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H2020 REALVALUE

D6.1 ROLE OF SETS IN EVOLVING EUROPEAN ENERGY SYSTEMS

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List of Abbreviations

Abbreviation	Definition
BRP	balancing responsible party
CBA	cost benefit analyses
CCS	carbon capture and storage
CHP	combined heat and power
COP	coefficient of performance
DH	district heat
EC	European Commission
EDSO4SG	European Distribution Systems Operators for Smart Grids
EEGI	European Electricity Grid Initiative
EHPA	European Heat Pump Association
ENTSO-E	European Network of Transmission System Operators for Electricity
ERGEG	European Regulators Group for Electricity and Gas
ETS	Emissions Trading System
EUA	Emission Unit Allowance
GHG	green house gas
HP	heat pump
NREAP	National Renewable Energy Action Plan
PPP	purchasing power parity
RES	renewable energy sources
SET Plan	Strategic Energy Technology Plan
SETS	smart electric thermal storage

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1. INTRODUCTION

The European Union promotes active and ambitious climate and energy policy with an emphasis on low carbon energy technologies and especially renewable energy sources. The aim is also to strengthen the competitiveness of the European economy by ensuring affordable energy to all consumers, and at the same time creating growth and new jobs. Improving security of energy supply by reducing dependence on imported energy is the third pillar at the heart of the energy policy. In addition, the long-term goal is also to achieve a sustainable energy system. Sustainability questions are mainly related to greenhouse gases and climate change.

A vigorously pursued course of action is to increase the production of renewable energy sources, for example hydro-, wave-, tide-, solar, wind- and biomass-based power generation. Of these, solar and wind power currently receive very strong attention, especially because of high capacity growths. However, the production of wind and solar power is intermittent, putting a strain on the European power systems because matching supply and demand becomes increasingly more complicated.

Smart electrical thermal storage, SETS, is a controllable local small-scale energy storage serving as a demand side management tool, and, thus, helping in the integration of variable electricity generation in the power system. SETS has minimal impact on consumer well-being, with no need to change consumer practices. However, some educational gaps remain at present, and an efficient deployment of SETS might require training.

Driving forces in the electricity markets

In what follows, three main drivers changing the market, namely tackling climate change, enhancing energy security through energy self-sufficiency and enhancement of smart grids are discussed in detail from the European perspective.

EU climate and energy policy

The climate target of limiting the maximum increase in global temperature to 2°Celcius, preferably just 1.5° Celsius, is the cornerstone of the European Union's climate policy. In order to tackle climate change, the EU has set itself both long and shorter term goals for its own greenhouse gas (GHG) emissions.

The low-carbon economy roadmap (EC, 2011a) marks out a pathway to achieve at least an 80% reduction of GHG emissions in 2050 compared to 1990. All sectors of the economy need to contribute to the change, as indicated in Figure 1.

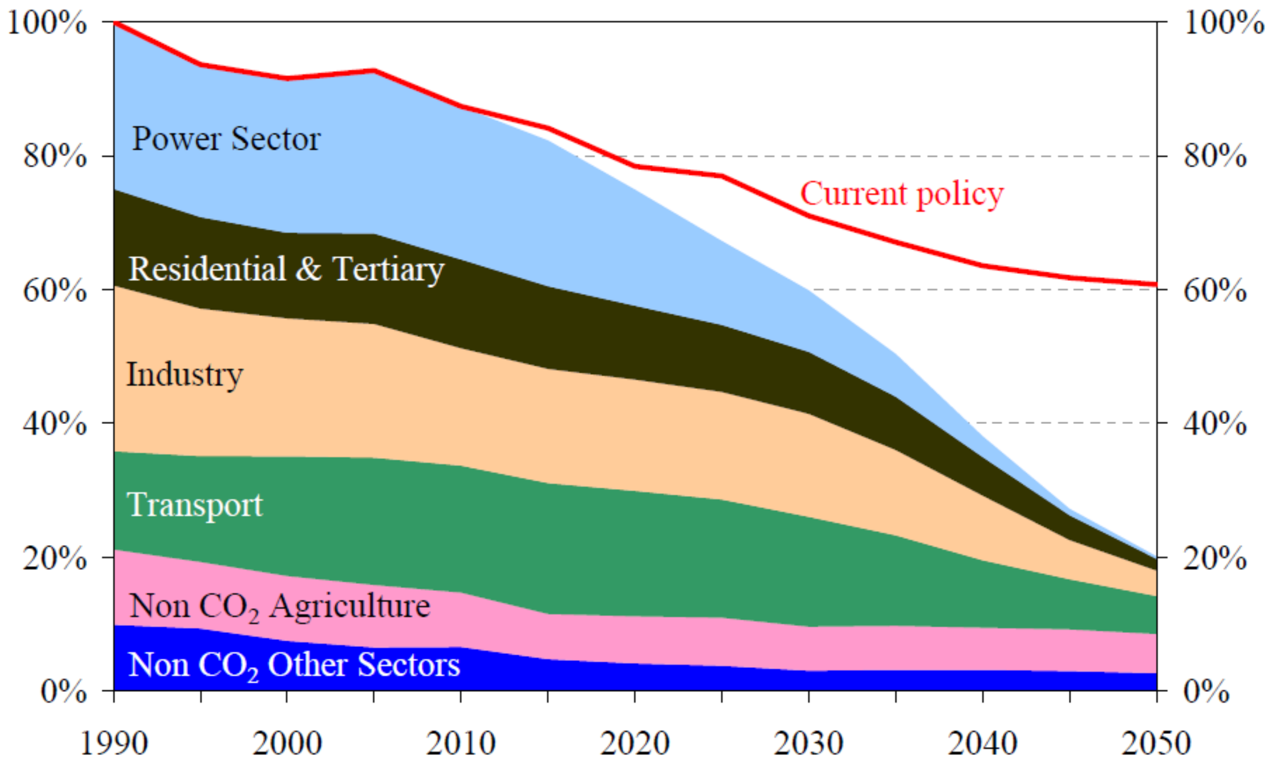

Figure 1: GHG emissions in the EU, in 1990 100%. (EC, 2011a).

The RealValue project focusses on two sectors of the economy: buildings and power generation. The roadmap seeks a very ambitious 90% GHG emissions reduction in the building sector – covering both housing and services (EC, 2011a). To this end, new low energy or passive housing construction technologies and energy efficiency renovations in existing building stock are relied upon. Fossil energy sources for space heating are to be replaced by electricity, district heat and fuels from renewable sources.

The power sector is anticipated to cut GHG emissions almost totally until 2050. This will require a high share of renewable electricity generation from sources such as wind, solar, biomass, and hydro. Other important alternatives are nuclear power and carbon capture and storage (CCS) technology for fossil fuels.

In addition to long term targets, the European Commission has also set shorter term subordinate targets. For example, the "Energy and Climate Package" sets these goals for the year 2020 (EC, 2009a):

- 20% cut in GHG emissions (from 1990 level)
- 20% of energy from renewable sources
- 20% improvement in energy efficiency
- 10% share of renewable energy in the transport sector

The Emissions Trading System (ETS) covers some 45% of EU's emissions. More than 11,000 entities from EU and EFTA states from the power and heat generation sector and from the manufacturing sector are affected by this directive[1] (EC, 2009b). The ETS system is designed as a "cap and trade" principle. It sets a limit (cap) on the maximum GHG emissions that can be emitted by the companies involved. In addition, the ETS auctions off an amount of emission unit allowances on the order of the cap. Currently the cap is reduced by 1.74% each year.

On an annual basis, participants in the ETS have to surrender emission unit allowances (EUA) to match their GHG emissions. To some degree, EUAs are given free of charge to selected entities, e.g. to mitigate carbon leakage from the EU to other countries. The amount of EUAs a company possesses needs to cover all GHG emissions of the company in a given year or otherwise heavy fines need to be paid. Superfluous EUAs can either be sold on the market or banked.

The emissions which are not covered in the ETS system are dealt with in the national emission reduction targets known as the effort sharing decision (EC, 2009c). This covers the remaining 55% of GHG emissions in the EU, includes sectors such as housing, agriculture, waste, and transport and sets binding national targets for the year 2020. National targets vary between – 20% and + 20% depending on the wealth of the country.

In addition to the targets for the year 2020, the European Commission has also formulated mid-term targets for the years 2020 through 2030 (EC, 2014a). The 2030 climate and energy framework sets the next milestone towards the low carbon economy. The 2030 targets are:

- At least 40% cuts in GHG emissions are sought (reference year 1990),
- at least 27% share of renewable energy sources in the energy sector, and
- at least 27% improvement in energy efficiency.

In the pursuit of a low carbon economy, new technologies play an essential role. The European Commission relies on several policy instruments to facilitate innovation, research and demonstration of low carbon technologies. Special regard is given to carbon capture and storage (CCS), energy efficiency and renewable energy technologies.

- The European Economic Recovery Program has allocated support to CCS and off-shore wind energy demonstration
- Strategic Energy Technology Plan (SET Plan) has a programme for research, development and demonstration of low carbon technologies.
- The Horizon2020 Research and Innovation programme finances R&D of low carbon technologies

[1] Aviation was also planned to be included early on, but this was postponed because of opposition from other countries.

Energy self-sufficiency

Energy self-sufficiency is one of the main arguments and motivations behind the European energy policy. First one, prices for fossil fuels, mainly oil and gas, have been very volatile over the last 15 years. Second, the domestic production of oil and gas has been declining in the EU (Ruska & Similä, 2011).

The prices of energy depend on the relation of supply to demand. As a consequence of increasing economic prosperity in the developing world, the demand for energy has increased. It is expected to further increase in the future. Fossil energy sources are, however, are limited. Conventional sources of oil and gas are depleting, not just in Europe but in many other production areas. These energy sources need to be replaced by non-conventional sources such as shale oil and gas, tar sands, deep sea or ultra-deep sea oil and gas etc. (IEA, 2014). Non-conventional sources are harder to reach, to explore and to exploit. As a consequence, the marginal cost of production will increase over time.

IEA's World Energy Outlook provides for three future projections for each of the three fossil fuels: coal, oil and gas prices. Four different scenarios are presented in the publication. "Current policies" builds the baseline scenario. "New policies scenario", which is referred to in **Figure** 2 below, assumes that agreed energy and climate policy actions are implemented, while the "450 Scenario" assumes strict policy actions with the aim of limiting the global temperature rise to below 2°C. A "Low Oil Price Scenario" assumes lower growth rates for the global economy, and expects a more rapid shift from fossil energy sources to low carbon technologies.

Despite the current significant reduction in the oil price in 2015 and early 2016, both oil and gas prices are expected to rise continuously from their present level to 2035, whereas coal prices are expected to stay fairly stable after 2020. The development of the coal price mainly depends on future climate polices. It can be replaced by natural gas in power generation. With rising CO_2 prices, the differences in the carbon intensity of coal compared to gas, we expect natural gas to replace coal. This should dampen the demand for coal, and, thus, put the coal price under pressure.

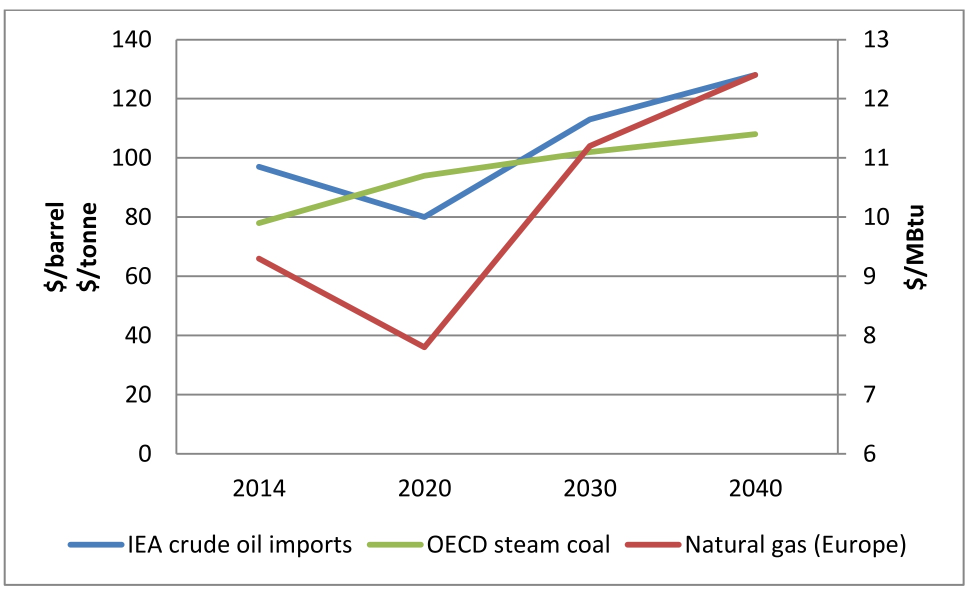

Figure 2: Future projections for fossil energy prices, New Policies Scenario, in terms of real 2014 prices (IEA, 2015).

The European Commission provides future projections regarding the import dependence of primary energy supply in the EU (EC, 2014). Until 2020, energy efficiency gains are expected to reduce final energy demand. At the same time, the European energy system is assumed to partially substitute fossil for renewable energy sources (RES). Altogether, this should overcompensate for the decline in domestic fossil fuel production resulting in a lower import dependence.

After 2035, the import dependence is expected to rise, despite a continuing decrease in fossil fuel consumption, as domestic sources deplete further. The rise is expected to be mainly due to natural gas, whose share is expected to be 9% of primary energy production in 2050 (Figure 3) (EC, 2014b).

The combination of volatile spot prices for crude oil and natural gas and increasing import dependence suggests that the EU has to spend more on fossil fuels in the future than it does presently. According to (EC, 2014b) expenditure is expected to rise 50% from 2010 to 2030 and 80% to 2050 in constant prices (Figure 4).

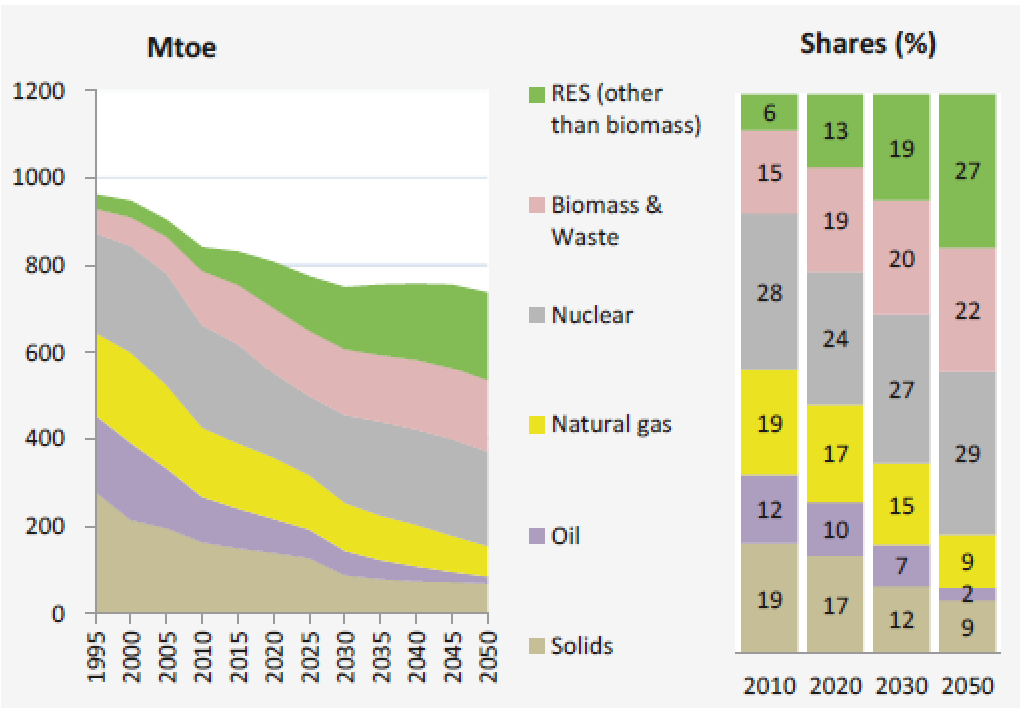

Figure 3: Primary energy production in the EU (EC, 2014b).

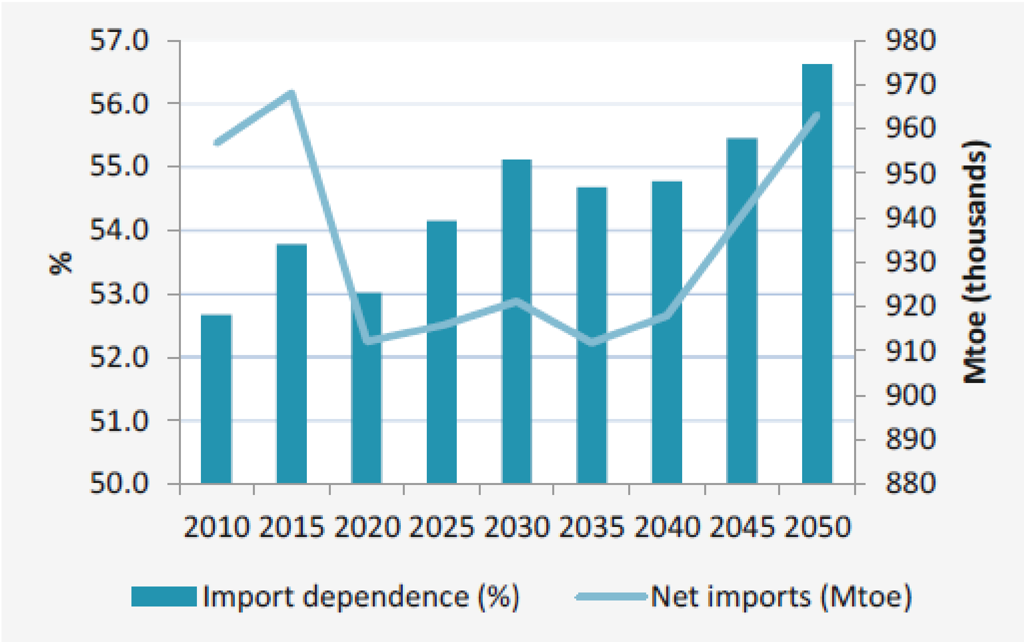

Figure 4: Import dependence of primary energy in the European Union expressed as a share of imported energy content in total primary energy consumption (EC, 2014b).

EU smart grid policy

The challenges of the European electricity grid are fourfold: First, there is a need to renew the aging infrastructure. Second, there is a need to meet growing electricity demand. Third, there is a need to enable a trans-European electricity market, and fourth, there is a need to integrate sustainable electricity generation (ETP, 2006). Several organizations and policies have been established to tackle these challenges in Europe.

European Technology Platform Smart Grids (ETP Smart Grids) is a key forum for discussion and proposing smart grid policy actions as well as technology research and development pathways. It was established in 2005 and has published the strategy paper referred to above. ETP Smart Grids is an independent platform offering guidance to its stakeholders, which include the European Commission as well as legislators, system operators, manufacturers, regulators, and academia. In 2007, the ETP Smart Grids published the Strategic Research Agenda (SRA), which was updated in 2012 and now has a time horizon to 2035 (ETP,2012).

The European Commission has set up the Smart Grid Task Force to receive advice. It consists of five expert groups working on standards, regulations, infrastructure and industrial policy.

One of the European Industrial Initiatives under the Strategic Energy Technology Plans (SET-Plan) is the European Electricity Grid Initiative (EEGI). It has published an EEGI Roadmap 2010-18 and Implementation Plan 2010–12, prepared by ENTSO-E, EDSO4SG and ERGEG, for the innovation and development of the electricity networks (EEGI, 2010).

The EU has set an objective to roll out approximately 200 million smart meters for electricity and 45 million for gas by 2020. 72% of electricity consumers and 40% of gas consumers will have a smart meter by then (EC, 2014c).

What is SETS?

Smart electrical thermal storage (SETS), is a form of electrical heating which has been developed for the household sector. Two types of devices exist: for space heating and for water heating purposes.

The SETS space heater consists of a heat storage core made of high density iron ore tablets. The normal operating temperature is 580°C, but during exceptional heating load a maximum temperature of 700°C can be reached. The iron core is surrounded by thermal insulation. Electrical resistance heating elements are located between the iron bricks. The heat output is controlled with a variable speed heat circulation fan. For water heating purposes, the heat storage medium is water. The input rating varies between 1.1 kW and 3.3 kW, and the maximum storage capacity is between 8 kWh and 23 kWh depending on the size.

The household can control the time and temperature of the heat release. The electronic control technology also allows a remote control for charging the SETS and releasing the heat. Both the space heater and water heater share the same control mechanisms.

Why SETS? Role in the changing energy markets

Increasing levels of intermittent solar and wind generation in the electrical grid stresses the need to deal with changing power input. There is a need for either direct (batteries, etc.) or indirect (pumped hydro, power to gas to power, etc.) electrical storage capacity. This way, excess electricity can be stored for later use for example when renewable energy generation is low, or demand side management (DSM) is needed.

Demand side management can provide short term virtual storage capacity for the electricity grid by adjusting the demand according to the production. Virtual storage capacity refers to a similar functionality as storage without the necessity of technically being a storage. That is, for example, by shifting the demand of a period to a later period, a household can utilise a production period that can offer more favourable prices, for example. This corresponds to the functioning of storage. In households relying on electrical heating, the electricity demand can be decoupled from the heat demand using the SETS device, which acts as a heat storage. It thus provides one way of shifting the electricity consumption from the time of heat demand to the time when excess electricity is available in the grid. In remote control mode, it could be used as a dispersed energy storage by an electricity system or market participant (aggregator, system operator, seller etc.).

There is a seasonal variation in the virtual storage potential that the SETS offer. During high demand for space heating in the winter months, the SETS can be used regularly, whereas during the summer months only hot water is needed. In spring and autumn, the space heaters provide regulating capacity to some degree. By regulating capacities, generally speaking, we mean energy production, generation, or storage capacity with a capability to adapt its production or consumption up or down. These capacities can be used as measures so as to manage the supply and demand balance of the electricity system on various timescales. As solar power production is much lower during the winter, SETS mainly provides regulating capacities to mitigate the consequences of wind power production. Therefore, SETS competes against other, regulating offerings already available: hydro (reservoir or pumped), interconnectors, district heating network, regulating generation capacity, etc. The smaller the shares of these existing competing alternatives that are available, and the larger the share of wind, the better the market is for SETS and other new alternatives (e.g. batteries, new pumped hydro, other demand side management solutions).

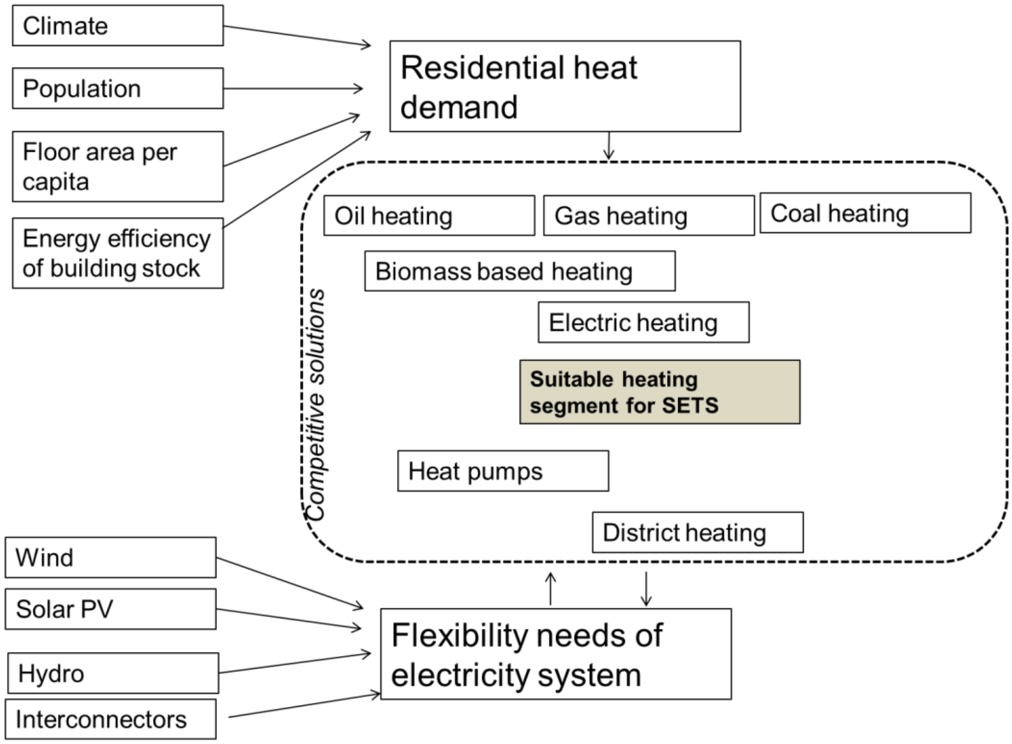

Figure 5. The Role of SETS in the energy system.

Figure 5 illustrates the role of SETS in the energy system. Altogether, the need for flexibility in the electricity system and the (residential) heat demand are expected to be the main determinants for the market potential for SETS. As European countries are very heterogeneous regarding population, climate, electricity supply and markets, as well as other drivers depicted in Figure 5, this report outlines the overall market environment for SETS.

The competitive situation for SETS is multi-dimensional. On the one hand, it competes with functions and technologies providing flexibility to the energy system (e.g. reservoirs or pumped hydro, batteries), and on the other hand, with functionalities and technologies serving residential heat demand (e.g. gas heating, oil heating, energy efficiency measures). We make an effort to explore the driving factors in Europe and discuss their impact on a quantitative basis. As a result, we draw a high-level profile on European countries with regards to their attractiveness for SETS. As this report is more about the high-level initial characterizations of European countries, future deliverables contain more in-depth analysis and especially concerning Germany, Ireland and Latvia. These countries are the main focus countries of the RealValue project.

As controllable thermal storage units, SETS competes against similar existing end-user solutions such as thermal storages in electrically heated houses or houses connected to district heating, as the district heating network is already one of the most cost-efficient ways to regulate power production. On the other hand, SETS could well be added to fossil fuel heated houses as a replacement or as an auxiliary heat source, if the costs are sufficiently low.

In general, SETS can be used to replace any heating source. This property is especially interesting, because the reliance on fossil fuels has to diminish in the long run in order for the EU to reach its climate and sustainability targets. Moreover, SETS can make use of time-differentiated electricity prices either at the wholesale (seller/aggregator) or the end-user level. A prerequisite is to have smart meters or at least a meter that can manage time-of-use measurements. A more demanding source of revenues is from system balancing, frequency services and the capacity markets value stream, but they are not for end-users directly but through aggregators/sellers, and they may usually involve severe national constraints or barriers.

2. SOCIO-ECONOMIC INDICATORS

Energy demand arises from economic activity. According to the International Energy Agency (IEA), energy demand grows by 0.5% for every 1% increase in GDP in the developed countries (IEA, 2014)]. In addition, socio-economic indicators have an impact on energy demand, too. In the following, the presented and expected future population in Europe is highlighted. Afterwards, we present historical and present economic indicators.

Population

Eurostat provides statistical information on population, such as measures regarding fertility, mortality and immigration. Projections for the European population until year 2050 are also available. The EU population is characterized by two developments. First, it is slowly increasing. Secondly, the average age of the population is increasing. Both trends are driven by increased life expectancy and low fertility rates of 1.55 children per female at the EU-level.

In the last 20 years, European annual population growth has been 2.7% on average, with variations between 1.4% and 4.1%. The natural change in population determined by fertility and mortality is very low in the EU, some 0.3% in recent years. There are significant differences between countries; for example, some countries such as Germany and the Baltic States have negative natural crude rates, whereas others like Belgium or the Scandinavian countries have positive crude rates. The crude rate of natural change is the ratio of the natural change during the year (live births minus deaths) to the average population in that year. The value is expressed per 1 000 persons.

A more important determinant is immigration, both between EU member States as well as from abroad. In recent years there has been a migration from EU countries with poor economic perspectives to areas with prospering economies. Germany has gained from this inner European migration at the cost of the Baltic States and the Mediterranean area.

Eurostat also provides future projections for population growth. Figure 6 below reflects the main scenario, with relatively modest migration from outside of the Union (approximately 1 million people annually). In May 2015 the European Commission published “A European Agenda for Migration” as a response to the high migration in 2015 (EC, 2015a). The agenda states that, within the next decade, the EU’s working age population will decline by 17.5 million people. In order to achieve a sustainable welfare system and economic growth, migration is inevitable.

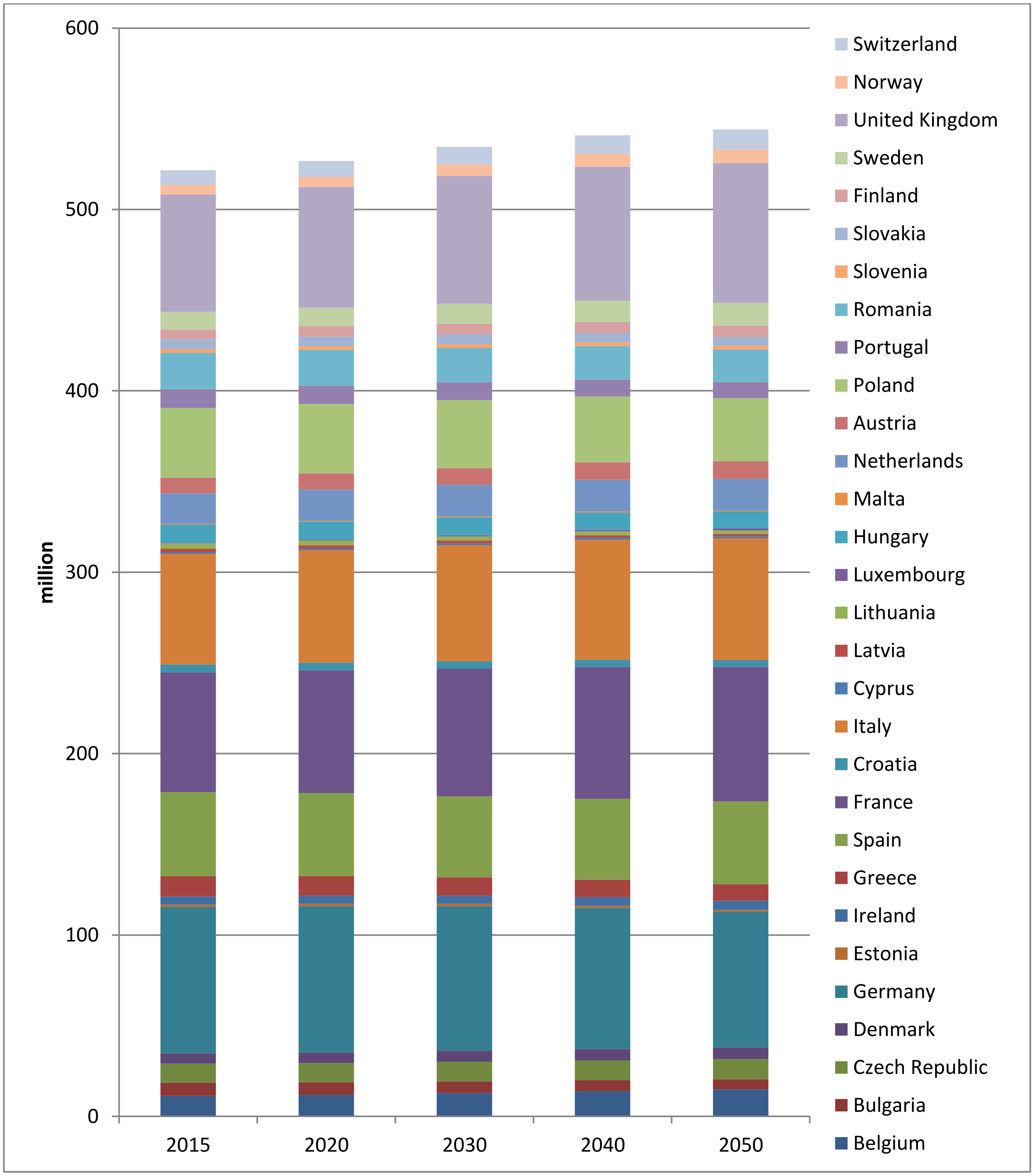

Figure 6: Population projections of the EU, Norway and Switzerland until 2050 (Eurostat, 2015).

