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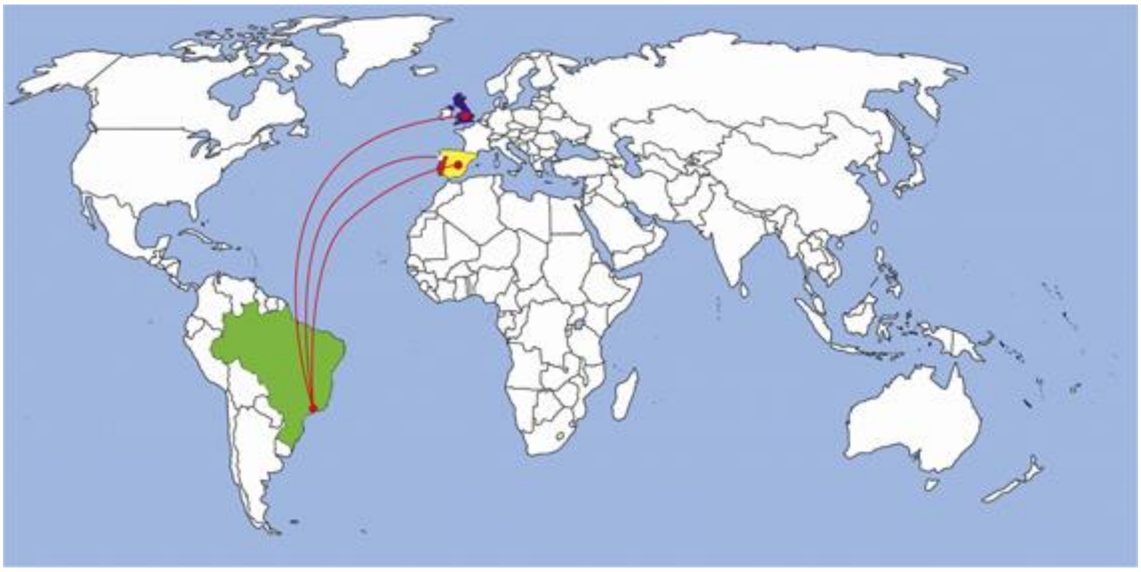

Report

Analysis of energy systems: Spain, Portugal, UK and Brazil.

Spain Energy and Emission Profile

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Country Overview

Spain has a population of around 47 million people distributed over an area of 505 000 km^2 (square kilometres). Since 2000, population has grown about 17%, as a result of high immigration (IEA, 2015). Within European context, Spain has been considered the fifth largest energy consumer (EIA, 2016). Between 2000 and 2008, Spain enjoyed economic growth, after which the country entered a period of economic recession (2008-2013). As a result, Gross Domestic Product (GDP) decreased by 3.8% in 2009, and the country resorted to European Union (EU) economic recovery program (IEA, 2015). Currently, service sector accounts for 72% of GDP, followed by manufacturing and construction sectors (25%) and agriculture (2.6%), with particular emphasis for tourism, retailing and banking sub-sectors (IEA, 2015). Moreover, despite economic recovery, most of the energy-related indicators featured in this overview still reflect this socioeconomic context. Additionally, in the context of the European Union (EU), Spain has undertaken a series of policy measures to meet EU 2020 targets in focal areas, such as increasing the contribution of renewable energy sources (RES), improvement of energy efficiency and reduction of greenhouse gas (GHG) emissions.

Main Energy-Related Indicators: Overview

In this chapter, a summary of main aspects/indicators of the evolution of the Spanish energy system is provided.

Energy Supply

Total Primary Energy Supply (TEPS)

According to International Energy Agency (IEA, 2015) estimates, Spain's Total Primary Energy Supply (TEPS) amounted to 113.9 million tonnes of oil-equivalent (Mtoe) in 2014. This represents a decrease of 18.1% comparatively to 2004 level (IEA, 2015). Since 2008, TEPS denotes a decreasing trend, which has results from improved efficiency in one hand, and economic crisis on the other ((IDAE(Instituto para la Diversificación y Ahorro de la Energía), 2010).

Spain's energy supply, as illustrated in Figure 1, results from a diversified energy mix, which includes non-renewable alternatives (solid fuels, natural gas, oil and nuclear) and a smaller yet increasing share of renewable energy sources (RES).

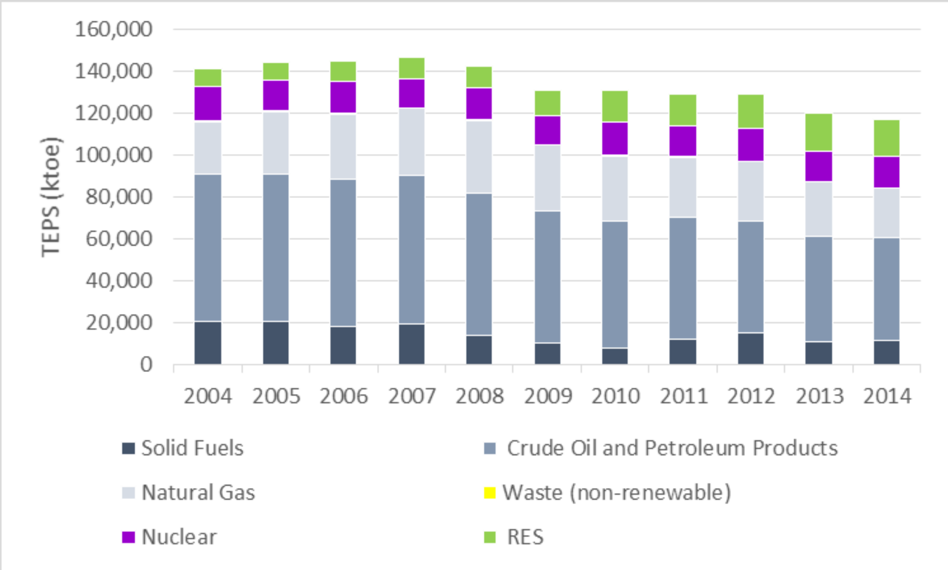

Figure 1- Evolution of Primary Energy Supply by source, for Spain (elaboration from (Union 2016))

The share of nuclear power decreased by 10%, though its contribution has been consistent, between 2004 and 2014. Meanwhile, contribution from RES saw a 102% increase for this time period. Whereas solid fuels registered most accentuated decrease (-45%), from 2004 to 2014. Within fossil fuels, natural gas registered the least accentuated decrease (-6%) comparatively to 2004 levels.

Therefore within a ten year timeframe (2004-2014), Spain's primary energy mix has seen a shift towards RES in detriment of fossil fuels. This is mainly due to the increase of wind and solar power alternatives. Wind power has increased from 1% of TEPS in 2004 to 4% in 2014 of RES, while solar power has increased from 0% to 1% of TEPS in 2014 with solar PV and 2% with solar thermal. A detailed contribution from renewables by fuel type is given in Figure 2.

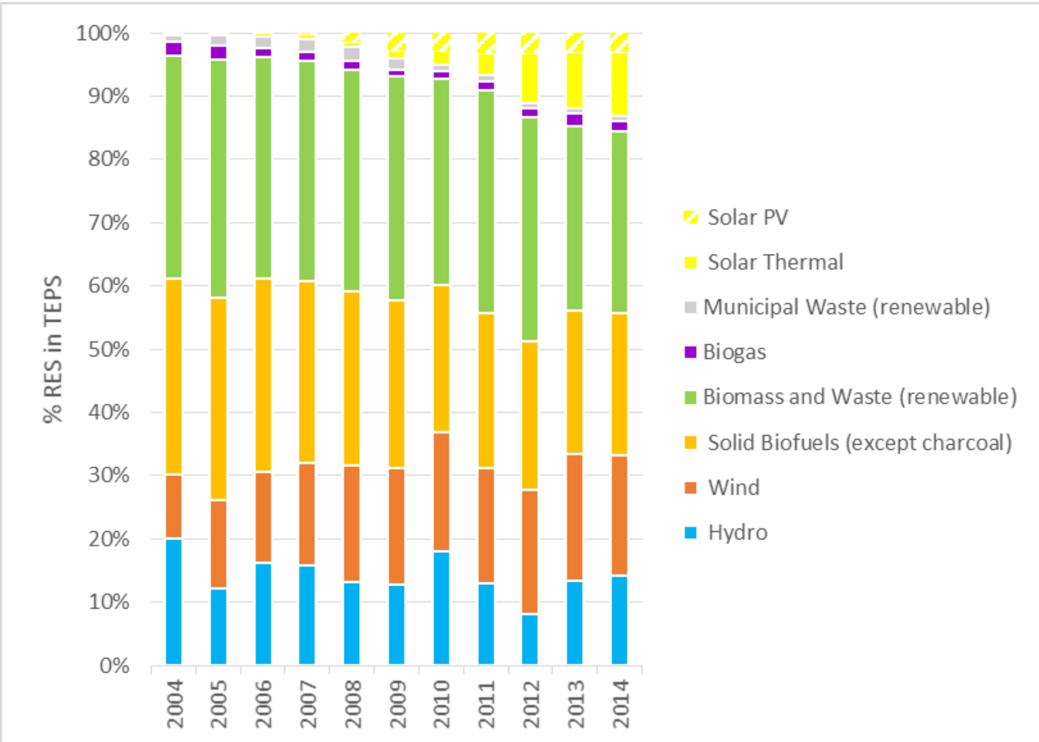

Figure 2- Share of RES in Primary Energy Production, for Spain (elaboration from (Union 2016))

Furthermore given high energy dependence and increasing energy and environmental constraints, it is expected that natural gas and RES contribution will be gradually more relevant, ensuring nearly 50% of primary energy by 2020, surpassing oil's contribution estimated at 36% of TEPS by 2020 (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010).

Energy Dependence

In spite of this, domestic energy supply only accounts for 30% of TEPS (IEA, 2015), which implies that fossil fuels still have a significant weight in national energy mix. It has been estimated that in 2014, this alternative accounted for 72.2% of TPES, from which 41.2% were oil, 20.8% were natural gas and 10.3% coal (IEA, 2015). Despite the increasing relevance of RES in energy supply, these values are indicative of a significant external energy dependence (ED), as illustrated in Figure 3.

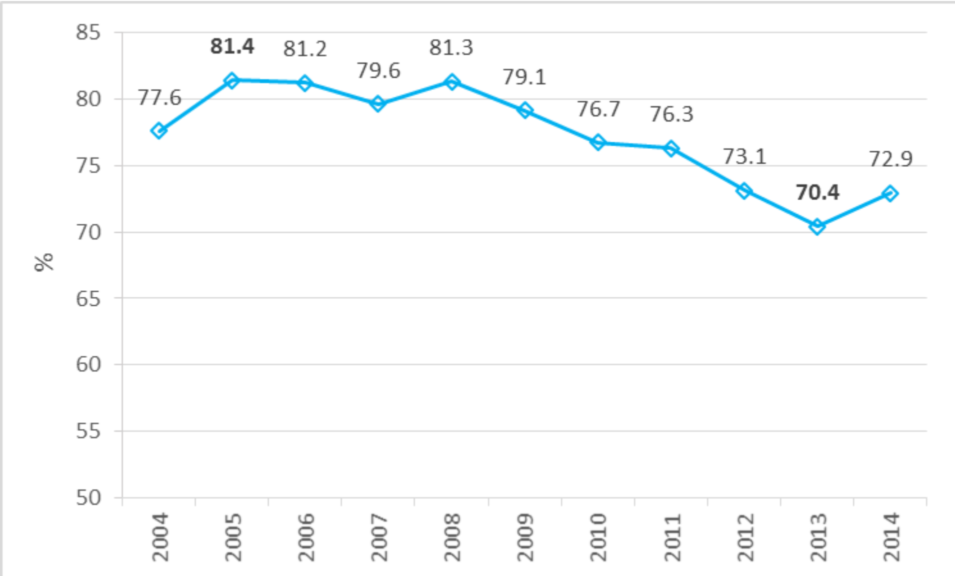

Figure 3- Evolution of Energy Dependence (ED) for Spain (elaboration from (Union 2016))

Energy dependence peaked in 2005 (81.4%), but overall presented a decreasing trend, with lowest point reached in 2013 (70.4%). If in one hand, increase in the share of renewables has contributed to decrease external energy dependence, and therefore increase energy security. On the other hand, higher figures of ED, denote vulnerability of RES to weather conditions, and subsequent need to rely on fossil fuel imports. Nevertheless, comparatively to 2004 (ED=77.6%), this indicator has seen an improvement of almost 5%, in 2014 (ED=72.9%).

Energy Demand

Total Final Energy Consumption

In 2014, Total Final Consumption (TFC) in Spain amounted to 83 525 ktoe, a decrease of 2.7% comparatively to 2013 (Calero 2014) This downward trend has been associated to the weak economic context (IEA, 2016 and MINETUR, 2014), with repercussions at sectorial level. As illustrated in Figure 4, transport sector has been the largest energy demanding sector, followed by industry and residential sector.

Figure 4- Evolution of sector share in TFC for Spain (elaboration from (Union 2016))

In spite of this, transport share in TFC has progressively declined since 2008, reaching its lowest point in 2013 (39%). This trend has been disrupted in 2014 (40%), with an increase of 1% in energy demand, comparatively to 2013. However, these figures are still lower than registered in 2004 (41%). Whereas energy demand for the industry sector has decreased 1% in comparison to 2013, and 7% in comparison to 2004. (Calero 2014) claims that the industry sector has kept a decreasing trend as a result of lower activity, as well as improvements at energy efficiency level (IEA, 2015). On the other hand, although the residential sector has seen a marginal increase comparatively to 2013, its share has increased a total of 4% comparatively to 2004. It is foreseeable that by 2020, the structure of demand will remain unaltered at sectorial level, with prevalence of transport sector followed by industry and other sectors (residential, service and agriculture) (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010). The following estimates for total final energy consumption (TFC) by sector are expected: 37. 470 ktoe for transport sector; 26.365 ktoe for industry and 29.764 ktoe for residential, service and other sectors) (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010).

Energy Intensity

Energy intensity indicator results from the ratio between energy consumption and the gross domestic product (GDP), measured in kgoe (kilogram of oil equivalent) per GDP in 1 000 EUR. It measures the energy consumption derived from the production of goods and services of an economy, and has been considered essential to assess its overall efficiency and sustainability (Union 2016; Calero 2014). Evolution of energy intensity (EI) profile for Spain showed a substantial decrease since 2004 (EI=142.8), followed by a stabilization period (2009 -2012) which culminated in its lowest point in 2014 (EI=112.3), as illustrated in Figure 5. This represents a reduction of 21%.

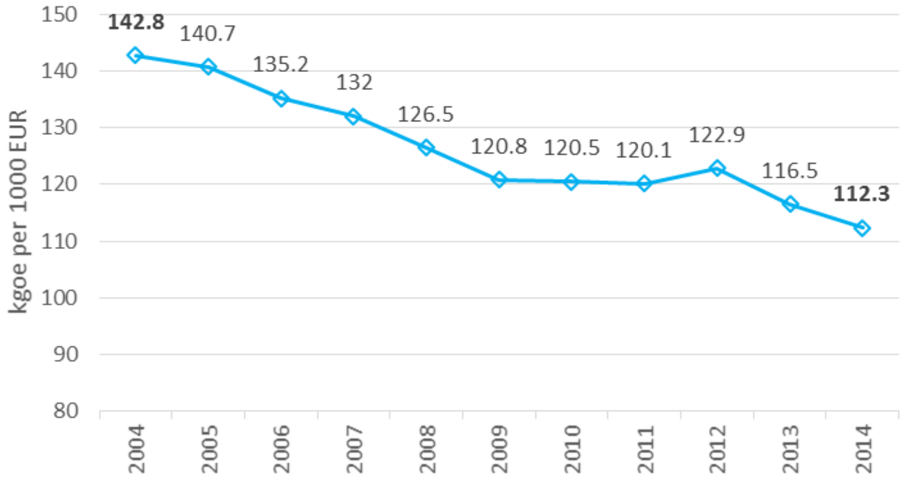

Figure 5- Evolution of Energy Intensity for Spain (elaboration from (Union 2016))

Improvements in energy efficiency trend have been considered a positive contribution towards sustainability, through reinforcement of energy security and reduction of external energy dependence (IEA 2015). However, there have been speculations with regards to whether this decrease has been mostly circumstantial, attributed to economic crisis, or the result of energy efficiency policies ((Deloitte 2015; IEA 2015). Meanwhile, (Calero 2014) has emphasized complementary role of these factors in obtained reduction.

Furthermore, between 2010 and 2020, with additional energy efficiency measures, improvement of this indicator is expected to reach 18.4%, resulting from the effort of energy efficiency measures undertaken for different sectors (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010).

Electricity Generation

As illustrated in Figure 6, electricity generation in Spain has fluctuated, reaching its peak (295.64 TWh) in 2008. Since then, electricity generation has decreased until 2013, reaching its lowest point in 2009 (278.27 TWh). In 2013 electricity generation reached 283.57 ktoe. This output is 1% higher than previous year (2012) and almost 9% higher than electricity generation in 2004. Overall Spain's electricity portfolio is diversified. Contribution of non-renewable energy sources has clearly decreased in favour of renewable energy sources, as shown in Figure 6. RES has increased its contribution by 62.82 TWh comparatively to 2004 level. Meanwhile, with the exception of natural gas, all non-renewable sources have seen their contribution decrease in a nine year period (2004-2013). According to (IEA 2015) estimates, the use of natural gas is expected to increase by 48%, becoming the main fuel for electricity generation in a near future (IEA 2015). This increase in the contribution of as natural gas and RES has contributed to reduce the weight of higher carbon content alternatives such as coal or oil. Additionally, electricity generation from RES has also consistently (since 2006) outpaced nuclear generation (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010).

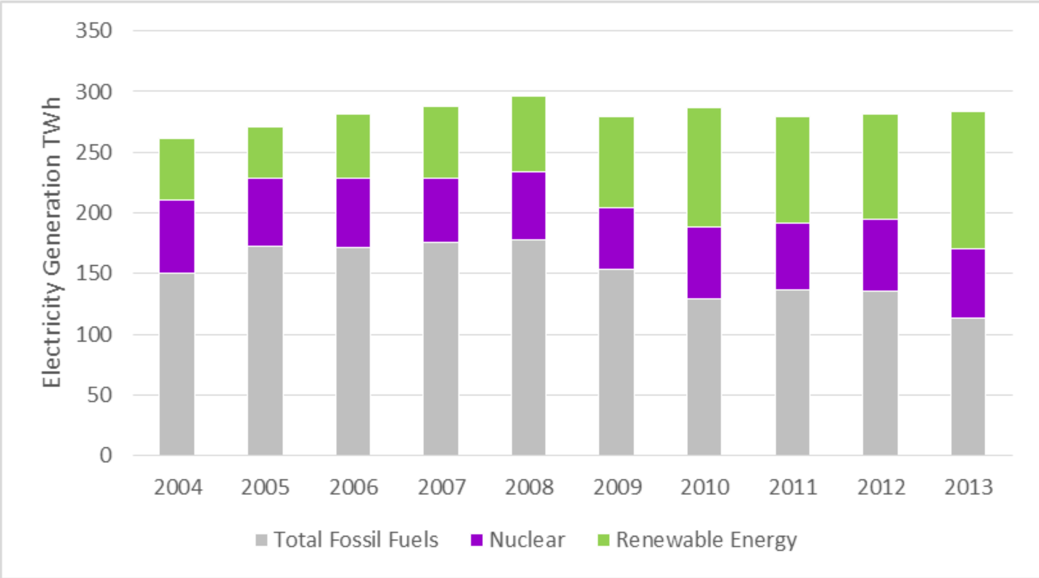

Figure 6- Evolution of electricity generation in Spain (elaboration from (U.S. Energy Information Administration 2016))

As illustrated in Figure 7, 40% of electricity was generated from RES in 2013, with the highest contribution from wind, followed by hydropower and solar energy. This corresponds to an increase of 31% comparatively to 2012; 81% comparatively to 2008 and 124% to 2004. Government projections estimate this trend is expected to continue, though at a slower rate (IEA 2015).

