European Commission

Review of Regulation 206/2012 and 626/2011

Air conditioners and comfort fans

Task 2 report

Final version

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Abbreviations

Cdc, Cdh	The cycling degradation coefficient for air conditioners in cooling (heating) mode
COP	Coefficient of Performance for air conditioners in heating mode
CDD	Cooling Degree Day
EER	Energy Efficiency Ratio for air conditioners in cooling mode
EPS	External Static Pressure for air conditioners
GNI	Gross national income
GWP	Global warming potential
H_{TO}	The number of hours the unit is considered to work in thermostat off mode for air conditioners
H_{SB}	The number of hours the unit is considered to work in standby mode for air conditioners
H_{CK}	The number of hours the unit is considered to work in crankcase heater mode for air conditioners
H_{OFF}	The number of hours the unit is considered to work in off mode for air conditioners
P_{TO}	The electricity consumption during thermostat off mode for air conditioners
P_{SB}	The electricity consumption during standby mode for air conditioners
P_{CK}	The electricity consumption during crankcase heater mode for air conditioners
P_{OFF}	The electricity consumption during off mode.
Q_{CE}	The reference annual cooling demand for air conditioners in cooling mode
Q_{HE}	The reference annual heating demand for air conditioners in heating mode
SHR	Sensible Heat Ratio for air conditioners
SEER	Seasonal Energy Efficiency Ratio for air conditioners, cooling mode
SCOP	Seasonal Coefficient of Performance for air conditioners, heating mode
VRF	Variable Refrigerant Flow

Introduction to the task reports

This is the introduction to the interim report of the preparatory study on the Review of Regulation 206/2012 and 626/2011 for air conditioners and comfort fans. The interim report has been split into five tasks, following the structure of the MEErP methodology. Each task report has been uploaded individually in the project's website. These task reports present the technical basis to define future ecodesign and energy labelling requirements based on the existing Regulation (EU) 206/2012 and 626/2011.

The task reports start with the definition of the scope for this review study (i.e. task 1), which assesses the current scope of the existing regulation in light of recent developments with relevant legislation, standardisation and voluntary agreements in the EU and abroad. Furthermore, assessing the possibility of merging implementing measures that cover the similar groups of products or extend the scope to include new product groups. The assessment results in a refined scope for this review study.

Following it is task 2, which updates the annual sales and stock of the products in scope according to recent and future market trends and estimates future stocks. Furthermore, it provides an update on the current development of low-GWP alternatives and sound pressure level.

Next task is task 3, which presents a detailed overview of use patterns of products in scope according to consumer use and technological developments. It also provides an analysis of other aspects that affect the energy consumption during the use of these products, such as component technologies. Furthermore, it also touches on aspects that are important for material and resource efficiency such as repair and maintenance, and it gives an overview of what happens to these products at their end of life.

Task 4 presents an analysis of current average technologies at product and component level, and it identifies the Best Available Technologies both at product and component level. An overview of the technical specifications as well as their overall energy consumption is provided when data is available. Finally, the chapter discusses possible design options to improve the resource efficiency.

Simplified tasks 5 & 6 report presents the base cases, which will be later used to define the current and future impact of the current air condition regulation if no action is taken. The report shows the base cases energy consumption at product category level and their life cycle costs. It also provides a high-level overview of the life cycle global warming potential of air conditioners and comfort fans giving an idea of the contribution of each life cycle stage to the overall environmental impact. Finally, it presents some identified design options which will be used to define reviewed ecodesign and energy labelling requirements.

Task 7 report presents the policy options for an amended ecodesign regulation on air conditioners and comfort fans. The options have been developed based on the work throughout this review study, dialogue with stakeholders and with the European Commission. The report presents an overview of the barriers and opportunities for the reviewed energy efficiency policy options, and the rationale for the new material/refrigerant efficiency policy options. This report will be the basis to calculate the estimated energy and material savings potentials by implementing these policy options, in comparison to no action (i.e. Business as Usual – BAU).

The task reports follow the MEErP methodology, with some adaptations which suit the study goals.

2 Task 2

Task 2 follows the MEErP methodology and includes the following:

1. Generic economic data: EU sales and trade data based on production, import and export is assessed based on PRODCOM data analysis, aiming at identifying any similarities with our established stock model and/or filling data gaps.
2. Market and stock data: The establishment of the EU installed base (stock) based on EU annual total sales and growth rates and average product lives.
3. Market trends: The trends have been assessed regarding products, product features, market channels, production structures and market players.
4. Consumer expenditure base data: Identifying average EU consumer prices, repair and maintenance costs, disposal tariffs and taxes, electricity prices and regional differentiations.

2.1 Generic Economic data

The PRODCOM statistics are the official source for product data on the EU market. It is based on product definitions that are standardised across the EU thus guaranteeing comparability between Member States. Data are reported by Member States to Eurostat.

The PRODCOM statistics have some limitations given the complexities in the market and so are they not always as detailed as necessary to support decision making within ecodesign preparatory studies (e.g. data for air conditioners).

Within this study, the PRODCOM statistics are used to compare against product data sourced from other data sources and expert assumptions in order to provide a higher degree of confidence in the final product dataset. The product data sourced was used to establish annual sales for product categories in scope, and subsequently for establishing the installed base in the EU (i.e. stock).

PRODCOM EU sales and trade (i.e. the EU consumption) is derived by using the following formula based on data from PRODCOM:

$$EU\ sales\ and\ trading = production + import - export$$

For air conditioners and comfort fans, the following PRODCOM categories have been used to search for available data in the database:

Table 1: Prodcom categories covering products relevant for this study.

PRODCOM code	PRODCOM Nomenclature
28.25.12.20	Window or wall air conditioning systems, self-contained or split-systems
28.25.12.50	Air conditioning machines with refrigeration unit (excluding those used in motor vehicles, self-contained or split-systems machines)
28.25.30.10	Parts for air conditioning machines (including condensers, absorbers, evaporators and generators)
27.51.15.30	Table, floor, wall, window, ceiling or roof fans, with a self-contained electric motor of an output <= 125 W

Furthermore, data for dehumidifiers and humidifiers have been searched with no results. Sales data regarding humidifiers and dehumidifiers could have potentially shown some general tendencies e.g. if air conditioners with more functions (dehumidification and humidification) have an impact on sales of this type of equipment.

Air conditioners

The available data on PRODCOM for air conditioners are very limited and not sufficient to calculate the EU sales and trading. The limited available data is shown in Table 2 for the year of 2015. The data in Table 2 represents the available data for the following PRODCOM codes 28.25.12.20 and 28.25.12.50 in year 2009 to 2015. For PRODCOM code 28.25.30.10 no data at all is available. Though is this code of less importance since it relates to parts for air conditioners.

Table 2: Example of available data on PRODCOM for air conditioners

INDICATORS	EXPQNT	IMPQNT	PRODQNT	QNTUNIT
France	:	:	:	p/st
Netherlands	:	:	1,817	p/st
Germany	:	:	:	p/st
Italy	:	:	66,918	p/st
United Kingdom	:	:	285,067	p/st
Ireland	:	:	:	p/st
Denmark	:	:	76	p/st
Greece	:	:	:	p/st
Portugal	:	:	0	p/st
Spain	:	:	125,048	p/st
Belgium	:	:	:	p/st
Luxemburg	:	:	0	p/st
Iceland	:	:	0	p/st
Norway	:	:	:	p/st
Sweden	:	:	:	p/st
Finland	:	:	81,424	p/st
Austria	:	:	:	p/st
Malta	:	:	0	p/st
Estonia	:	:	0	p/st
Latvia	:	:	:	p/st
Lituania	:	:	0	p/st
Poland	:	:	:	p/st
Czech Republic	:	:	:	p/st
Slovakia	:	:	0	p/st
Hungary	:	:	0	p/st
Romania	:	:	0	p/st
Bulgaria	:	:	:	p/st
Slovenia	:	:	0	p/st
Croatia	:	:	0	p/st
EU25TOTALS	:	:	:	:
EU27TOTALS	:	:	3,151,669	p/st

The available production data for the PRODCOM codes 28.25.12.20 and 28.25.12.50 are shown in Figure 1.

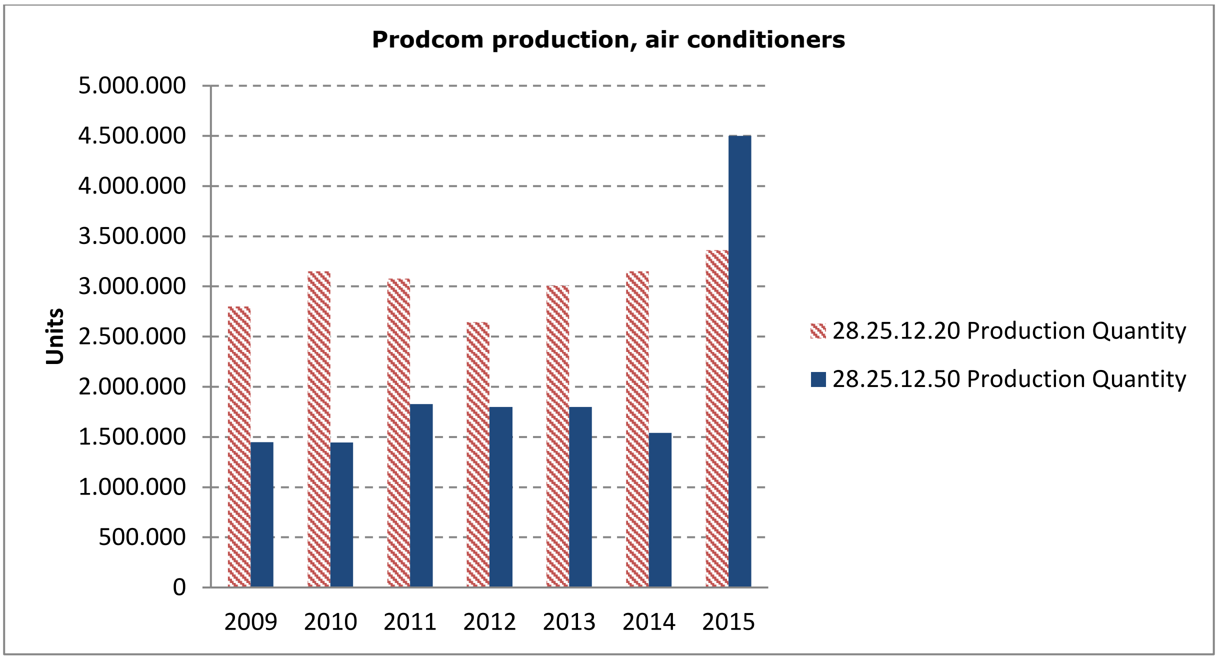


Figure 1: Total production of air conditioners (PRODCOM code 28.25.12.20 and 28.25.12.50). PRODCOM assessed April 2017.

