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EU energy end-uses analysis and 2050 Low-Carbon scenarios

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Abstract

The main targets of the European Union strategy in the climate and energy fields are the greenhouse gases emissions cut and the reduction of energy dependence. Aim of the strategy is to ensure the supply security in the medium and long term and to fulfil the commitments taken at the international level, in compliance both to the Kyoto Protocol and to the United Nations Framework Convention on Climate Change (UNFCCC). The final energy demand reduction is one of the main cards available to the European Union for influence the global energy market and to ensure the supply security in the medium and long term. Another main card is the fuel-switching from fossil fuels to renewable energy sources.

The paper presents the analysis of the European Union final energy demand, through an overview of three macrosectors: buildings, industry, transport. The analysis is based on statistical and surveys data collected from Eurostat and Odyssee. The building sector is taken in account splitting it in the households sector and services sector, and analysed both from the demand side and the supply side points of view. As analysis complement, the paper presents the European Union energy trends in 2050, linking the low carbon strategies among them and introducing the "Low Carbon Economy 2050" concept.

Keywords: energy end-uses; decarbonization; European Union; 2050 Roadmap.

Introduction

The main targets of the European Union (EU) strategy in the climate and energy fields [1] are the Green House Gases (GHG) emissions cut and the energy dependence reduction, in order to ensure the supply surety on the medium and long term, and to fulfil the international commitments, both respect to the Kyoto Protocol [2] and respect to the United Nation Framework Convention on Climate Change (UNFCCC) [3].

The final energy demand reduction is, together with the fuel-switching from fossil fuels to Renewable Energy Sources (RES), one of the main cards available to the EU for influence the global energy market, and for ensure the supply surety on the medium and long term. Also, the final energy demand reduction is suitable to achieve the targets established from the EU in 2020 through the "20-20-20 Package" [4]: 20% GHG emissions cut in comparison to 1990; 20% RES share in gross final energy consumption; 20% energy efficiency increase.

The report "Energy 2020 – A strategy for competitive, sustainable and secure energy" [5] indicates that the energy efficiency is the fulcrum of the EU strategy in 2020, aimed to decoupling the energy consumption from the economic growth. The report "Action plan for energy efficiency: realising the potential" [6] underlines the high energy efficiency potential currently available. The energy targets achievement under the condition of parallel economic effectiveness is a very relevant topic across the EU policy in the climate and energy fields.

Aim of the paper is the EU final energy demand analysis, both in the current configuration and in the 2050 foreseen configuration, through a macrosectoral criteria based on statistical and surveys data and reports published from the European Commission. The analysis is carried out focusing on the buildings sector, and highlighting the RES role.

1 – Final energy demand in EU-28

According to Eurostat [7] data, the buildings sector final energy demand represents the 40,6% of the EU overall final energy demand. The complementary share is split between the

industry sector and the transport sector, respectively 25,1% and 31,6%, and agriculture sector (marginal). During the 1990-2013 period the industry trend decreased, while the buildings and transport trends increased, as shown in Figure 1. During this period, the overall energy consumption remained almost unchanged.

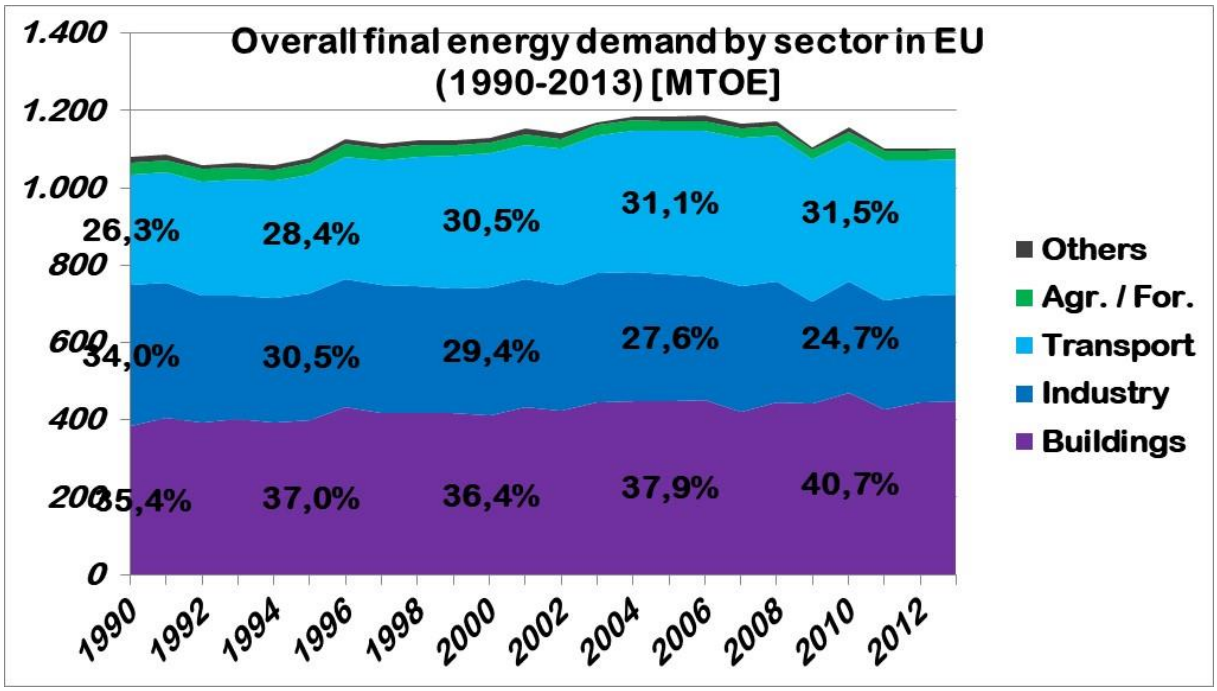

Figure 1: Overall final energy demand by sector in EU (1990-2013). Source [7]

According to the same data, the buildings sector electricity final energy demand represents the 61,6% of the EU overall electric final energy demand. The complementary share is split between the industry sector and the transport sector, respectively 36,0% and 2,3%. During the 2000-2013 period these shares remained almost unchanged. During the same period the overall energy consumption increased, as shown in Figure 2.

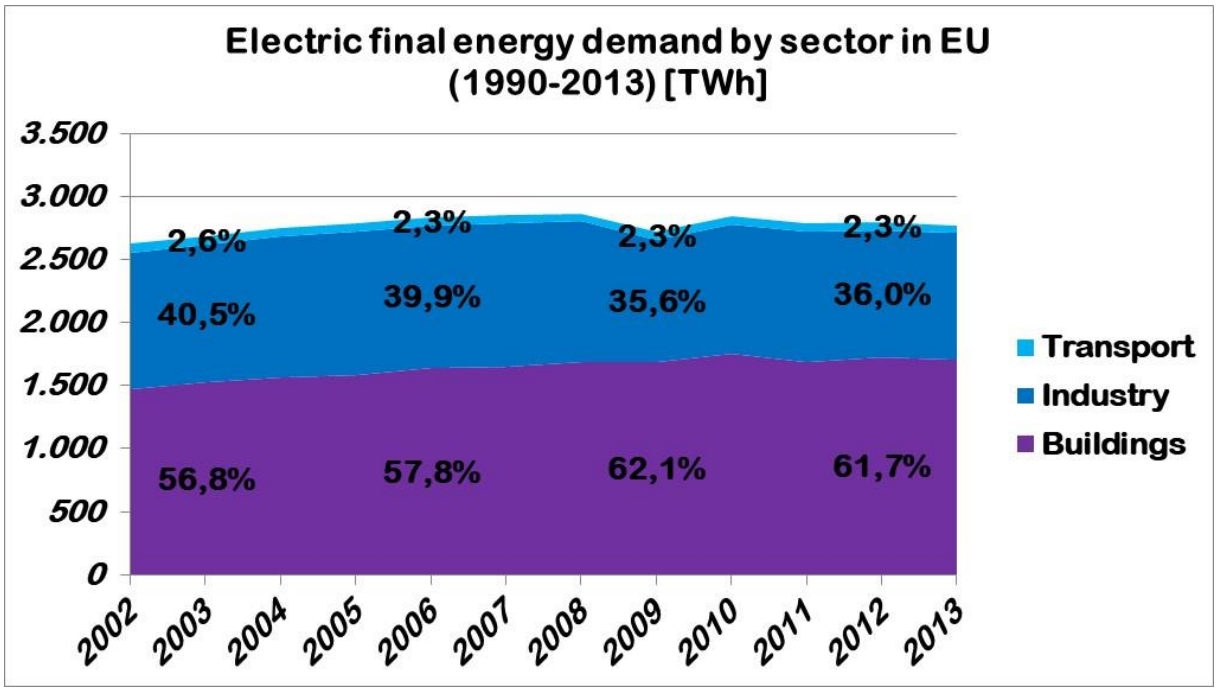

Figure 2: Electric final energy demand by sector in EU (1990-2013). Source [7]

In the buildings sector, over half of the overall final energy demand increase is due to the electric final energy demand increase. The share fuelled from RES is marginal, as shown in Figure 3.