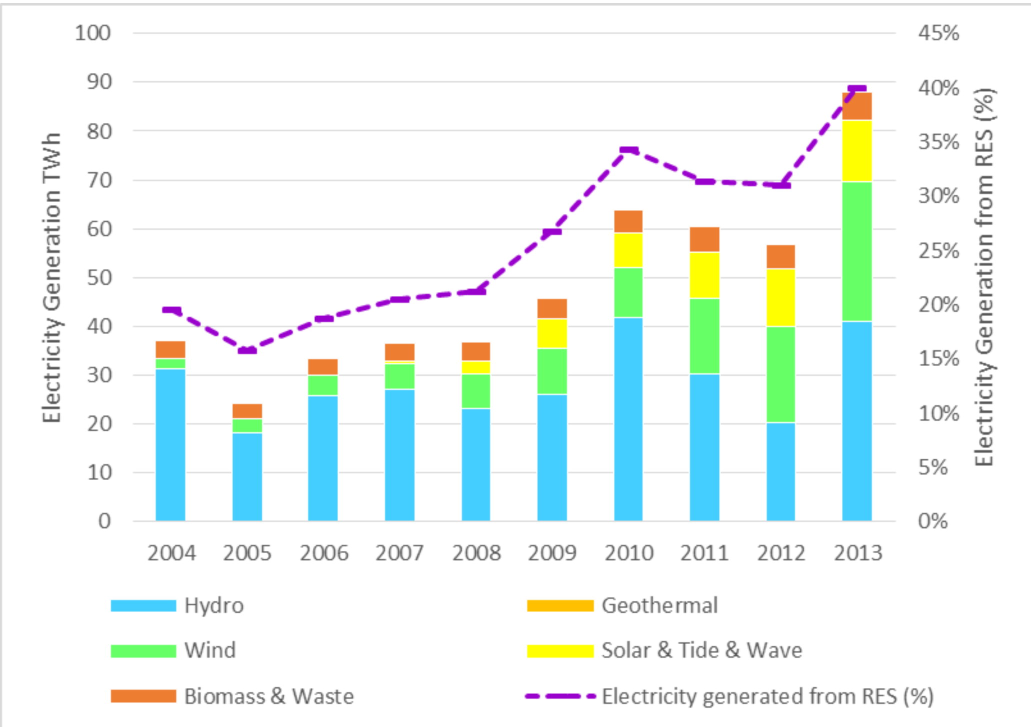

Figure 7- Evolution of electricity generated by RES in Spain (elaboration from (U.S. Energy Information Administration 2016))

Between 2010 and 2020, electricity generation is expected to increase by 6.34%, covering over 40% of electricity demand. Amongst renewables, wind power will continue to dominate accounting for 52% of electricity generation in 2020; followed by hydro and solar power (thermal and PV), accounting for 8.3% and 7.4% respectfully (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010).

Installed Generating Capacity

Total installed capacity increased by 87%, between 2001 and 2008 (IEA, 2015), associated to significant structural changes in the energy mix (Eurostat, 2016). From 2008 onwards, although electricity generation has decreased, installed capacity has increased, in virtue of increasing integration of RES, namely wind and solar power, as illustrated in Figure 8.

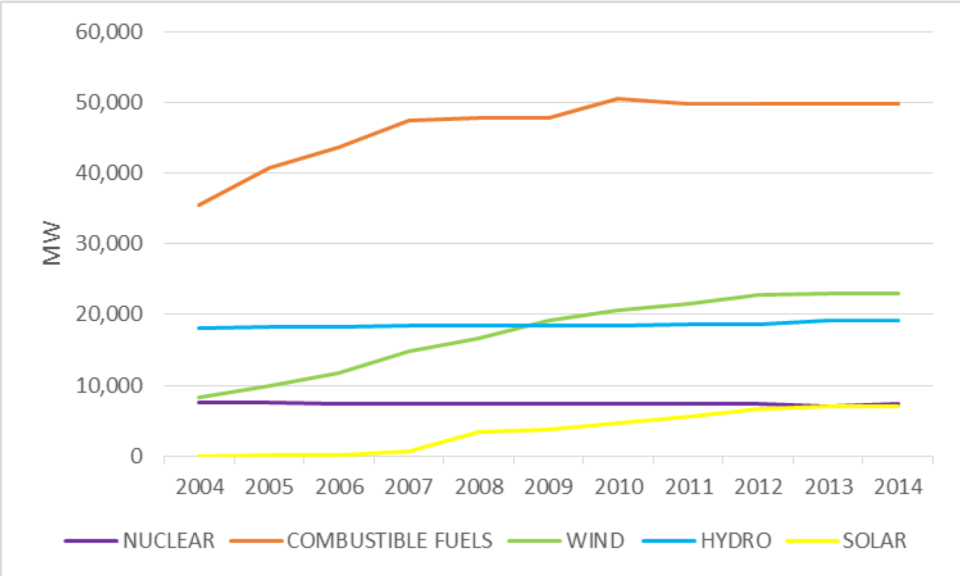

Figure 8- Evolution of installed capacity for electricity generation by source (elaboration from (Union 2016))

In 2013, installed wind power capacity has increased by 14,658 MW comparatively to 2004, while solar energy increased by 7,050 MW. Meanwhile, alternatives such as nuclear and hydropower have kept a stable, with less accentuated variations in each contribution. However, despite the increase of RES alternatives, contribution of fossil fuel alternatives (included in combustible fuels) is still very significant, but without significant increases in recent years, as shown in Figure 8. Moreover, increasing contribution from alternative energy sources has contributed to decrease CO2 emissions in the power sector.

Energy-Related GHG Emission Trends

Between 2004 and 2014, energy related GHG emissions have seen an accentuated decrease (-22%), as illustrated in Figure 9. This outcome has been partly attributed to economic (Deloitte 2015; IEA 2015), but also, as illustrated in Figure 7, to the increase in the share of RES in the power sector.

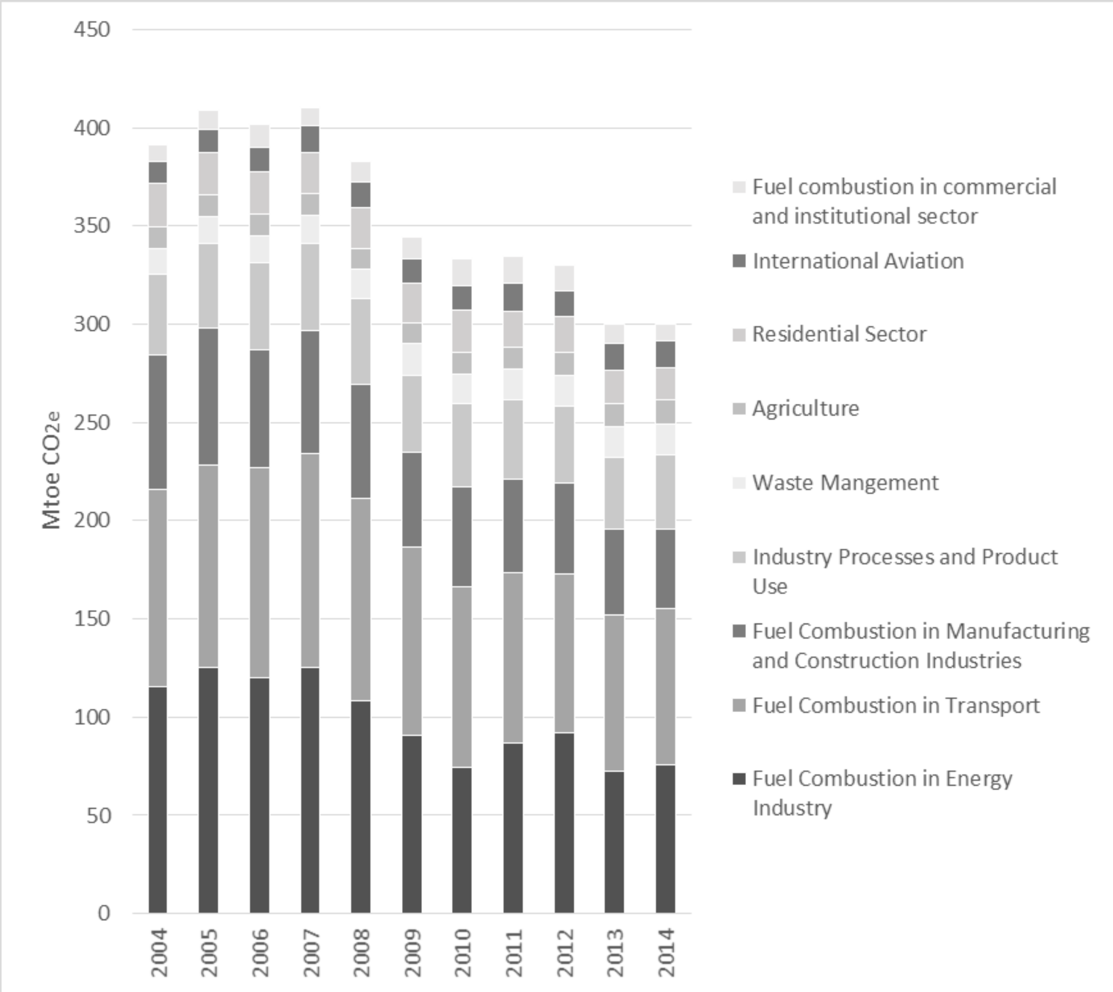

Figure 9- Evolution of GHG emissions by sector in Spain (elaboration from (Union 2016))

The power sector has been considered, one of the largest emitting sectors in Spain, accounting 23% of total emissions in 2014. However, the energy industry, has also been responsible for the most accentuated decrease in overall emissions (-34%) in the period of ten years (2004-2014). In contrast, although emissions from transport sector have decreased comparatively to 2004, the transport sector still accounts for a relevant part (24%) of overall emissions in 2014. Emissions have also declined substantially in manufacturing sector (-41%) and households (-24%). Conversely, agriculture and commercial sectors, have increased their emissions by 8% and 6% respectively, in comparison to 2004 period. Additionally, (IEA 2015) emphasized that in 2013, emissions from oil have accounted for 56.4% of energy-related emissions; natural gas for 25.1%; coal for 18.2% and industrial and non-renewable municipal waste for 0.3%. Expected growth of RES, particularly in the energy sector, has largely contributed to decrease in a sustainable manner energy-related GHG emissions. For instance, increase in integration of RES, between 2010 and 2020 is expected to prevent over 22.214 tCO_2/year in electricity generation and 5.466 tCO_2/year in the transport sector respectfully (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010). Overall, increase in RES is expected to reduce CO_2 emissions in Spain by 37.3 Mtoe CO_2 in 2020 respectfully (IDAE(Instituto para la Diversificación y Ahorro de la Energía) 2010).

Carbon Intensity

In spite of this, changes at sectoral level have contributed to the positive evolution of aggregate carbon intensity of energy consumption. This indicator is given by the ratio between GHG emissions and gross inland energy consumption (Eurostat, 2016). Comparatively to base year (2000), it has seen a steady decrease between 2000 and 2014, reaching its lowest point in 2013 (CI= 88.1), as illustrated in Figure 10.

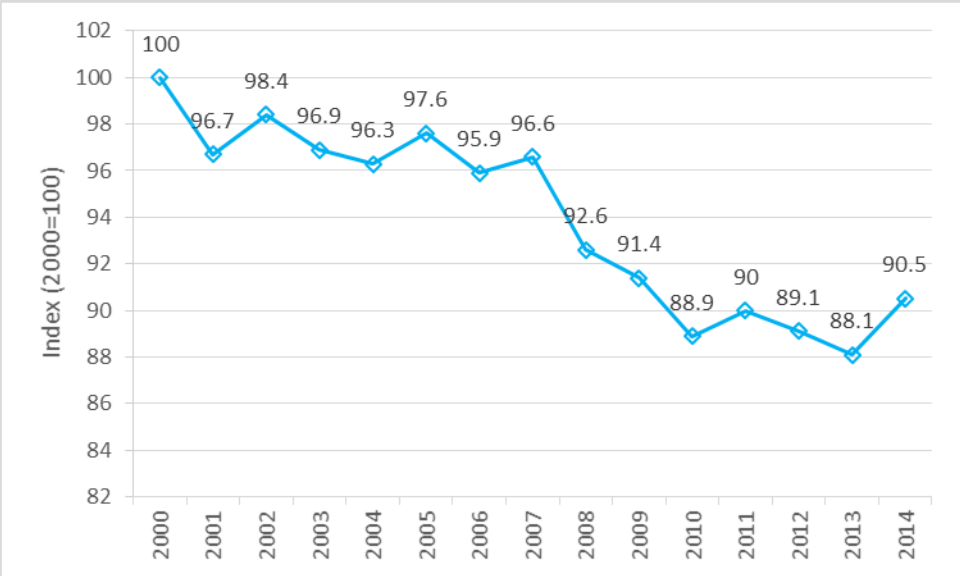

Figure 10- Evolution of carbon intensity (CI) in Spain (elaboration from (Union 2016))

Accentuated reduction of carbon intensity in Spain, has been associated to decarbonisation of the power sector. In 2013, CI was 12% lower than its 2000 level, with almost 34% of electricity generated from RES. By 2014, the share of RES in electricity generation had increased by 3.2%, as shown in Figure 7. In fact, Eurostat (2016) acknowledged the relevance of the increase in RES, comparatively to other drivers, such as fuel switching for this period of time. These efforts have contributed towards the compliance of energy and climate policy goals.

Key Energy and Climate Policy Frameworks

As a member of European Union (EU), Spain's energy and climate policies are shaped by EU's directives. Therefore, Spain is committed to 2020 EU targets regarding GHG emission reduction, renewable energy integration and energy efficiency improvements. In spite of this, measures undertaken to limit carbon emissions, though focusing these three vectors, are country specific. Key aspects of climate change/ energy policy framework, are currently listed in the 2014-2020 National Energy Efficiency Action Plan (NEEAP) and the 2011-2020 National Renewable Energy Action Plan (NREAP). According to (IEA 2015)and (Deloitte 2015), main goals include:

- 26.4% reduction of GHG emissions in primary energy consumption, comparatively to 2005 levels;
- 20% share of RES in final energy consumption (20.8% as Spain's national target);
- 10% reduction of GHG emissions for sectors outside the European Union Emissions Trading Scheme (EU-ETS), and 21% for sectors contemplated in the EU-ETS, both cuts comparatively to 2005 levels.

Beyond 2020 EU targets, 2030 climate and energy framework established the following targets (European Commission 2016):

- 40% cuts in GHG emissions (from 1990 levels);
- 27% share for renewable energy;
- 27% improvement in energy efficiency.

Additionally, a reduction of 80 to 95% in GHG emissions, comparatively to 1990 levels, is targeted by Spain and other developed countries by 2050 (IEA 2015).
As a Kyoto Protocol party, climate change targets for Spain are binding, in contrast to energy efficiency policies. Among EU energy efficiency directives and regulations, (IEA 2015)emphasized targets for 2016-2020, which aim towards a 9% reduction in final energy consumption in non-EU-ETS sectors, from 2000 levels. The purpose of the Energy End-Use Efficiency and Energy Services Directive (2006/32/EC), is to promote energy efficiency through the "development of a market for energy services" and also to promote programmes and measures directed to end-user level (IEA 2015). Because improvements in energy efficiency in Spain have been largely associated to economic recession, supplementary measures will be required to reach 2020 target (Deloitte 2015). As a result, Energy Efficiency Directive 2012/27/EC (EED) has been developed (IEA 2015). Amongst other binding measures, IEA (2015) emphasizes some EDD targets requires Spain to:

- Set an indicative national energy savings target for 2014-2020 period, in line with the EU-wide 20% by 2020 target;
- Energy suppliers need to achieve a cumulative end-use energy savings by 2020 equivalent to 1.5% of annual energy sales from 2014 to 2020.

Though total saving target for 2014-2020 is 15 979 thousand tonnes of oil-equivalent (ktoe), the NEEAP, specifies targets by sector. Industry sector is expected to reach 54.6% of the savings, in transport 25.3%, in buildings and equipment 15.3%; and in the public sector, agriculture and fishing sectors a 4.8% of savings. The objective of reaching 80.1 Mtoe in 2020, should be met through three different mechanisms: "40% of total volume target in 2020 through energy efficiency obligation system; projects financed from EU and other funds (31%), and alternative measures according to Article 7(9) of the Energy Efficiency Directive (29%)" (IEA 2015).

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Portugal Energy and Emission Profile

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Country Overview

Portugal has a resident population of around 10.39 million people distributed over an area of 92 212 km^2 (square kilometres). Between 2001-2011 resident population growth rate was positive (0.197%) but lower prior decade (0.489%, from 1991 to 2001) (PORDATA, 2016). Economic growth rates from 2009 up to 2013 have been negative, associated to economic recession the country underwent. As a result, in 2014, the country resorted to European Union (EU)/International Monetary Fund (IMF) Economic and Financial Assistance Programme. A wide range of structural reforms have been implemented, in order to "rebalance" national accounts (International Energy Agency (IEA) 2016). A slight recovery has been verified in 2015, with domestic demand and business investments starting to rise (International Energy Agency (IEA) 2016). Therefore, energy indicators (Total Primary Energy Production (TEPS); Total Final Consumption (TFC); electricity generation and GHG emissions), are expected to reflect socioeconomic context and policy measures adopted within EU context to meet EU 2020 targets.

Main Energy-Related Indicators: Overview

In this chapter, a summary of main aspects/indicators of the evolution of the Portuguese energy system is provided.

Energy Supply

Total Primary Energy Supply (TEPS)

Estimates for Portugal's Total Primary Energy Supply (TEPS) amounted to 21.1 million tonnes of oil-equivalent (Mtoe), in 2014 (IEA, 2016). This represents a decrease of 17% in overall primary energy supply, comparatively to 2004 levels. Portugal has virtually no fossil fuel resources (DGEG, 2016 and IEA, 2016), however non-renewable energies (non-RES) has ensured 75% of energy supply in 2014, as illustrated in Figure 1.