After a minor decrease in production numbers in 2011 and 2012 are the production increasing within EU for the products covered by the PRODCOM code 28.51.12.20 (window or wall air conditioning systems, self-contained or split-systems). Since 2012 the production of air conditioners has increased steadily with an average increase of 8 % per year.

According to products covered by the PRODCOM code 28.51.12.50 (air conditioning machines with refrigeration unit (excluding those used in motor vehicles, self-contained or split-systems machines)) the production has more than doubled in 2015 compared to 2014. The data from PRODCOM is insufficient for calculating apparent sales and trade, therefore will not be used to establish sales and stock of air conditioners in this study.

Unfortunately, it was not possible to include data from 2016 due to unreliable values and missing total numbers.

Comfort fans below 125 W

Figure 2 illustrate the EU-28 production, import and export quantity according to PRODCOM data for comfort fans below 125 W and Figure 2 shows the calculated EU sales and trading for comfort fans below 125 W. The most recent data retrievable from PRODCOM at the time of writing the report (April 2017) were from 2015.

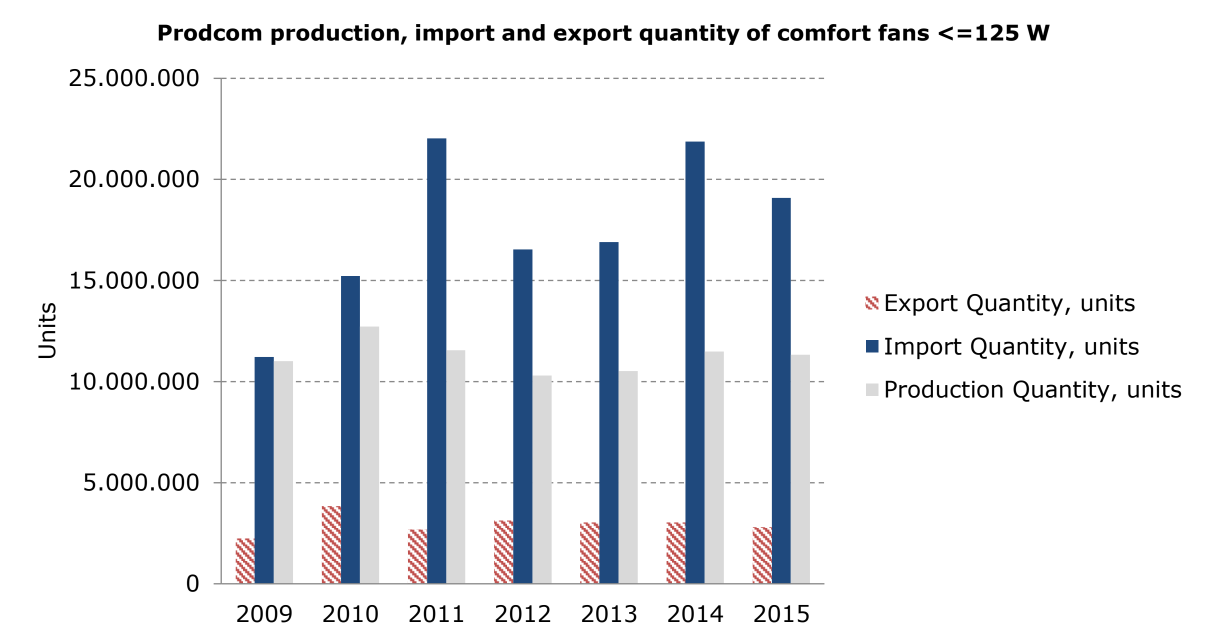


Figure 2: Total production, import and export quantity of comfort fans below 125 W 2009-2015. PRODCOM assessed April 2017.

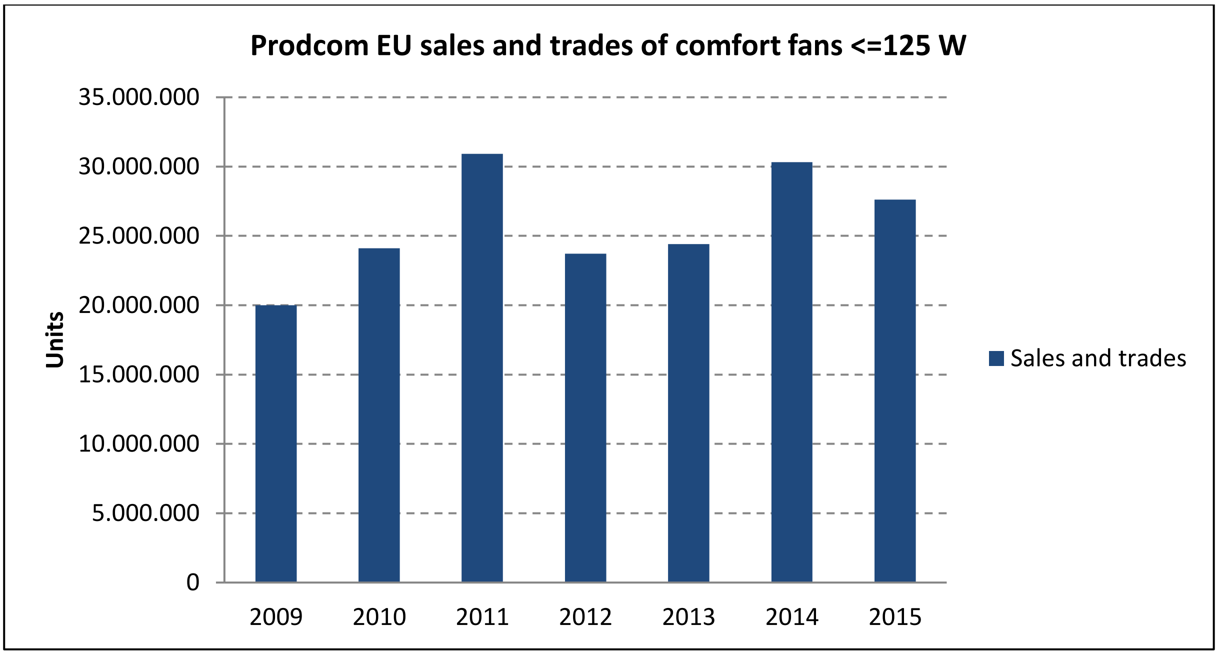


Figure 3: Total EU sales and trading of comfort fans below 125 W 2009-2015. PRODCOM assessed April 2017.

The general tendency is a slight increase in the period from 2009 to 2015. The sales and trading are expected to be highly connected with the weather in the year concerned, so over a period of time one must expect some fluctuation in the sales and trading. Since 2012 the EU sales and trading of comfort fans has increased with an average increase of 5 % per year. This increase is highly connected with the increase in import. The production and export of comfort fans only have minor fluctuation over the years with an almost flat trend.

In case of no other data available for comfort fans, PRODCOM data would be used in the later tasks. Data shows that the sales and trades of comfort fans in EU countries is in the range of 20 to 30 million units per year. This meets the criteria set in Ecodesign Directive Article 15 that "the product shall represent a significant volume of sales and trade, indicatively more than 200 000 units a year within the Community according to the most recently available figures".

2.2 Market and Stock data

This section presents estimated market and stock data for each of the product types within scope as defined in task 1.

2.2.1 Present market

EU wide, main types of air conditioners in use are single duct (and double duct) air conditioners and split systems. Other types have very low sales:

- window / through the wall air conditioners: about 4000 units sold in 2015[1] (about 20000 in 2005 according to Lot 10 preparatory study)
- in the portable segment, mobile split air conditioners have almost disappeared with total sales below 1000 units in Europe[2];
- mini-VRF multisplit systems: this is a new product on the market; total EU sales of VRF are about 100000 units in 2015, of which maximum 30000 units have cooling power below 20 kW[3]; still, very few models are available below 12 kW but their number is growing; so sales of mini-VRF are likely to be below 10000 units[4] per year so far but are likely to increase with the consolidating offer.
- ventilation exhaust recovery heat pumps: EHPA statistics indicate figures about 10000 units in 2015 but it probably also encompasses exhaust air to water heat pumps, and not only air-to-air units.

It is thought that the sharp decrease in sales of window air conditioners and mobile split is in part due to the effects of the Regulation (EU) No 206/2012, where these products are classified with fixed split systems.

Total sales of air conditioners were about 4.2 million units in 2015, a figure about 40 % lower than the 2007 sales (Figure 4), before the economic crisis. The sales of portable air conditioners were about 0.6 million units in 2015, which is similar to 2005 sales (as modelled in EuP lot 10 preparatory study). The share of portable air conditioners in sales is similar in 2015 and in 2005 about 14 %, varying depending on the years between 10 and 15 % according available information.

[1] Source BSRIA
[2] Source GfK
[3] Source BSRIA
[4] Estimate built upon UNICLIMA statistics for France.

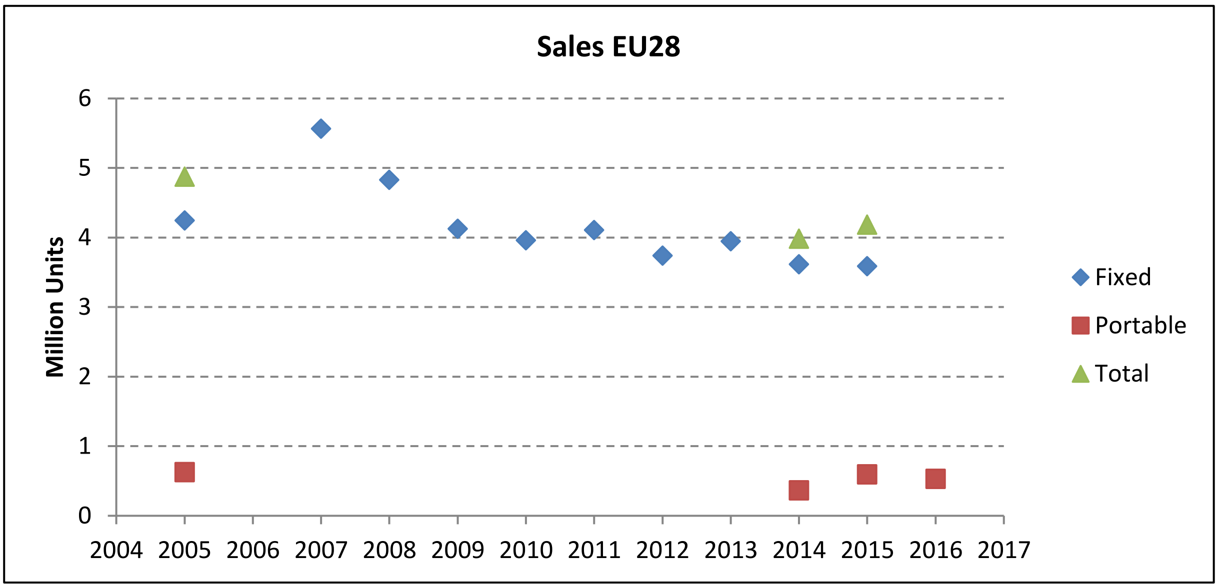


Figure 4: Total EU sales in units, 2005 data - EuP Lot 10 preparatory study (2008), other split data - BSRIA source adapted, other portable data - BSRIA and GfK source adapted.