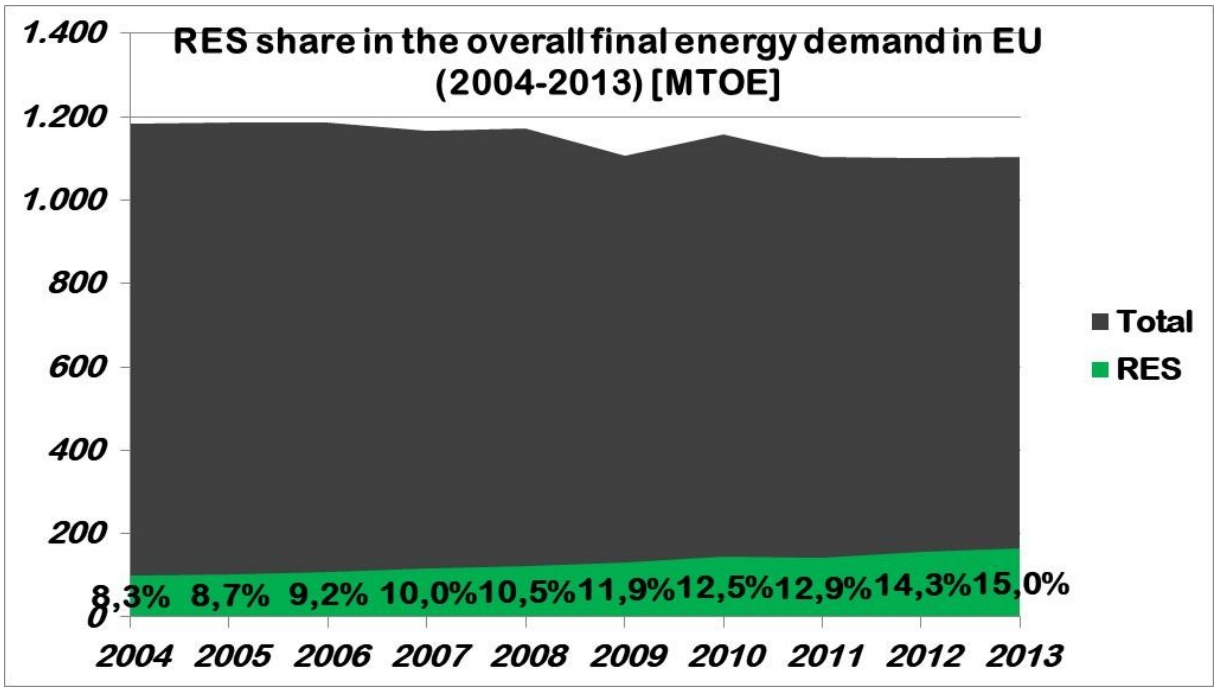

Figure 3: RES share in the overall final energy demand in EU (2004-2013). Source [7]

1.1 – Final energy demand in the buildings sector

In compliance with the research project "Odyssee" [8], related to the EU energy efficiency indicators, the buildings sector analysis has been carried out splitting it in the households sector and the services sector. The Odyssee data show that in 2012 the households sector represents the 74% of the overall buildings stock, of which 66% are dwellings and 34% are flat blocks, and the services sector represents the 26%. The EU average value of energy need in the services sector, 286 kWh/m²year, is higher than the one in the households sector, 185 kWh/m²year.

The split among energy carriers of the overall final energy demand, Figure 4, shows that in the households sector the gas is the main energy carrier, and the electricity is the sequent. Both are increased from 1990. During the 1990-2012 period the end-uses shares fuelled from district heating and biomass remained almost unchanged. In this period happened a fuel-switching from fossil fuels to electricity, and from coal and oil to gas.

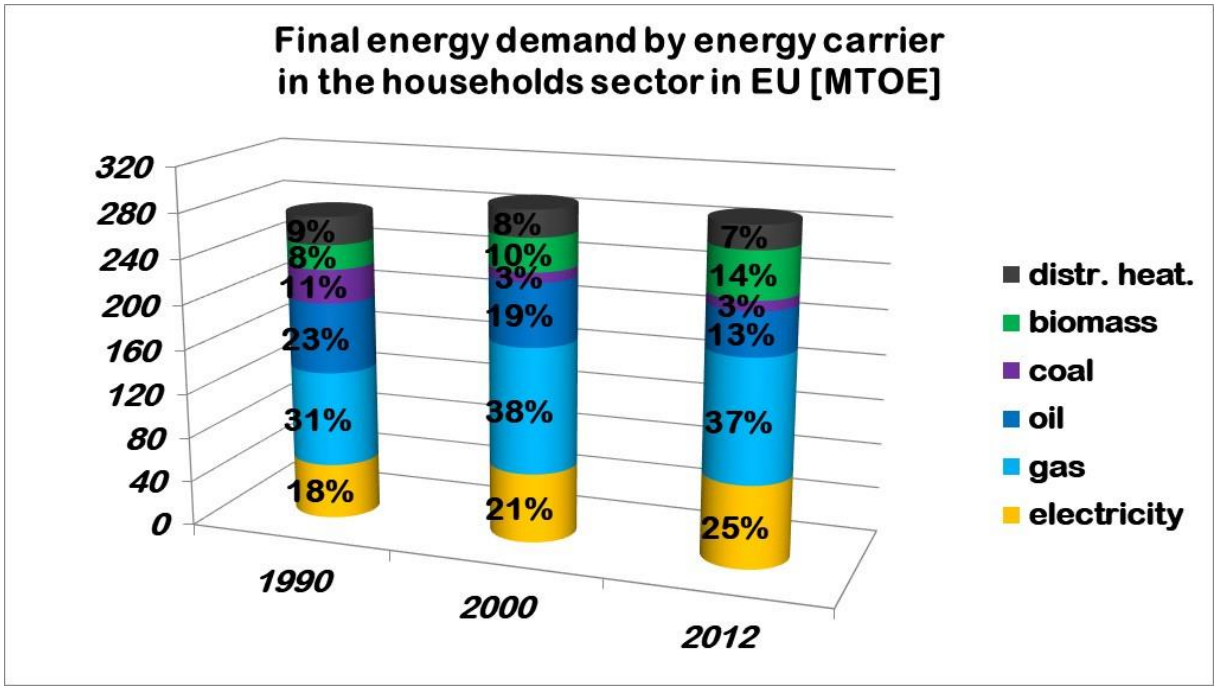

Figure 4: Final energy demand by energy carrier in the households sector in EU. Source [8]

The split among energy carriers of the overall final energy demand, Figure 5, shows that in the services sector the electricity is the main energy carrier, and the gas is the sequent. Both are increased from 1990. During the 1990-2012 period the end-uses shares fuelled from district heating and biomass remained almost unchanged. In this period happened a fuel-switching from fossil fuels to electricity and from coal and oil to gas.