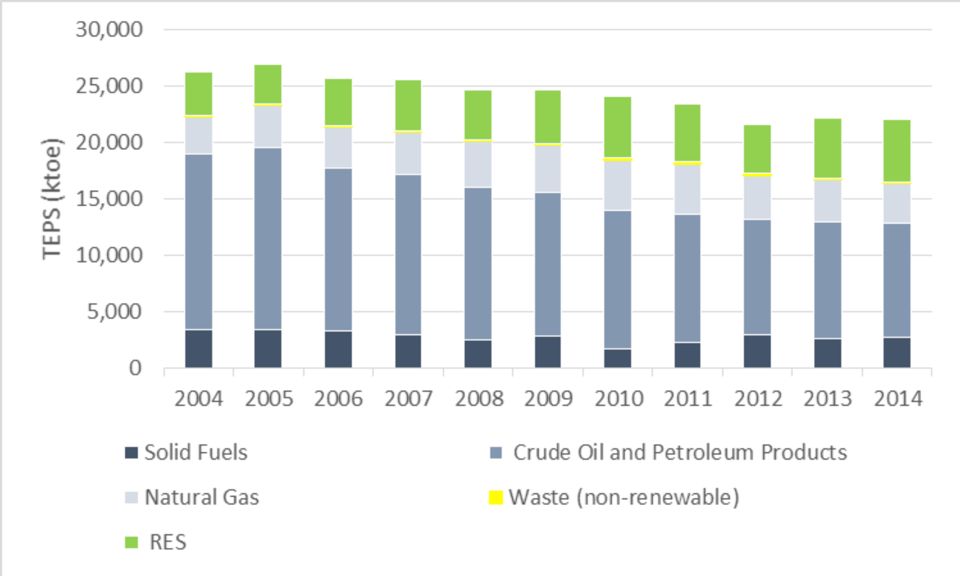

Figure 1- Evolution of TEPS by source, for Portugal (elaboration from Eurostat, 2016)

Therefore, despite high weight of non-RES imports, within a ten year timeframe (2004-2014), Portugal's domestic primary energy mix has seen a consistent and increasing contribution from RES. In addition, as illustrated in Figure 2, there has been a diversification regarding the structure of the energy mix.

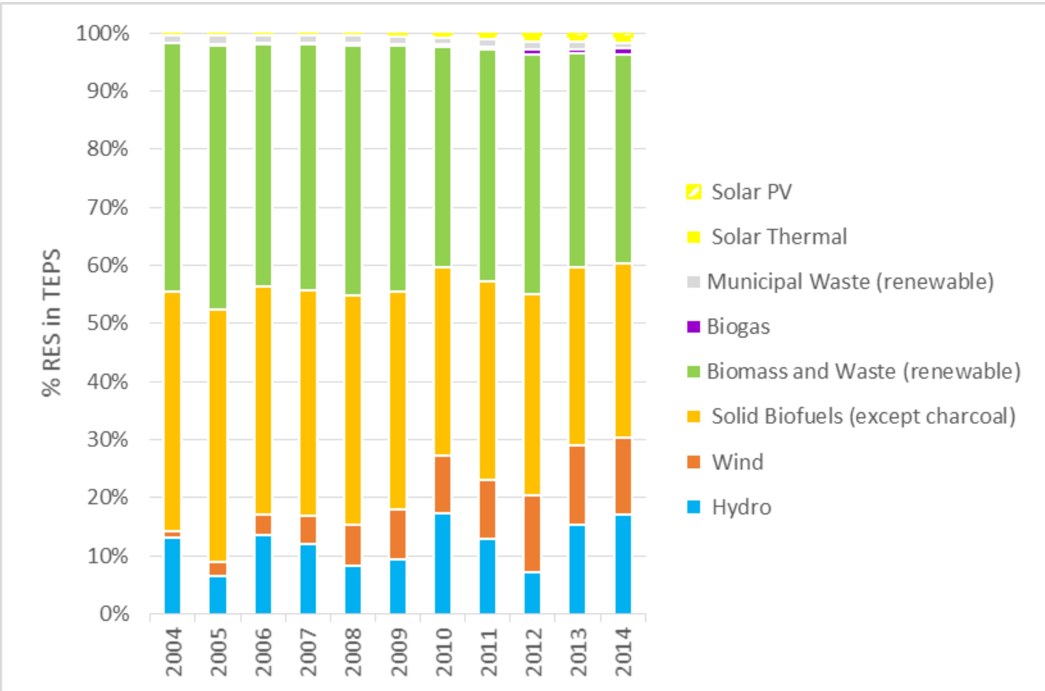

Figure 2- Share of RES in TEPS, for Portugal (elaboration from Eurostat, 2016)

Main contribution by energy source resulted from increases in wind power from 70.20 ktoe in 2004 to 1041.40 ktoe in 2014; solar power (PV) from 0.30 ktoe up to 53.90 ktoe in 2014; followed by biogas increase from 4.50 to 82.00 in 2014 and also hydro with a 58% increase within a ten year period (2004-2014). Comparatively to 2013, wind and solar power increases (31% and 20% respectfully) have been considered main drivers for endogenous production (International Energy Agency (IEA) 2016).

Also, within RES, although biomass contribution is still significant in TEPS, its share has decreased by 1%, between 2013 and 2014. Overall, contribution from RES in final energy consumption, was 25.7%, this figure is above the national target established by PNAER for 2013 (23.7%) (DGEG 2016). In spite of this, economic recession has altered national patterns of primary energy consumption, as well as forecasts towards 2020 targets (República Portuguesa 2010). As so, Portuguese Government expects/estimates primary energy demand will increase in coming years, reaching 13.5% higher in 2020, comparatively to 2020 level (International Energy Agency (IEA) 2016).

Energy Dependence

However, despite endogenous energy production being predominantly of a renewable nature, fossil fuels still play a relevant role in national energy mix. This implies a significant external energy dependence[1] (ED), with fossil fuels imports accounting for 74.3% of TEPS, in 2014 (International Energy Agency (IEA) 2016). From which, 45.1% were oil; 16.4% were natural gas and 12.7% were coal (International Energy Agency (IEA) 2016). Nevertheless, (Fernandes et al. 2015) has emphasized that its relative weight has declined and, along with it the degree of external dependence, as illustrated in Figure 3.

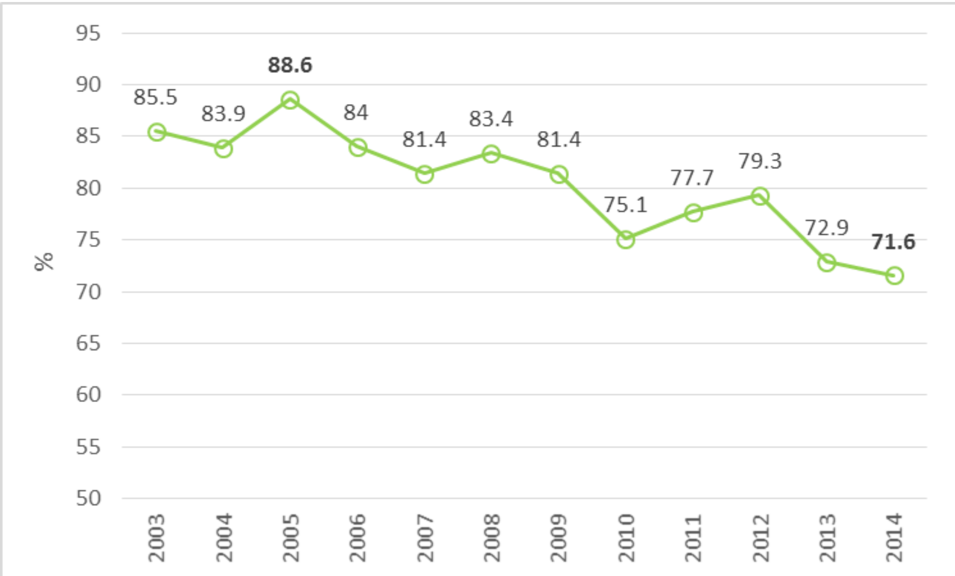

Figure 3- Portugal's Energy Dependence (elaboration from Eurostat, 2016)

Energy dependence peaked in 2005 (88.6%), but overall presented a decreasing trend, with lowest point reached in 2014 (71.6%). If in one hand, increase in the share of renewables has contributed to decrease external energy dependence, and therefore increase energy security. On the other hand, higher figures of ED, denote vulnerability of RES to weather conditions, and subsequent need to rely on fossil fuel imports. For instance, decade record registered in 2005, resulted from a lower hydropower production, associated with a less favourable (dryer) hydrological year (DGEG 2016). Therefore, higher external dependence, also verified in 2011,

[1] Energy dependence (ED) is calculated by the ratio between net imports and the sum of gross inland energy consumption plus bunkers (Union 2016; DGEG 2016)

stemmed from an increase in coal for electricity generation, in order to compensate lower contribution from RES (DGEG 2016). Nevertheless, comparatively to 2004 (ED=83.9%), this indicator has seen an improvement of 12.3%, in 2014 (ED=71.6%). A reduction in energy consumption, has implied a decrease in fossil fuel (natural gas and oil) imports that contributed to accentuated reduction of ED between 2013 and 2014 (DGEG 2016).

Energy Demand

Total Final energy Consumption

In 2014, Total Final Consumption (TFC) in Portugal amounted to 15,8 Mtoe, 17% lower than 2004 level. Transport sector has been the sector with the largest TFC in 2014 (41%), followed by industry (28%), residential (16%) and service sectors (12%), as illustrated in Figure 4.

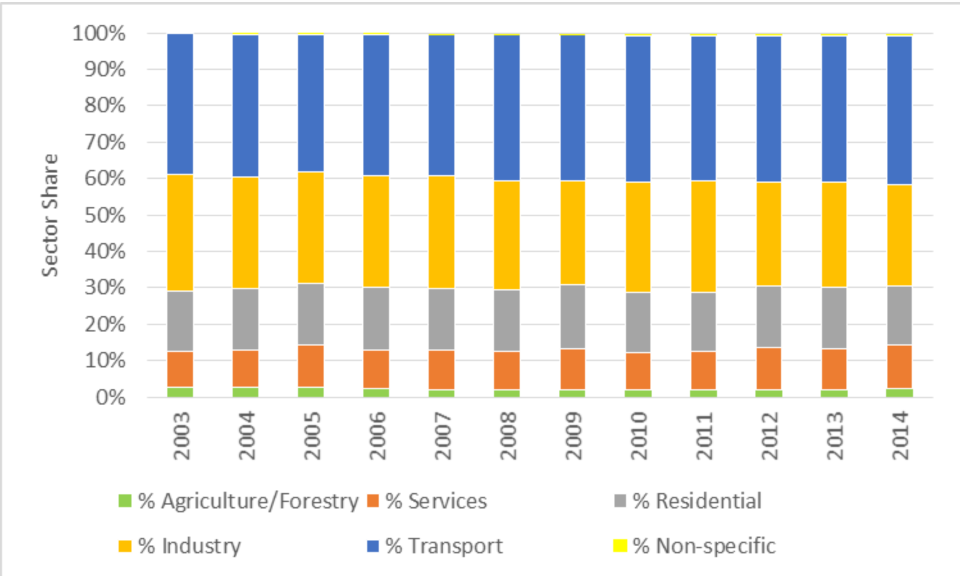

Figure 4- Evolution of sector share in TFC for Portugal (elaboration from Eurostat, 2016)

As the leading sector, transport has seen its share increase by 1% between 2013 and 2014, being 2% above 2004 level. In spite of this, its share has stagnated between 2008 and 2013. Similarly, energy demand in the service sector has increased by 1% between 2013 and 2014, and a total of 2% comparatively to 2004 level. EEA (2014), claims since 2005 decrease in TFC has been associated by lower economic performance and structural changes, as well as energy efficiency improvements. Decrease in the shares of industry sector contrast with increase in the shares of service sector, being indicative of a transition from industry to service sector. Although being one of the most demanding energy sectors, residential sector has seen a decrease in short (2013-2014) and long- term trends (2004-2014), by -1% and -0.39% respectfully. Whereas, agriculture and fisheries and non-specific sectors were the less representative shares in 2014, with 2% and 0.2%, respectfully.

Energy Intensity

Energy intensity indicator results from the ratio between energy consumption and the gross domestic product (GDP), measured in kgoe (kilogram of oil equivalent) per GDP in 1 000 EUR (€). It measures the energy consumption derived from the production of goods and services of an economy, and has been considered essential to assess its overall efficiency and sustainability (Eurostat, 2016 and MINETUR 2014). Evolution of energy intensity (EI) profile for Portugal showed since 2005 a decreasing trend, as illustrated in Figure 5.

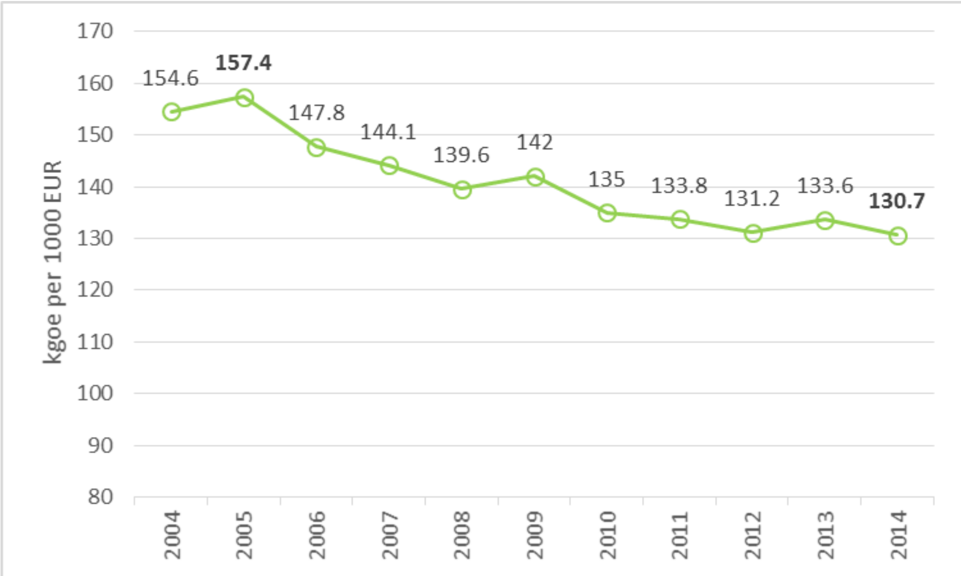

Figure 5- Evolution of Energy Intensity (EI) for Portugal (elaboration from Eurostat, 2016)

In 2014, EI was 130.7 kgoe/1000 € (-2% than 2013), and 15% lower comparatively to 2004 (EI= 154.6). Its highest and lowest peak have been reached during 2005 and 2014, respectfully. Therefore, there has been an effort to decouple economic growth from resource (energy) use, through the use energy efficiency measures (Fernandes et al. 2015). In spite of this improvement, Portugal's EI trend is still above EU's average (Fernandes et al. 2015).

Electricity Generation

As illustrated in Figure 6, electricity generation trend in Portugal has fluctuated, reaching its peak in 2010, with 51.91 TWh. Since then, electricity generation has decreased until 2013, reaching its lowest point in 2012, with 43.41 TWh. Yet in 2013, electricity production reached 51.67 TWh. Therefore, 11% higher than previous year (2012) and 15% higher in relation to 2004. These fluctuations have been attributed to variability in hydropower generation, given its weight in the national power generation matrix (International Energy Agency (IEA) 2016).

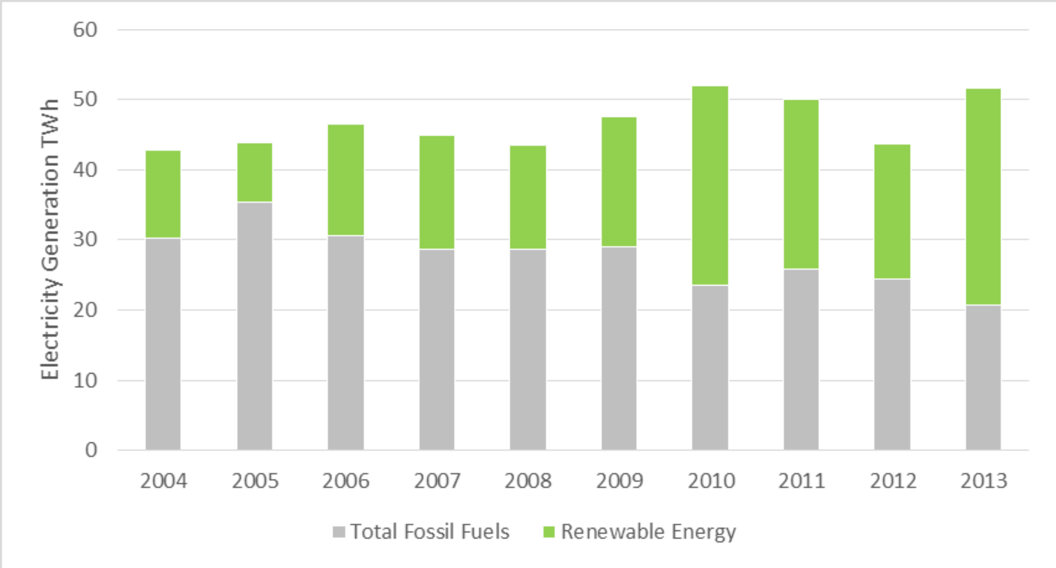

Figure 6- Evolution of electricity generation in Portugal (elaboration from EIA, 2016)

In spite of this, portfolio for electricity generation has become increasingly diversified, with the contribution from RES and non-RES alternatives. As shown in Figure 6, RES has outweighed non-RES contribution in 2013, reaching 30. 90 TWh. This represents an increase of 18.42 TWh, comparatively to 2004 level. Meanwhile, total fossil fuels have registered a decrease in their contribution (-31%) for this period (2004/2013).

Analysis by source in 2013, emphasizes the contribution of hydropower (29%), followed by wind (23%), biomass (6%), solar energy (1%) and geothermal (0.4%), as illustrated in Figure 7.