These sales are worth 2.7 billion euros, of which about 0.2 billion euros are for the portable air conditioners and 2.5 billion euros for fixed split. Above the decreasing sales from 2007 to 2015, the average value of split unit sold decreased. The total value of split sales sank from a high at 4.7 billion euro in 2007 down to 2.5 billion euro in 2015.

According to BSRIA, more than 99% of portable air conditioners are imported with small production in the Netherlands and in Sweden. The situation is different for split air conditioners, for which a larger proportion is produced in Europe. The share of production in sales however is not known at EU scale.

It is important to have an order of magnitude of what these sales mean in terms of installed power. EU28 sales represent about 16 GW cooling capacity or around 4.5 electric GW in peak conditions. Only a small portion of the sales being replacements, there is a net electric load addition of over 3 GW per year due to these products.

The analysis by country for split air conditioners (Figure 5), shows that largest AC countries, Spain and Italy, most suffered from the crisis, as their relative share of the EU market significantly decreased, in addition to the general sales decrease. Main markets are still Spain, Italy and Greece, but they only represent 45 % of 2015 sales versus 65 % in 2007.

Regarding mobile air conditioners (Figure 5), Spain, Italy and Greece only represent about 35 % of the sales, while biggest EU countries Germany, France and the UK gather nearly 40 % of the sales.

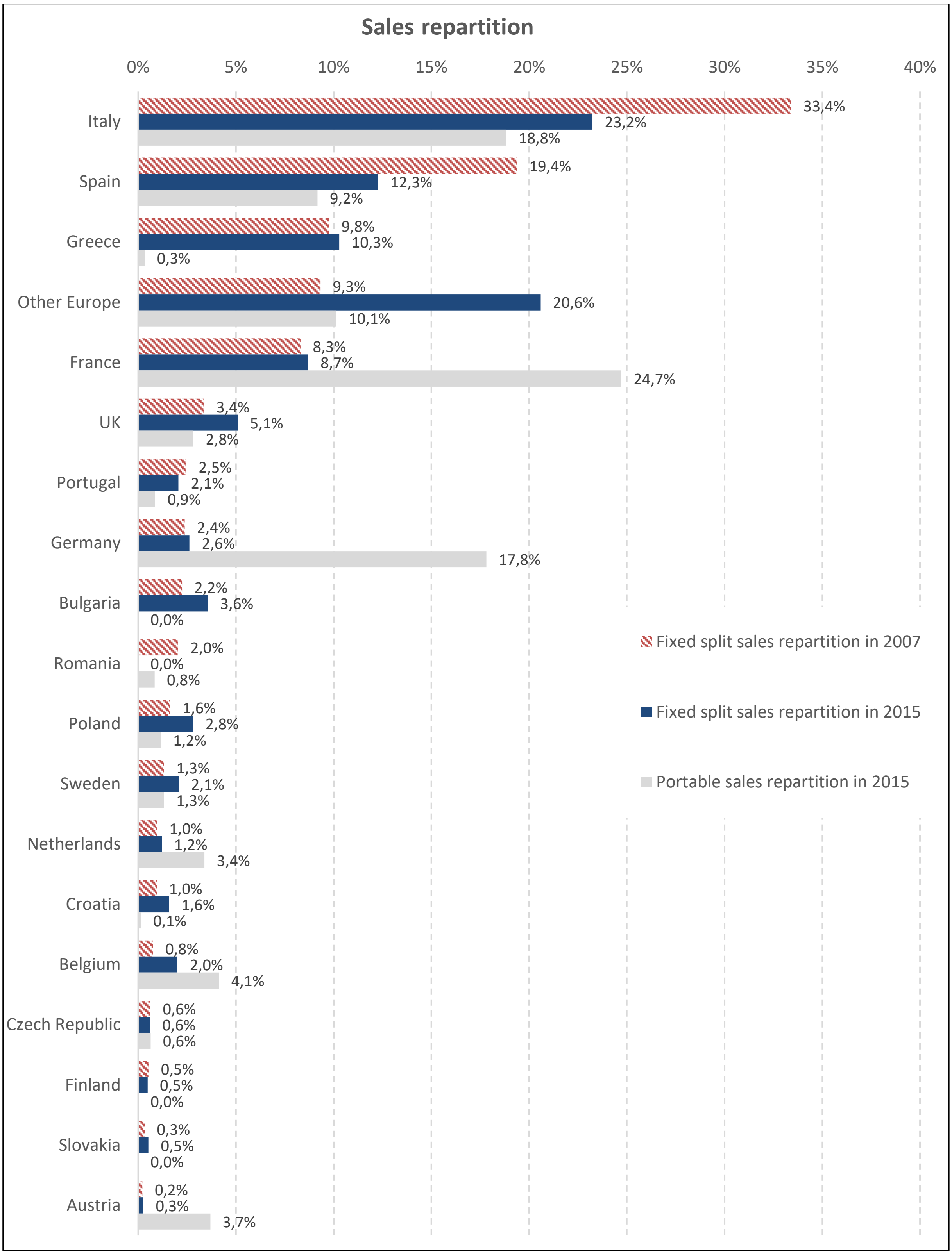


Figure 5: Portable and Split air conditioners repartition by country of EU28 sales in 2007 and in 2015, sources BSRIA and GfK adapted.

The primary driver of energy consumption is the unit size (supposing adequate sizing of the unit to the cooling needs). The analysis by size is shown Figure 6 for portable air conditioners. The weighted average size of portable is 2.6 kW.

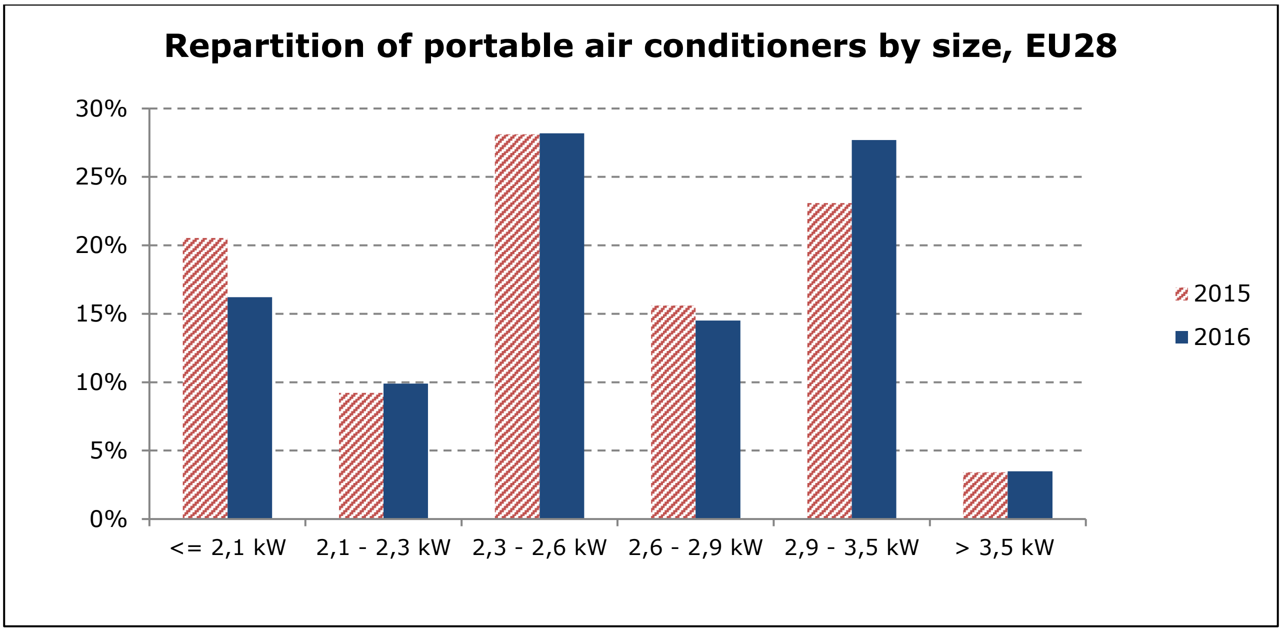


Figure 6: Portable sales distribution by size, sources BSRIA and GfK adapted.

Sales distribution for split are shown in Figure 7. The weighted average unit size is of 4.2 kW. In Regulation (EU) No 206/2012, two different capacity segments are used, 0-6 kW and 6-12 kW, they respectively represent 80% and 20% of the sales, and 2/3 and 1/3 of the sold cooling capacity. Multisplit units represent about 18% of the sales in number of units and close to 20% in terms of cooling capacity.

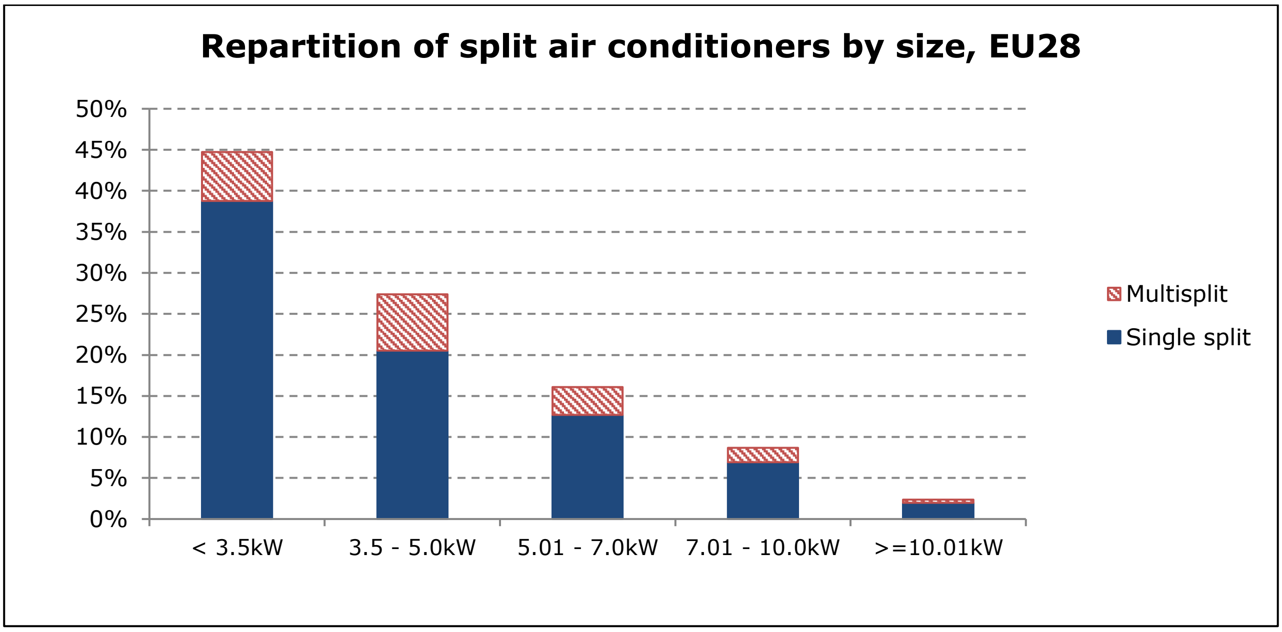


Figure 7: Split sales distribution by size, source BSRIA.