Economic indicators

Economic activity is the main driver of energy consumption. As the economy grows, it tends to create more demand for energy services. Income elasticity of energy demand is defined as the ratio between primary energy demand and GDP expressed in terms of purchasing power parity, PPP. Figure 7 shows this indicator for various economic areas. Generally speaking, more advanced economies tend to have larger service sectors compared to less developed economies. Because the service sector generally has a lower energy intensity compared to the industrial sector, this leads to a weaker correlation between economic activity and energy demand.

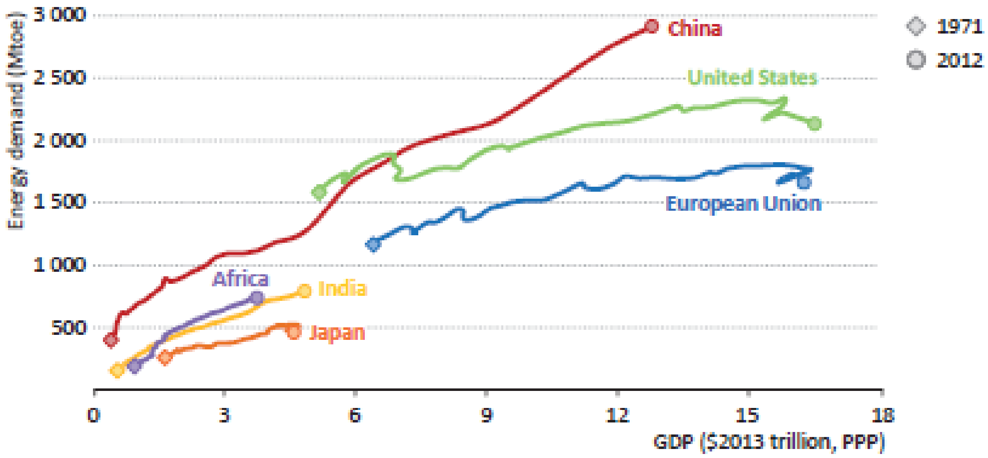

Figure 7: Correlation between economic activity and primary energy demand (IEA, 2014).

According to the IEA, world primary energy demand increased by approximately 0.6% for each percentage point of GDP growth (IEA, 2014), while some advanced economies have demonstrated a decoupling of energy demand for growth: demand is saturated and is gradually declining despite continued growth (Figure 9)

In Europe, the economy has grown on average 2.4% annually between 1995 and 2008. The economic crisis in 2009 has reduced economic output significantly. It took until 2014 for the EU to reach the output level observed 5 years earlier in 2009. However, the impact of the crises has been very heterogeneous across Europe. In 2014, the Mediterranean area and parts of the Balkans, e.g. Croatia, experienced pre-crisis output levels. In Greece, the downward spiral has been extremely severe, reducing GDP by 20% in comparison to the level before the crisis. In Germany, the Baltic States and some other countries such as Sweden, Ireland and Poland, the economy has been growing by 10–25% with respect to pre-crises levels.

There are significant variations between countries in economic output per capita. Luxembourg, Norway and Switzerland have a GDP of more than €50 000 per capita expressed in the constant prices of 2010. In comparison, countries on the lower end of distribution of GDP per capita, such as Romania, Bulgaria, Poland, Hungary or Latvia each experience an annual GDP per capita ratio not exceeding €10 000.

Accommodating to national price levels, purchasing power parities (PPP) allows for a better comparison of material wealth. Figure 8 illustrates that the outcome of country comparisons depends on the choice of the indicator.

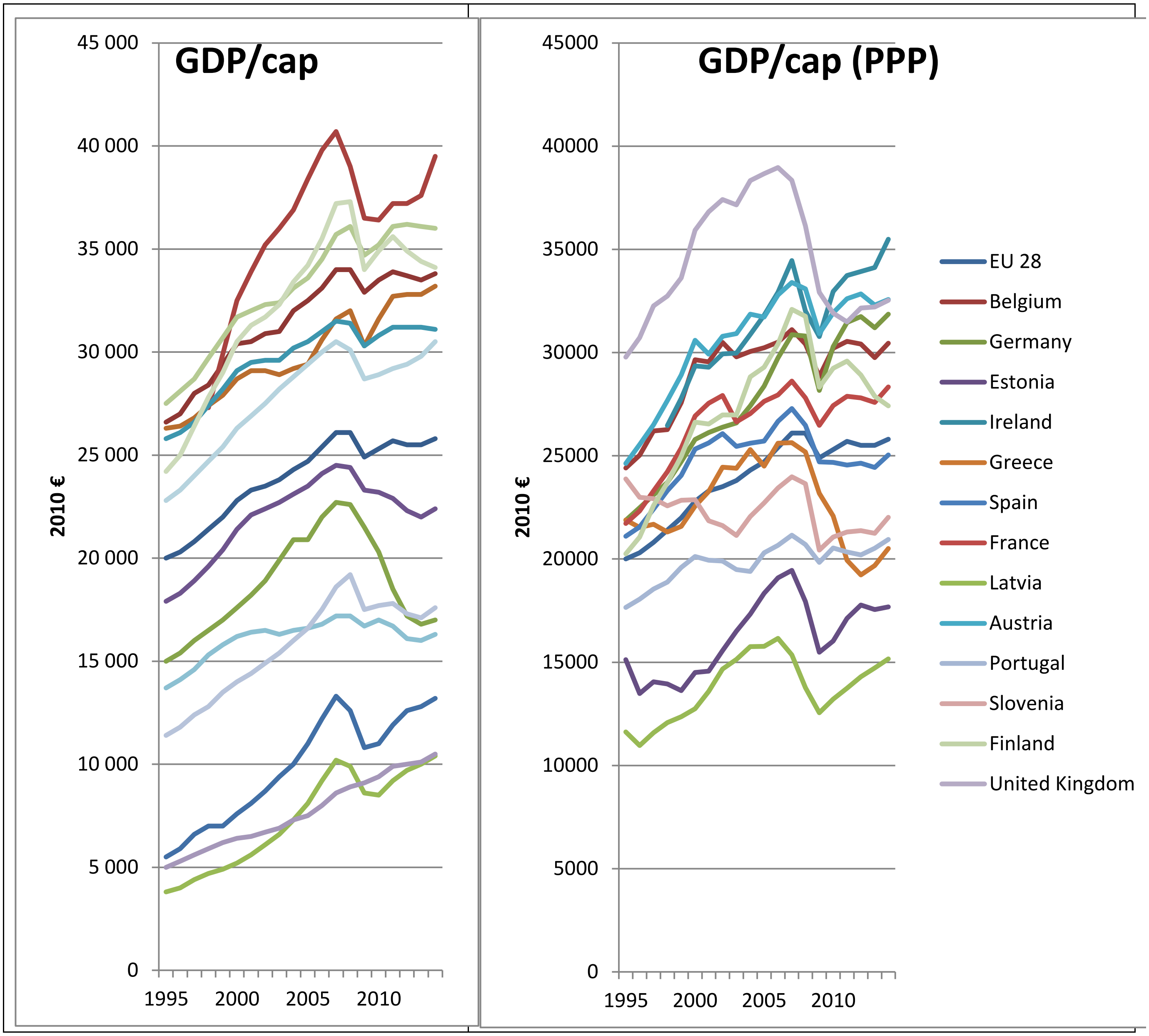

Figure 8: GDP per capita, PPP corrected (Eurostat, 2015).

3. POWER AND HEAT MARKETS

Increasing renewable electricity generation in the EU is seen as one of the key drivers for the need of flexibility and thereby has an effect on the market penetration of SETS. Of course, other power system characteristics also have an influence. Heat production and consumption modes and technologies constitute competing alternatives to SETS and have their obvious impacts on market penetration as well. That is, if a competing alternative has an advantageous competitive position and can, therefore, supply heat at competitive price, the more difficult it is for SETS to achieve market share. Furthermore, district heat and hydropower, especially, act as major flexibility resources. This refers to their ability of being used in balancing the supply and demand in the electricity system. Therefore, these technologies compete with the key functionality of SETS devices. Also, cross-border transmission capacity has its effect on electricity markets and flexibility supply. From these viewpoints, in this chapter we analyse the major power and heat market characteristics in Europe.

Gross energy consumption

Figure 9 presents the energy consumption of the European countries with the largest consumption. Highly populated and large economies, such as Germany, France, the United Kingdom, Italy, and Spain appear as the largest consumers. Generally speaking, the level of consumption increased moderately during the period 1990–2013, although there are signs of a decline beginning in the mid-2000s. To give some perspective, the total gross inland consumption of the EU-28 was nearly 70 000 PJ in 2013.

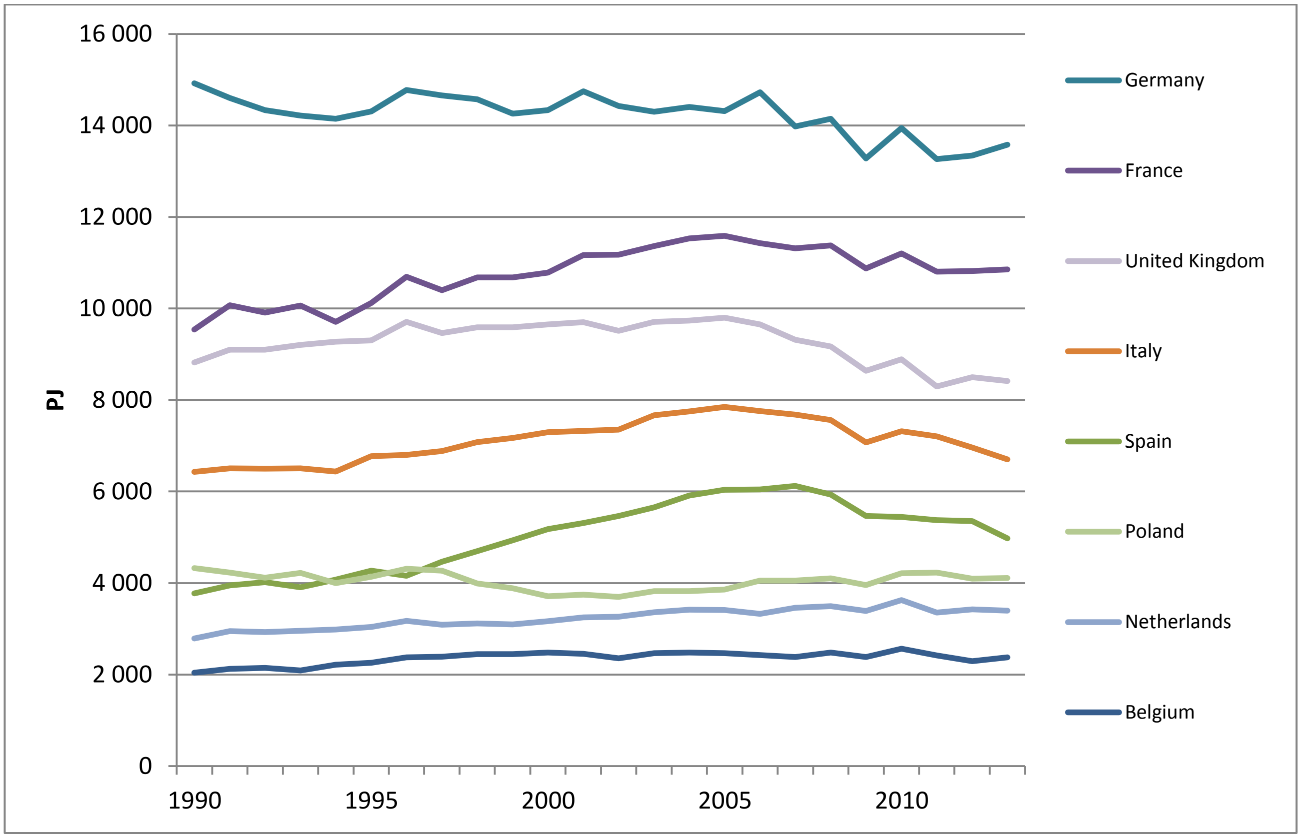

Figure 9. Gross inland consumption of energy. (Data source: Eurostat[2])

2 Data behind the figures were extracted from the Eurostat database, http://ec.europa.eu/eurostat/data/database. Figures prepared by the authors. Notation "Data source: Eurostat" refers to this combination throughout this report.

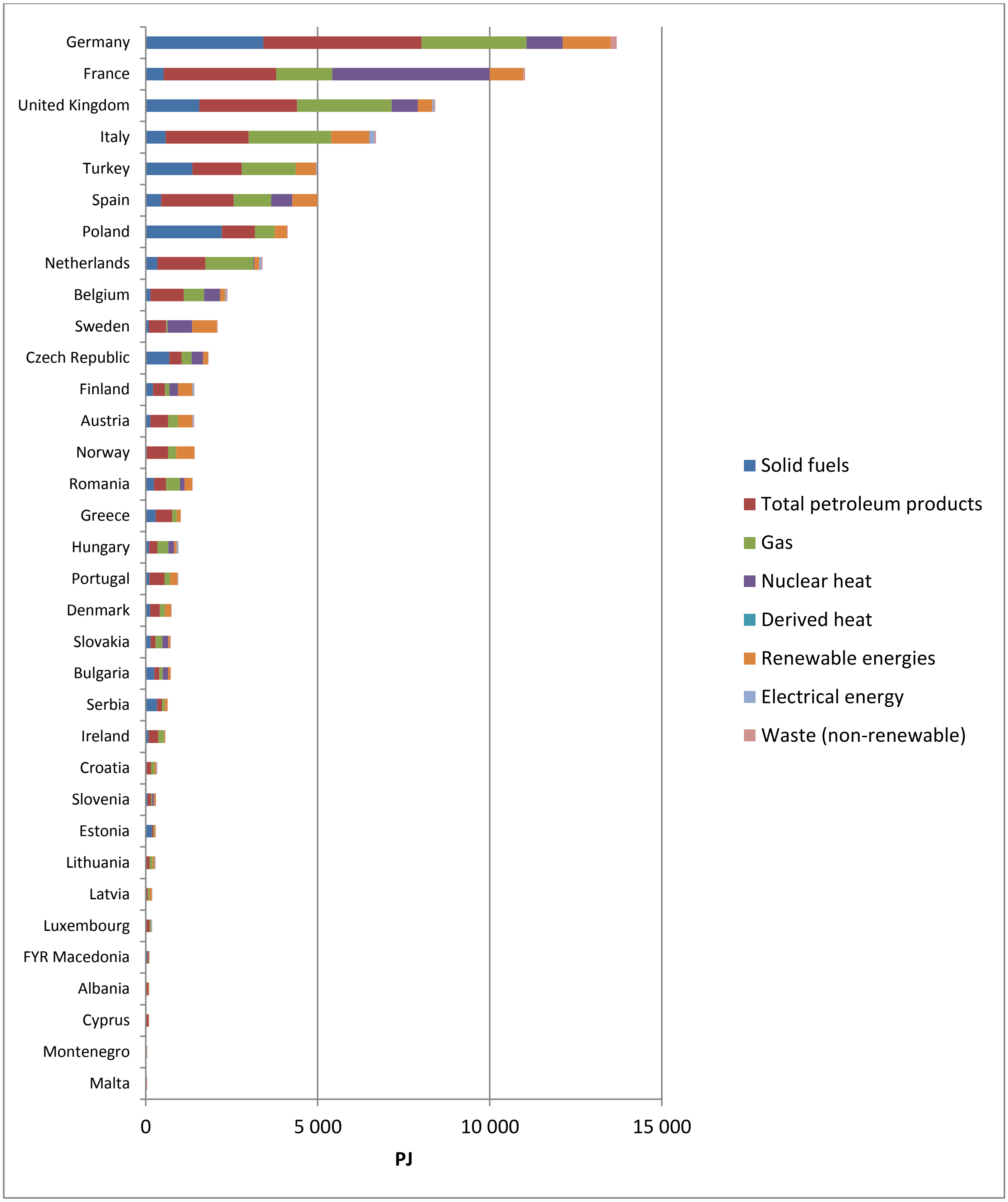

Figure 10. Gross inland consumption of energy by fuel and country, 2013. Negative values refer to net exports of electricity. (Data source: Eurostat)

Figure 10 represents the breakdown of gross inland consumption by country and fuel. Electrical energy refers here to net imports, so does derived heat, which is zero in most countries. The key observation here is that most of the gross inland consumption is still predominantly based on petroleum products, gas, solid fuels (importantly coal, lignite), and nuclear.

Electricity

Figure 11 shows the final electricity consumption[3] in major European markets with the largest consumers being Germany, France, the United Kingdom, Italy, and Spain Electricity consumption in each of these five countries exceeds 200 TWh. In practice, there is very low growth in electricity consumption after the year 2005 and the impact of the financial crisis of 2009 is clearly visible. However, compared to overall energy consumption, the slow-down in the growth of electricity seems to have started later. To give some perspective, the final electricity consumption of the EU-28 was some 2 770 TWh in 2013. Figure 11 essentially shows the 10 European countries with highest final electricity consumption. However, as key countries of the RealValue project, the chart is complemented by Latvia (6.6 TWh in 2013) and Ireland (24.4 TWh), and Finland (79.8 TWh).

[3] The term 'final consumption' (equal to the sum of the consumption in the end-use sectors) implies that energy used for transformation processes and for own use by the energy producing industries is excluded. Final consumption reflects for the most part deliveries to consumers. (International Energy Agency. Energy statistics of OECD Countries. 2014 Edition)

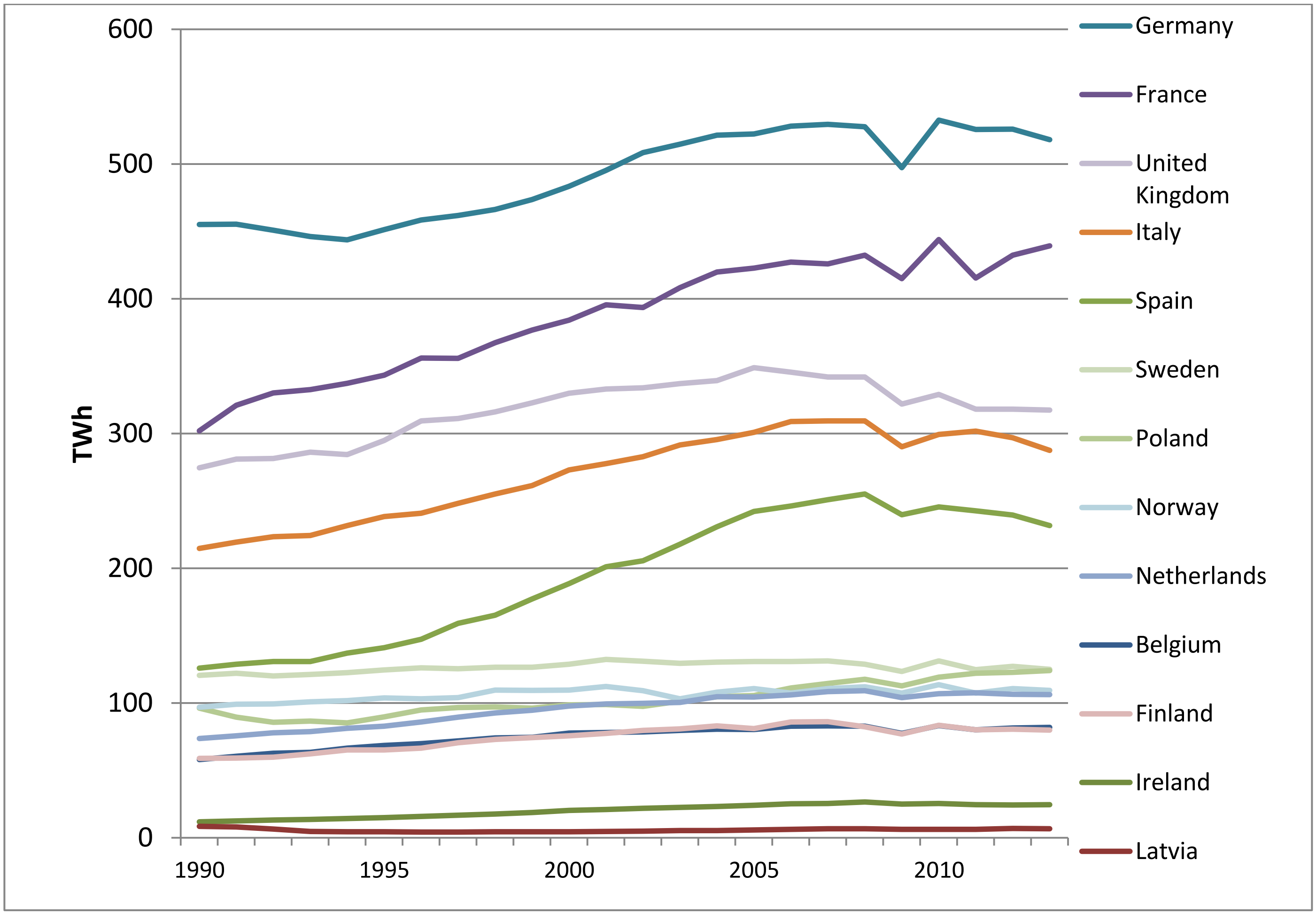

Figure 11. Final electricity consumption by countries, major consumers, 1990–2013. (Data source: Eurostat)

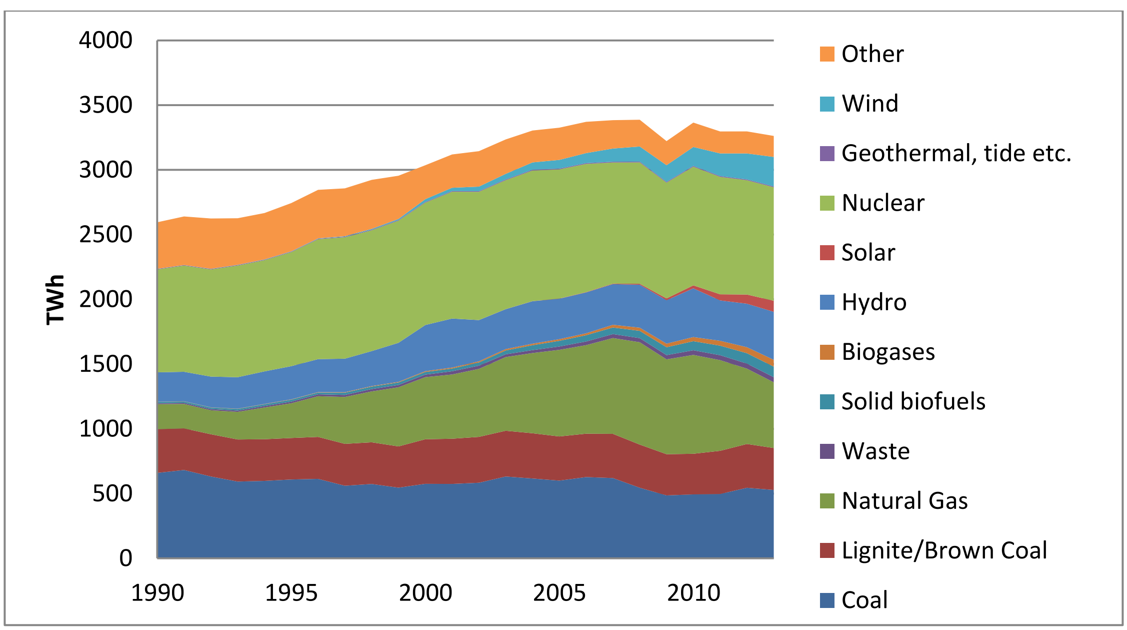

Figure 12. Gross electricity generation in the EU-28 by source + Norway, 1990-2013. (Data source: Eurostat)

Figure 12 presents the fuel mix in the EU for the time period 1990 to 2013. The reader can easily discern the increase in the share of renewables. However, electricity generation still mostly relies on fossil sources, such as lignite, hard coal, and natural gas as well as nuclear power. In the 2010s, a combination of low coal price, low emission prices, and high gas prices has reduced the amount of natural gas used in electricity production.

Figure 13 shows observed electricity production capacity in the EU-28. A rise in varying PV and wind power production driving the markets for SETS is already visibly present in this statistics. It is interesting to note that, even though electricity production has been fairly stable or even shrunk slightly since 2005, capacity has grown by 30% in the same time. This has been mainly caused by investments in PV and wind energy – which both have low capacity factors and in addition need reserve capacity. Additionally, variable renewable production is often must-run capacity that has a priority of generating electricity ahead of conventional plants – leaving this type of generation capacity partly unused.

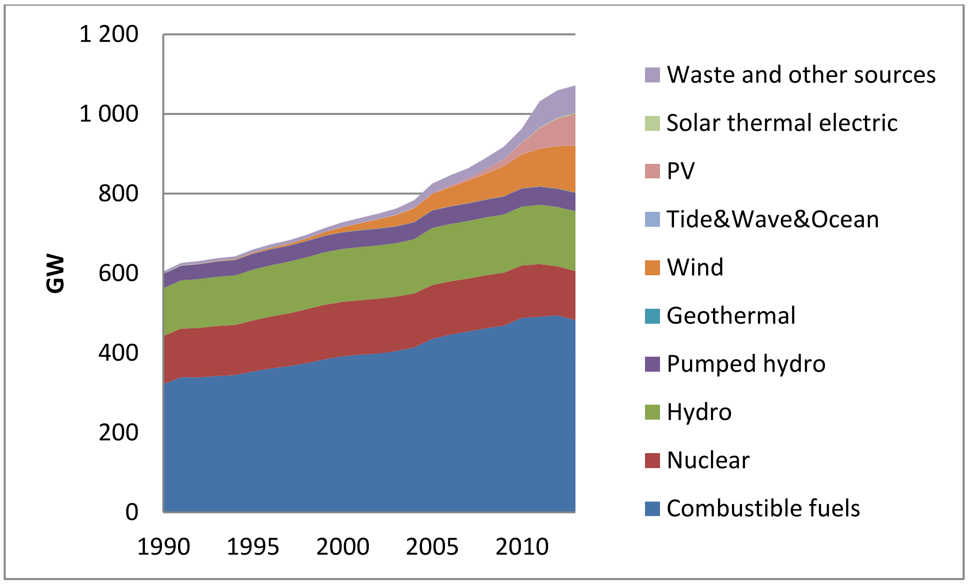

Figure 13 . Electricity production capacity in the EU-28 by generation type, 1990-2013. Data source: Eurostat.

Figure 14 shows the country-specific electricity mix in 2013. Highly varying electricity production patterns between countries can be observed. Germany's highly diversified production structure and the nuclear-dominated production capacity of France are the most striking observations on electricity production in the major markets. Similarly, of the eye-catching peculiarities of the 10 largest producers Poland's high dependence on coal, as well as Norway's vast hydropower resources, could be mentioned.

From a SETS viewpoint, particular interest can be seen to be associated with countries having a high share of variable renewable electricity (RES) production. Portugal (23.3 % wind, 0.9 % solar), Spain (19.0 % wind, 4.5 % solar) and Denmark (32.0 % wind, 1.5 % solar) show the highest relative shares of variable RES electricity in 2013. National support policy emphasis and wind and solar resource conditions have a major impact on the future development and the corresponding environment for SETS towards 2020 and beyond. In this respect, we look closer at the planned variable RES-share of wind and solar power in 2020 in European countries according to the National Renewable Energy Action Plans (NREAPs) published in 2009-10 (Ruska & Kiviluoma 2011). The NREAP plans indicate Ireland, Denmark, Greece, Spain, Portugal, Germany, Netherlands and the United Kingdom as being the markets with greatest potential, using planned capacities of variable RES-shares as metrics. This is more thoroughly discussed in the section analysing the future development, attached to Figure 23 and Figure 24.

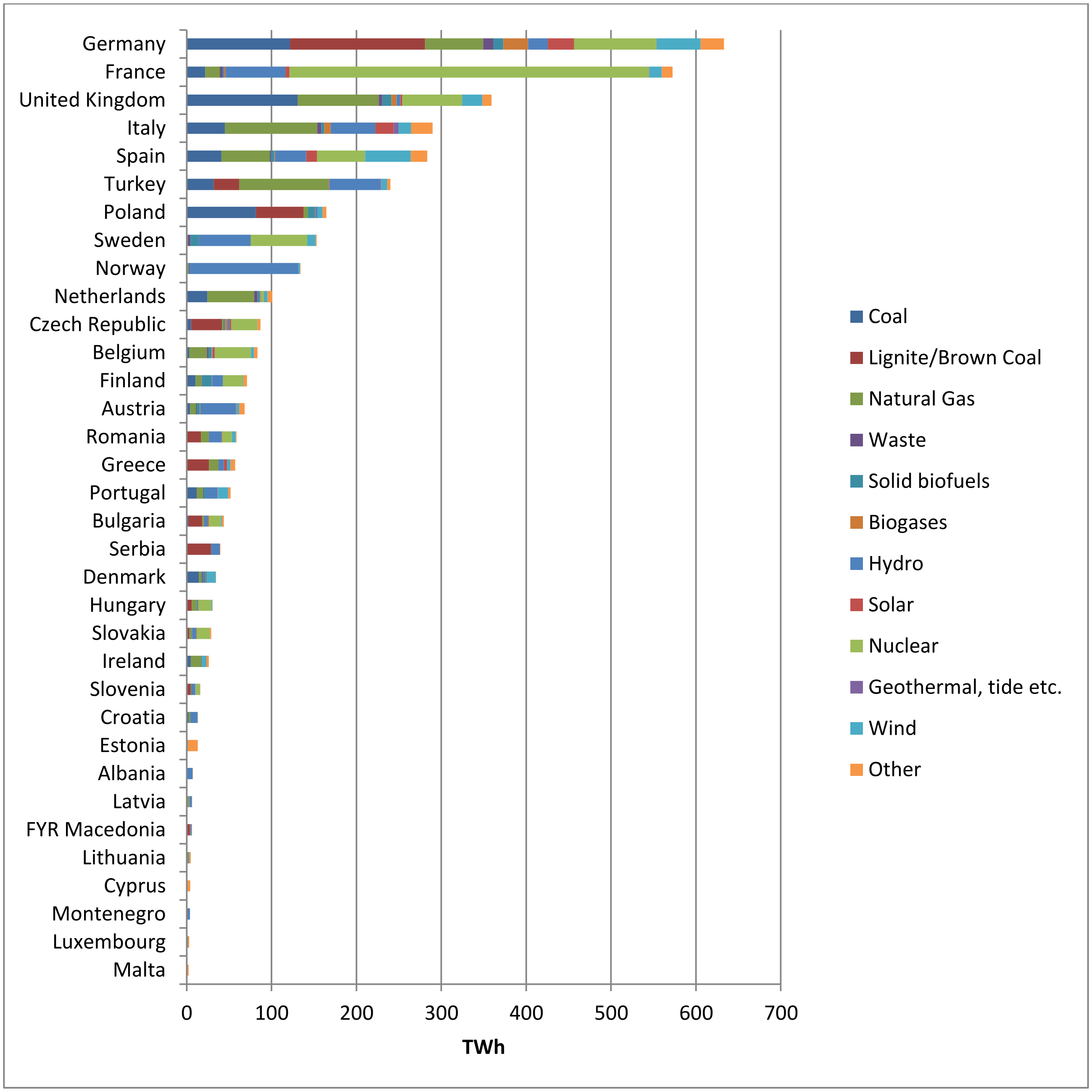

Figure 14. Gross electricity production by fuel in the European countries, 2013. Data source: Eurostat.