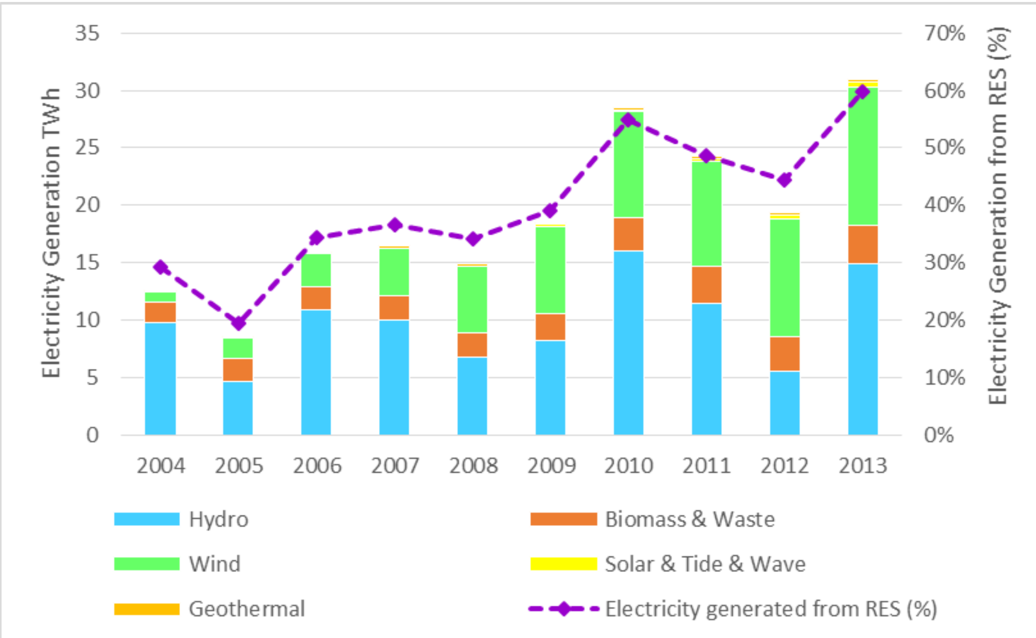

Figure 7- Evolution of electricity generated by RES in Portugal (elaboration from Eurostat, 2016)

Within RES, relevance of the contribution from wind and solar power has been emphasized. Wind power share ascended from 2% in 2004 to 23% in 2013; whereas solar power share ascended from 0.01% in 2004 up to 1% in 2013. According to International Energy Agency (IEA), (2016) estimates, though solar power contribution is still currently conditioned by technology cost, it is expected to play a more significant role in the future. Biomass has consistently contributed for electricity generation, and is also expected to increase its future contribution (International Energy Agency (IEA) 2016).

Installed Generating Capacity

Between 2004 and 2014, total installed capacity has increased by 50%. From which, hydropower accounted for 5.709 MW; wind power for 4. 856 MW in 2014, followed by solar power with 415 MW, and geothermal with 25 MW. Contribution by source in 2014 was led by wind, hydro and solar power, as illustrated in Figure 8.

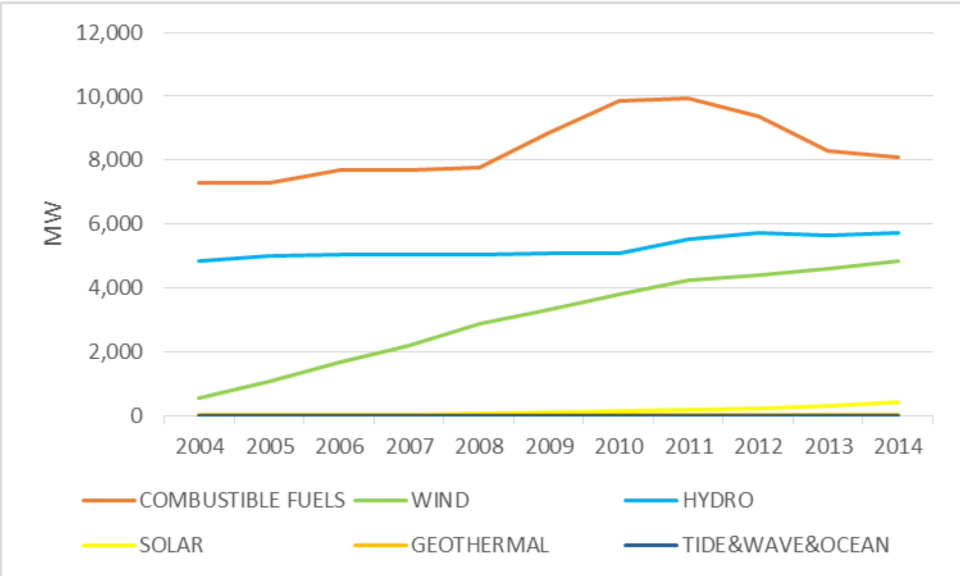

Figure 8- Evolution of installed capacity for electricity generation by source in Portugal (elaboration from Eurostat, 2016)

Comparatively to 2004 each of these alternatives grew by 4. 303 MW, 883 MW and 403 MW respectfully. Additionally, according to (International Energy Agency (IEA) 2016)estimates, installed capacity for wind power in 2020, will be 5 300 MW, of which 5 273 MW will be onshore; for solar power, namely concentrated solar thermoelectric (CSP), will increase more 50 MW by 2020. Meanwhile, biomass, will increase from 656 MW in 2013 up to 769 MW in 2020. Significant efforts have also been developed to explore the potential of other alternatives, such as geothermal and ocean and wave energy (e.g. "enhanced geothermal systems (EGS) and Project Pelamis) (see (International Energy Agency (IEA) 2016). Moreover, increasing contribution from alternative energy sources has contributed to decrease CO2 emissions in the power sector.

Energy-Related GHG Emissions

Between 2004 and 2014, energy related GHG emissions have seen an accentuated decrease (-25%), as illustrated in Figure 9. Decline from peak emissions in 2005 has been attributed to an increase in wind power deployment and lower economic activity (International Energy Agency (IEA) 2016).

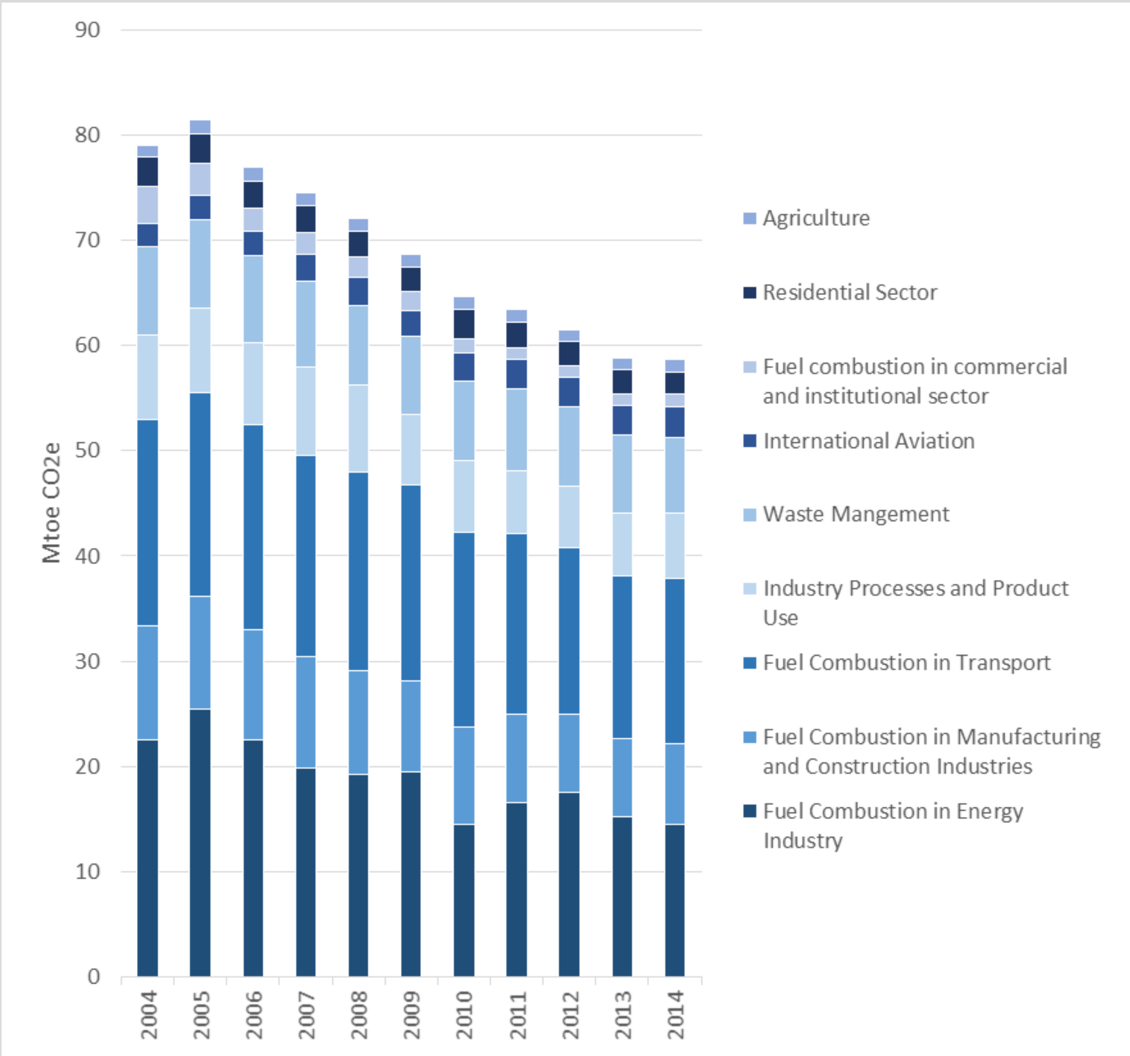

Figure 9- Evolution of GHG emissions by sector in Portugal (elaboration from Eurostat, 2016)

Amongst different sectors, energy industry has been considered the largest emitter, followed by transport sector, manufacturing, residential and service or commercial sectors. In spite of this, the energy sector has seen one of the most accentuated reductions in 2014, less 35% comparatively to 2004 and less 1% in relation to 2013 level. Meanwhile, although transport and manufacturing and commercial sector have also seen significant reductions comparatively to 2004, decreasing by - 20%;-29% and -68% less, respectfully. Emissions from these sectors have also seen an increase comparatively to 2013 level, by +2%; +4% and +8%, respectfully. On the other hand, household sector has seen a decrease in its emissions (-21%), over the past ten years (2004-2014) and less 4% in comparison to 2013. Emissions have also declined for agriculture and forestry, considered the smallest emitting sector, having reduced its emissions by -4% comparatively to 2004 and by -3% comparatively to 2013. Reductions reached in multiple sectors have contributed for decrease in overall carbon intensity indicator. Furthermore, implementation of multi-sectoral efficiency programs, will bring socio-economic and environmental benefits, amongst which are carbon emission savings. For instance, by 2020, it is estimated that PNAER will promote 422.4 tCO2 reduction in the transport sector; 2.543.7 tCO2 in the residential and service sector; 890.8 tCO2 and 123.5 tCO2 emission savings in industry and agriculture sectors.

Carbon Intensity

Abovementioned, changes at sectoral level have contributed to the positive evolution of aggregate carbon intensity of energy consumption. This indicator is given by the ratio between GHG emissions and gross inland energy consumption (Eurostat, 2016). Comparatively to base year (2000), Portugal has seen a substantial decrease in carbon intensity, between 2000 and 2014, reaching its lowest point in 2010 and 2013 (CI= 87.4), as illustrated in Figure 10.

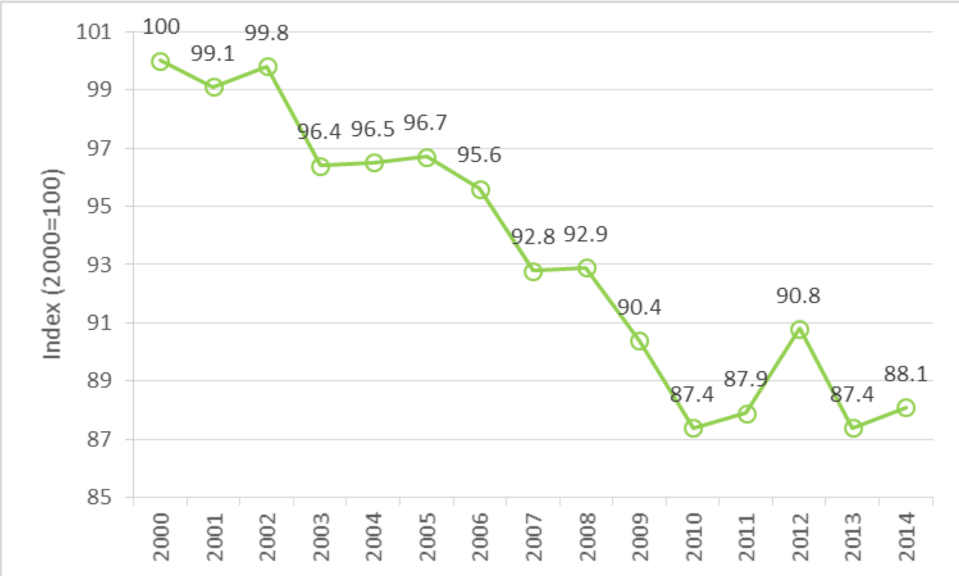

Figure 10- Evolution of carbon intensity (CI) in Portugal (elaboration from Eurostat, 2016)

This decrease follows the implementation of several measures, being partly attributed to the increase of renewable energy contribution particularly for electricity generation, introduction of natural gas, and efficiency improvements at industry and transport sectors ((Ferreira & Pereira 2016). Therefore, the process of decarbonisation of economy in Portugal, has been ongoing since 2005 fall in intensity (International Energy Agency (IEA) 2016; Fernandes et al. 2015). On the other hand, this outcome is also reflective of the economic recession, which has also contributed to slowdown industrial activity (Ferreira & Pereira 2016).
As illustrated in Figure 7, a greater contribution of RES (namely from hydropower and wind) in 2014, has contributed to a substantial decrease (11.9%) comparatively to 2000 level. Also, between 2013 and 2014 increase in EI has been marginal (0.7%) in virtue of a greater contribution from RES. These efforts have contributed towards the compliance of energy and climate policy goals.

Key Energy and Climate Policy Frameworks

As a member of the European Union and signatory of the Kyoto Protocol, Portugal has a number of climate and energy plans in place. Main national strategies consist of the National Renewable Energy Action Plan (NREAP) for the period of 2013-2020 and National Energy Efficiency Action Plan (NEEAP) for the period of 2013-2016. These plans have been revised and integrated in 2008, emphasizing at national level, the promotion of energy efficiency and energy use from RES (IEA, 2016). This tool constitutes the main lines to mitigate climate change; reduce energy dependence; ensure energy security and increase energy efficiency while contributing for economic competitiveness (IEA, 2016). Within this context, Portugal aims to fulfil in 2020:

- A 20% reduction of GHG emissions from 1990 level;
- A 20% increase of RES in final energy consumption;

- A 20% reduction in primary energy consumption from 2007 baseline.

As national goals for 2020, Portugal established an overall decrease of 25% in primary energy consumption, along with a specific target of 30% reduction in public administration, to be achieved through the increase of energy efficiency (República Portuguesa 2010). Regarding energy saving goals PNAEE 2016 also aims to fulfil in 2016, a 9% reduction in energy consumption for the period between 2001 and 2005. This plan contemplates 10 programs for efficiency improvements for a total of six sectors: transport, residential and service, industry, behaviour and agriculture sectors. Overall, Portugal expects to achieve a reduction of 8.2% (1.501 ktoe) by 2016 and a 26% reduction by 2020 (22.1 ktoe), thereby close 2016 target, while surpassing 2020 target (20%) (República Portuguesa 2010; International Energy Agency (IEA) 2016). Energy savings at sectoral level estimate 17.643 toe savings in the transport sector; 55.009 toe in residential and services; 34.500 toe in the industry sector and 23.050 in State sectors by 2020 (International Energy Agency (IEA) 2016).

Regarding energy from RES, Portugal established for 2020, a 31% increase in final energy consumption, along with a specific target of 10% of energy consumption in the transport sector (República Portuguesa 2010). Other targets at sectoral level, comprehend a share of 30.6% in heating and cooling sector and 60% in the electricity sector (International Energy Agency (IEA) 2016). Government projections, estimate RES target in 2020, will be achieved through integration of 59.6% of electricity generation from renewable sources (República Portuguesa 2010). This increase in RES would enable an emission reduction estimated in 28.6 Mtoe by 2020, equal to 286 million euros (República Portuguesa 2010).

Additionally, between 2013 and 2020, Portugal should limit the increase of GHG emissions from sectors not covered by European Emission Trading Scheme (EU-ETS) to 1.0% above its 2005 levels by 2020 (República Portuguesa 2010; International Energy Agency (IEA) 2016). Beyond 2020 period, Portugal also committed to a 27% share of RES in final energy consumption; 27% improvement in energy efficiency by 2030.

Also, Portugal recently developed a strategic framework for climate policy, in order to better articulate different tools within 2020-2030 horizon. Strategic Framework for Climate Policy (QEPiC) integrates 2020-2030 National Program for Climate Change (PNAC) and 2020 National Framework for Climate Change Adaptation (ENAAC). Its main goal is to ensure compliance with 2020 and 2030 national targets, in the EU context (Fernandes et al. 2015).

PNAC's main focus is climate change mitigation, with the objective to promote a transition towards a low carbon economy, fostering green growth, and to ensure a sustainable reduction of GHG emissions for 2020-2030 targets (-18% to -23% in 2020 and -30 to -40% in 2030, from 2005 levels) (Fernandes et al. 2015). Whereas ENAAC's main concern is climate change adaptation, to raise awareness, promote and integrate adaptive measures to public policies of different sectors (Fernandes et al. 2015). Other relevant tools to comply with Kyoto Protocol, at national level include the National Low-Carbon Roadmap and Green Growth Commitment. The former estimates a set of "long-term" and "cost-effective" paths to reduce GHG emissions and the latter establishes goals and initiatives on multiple levels, with the aim of conciliating "economic growth with lower consumption of natural resources, social justice and quality of life for the population" (International Energy Agency (IEA) 2016), p.39). The Portuguese Carbon Fund and Green Taxation Reform also play a key role at financial level, to ensure compliance with climate change targets and promote sustainable development (International Energy Agency (IEA) 2016).

Additionally, a reduction of 80 to 95% in GHG emissions, comparatively to 1990 levels, is targeted by Portugal and other developed countries by 2050 ((European Commission 2016).

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UK Energy and Emission Profile

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Country Overview

United Kingdom (Great Britain and Northern Ireland) has a population of around 65 million people distributed over an area of 244, 000 km^2 (square kilometres) (The World Bank Group 2016; International Energy Agency (IEA) 2012). Between 1990 and 2013, population growth rate has increased by 12% (IEA, 2015), largely due to immigration (International Energy Agency (IEA) 2012). It has been considered the fifth-largest economy worldwide, although with one of the lowest energy intensities of the economy, within European context (U.S. EIA 2011). In spite of this, UK's economic growth rate decreased by 4.4% in 2009, as a result of the economic recession in 2008 (International Energy Agency (IEA) 2012). Currently, the country's economic structure is dominated by service sector, with special emphasis for banking, insurance and business activities (International Energy Agency (IEA) 2012). Traditionally, energy production has been associated to non-renewable energy sources. However, the need to shift towards renewable energy resources has been recognized (United Kingdom Government 2009), and has led to a wide range of policy efforts in order to meet 2020 targets. The increase in the contribution of renewable energy sources (RES), improvement of energy efficiency and reduction of greenhouse gas (GHG) emissions, are some of the measures, United Kingdom has undertaken in the context of the European Union (EU) energy-climate scope.

Main Energy-Related Indicators: Overview

In this chapter, a summary of main aspects/indicators of the evolution of the British energy system is provided.