Indoor units of split systems may have different mounting types, with different typical technical characteristics, including differences in average capacity and efficiency levels. Distribution of indoor units of single split air conditioners is shown in the table below in terms of number of units and in terms of capacity.

In Table 3, indoor unit type is shown by product type, separating multisplit air conditioners, while in Table 4, the indoor unit type of split and multisplit air conditioners are added to have a single distribution of all indoor unit types.

Table 3: Distribution of split systems by type of indoor unit, BSRIA source

Distribution of split systems by type in number						
	Single split					Multi-split
Capacity range in kW	Wall	Ceiling type	Floor/vertical or consoles	Cassette	Ducted	All types
0-5	74%	2%	2%	2%	3%	18%
5-12	39%	6%	1%	20%	17%	17%
7-12	17%	8%	1%	35%	24%	15%
0-12	63%	3%	1%	8%	7%	17%
Distribution of split systems by type in capacity						
	Single split					Multi-split
Capacity range in kW	Wall	Ceiling type	Floor/vertical or consoles	Cassette	Ducted	All types
0-5	73%	2%	2%	3%	3%	18%
5-12	35%	6%	1%	23%	19%	16%
7-12	16%	8%	1%	35%	25%	14%
0-12	54%	4%	1%	13%	11%	17%

Table 4: Distribution of indoor units of split and multisplit systems by type of indoor unit, BSRIA source

Distribution of indoor units of split and multi-split systems by type in number					
Capacity range in kW	Wall	Ceiling type	Floor/vertical or consoles	Cassette	Ducted
0-5	91%	2%	2%	3%	3%
5-12	74%	4%	2%	11%	9%
7-12	20%	9%	2%	38%	30%
0-12	83%	3%	2%	6%	6%
Distribution of indoor units of split and multi-split systems by type incooling capacity					
Capacity range in kW	Wall	Ceiling type	Floor/vertical or consoles	Cassette	Ducted
0-5	90%	2%	2%	3%	3%
5-12	47%	7%	2%	23%	21%
7-12	20%	9%	2%	38%	30%
0-12	71%	4%	2%	12%	11%

Over the 0-6 kW capacity range, single split with wall indoor unit is clearly the most common product type. However, above 7 kW, the most common product type is a single split unit with cassette type indoor unit.

Air conditioners below or equal 12 kW do not only serve the residential sector. The sector of use is differentiated depending on the type of unit. This is an important matter to then evaluate the cooling needs and the energy consumption of units as internal loads and hours of use are very different depending on the sector of use. Portable are more likely to be found in residences while larger split and multisplit air conditioners are mostly installed in the service sector. However, there are large variations on a country by country basis. Destinations are shown for 5 countries and in average for portable and split air conditioners in Figure 8 below. In average about 75 % of portable sales are in the residential sector, and only 65 % for split. However, there is marked variation with size: for larger than 5 kW units, the share of the sales in the residential sector falls down to 33% in average.

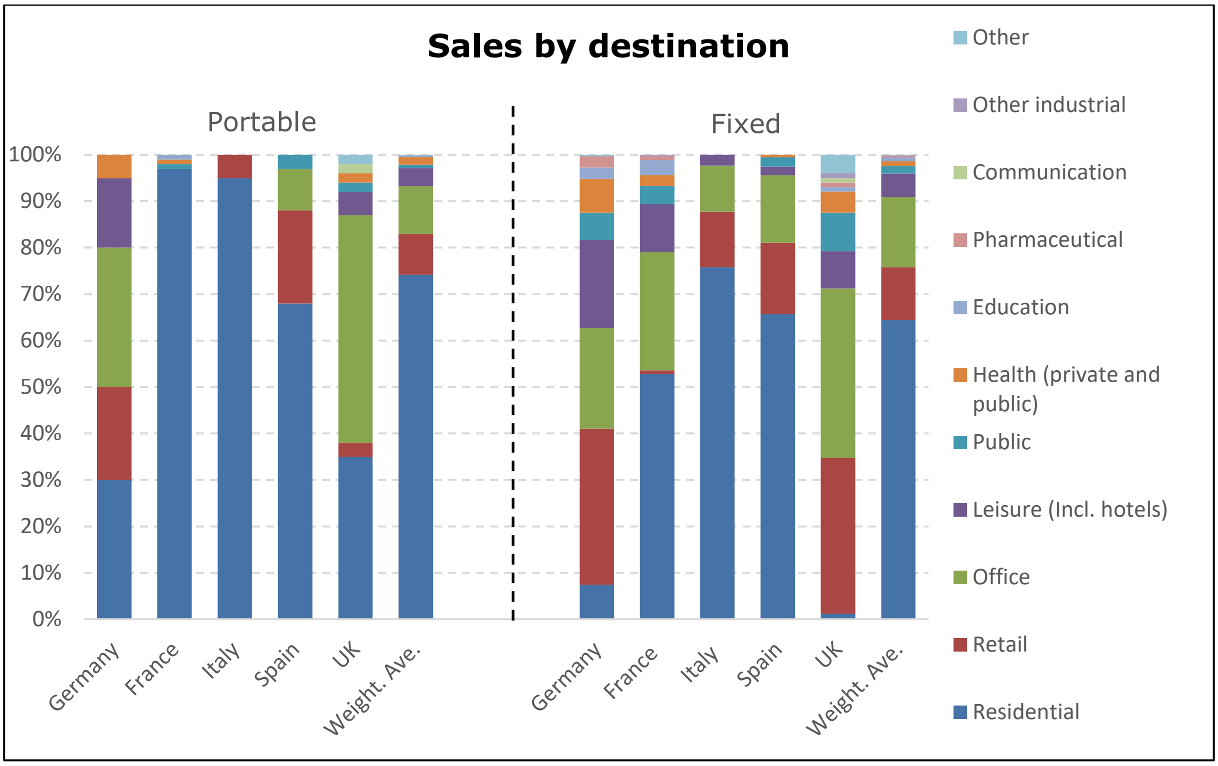


Figure 8: Repartition of portable and fixed split sales by sector of use, source BSRIA.

For the market dynamics, it is essential to know the application type, i.e. whether the sales are for replacement, first time installation in an existing building or in a new building. In a completely saturated market, the stock of products in use only grows by new building installations and there is no sale corresponding to first time installation in existing buildings. As shown in Figure 9 below, the majority of sales of both portable and split air conditioners are still largely first-time installations in existing building, 70 to 80 % in average.

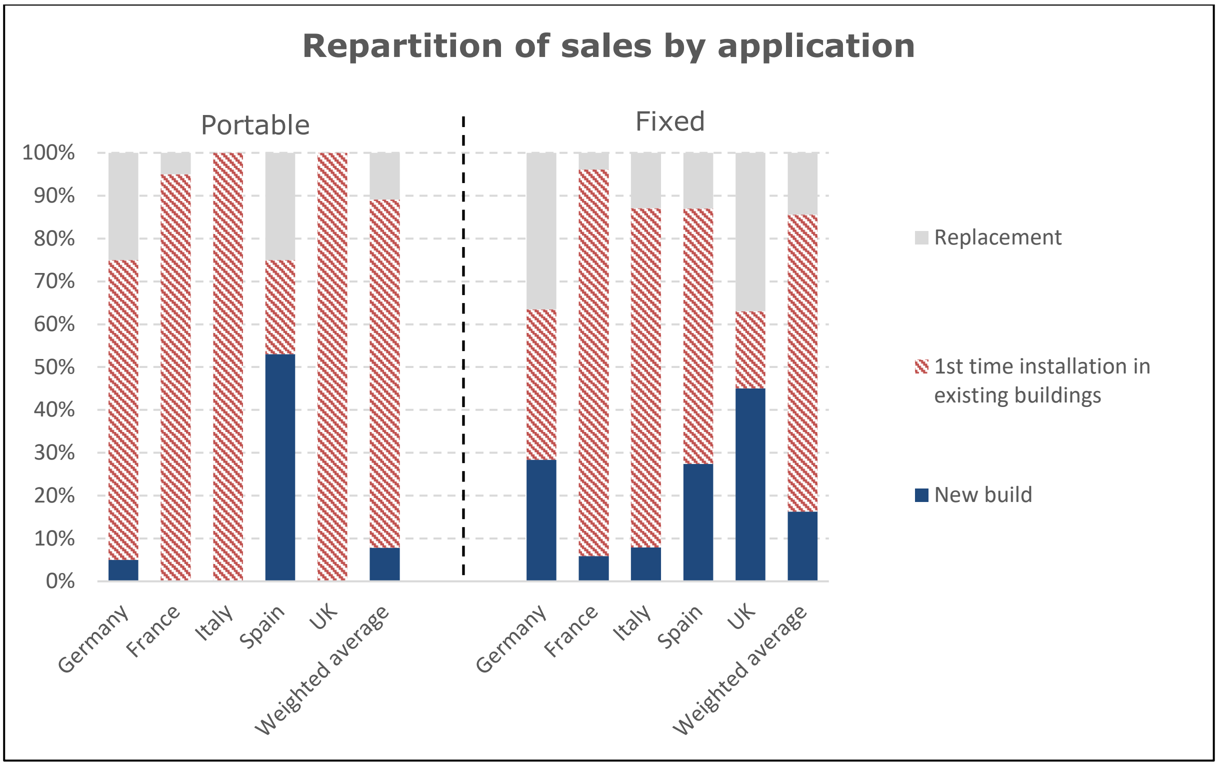


Figure 9: Repartition of portable and split sales by application, source BSRIA.

Reversibility is an essential characteristics of air conditioners as the heating function may be the main reason to buy an air conditioner in some cases.

The trend observed in EuP Lot 10 study for split air conditioners have been confirmed: cooling only units have almost completely extinguished. BSRIA sales indicate their share moved from about 10% in 2007 to roughly 3 % in 2015. In the ECC certified product database 2016 catalogue, there only remains 90 multisplit over 2200 models that are not reversible, or about 4 % of the models (note: the share of cooling only units were about 60 % in 2000 and 30 % in 2005 in the same database).