Derived heat

Figure 15 presents the break-up of derived heat in the EU-28 by sectors. Derived heat consists of heat sold, and covers the total heat production in heating plants and in combined heat and power plants. Derived heat is not the same as district heat, as derived heat also includes industrial on-site heat and steam production where producer and user are separate entities. Figure 15 reveals the derived heat in these sectors as being relatively constant during the period 1990–2013 in residential and services sectors. The residential and services sectors are of particular interest in SETS market potential analysis. What is more, some applications of SETS devices can even give energy efficiency gains. The smartness of the SETS device may enable features not reachable by all of the conventional solutions. The household indoor temperature can be allowed to vary according to planned occupancy. Similar possibilities might arise in the service sector, for example the heating of hotel rooms could be centrally controlled according to occupancy and empty rooms be kept colder and the heat released as soon as the client checks in, etc. In contrast, generally speaking, industrial processes can be described with specified, large-scale and often high temperature heat demands and the tailored design of devices.

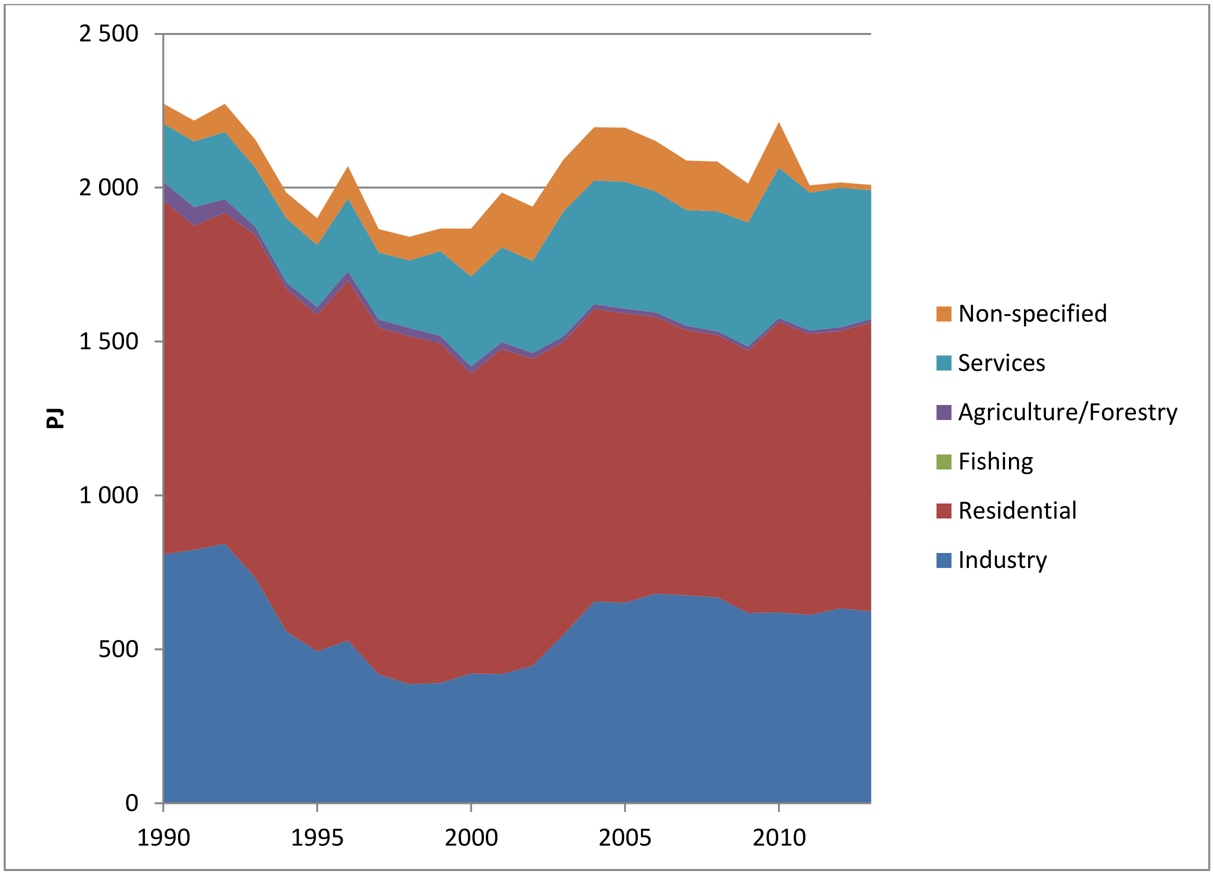

Figure 15. Derived heat in the EU-28 by sectors, 1990-2013. Data source: Eurostat.

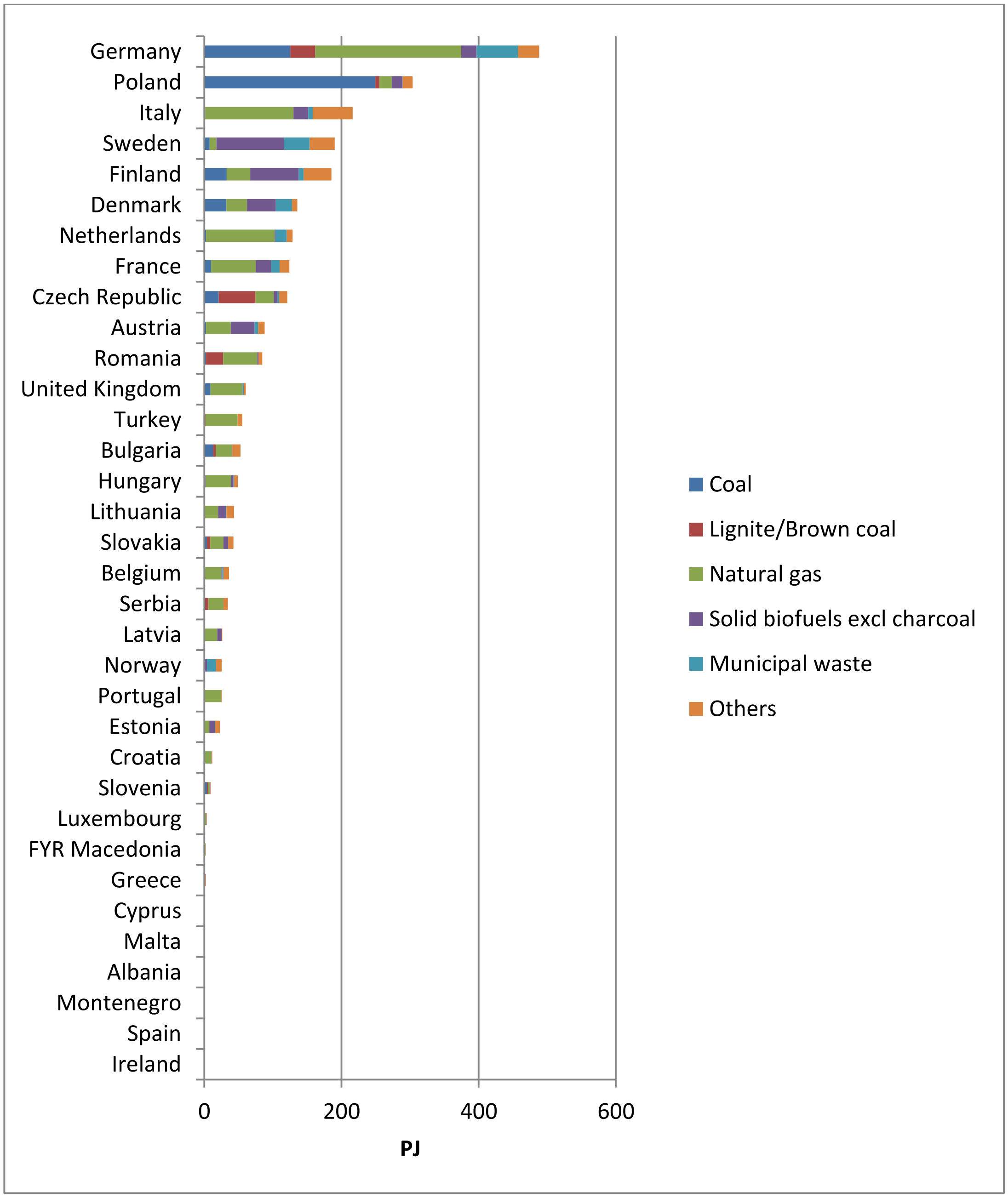

Figure 16. Derived heat production by fuel in the European countries in 2013. Data source: Eurostat.

Figure 16 shows derived heat production by fuel in the European countries in 2013. This is of interest for SETS since, as it represents an alternative technology to heat supply, the economics of fuels and electricity has an impact on its profitability and market penetration. Regarding fuels in derived heat production in the five largest European markets, it is seen that Poland is highly dependent on coal, Italy on natural gas, as Germany uses roughly an even share of both. It can also be observed that Finland and Sweden are positioned high in solid biofuels-based heat production. In other European countries, natural gas, coal, and lignite/brown use generally dominate.

To characterize a market environment for SETS, a further distinction between countries and derived heat usage in residential, service, and industrial sectors, is useful (Figure 17). Germany, Poland, Sweden, and Finland are the countries with the largest total derived heat consumption. Interestingly, the picture is different from that of the economy or electricity production. These statistics are generally led by the largest and most populated countries. Thus, differences between countries that can result from characteristics in heating infrastructure, technologies, and demand for heating, are identified.

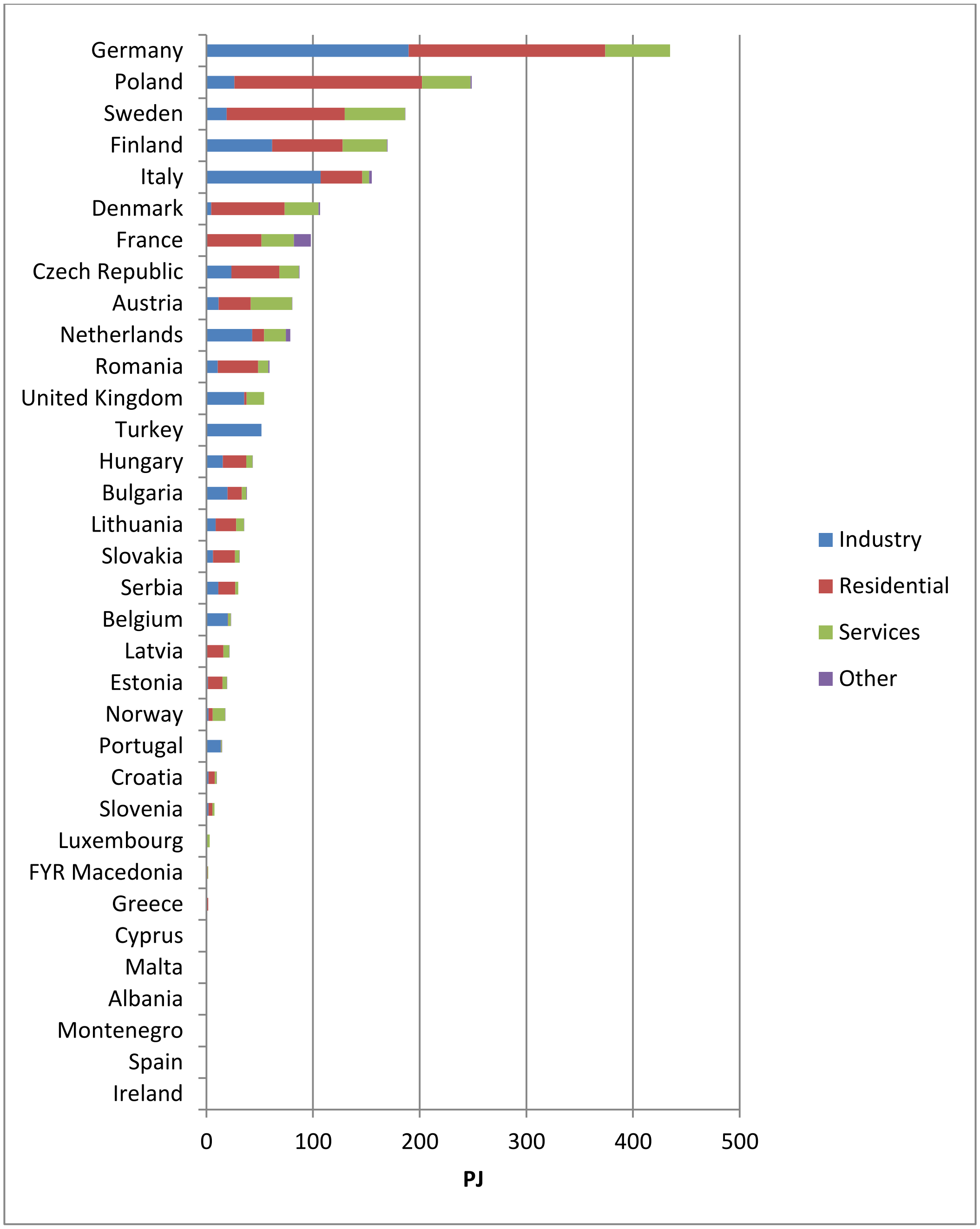

Figure 17. Final energy consumption of derived heat by sectors, 2013. (Data source: Eurostat)

Considering the design of SETS, space heating of service and residential sectors appear, at least in first attempt, as the primary target sectors. However, derived heat presents only a proportion of heat demand in these sectors, as decentralized heating solutions are not included, as will be further discussed in Chapter 4. District heating networks have the ability to use electric boilers or heat pumps, heat storages, and combined heat and power (CHP), and heat-only boilers on a larger and more economical scale than SETS. Also, countries with large district heating systems have a good opportunity to use them for the balancing of the electricity production, thus restricting the market potential for SETS. Consequently, district heated houses cannot be seen as prime target market for SETS, and district heating systems as such eat away at the value of the flexibility of SETS.

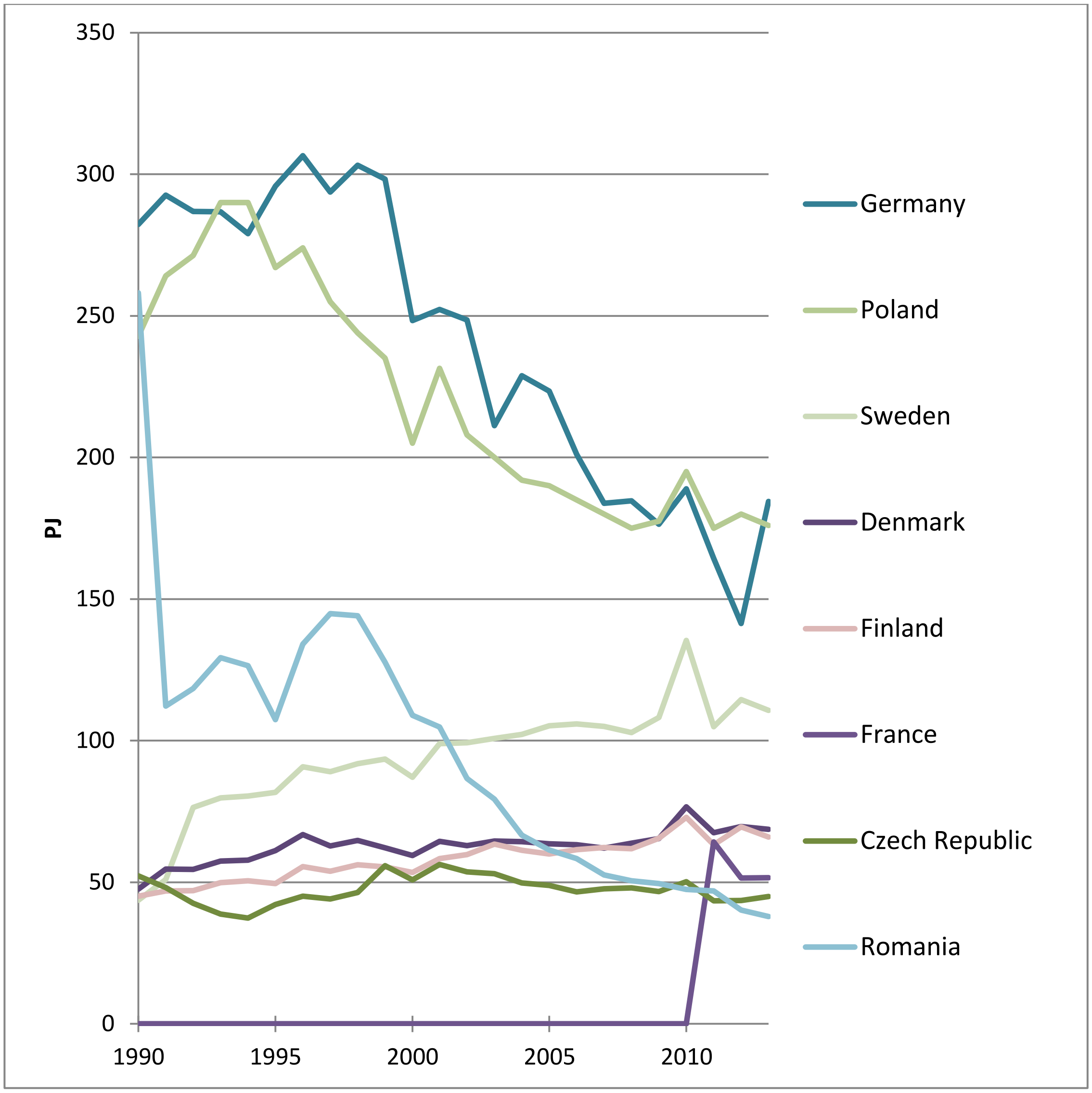

Figure 18: Final energy consumption of derived heat in major European markets, residential sector, 1990-2013 (Data source: Eurostat).

Trends most relevant for SETS potential are observable based on Figure 18 which shows consumption of derived heat in the residential sector in major European markets between 1990 and 2013. Germany, Poland, Sweden and Finland, Denmark, France, Romania and Czech Republic appear as those countries with the largest derived heat consumption in the residential sector. Interesting structural changes can be observed compared to relatively smoothly developing electricity production. Decreasing residential derived heat trends are observed for countries with ties to the former Eastern bloc ([East-]Germany, Poland and Romania). The trend might be explained by efficiency improvement of district heating supply brought by renewal in economic and administrative systems from the early 1990s. Also, building stock use changes including demolition of energy-inefficient apartment buildings might have its impact on the observed statistical trend in Germany, Poland and Romania. In the Nordic countries (Sweden, Finland, Denmark), the development is smooth in comparison.

Addressing different populations in the countries, the role of derived heat is better illustrated in Figure 19 providing with estimated derived heat consumption / capita in 2013. There, the Nordic countries Finland, Sweden, and Denmark show a high utilization of derived heat in the residential sector, signalling widespread district heating infrastructures, which might be partly the result of their relatively cold climate (see e.g. the heating degree days in Figure 36). The share of industrial heat consumption per capita is a strikingly observable peculiarity of Finland, and has to do with the large energy intensive industry to a noticeable extent outsourcing its heat generation.

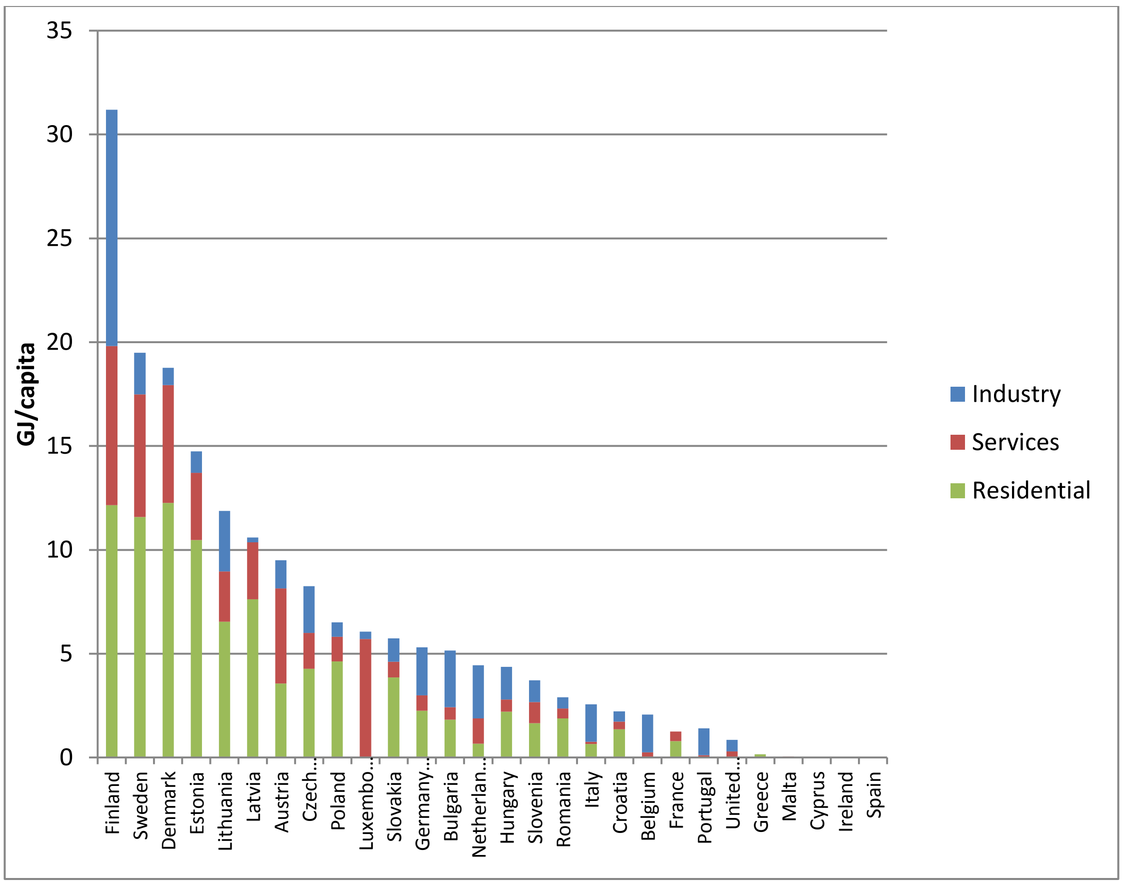

Figure 19. Final energy consumption of derived heat per capita in the European countries, 2013 (Data source: Eurostat, author's calculation for this report)

District heat (DH) networks form a very usable flexibility reservoir, as can be seen, for example, in Denmark. Excess wind energy can be turned into heat using electric boilers or heat pumps, saving fossil fuels. Large heat storages are also significantly cheaper than electricity storage solutions, so the produced heat does not have to be consumed immediately in the district heating networks. As CHP is or can be common in DH, there can be a twofold advantage during times of high wind production: electricity can be used to produce heat in electric boilers, as already mentioned, and at the same time CHP production of both heat and electricity can be reduced. With the help of heat storages, the possibilities increase even further. Overall, the greater the size of the district heating market compared to the electricity market, see Figure 20, the better flexibility opportunities are available and the worse it is for SETS potential.

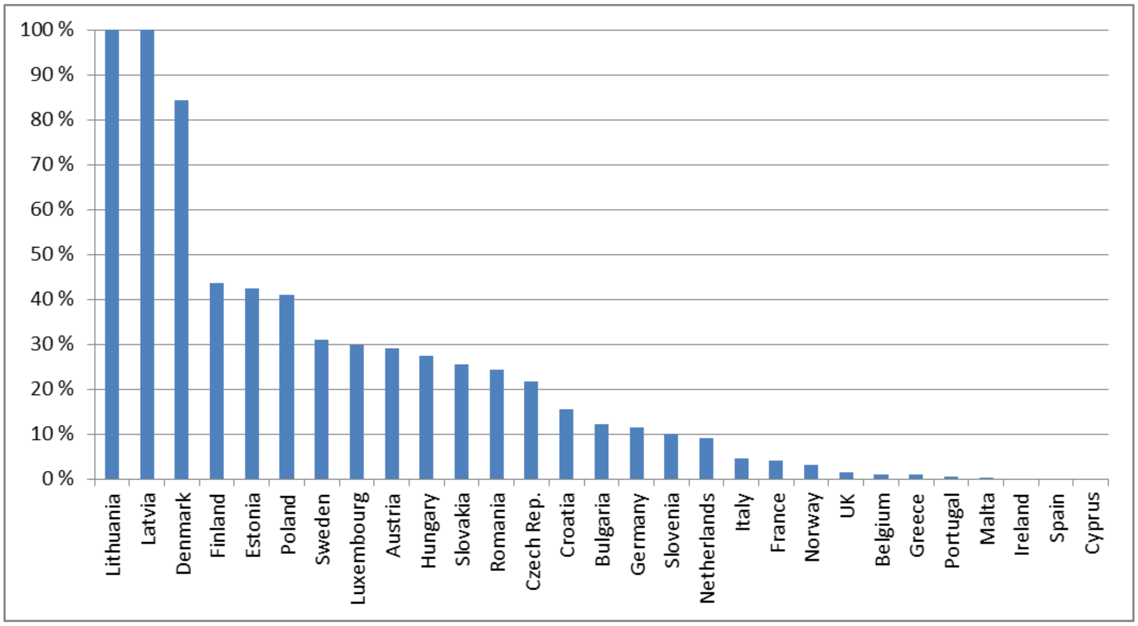

Figure 20. DH market size compared to the electricity market in 2013. The DH market is represented by derived heat in residential and service sectors and electricity market by the net electricity production. The y-axis is cut off at 100% for reasons of visual clarity, although the value for Lithuania is 166%. The numerical values referring to year 2013 are given in the Appendix (Data source: Eurostat).

Cross-border transmission capacity

Balancing of a power system does not have to be restricted to generation, demand side or storage actions; imbalances can also be traded. The stronger cross-border connections a country has, the better and the cheaper imbalances can be managed, especially as the EU is striving towards a more or less common electricity market.

Figure 21 shows the interconnector capacity in relation to the installed electricity production capacity for each country. Although, for example, Denmark has a record high share of wind power, the interconnectors to Norway, Sweden and Germany are strong, thus reducing the need for additional balancing measures, although the balancing possibilities from the widespread district heating also helps a great deal.

The Nordic countries are characterized by high interconnector capacity. Norway, Sweden and Finland have substantial hydropower capacity, although no pumped hydro capacity. According to a Communication from the European Commission (EC, 2015b), here used for European interconnection analysis, the transmission capacity in the Baltic states as a whole is only 4% of generation capacity. However, as of now the interconnectivity of the Baltic States has increased as a result of new connections (EstLink 2, LitPol and NordBalt), and the present ratio of interconnectors per installed generation capacity is 22 %. In addition, it is important to note that the interconnection of the Baltic States is calculated differently from all the other EU countries in (EC, 2015b): The three Baltic States – Estonia, Latvia and Lithuania – are not yet synchronised with the European grid and need, therefore, to be taken as one entity. For these reasons, we use the value of 22 % of interconnections per installed generation capacity for all the Baltic States (EE, LT, LV).

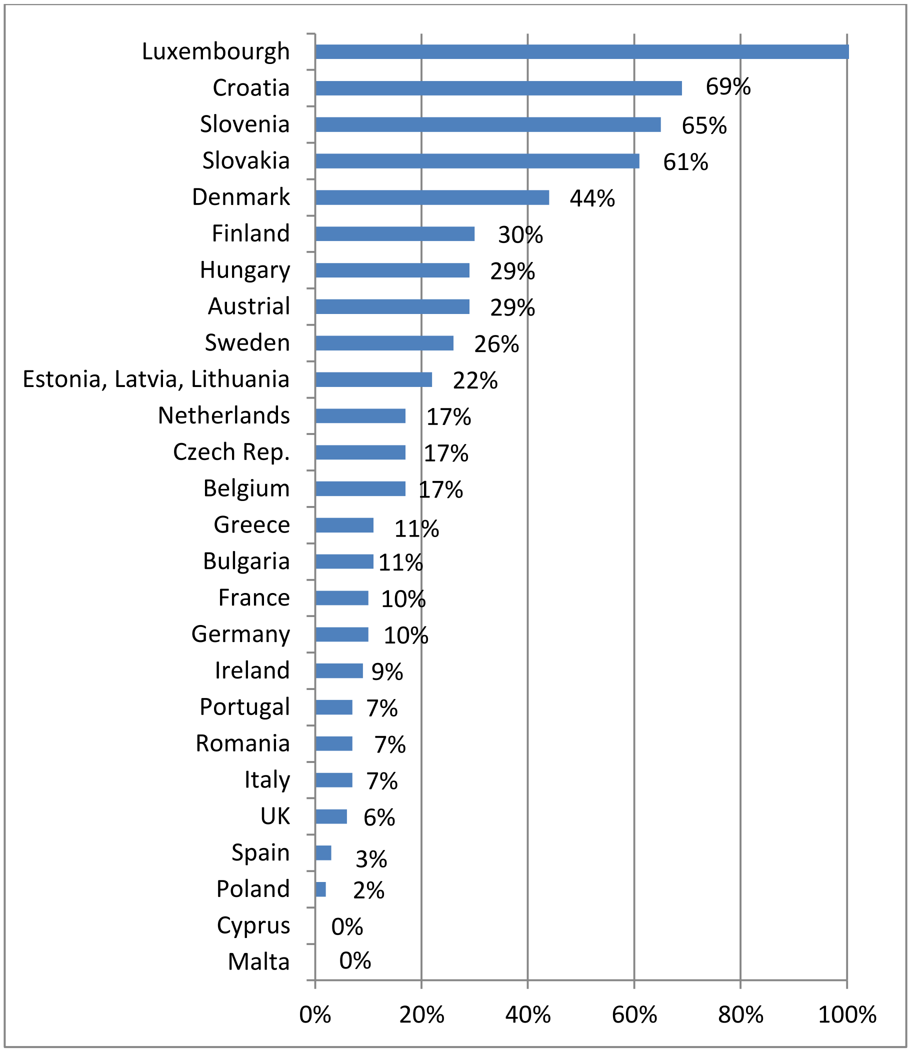

Figure 21. Interconnector capacity per installed electricity production capacity. Luxembourg's 245% is here cut off. (Data source: EC 2015b)

Hydropower

Hydropower plants are classified in three categories, which serve different functions in the grid.