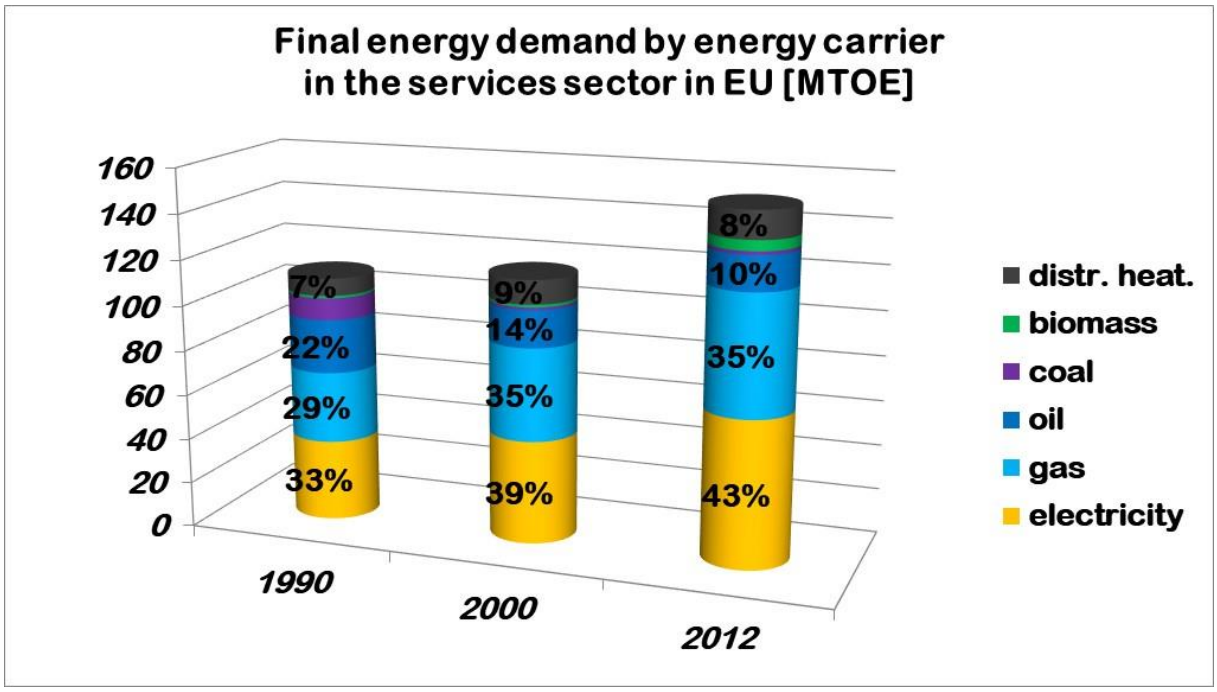

Figure 5: Final energy demand by energy carrier in the services sector in EU. Source [8]

2 – Energy use in the households sector in EU-28

The households sector analysis has been carried out taking in account both the demand side and the supply side. The combination of Eurostat data and Odyssee data shows that the heating is the main energy end-use. The complementary share is split among Domestic Hot Water (DHW) production, cooking, illumination and appliances. During the 2000-2012 period the overall final energy demand remained almost unchanged. In this period the heating need decreased while the illumination and appliances needs increased, as shown in Figure 6.

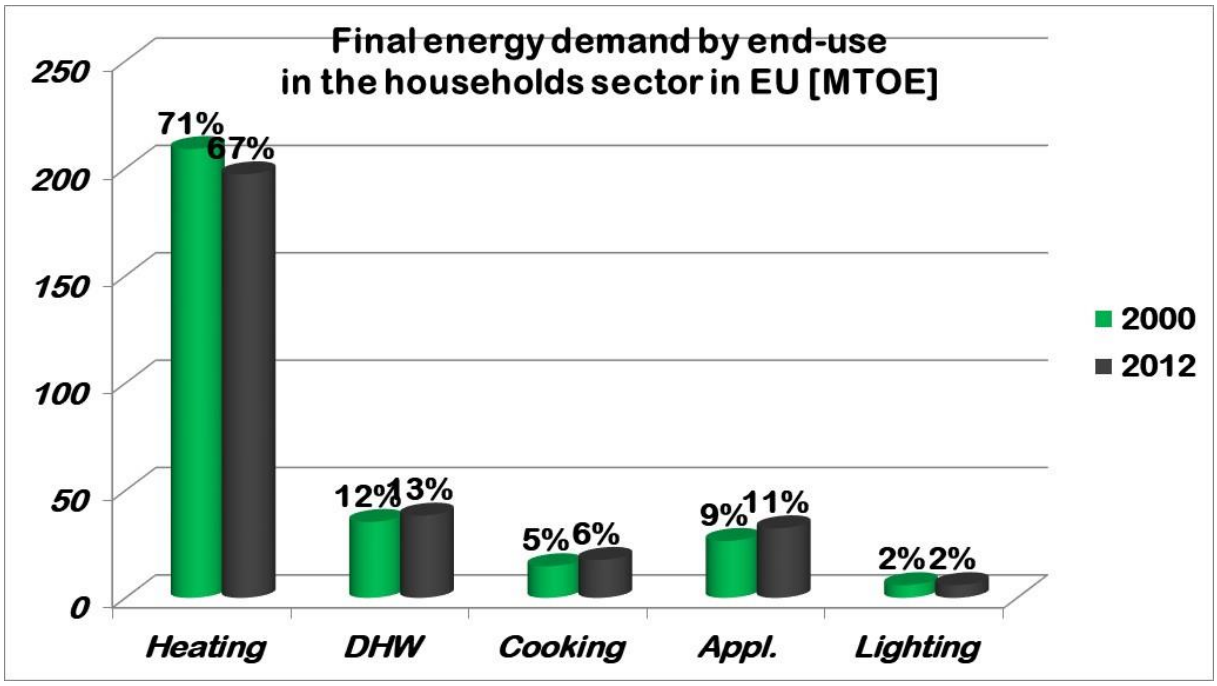

Figure 6: Final energy demand by end-use in the households sector in EU. Source [7] [8]

According to Odyssee data, during the 2000-2012 period the average EU annual growth of the households sector final energy demand has been equal to 1,8%. The energy savings in this sector, cumulated from 1990 to 2012, are equal to 110 MTOE. They are due to the energy efficiency increase and to the users behaviour awareness, as a consequence of the energy costs rise.

During the 2000-2012 period the overall energy consumption amount remained almost unchanged. The energy efficiency increase has been compensated from the final energy demand increase, due to some factors: urban expansions; rise of the flats average area (in East Europe countries); installation of air-conditioning devices (in Mediterranean Europe countries); widespread of appliances.

2.1 – Electricity end-uses in the households sector

In 2012 the appliances are the main share of electric final energy demand in the households sector. The heating is the sequent share, mostly due to France and Scandinavian countries. The complementary share is split among lighting, DHW production and cooking.

The air conditioning is relevant only in Malta, Cyprus, Bulgaria, Italy, Spain, Slovenia, Greece and Portugal (about 10% of the overall electricity consumption).

During the 1998-2008 period the average EU annual growth rate of electric final energy demand due to lighting and appliances has been equal to 1,2%/year. The lighting represents about 15% and the appliances about 85%. In 2012 the market share of Class A or higher appliances has been beyond 90%. In 1998 the same market share was 10%. The energy savings consequent to Class A widespread are compensated from the increase of average devices number for each flat/dwelling. Similarly, the energy saving consequent to installations of "Compact Fluorescent Lamp" has been compensated from the increase of average lighting points for each flat/dwelling.

In the countries where it is used, the air conditioning presents high growth rates: beyond 30% in Slovenia, during the 2000-2008 period; beyond 45% in Bulgaria, during the same period. The "split" devices are about 95% of the air conditioning devices market, in the sector of cooling capacity less than 14 kW. The average energy efficiency of "split" devices is increased about 30% from 2002 to 2009.

The surveys presented from Odyssee are in agreement with those presented from Joint Research Centre (JRC) [9], related to 2009. The surveys show that the electric final energy demand in the households sector (about 820 TWh) is almost equal to that one in the services sector (about 867 TWh). The split of the electric final energy demand by sectors and by end-uses indicates that the main share are the appliances, not the air conditioning, as shown in Figure 7 and Figure 8.