Reversibility is also present for portable air conditioners. Based on GfK information, at least 5 % of portable units sold in Europe were reversible in 2015 and 11% in 2016. These figures are for thermodynamic heating. However, some of the reversible models proposed are not using the thermodynamic cycle for heating but rather a simple electric resistance. According to BSRIA information, this is limited however to about 3 to 4 % of the sales of portable air conditioners. This to be compared with the situation in 2002-2005 described in Figure 10 below extracted from EuP Lot 10 study. It appears that the proportion of reversible portable air conditioners sold did not change but that reversible products using electric resistance have been replaced partly by thermodynamic heating.

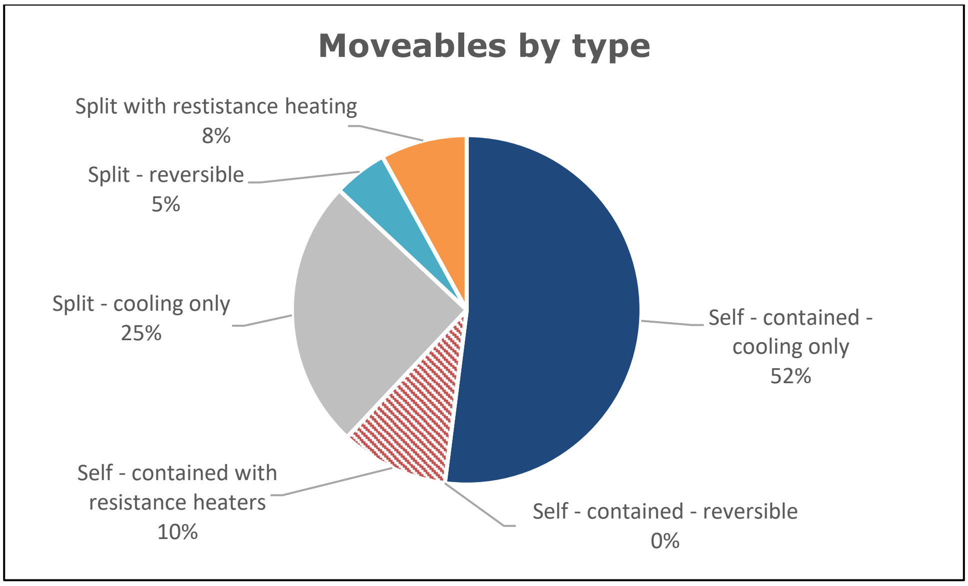


Figure 10: Portable air conditioners share by type and reversibility in Europe in years 2002-2005, source EuP Lot 10 study.

Product life time is a necessary input to compute the stock of models in use. In the Lot 10 preparatory study, 12 years was used for both splits and portable air conditioners. This value is conserved for split air conditioners, as data collection from industry stakeholders have confirmed the lifetime for split air conditioners is 12 years[5]. For portable air conditioners, more recently, US DOE[6] used a 10.5 year average lifetime with a rather large dispersion however (standard deviation close to 5 years). This average life time is close to the one in the ENEA study (referred to in the EuP Lot 10 preparatory study) of 10.5 years average life time. For ease of calculation, this value is rounded to 10 for stock calculation here after.

2.2.2 Model for estimating sales and stock

2.2.2.1 General outline of the model

A sales and stock model is necessary to estimate present values and to build scenarios in Task 7. As explained in previous EuP Lot 10 study, air conditioning sales depend on climate and economics, but also on cultural and building construction habits. The EU28 dynamics is thus best represented at country level (or at lower scale, but there finding information is nearly impossible).

A similar model to the one developed for Lot 10 study has been used. Sales are projected to reach a defined air conditioning penetration level (called saturation hereafter) at a long-term horizon depending on climate. Climate change impact on saturation levels has been included. This model is adapted to model the sales of countries for which limited information on sales is available.

In order to better represent the penetration of air conditioning in the building sector and its evolution towards saturation levels, the share of units installed in the tertiary sector

[5] Data collection from industry stakeholders, June 2017.
[6] https://www.regulations.gov/document?D=EERE-2013-BT-STD-0033-0047

have been represented and the other air conditioning systems (Package, VRF, Chillers) as well.

Note that this model has been first developed by Armines in the frame of the H2020 Heat Roadmap Europe project[7] and adapted for this review study.

More details on the methodology, equations, assumptions, and data sources used in the model are given here after and in Annex 1: Test conditions for SEER and SCOP determination of exhaust air-to-outdoor air heat pumps and air conditioners

2.2.2.2 2015 stock estimate

Stock estimate, in number of units and in kW rated cooling capacity, is based on sales data, lifetime and average product size by product type and sector for years 1992-2015 for 16 EU member states: Austria, Belgium, Czech Republic, Greece, Finland, Italy, France, Germany, Hungary, Netherlands, Poland, Portugal, Romania, Sweden, Spain and UK. This mean that the stock model is an upper estimate driven by economic and sales data.

The stock *s* at the end of year *n* for each country (16), each sector and technology is given by:

$$s_n = \sum_{i=n-L+1}^{n} v_i \qquad \text{(Eq. 1)}$$

where *L* is the average lifetime and *v* the sales.

For the other 12 EU countries for which there is not enough sales data available (Bulgaria, Croatia, Cyprus, Denmark, Estonia, Ireland, Latvia, Lithuania, Luxembourg, Malta, Slovakia, Slovenia), the procedure presented in Annex 2: Estimating 2015 stock for countries with insufficient sales dataAnnex 1: Test conditions for SEER and SCOP determination of exhaust air-to-outdoor air heat pumps and air conditioners is used to estimate the 2015 stock. Note: these 12 countries represent about 7% of the total EU population.

2.2.2.3 Future sales and stock projection

A logistic function with three free parameters (Eq. 2) is used to model the growth of total power sold in each of the 16 countries with past sales information, separately for each sector, until 2050 which then allows to calculate the future total installed capacity as explained above for 2015.

$$power\ sold\ in\ year\ y = \frac{\boldsymbol{L}}{1 + exp[-\boldsymbol{k}\,(y - \boldsymbol{y_m})]} \quad \text{(Eq. 2)}$$

L is the upper asymptote, k the 'steepness' and y_m the midpoint (and inflection point) about which the curve is symmetric. The three free parameters are calibrated using three points:

1) The power sold in 2015 for all unit types
2) The power sold in 2020 estimated by linear growth based on the compound (growth of the installed rated cooling capacity by country and sector) annual growth rate before the economic crisis (1994-2007) derived from the sales data.
3) A market saturation limit represented by the total cooled indoor floor area derived from the stock.

[7] http://www.heatroadmap.eu/

The capacity sold and stock are then redistributed into the different technologies based on past years' sales repartition trends (Table 26 and Table 27).

This procedure is illustrated below (Figure 11) for the residential sector in Spain. In that case, the Spanish market is estimated to reach again its highest level of 2007 around 2045.

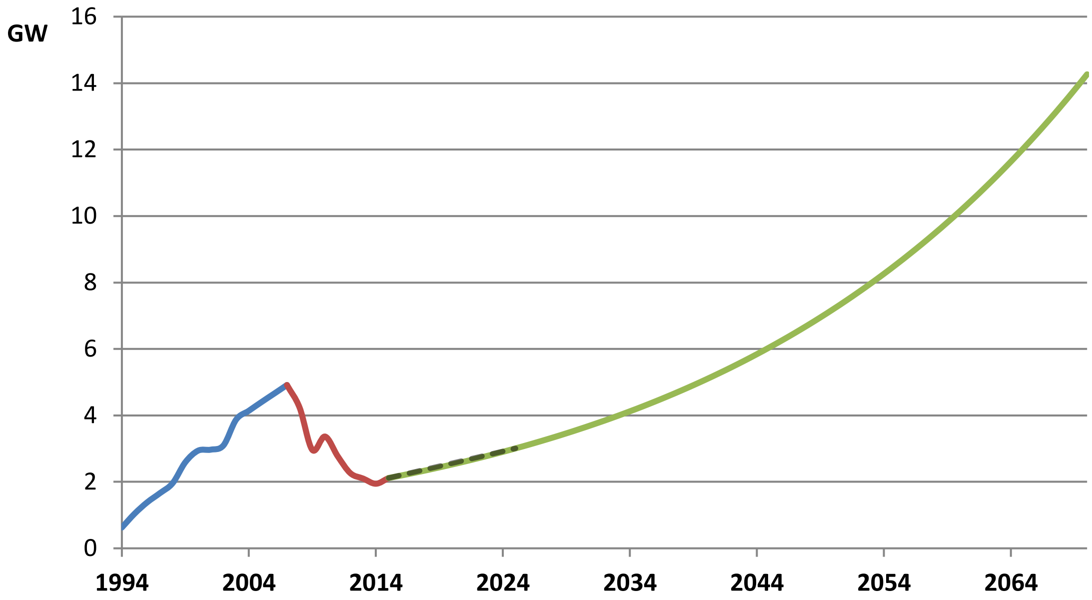


Figure 11: Air conditioning sales in the residential sector in Spain (in GW of rated cooling capacity); past sales - in blue (before crisis) and in red (post crisis); sales projection - in green ; sales growth 2015-2025 in black dash line.

Compound annual growth rates of sales of rated cooling capacity of all product types for years 1992-2015 are shown in Table 5 below.

Table 5: Compound annual sales growth rates of standard rated cooling capacity by country for 16 EU countries, 1992-2015, sum of all product types and sectors

Country	1992-2007	2007-2015	1992-2015
Austria	11%	-3%	6%
Belgium	10%	1%	7%
Czech Republic	15%	-4%	8%
Finland	8%	-8%	2%
France	10%	-4%	5%
Germany	10%	-1%	6%
Greece	10%	-5%	4%
Hungaria	15%	-6%	7%
Italy	12%	-7%	5%
Netherlands	7%	0%	4%
Poland	14%	2%	10%
Portugal	12%	-11%	3%
Romania	18%	-2%	10%
Spain	14%	-9%	5%
Sweden	11%	-1%	6%
UK	11%	-1%	7%

For the 12 EU countries with limited information, the development of the stock is modelled directly, based on a logistic curve connecting the current cooled floor areas to the supposed saturation. By reverting the logic of the stock model from the point of projected saturation sales data going back to 2015 can be deduced, following Eq. 3 below, adapted from Eq. 1 above.

$$v_n = v_{n+L} + s_{n+L-1} - s_{n+L} \qquad \text{(Eq. 3)}$$

The total EU building stock is supposed to grow annually at a constant growth rate, the same for both sectors, so that the stock of air conditioning products goes on growing slightly even after the saturation has been reached.

For the 12 EU countries with limited information, hence, sales after saturation continue growing as follows (Eq. 4):

$$v_{n+L}{}^{(sat)} = v_n{}^{(sat)}(1+r)^L \qquad \text{(Eq. 4)}$$

where r is the rate of growth of the total floor area which drives the growth at saturation and L the product lifetime. This assumption allows to deduce the sales figures by relating v_{n+L} to v_n reducing Eq. 3 to one unknown.