Run-of-river plants use the water flow of a river within the rivers' natural range and in this way have no or almost no storage capacity. Therefore, this type of plants can provide almost no adaptation to demand.

Reservoir type hydropower plants include an upstream water reservoir behind a dam. This allows flow regulation and enables adjustments of power generation. Commonly, the plants are used for the generation of peak-load energy and regulation. Depending on the size of the reservoir, they can provide long-term and large-scale energy storage. The response time is less than 5 minutes and, therefore, the plants can be used to meet sudden changes in demand. A reservoir hydropower plant can also reduce power output and adjust to time with high variable renewable electricity production, thus forming a competition to SETS flexibility functionality.

Pumped storage hydropower plants operate with two reservoirs, one lower and the other one higher. It can be differentiated between mixed plants being part of a natural river flow with pumping capacity and pure pumped storage. This type of plant operates as huge electricity storage resource and, therefore, competes with SETS. Eurostat compiles statistics only with the classification hydro / pumped hydro. Mixed plants are not classified as pumped hydro plants. Eurelectric uses a more sophisticated classification, with pumped hydro plants also including mixed plants and the distinction between run-of-river and reservoir plants (Figure 22).

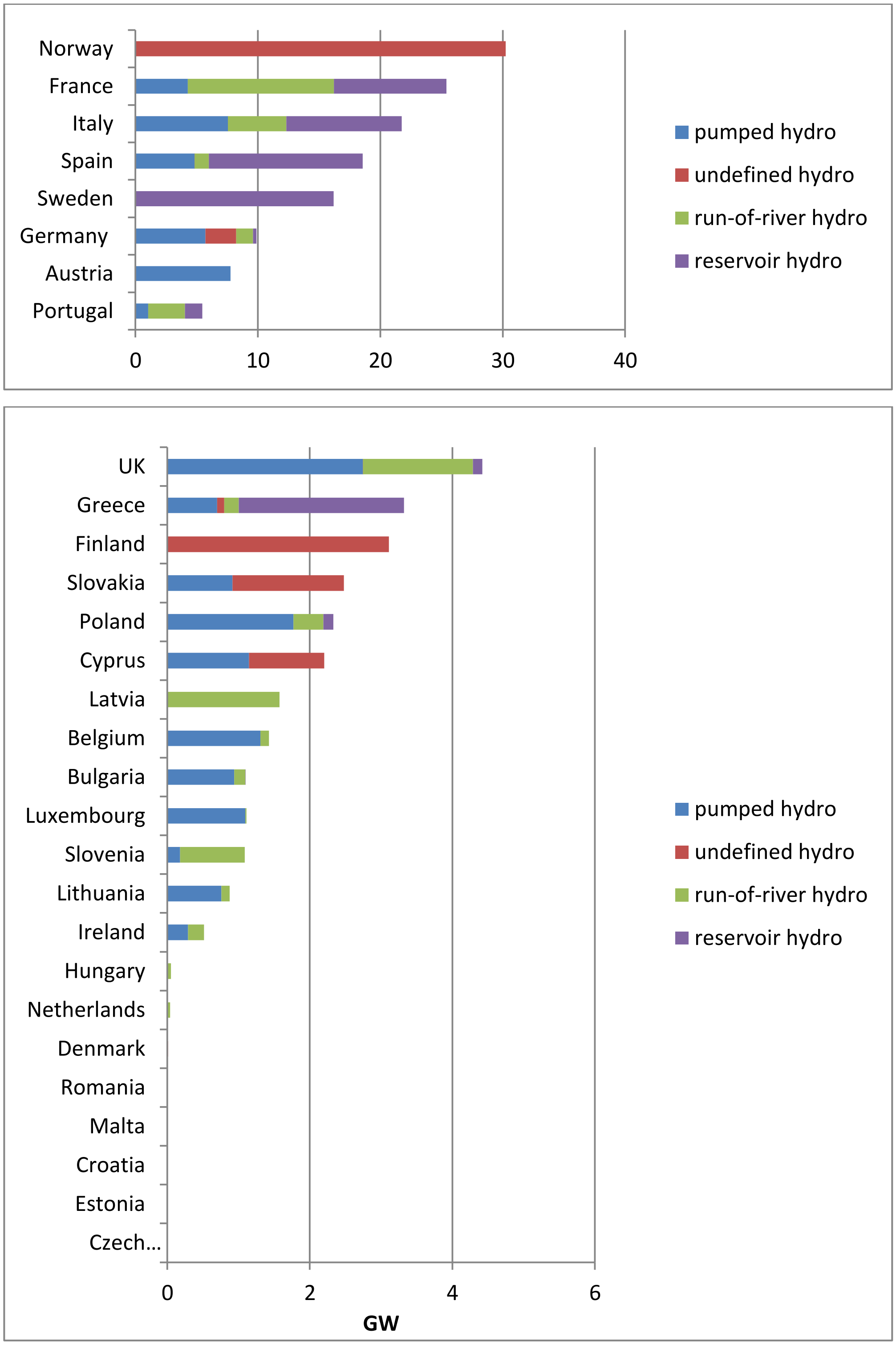

Figure 22: Hydropower capacity in 2011 by plant type and country. Note the two different scales (Eurelectric, 2013a).

Future of power generation in Europe: role of variable renewables

Figure 23 shows the variable RES-share (wind and solar power) of total gross generation in 2013 in European countries. Portugal, Spain and Denmark score the highest in this respect. This is of interest, since one can expect the high share of low variable cost RES to have a dampening effect on short-term marginal price in times of high variable RES electricity production. As low electricity prices are one driver for the competiveness of SETS, high RES electricity share could be expected in this way to boost the business case for them. Generally speaking, as heating devices, SETS provide balancing opportunities for variable sources of electricity during the heating season. As solar power production is generally at its lowest during the heating season of the winter months in Europe, wind power share can primarily be seen as more meaningful for SETS profitability.

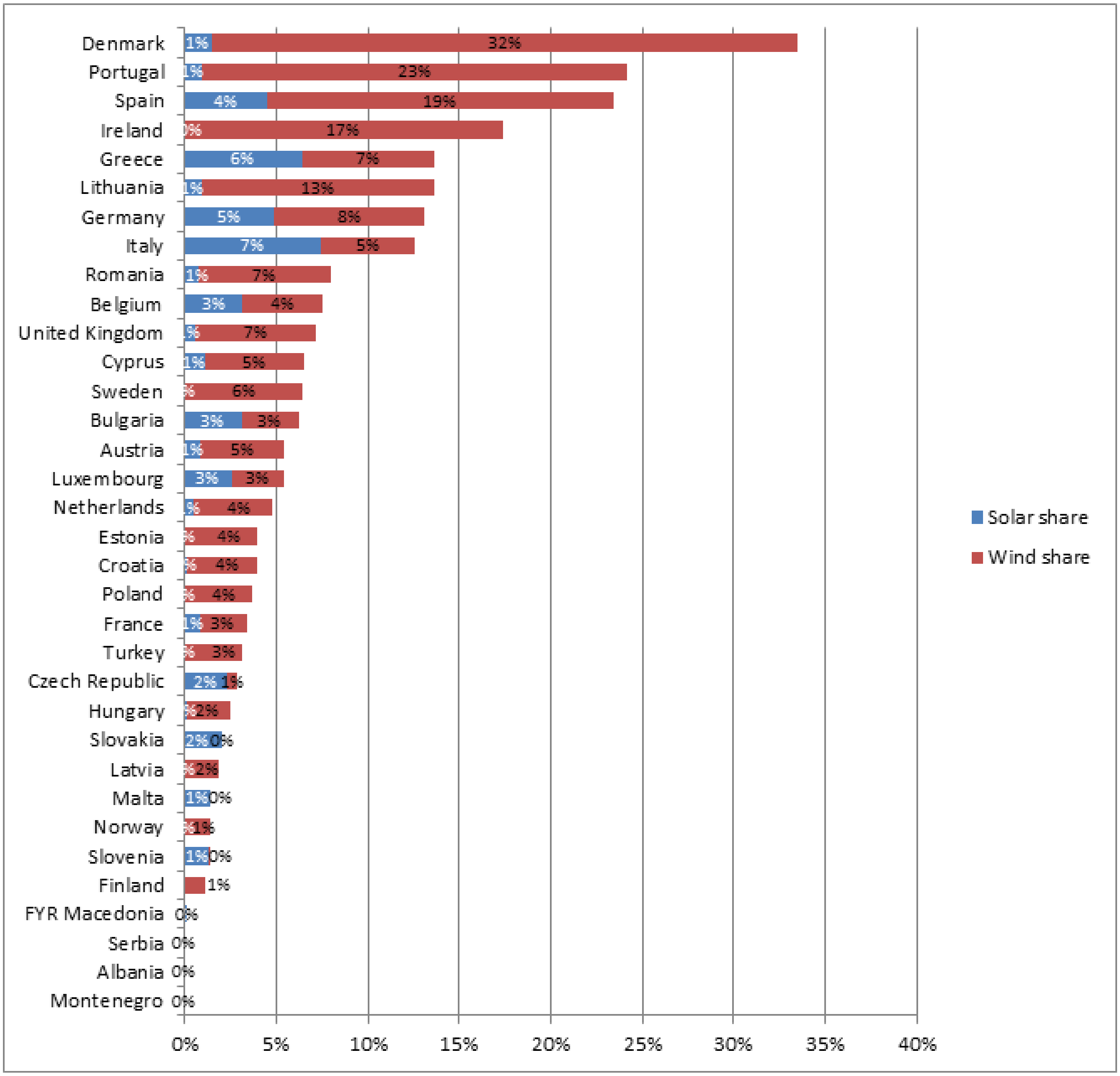

Figure 23. Variable RES-share of total gross electricity generation in the European countries, 2013. (Data source: Eurostat)

All member states of the EU were obliged to deliver a National Renewable Energy Action Plan (NREAP) in 2010. The Renewables Directive (EC, 2009a) sets legally binding targets for 2020 for the renewable energy exploitation in each member state. NREAPs provide a roadmap setting sectoral and technology specific targets. Figure 24 shows planned shares of wind and solar power in 2020 in European countries according to the NREAPs (Ruska, Kiviluoma 2011). Ireland, Denmark, Greece, Spain, Portugal, Germany, Netherlands, and the United Kingdom are seen as being the most potential markets according to planned capacities and these metrics. Interestingly, there is quite a sharp distinction between the countries aiming at 20% – 30% wind shares and others aiming at a 10% or lower share, respectively. Compared with recorded development, in the case of Ireland, Greece, Germany, Netherlands and United Kingdom, there is still a noticeable gap between the realized development hitherto and the plan.

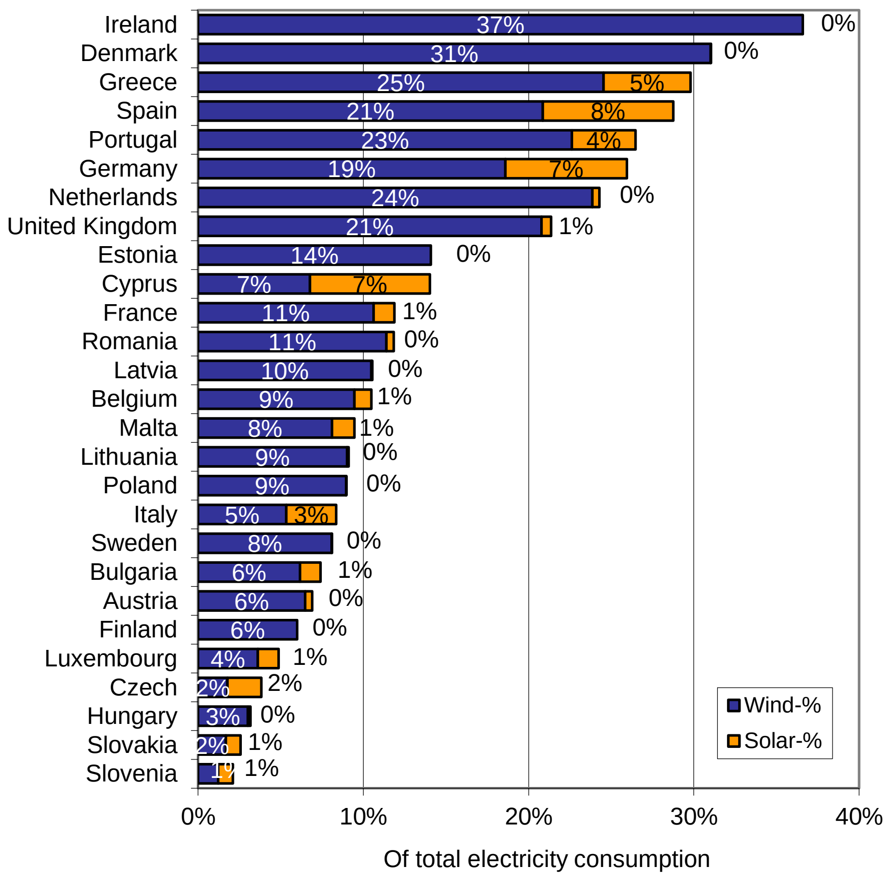

Figure 24. Variable RES-share in 2020 in European countries according to National Renewable Energy Action Plans. (Ruska, Kiviluoma 2011).

Taking a look farther in the future, Figure 25 shows net Installed Power Capacity in Europe according to scenarios analysed in EU Energy Roadmap for 2050 (EC 2011c). The EU has set a target of 80–95% GHG reduction until 2050 compared to 1990. This roadmap generates seven scenarios, one of them called the reference scenario, with varying emphasis on energy efficiency, renewable energy, nuclear energy and carbon capture and storage. Clearly, an increase of varying PV and wind power production is present in each of the projections.

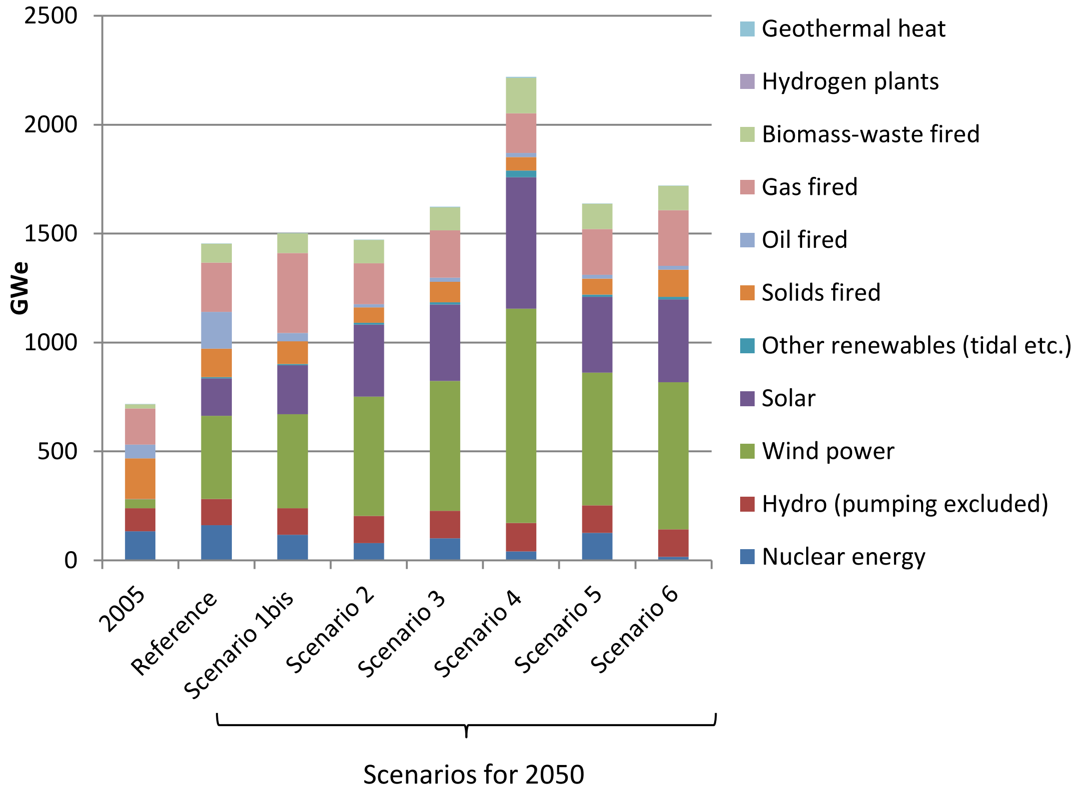

Figure 25. The Reference, Current Policy Initiatives and the five decarbonisation scenarios of the electricity production by source in the EU in 2050. The scenarios for 2050 present Business as usual (Reference), 1: Current Policy Initiatives – CPI scenario (updated Reference scenario), and decarbonisation scenarios, 2: High energy efficiency, 3: Diversified supply technologies, 4: High RES, 5: Delayed CCS, 6: Low nuclear (EC, 2011).

To take a look at the tendencies of countries' electricity production, an update and extension report of trend scenarios for development of energy systems in the EU countries (EC 2013) is analysed. The new Reference scenario analysed by the PRIMES model determines as core element the development of the EU energy system under current trends and adopted policies. Figure 26 shows the projected development of electricity generation in the EU-28 towards 2050. The rise of wind (25 % of gross generation in 2050), especially, and solar (8% of gross generation in 2050), are clearly observable.

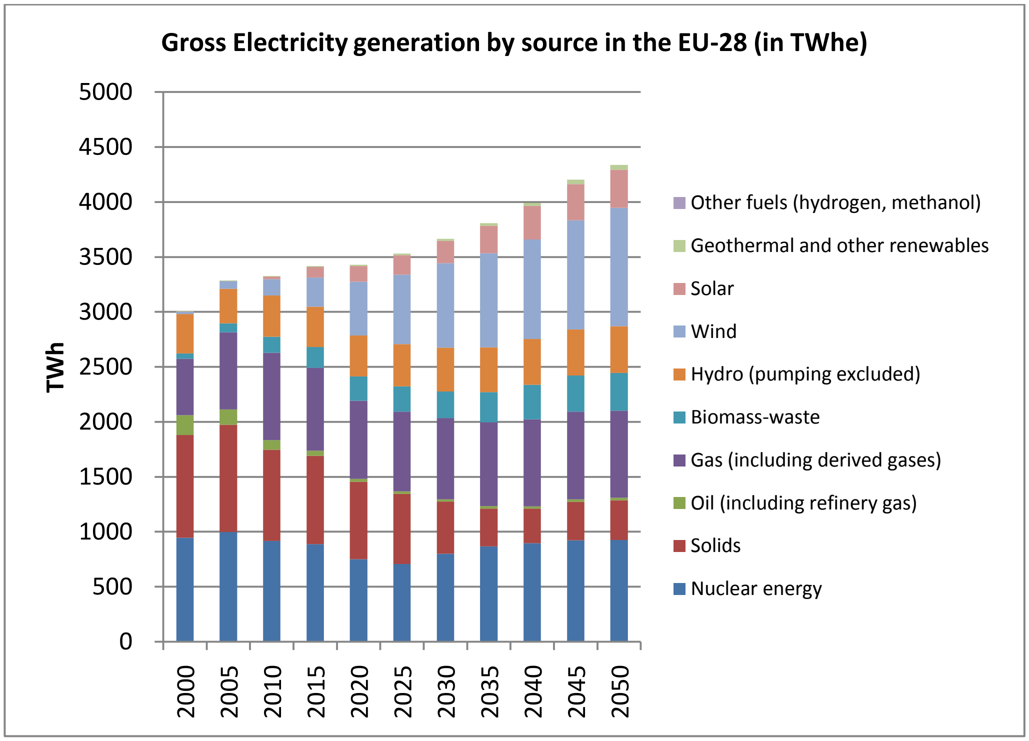

Figure 26. Gross electricity generation by source according to the Reference scenario 2013 (in TWhe) (Data source: EC 2013).

For country-specific observations and rough indications on future development directions, Figure 27 shows the shares of wind and solar power in 2050 in European countries according to the Reference scenario based on EC (EC,2013). Portugal, Denmark, Malta, Greece, Ireland, Estonia and United Kingdom are seen as the most potential markets according to planned capacities and these metrics.

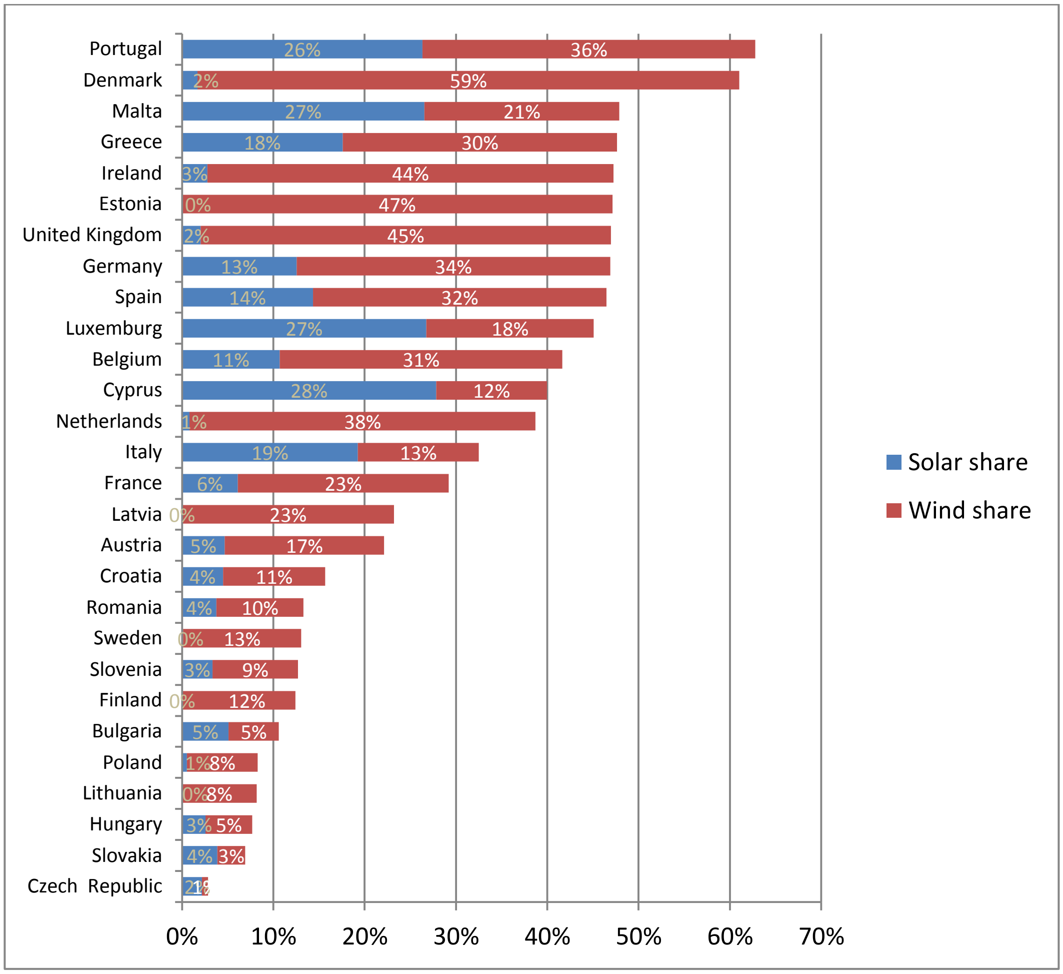

Figure 27. Wind and solar power shares in 2050 in the European countries in the Reference scenario. (Data source: own calculations based on the EU References scenario data 2013 (EC 2013))

4. RESIDENTIAL SECTOR

Overall, we can compare unit consumption of space and domestic hot water heating demand per dwelling in the different European countries, see Figure 28. The colder the climate, the more heating is used per dwelling. Of course, other factors such as average size, number of inhabitants, insulation level, heating source and efficiency and average indoor temperature of the dwelling all matter.

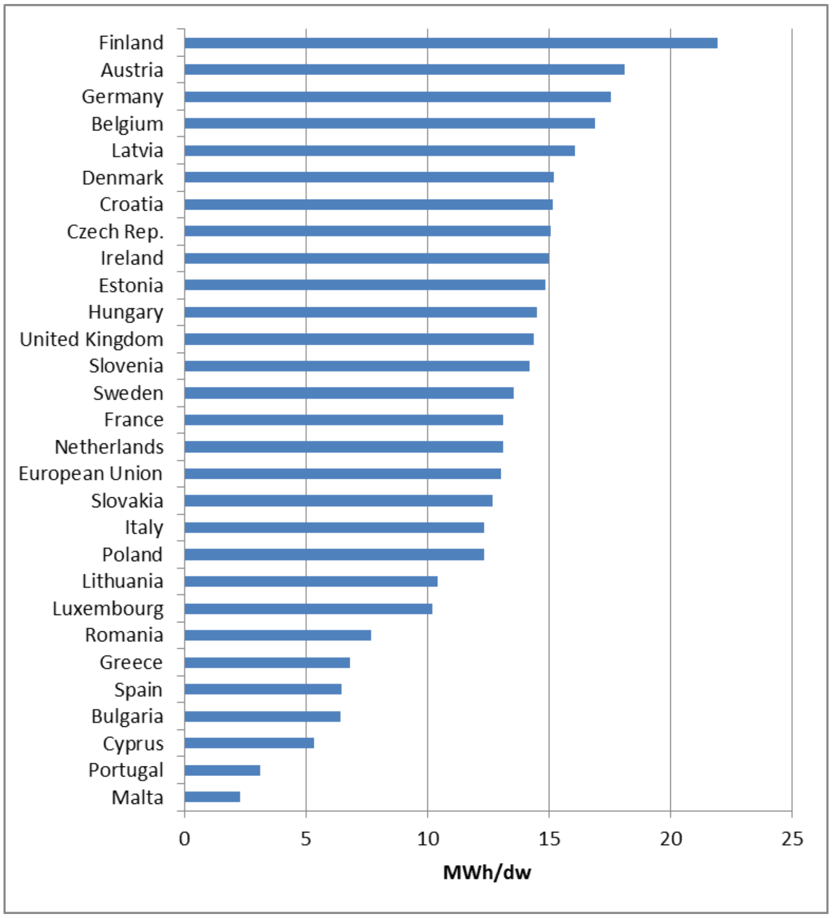

Figure 28. Unit consumption, MWh/dwelling, of space heating and water heating in 2013 (however, EU 2012, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2010, Netherlands 2012, Romania 2011, UK 2012, and Norway data are missing altogether). (Data source: Enerdata 2015)

Space heating

Heat demand and sources

Final energy demand refers to the consumption in[4] the end-use sector, thus excluding the energy used in the transformation sector. Final energy demand of a country for space heating is dependent on several factors, but the population and the climate are two of the most important ones, as can be seen in Figure 29. Germany is the overall largest market for residential heat and Malta the smallest.

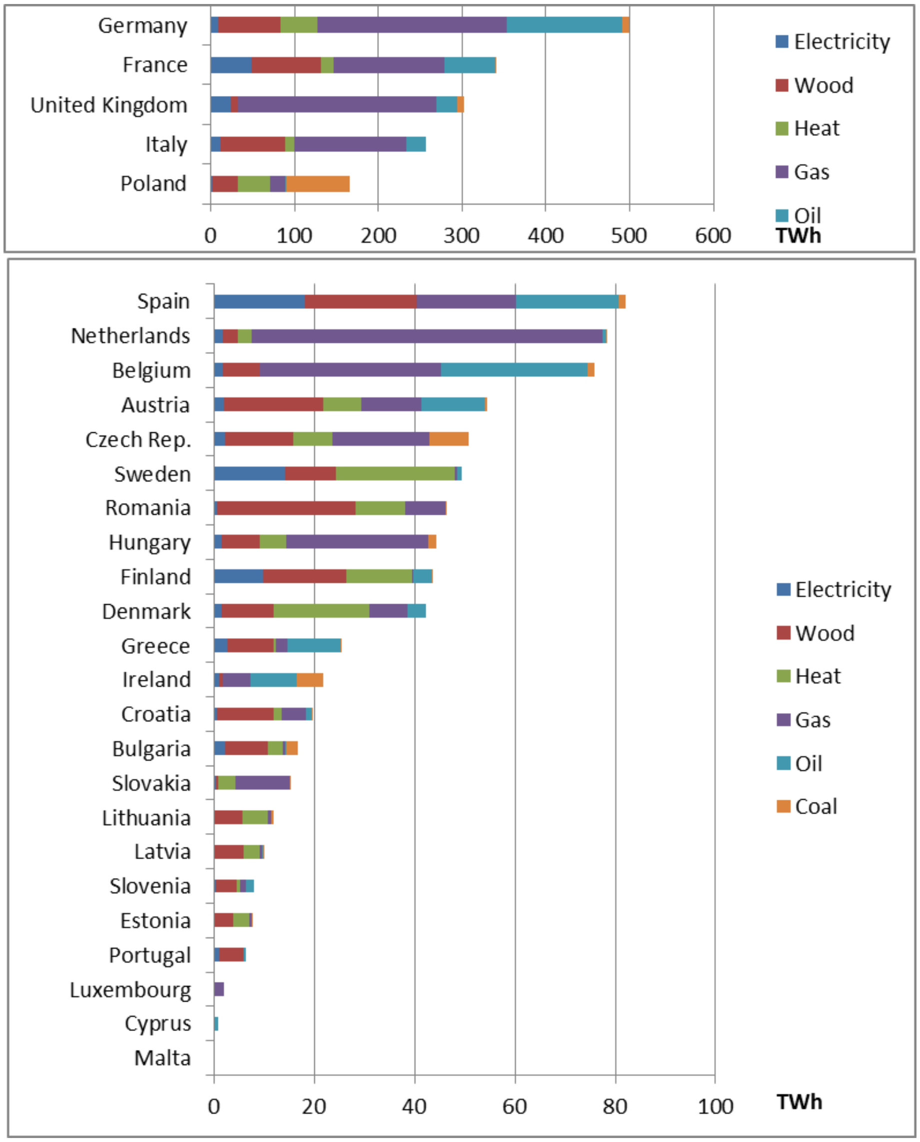

Figure 29. Heat deliveries according to heat source in the residential sector for space heating in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011 and UK 2012). NB The x-axis scales are different in these two graphs, 0-600 TWh in the upper and 0-100 TWh in the lower. (Data source: Enerdata 2015)

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[4] In the energy statistics, final energy consumption is defined as the energy put into respective end-use sector. For households, that means from the outside procured fuels, electricity and heat. Self-produced electricity (e.g. PV) or heat (solar thermal or ambient heat for heat pumps), however, are not procured from the outside but produced within the house boundaries.

On-site solar heat is per definition not included in final energy use, although it is part of useful energy usage, and neither is geothermal heat or ambient air heat. The EU is striving to reduce greenhouse gas emissions, to increase renewable energies and to increase self-sufficiency, as explained in Chapter 1. In this respect, coal and oil are the first sources to be replaced with more sustainable solutions. Coal (including peat) is notably used only in Poland, the Czech Republic and Ireland, but even though the coal share is small in Germany and the UK, the coal energy amounts are nevertheless significant, 9 TWh and 8 TWh, respectively.