Energy Supply

Total Primary Energy Supply (TEPS)

Estimates for United Kingdom's Total Primary Energy Supply (TEPS) amounted to 201 million tonnes of oil-equivalent (Mtoe), in 2014 (DECC 2015a). This represents a 1.7% decrease comparatively to 2013, its smallest fall since 2002 (DECC 2015a). As illustrated in Figure 1, although fossil fuels are still dominant in primary energy mix, its trend is clearly decreasing. In fact, in 2014, these alternatives accounted for its lowest share (84.5%) (DECC 2015a). In contrast, renewable energy alternatives have increased their share by 268%, between 2004 and 2014. Conversely, oil and natural gas decreased by -17% and -32% for this period. Meanwhile, nuclear energy has reduced its contribution by -20% comparatively to 2004 level.

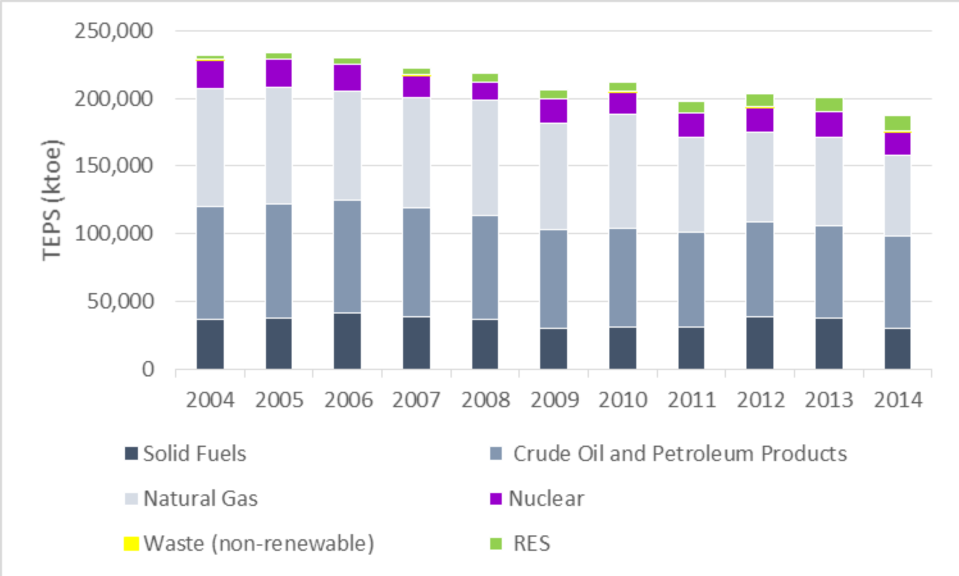

Figure 1- Evolution of Primary Energy Production by source, for United Kingdom (elaboration from (Union 2016))

This trend is expected to continue, as (UK Department of Energy and Climate Change (2015) projects an 11% decrease in the next 10 years, as a result of energy efficiency and energy saving policies.

Therefore, as illustrated in Figure 2, UK has gradually shifted towards RES, contributing to diversify primary energy mix and towards the compliance of 2020 targets.

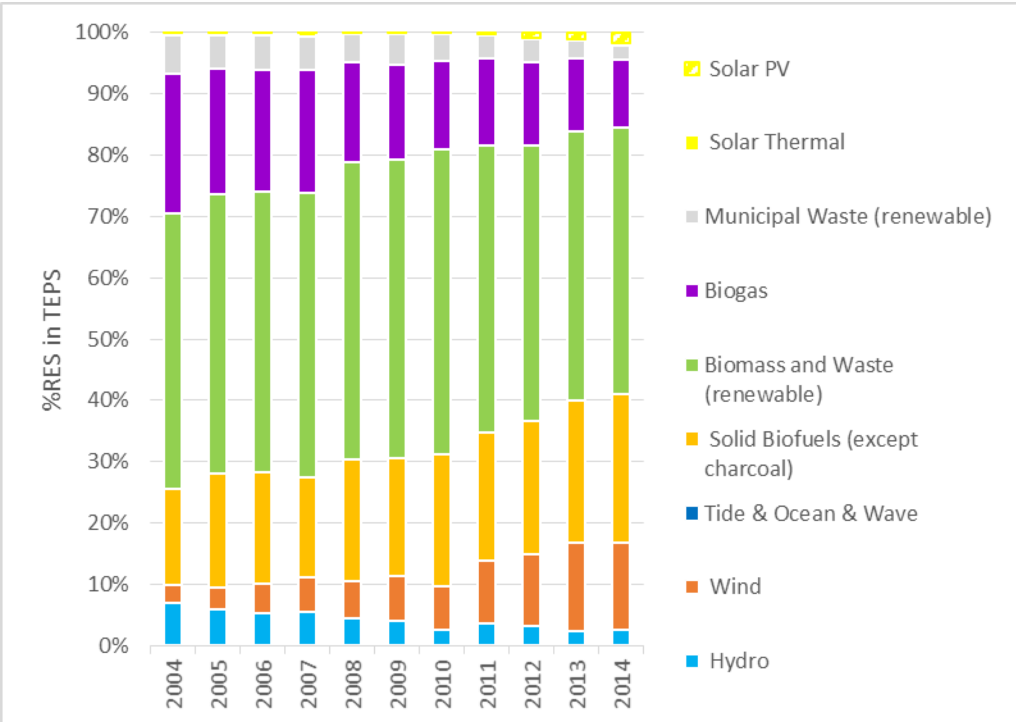

Figure 2- Share of RES in TEPS, for United Kingdom (elaboration from (Union 2016))

Substantial increase of renewables in TPES, has resulted from the contribution of a diversified range of alternatives, with special emphasis for wind, solar power, solid biofuels, biomass and tide, ocean and wave power. Solar PV increased from 0.30 ktoe in 2004 up to 348.20 ktoe in 2014, whereas wind power has increased from 166.40 ktoe in 2004 up to 2752.80 ktoe. Other alternatives, such as ocean and wave power, solid biofules and biomass, have increased by 100%; 406% and 215% comparatively to 2004 values. According to (International Energy Agency (IEA) 2012), the relevance of renewable energy integration is expected to increase by 16.6% by 2020. From which, 14% are from biofuels and waste and 22% from wind power. This increase will contribute to compensate expected decreases from coal and nuclear closing facilities (International Energy Agency (IEA) 2012; Hagemann et al. 2011). Yet, despite the fact that imports in 2014, have reached their lowest level (1684.8 Mtoe), they still represented 46% of energy used (DECC 2015a). Moreover, this transition of UK from net exporter to net importer of fossil fuels, has contributed to increase the country's external dependence.

Energy Dependence

The non-renewable nature of United Kingdom energy mix, and the inability to answer energy needs with domestic production, implies a significant increase in external energy dependence (ED). Since 2004, this indicator has increased by 41%, reaching its peak in 2013 (ED= 46.4). In fact, in 2004 UK became a net importer again, with net imports accounting for 4.5% of total primary energy supply (TEPS) (DECC 2015c). Crude oil, natural gas and coal production have decreased after reaching record levels, denoting increasing reliance on imports (Deloitte Counceil 2015). However, the decrease between 2013 and 2014 (-0.9%), has been attributed to a fall in primary energy supply from coal, oil and natural gas, allied to "full operation" of nuclear power and growth in RES share (DECC 2015c).

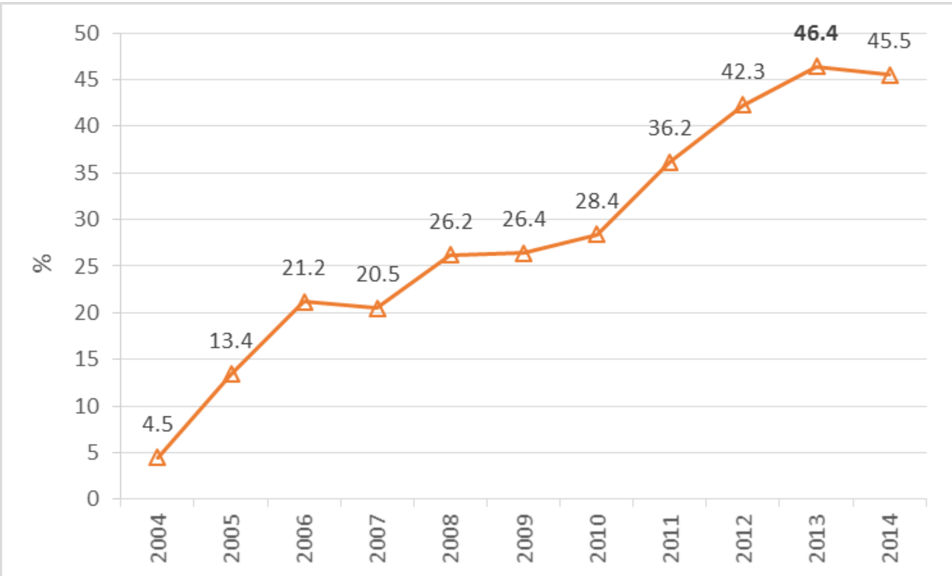

Figure 3- Evolution of United Kingdom Energy Dependence (ED) (elaboration from Eurostat, 2016)

Therefore, United Kingdom needs to increase the contribution of RES, in order to reduce external energy dependence, thereby increasing national energy security of supply, while decreasing energy-related GHG emissions. Additionally, (Department of Energy and Climate Change 2009) claims nuclear power and carbon capture and storage (CCS) should also play a crucial role in national efforts to reduce GHG emissions.

Energy Demand

Total Final energy Consumption (TFC)

In 2014, Total Final Consumption (TFC) in United Kingdom amounted to 129750.2 ktoe, 15% lower than 2004 level. Transport sector has been the largest consuming sector in 2014 (38%), followed by residential (27%), industry (17%), service (13%) and non-energy (5%) sectors (UK DUKES, 2015 chapter1), as illustrated in Figure 4.

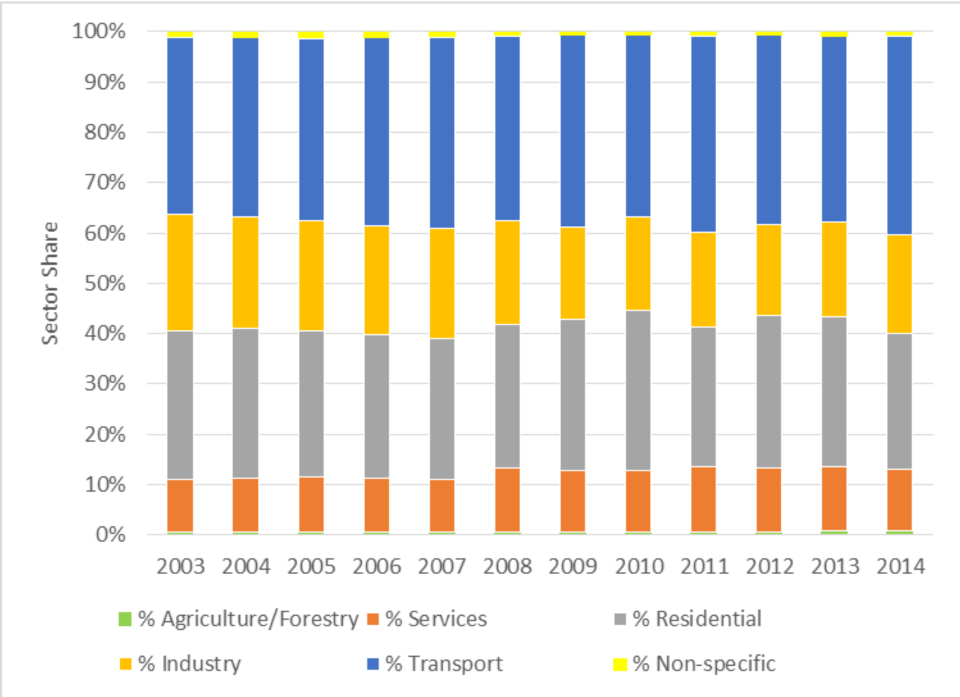

Figure 4- Evolution of sector share in TFC for United Kingdom (elaboration from Eurostat, 2016)

In 2014, TFC has seen a sharp decrease (-15%) compared to 2004 level. By sector, only transport and service sectors have seen their shares increase by 4% and 1%, respectfully. Whereas remaining sectors, have seen their shares decrease, with emphasis for industry and residential sectors, 3% drop. Between 2013 and 2014, TFC has kept a decreasing trend (-5.4 %). The sharp falls in residential (-3%) and service sectors (-1%) have been associated to reduced energy demand for heating, due to warm weather (Department of Energy and Climate Change & (DECC) 2015). Additionally, these prospects are expected to continue for the next 20 years, with transport sector accounting for the greater proportion of TFC (40%) and industry, decreasing by almost 10% (UK Department of Energy and Climate Change 2015).

Energy Intensity

A general idea of how efficiently energy is being used over time is given by energy intensity indicator (UK energy brief, 2015). Energy services (energy consumption by output generated by that energy consumption), can be measured in terms of its economic value, through energy intensity of the economy (the ratio between GDP and energy consumption) (UK Energy efficiency summary, 2015). Energy intensity trend in the UK has improved significantly (-28%) between 2004 (EI= 134.6 kgoe/1000€) and 2014 (EI=96. 3 kgoe/1000€). Consequently moving from highest energy intensity (in 2004) to lowest energy intensity level (in 2014), as illustrated in Figure 5.

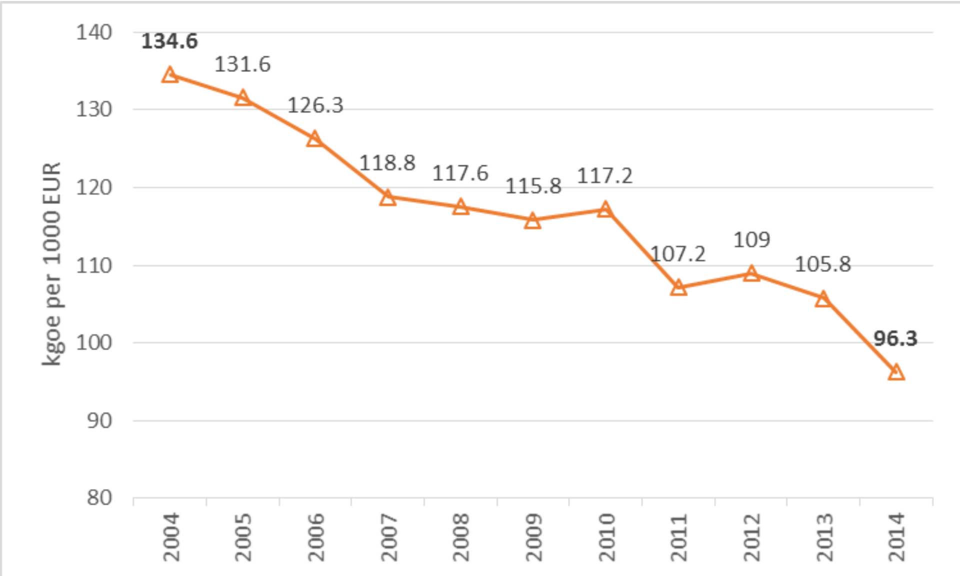

Figure 5- Evolution of Energy Intensity for United Kingdom (elaboration from Eurostat, 2016)

Least energy intensive economy resulted partly from structural shifts from industry to service sector (IEA, 2012), as well as improvements of technological efficiency. Furthermore, through energy efficiency, the Government expects that 42% of energy savings comes from transport sector; 30% from residential sector and 27% from industry and service sectors, by 2030 (DECC 2015b).

Electricity Generation

As illustrated in Figure 6, electricity generation trend in UK has reached its peak in 2005, with 370.60 TWh. Since then, electricity generation has decreased until 2013, reaching its lowest point in 2012, with 335.69 TWh. In 2013, electricity generation has seen a slight increase up to 359.15 TWh. This outcome is 7% higher than previous year (2012) and -3% lower in relation to 2004. Though non-renewable alternatives clearly dominate electricity generation in the UK, with special emphasis for natural gas and coal, its weight in the energy mix has been decreasing. Comparatively to 2004 level, total fossil fuels have decreased by -17%, and less -1% between 2012 and 2013. Yet, for instance, coal steady decline is expected to continue, in virtue of plant closures (International Energy Agency (IEA) 2012). A similar trend is expected for nuclear power that has decreased by 12% in 2013, as power plants reach their operating lifetime expectancy (International Energy Agency (IEA) 2012).

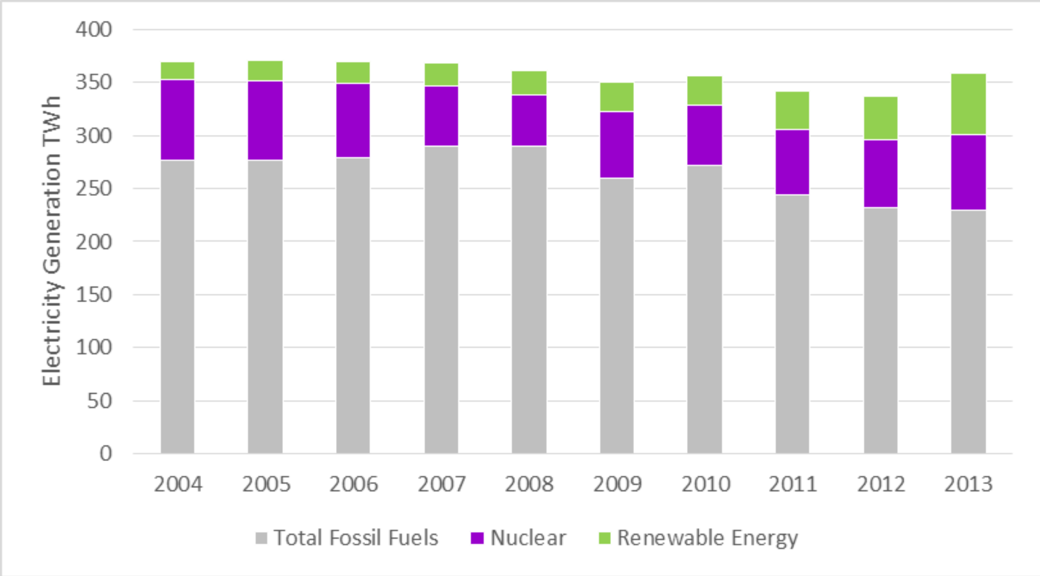

Figure 6- Evolution of electricity generation in United Kingdom (elaboration from EIA, 2016)

In contrast, RES alternatives have seen a substantial increase (from 16.26 TWh in 2004 up to 58.86 TWh in 2013). A more detailed contribution for electricity generation by source, is given in Figure 7.