2.2.2.4 Saturation of air conditioners market

In the residential sector, the total cooled floor area at market saturation of the EU 28 is modelled as a function of the cooling degree days (CDD) and additionally as a function of the average household income for the residential sector. The household income is estimated by the average Gross national income (GNI) per capita at purchasing power parity in 2015 US$ multiplied by the countries average household size. The US market saturation is assumed to be limited only by climate and not by income. The values obtained this way are then corrected for income which results in the following overall equation for the residential sector:

$$share\ of\ residential\ cooled\ floor\ area = \frac{1-\exp(a \times CDD)}{1+b \times \exp(c \times GNI/household)} \qquad \text{(Eq. 5)}$$

where a, b and c are regression parameters; a is calibrated based on the US market (denominator assumed to tend to zero at high income) and b and c are given by a calibrated model by McNeil et Letschert (2010)[8].

Service sector penetration at saturation is supposed to depend only on climate (Eq. 6), where d is a regression parameter.

$$share\ of\ service\ floor\ area\ cooled = 1 - \exp(d \times CDD) \qquad \text{(Eq. 6)}$$

Both correlations of (Eq. 5) and (Eq. 6) as well as US zones computed from US EIA residential 2009 microdata and 2012 commercial microdata[9] are shown on Figure 12 below.

[8] http://www.sciencedirect.com/science/article/pii/S0378778809003119
[9] https://www.eia.gov/consumption/

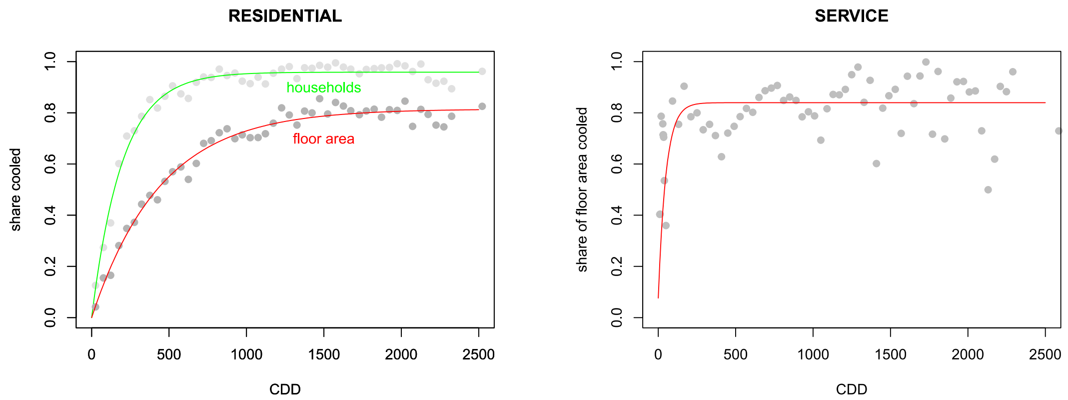


Figure 12: Saturation models and US penetration data (source EIA) of air conditioning in the residential (left) and service sector (right),

Because of global warming, cooling degree days evolve in time, increasing the market saturation level. The same is true for GNI while number of people per household rather tends to decrease in Europe.

Yearly values of cooling degree days are computed from the maximum and minimum temperatures for each day of the year, by comparing their average to a reference temperature (here 18°C).

$$CDD = \sum_{i=1}^{days\ of\ year} max\left(0 \ , \frac{(T_{max}(i)+T_{min}(i))}{2} - T_{ref} \right) \quad \text{(Eq. 7)}$$

The expected change over time up to 2050 of the CDD is modelled based on the Representative Concentration Pathway (RCP) 4.5 scenario developed for the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). CDD are calculated from daily temperature maxima and minima projections by the model of the French Centre National de la Recherche Météorologique (CNRM) based on the RCP scenario. The results are provided by the public NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset. A population weighted average of the largest urban centres (between 1 and 8 locations depending on the spacial population distribution of the country) is chosen to represent the countries' climates (this distribution is given in Annex 3: Cities by country to compute national average CDD from CNRM model).

Figure 13 shows the projection of CDD according to the CNRM model and RCP4.5 scenario for six specific countries (All the modelled countries are shown in Annex 4: CDD evolution and GNI per capita). Yearly variability has been erased to exhibit climate evolution trends.

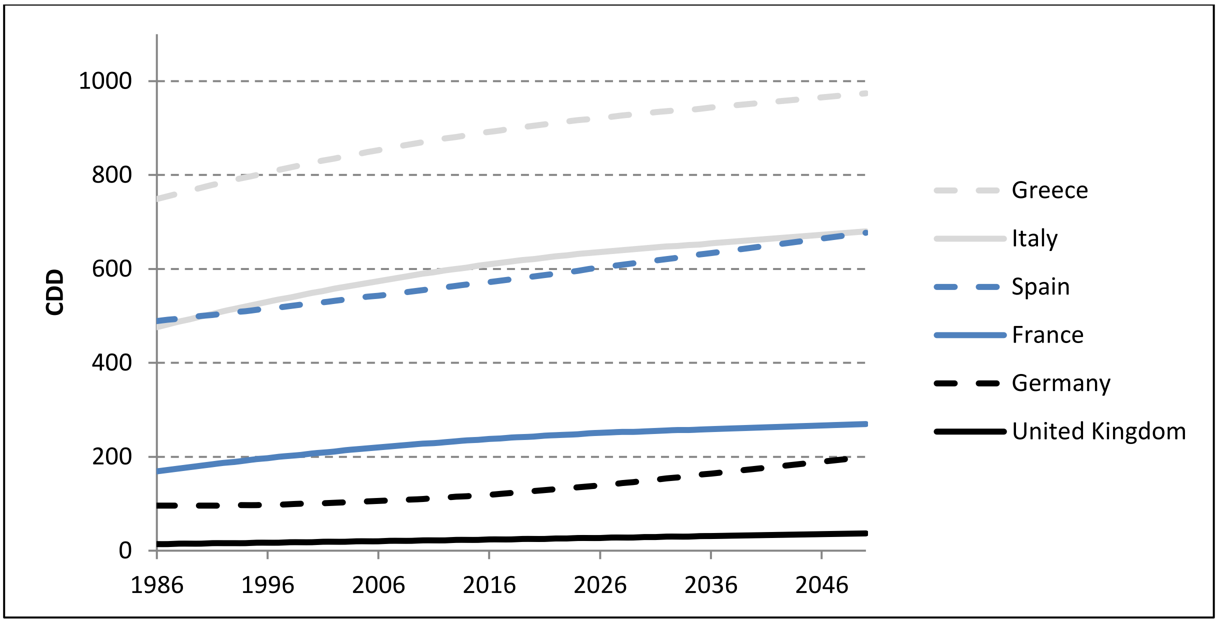


Figure 13: CDD evolution following climate change impact according to CNRM model, scenario RCP4.5, and country model according this report

GNI ppp (Purchasing Power Parity) per capita are available from the World Bank. Number of people per household are available from Eurostat. GNI ppp per capita and linear projections to 2030 are shown on Figure 14 below.

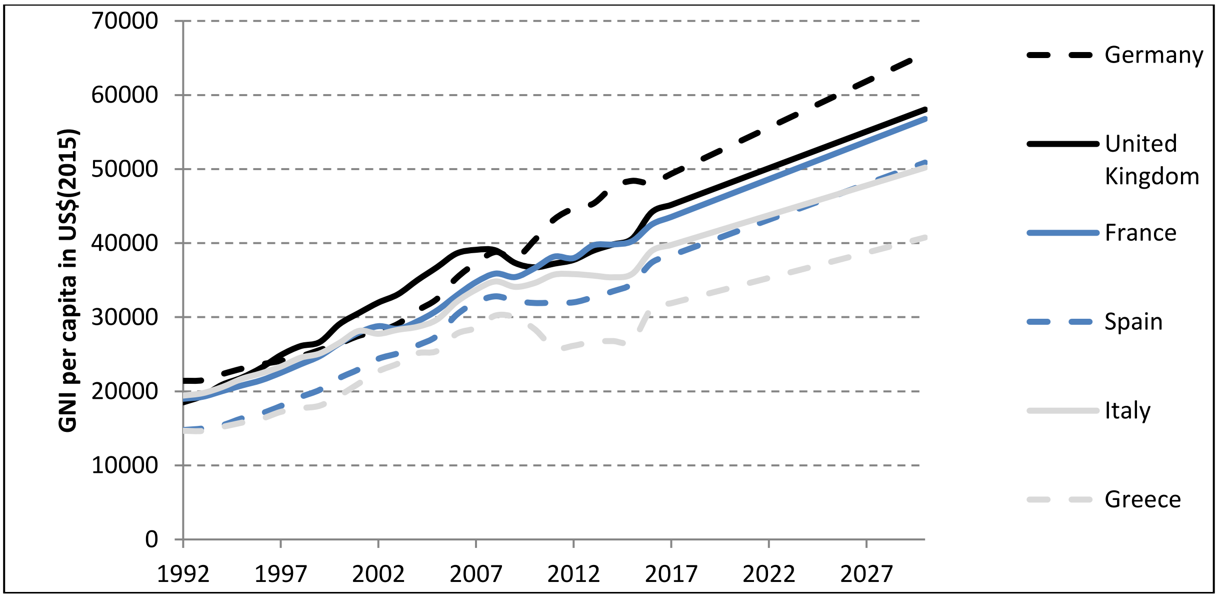


Figure 14: GNI per capita in US$(2015), source World Bank, and linear projections to 2030

The impact of CDD and GNI per household variations in time (considering constant 2015 number of people per household) is shown in Table 6 below. Looking at countries with limited change in CDD between 2015 and 2030, it appears the main impact in the saturation formula is due to the GNI evolution. Countries with lower GNI per capita levels see their saturation level increasing more strongly between 2015 and 2030. To estimate future saturation levels, supposed to be reached by 2060, 2030 saturation levels calculated have been kept avoiding hazardous projections of GNI and number people per households at a longer time horizon.

The comparison between saturation levels and penetration levels shows that the potential for growth is still very high, that it will increase significantly with climate change and that it is very sensitive to household purchasing power for EU countries with lower GNI per capita and hence to product price evolution.