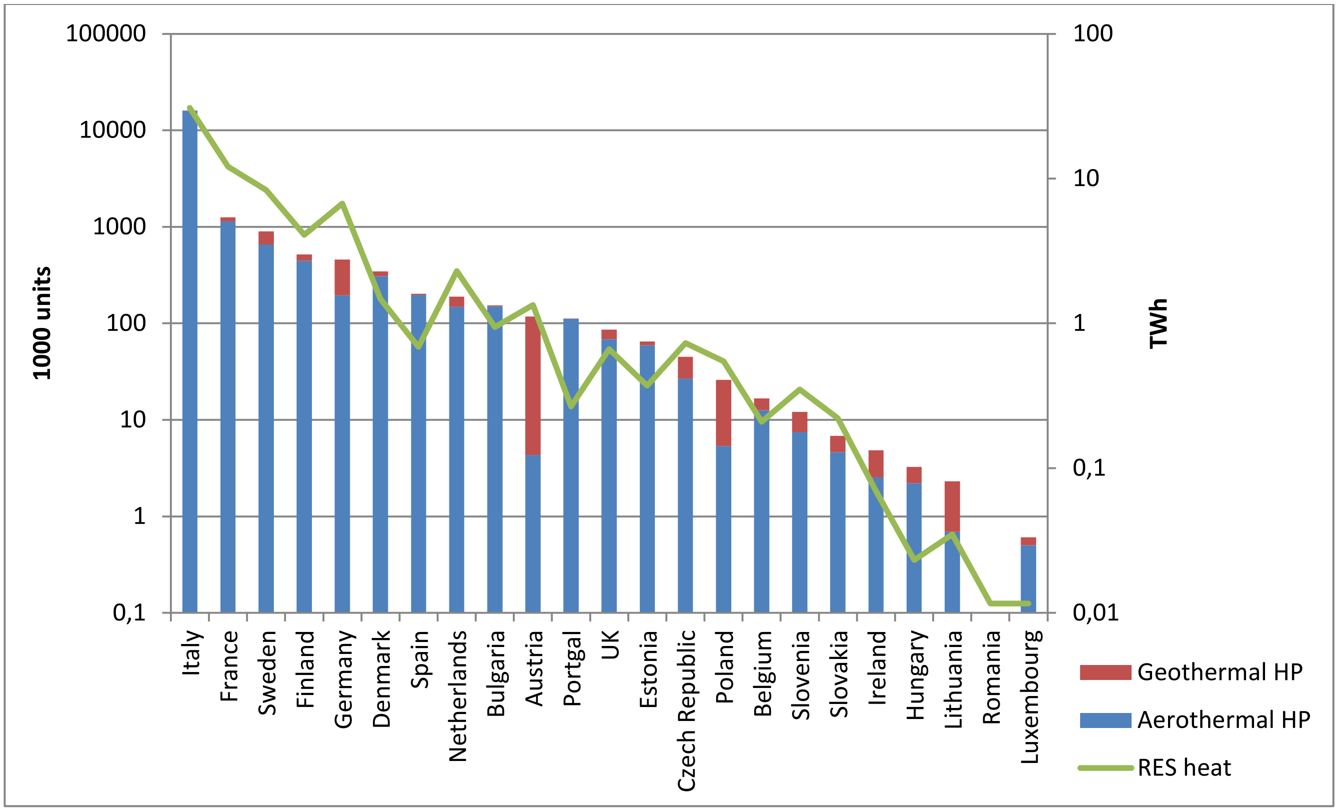


Figure 30 : Installed heat pumps in 1000 units and the associated renewable heat generation in 2012. The scale is logarithmic (Eurobserver, 2013).

One low cost heat source that the SETS has to compete with is heat pumps (HP). Heat pumps use electricity to pump ambient heat from the air or the ground with good energy efficiency. The European Heat Pump Association EHPA has estimated the cumulative installed heat pumps in the European market and the associated energy production (Eurobserver, 2013). The numbers in Figure 30 refer to the year 2012. Heat pumps are divided in two categories: ground source HPs and air source HPs. Heat pumps can be used either for heating purposes only, or if they are reversible, they can also serve for cooling. In the northern countries heat pumps are used almost solely for heating and thus form a competing technology for SETS. In southern countries, especially Italy, Spain and France, the reversible technology dominates and so is also used for cooling.

Households can have multiple heat sources. Overall, the penetration of (auxiliary) low cost heat sources such as air/air heat pumps will have a negative impact on the market for SETS. Ground source heat pumps, on the other hand, need higher investment costs. If heat can be produced with a coefficient of performance (COP) of 3–5[5] in a heat pump, the extra benefits given by SETS must be that more attractive to spur investing in it. COP refers to the ratio of heat provided to the work required.

As already noted, the heating source distribution for space heating varies according to country. In the following (Figure 31 – Figure 35) we show the share of electricity, gas, oil, heat, and wood for space heating in 2013, ordered according to share size. The values here refer solely to space heating, not to heating of hot water. As the fuel efficiencies differ between the technologies, heating share according to useful energy (the heating need, i.e. including inhouse energy production but not excluding conversion losses) by source might look different.

Electric space heating

Generally speaking, the higher the share of electricity in heating solutions, see Figure 31, the more attractive the market is for SETS. However, the opposite can also be true, if heat storage is common. Houses with heating storages will not be inclined to invest in new storages.

A study carried out by Kema Nederland (Raadschelders et.al., 2013) has estimated the electricity heating markets in all the EU countries, Switzerland and Norway. It came to the conclusion that roughly 13% of all electrically heated dwellings are associated with some kind of storage – either static or dynamic. If underfloor heating is counted as an electrical heating with storage, the share rises to 24%. The remaining units with no associated storage consist of convector panel heaters, radiators, fan heaters, and radiant panel heaters. The replacement potential was estimated in France (96 GW), UK (13 GW), Germany (14 GW) and the Nordic countries (22 GW).

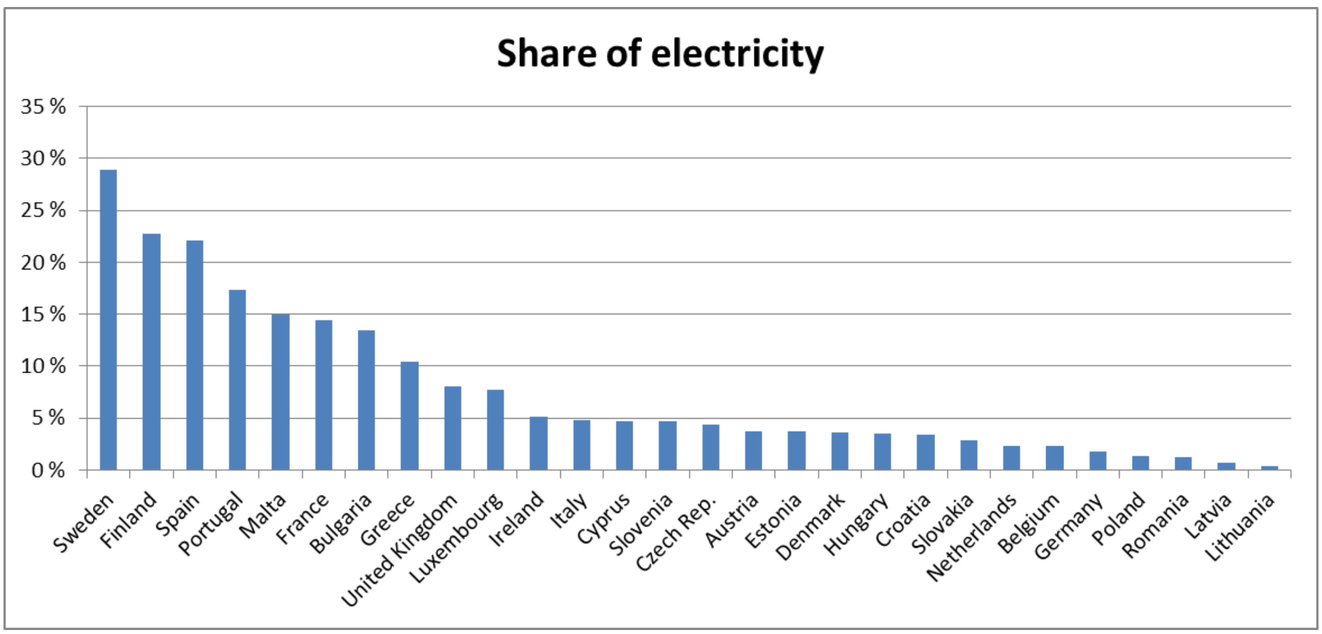


Figure 31. Share of electricity in space heating in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011, and UK 2012). (Data source: Enerdata 2015).

5 For example, a COP of three means that with one unit of electricity, three units of heat are produced.

Gas or oil space heating?

The use of gas might be prohibitive for the introduction of SETS, if the price of gas is clearly below the price of electricity for the end-user. On the other hand, if the price of gas is close to the price of electricity, there can be a market potential if SETS can use very cheap electricity at times. Of course, this is true of all heat source solutions. The penetration of condensing boilers will, on the other hand, have a contrary effect as they present efficiencies above 100 % (NB: lower heating value[6]). The following graph includes only gas delivered to the households, i.e. gas used for district heating generation is excluded.

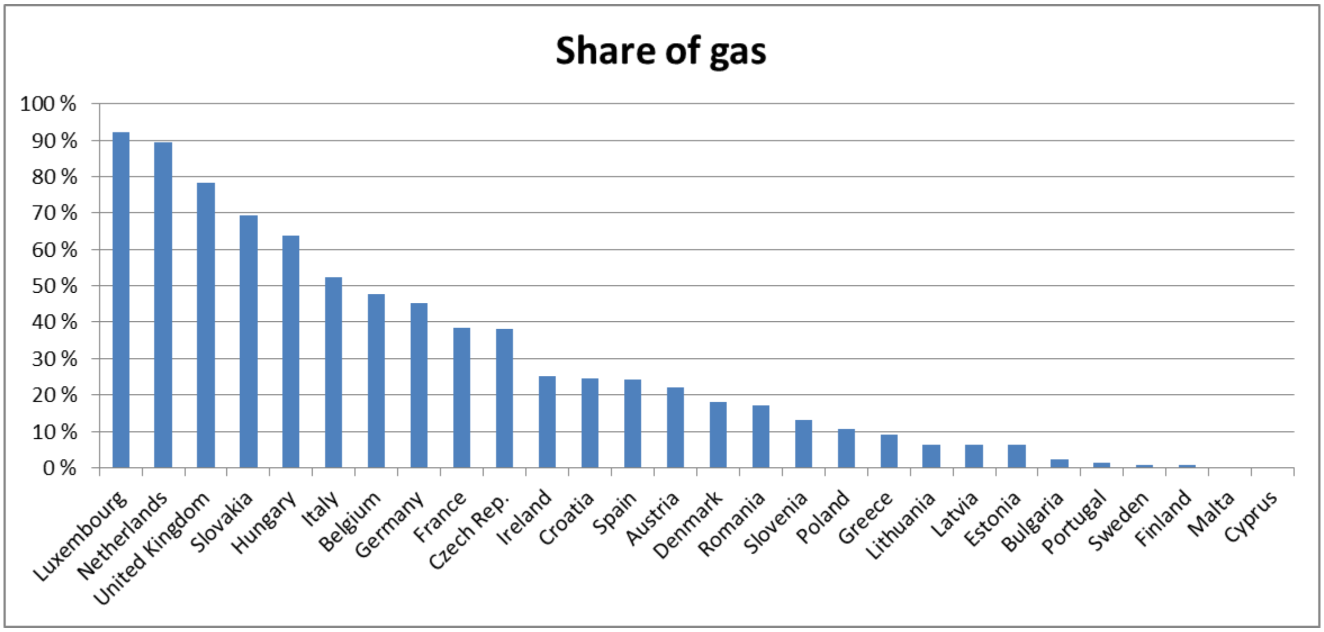


Figure 32. Share of gas in space heating in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011, and UK 2012). (Data source: Enerdata 2015).

Oil is usually more expensive than gas, and a high share of oil heating might prove to be an indicator for a suitable market, especially if the boiler equipment is old and inefficient on average. On the other hand, oil heating is usually based on central heating with water circulation. This might form a barrier for an investment in SETS.

[6] The difference between the lower and the higher heating value is the latent heat of vaporization of the water produced during combustion of the fuel. For natural gas this difference is around 10%. Thus a condensing boiler, which recuperates the condense heat, can achieve efficiencies above 100% when calculated with lower heating values, which is common in electricity and heat production calculations, as traditionally condensing flue gases was avoided at all costs because of high corrosiveness risk.

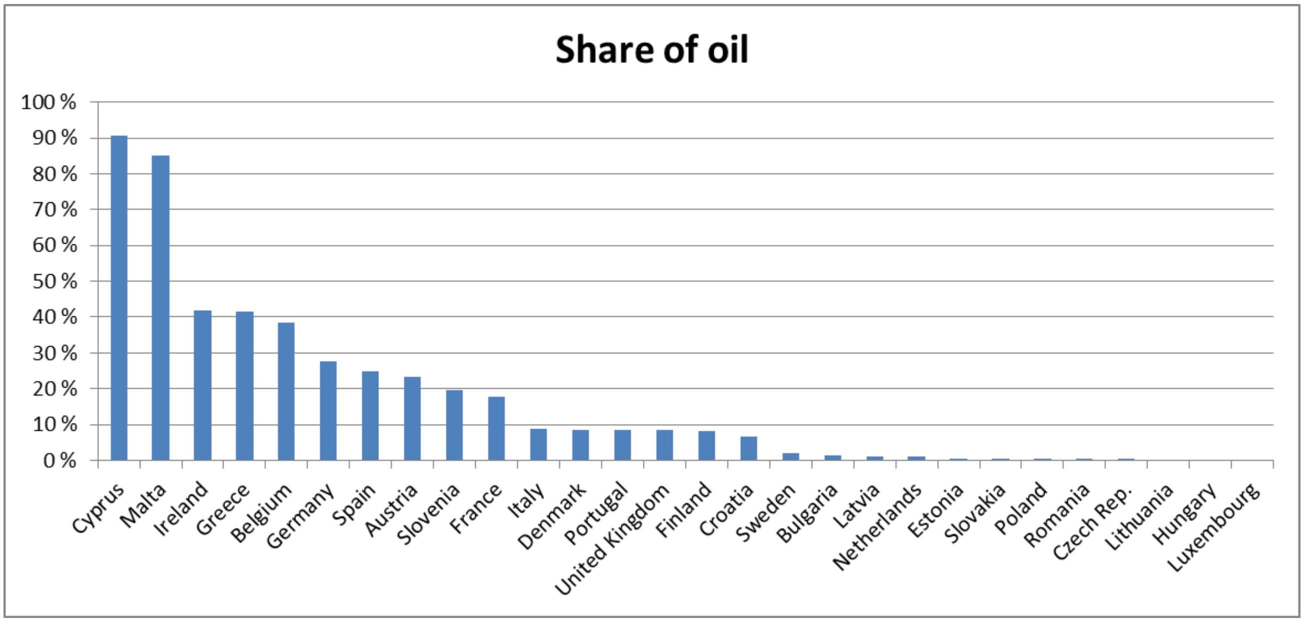


Figure 33. Share of oil in space heating in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011, and UK 2012). (Data source: Enerdata 2015).

District heat in space heating

The higher the share of district heating, the worse it is for SETS in general. District heating is usually quite competitively priced, although this, of course, depends on the local system and the utility. District heating systems have the benefit of being able to use cheaper solid fuels, waste or deep geothermal sources, which might be difficult for individual small-scale heating solutions. Smaller district heating networks, area networks, especially in Denmark, are also based on solar heating with seasonal storages. District heating in general is, however, targeted at more densely populated areas and thus especially for apartment houses, and there the measurements are presumably more often central, which demolishes the business case for SETS unless the electricity is also centrally billed.

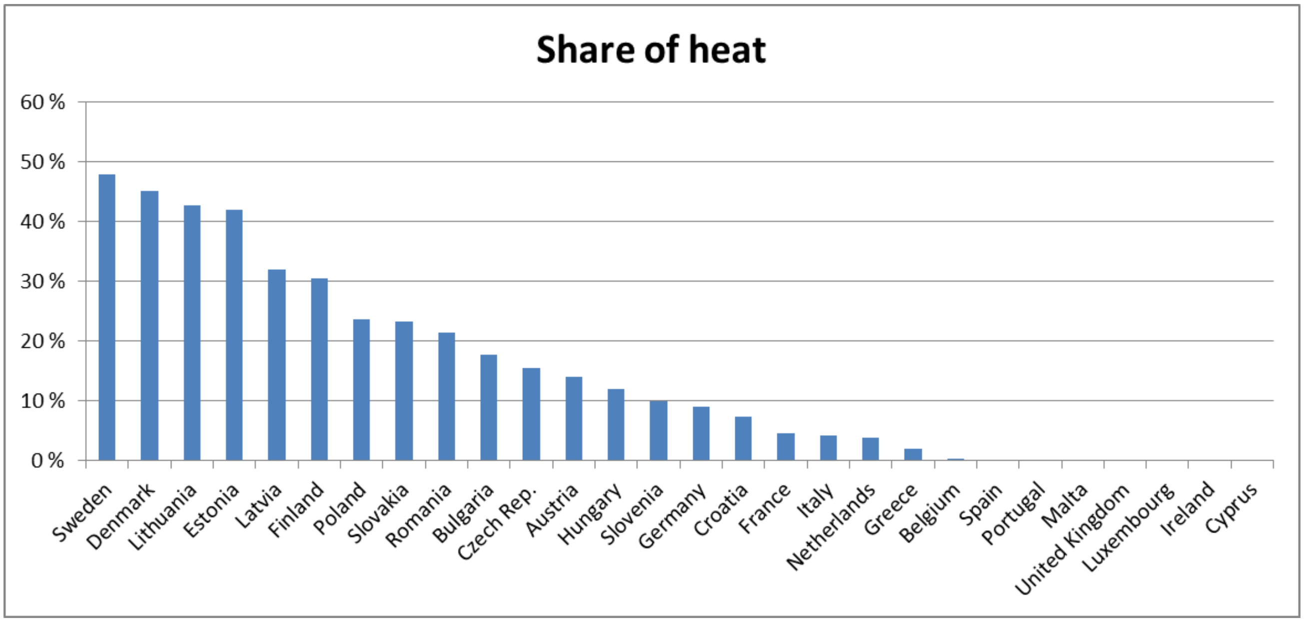


Figure 34. Share of district heat in space heating in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011, and UK 2012). (Data source: Enerdata 2015).

Apart from Enerdata, Euroheat & Power (2015) is another data source providing statistics on heat demand for some countries of Europe. In Table 1, total heat demand for residential heating and the share of residential derived heat in this is given. Clearly, markets with a huge residential heating demand but a low penetration of district heating seem to be the most interesting from the viewpoint of SETS. In absolute terms, the largest residential heating markets in this sample are the population-richest, Germany and France. However, climatic conditions clearly have an influence on the differences. For example, despite the fact that the populations of Germany and Finland vary by a factor of 15, the demand for residential heating is only 8 times bigger in Germany.

Table 1. Heat demand for residential heating in selected European countries. (Source: Euroheat & Power (2015), Eurostat database 2015, author's calculations)

	Heat demand for residential heating (TJ)	Residential derived heat (TJ)	Estimated share
Germany	1 664 400	184 486	11.08%
Finland	198 500	65 920	33.21%
France	1 050 000	51 565	4.91%
Austria	205 030	30 114	14.69%
Bulgaria	70 000	13 328	19.04%
Croatia	38 686	5 784	14.95%
Czech Rep.	172 070	44 997	26.15%
Denmark	131 187	68 726	52.39%
Italy	741 763	38 959	5.25%
Lithuania	25 500	19 455	76.29%
Netherlands	270 000	11 144	4.13%
Poland	431 853	176 000	40.75%
Slovenia	29 523	3 410	11.55%
Sweden	289 080	110 693	38.29%

Wood based space heating

A high share of wood is not good for the potential of SETS. Wood, even in pellet form, is relatively cheap compared to electricity, although there might be regional or country wise exceptions. A large part of the wood used in Finland for heating is from own forest or in the form of cost-efficient firewood billets. Wood is also used as auxiliary heat source in ovens and fireplaces as a cost-reducing element, for example in electrically heated houses.

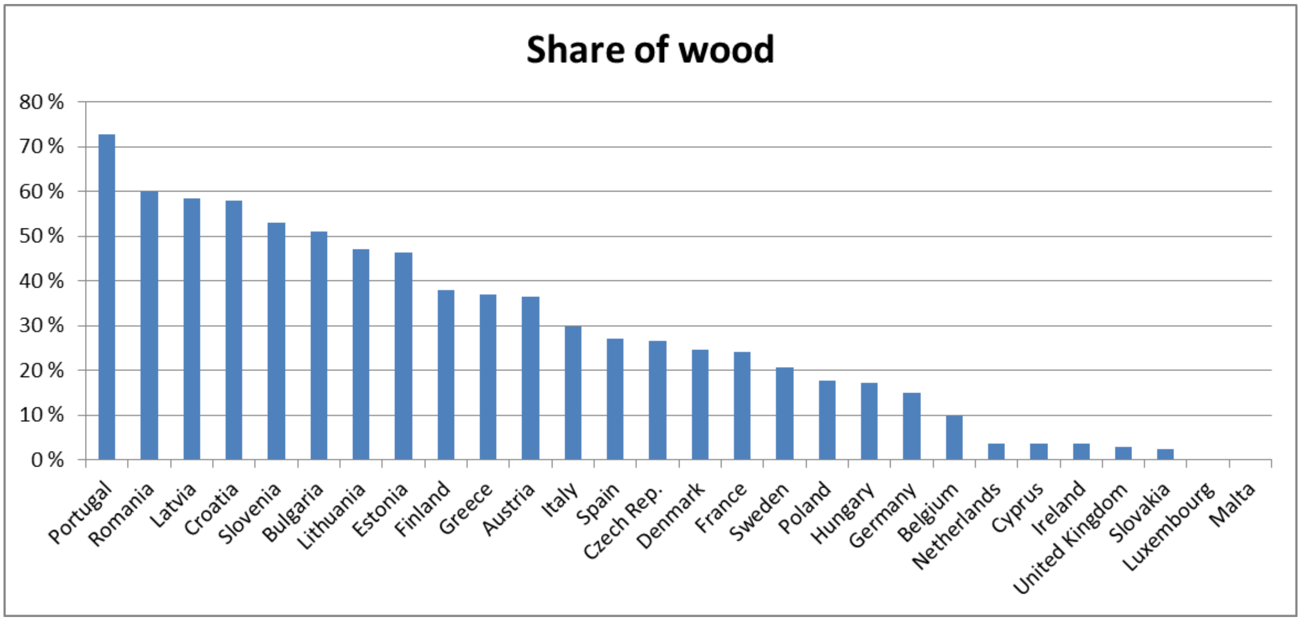


Figure 35. Share of wood in space heating in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011, and UK 2012). (Data source: Enerdata 2015).

Climatic aspects

Space heating per person tells us a little more about where space heating solutions matter more. Figure 36 shows person-specific space heating in 2013 in different EU countries in relation to average heating degree days. Heating degree day is a metric reflecting the demand for heating energy needed in a building and is derived from measurements of outside air temperature. As can be seen in the chart, climate is not the only factor affecting the need for space heating. Level of insulation, dwelling size per person as well as housing habits such as indoor temperature play a crucial role as well.

According to the specific space heating demands, discarding south-eastern and south-western countries, most European countries have quite similar demands independent of their latitudes. The space heating difference between UK and Italy is just a little more than 10 %.

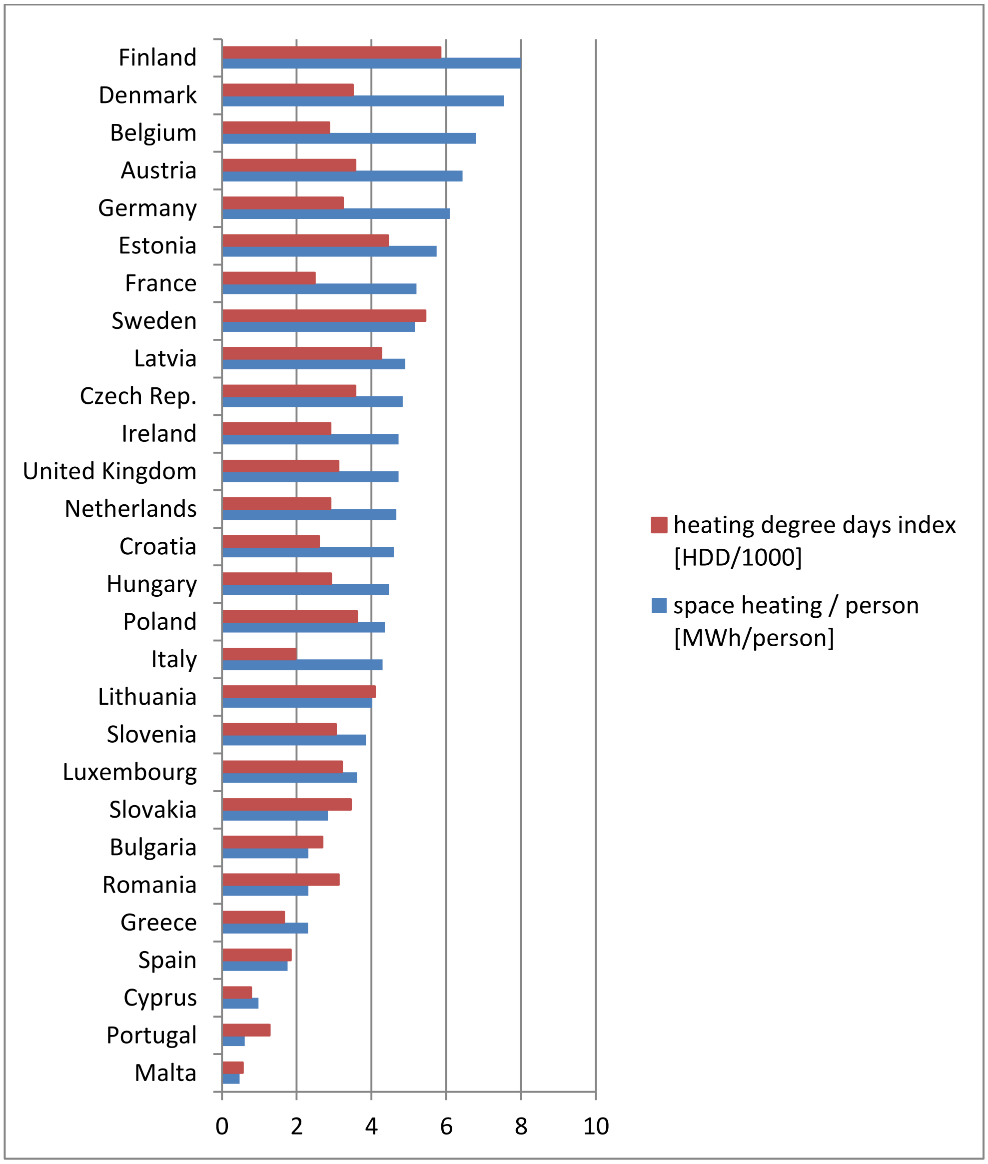


Figure 36. Space heating in the residential sector per inhabitant (MWh per inhabitant) in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011 and UK 2012) compared to the mean heating degree days 1990-2004 (degrees divided with 1000). (Data source: Enerdata 2015, except mean heating degree days Eurostat, 2015).

Heating of domestic hot water

Heat is also used for water heating in households. Final energy by heat source for water heating in different EU countries in 2013 is shown in Figure 37. Water heating is mainly determined by the population size, but also by other factors such as the share of heat based on on-site renewable energy sources, the efficiency of the energy conversion and the availability and use of heated water. Water heating with solar energy is the more popular the further south one goes, especially if the alternatives are expensive.

Electric water heating is usually combined with heat storage, as direct electric water heating would demand very high currents in respect to the fuses. The function of fuses is to set limits to the level of current. Electricity is much more popular as a heating source for water heating than for space heating.

SETS bring in that sense nothing new to the water heating market. Gas is the most used energy source. District heat is also very popular in the North and in Eastern Europe. Wood- or coal-based water heating is combined with heat storages, as the time lags are impossible for direct action. The market potential for electric water heating systems is mostly in oil and coal uses and to some degree as alternative to more primitive wood systems.

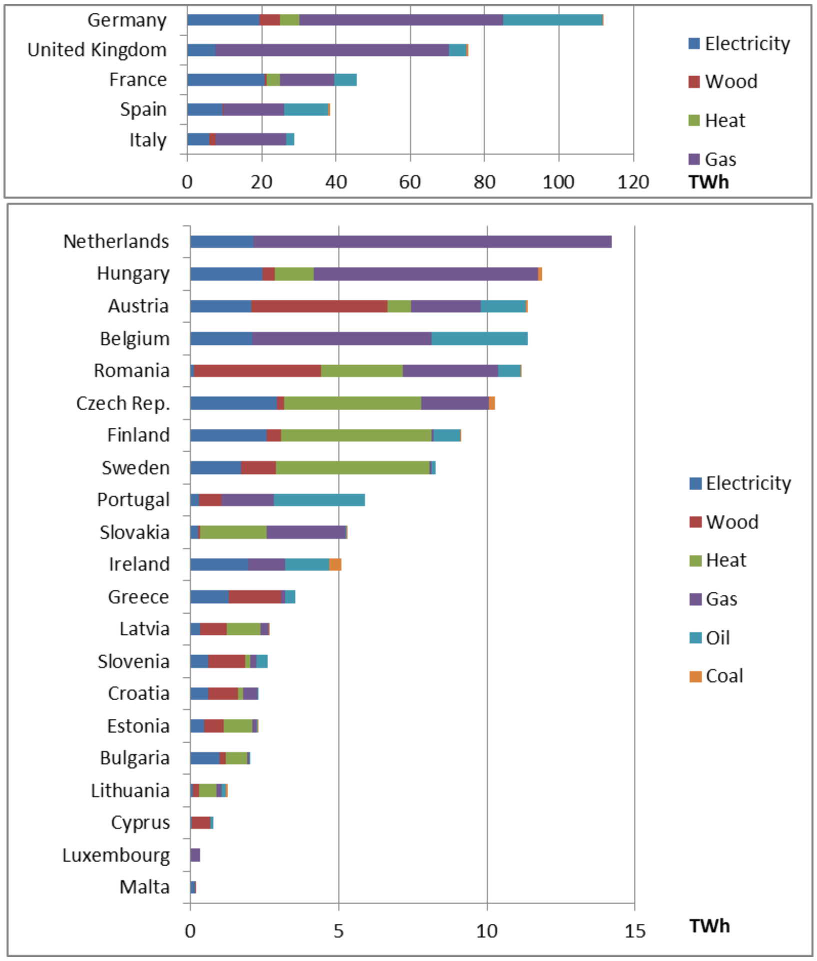


Figure 37. Heat sources for water heating in the residential sector in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011 and UK 2012, and Denmark and Poland data missing altogether). NB The x-axis scales are different in these two graphs, 0-120 TWh in the upper and 0-15 TWh in the lower. (Data source: Enerdata 2015)

Of Southern European countries, the ratio of space heating to water heating is very low in Cyprus (1.1), Portugal (1.1), Malta (1.3) and Spain (2.1), whereas it is very high in Greece (7.1), Croatia (8.4) and Italy (8.9). A very low ratio can be the result of missing heating solutions, whereas a very high ratio can be the result of solar-based water heating and/or weak insulations. Lithuania has the highest ratio with 9.1; the UK, Ireland, Germany and Finland all have similar ratios, between 4 and 5.