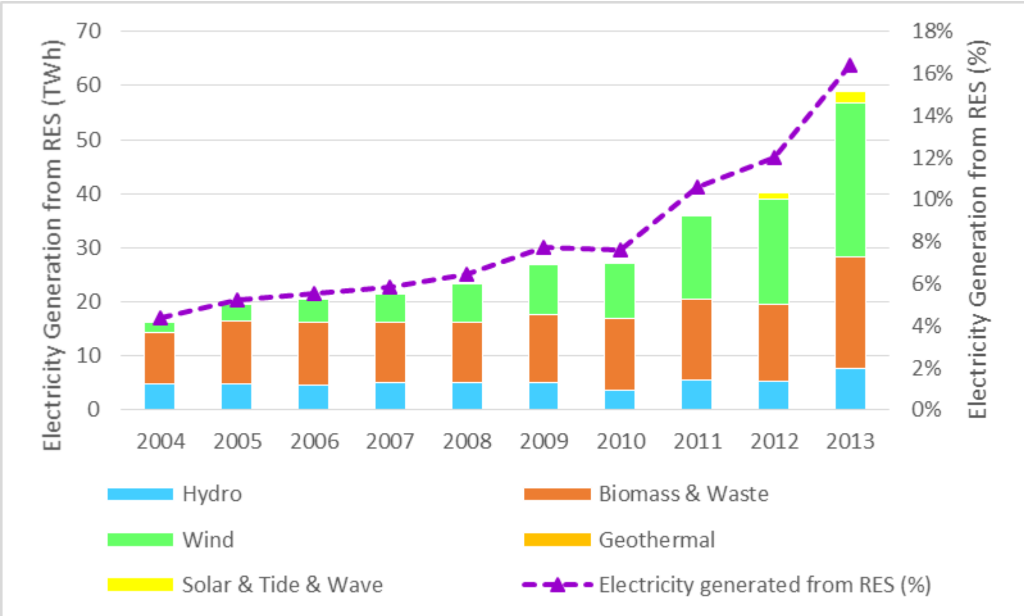

Figure 7- Evolution of electricity generated by RES in United Kingdom (elaboration from EIA, 2016)

Within RES, relevance of the contribution from wind, solar power and biomass has been emphasized. Wind power has seen its share increase from 1.94 TWh in 2004 to 28.43 TWh in 2013; whereas solar power has increased its contribution from 0.004 TWh to 2.04 TWh, between 2004 and 2013. On the other hand, biomass has seen its share increased by 118% in relation to 2004 level. However, in spite of this substantial increase and diversification of the energy mix, RES only accounted for 16% of electricity generation in 2013. Therefore, the need to further increase the contribution from RES to meet 2020 targets, has already been recognized (see (International Energy Agency (IEA) 2012)). Within this context, Government projections expect RES contribution could answer 30% of electricity demand (United Kingdom Government 2009). Wind power should generate "75 TWh in 2020, representing around 20% of total electricity generation" ((International Energy Agency (IEA) 2012), p. 107).

Installed Generating Capacity

Between 2004 and 2014, total installed capacity has increased by 20%. From which, largest contributions came from solar and wind power, with 11.639 MW and 5.369 MW increases respectfully. UK energy summary (2015) claims installed capacity from renewables has increased by almost 11 times from 1996. Contribution by source is illustrated in Figure 8.

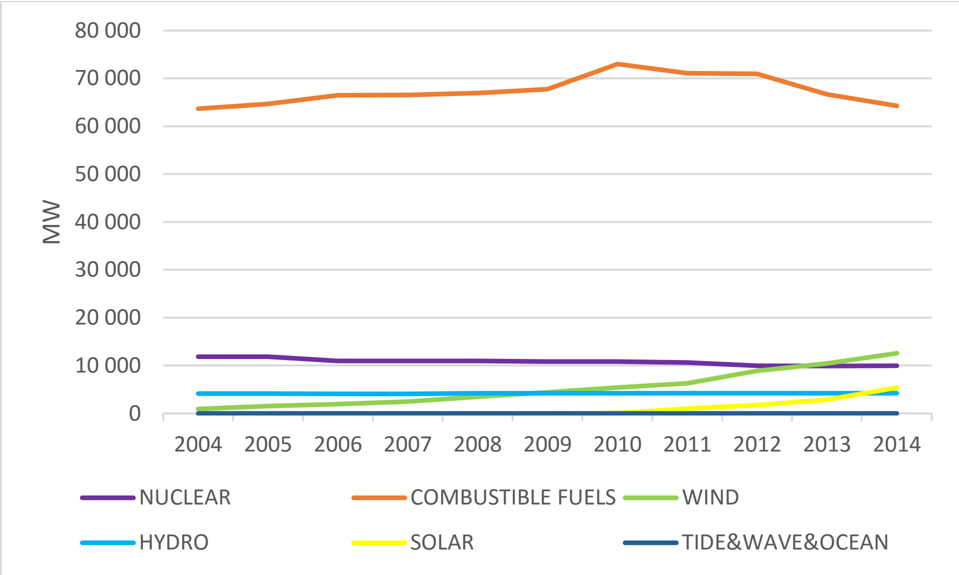

Figure 8- Evolution of installed capacity for electricity generation by source (elaboration from Eurostat, 2016)

Although contribution from combustible fuels has been consistent, their installed capacity has decreased in 2014 by 4% in comparison to previous year (2013). Similarly, installed capacity for nuclear power has seen a marginal increase (0.3%). In fact its capacity has remained unaltered at 9.9 GW, for this period (Department of Energy and Climate Change & (DECC) 2015). These trends are expected to continue decreasing, as large combustion and nuclear power plants close down (DECC 2015a). Additionally, replacement of nuclear capacity is expected, after electricity market reforms by 2025 (International Energy Agency (IEA) 2012).

Energy-Related GHG Emissions

Between 2004 and 2014, energy related GHG emissions have seen an accentuated decrease (-24%), as illustrated in Figure 9. Within a decade all sectors have seen a reduction in their shares, contributing to decrease overall emissions.

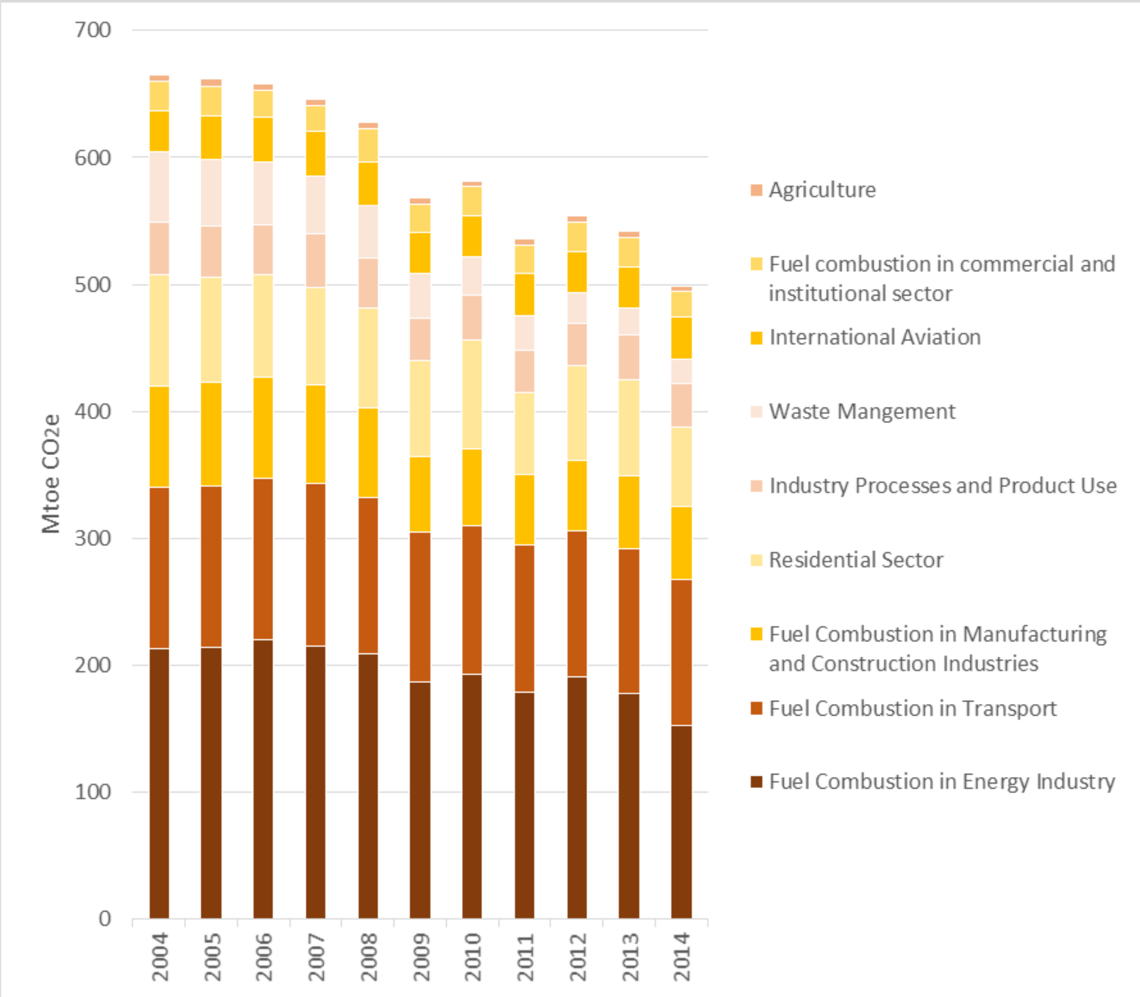

Figure 9- Evolution of GHG emissions by sector in United Kingdom (elaboration from (Union 2016))

Both energy industry and transport sectors, play a relevant role in total emissions, each accounting for 27% and 21% of total emissions in 2014. However, whereas most accentuated reduction has resulted from waste management (-66%), followed by the energy industry (-29%), manufacturing and construction (-29%) and industry sectors (-15%). Least accentuated reduction has resulted from transport sector's contribution (-8%). International Energy Agency (IEA) (2012) claims that the decrease of emissions in these sectors, result from fuel switching (from coal to natural gas), and more recently associated to transition towards less energy intensive sectors (industry towards service sectors), as well as improvements at efficiency level. In contrast, in the next 20 years, it is expected that nearly all sectors see emission decreases, with the exception of the household sector that rises 5% (UK Department of Energy and Climate Change 2015).

Additionally, overall emission decrease since 2013 has been attributed to decreases from electricity generation and also 2014 warmer temperatures comparatively to 2013 (Department of Energy and

Climate Change & (DECC) 2015). Therefore, the increasing role of RES, particularly in the energy sector, should also be emphasized in this context.

Carbon Intensity

Carbon intensity of economy is given by the relationship between carbon emissions and GDP. Comparatively to base year (2000), United Kingdom has seen a substantial decrease in carbon intensity, between 2000 and 2014 (-10.6%), reaching its lowest point in 2014 (CI= 89.4), as illustrated in Figure 10.

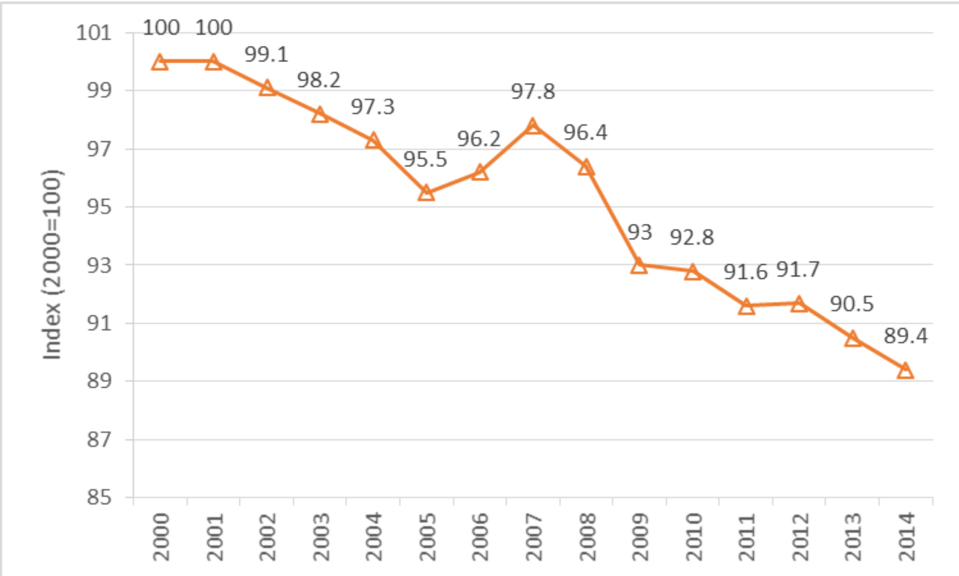

Figure 10- Evolution of carbon intensity (CI) in United Kingdom (elaboration from Eurostat, 2016)

This downward trend has resulted from multiple factors, amongst which (Department of Energy and Climate Change & (DECC) (2015), emphasizes the switch towards "more carbon efficient fuels" and renewable energy sources. Additionally warmer temperatures registered in 2014, have also contributed to decrease energy consumption and improve energy intensity (Department of Energy and Climate Change & (DECC) 2015). Greater reductions of this indicator are expected in future terms, as a result from the increasing integration of RES, nuclear power and CCS in the energy mix (International Energy Agency (IEA) 2012). Furthermore, a slower but accentuated trend from carbon intensity is expected as a result of closure of most carbon intensive power plants before mid-2020 ((UK Department of Energy and Climate Change 2015).

Key Energy and Climate Policy Frameworks

As a party to the United Nations Framework Convention on Climate Change (UNFCCC) and to the Kyoto Protocol (International Energy Agency (IEA) 2012), United Kingdom's climate change commitments have a binding nature. Within EU context, UK has committed to EU ETS reduction targets of 21%, between 2005 and 2008. Also, beyond 2020, for non-ETS sectors, UK will have to limit emissions by 16% from 2005 level (EIA, 2012). Similarly to EU, relevance of renewables for UK's

energy strategy is patent in the 2009 UK National Renewable Energy Action Plan and UK National Energy Efficiency Action Plan (NEEAP).
In addition, UK has also established an ambitious set of national targets, for beyond 2020 period, through 2008 Climate Change Act. This framework, sets long-term (2050) GHG emissions reduction target by at least 80% in 2050 from 1990 targets (International Energy Agency (IEA) 2012). The accomplishment of this reduction is to be ensured through a system of “carbon budgets” over a five-year timeframe (IEA, 2012). This national target is in keeping with EU’s 2030 climate and energy framework (site EU, 2016), which determined three key targets for the year 2030:

- 40% cuts in GHG emissions (from 1990 levels);
- 27% share for renewable energy;
- 27% improvement in energy efficiency.

Furthermore, a reduction of 80 to 95% in GHG emissions, comparatively to 1990 levels by 2050, is also targeted by developed countries, within EU context (European Commission 2016).

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Brazil Energy and Emission Profile

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Country Overview

Brazil is the largest country in Latin America (International Energy Agency (IEA) 2006), with a population of around 2.417 trillion people spread over an area of 8.516.000 km2 (square kilometres) (The World Bank Group 2016). However, population growth rates have been gradually decreasing, a trend that should last in coming years (PDE 2024). PDE 2024 estimates that between 2015 and 2024, population growth rates should decrease from 1.0% to 0.7% per annum.

In 2014, Brazil was the eighth-largest energy consumer in the world, only being surpassed by United States and Canada, in the American Continent (U.S. EIA 2015). On the other hand, Brazil has also in recent years, established itself as a relevant energy producer, being ranked as the 9th-largest oil producer in the world (U.S. EIA 2015). In spite of this, Brazil's energy matrix has been considered one of the least carbon intensive at worldwide level, occupying the 18th place regarding country emissions from the energy sector (EPE, RIO+20, 2015). Between 2003 and 2014 Brazil underwent a sustained economic growth period that has contributed to increase the living standards of more than 29 million people. Over this period, the income of the poorest segment of population has increased by 40% (The World Bank Group 2016).

Currently, Brazil is undergoing an economic recession, aggravated by political instability, which has led to a sharp decrease in GDP growth rate in 2015 (-3.5%) (The World Bank Group 2016). National public accounts have deteriorated over the last years, as a result of international crisis in developed countries and subsequent slowdown of China's economic growth rate (Ministério de Minas e Energia 2015). Therefore, it is expected that main energy indicators reflect to some extent, these alterations in socioeconomic context as well as, the diversified nature of the Brazilian energy system and policy measures adopted within this context.

Main Energy-Related Indicators: Overview

In this chapter, a summary of main aspects/indicators of the evolution of the Brazilian energy system is provided.

Energy Supply

Total Primary Energy Supply (TEPS)

Brazil's primary energy supply amounted to 305.589 ktoe thousand tonnes of oil-equivalent (ktoe), in 2014 (EPE – Empresa de Pesquisa Energética 2015). This represents an increase of over 43% in overall primary energy production, comparatively to 2004 levels. This increase in TEPS has resulted from a diversified energy mix, with the contribution of renewable and non-renewable alternatives, as illustrated in Figure 1.

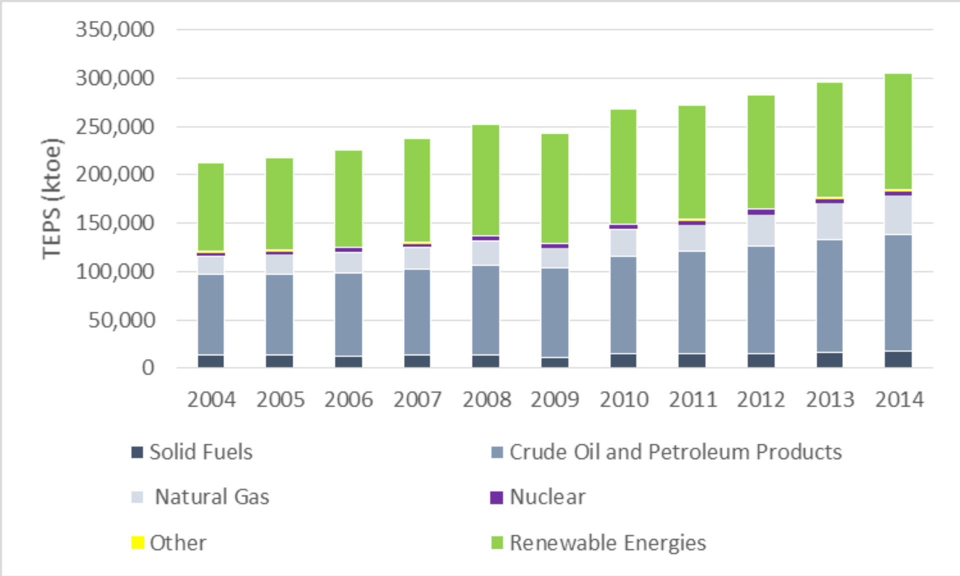

Figure 1- Evolution of Primary Energy Supply by source, for Brazil (elaboration from (EPE – Empresa de Pesquisa Energética 2015)

With the contribution of over 40% of RES, Brazilian energy matrix has been considered one of the most renewable at worldwide level (Ministério de Minas e Energia 2015). In spite of this large contribution from RES alternatives, primary energy mix has been dominated by non-RES alternatives. In 2014, 60.6% of primary energy was ensured by fossil fuels, versus 39.43% contribution from RES. This represents, from 2004 level, a 4% increase for non-RES. Greatest growths were from natural gas (+4.6%) and oil (+0.1%), in contrast with decrease from nuclear power (-0.6%). Whereas RES alternative decreased approximately 4% in 2014 comparatively to 2004 level (43.4%).

Yet, contribution of RES by source, as illustrated in Figure 2, shows an increasing diversification of the energy mix.

