistical Review of World Energy*. 66th edition.
- Colmenar-Santos, A., Folch-Calvo, M., Rosales-Asensio, E. & Borge-Diez, D. (2016a) The geothermal potential in Spain. *Renewable and Sustainable Energy Reviews*, 56, 865-886.
- Colmenar-Santos, A., Perera-Perez, J., Borge-Diez, D. & Palacio-Rodríguez, C. (2016b) Offshore wind energy: a review of the current status, challenges and future development in Spain. *Renewable and Sustainable Energy Reviews*, 64, 1-18.
- Energy Regulatory Office (2017) *National Report*. The President of the Energy Regulatory Office in Poland.
- EWEA (2016) *Wind in power. 2015 European statistics*. The European Wind Energy Association.
- Fantini, A. M. & Quinn, M. (eds.) (2017) *OPEC Annual Statistical Bulletin*. Organization of the Petroleum Exporting Countries.
- Gnatowska, R. & Waş, A. (2017) Wind Energy in Poland – economic analysis of wind farm. *E3S Web of Conferences*. [Online] 14, 01013. Available from: <https://doi.org/10.1051/e3sconf/20171401013> [Accessed 10th August 2018].
- GWEC (2016) *Global Wind Report 2015 – Annual market update*. Global Wind Energy Council.
- IGME (2018) *El potencial geotérmico en España* [Online] Available from: <http://www.igme.es/geotermia/potencial%20geot%E9rmic.htm#> [Accessed 10th August 2018].
- López-Prol, J. & Steininger, K. W. (2017) Photovoltaic self-consumption regulation in Spain: Profitability analysis and alternative regulation schemes. *Energy Policy*. [Online] 108, 742-754. Available from: <https://doi.org/10.1016/j.enpol.2017.06.019> [Accessed 10th August 2018].
- Lund, J. W. & Boyd, T. L. (2016) Direct utilization of geothermal energy 2015 worldwide review. *Geothermics*, 60, 66-93.
- Marciukaitis, M., Katinas, V. & Kavaliauskas, A. (2008) Wind power usage and prediction prospects in Lithuania. *Renewable and Sustainable Energy Reviews*, 12(1), 265-277.
- Ministerio de Industria, Energía y Turismo (2015) *La energía en España*. Secretaría de Estado de Energía.

Mir-Artigues P., Cerdá, E. & Río, P. (2015) Analyzing the impact of cost-containment mechanisms on the profitability of solar PV plants in Spain. *Renewable and Sustainable Energy Reviews*, 46, 166-177.

PWEA (2016) *The State of Wind Energy in Poland in 2016*. Polish Wind Energy Association.

RD-1: Boletín Oficial del Estado (2007) *Real Decreto 661/2007, de 25 de mayo, por el que se regula la actividad de producción de energía eléctrica en régimen especial*. Ministerio de Industria, Turismo y Comercio. «BOE» núm. 126, de 26 de mayo de 2007.

RD-2: Boletín Oficial del Estado (2006) *Real Decreto 314/2006, de 17 de marzo, por el que se aprueba el Código Técnico de la Edificación*. Ministerio de Vivienda. «BOE» núm. 74, de 28 de marzo de 2006.

REN21 (2017) *Renewables 2017. Global Status Report*. Renewable Energy Policy Network for the 21st Century.

Sowizdział, A. (2018) Geothermal energy resources in Poland – Overview of the current state of knowledge. *Renewable and Sustainable Energy Reviews*, 82(3), 4020-4027.

Valančius, R., Jurelionis, A., Jonynas, R. & Perednis, E. (2015) Analysis of Medium-Scale Solar Thermal Systems and Their Potential in Lithuania. *Energies*. [Online] 8(6), 5725-5737. Available from: <https://doi.org/10.3390/en8065725> [Accessed 10th August 2018].

WEB-1 <https://www.maxpixel.net/Hydro-Power-Dam-Water-Hydroelectricity-Electricity-2492809>

WEB-2: U. S. Department of Energy (2018) *Office of Energy Efficiency and Renewable Energy*. [Online] Available from: <https://www.energy.gov/eere/> [Accessed 10th August 2018].

WEB-3: LWEA (2018) *Lithuanian Wind Energy Association* [Online] Available from: <http://www.lwea.lt/> [Accessed 10th August 2018].

WEB-4: Energy Agency (2018) *VĮ Energetikos agentūra* [Online] Available from: <http://www.ena.lt/en/default.htm> [Accessed 10th August 2018].

WEB-5: IDAE (2018) *Instituto para la Diversificación y Ahorro de Energía*. Ministerio de Industria, Turismo y Comercio. [Online] Available from: <http://www.idae.es/> [Accessed 10th August 2018].

WEB-6: EurObserv'ER (2018) *All Photovoltaic barometers*. [Online] Available from: <https://www.eurobserv-er.org/category/all-photovoltaic-barometers/> [Accessed 10th August 2018].

WEB-7: EurObserv'ER (2018) *All Solar thermal and CSP barometers*. [Online] Available from: <https://www.eurobserv-er.org/category/all-solar-thermal-and-concentrated-solar-power-barometers/> [Accessed 10th August 2018].

WEB-8: Red Electrica de España (2018) *Sistema de Información del Operador del Sistema* [Online] Available from: <https://www.esios.ree.es/es> [Accessed 10th August 2018].

WEB-9: European Commission (2018) *Eurostat. Your key to European statistics*. [Online] Available from: <http://ec.europa.eu/eurostat> [Accessed 10th August 2018].

World Energy Council (2014) *Energy sector of the world and Poland. – Beginnings, Development, Present State*. Polish Member Committee of the World Energy Council.

World Energy Council (2016) *World Energy Resources. Geothermal* [Online] Available from: https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Geothermal_2016.pdf [Accessed 10th August 2018].

Zinevicius, F., Sliaupa, S., Mazintas, A. & Dagilis, V. (2015) *Geothermal Energy use in Lithuania*. In: International Geothermal Association. *Proceedings World Geothermal Congress 2015, Melbourne, Australia, 19-25 April 2015*.