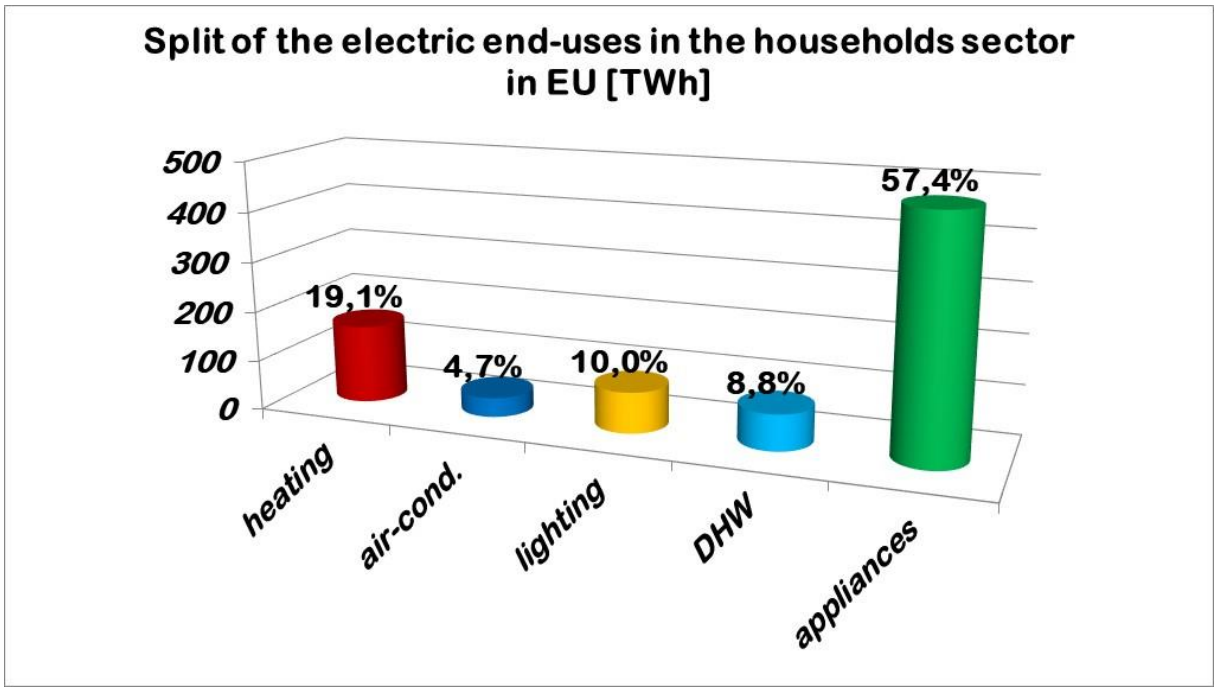

Figure 7: Split of the electric end-uses in the households sector in EU. Source [9]

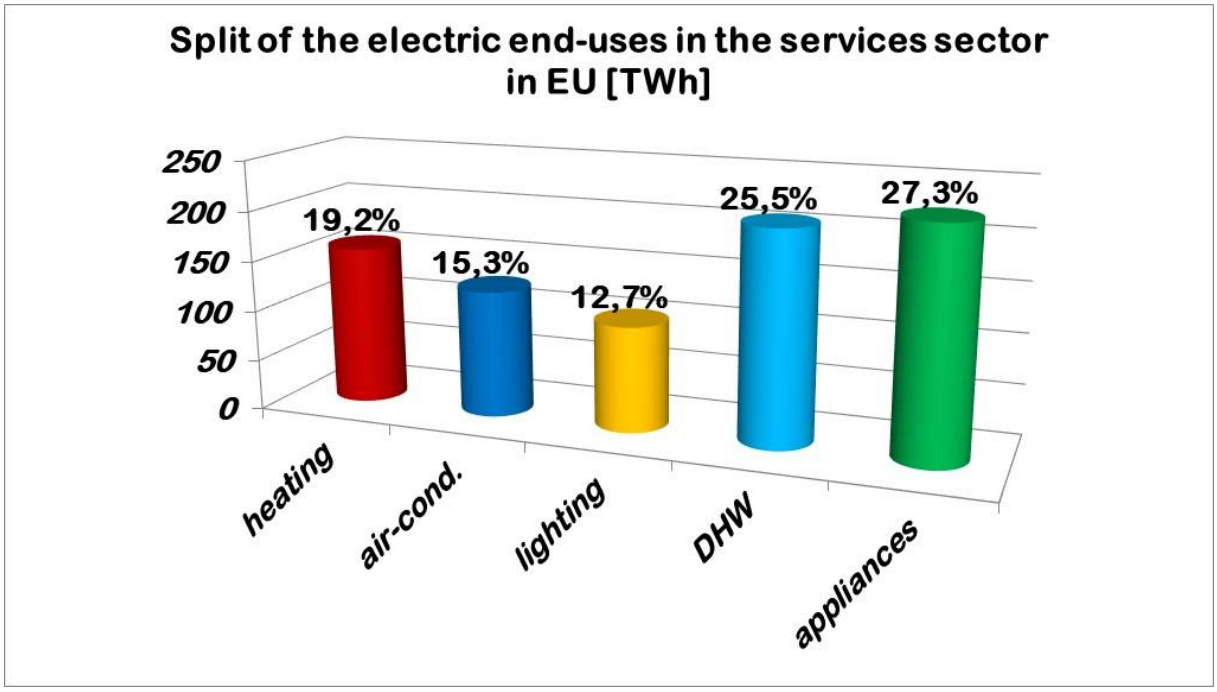

Figure 8: Split of the electric end-uses in the services sector in EU. Source [9]

From the combination among Eurostat, Odyssee and JRC data it results that in the current average EU final energy demand of the buildings sector the fossil fuels consumption for heating is prevalent, and the electricity consumption for appliances is relevant. During the

1990-2012 period this configuration remained almost unchanged on the demand side. In the same period the shares of fossil fuels have been changed on the supply side. The gas share increased, whilst the coal and oil shares decreased. In general, the heating trend shrinks and the appliances trend growths.

During the 2004-2013 period the RES growth rate has been equal to 7,5%/year, related to the overall final energy demand. During the 2000-2012 period in the buildings sector the electrification average growth rate has been equal to 2,6%/year, related to the overall final energy demand, higher in the services sector and lower in the households sector.

3 – Energy prices

In a worldwide perspective, the Figure 9, based on British Petroleum data [10], shows the "financial crisis 2008-2012" effect on the fossil fuels prices in the global market. This effect inverted the growth trend started at the beginning of the XXI century, after a stability decade. During the crisis, the oil (Brent index) has been less stable than the gas and the coal. Starting from 2010 the growth trend is again lining up to the one before the crisis.