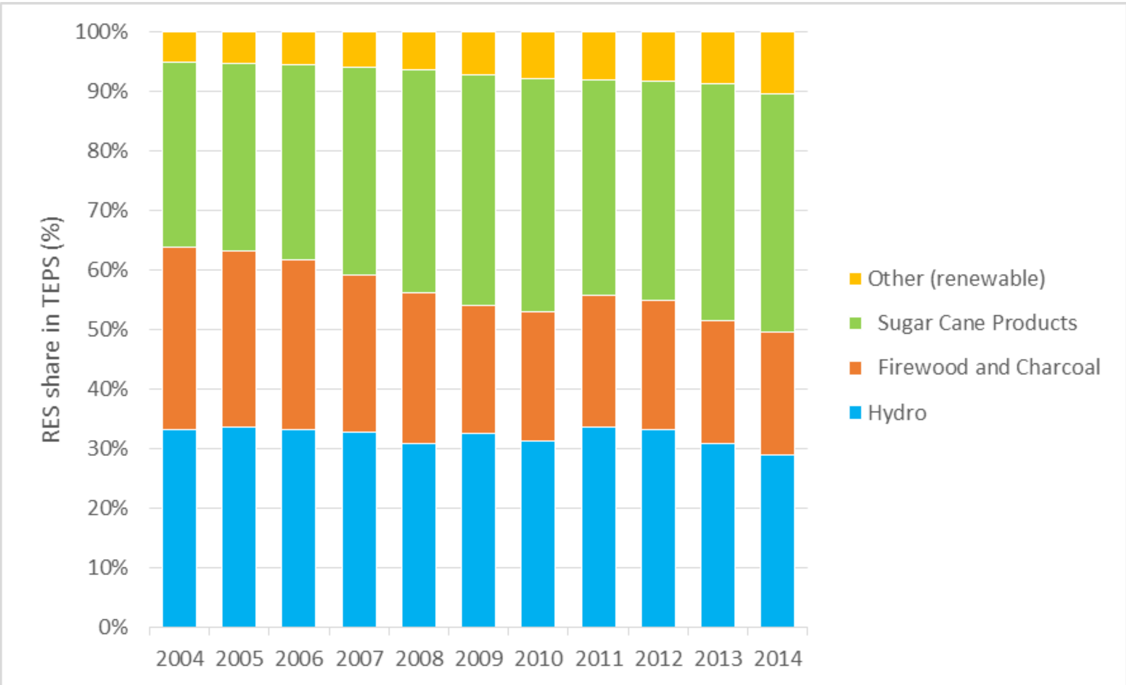

Figure 2- Share of RES in TEPS, for Brazil (elaboration from (EPE – Empresa de Pesquisa Energética 2015)

Hydropower's contribution, though consistent, has been gradually reducing its share by 3.0% between 2004 and 2014 and by 1.1% between 2013 and 2014. Similarly, firewood has seen its share decrease by 5.2% between 2004 and 2014 and by 0.3% comparatively to previous year (2013-2014). Meanwhile, other renewables and sugar cane products have seen their shares in the primary energy mix increase by 1.9% and 2.2% from 2004 level, respectfully. Ministério de Minas e Energia (2015) projections estimates a strong growth and diversification of renewables by 2024, reaching 45.2% of national energy matrix (Ministério de Minas e Energia 2015). Yet, increasing share of non-RES alternatives in the primary energy mix, raise concerns regarding energy dependence and energy security.

Energy Dependence

Despite high integration of RES, fossil fuels still play a relevant role in the national primary energy mix. Whereas renewable alternatives, such as hydropower and biofuels, have been decreasing their shares, non-renewable alternatives have been increasing their shares. As illustrated in Figure 3, ED positive values shows that Brazil is currently a net importer status. This indicator has seen a marginal decrease (-0.1%), between 2004 and 2014, reaching its peak in 2013 (ED=14.4%). For which, has contributed to a greater extent dependence in coal (74.9%), followed by natural gas (44.3%) and to a least extent oil (6.3%). Meanwhile, its most substantial decrease has been verified in 2009 (-8.9% from 2004 level), and has been associated with economic recession constricting influence on energy consumption (Observatory of Renewable Energy in Latin America and The Caribbean 2011).

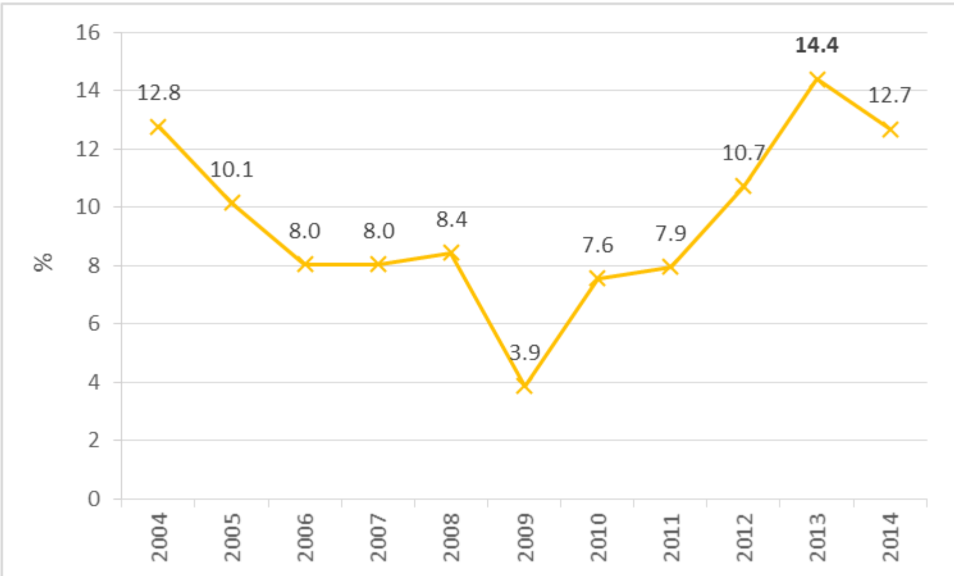

Figure 3- Evolution of Energy Dependence (ED) for Brazil (elaboration from (EPE – Empresa de Pesquisa Energética 2015)

However, the recent discovery of large offshore deposits of fossil fuel derivates (such as pre-salt oil and shale gas) (International Energy Agency (IEA) 2006), might change this prospect. In fact, EIA (2016) estimates that in 2016 for the first time since 2008, production might exceed consumption of oil, making Brazil a net exporter. This transition would contribute to decrease external dependence on imports. Notwithstanding, according to International Energy Agency (IEA) (2006) although seeking to reduce import dependence, environmental concerns of these Governmental choices should be further addressed.

Energy Demand

Total Final Energy Consumption (TFC)

In 2014, Total Final Energy Consumption (TFC) amounted to 222. 415 ktoe, 32% higher than 2004 level. Transport and industry sectors have been the sectors with the largest shares of TFC in 2014 amounting to 39%, followed by residential (11%), service sectors (6%) and agriculture (5%), as illustrated in Figure 4.

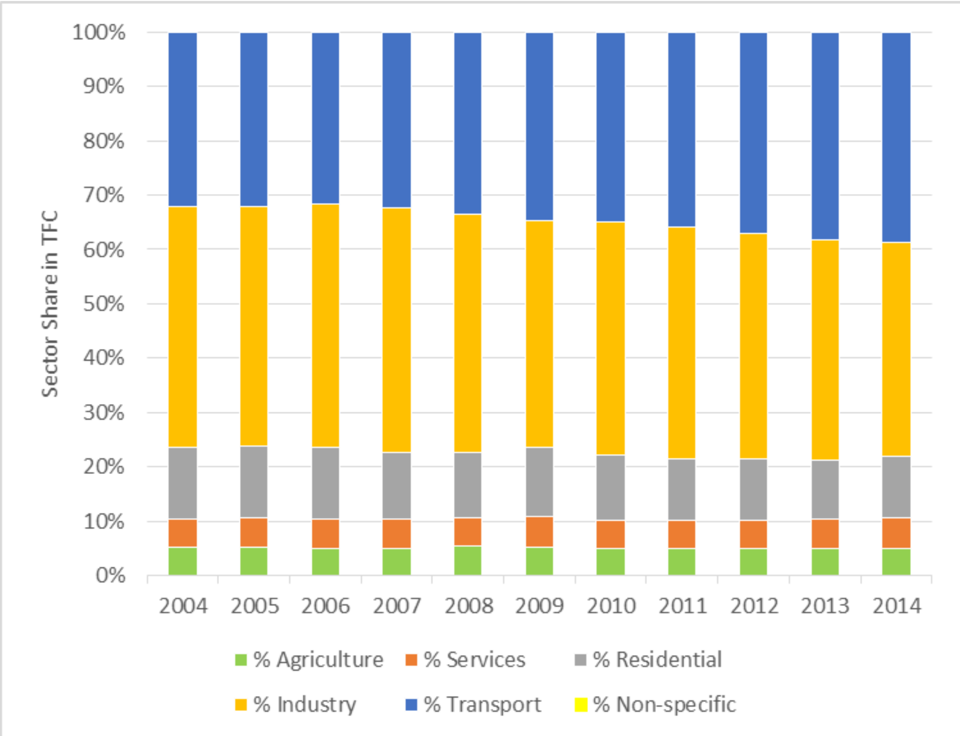

Figure 4- Evolution of sector share in TFC for Brazil (elaboration from (EPE – Empresa de Pesquisa Energética 2015)

However, transport and industry sectors show opposing trends between 2004 and 2014. While the transport sector increases by 6.7%, industry decreases by 5%, from 2004 level. Remaining sectors also show reductions, with the exception of service sector that has seen a small increase (+0.4%) in ten years (2004-2014). Yet, agriculture and residential sectors have seen a slight recovery between 2013 and 2014 (+0.2%). Overall, performance of Brazilian economic sectors reflects economic recession aftermath that along with national challenges, such as consumer purchasing power loss, have led to lower economic outcome (Ministério de Minas e Energia 2015). In spite of this, ten year time projections estimates substantial expansion of agriculture sector with annual increases of 3.7% per year; followed by service sector with average annual increases of 3.3% per year and at a lower rate industrial sector (2.8% per year) (Ministério de Minas e Energia 2015). Also, evolution of energy consumption in the residential sector, has been associated to multiple factors, namely increase in number of households, increase in the ownership and use of household appliances, and their energy efficiency. Given this, it is estimated that households with energy supply increase from 65 million up to 77 million by 2024 (Ministério de Minas e Energia 2015). As for transport sector, its performance in the next decade will be strongly influenced by slowdown in the car industry in 2014 (Ministério de

Minas e Energia 2015). Energy sector is expected to increase its relevance in 2024, in detriment of industrial, residential and transport sectors (Ministério de Minas e Energia 2015).

Energy Intensity

Energy intensity indicator results from the ratio between TEPS and the gross domestic product (GDP), measured in toe (tonnes of oil equivalent) per GDP in 1 000 US dollars ($). It is often used as an indicator/ measure for overall efficiency (Luomi 2014). Evolution of energy intensity (EI) profile for Brazil showed since 2005 a stagnating trend, as illustrated in Figure 5.

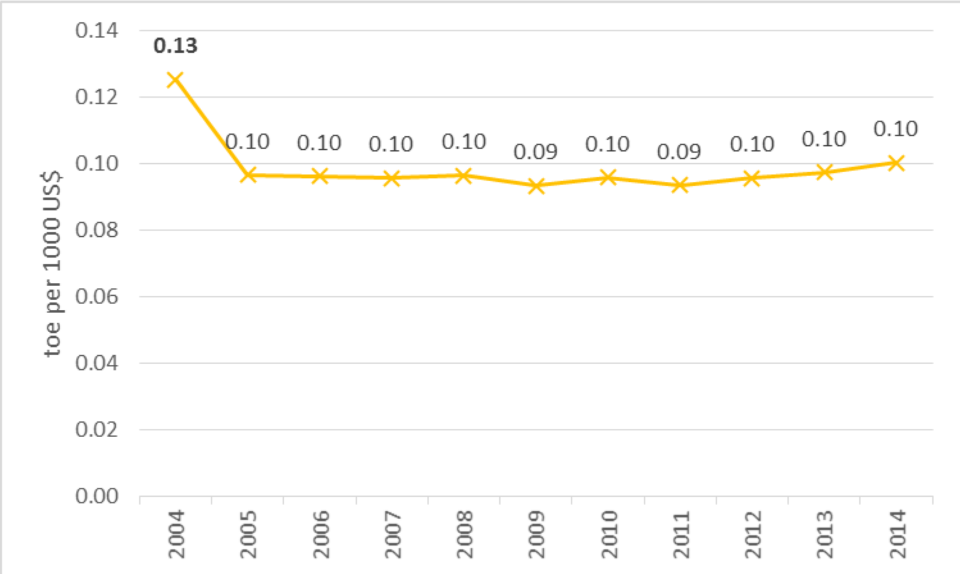

Figure 5- Evolution of energy intensity (EI) for Brazil (elaboration from (EPE – Empresa de Pesquisa Energética 2015))

In 2014, EI was 0.10 toe/1000 US$, 20% lower than 2004 value (EI= 0.13 toe/1000 US$). Despite this improvement, comparatively to energy intensity peak in 2004, there has been virtually no annual improvement of this indicator. In fact, annual variation rate between 2013 and 2014 shows a slight increase of 3% in EI. Therefore, although there have been significant improvements within a ten year period, yearly variations show that there is the need to address/improve efficiency issues in the Brazilian energy system. Low energy intensity has been attributed to the dominance of hydropower in the electricity mix ("with low conversion losses") and reduced levels of levels of "heating and cooling in buildings" (Luomi, 2014). In spite of this, (Ministério de Minas e Energia 2015), projections estimates improvements in energy intensity up to 0.060 reais (R$) [2010] in 2024 that will lead to energy savings at sectoral level. It has been projected that in 2024, savings for industry sector will amount to 5.2% of TFC (equivalent to approximately 8.7 Mtoe); 3.9% (approximately 4.6 Mtoe) in transport sector; (approximately 1.6 Mtoe) in residential sector and 4.8% in service and agriculture sector (approximately 935 and 655 ktoe respectfully (Ministério de Minas e Energia 2015).

Electricity Generation

As illustrated in Figure 6, electricity generation trend in Brazil has increased, reaching its peak in 2013, with 570.33 TWh. This represents a 50% increase in comparison to lowest level, reached in 2004 (381.18 TWh). Main drivers for this increase have been associated to improvements of living standards and to a less extent to population growth as main drivers, with residential and service sectors as main end-users for this commodity (Luomi 2014).

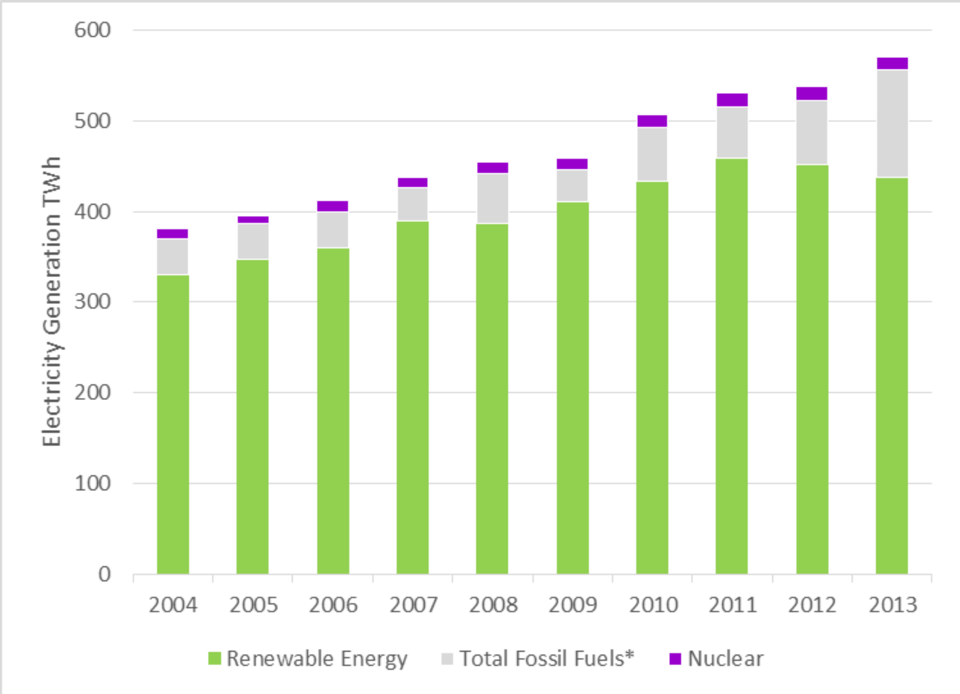

Figure 6- Evolution of electricity generation in Brazil (elaboration from (U.S. Energy Information Administration 2016)

Renewable energies dominate electricity generation matrix, accounting for 77% of electricity produced in 2013. Yet, its share has decreased annually by less 3% between 2012 and 2013. Therefore increase in demand has been supressed by the increase of non-renewable alternatives, such as oil, coal and natural gas. The share of total fossil fuels has increased by 66% between 2012 and 2013 and 198% in relation to 2004 level. Within fossil fuels natural gas has been increasingly used for backup to hydropower variability (Luomi 2014). If in one hand, this has diversified the energy matrix, it has also risen concerns regarding increase in energy-related GHG emissions and import dependency. Meanwhile, nuclear power has seen an increase comparatively to 2004 (+26%), its contribution has decreased on a yearly basis, between 2012 and 2013 (-3%). Therefore, as illustrated in Figure 7, increase in fossil fuels, has implied a decrease in electricity generated from RES, albeit the increase in its diversification.

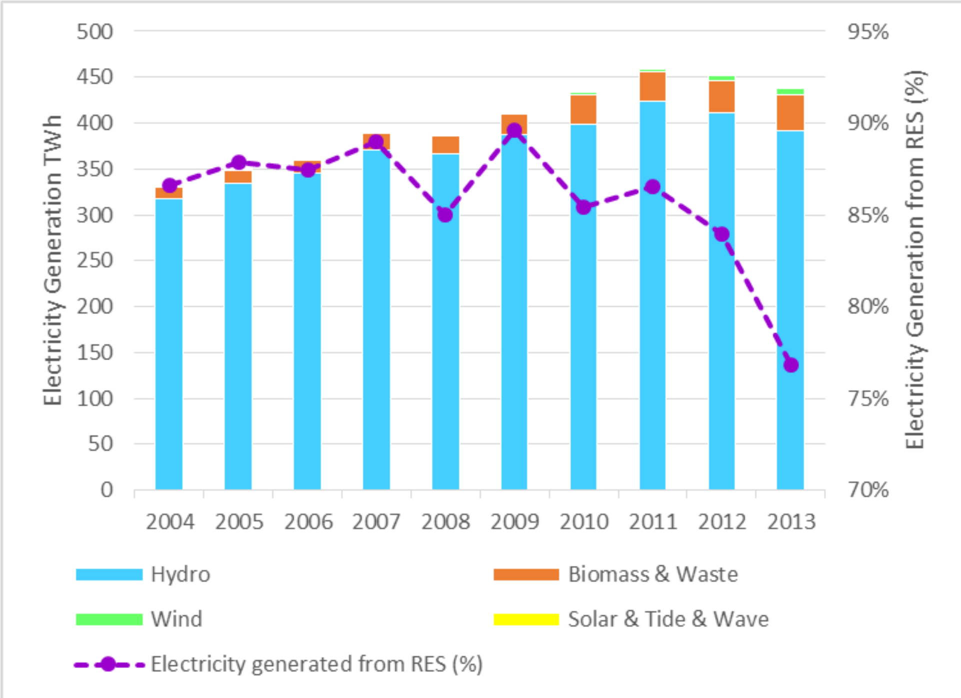

Figure 7- Evolution of electricity generated by RES in Portugal (elaboration from (U.S. Energy Information Administration 2016)

Along with 5% decrease in hydropower between 2012 and 2013, other renewable alternatives, such as biomass, wind and solar power have increased their shares, contributing to further diversify electricity sector. Biomass has seen its weight increase from 3% in 2004 to 7% in 2013, followed by wind power that increased from 0.02% in 2004 up to 1.2% in 2013. Whereas, solar power's contribution is still insipient. However, expansion of electricity generation in ten years, estimates an increase of other renewables, including biomass, wind and solar by 27.3% by 2024 (Ministério de Minas e Energia 2015). Whereas nuclear power is expected to suffer a slight increase from 1.2% to 1.6%, in virtue of the entry into operational of Angra 3 facilities; while hydropower decreases by 8.8% in 2024 (Ministério de Minas e Energia 2015).