Table 6: Comparison of CDD, saturation level in residential and service sectors, penetration level in residential and service sectors in 2015 and 2030

	2015 CDD	2030 CDD	Sat. res. 2015	Sat. res. 2030	Sat. ser. 2015	Sat. ser. 2030	Res. pen. 2015	Ser. pen. 2015
Austria	226	280	30%	38%	77%	80%	1.2%	13.5%
Belgium	89	95	14%	16%	53%	55%	1.7%	41.2%
Bulgaria	317	384	4%	15%	81%	83%	4.2%	26.2%
Croatia	325	377	15%	39%	82%	83%	5.8%	27.3%
Cyprus	1417	1467	56%	77%	85%	85%	35.0%	84.7%
Czech Republic	117	161	10%	22%	61%	69%	1.5%	18.1%
Denmark	43	74	6%	12%	35%	48%	0.6%	6.6%
Estonia	30	59	2%	9%	28%	42%	0.4%	6.1%
Finland	24	49	3%	8%	24%	38%	0.3%	16.8%
France	236	254	28%	35%	77%	79%	5.1%	33.1%
Germany	118	149	16%	23%	61%	67%	0.5%	15.6%
Greece	889	931	25%	60%	85%	85%	18.1%	76.3%
Hungary	259	320	10%	30%	79%	82%	2.4%	17.2%
Ireland	6	7	1%	1%	12%	13%	0.3%	4.9%
Italy	607	644	42%	60%	85%	85%	13.2%	79.1%
Latvia	42	82	2%	11%	34%	51%	0.5%	6.6%
Lithuania	76	123	4%	18%	49%	62%	0.9%	8.0%
Luxembourg	115	121	19%	19%	60%	62%	1.8%	10.1%
Malta	1258	1321	59%	74%	85%	85%	31.0%	84.7%
Netherlands	42	48	7%	8%	34%	37%	0.8%	17.1%
Poland	109	157	8%	22%	59%	69%	0.9%	19.5%
Portugal	418	491	26%	49%	84%	84%	3.2%	31.0%
Romania	437	495	14%	39%	84%	84%	6.0%	45.8%
Slovakia	168	214	17%	31%	70%	76%	2.3%	13.1%
Slovenia	243	283	17%	35%	78%	80%	3.9%	19.0%
Spain	569	615	44%	60%	84%	85%	10.8%	79.8%
Sweden	18	39	2%	7%	20%	33%	0.8%	31.0%
UK	23	29	3%	5%	24%	27%	0.9%	48.4%

2.2.3 Estimated sales and stock

Based on the data described in part 2.2.1 and the model presented in part 2.2.2, the sales and stock estimates by country have been calculated from 2010 to 2050 and are presented below. These are the sum of portable and split sales and stock. Sales are shown in Table 7 and Figure 15. Sales growth corresponds to almost a doubling of the sales by 2025. Detailed data by country and product categories, in MW and number of units are given in Annex 3. Portable sales have been set almost constant (growing with the building stock growth rate estimate)[10] although the sales history of portable air conditioners do not confirm that hypothesis. It might be however that the 2020 ban on portable air conditioners

[10] Supplementary hypothesis made after a suggestion by Delonghi, April 2017

using higher than GWP 150, by imposing a refrigerant restriction for the EU market lead to a large increase of portable unit prices and consequent sales stalling.

Table 7: EU sales estimate and prevision of less than 12 kW units (in thousands), from year 2010 to 2050

Country	2010	2015	2020	2025	2030	2035	2040	2045	2050
Austria	12	33	22	24	27	30	34	38	42
Belgium	95	100	93	103	110	118	126	135	145
Bulgaria	52	78	88	120	131	144	174	184	212
Croatia	19	51	51	91	94	100	144	149	157
Cyprus	89	91	94	97	100	103	106	109	112
Czech Republic	31	27	37	46	56	67	80	95	110
Denmark	9	20	24	48	48	52	83	89	121
Estonia	0	1	1	2	2	2	4	4	6
Finland	5	3	4	4	4	5	5	5	6
France	517	506	532	626	732	847	973	1108	1253
Germany	196	214	209	243	282	326	376	431	492
Greece	259	336	373	416	461	508	558	613	673
Hungary	66	41	59	74	94	117	146	181	222
Ireland	2	3	4	5	5	6	7	7	8
Italy	1194	970	1248	1465	1706	1979	2290	2648	3056
Latvia	1	1	2	5	4	4	8	8	12
Lituania	2	3	6	11	11	11	19	20	29
Luxembourg	1	3	3	5	5	6	9	9	12
Malta	33	34	35	37	38	39	40	41	42
Netherlands	107	68	82	95	109	124	140	157	174
Poland	121	118	150	184	221	262	306	350	396
Portugal	320	260	278	286	304	320	339	364	389
Romania	78	88	117	143	171	201	235	273	314
Slovakia	12	29	32	59	62	68	99	107	137
Slovenia	7	16	17	30	32	36	51	55	70
Spain	935	573	727	850	983	1130	1294	1484	1706
Sweden	87	84	95	99	104	109	115	121	128
United Kingdom	198	234	240	249	259	270	281	293	306
EU28	4450	3984	4622	5418	6156	6986	8041	9077	10330
Norway*	87	59	74	79	83	87	91	95	99

**Sales data provided by Norway.*

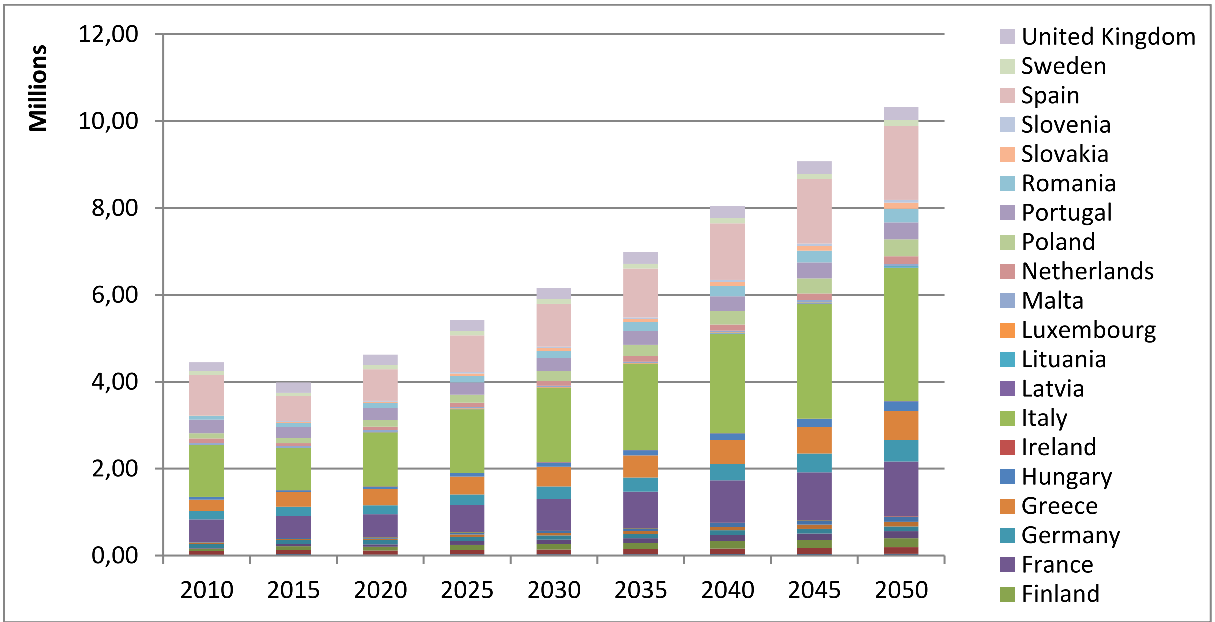


Figure 15: Sales estimates for EU28 countries of portable + split air conditioners, 2010-2050

Stock estimates for EU 28 as a total and each Member State are given below in Table 8.

Table 8: EU stock estimate and prevision of less than 12 kW units (in millions), from year 2011 to 2050

	2011	2015	2020	2025	2030	2035	2040	2045	2050
Austria	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4
Belgium	0.5	0.8	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Bulgaria	0.5	0.7	0.9	1.1	1.3	1.5	1.8	2.0	2.2
Croatia	0.3	0.4	0.5	0.7	0.9	1.1	1.4	1.6	1.8
Cyprus	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3
Czech Republic	0.4	0.4	0.4	0.4	0.5	0.7	0.8	0.9	1.1
Denmark	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.1
Estonia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Finland	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1
France	4.8	5.5	5.5	6.1	7.3	8.5	9.9	11.4	13.0
Germany	1.7	1.9	2.1	2.3	2.8	3.2	3.7	4.3	5.0
Greece	4.6	4.3	3.8	4.4	4.9	5.5	6.0	6.6	7.3
Hungary	0.7	0.7	0.6	0.7	0.9	1.1	1.4	1.7	2.1
Ireland	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Italy	17.5	16.7	13.1	14.4	17.2	20.0	23.3	27.0	31.2
Latvia	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Lituania	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2
Luxembourg	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Malta	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
Netherlands	0.6	0.8	0.8	0.9	1.1	1.3	1.4	1.6	1.8
Poland	0.9	1.2	1.5	1.8	2.2	2.6	3.1	3.6	4.1
Portugal	1.0	0.9	0.7	0.7	0.8	1.0	1.2	1.4	1.7
Romania	0.8	1.1	1.1	1.4	1.7	2.0	2.4	2.8	3.2
Slovakia	0.2	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.3
Slovenia	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7
Spain	12.3	11.0	8.1	8.4	10.0	11.6	13.3	15.3	17.6
Sweden	0.6	0.8	1.0	1.1	1.2	1.2	1.3	1.4	1.4
United Kingdom	2.6	2.6	2.5	2.8	2.9	3.0	3.1	3.3	3.4
EU28	51.6	51.9	46.1	51.3	60.1	69.6	80.1	91.7	104.5
Norway*	0.5	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.1

**Stock data provided by Norway.*

The impact of the economic crisis as modelled is a stock decrease in traditional air conditioning countries, is leading to a nearly constant stock at EU28 level from 2011 to 2020. It is surprising to see the stock decrease slightly around 2015. In real life, it may mean that people have differed their decision to renew their air conditioner because of the economic crisis, with then temporary longer average lifetimes than modelled, which is not captured by the model. The stock starts again to grow by 2020 and doubles between 2045 and 2050.

2.3 Market trends

2.3.1 General market trends

The main change in the market in the recent years is the replacement of the Energy label in 2013 and the adoption of MEPS for both portable and split air conditioners in 2013 and 2014, together with the shift from full capacity ratings to seasonal performance ratings for split units.

For split air conditioners, it is not possible to directly compare SEER and SCOP values before and after regulatory changes because of the metrics change. What can be tracked are two important efficiency drivers, which are inverter rate penetration and EER and COP at rating conditions.

Regarding penetration of inverter driven compressors in the fixed air conditioner segment, it was estimated to be about 60 % already in France in 2006 (EuP Lot 10 study). Recent BSRIA data for Germany, France, Italy, Spain and the UK confirm this rate to be 100 % for all split air conditioner sold in 2015 (lowest penetration value in 2015 was 99.7% in Spain). For portable air conditioners, only a few double duct models (concentric tubes type) could be identified so the market is almost 100% without inverter, which mainly translates the fact that EU regulation does not value it.