Looking at water heating per person we notice that there are larger differences, with Estonia and Finland showing the highest consumptions and Bulgaria, Greece and Malta showing the lowest. One reason for the high Finnish value may be the frequent sauna bathing that Finns indulge in in their homes (Figure 38).

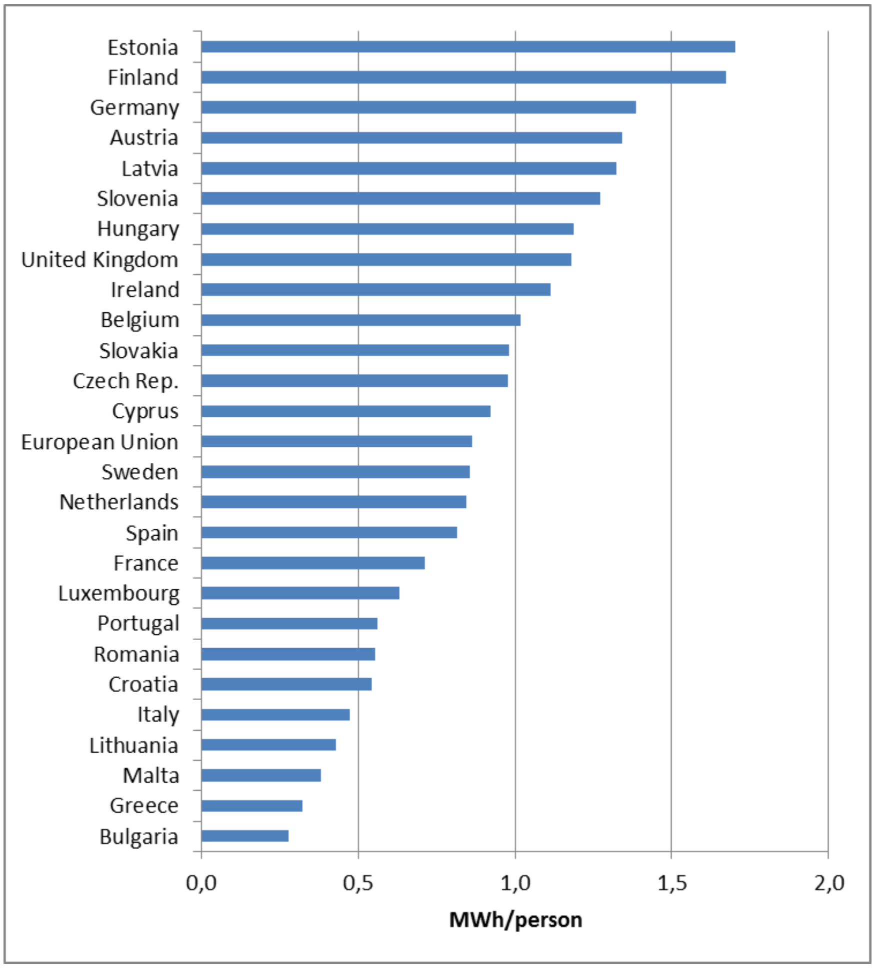


Figure 38.Energy use per person for water heating in the residential sector in different EU countries in 2013 (however, Estonia 2010, Hungary 2010, Lithuania 2012, Malta 2012, Netherlands 2012, Romania 2011 and UK 2012, and Denmark and Poland data missing altogether). (Data source: Enerdata 2015)

Aspects related to building types

A breakdown of the building stock by building type in the residential sector is presented in Figure 39, and it reveals major differences between the largest economies (BPIE 2015). Remarkably, the share of single-family buildings in the UK is quite large as is the share of multi-family buildings in Italy, on the other hand. SETS are suitable for dwellings irrespective of building type, but there might be differences between countries on how heating options are organized in multi-family buildings: whether there are central heating solutions or if the heating solution varies from apartment to apartment. Clearly an apartment-specific heating solution is favourable for SETS.

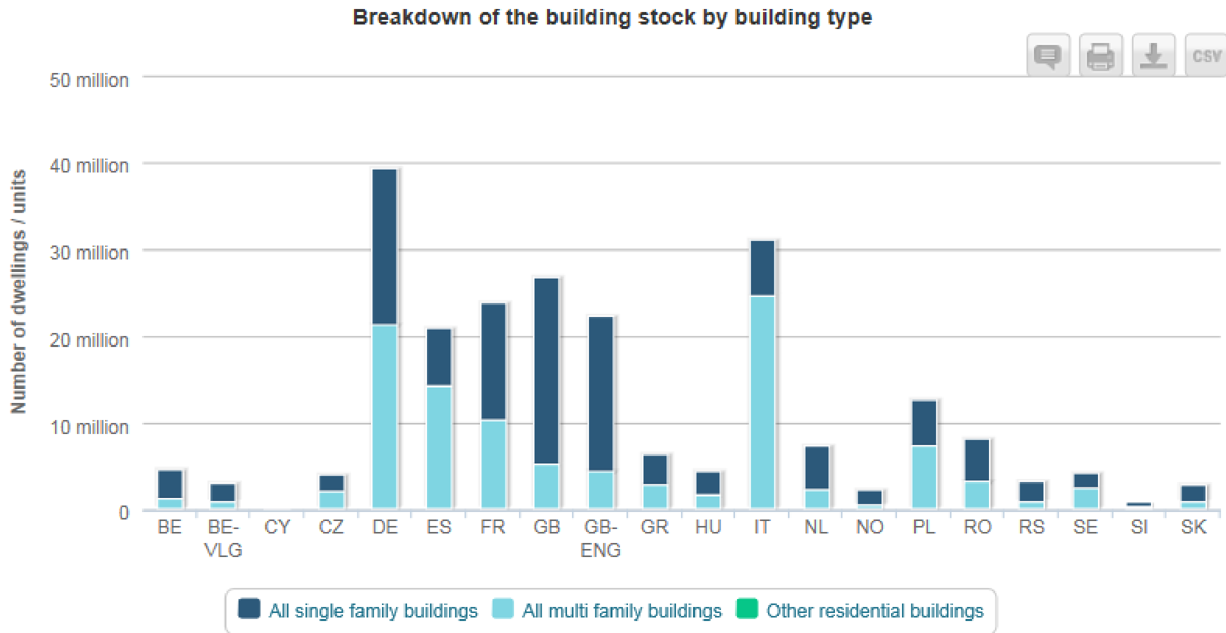


Figure 39.Breakdown of the building stock by building type (Source: BPIE 2015).

Data on heat deliveries is not available to a similar degree if we look at single-family houses, and fewer than ten European countries can be analysed, see Figure 40. Germany, the UK and France have large usages of coal and oil, and Austria and Italy also notable shares of oil use. The UK, France and Sweden have electric heating, although for example most of Sweden's electric heating is to a large degree not direct electric heating suitable for SETS.

Comparison of heating patterns for single family houses (Figure 40) and overall building stocks (Figure 29) is possible for these less than ten countries. Gas is the main fuel by a large margin in the overall building stock of the UK, and the same is true for single-family buildings. Similarly, according to the data, the significance of gas in single-family buildings in Italy is very high. This is contributed by the fact that wood heating in Italy is not observed in the statistics concerning single-family houses. Of the largest economies, Germany and France have somewhat more diversified heating fuel structures in both single family houses and the overall building stock, respectively. Oil and wood in both countries, and additionally electricity in France, represent significant heating solutions in addition to gas. From countries with widespread district heating infrastructure, most visibly Sweden and Denmark, it can be observed that this district heating is concentrated to multi-family houses.

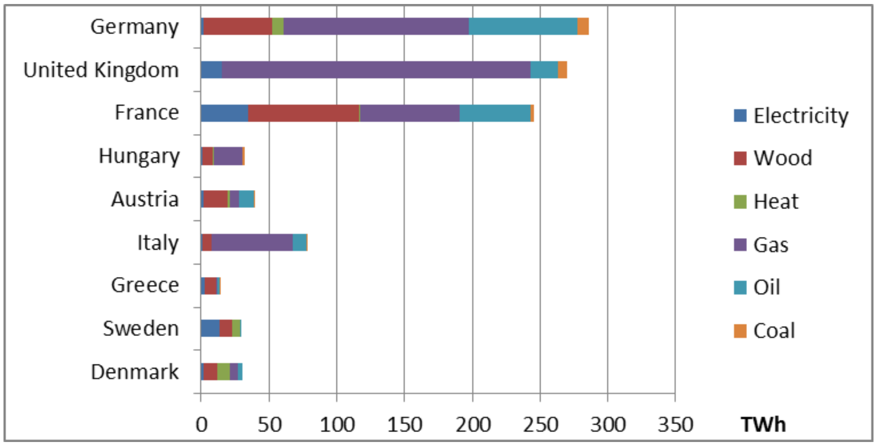


Figure 40. Heat deliveries according to heat source in the residential sector for space heating in single-family houses in different EU countries in 2013 (however, Germany 2011, Hungary 2010, Italy 2006 and UK 2006). (Data source: Enerdata 2015).

Single-family houses are best suited for SETS, as they are responsible for their own heating as well as electricity usage. Apartment houses can have flat-based heating systems but also central heating, where the usage in a single apartment is not measured separately. Although this will change with new builds, the large existing stock will not change. It would be too expensive to install apartment-specific measurements in most of them. The electricity can be measured and billed apartment by apartment, but there are also solutions where there is only a joint bill. So the general energy measuring and billing constellation in apartment houses can have a large impact on the potential for SETS. For example, in general for apartment houses:

- In Finland, heating is jointly measured and billed, but electricity usage is per apartment; thus there is no potential for SETS.

- In Ireland there is some housing where the heating and the electricity is managed by the landlord, offering a potential for SETS: if the houses are owned by a local authority or housing association they may already have a heating refurbishment programme in place in which case they have money to spend on changing the existing electric heating system to a more efficient one. The social housing segment comprises some 130000 appartments.

- In Germany generally speaking the heating and electricity are managed and paid separately by the tenant on top of the monthly rent (Mieterbund, 2016). This might become an obstacle to SETS, since the landlord has no motivation to make investments, which solely benefit the tenant. On the other hand, the tenant is not willing to invest in an apartment/house which does not belong to him. One possible solution might be an aggregation business model, where the aggregator makes the investment in the devices.
- In Latvia, electricity is billed per apartment and paid individually by the tenant or the owner of the apartment (most of apartments are privately owned). Heat consumption is usually metered for the whole building and then apportioned to each apartment based on the floor space. Hot water consumption is mostly billed individually for each apartment. Only a few apartment houses (recently built or retrofitted buildings) have heat meters installed in each apartment, which allows individual billing for the heating. Individual apartment heating is much less popular in apartment buildings in comparison to district heating, thus offering little potential for

SETS. However, electric heating is sometimes used as an additional heat source for extra comfort, since district heating sometimes does not provide enough heat especially at the beginning and at the end of the heating season (in autumn and spring).

Residential power and gas prices

The end-user price of electricity consists of energy and supply costs, paid to the seller, with network costs paid to the deliverer, i.e. the network company, and taxes and levies which end-up in state coffers. Figure 41 shows the end-user prices of electricity and gas including all taxes and levies for 2014 (second half-year). These costs are annual averages including fixed and variable cost items, so they are not directly comparable: even without SETS, an end-user would have to pay for the fixed costs of electricity. These costs do, however, give a notion of the competition setup. Just the network costs and levies and taxes are higher than the cost of gas in all countries but the UK, Spain and Bulgaria (NB! Part of the taxes here are VAT for the energy and supply). As can be seen, for example Germany and Italy have high prices of electricity while their gas prices are low. To switch from gas to electric heating would demand quite highly valued benefits from the controllability of SETS. Even if the energy and supply of electricity were free of charge at times of high winds, gas would be a strong competitor. Currently only the wholesale price of electricity at times of high winds can be zero, which does not translate to zero retail price taking into account network charges, surcharges and taxes. Can SETS be a replacement or be used as auxiliary heaters in fossil fuel-heated houses, and what about biomass or district heated houses? The costs of other heating alternatives such as district heat, wood logs or pellets or oil are not readily available and will have to be scrutinized when more in-depth analyses of individual countries and cases are made. Heat pumps use electricity, but as the coefficient of performance (COP) can be well above 3 and the variable costs then are less than a third, it gives a strong competitive advantage, which the benefits of the controllability of the SETS might find hard to match.

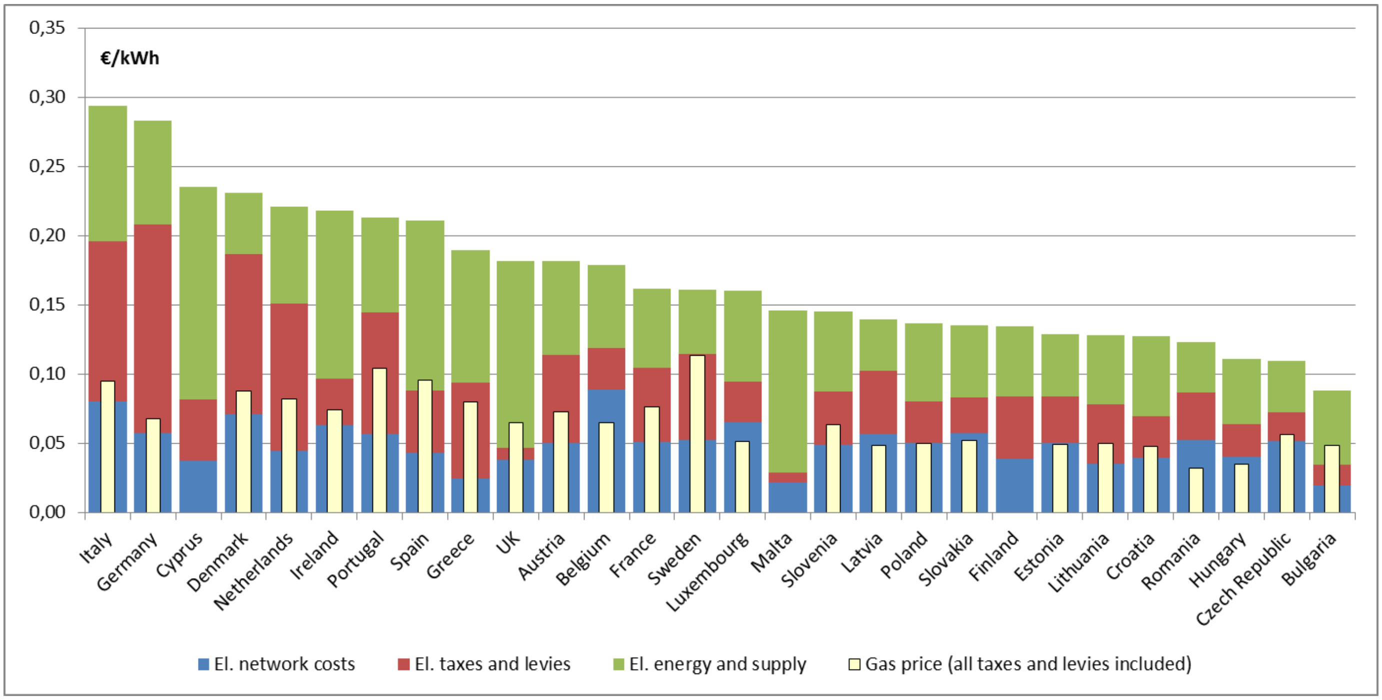


Figure 41. End-user price of electricity (5…15 MWh/a) and gas (20…200 GJ/a) including all taxes and levies. Data source: Eurostat 2015.

If the end-user prices have time-dependent components, SETS could directly benefit from the price difference of the different time slots. In modern markets and with automatic meter reading, as for example in Finland, the energy and supply price of electricity can even be directly dependent on the spot price each hour (or equivalent time step), allowing the end-user to directly benefit from his demand side management actions. In other markets, perhaps a go-between is needed (an aggregator, seller, …) who controls the SETS and benefits from the price differences on the market and in turn is able to give discounts to controlled end-user. An aggregator may, for example, have access to more profitable flexibility markets than a single end-user, such as balancing or reserves markets.

The more comprehensively the real costs of an electricity system are reflected in end-user tariffs, the more economically justified the market-based environment is set for the penetration of SETS, or any other demand side technology. As an opposite example, if end-user charging is based on static and embedded cost-based regulation rates reviewed e.g. once a year, it is a challenging incentive environment for flexible end-user solutions. To understand the different tariff scheme practices in European countries, we here a look at the power tariff structure in Europe. Both network and energy tariff structures have a potential effect on profitability of demand-side technologies and consequently on their market potential.

Table 2 presents the network tariff structure from the end-users' perspective in European countries based on the EURELECTRIC survey (Eurelectric, 2013b). The tariff structure is divided into fixed charges, capacity-based charges, energy charges, reactive energy and other. Fixed charges (€) do not depend on the energy use pattern of the end-user. Capacity-based charges, also referred to as demand charges, are charged per capacity (€/kW), e.g. based on peak usage. Energy charges (€/kWh) are based on the volume of energy used. Reactive energy charge (€/kvarh) is mostly relevant for industrial end-users, for whom they are targeted in most countries. Immediately, significantly different tariff structures in Europe can be observed. According to the EURELECTRIC (2013) survey, network costs induced by household customers are to a large extent recovered from volumetric (€/kWh) tariffs, approximately 50–70% in most countries.

Table 2. Current network tariff structure in 16 reviewed European countries (source: EURELECTRIC 2013b).

Country	Structure of network tariffs for household customers				
	Fixed charge [€]	Capacity charge [€/kW]	Energy charge [€/kWh]	Reactive energy (€/kvarh)	Other
BE	Yes	No	Yes	No	N.A.
CH	Yes (max 30%)	Seldom	Yes (at least 70 %)	No	
CZ	Yes	No	Yes	No	N.A.
DE	Possible	No	Yes	No	N.A.
DK	Yes	No	Yes	No	N.A.
EE	Yes	No	Yes	No	N.A.
ES	No	Yes	Yes	No	Meter rental
FI	Yes	No	Yes	No	Metering fee
FR	Yes	Yes	Yes	No	N.A.
GR	No	Yes	Yes	No	N.A.
IT	No	Yes	Yes	No	N.A.
LT	Possible**	No	Yes	No	N.A.
NL	Yes	Yes	No	Possible, depends on DSO	N.A.
NO	Yes	Seldom+	Yes	No	N.A.
PL	Yes	No	Yes	No	N.A.
PT	No	Yes	Yes	No	N.A.
SE	Yes	Seldom+,	Yes	No	N.A.

+ implemented for few DSOs

From a SETS point of view, seasonal/time-of-day characteristics are of special interest. The EURELECTRIC (2013) survey revealed that in 10 out of 16 countries participating in the survey, some form of time-of-use network tariff options exist (e.g. peak/off-peak, day/night, seasonal: summer/winter).

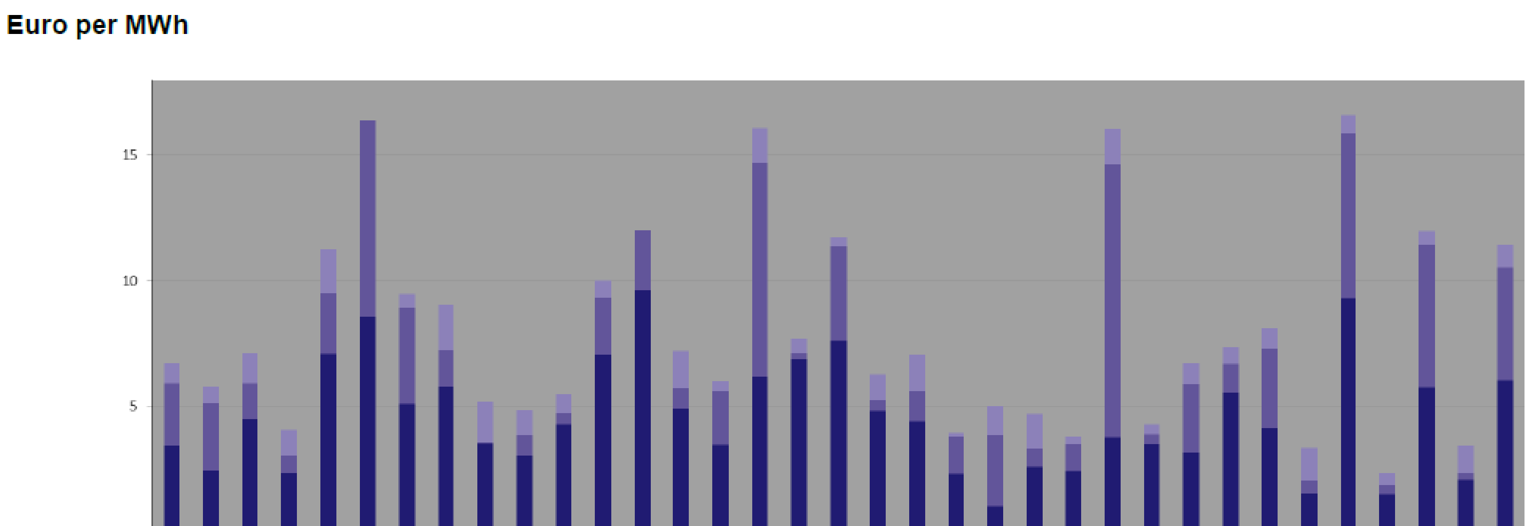
A conclusion in line with EURELECTRIC (2013) was documented in a study by AF-Mercados, REF-E & Indra (2015), commissioned by DG Energy. In the report, the electricity distribution tariffs in Europe were studied in 28 European countries. 15 of the 25 European countries that responded announced that time differentiation exists in electricity distribution tariffs for the consumer group “Households”. These countries are Austria, Croatia, Czech Republic, Estonia, France, Greece, Ireland, Lithuania, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, the UK, and also Finland can be added to this group. Sweden and Slovakia pinpointed that there is some variation between the individual DSOs on the issue. Additionally, the tariffs for small-scale and large-scale industries were reviewed; however, they are not considered being primary markets for SETS.

Tariffs for distribution and transmission are not usually separated in end-user bills (EURELECTRIC 2013). However, the transmission tariffs in Europe are generally various. *ENTSO-E Overview of Transmission Tariffs in Europe: Synthesis 2015* reveals that at least 14 European countries are equipped with at least one time differentiation in transmission tariffs (ENTSO-E 2015). The countries identified are Belgium, Croatia, Estonia, Finland, France, the UK, Greece, Montenegro, Northern Ireland, Norway, Portugal, Serbia, Slovenia, and Spain.

In addition to time differentiation, there are many other differentiation factors in transmission tariff schemes, according to which the final transmission tariffs are determined. In the following a few possibilities, according to which the tariffs can differ, are given:

- Locational charges: the tariffs might differ according to geographical location of the generator or consumer. This differentiation may target to allocating the cost burden of transmission network according to cost-causality principle. For example, if it is costly for certain location to arrange transmission service, the grid users in that area may be charged higher tariffs.
- Inclusion of support schemes: the tariffs may include component to collect funding for e.g. support for renewable energy. These tariff components are reflected in the taxes and levies block for the final consumer.
- Differentiation between consumer classes: large consumers might be charged on a different basis than small-scale consumer, for example based on the fuse size.

For the big picture, Figure 42 shows components of unit transmission costs in European countries divided into losses, system services, and infrastructure. The total unit transmission tariff for 2015 exhibits a strikingly wide range, between 2.35 EUR/MWh of Slovenia to 16.61 EUR/MWh of Slovakia.



	AT	BE	BA	BG	HR	CY	CZ	DK	EE	FI	FR	DE	GB	GR	HU	IE	IS
Losses	0,78	0,62	1,16	1,02	1,72	0,00	0,57	1,82	1,64	1,02	0,76	0,67	-	1,50	0,40	1,36	0,57
System Services	2,51	2,71	1,42	0,69	2,45	7,80	3,80	1,46	0,03	0,77	0,42	2,29	2,39	0,84	2,14	8,50	0,26
Infrastructure	3,46	2,46	4,55	2,37	7,10	8,60	5,14	5,79	3,55	3,09	4,32	7,08	9,64	4,89	3,48	6,21	6,88

	IT	LV	LT	LU	MK	ME	NL	NI	NO	PL	PT	RO	RS	SK	SI	ES	SE	CH
Losses	0,37	1,01	1,44	0,14	1,20	1,40	0,31	1,36	0,41	0,85	0,68	0,86	1,33	0,75	0,46	0,58	1,09	0,91
System Services	3,74	0,44	1,21	1,50	2,82	0,72	1,07	10,89	0,37	2,70	1,11	3,11	0,52	6,54	0,38	5,69	0,26	4,49
Infrastructure	7,62	4,84	4,41	2,33	1,05	2,61	2,44	3,79	3,52	3,19	5,58	4,17	1,53	9,33	1,51	5,76	2,09	6,06

Figure 42. Components of the Unit Transmission Tariffs (Source: ENTSO-E 2015).

5. MARKETS AND MARKET CONSTRAINTS/ BARRIERS FOR SETS

What profit can be made with the “smartness in SETS”, and in which markets? And are there barriers? This is a quite demanding and multidimensional question and is best answered looking at each country and market separately. However, some general observations can be made.

SETS can face several kinds of barriers for market penetration. Since one key aspect is the profitability of the devices, economic aspects are among the most striking. However, other aspects exist as well as market design-related, regulatory, technical barriers and barriers related to the interaction with the end-users. We use as a basis for our analysis the work done by EU-DEEP project (EU-DEEP, 2009), which has analysed a number of aggregation business cases from the profitability point of view. The analytical tool developed is here examined from the SETS perspective.

Aspects related to power market design

European power market design characteristics[7]

European power markets are increasingly integrated, and as their integration and liberalization as a long-term EU target proceeds, the structure of power trading and markets have a reason to become more harmonised. In practice, there are still many shortcomings and market barriers in the European power markets. Typically, the power market is organised into financial power markets and physical power markets as presented in Figure 43[8].

The largest physical power market is the day-ahead power market, where a spot market price for electricity for each hour of the delivery day is determined. These prices are determined according to supply and demand bids of market participants. Bidding closes 12–36 hours before the delivery hour; this is referred to as gate closure. Intraday market is a continuous trading market where adjustments to trades made in the day-ahead market are typically made until one hour prior to delivery. The market opens after the day-ahead market is closed.

The regulating or balancing power market is a tool for the transmission system operator (TSO) to maintain a balance between generation and consumption in real time. Since the electricity market liberalization beginning in the late 1980s, TSOs no longer necessarily hold generation resources in direct ownership, and balancing services may need to be procured. It must be noticed that terminology related to markets, especially considering intra-day and balancing markets, is not always unambiguously used.

[7] This section describing the terminology and areas of electricity markets is based on Ruska & Similä (2011)
[8] Details differ between market areas. The details of the characteristics here primarily follow the Nordic market. The markets will also evolve. For example, balancing issues have produced the need for shorter time steps, half an hour or even quarter hour steps.

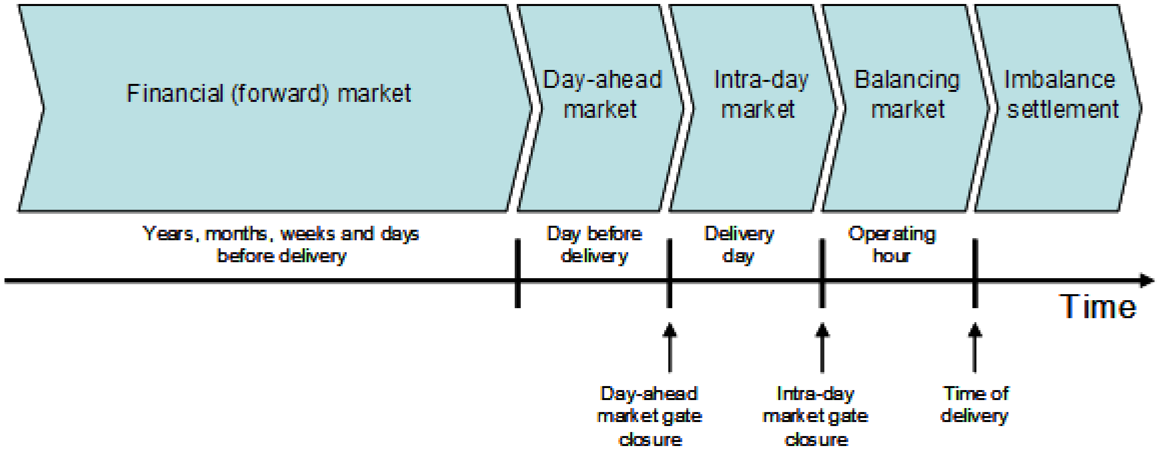


Figure 43. Structure of power trading. Gate closure refers to the moment after which the bids submitted to the exchange cannot be modified (Ruska & Similä 2011).

Imbalance settlement

The most important gate closure is a day ahead of delivery. Almost all markets allow intraday trading, which shortens the time gap between gate closure and real time delivery. This generally reduces the need for balancing settlements and thus also reduces related costs for market actors. Below Table 3 lists the countries, where intraday markets either exist or are planned for in the near future.

Table 3: Existence of intraday markets. Based on (EWEA, 2012), updated information.

	Intraday market	Is load accepted in energy balancing?
Austria	X	N/A
Belgium	X	N/A
Bulgaria	X	N/A
Cyprus	X	N/A
Czech Republic	?	N/A
Denmark	X	yes
Estonia	X	N/A
Finland	X	yes
France	X	yes
Germany	X	yes
UK	X	yes
Greece	X	No
Hungary	Intraday market launch in Q1 2016	yes
Ireland	Intraday market launch in 2016	yes

Italy	X	N/A
Latvia	X	N/A
Lithuania	no	N/A
Luxembourg	no	N/A
Malta	no	N/A
Northern Ireland	ID market launch in 2016	yes
Norway	X	yes
Poland	X	N/A
Portugal	X	N/A
Romania	X	N/A
Slovakia	X	Yes
Slovenia	no	yes
Spain	X	N/A
Sweden	X	yes
Switzerland		yes
Netherlands	X	yes

Despite the general EU target aiming at harmonization, market designs in Europe vary, having their impact on the potential of SETS. The time from gate closure to delivery can vary from 1 hour to 24 hours. The longer the time gap, the greater the risk of forecast errors either in production or consumption or both and, therefore, the need for balancing actions. Thus, a combination of a long time gap and the ability to use DSM for balancing provides encouraging incentives for SETS utilization.