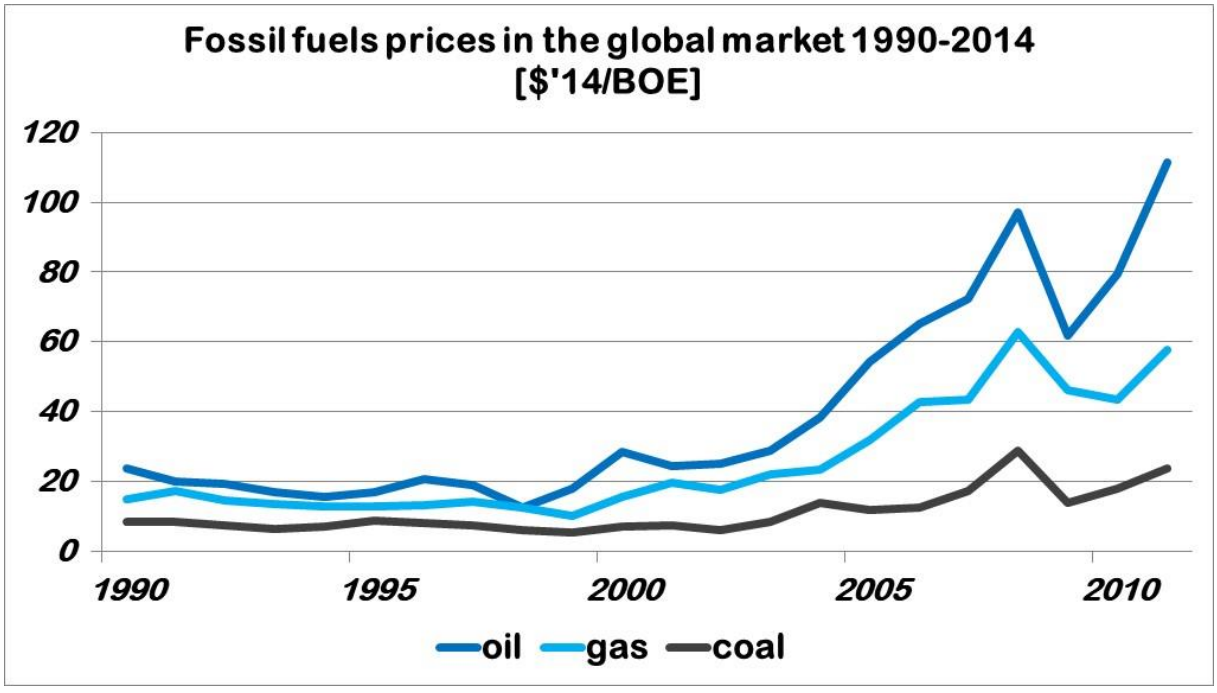

Figure 9: Fossil fuels prices in the global market 1990-2014. Source [10]

The fossil fuels prices in the global market affect the energy costs, both in the primary energy carriers consumption and in the secondary energy carriers production. At EU level the effects of the global market during the crisis have been deeper for the gas in comparison to the electricity, as shown in Figure 10 and Figure 11. The gas price higher sensitivity is mainly due to the EU energy dependence, which in 2009 was beyond 60% of the gross inland consumption. The electricity price lower sensitivity is mainly due to the power sector mix configuration: in 2010 the thermoelectrical share was about 50%, whilst the nuclear share 30% and the RES share 20%. Furthermore, the thermoelectrical production is fuelled for over half from coal, the more stable fossil source, and marginally from oil, the less stable fossil source.

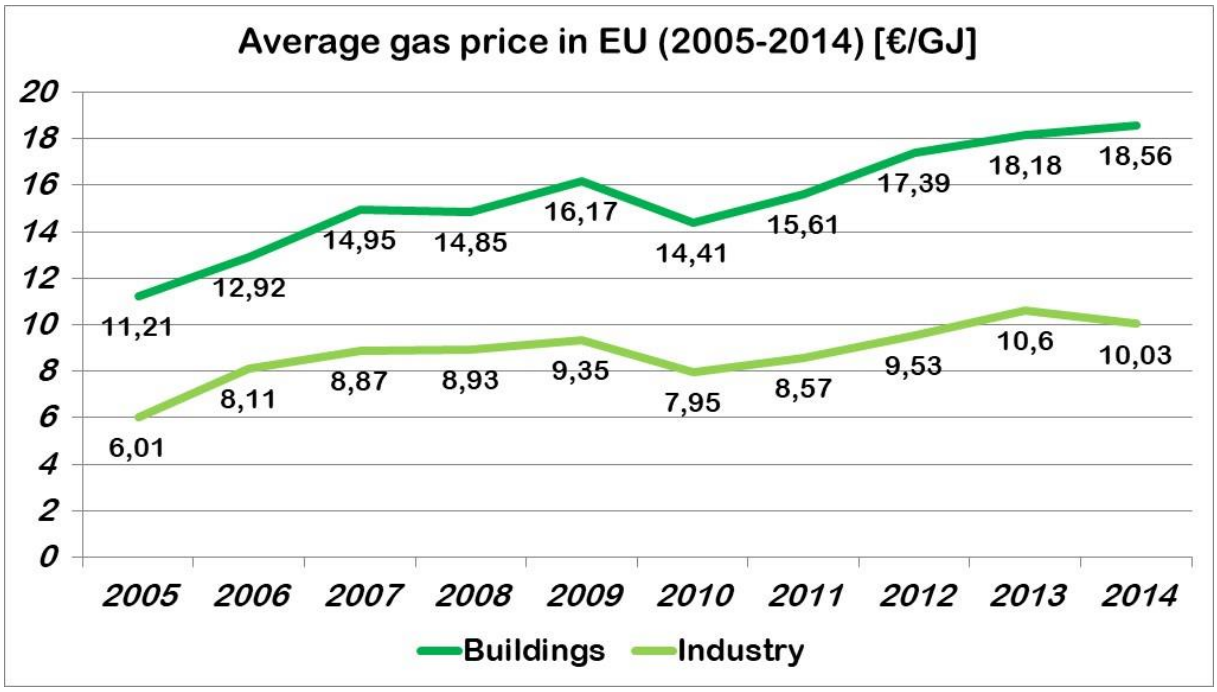

Figure 10: Average gas price in EU (2005-2014). Source [7]

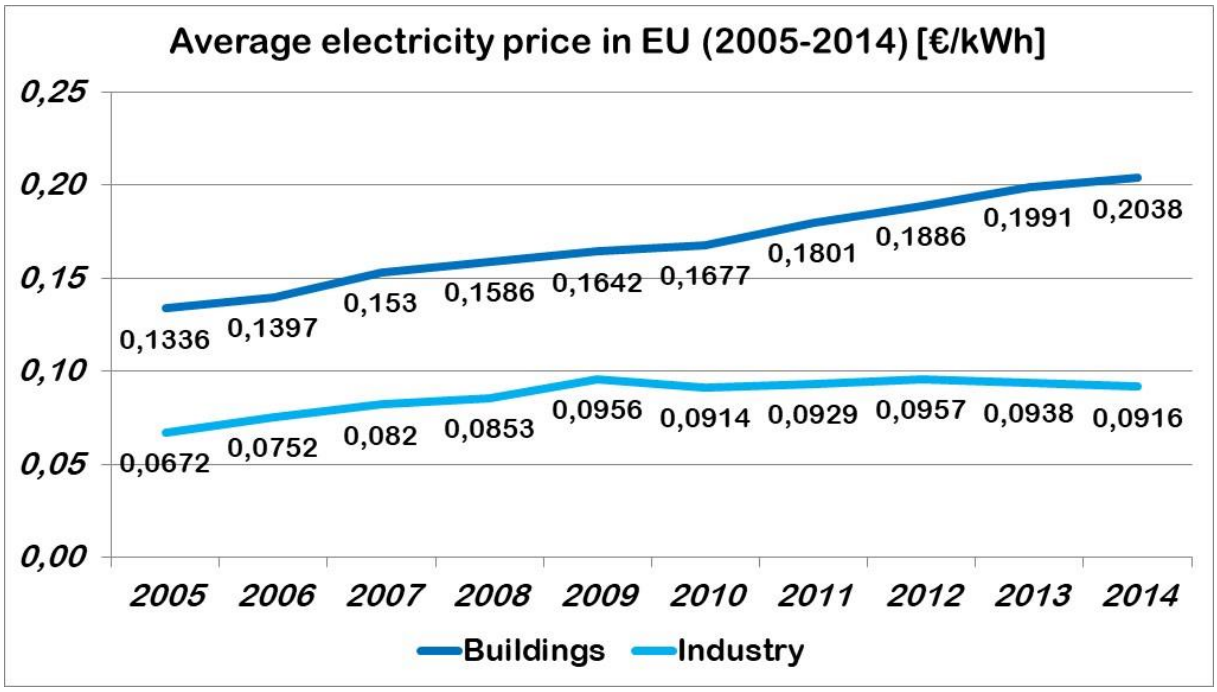

Figure 11: Average electricity price in EU (2005-2014). Source [7]

4 – "Energy Roadmap 2050"

The EU is committed to cut its GHG emissions in 2050 of 80-95% in comparison to 1990. The overall strategy is presented in the European Commission Communication "Roadmap for moving to a competitive low-carbon economy in 2050" [11]. The effects and the implications for the energy sector are analysed in the European Commission Communication "Energy Roadmap 2050" [12]. The analysis is carried out under the condition of ensure the energy supply security and the competitiveness. The measures currently implemented in order to achieve the "20-20-20" targets are ambitious but not enough to decarbonize the EU economy, because they allow in 2050 a 40% GHG emissions cut in comparison to 1990. The investments in the energy sector need time for give results. The "Energy Roadmap 2050" document explores different decarbonization scenarios of the EU energy sector, as support to the measures that should be implemented and to the medium and long term investments.