Installed Generating Capacity

Installed capacity has seen a 30 % increase over the period between 2005 and 2012 (from 93.25 GW to 121.68 GW). As illustrated in Figure 8, contribution by source is led by hydropower, accounting for 84.29 GW, followed by fossil fuels with 22.79 GW and biomass with 10.20 GW. However, greatest increase in installed capacity has been attributed to wind power, whose contribution went from 0.03% in 2005 up to 2% in 2012.

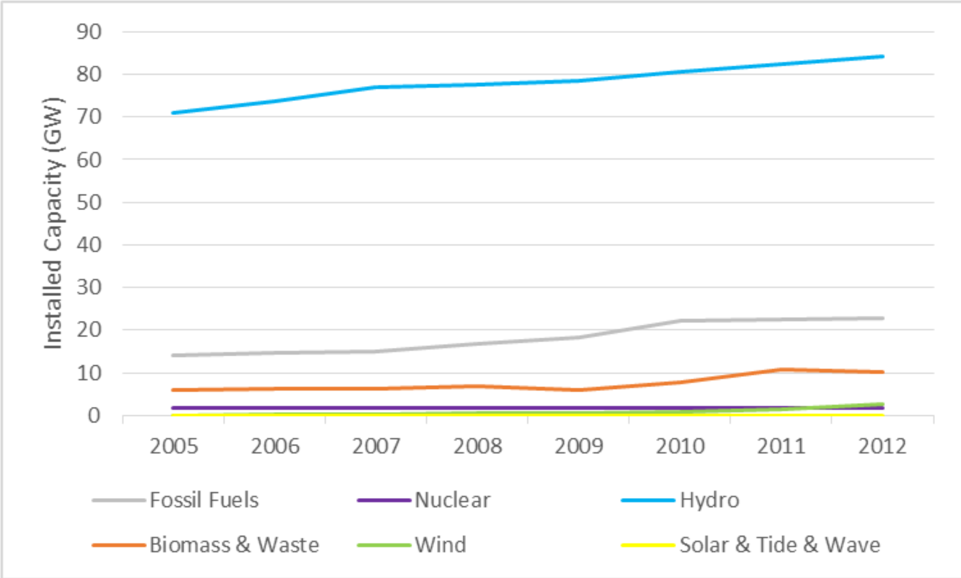

Figure 8- Evolution of installed capacity for electricity generation by source in Brazil (elaboration from (U.S. Energy Information Administration 2016)

In 2014, installed capacity amounted to a total of 133 GW, and is expected to increase to 206 GW in 2024 (Ministério de Minas e Energia 2015). From which, hydropower will see its capacity increase by 27 MW in 2024, though its share in the overall electricity mix is expected to decrease from 67.6% to 56.7%. Thermoelectric power plants are also expected to increase, totalling up to 11 647 MW of installed capacity (PDE, 2024), with greater emphasis on natural gas and to a less extent coal and nuclear sources. These alternatives, will increase energy security, by reinforcing the interconnectivity of the energy system, given their lower vulnerability to weather conditions (Ministério de Minas e Energia 2015).

Nuclear power will rise its capacity by 1 GW, increasing slightly its share from 1.5% to 1.6% for the same period. Similarly to the trend between 2005 and 2012, greatest upsurges in installed capacity come from wind and solar power. Wind power will increase from 5 GW (3.7%) in 2014 to 24 GW (11.6%) in 2024, while solar power will see its capacity increase by 3.3% (7GW) in 2024 (Ministério de Minas e Energia 2015). Additionally biomass contribution will increase from 8.3% to 8.7% (11 GW in 2014 up to 18GW in 2024) (Ministério de Minas e Energia 2015). Moreover, diversification of the energy mix based on renewable alternatives is expected to have positive repercussions regarding energy-related GHG emissions.

Energy-Related GHG Emissions

In 2014, total GHG emissions, including change in land use and forestry (LULUCF), amounted to 1.558 Mtoe of CO2e (Observatório & (OC) 2014), which was slightly less (-1%) than previous year (2013), and significantly less (-45%) than 2004, as illustrated in Figure 9.

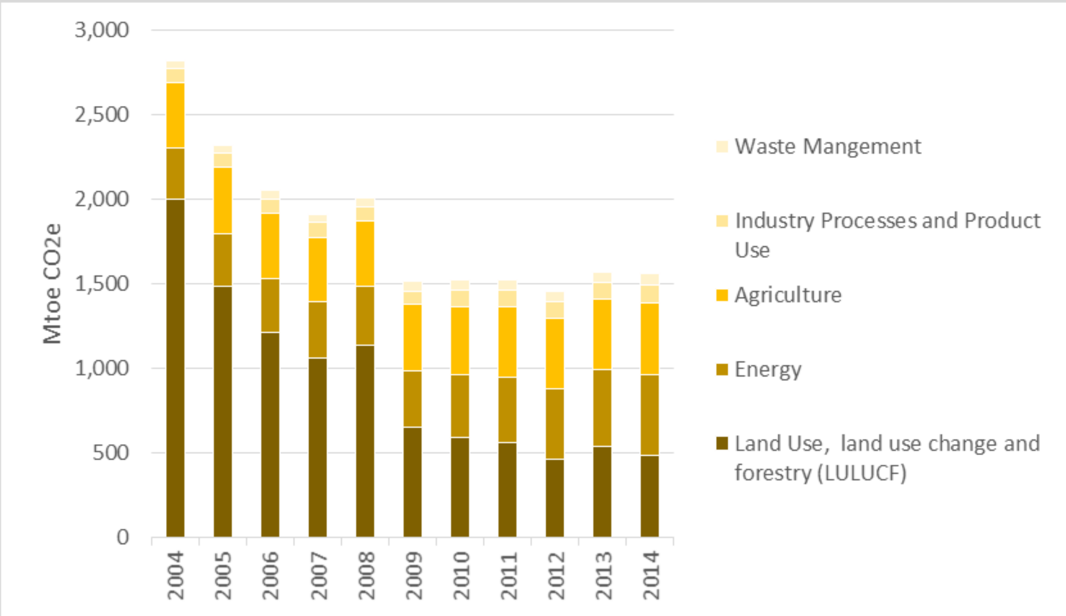

Figure 9- Evolution of GHG emissions by IPCC sector in Brazil (with LULUCF) (elaboration from (System Study Greenhouse Gas Emissions Estimates (SEEG) 2016)

Decline from peak emissions in 2004 (GHG= 2817.4 Mtoe CO_2e) has been attributed to an accentuated reduction in Amazonia's deforestation (Observatório & (OC) 2014). Yet, in spite of overall reduction, GHG emissions have increased at sectoral level, with the exception of LULUCF (Observatório & (OC) 2014), as illustrated in Figure 10. Despite significant weight of energy, agriculture and industry sectors, greatest increases, between 2004 and 2014, have been attributed to electricity generation (209%), transport (58%) and waste management (53%) sectors. Emission growth in the power sector is reflective of adverse climate conditions that require increased participation of thermoelectric power plants in the energy system (Ministério de Minas e Energia 2015). In fact, fuel production has seen one of the most significant increases in 2014, by nearly 58% when compared to 2004 levels.

Therefore, prospects between 2020 and 2024, estimate an upsurge of energy-related emissions associated to economic growth and increased electricity demand, in spite of high contribution of RES in the energy matrix (Ministério de Minas e Energia 2015). Additionally, it is expected that 89% of electricity generation in 2024 will result from other renewables, and could reach 92% from non-emitting sources if nuclear power is taken into consideration (Ministério de Minas e Energia 2015).

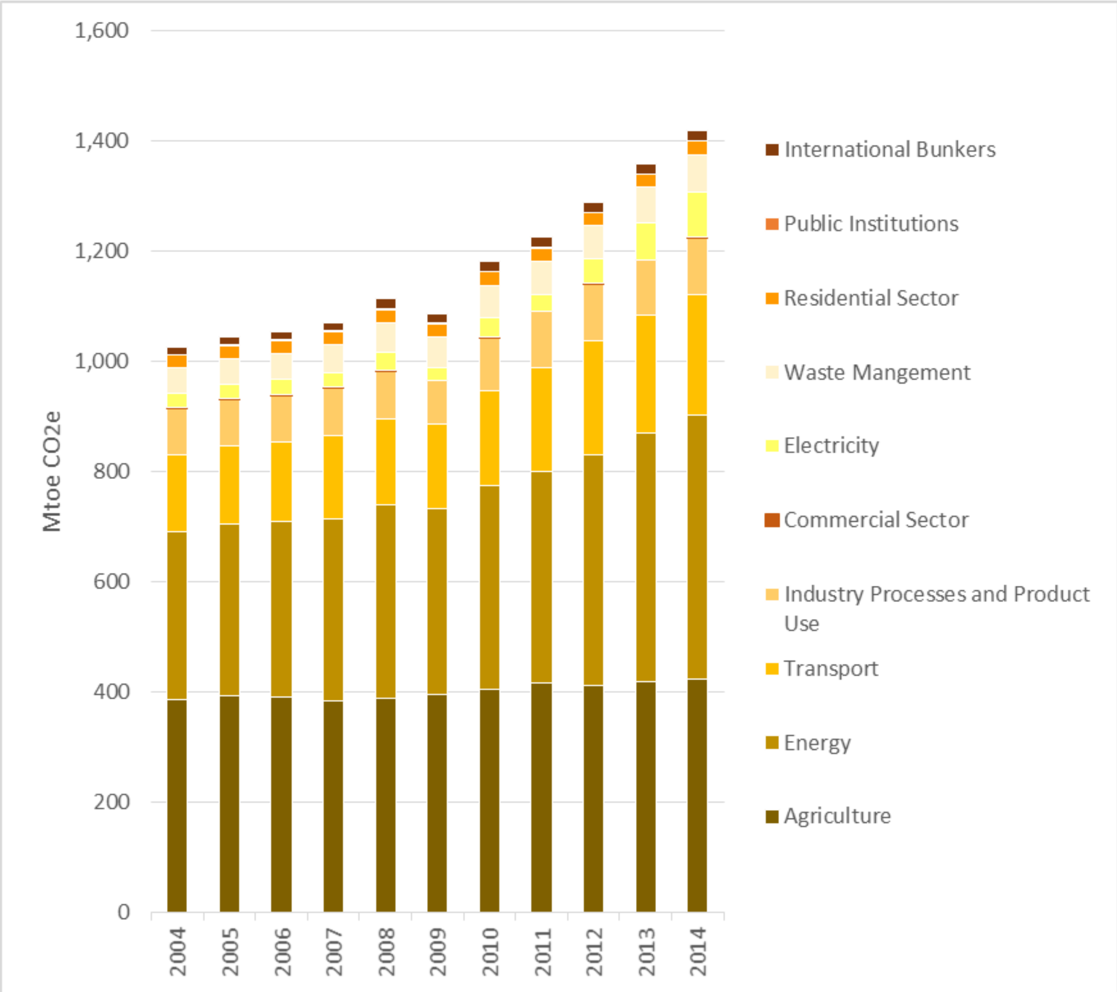

Figure 10- Evolution of GHG emissions by IPCC sector in Brazil (without LULUCF) (elaboration from (System Study Greenhouse Gas Emissions Estimates (SEEG) 2016)

Thus, renewably- based diversification of the energy mix, could contribute to prompt a transition towards green-growth and the accomplishment of GHG emission targets.

Carbon Intensity

Carbon intensity of economy is given by the relationship between carbon emissions and GDP, and can be considered as a measure of its environmental quality (EPE – Empresa de Pesquisa Energética 2009). Brazil has seen a substantial fluctuations in its carbon intensity (CI) trend, as illustrated in Figure 11. Between 2000 and 2009 energy intensity has decreased by 16%, reaching its lowest point in 2009 (CI= 83.7). However, from 2009 until 2013 Brazil has seen its CI increase, reaching its highest point in 2013 (CI=102.0). This represents a 2% comparatively to base year (2000), and a 22% increase comparatively to 2009 values.

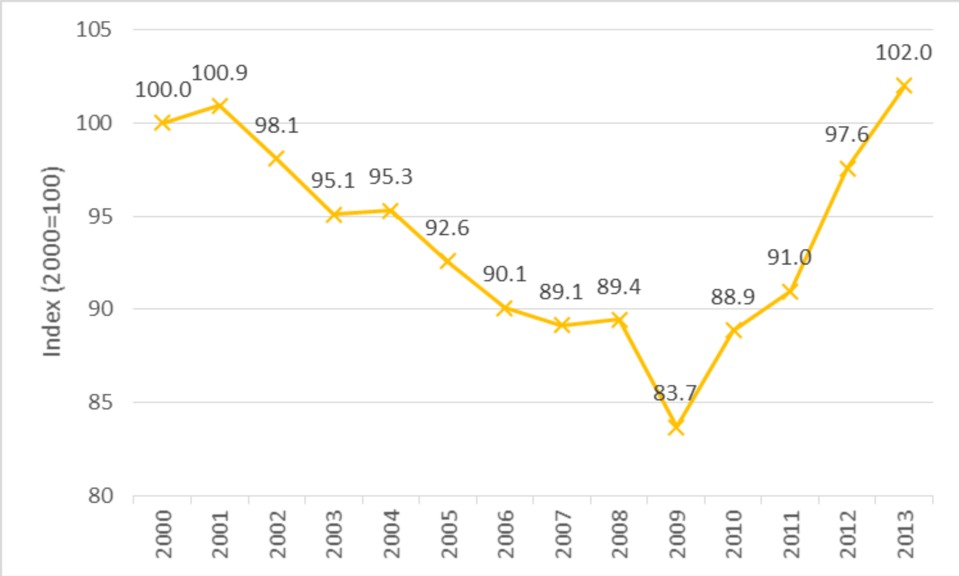

Figure 10- Evolution of carbon intensity (CI) in Brazil (elaboration from (International Energy Agency (IEA) 2015)

A considerable increase in the use of thermoelectric power plants, to compensate lower hydropower contribution for power generation, has been considered at the base of rising CI trend (Ministério de Minas e Energia 2015). In spite of this, (Ministério de Minas e Energia 2015) estimates by 2024 are positive. It is estimated that CI will decrease to values bellow 2005 threshold, reaching 105,5 kgCO2eq/1000 R$ [2010]. Moreover, this reduction is also somewhat reflective of low carbon strategy adopted for the development of the energy system in Brazil.

Key Energy and Climate Policy Frameworks

Although a party of United Nations Framework Convention on Climate Change (UNFCCC), being an emerging country, Brazil is not required to meet legally binding GHG emission targets, within Kyoto Protocol scope (Ministério de Minas e Energia 2015). Nevertheless, Brazil is committed to mitigate climate change. In 2009, during Copenhagen UNFCCC Conference, Brazil established voluntary pledges for GHG emission reduction in 2020, between 36.1% and 38.9% of total emissions compared to business as usual (BAU), from 2005 level (Nachmany, M. 2016). This target has been transposed for national legal framework by Law nº 12.187/09 (National Policy on Climate Change), which delineates main lines for climate change mitigation and adaptation. Emission targets have been determined for the following key sectors:

- Deforestation (24.7%);
- Agriculture and livestock sector (4.9% to 6.1%);
- Energy sector (6.1% to 7.7%);
- Steel sector (0.3% to 0.4%)

Additionally in 2010, Brazil fixed a limiting target of 680 MtCO2e by 2020, with the goal of keeping a high contribution of RES in the energy matrix, ensuring that carbon intensity of the economy does not surpass 2005 level, based on Brazilian inventory of Anthropic Emissions and removal of Greenhouse Effect Gases (Ministério de Minas e Energia 2015). In addition to commitments to reduce deforestation and restore different biomes, several sectoral actions plans to outline main mitigation measures, are currently in different stages of implementation (e.g. the Action Plan to

Prevent and Control Deforestation in the Amazon (PPCDAm); the Action Plan to Prevent and Control Deforestation and Fire in the Cerrado (PPCerrado); the Low-Carbon Agriculture Plan (ABC Plan); the Ten-Year National Energy Expansion Plan (PDE)) (Nachmany, M. 2016)

In 2015, within COP-21 Paris Conference context, a new climate agreement with binding targets for post-2020 period has been reached, under shared responsibility premise, i.e. with the contribution from developed and emerging countries, though at different degrees (Observatório & (OC) 2014). Brazil presented its intended Nationally Determined Contribution (iNDC), which consisted of an absolute target to reduce GHG emissions, with LULUCF, by 37% below 2005 levels in 2025. In addition to, an indicative contribution to reduce GHG emissions by 43% below 2005 levels in 2030 (Federative Republic of Brazil 2015; Climate Action Tracker 2015). Amongst measures envisioned to accomplish these targets, Brazil intends to achieve 45% of renewables in the energy mix by 2030, through:

- “Increase the use of RES other than hydropower in the total energy mix to between 28% and 33% by 2030;

- Expand the use of non-fossil fuel energy sources domestically, increasing the share of renewables (other than hydropower) in the power supply to at least 23% by 2030, including by raising the share of wind, biomass and solar;

- achieving 10% efficiency gains in the electricity sector by 2030” (Federative Republic of Brazil 2015).

Energy efficiency also plays a key role regarding accomplishment of international pledges. National Energy Efficiency Plan, establishes main lines regarding energy efficiency approach for several sectors, such as energy or industry. Amongst existing programs emphasis should be brought to the Brazilian Labelling Program (PBE), the Electricity Conservation National Program (PROCEL) and the Oil Derivatives and Natural Gas Conservation National Program (CONPET). It is expected that the implementation of this Plan will contribute to provide substantial energy (106 TWh) and emission (174 million tCO_2) savings in the coming decades (Nachmany, M. 2016; EPE – Empresa de Pesquisa Energética 2009).

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