The market actors responsible for balancing can trade until gate closure, but need then to report the contract positions to the system operator. After the delivery, actual and notified positions are compared and the differences are paid for through imbalance settlement mechanisms. In some markets, only the aggregated values of the portfolio have to be sent allowing balancing after gate closure. In other markets, the balance responsible party (BRP) has to notify of planned generation, from each unit, and consumption separately. Figure 45 below shows a map of Europe listing the countries according to the balancing process. In countries with a self-dispatch portfolio based balancing process, an aggregator is able to save settlement fees by correcting the forecast errors in supply or demand through the flexibility provided by SETS.

Capacity mechanisms

As an additional element to so-called energy-only market design (Figure 43), **capacity mechanisms** are a regulatory intervention to improve the functioning of electricity markets. Lack of price-responsive demand and limitations in storing the product are well-known characteristics of electricity as a product. These issues have an effect on exposing the market on market power during times of high demand. The market power issue can be tackled with selected measures such as price caps. However, as a result, it has been questioned whether market prices give sufficient incentives for investments in new capacity. This set-up has facilitated the rather exceptional discussion of capacity mechanisms within the electricity sector that has been going on even for decades.

Rapid growth of subsidized intermittent renewable electricity has further raised the issues of its effects on utilisation and profitability of conventional generation. Does an energy-only market produce sufficient amounts and the right type of capacity under these circumstances? This has intensified the discussion on the capacity mechanisms in Europe in recent years. On the other hand, capacity mechanisms have been criticized for their potential favouring of (fossil) capacity and concentration on the generation side at the expense of the demand-side. Furthermore, issues of their distortion of the market signals, with national mechanisms creating a barrier for market integration, and for imposing a regulatory risk for market participants, have been brought up (Koreneff et al. 2014).

Capacity mechanism represent a means to compensate generators for the capacity needed to give the consumers the standard of security that they would (collectively) like. Typically, a capacity mechanism organiser, e.g. system operator or regulatory body, affects the outcome of the mechanisms directly or indirectly. This can be done either by determining the payment or an amount of capacity to be auctioned. Capacity mechanisms can take many forms and designs, as many different capacity mechanism designs have been implemented and/or are under discussion throughout the world. As can be seen from Figure 44 also other big European markets, United Kingdom, Germany, France, Italy, and Spain, have their own approach and status on the capacity mechanism issue.

Capacity payments can be described as a traditional type of mechanisms. Systems used in Spain an in the All-Island market (i.e. Ireland and Northern Ireland) belong under a type of capacity payments. For example, the capacity payment used in Spain since 2007 is a typical availability-based capacity mechanism. In these systems, generators offering capacity in the energy market would receive an administratively determined payment as compensation for having capacity available, regardless of whether it was dispatched to run.

Capacity markets are a market-oriented way for capacity mechanism. That is, they can be described as a marketplace which sets a price for capacity units according to their supply and demand. Of the largest European economies, United Kingdom launched its version of the capacity market in late-2014. The first auction was run four years ahead of the year in which capacity must be delivered, i.e. the auction arranged in December 2014 concerns winter 2018/19 (“T-4” auction) (Koreneff et al. 2015).

From a SETS point of view, it is of essential importance how capacity mechanisms – if implemented – treat demand-side resources. An extensive review by Koreneff et al. (2014), based on international experiences and research, found various examples of capacity mechanisms where the demand-side can also be included, principally opening a door for a SETS type of technology. However, the exact designs of each market must be carefully analysed. The challenge related to SETS in capacity markets might be an uncertain availability of demand-side resources up to several years ahead. In the capacity market of United Kingdom, this challenge is partly tackled by secondary auctions that are scheduled to be run one year before delivery (“T-1” auction). They are intended for updating the positions of T-4 auctions and to attract bidding of demand-side resources. In the approach of United Kingdom, it is envisaged that DSR will participate in 1-year auctions, fully run for the first time in 2017, but there are plans for transitional arrangements before the first full auction is run, that is, specific DSR auctions to be run in 2015 and 2016 (Koreneff et al. 2015).

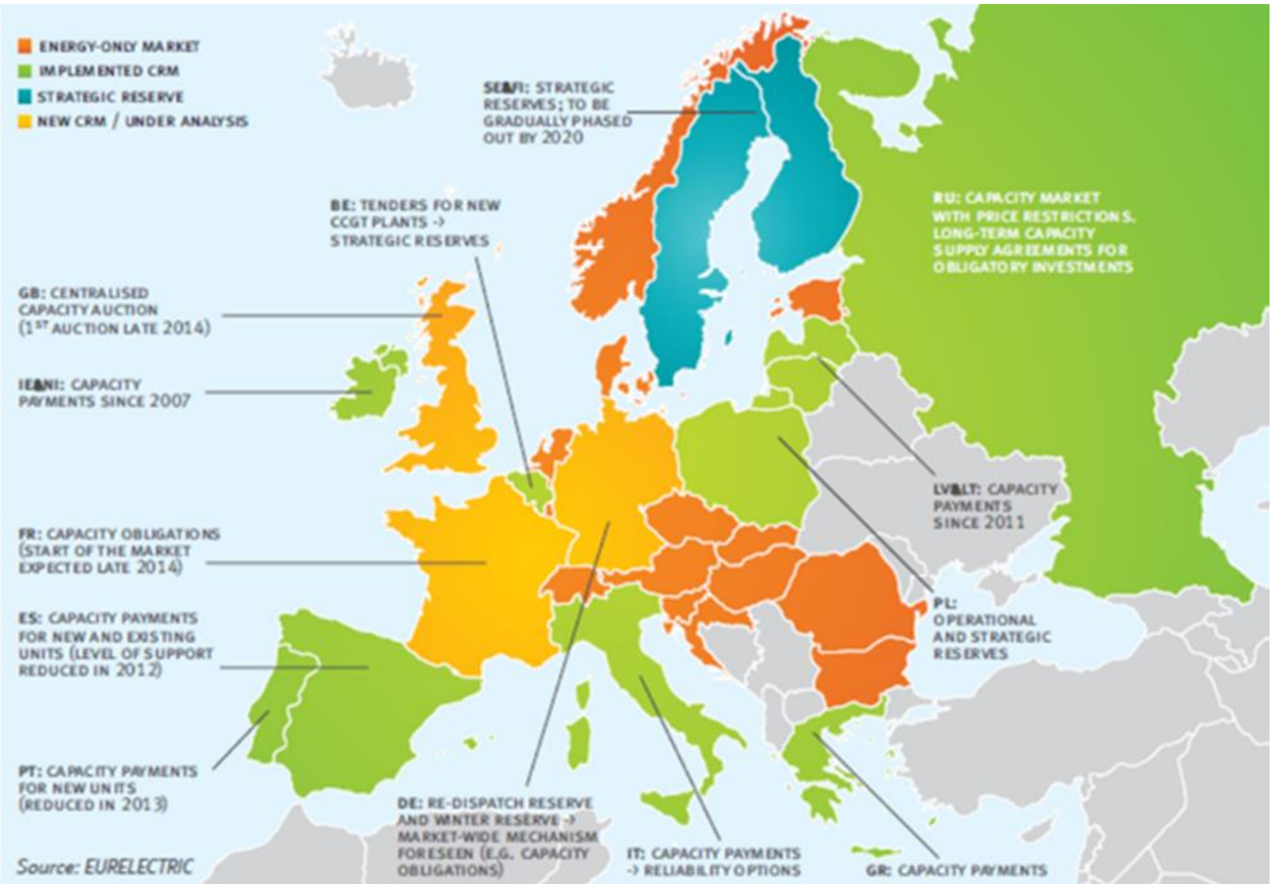


Figure 44: The state of capacity mechanisms in European countries (Eurelectric, 2014).

Balancing market

The transmission system operators have to ensure a balance between generation and demand, i.e. TSOs need to increase either demand or generation depending on whether there is too much or too little generation in relation to load. Also, the system frequency needs to be maintained at 50Hz: if demand is greater than supply, frequency falls and vice versa. Energy market actors including aggregators can provide balancing services to the system operator through generators, energy storages and large (industrial) or small-scale (households) demand responses. Depending on the market, only generation or a combination of two or all three can enter the balancing market. The market actors provide the service at a self-defined price and generally the cheapest bid wins. Greece is the only market, where load cannot provide such services in the balancing market – a market situation which clearly hinders one type of generating revenues from SETS by an aggregator. On the other hand, there are several countries where load is accepted in the balancing market: Denmark, Finland, Germany, the UK, Ireland, Hungary, Norway, Sweden, Switzerland, Netherland, Slovakia, Slovenia. For the remaining countries, the situation is unclear (ENTSO-E, 2015). Even if loads are allowed, they may still be restricted by high minimum sizes, for example 10 MW, for balance market offers.

Also the type of the balancing process differs from country to country: whether it is a central dispatch or a self dispatch (unit based or portfolio based), (Figure 45).

In addition to the balance market, the system operator might wish to make sure that there are enough reserves available for the case that the balancing service providers are not able to provide enough energy. These reserve product auctions are held well beforehand – in minimum days to over one year before real time. Because of the large time gap between the auction and the real time, SETS is not a suitable tool. There are also other system reserves, for example for frequency control. Here there are also differences between countries: in some countries only producers are allowed to provide system reserves whereas in other markets demand side actions are allowed as well.

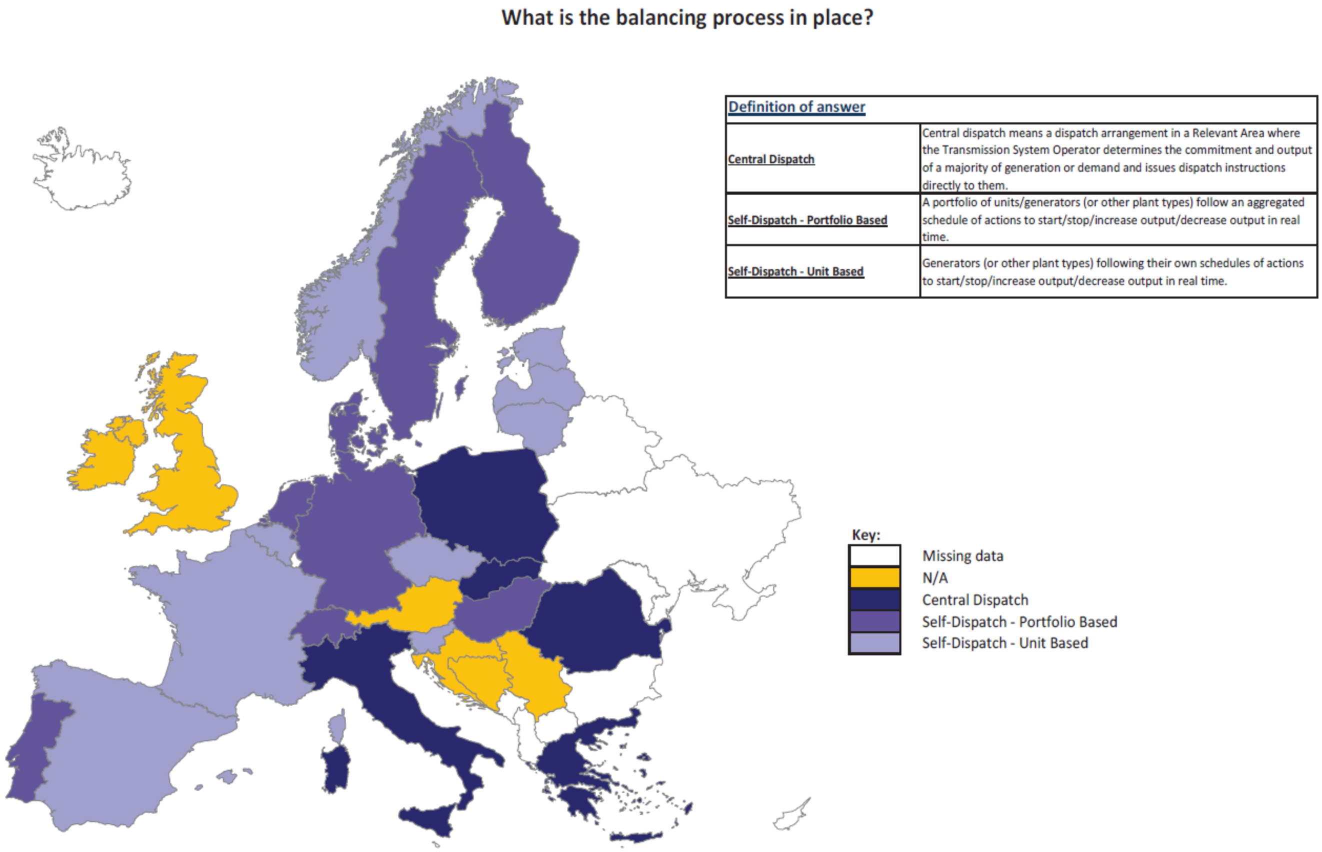


Figure 45: Types of balancing process (ENTSO-E, 2015).

SETS business opportunities

Two relevant revenues for aggregators are related to reducing imbalance costs and obtaining the best possible electricity prices on the market. Since SETS can help in balancing the market, clearly higher imbalance settlement fees can bring higher revenues for SETS based aggregation business. However, one has to notice that the price of imbalance settlement depends on the market situation. If there are too many balancing resources available, then the requirement for such will be swamped and the price will collapse – e.g. in Ireland the requirement for spinning reserve is about 350MW, but if all electric heating in the country were activated with SETS, then there would be far more flexibility available than required; hence the market saturates and the price collapses.

If the price of electricity varies a great deal, this opens possibilities for exploiting the price difference through time-shifting of SETS loads. When the priced is high, one can use the flexibility of SETS and either avoid buying electricity or – if one is also a producer – one can sell the electricity at a high price. And when the price is low, one can use the electricity to store heat for later use with the help of SETS. Generally speaking, high variability of spot price and high imbalance fees seem favourable for SETS, whereas low spot price variability and low imbalance fees give smaller financial incentives for SETS investments.

SETS might also provide other power system reserves and services, e.g. frequency control services, but that is very much system-dependent. From a monetary perspective, system services may well be very profitable. The same control feature can, however, only be sold to one place. If the balancing ability is sold to the balancing market, it cannot be used to reduce imbalances, etc.

Depending on market design, (network) end-user tariffs can be based partly on a payment for the connection capacity/fuse size or peak power (kW in a given time period). SETS can help to reduce the peak power and thus the cost component related to it. This concerns also the fuse size, as some countries such as Italy have dynamic software-based fuses.

Power market design: aspects related to SETS potential	Time from gate closure to delivery.
	Is balance adjustment of the portfolio possible after gate closure?
	Is demand response accepted in the balancing market?
	Can frequency control services be offered by demand, i.e. SETS?
	Are there peak demand/software fuse size-related components in the price of electricity?

Regulatory issues

Smart metering

Several regulatory aspects affect the markets for SETS. The most obvious one is the **availability of smart meters** in homes. Smart meters are not a prerequisite for the use or control of SETS as such, but in most cases for the verification of time of use of electricity. To be able to reap the profits of load shifting or balancing, the load has to be measureable on a suitable time scale, e.g. hourly.

Cost-benefit analyses (CBA) of smart metering were carried out in 2012, and the target was set to reach at least an 80% roll-out by 2020 in those countries with a positive outcome of the analysis (EC, 2014c). In 2014, the EC conducted a study to measure the progress of the deployment of smart meters in the EU. Figure 46 comprises the outcomes of the country specific CBA and their plans regarding the roll-out.

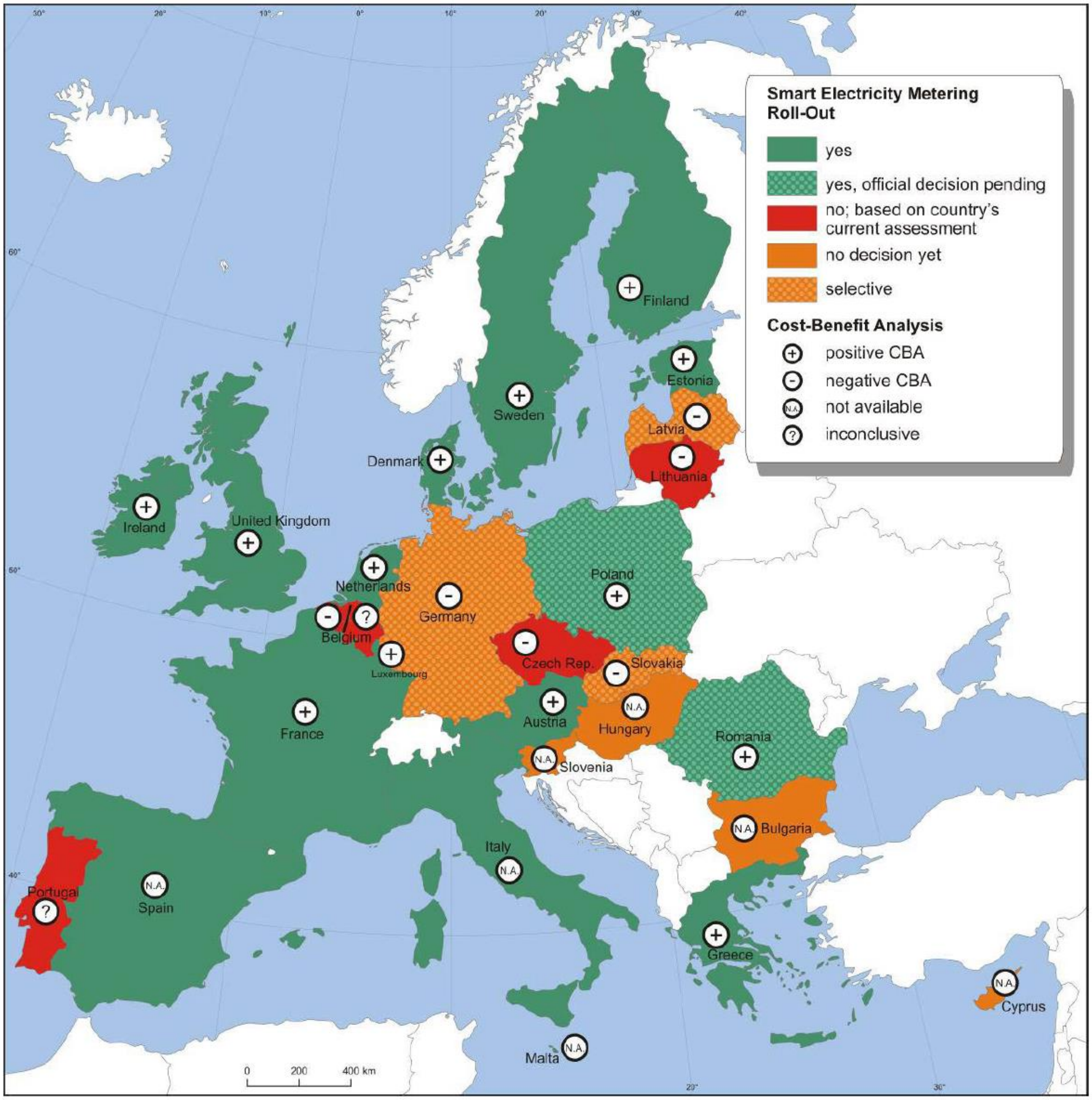


Figure 46: Plans for smart metering roll-out in the EU and outcomes of the CBA (EC, 2014c).

- 18 countries (Austria, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Luxemburg, Malta, the Netherland, Poland, Romania, Spain, Sweden and the UK) have already carried out or will carry out a large scale roll-out of smart meters by 2020.
- In Poland and Romania, the decision for large-scale roll-out of smart metering is still pending.
- Belgium, Lithuania and Czech Republic have decided not to proceed with the large-scale roll-out
- In Portugal, the CBA was inconclusive and will be updated annually.

- In Germany, Latvia and Slovakia the outcome of the CBA is negative for a full scale roll-out, but is positive for some specific groups of customers.
- In Bulgaria, Cyprus, Hungary and Slovenia the CBAs are not available. These countries have not expressed any intentions regarding large-scale roll-out of smart meters.

Support incentives that SETS could benefit from – or suffer from – are other regulatory aspects that may affect SETS market penetration.

Building codes

Electric heating is counteracting with energy efficiency policies – as electric heating may have a lower primary energy efficiency when compared to oil- or gas-fired heating systems, it is often regarded as an inefficient heating solution. Looking at final energy demand in households, electric heating has approximately a 100% efficiency, but modern gas boilers can top that with efficiencies over 105%. **National building codes** can, therefore, set some limitations to the use of direct electrical heating systems. In Sweden, if a new building has electrical heating, stricter energy efficiency standards are used (Boverket, 2015). Also, in Denmark there are restrictions: the use of electric heating in new buildings located within a district heating or natural gas supply network is not allowed. Since 1994 it is forbidden to change to electric heating in existing buildings (IEA, 2015). The new low energy houses might change the negative image of electrical heating: in this type of house the need for heating energy is very low and, therefore, an investment in a fuel-based heating system might be too expensive. Electrical heating has very low investments costs and could thus become more acceptable in the future.

Regulatory aspects	Are smart meters with hourly metering available?
	Does the building code limit the use of electricity in heating?
	Are there any support incentives that SETS could benefit from?

Technological aspects

Distribution networks have restricted capacities. With the introduction of smart grids, that is, a lot of automation and measuring, distribution networks will fare better. They will be better able to assess the state of the network and they can, thus, operate it more efficiently and with lower line capacity margins. Electric vehicles will shift energy demand from fuels to electricity at end-users. This will be a stress factor for many networks which were not built for that kind of loads. At the same time, increasing amounts of variable electricity production –which might often be connected to the distribution grid, is another source of stress not seen before. If the distribution networks were not planned for electric heating either, then there might be local restrictions for SETS to replace non-electric heating media. On the other hand, because SETS offers local flexibility, it can be the answer to local grids having troubles with increased loads. If electric heating can be load-shifted, as it can with SETS, this can have value for the distribution system operator.

Existing central heating delivery systems do also form a hindrance, as SETS will have a harder job to break through in such environments. For example, the operation as auxiliary heaters would need some kind of control of both the primary heating system, and SETS as auxiliary heat source. Metering is also a larger issue in apartment houses. If the building has a central heating system, are apartments metered separately? Is electricity metered, and billed, separately or not?

Passive or near zero houses of the future will have very low heating demands, which might affect the usability of SETS. This would have an impact on the size of the SETS, perhaps making them smaller, and that change may in turn induce other problems. But at the same time, with passive house standard, it no longer is economically viable to have central heating systems to provide for the small remaining heat demand. Thus, heat exchange systems are essential for ventilation, but might be complemented with some additional heat from electric heating.

Technological aspects	Distribution networks	Will SETS installation cope with the capacity limit of the distribution networks?
	IT	Smart meters, controller, energy management software
		Communication
	Metering points in apartment houses	Central or individual metering and/or billing of heat
		Central or individual metering and/or billing of electricity

End-user involvement

The end-user interaction has two aspects to be considered. One aspect is the behaviour or cultural questions related to the inhabitant of the home. There might be a lack of time or interest in demand-side management or difficulty in changing routine or behaviour. Since SETS are designed in such a way that the need for user interaction is minimized, it does not differ much from traditional electrical heating. However, in order to reap some of the benefits, the user needs to be willing to trust an external actor like an aggregator to take some control of the heating system – that is, to interact in the domain of privacy. Clearly not all end-users are willing to take this step, which might shrink the potential markets for SETS. Other questions and aspects:

- Are the devices working in a reliable manner and is the maintenance service provided by professionals?
- Is the investment financially competitive when compared to other alternatives?
- Can I trust the profitability analysis provided to me?
- Technology is developing – is it reasonable to expect that the cost of the device will come down in the future?
- Also, the willingness to take active steps in environmental protection and to pay something extra for it might vary depending on the values of the end-user.

One aspect is the amount of energy that can be shed due to the SETS. In addition to strictly end-user related restrictions, clearly the drawback of SETS is that the need for heating is to a large degree limited to the heating season, which varies depending on climatic conditions. On the other hand, heating energy forms a remarkable share of the total energy consumption of a household – in northern countries even more so. During the heating season the flexibility is available in principle 24 hours per day whereas during summer months, with a peak in solar electricity production, heating SETS cannot be used as storages.

Depending on the market, the maximum number of calls might be restricted affecting the usability of SETS as storage. Also the end-user has the possibility to reject the call.

End-user interaction	Domain of privacy/ willingness to trust an external actor to take control?
	Lack of interest or time
	Difficulty to change routine or behaviour
	Reliability and maintenance of the devices
	When is the correct time for investment?
	Profitability of the investment in relation to alternatives
	Willingness for environment protection
	Acceptance of electricity in heating
Available flexibility	Amount of energy that can be shed
	Maximum number of calls per day
	Maximum duration of flexibility (daily basis/ weekly basis) Ratio of end-users rejecting the call

6. Market characterisation matrix

In this chapter, the market characterization matrix is explained and presented with the help of several charts. In numerical form the matrix can be found in Appendix 1.

The market characterization matrix is divided into two parts: the first part aims at the characterization of the country in relation to the other countries. It is based on indexes, which help to compare the various countries with each other from the perspective of SETS. It gives an understanding of what factors are appealing for SETS in each country and, on the other hand, which factors might become a barrier for the SETS market penetration. The market size indicator matrix on the other hand is based on absolute values and draws a picture of the absolute market sizes based on both need for flexibility and suitability of heating segment.

Country characterization

The metrics used for the country characterisation give answers to the questions related to the driving force for SETS, competing flexibility options and potential market segment for SETS.

Two of the metrics selected for the country characterization matrix deal with residential space heating consumption, thus reflecting the potential market segment of SETS: space heating per inhabitant and share of electricity in space heating. The remaining metrics relate to the electricity generation and large-scale flexibility options: planned value for wind production share in 2020 provides the driving motivation for SETS: the higher the share of wind electricity production, the higher is the need for flexibility options. The remaining metrics reflect competing flexibility options for SETS: share of hydropower production, interconnector capacity per installed electricity production capacity and district heating market compared to the electricity market. These have an inverse effect on the potential of SETS: the stronger the competition, the smaller the potential for SETS.

The metrics shown in Table 4 and their scaling are chosen in such a way that values closer to one, the outer circle, indicate a good market potential for SETS, whereas for values closer to zero, the centre, the opposite is true. It has to be noted that the graphs show only indexes, not actual values. For example, the index for the share of electricity in space heating does not give the actual share of electrical energy in space heating. The values of the indexes are chosen in such a way that differences between the countries become visible on the chart, i.e. the country with the highest value, mostly get index value 1. The actual country-specific numerical values of the metrics can be read in Appendix 1.

Table 4: Explanatory notes on the axis and indexing evaluations used in the later graphs.

Index	Index is based on	Index value 0, centre	Index value 1, outer circle
Heat demand	Space heating per inhabitant	0 MWh/ person	8 MWh/ person
Electric. heating	Share of electrical heating of total space heating energy	0%	30%
Interconnector	Interconnector capacity per installed electricity production capacity, inverse	>40%	5%

Hydropower	Share of hydropower production	40%	0%
Wind 2020	Wind production share in 2020	0%	40%
DH/ El. Prod.	DH market size compared to electricity production	60%	0%

The countries are divided into four groups according to their geographical location in Europe as shown in Figure 47 – Figure 50. Each country is presented by a line on the graph and the closer the line to the outer circle, the more suitable the market is for SETS – in comparison to other European countries.

In general, it can be stated, that the Eastern European countries seem to be very homogenous, characterized by a low share of variable renewable electricity production, unambitious future plans to increase it, and a relatively low share of electricity in space heating (with the exception of Bulgaria); thus, the primary attraction for SETS in these countries seem to be missing.

In the Mediterranean area, the share of renewable electricity production is now already fairly high, but only in Portugal and Spain is it based on wind energy, whereas the remaining countries concentrate on solar electricity. Portugal, Spain and Cyprus are all planning to increase their share of wind electricity further in the coming years. The share of hydropower production is fairly low with the exception of Portugal (26%) and Italy (18%). The area is also characterized by fairly poor interconnector capacities. Space heating per inhabitant is low in comparison with colder climates, but Portugal and Spain have rather high shares of electrical heating (approx. 20%). Based on these indicators, Spain appears to be an interesting market for SETS.

The Nordic countries are characterized by a considerable need for space heating, in the Baltic States somewhat less. Sweden and Finland have a high share of electricity in space heating. Norway is not included in the chart, because of missing information on the residential sector. Denmark has already today a high share of wind electricity (31%), but the other countries have plans to increase it to almost or even above 10% by 2020. The area is connected and forms a single electricity market, the NordPool. The Nordic countries are characterized by high interconnector capacity. The Baltic States are treated as one entity with a transmission capacity of 22% of the electricity generation capacity to Finland, Sweden and Poland. Norway, Sweden and Finland have substantial hydropower capacity, although no pumped hydro capacity.

The Central-Western European countries are characterized by a relatively high need for space heating and – with the exception of France – a low share of electricity as a heating source. Ireland has already presently a high share of wind electricity (17%) but will strive to double it by 2020. Also Germany, UK and the Netherlands have ambitious plans with wind shares exceeding 20%. Austria is the only country with a substantial hydropower capacity, including also pumped hydro capacity.

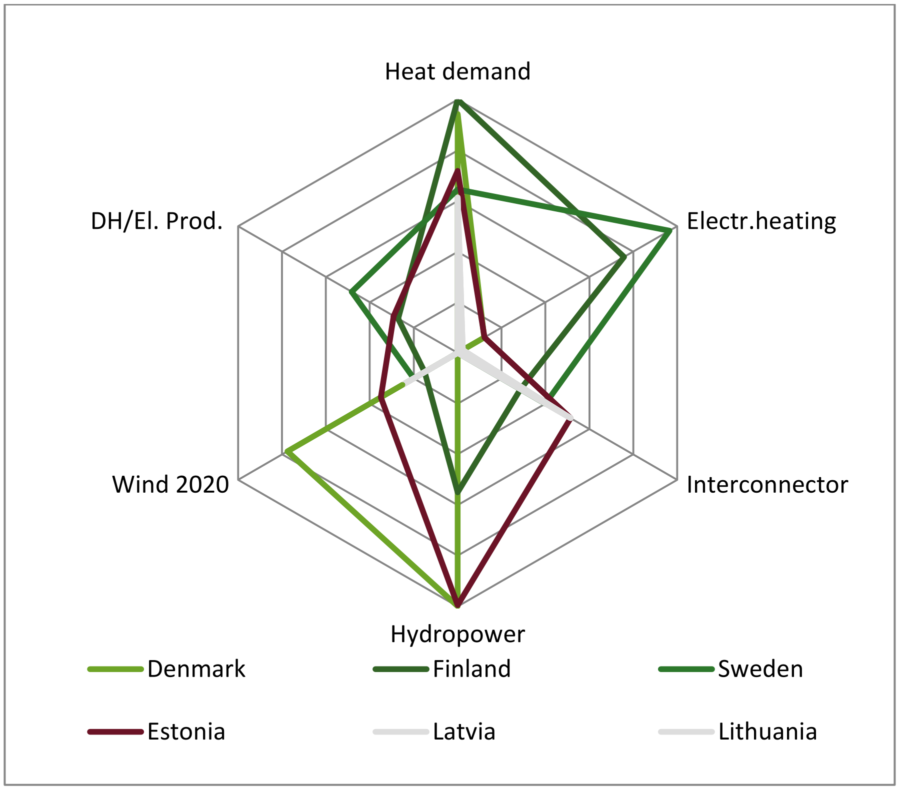


Figure 47 : Characterisation of the SETS markets in the Nordic and Baltic countries.