The "Impact Assessment" document [13], published as a complement of the "Energy Roadmap 2050" document, describes seven different configuration scenarios of the EU energy sector, developed through PRIMES model. Five scenarios are developed starting from

the same demographic and macroeconomic (sectorial) bases, that foresight a transition from the current phase of high operational costs to a future phase of high investment costs. They are diversified from each other for the different combination of the decarbonization strategies.

1) Reference Scenario: the scenario is based on the current trends and on the long-term economic growth foresights. It takes in account the EU energy-policy implemented until 2010, comprising the "20-20-20" strategy;

2) Current Policy Initiatives: the scenario is based on the Reference Scenario widening, in order to take in account the proposed or adopted strategies complementary to the "20-20-20" strategy and beyond the 2020;

3) Energy Efficiency Scenario: the scenario is based on a deep application of the energy efficiency strategies in all the energy sectors, and on a strong reduction of the primary energy consumption;

4) Diversified Supply Technologies: the scenario is based on the hypothesis that the competition among energy sources be driven through market rules, without support measures for the energy efficiency and for the RES;

5) High RES: the scenario is based on the hypothesis of a high RES penetration in all energy sectors. In the power sector, the installed capacity should reach 1.900 GW (eight time than currently);

6) Delayed CCS: the scenario is based on the hypothesis of limited CCS implementation, due to transport and storage problems, and of widespread nuclear use;

7) Low Nuclear: the scenario is based on the hypothesis of limited nuclear use, due to risk perception and waste management problems, and of widespread CCS implementation.

The final energy demand remains almost unchanged in the Reference Scenario and in the Current Policy Initiatives scenario, and strongly falls in the decarbonization scenarios, as shown in Figure 12.

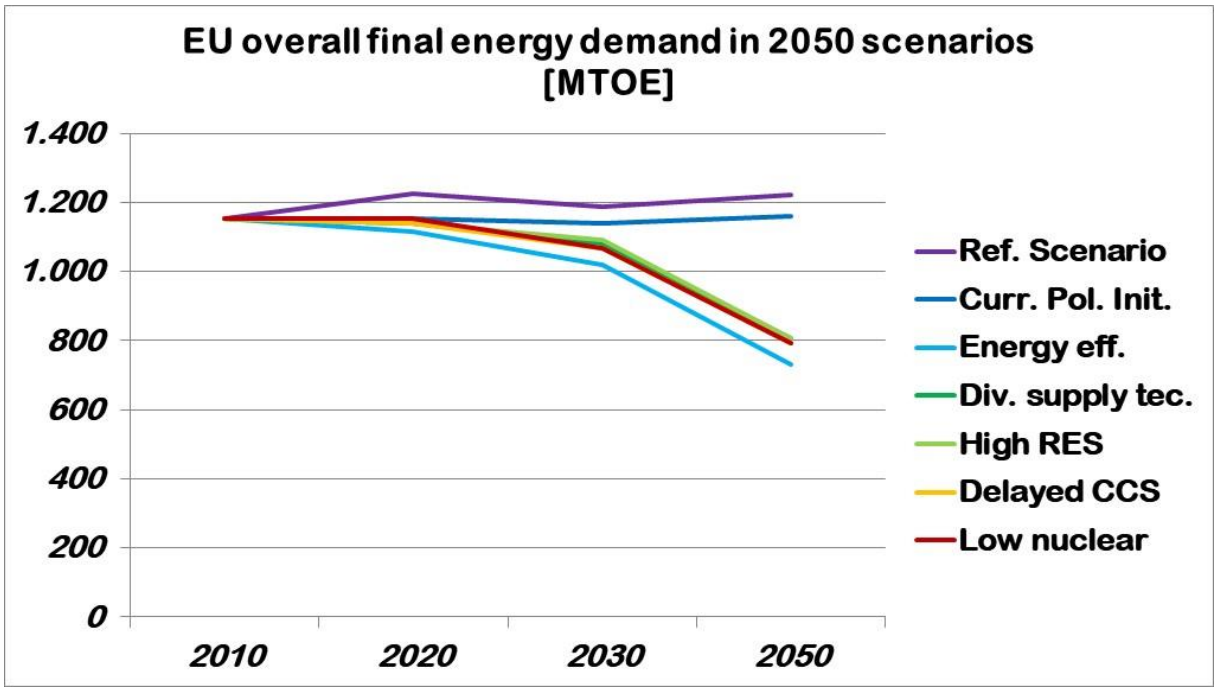

Figure 12: EU overall final energy demand in 2050 scenarios. Source [13]

The Energy Efficiency scenario foresights a 14% decrease in 2030 and a 40% decrease in 2050, in comparison to the Reference Scenario. In comparison to the same scenario, the decarbonization scenarios foresight at least a 8% decrease in 2030 and at least a 34% decrease in 2050. In these scenarios, the electricity becomes the main energy carrier that fuels the final energy demand. The achievement of the energy sector decarbonization is function of the power sector decarbonization. In the Energy Efficiency scenario the final energy demand reduction in the households and services sectors is respectively – 47% and – 44% (overall – 36%), as shown in Figure 13.

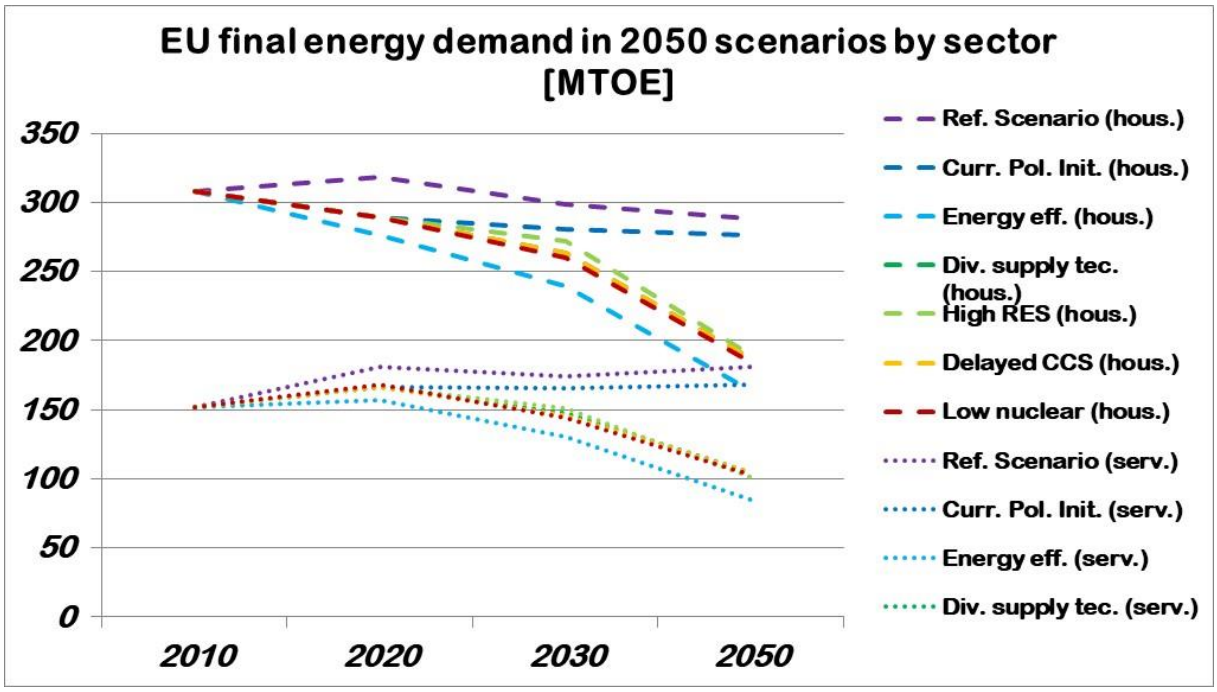

Figure 13: EU final energy demand in 2050 scenarios by sector. Source [13]

In comparison to the Reference Scenario, the Energy Efficiency scenario foresights an overall final energy demand reduction of 20% in 2030 and 43% in 2050 in the households sector, and of 25% in 2030 and 53% in 2050 in the services sector.

The "Impact Assessment" document indicates that the decarbonization achievement needs a strong drop of the EU economy energy intensity and carbon intensity. The first parameter represents the energy consumed to produce one unity of Gross Domestic Product (GDP), and the second parameter represents the GHG emitted to produce one unity of GDP. The drop should be reached through RES, nuclear and CCS. In comparison to 1990 the decarbonization scenarios foresight in 2050 an energy intensity drop ranging from 73% to 76%, and a carbon intensity drop ranging from 76% to 78%.

The supply side analysis shows that the scenarios are strongly differentiated among them for the fuel-switching deepness from oil and gas to electricity and RES. In Figure 14 are illustrated the minimum and maximum levels foreseen in 2030 and in 2050 for each energy carrier.

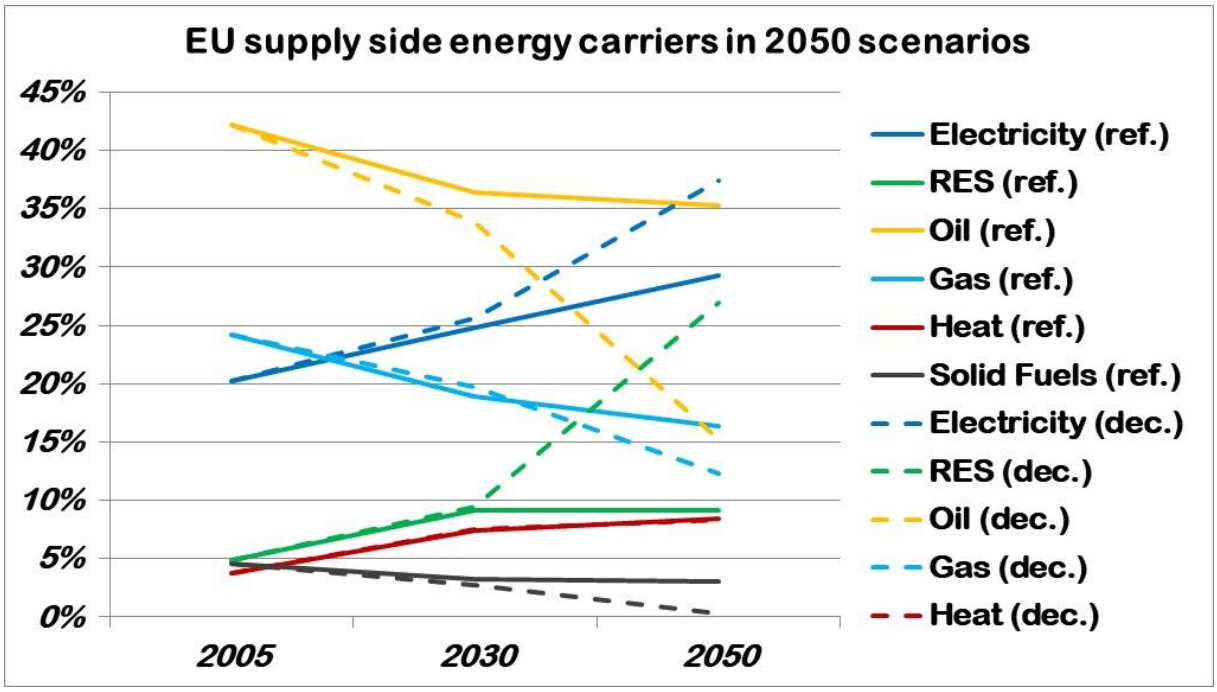

Figure 14: EU supply side energy carriers in 2050 scenarios. Source [13]

In the Reference Scenario the oil drops 16-17% in 2050 in comparison to 2005, and the gas drops 31-33% in comparison to the same year. In this scenario the fossil fuels continue to play a primary role, fuelling over half of the overall final energy demand, whilst the electrification and the RES penetration growth at low rate. In 2050 the electricity growth is 44-46% in comparison to 2005, and the RES growth is 84-92% in comparison to the same year. In the decarbonization scenarios the oil drops 63-65% in 2050 in comparison to 2005, and the gas drops 48-51% in comparison to the same year. In these scenarios the fossil fuels go to play a secondary role, fuelling less than one third of the overall final energy demand, whilst the electrification and the RES penetration growth at high rate. In 2050 the electricity growth is 72-92% in comparison to 2005, and the RES growth is 386-512% in comparison to the same year.

4.1 – RES in "Energy Roadmap 2050"

The RES play a primary role in Energy Roadmap 2050, representing one of the four decarbonization strategies. The RES penetration is relevant in all scenarios.

The overall final energy demand fuelled from RES is different among scenarios, as shown in Figure 15. In 2050 the RES reach a 75,2% share in the "High RES" scenario, and a 55% share in the others decarbonization scenarios.

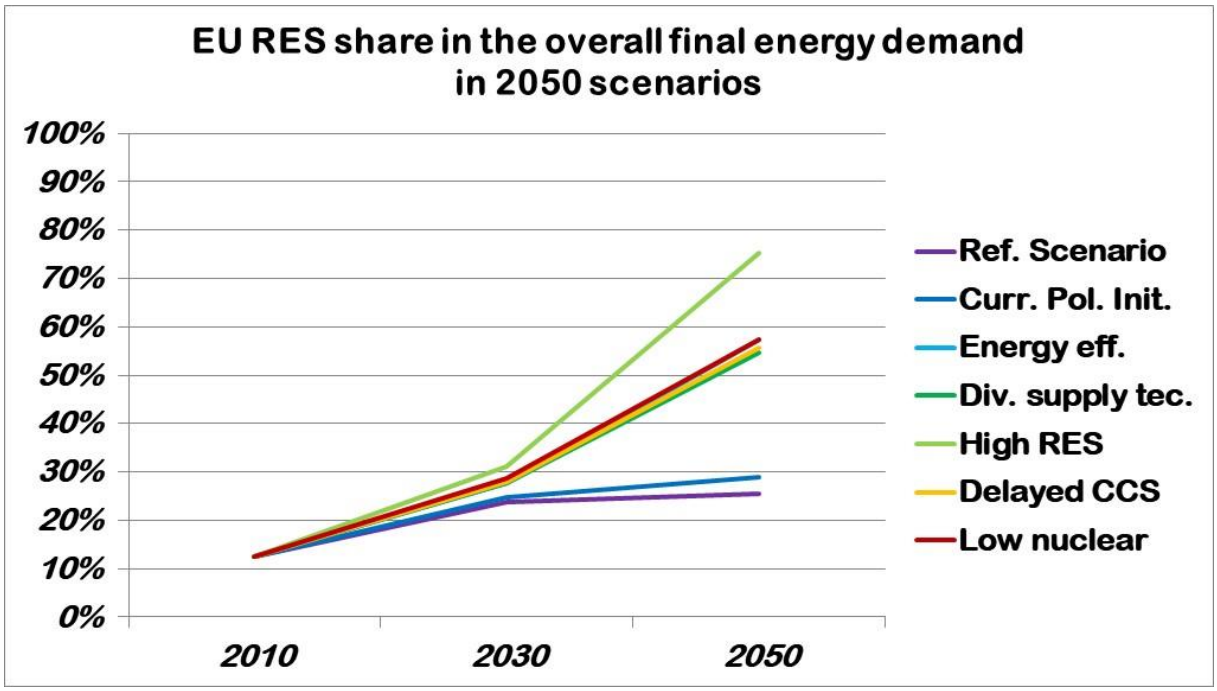

Figure 15: EU RES share in the overall final energy demand in 2050 scenarios. Source [13]

Regarding the heating/cooling final energy demand, the RES fuelled share, both from distributed generation and from district heating/cooling, should increase from the 20% in 2020 to 25% in 2050 in the Reference Scenario, to 55% in 2050 in the "High RES" scenario and to 45% in 2050 in the others decarbonization scenarios.