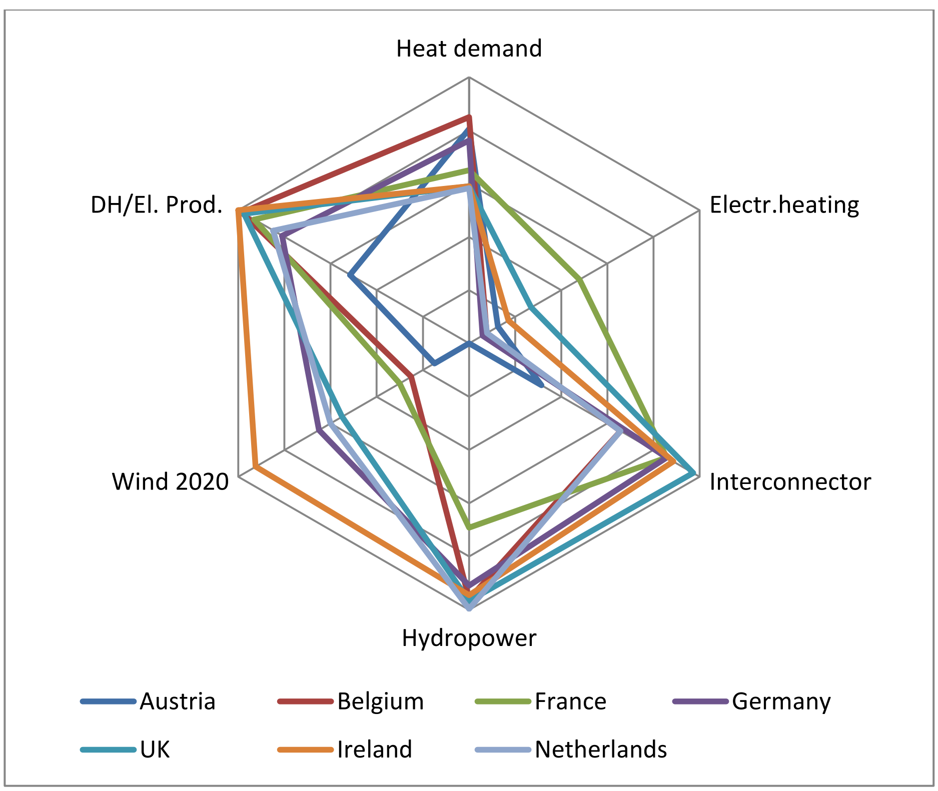


Figure 48: Characterisation of the SETS markets in Western Europe.

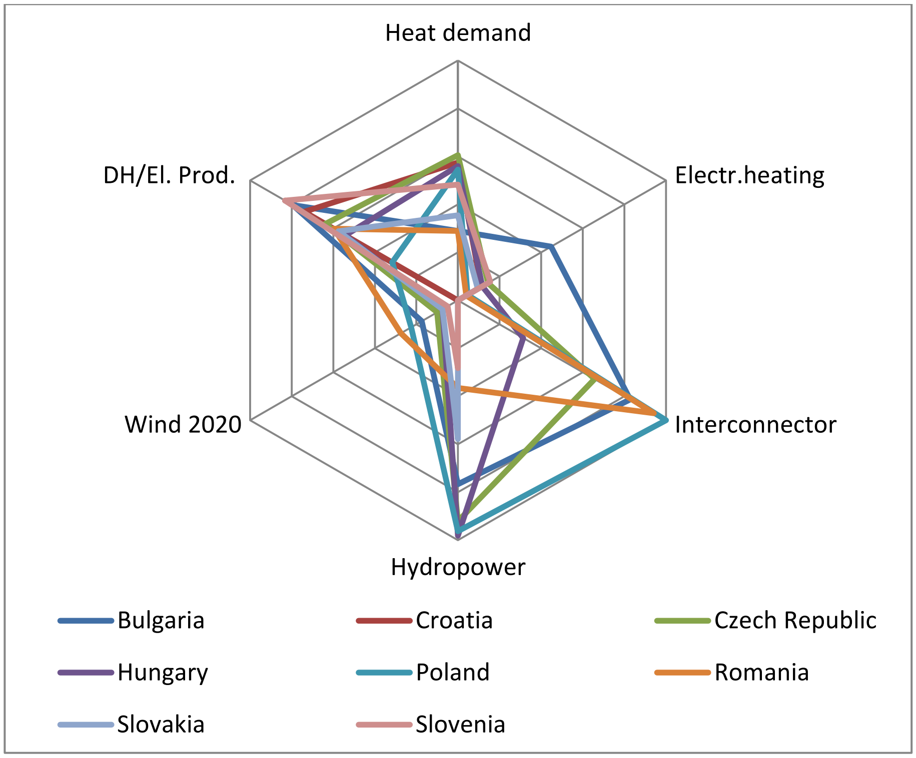


Figure 49: Characterisation of the SETS markets in Eastern Europe.

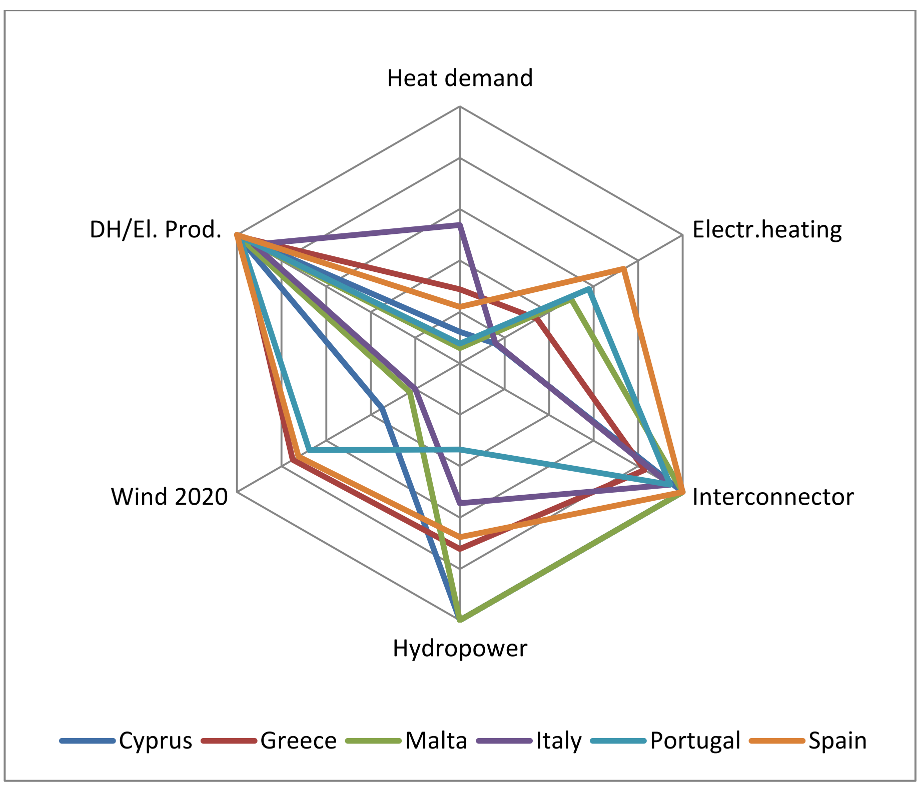
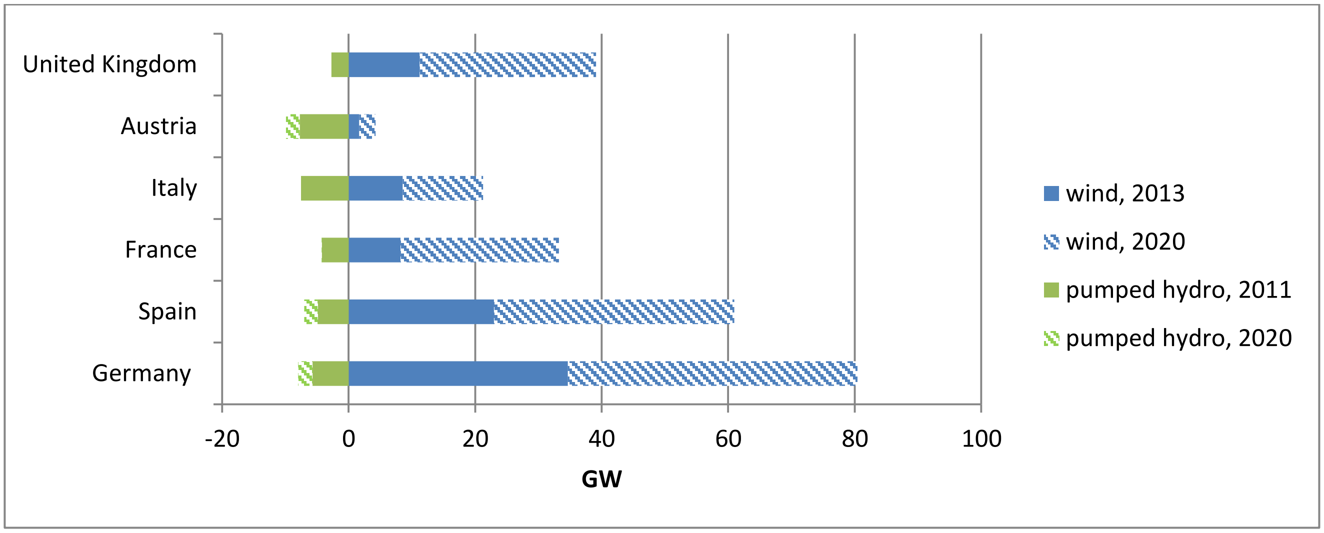


Figure 50: Characterisation of the SETS markets in the Mediterranean countries.

Market size indicators: flexibility and suitable heating segment

One useful metric for SETS market size based on the need for flexibility is based on electricity generation capacity. Since the production of electricity can vary substantially over the year, it is useful to look at the installed generation capacity. Pumped hydro capacity (green bars below zero) can absorb the excess wind capacity (blue bars above zero level) in the grid. Reservoir hydro capacity can also adjust to the momentary grid situation but, since reservoir hydro is not differentiated in the statistics as such, but is accounted for as “hydro”, it cannot be shown on the graph. Some additional information is given through the future plans for 2020, both for wind and pumped hydro capacity. From the SETS perspective, a country with high wind generation capacity and additionally low pumped hydro capacity is attractive (Figure 51).



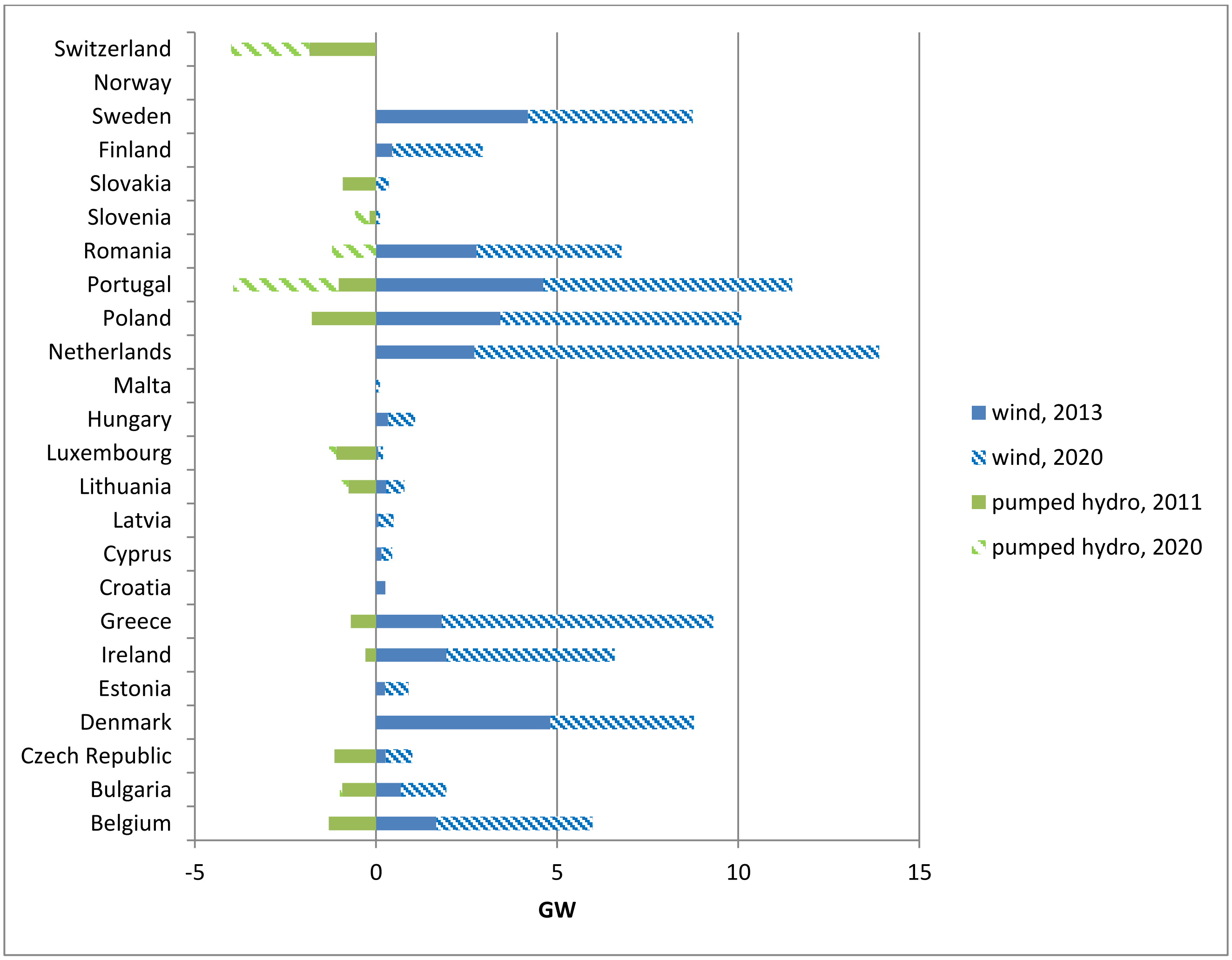


Figure 51: Market size indicator based on generation capacity. Note the different scales (Eurelectric, 2014), (Ruska et.al., 2011).

Some high-level indication of the need for flexibility can be discussed based on Figure 51. Generally speaking, if need for flexibility is foreseen to grow more rapidly than measures to tackle it, some kind of indication of the markets for SETS devices as flexibility providers can be discussed. In Figure 51, wind power capacity and pumped hydro capacity are used as indicators. However, it must be admitted that Figure 51 describes the situation only partially, as there are several other flexibility need drivers and measures affecting the markets. Regarding wind energy, it has to be noted that the wind capacity factor is fairly low, based on Eurostat data approximately 20% calculated is the average for Europe. Wind turbines seldom work with their nominal capacity at the same time. Therefore, taking the capacity factor into account, a reasonable estimation would be to compare some 20–25% of the wind capacity with the pumped hydro capacity.

Another way of analysing the absolute size of the potential market for SETS in each country is by comparing the annual wind energy production, added with planned wind electricity production in 2020 with the hereto suitable space heating demand. Only 75% of the existing electrical space heating is assumed to form a possible market for SETS (see Chapter 4). In addition to electrical heating, existing coal and oil heating is shown in Figure 52 There is a need to replace fossil energy carriers with low carbon energy sources, but on the other hand, if a heat delivery system based on water circulation already exists in the household it is disputable if such a system will be replaced by SETS. For these systems, gas, wood pellets, ground source heat pumps or even electric boilers might be more suitable, depending on the competitiveness.

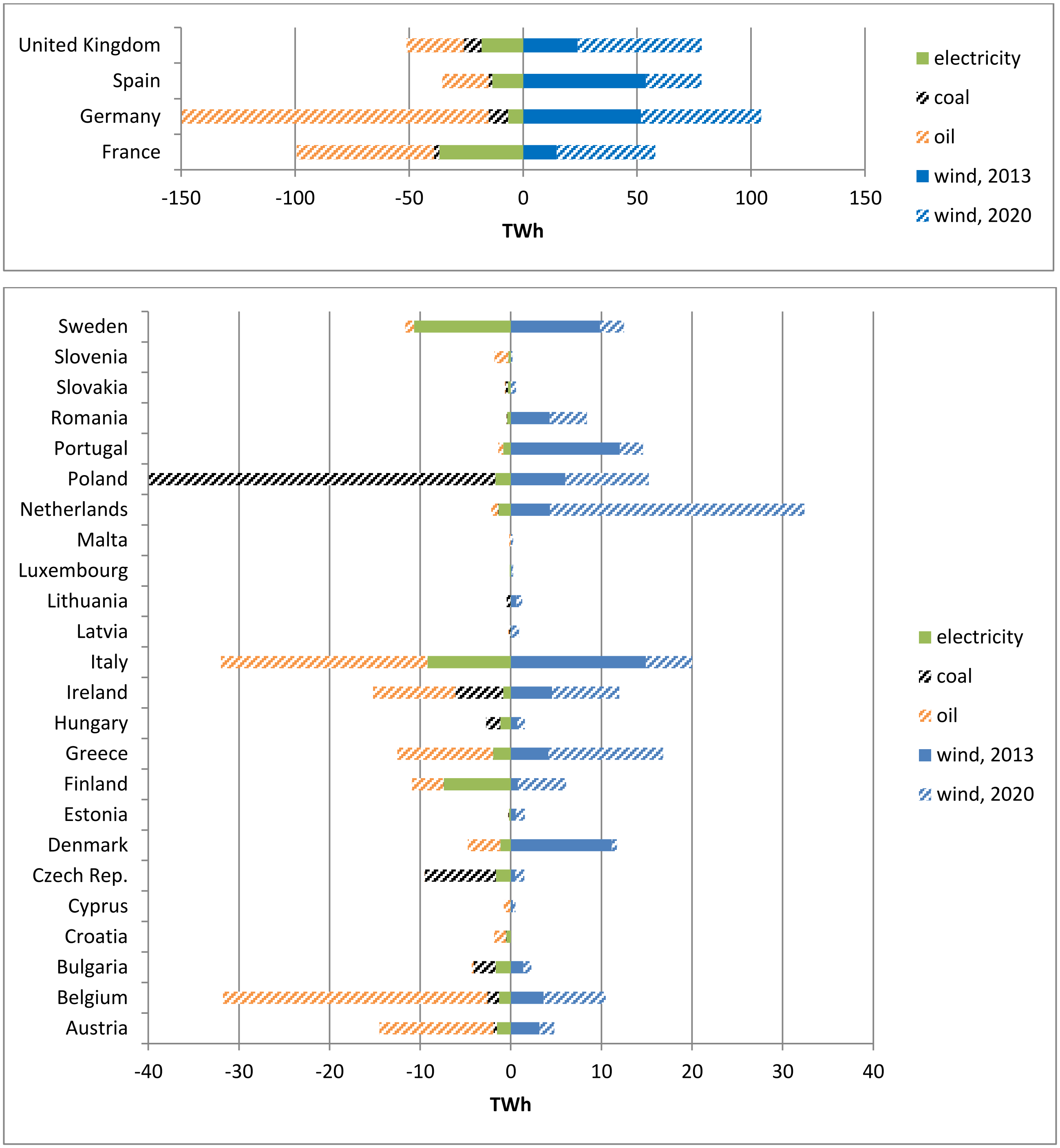


Figure 52: Markets size indicator based on electrical energy. Note the different scales.

Traffic lights of the European SETS market - matrix

Yet another approach to characterizing the European SETS markets is via traffic lights. The indicators used are partly the same or similar as in the above presentations. They are grouped under flexibility needs, competition, suitable heating segment and end-user electricity markets. The thresholds between the colours are based on quartiles: the lowest quartile is red, the highest is green and the two middle quartiles are yellow. An evaluation score is calculated based on the listed metrics: red gives no points, yellow one and green two. The concluding evaluation of each country can be found in the last row. The division between the colours is given in Table 5.

Table 5 Traffic light indicators

	(red)	(yellow)	(green)
Flexibility needs			
Planned wind share in electricity production	<10%	10 % – 20 %	>20 %
Flexibility competition			
Pumped+ reservoir /NGC	>20 %	3 % – 20 %	< 3%
DH/El. prod.	>40 %	15 % – 40 %	<15 %
Interconnector capacity per installed electricity production capacity	>40 %	15 % – 40 %	<15 %
Suitable heating segment			
space heating per inhabitant	< 2.5	2.5 – 4.5	> 4.5
share of electricity in space heating	< 3%	3 % – 20 %	>20 %
End-user electricity markets			
Smart meters	no	No decision yet	yes
Time-of-use tariffs	no	n.a.	yes
Evaluation score	≤ 8	9–12	≥ 13

The traffic lights grouped according to geographical location are presented in Table 6 –

Table 9. The traffic lights should be understood as a first attempt to compare the European countries with each other and find those markets which could be suitable for SETS. After this first selection based on electricity generation structure, some market characteristics and the domestic heating structure, the relevant countries should be analysed in greater detail, also taking into account price information.

In the Nordic countries Lithuania received a red light. Lithuania has not made a decision on a large-scale roll-out of smart meters, which essentially is a prerequisite for the profitability of SETS. Estonia and Finland have the highest score – in the Finnish case this is somewhat disputable. Finland has large hydroelectricity generation capacity, which in the statistics is calculated as run-of-river plants. In reality, some of the plants are providing balancing and can to some extent serve as storage capacity, which forms a competition situation to SETS.

Belgium, along with Northern Ireland, is the only western European country with no plans for a large scale roll-out of smart meters and thus is not suitable for SETS. Luxemburg has high interconnector capacity, high levels of pumped hydro capacity and unambitious plans for wind electricity generation and is, therefore, uninteresting. On the other hand, France, Germany, UK, Ireland and the Netherlands have all received high scores in the analysis. In Germany and the Netherlands, the share of electricity in space heating is fairly low, but one has to bear in mind the absolute size of the housing sector. Kema Nederland has estimated the replacement potential for electrical heating in Germany to be 14 GW (Raadschelders et.al, 2013).

In the Mediterranean area, Greece, Portugal and Spain have similar characteristics and therefore reach the highest scoring in the evaluation: high levels of wind generation, high levels of electricity in space heating and low levels both in district heating as well as interconnector capacities. The Eastern European countries seem to be an uninteresting market for the SETS.

Table 6: Traffic lights for the Nordic countries.

	Denmark	Estonia	Finland	Latvia	Lithuania	Sweden
Flexibility needs						
Planned wind share						
Competition						
DH/El. Prod.						
Interconnector capacity / NGC						
Pumped+reservoir/NGC						
Suitable heating segment						
Share of el. in space heating						
Space heating /inhabitant						
End-user electricity markets						
Smart meters						
Time-of-use tariffs						
Score	10	12	12	9	5	10
Evaluation						

Table 7:Traffic lights for Western Europe

	Austria	Belgium	France	Germany	UK	Ireland	Luxembourg	Netherlands
Flexibility needs								
Planned wind share								
Competition								
DH/El. Prod.								
Interconnector capacity / NGC								
Pumped+reservoir/NGC								
Suitable heating segment								
Share of el. in space heating								
Space heating /inhabitant								
End-user electricity markets								
Smart meters								
Time-of-use tariffs								
Score	9	7	14	12	13	15	6	12
Evaluation								

Table 8:Traffic lights for Mediterranean area

	Cyprus	Greece	Italy	Malta	Portugal	Spain
Flexibility needs						
Planned wind share						
Competition						
DH/El. Prod.						
Interconnector capacity / NGC						
Pumped+reservoir/NGC						
Suitable heating segment						
Share of el. in space heating						
Space heating /inhabitant						
End-user electricity markets						
Smart meters						
Time-of-use tariffs						
Score	8	13	10	11	12	13
Evaluation						

Table 9:Traffic lights for Eastern Europe.

	Bulgaria	**Czech Republic**	**Hungary**	**Poland**	**Romania**	**Slovakia**	**Slovenia**
Flexibility needs							
Planned wind share	Red	Red	Red	Red	Yellow	Red	Red
Competition							
DH/El. Prod.	Green	Yellow	Yellow	Red	Yellow	Yellow	Yellow
Interconnector capacity / NGC	Green	Yellow	Yellow	Green	Green	Red	Red
Pumped+reservoir/NGC	Yellow	Green	Green	Yellow	Green	Yellow	Yellow
Suitable heating segment							
Share of el. in space heating	Green	Yellow	Yellow	Red	Red	Red	Yellow
Space heating /inhabitant	Red	Green	Yellow	Yellow	Red	Yellow	Yellow
End-user electricity markets							
Smart meters	Green	Red	Green	Yellow	Yellow	Green	Green
Time-of-use tariffs	Yellow	Green	Yellow	Green	Yellow	Green	Green
Score	10	9	9	7	8	6	8
Evaluation	Yellow	Yellow	Yellow	Red	Red	Red	Red

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APPENDIX 1

	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Rep.	Denmark	Estonia	Finland
Existence of ID markets?	X	X	X		X	?	X	X	X
Self-dispatch portfolio based balancing process	N/A	no	N/A		no	no	X	no	X
Is load accepted in energy balancing?	N/A	N/A	N/A		N/A	N/A	X	N/A	X
Smart meters (large scale roll-out latest by 2020)	X	no	X		X	no	X	X	X
Space heating per inhabitant	6.44	6.79	2.31	4.59	0.98	4.84	7.54	5.74	7.,99
Share of electricity in space heating	4 %	2 %	13 %	3 %	5 %	4 %	4 %	4 %	23 %
Share of oil in space heating	23 %	39 %	1 %	7 %	91 %	0 %	9 %	1 %	8 %
Share of coal in space heating	1 %	2 %	14 %	0 %		15 %	0 %	1 %	0 %
Share of gas in space heating	22 %	48 %	2 %	24 %		38 %	18 %	6 %	1 %
Share of heat in space heating	14 %	0 %	18 %	7 %		15 %	45 %	42 %	30 %
Share of wood in space heating	36 %	10 %	51 %	58 %	4 %	27 %	25 %	46 %	38 %
Share of heat pumps in space heating	2 %	0 %			6 %	1 %	3 %	5 %	9 %
Share of hydropower production	61 %	2 %	9 %	60 %	0 %	3 %	0 %	0 %	18 %
Share of wind in electricity production	5 %	4 %	3 %	4 %	5 %	1 %	32 %	4 %	1 %
NREAP plans for wind share in 2020	6 %	9 %	6 %		7 %	2 %	31 %	14 %	6 %
Interconnector capacity per installed electricity production capacity	29 %	17 %	11 %		0 %	17 %	44 %	4 %	30 %
DH/El. Prod.	29 %	1 %	12 %	16 %	0 %	22 %	84 %	43 %	44 %
Pumped + reservoir hydro / el. production	33 %	6 %	7 %		71 %	0 %	0 %	0 %	0 %

	France	Germany	UK	Greece	Hungary	Ireland	Italy	Latvia	Lithuania
Existence of ID markets?	X	X	X	X	ID market launch 2016	ID market launch 2016	X	X	no
Self-dispatch portfolio based balancing process	no	X	N/A	no	No	N/A	no	no	no
Is load accepted in energy balancing?	X	X	X	no	X	X	N/A	N/A	N/A
Smart meters (large scale roll-out latest by 2020)	X	X	X	X	X	X	X	X	no
Space heating per inhabitant	5.21	6.09	4.72	2.30	4.47	4.72	4.30	4.91	4.01
Share of electricity in space heating	14 %	2 %	8 %	10 %	4 %	5 %	5 %	1 %	0 %
Share of oil in space heating	18 %	28 %	8 %	42 %	0 %	42 %	9 %	1 %	0 %
Share of coal in space heating	1 %	2 %	3 %	0 %	4 %	24 %	0 %	1 %	4 %
Share of gas in space heating	39 %	45 %	78 %	9 %	64 %	25 %	52 %	6 %	6 %
Share of heat in space heating	5 %	9 %	0 %	2 %	12 %		4 %	32 %	43 %
Share of wood in space heating	24 %	15 %	3 %	37 %	17 %	3 %	30 %	59 %	47 %
Share of heat pumps in space heating	4 %	1 %	0 %		0 %	0 %	12 %		0 %
Share of hydropower production	12 %	4 %	1 %	11 %	1 %	2 %	18 %	47 %	11 %
Share of wind in electricity production	3 %	8 %	7 %	7 %	2 %	17 %	5 %	2 %	13 %
NREAP plans for wind share in 2020	11 %	19 %	21 %	25 %	3 %	37 %	5 %	10 %	9 %
Interconnector capacity per installed electricity production capacity	10 %	10 %	6 %	11 %	29 %	9 %	7 %	4 %	4 %
DH/El. Prod.	4 %	11 %	2 %	1 %	27 %	0 %	5 %	100 %	166 %
Pumped + reservoir hydro / el. production	10 %	3 %	4 %	17 %	0 %	3 %	14 %	0 %	19 %

	Luxem -bourg	Malta	Poland	Portugal	Romania	Slova-kia	Slovenia	Spain	Sweden	Nether-lands
Existence of ID markets?	no	no	X	X	X	X	no	X	X	X
Self-dispatch portfolio based balancing process	N/A	N/A	no	X	no	no	no	no	X	X
Is load accepted in energy balancing?	N/A	N/A	N/A	N/A	N/A	X	X	N/A	X	X
Smart meters (large scale roll-out latest by 2020)	X	X	N/A	N/A	N/A	X	X	X	X	X
Space heating per inhabitant	3.61	0.47	4.36	0.62	2.31	2.84	3.86	1.76	5.16	4.66
Share of electricity in space heating	8 %	15 %	1 %	17 %	1 %	3 %	5 %	22 %	29 %	2 %
Share of oil in space heating	0 %	85 %	1 %	9 %	0 %	1 %	20 %	25 %	2 %	1 %
Share of coal in space heating	0 %	0 %	46 %		0 %	2 %	0 %	2 %		0 %
Share of gas in space heating	92 %	0 %	11 %	1 %	17 %	69 %	13 %	24 %	1 %	89 %
Share of heat in space heating	0 %	0 %	24 %	0 %	21 %	23 %	10 %	0 %	48 %	4 %
Share of wood in space heating	0 %	0 %	18 %	73 %	60 %	2 %	53 %	27 %	21 %	3 %
Share of heat pumps in space heating	1 %		0 %	4 %	0 %	1 %	4 %	1 %	17 %	3 %
Share of hydropower production	36 %	0 %	1 %	27 %	25 %	17 %	29 %	13 %	40 %	0 %
Share of wind in electricity production	3 %	0 %	4 %	23 %	7 %	0 %	0 %	19 %	6 %	4 %
NREAP plans for wind share in 2020	4 %	8 %	9 %	23 %	11 %	2 %	1 %	21 %	8 %	24 %
Interconnector capacity per installed electricity production capacity	245 %	0 %	2 %	7 %	7 %	61 %	65 %	3 %	26 %	17 %
DH/El. Prod.	30 %	0 %	41 %	1 %	24 %	25 %	10 %	0 %	31 %	9 %
Pumped + reservoir hydro / el. production	60 %	0 %	5 %	14 %	0 %	11 %	6 %	17 %	42 %	0 %