4.2 – Electric and thermal final energy demand in "Energy Roadmap 2050"

The thermal final energy demand in the households and services sectors should decrease. The overall final energy demand increase is due to the industry sector, as shown in Figure 16.

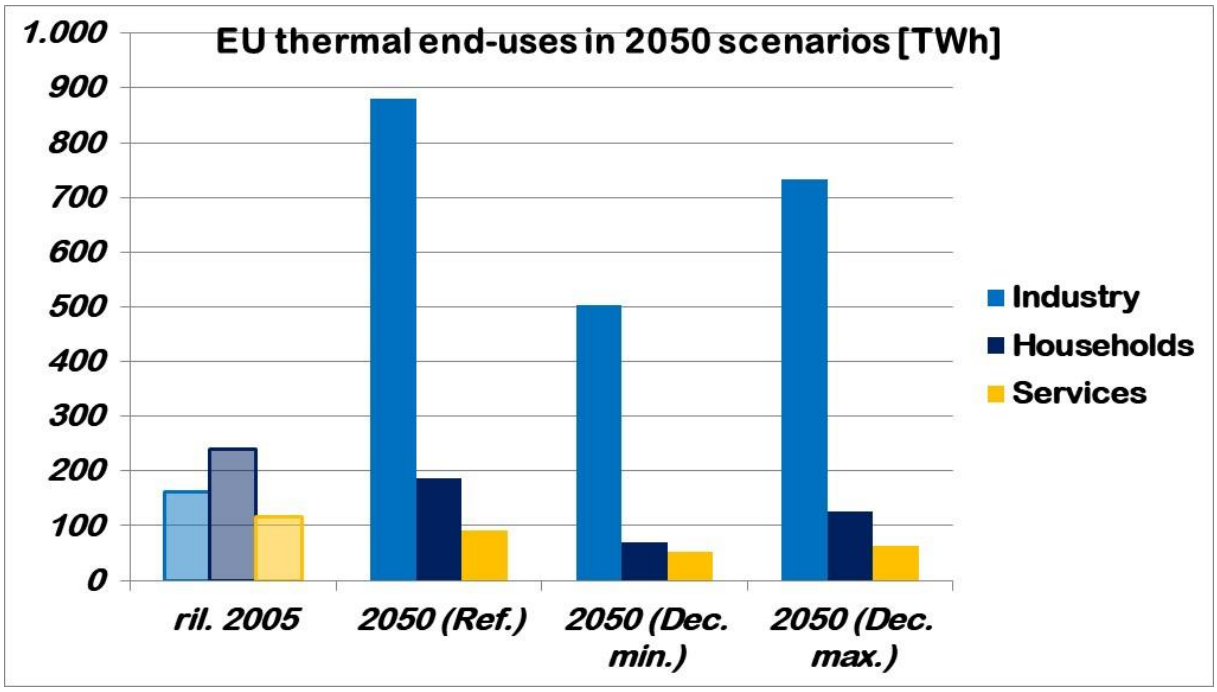

Figure 16: EU thermal end-uses in 2050 scenarios. Source [13]

During the 2005-2050 period the electric final energy demand should increase in all scenarios and in all sectors, except the services sector. This occurrence is more deep in the Reference Scenario, and less deep in the "Energy Efficiency" scenario, as shown in Figure 17.

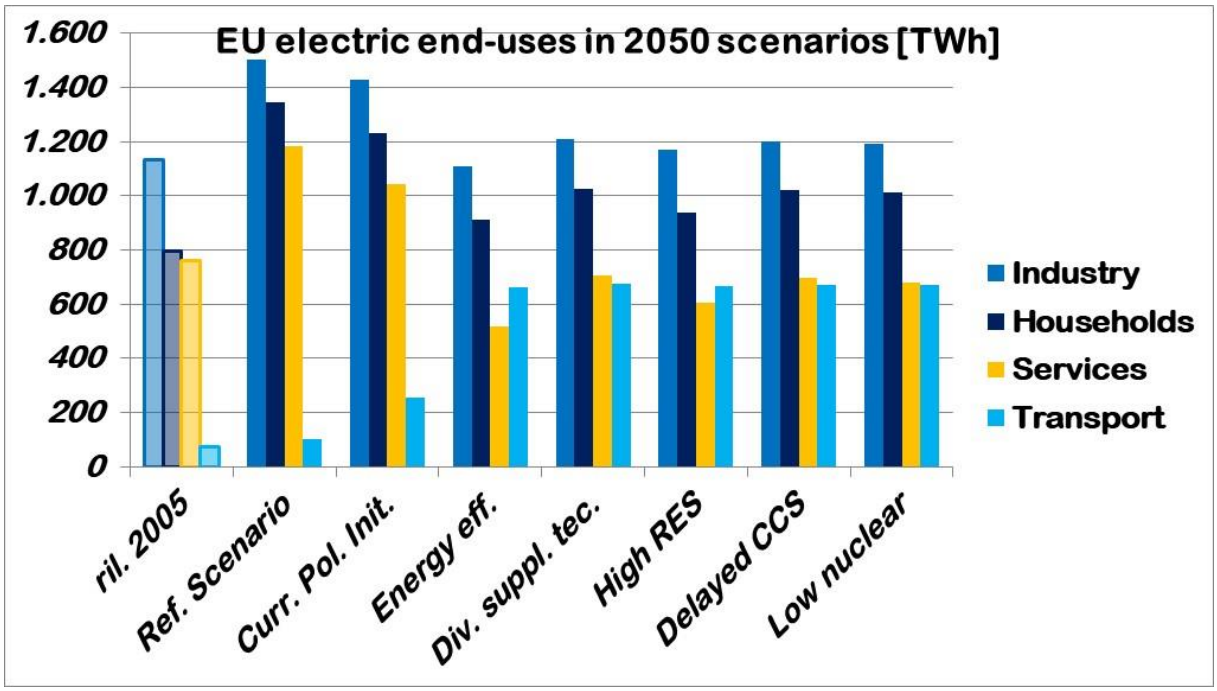

Figure 17: EU electric end-uses in 2050 scenarios. Source [13]

The final energy demand increase in the buildings sector is due to the fuel-switching from fossil fuels to electricity in the heating plants, and from the widespread of the appliances end-use. In the households sector prevails the final energy demand increase, whilst in the services sector prevails the energy efficiency increase.

Conclusions

The carried-out analysis shows that, from a macrosectorial and demand side point of view, during the 2000-2010 period the final energy demand configuration in the EU remained almost unchanged. Furthermore, from a supply side point of view, it shows that, during the same period, a fuel-switching from oil to coal and gas happened, and an end-uses electrification happened. Instead the RES penetration progressed at low growth rate.

The EU is committed to cut its GHG emissions in 2050 of 80-95% in comparison to 1990. The currently implemented measures, aimed to achieve the "20-20-20" targets, are ambitious but not enough to reach the EU energy sector decarbonization, because in 2050 they allow a 40% GHG emissions cut in comparison to 1990. As foresight in the "Impact Assessment" document, developed to explain the "Energy Roadmap 2050" strategy, it is necessary a deep modification of the EU energy sector configuration, pointing to: energy efficiency, RES, nuclear, CCS. This deep modification directly affects the final energy demand: the overall absolute value should decrease, and the electricity and the RES should become the main supply energy carriers. The final energy demand reduction is, together with the fuel-switching from fossil fuels to RES, one of the main cards available to the EU to influence the global energy market and to ensure the supply security in the medium and long term. In the households and services sectors a thermal final energy demand decrease and an electric final energy demand increase are foreseen. The progressive end-uses electrification is aligned with the growth trend of electric end-uses, that is appliances and air-conditioning, mostly in the Mediterranean Europe. Also, it is aligned with the aim of exceed beyond the 20% in 2020 the RES share in gross final energy consumption, until to reach a 50% share in

2050. This aim is function of an electrical-RES widespread, mostly due to photovoltaics and onshore/offshore wind capacity installations.

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