The ECC[11] database has been used to identify changes in split air conditioner efficiency in Europe from 2006 to 2016, for EER (Figure 16) and COP (Figure 17). The below data is also available as tables in Annex 5: Changes in split air conditioner efficiency in Europe from 2006 to 2016

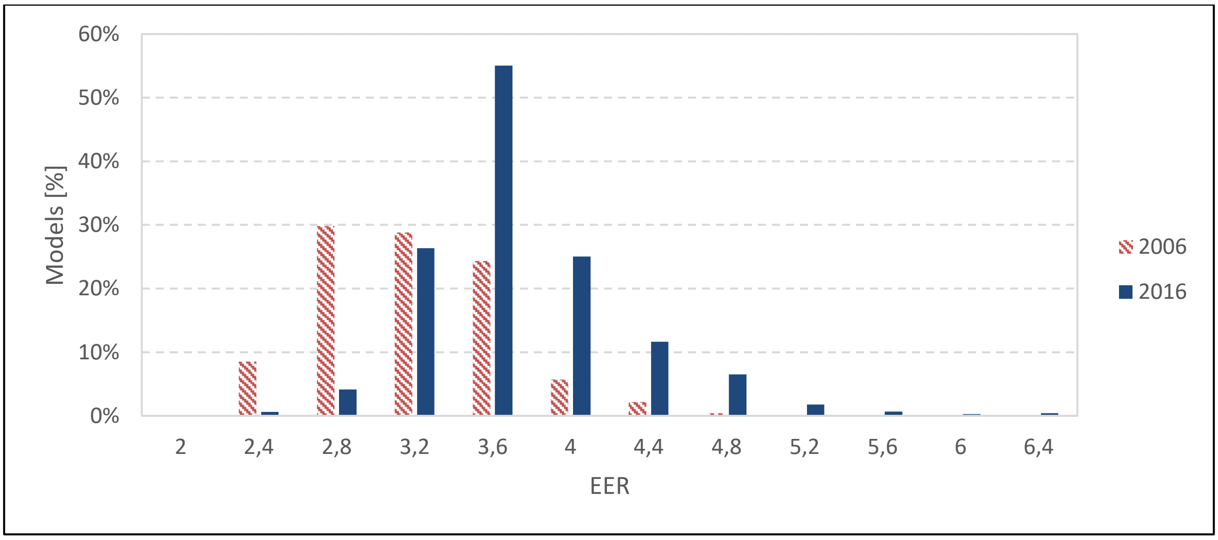


Figure 16: Eurovent Certita Certification split air conditioners below 12 kW certified products, EER evolution 2006/2016

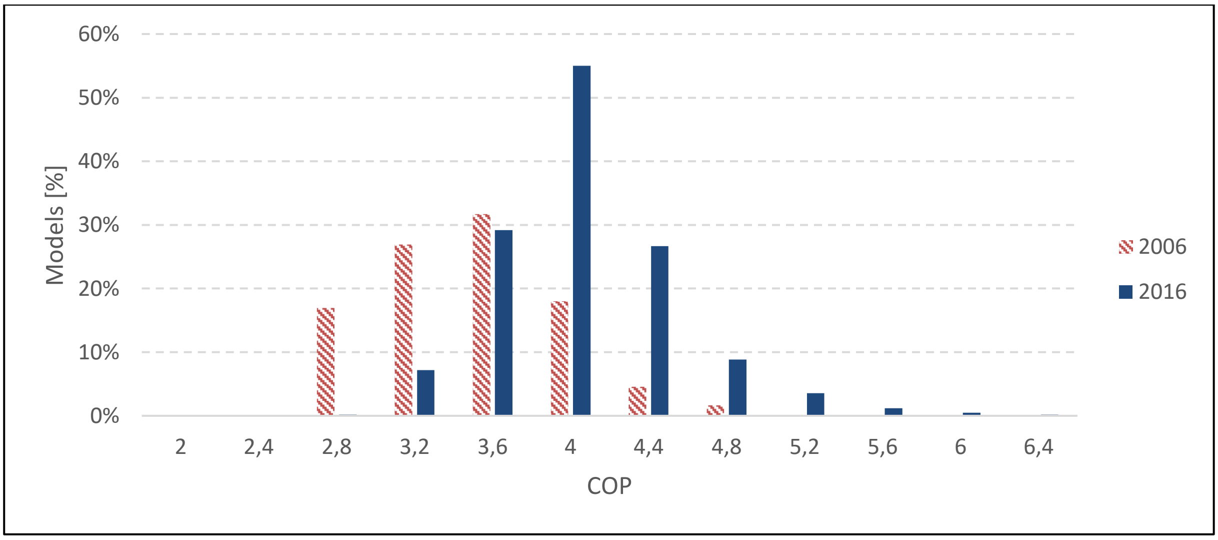


Figure 17: Eurovent Certita Certification split air conditioners below 12 kW certified products, COP evolution 2006/2016

[11] http://www.eurovent-certification.com/

Median EER increased from 2.9 to 3.4 from 2006 to 2016, which is comparable to the previous decade 1996 to 2006, where it had increased from 2.5 to 2.9. Median COP increased from 3.2 to 3.7 from 2006 to 2016, which is more than during the previous decade 1996 to 2006, where it had increased from 2.9 to 3.2.

The declared sales efficiency of split and portable air conditioners sold in Europe (GfK data for 10 EU countries) are presented in Figure 18 and Figure 19 regarding the efficiency of heating and cooling, respectively. For split air conditioners, total sales are very low as compared to total sales for these countries, so that values may not be completely representative. Not all products seem to be labelled properly, more often for portable than for split, and SCOP appear to be indicated largely below MEPS levels for a significant portion of the sales. From this data (taking only authorized declarations), it is possible to compute sales weighted efficiency values, which gives: portable EER = 2.65, portable COP = 2.53, split SEER = 5.7, split SCOP = 4.0.

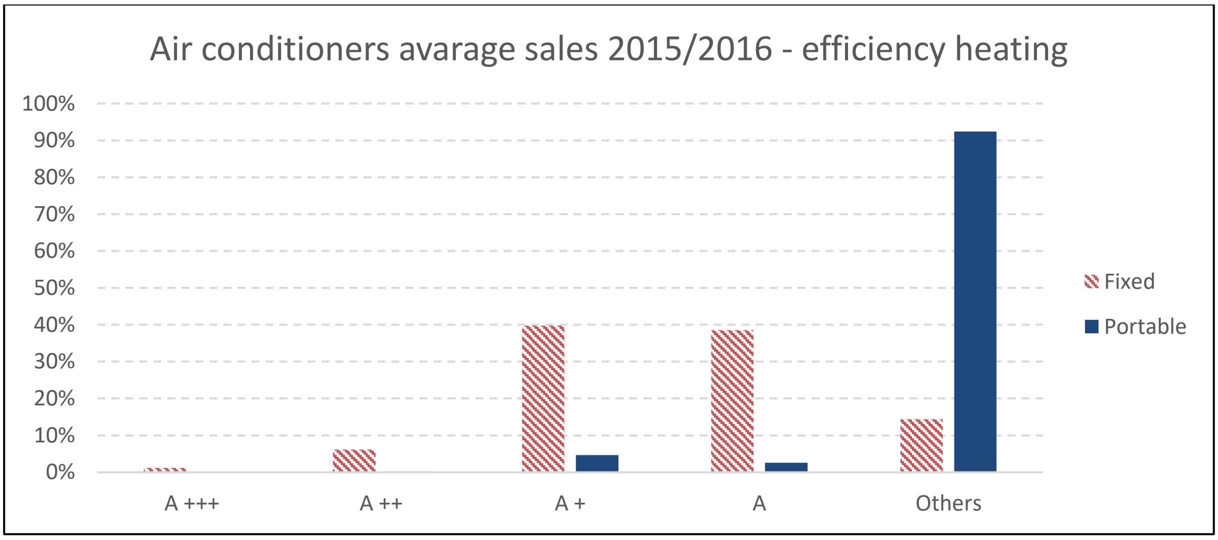


Figure 18: Air conditioners average sales 2015/2016 - efficiency heating

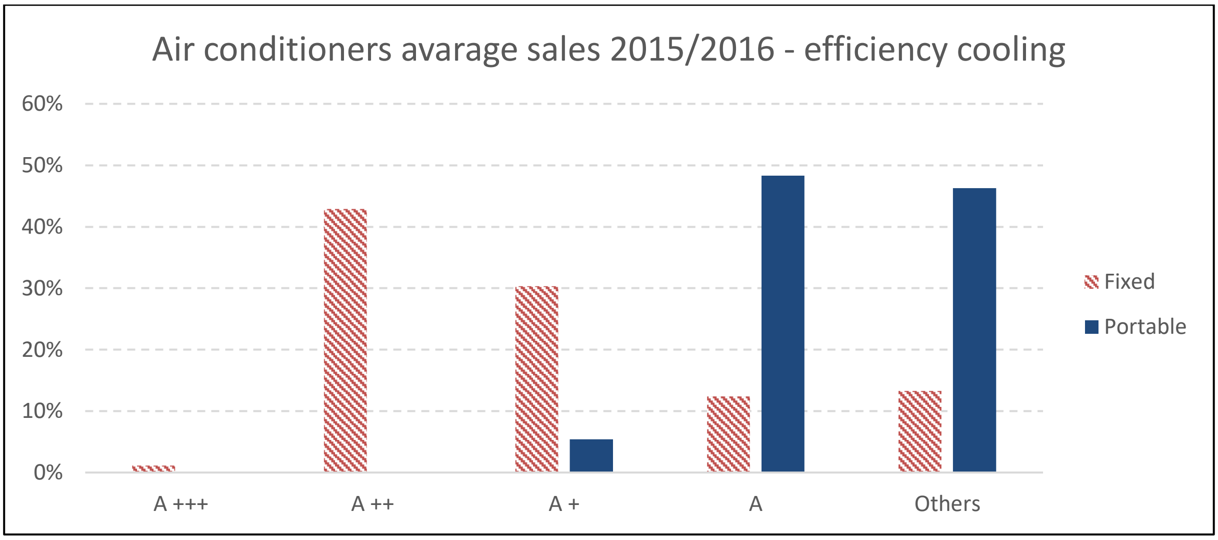


Figure 19: Air conditioners average sales 2015/2016 - efficiency cooling

For split air conditioners, these values are lower than average certified SEER and SCOP values in ECC directory: average SEER 6.2 and SCOP 4.1. It is of interest to remark that the fixed air conditioner A+++ label classes are already populated, although the label with the A+++ indication can only be introduced in 2019 according to Energy Labelling Regulation (EU) No 626/2011 It should be emphasised that it is not lawful to use A+++ indication before 2019.

The most efficient air conditioners seem to be the air conditioners with the lowest capacity. The correlation between capacity (pdesignc) and efficiency is assessed through available data from the ECC database. In Figure 20 is the correlation between capacity and seasonal efficiency for single split air conditioners shown.

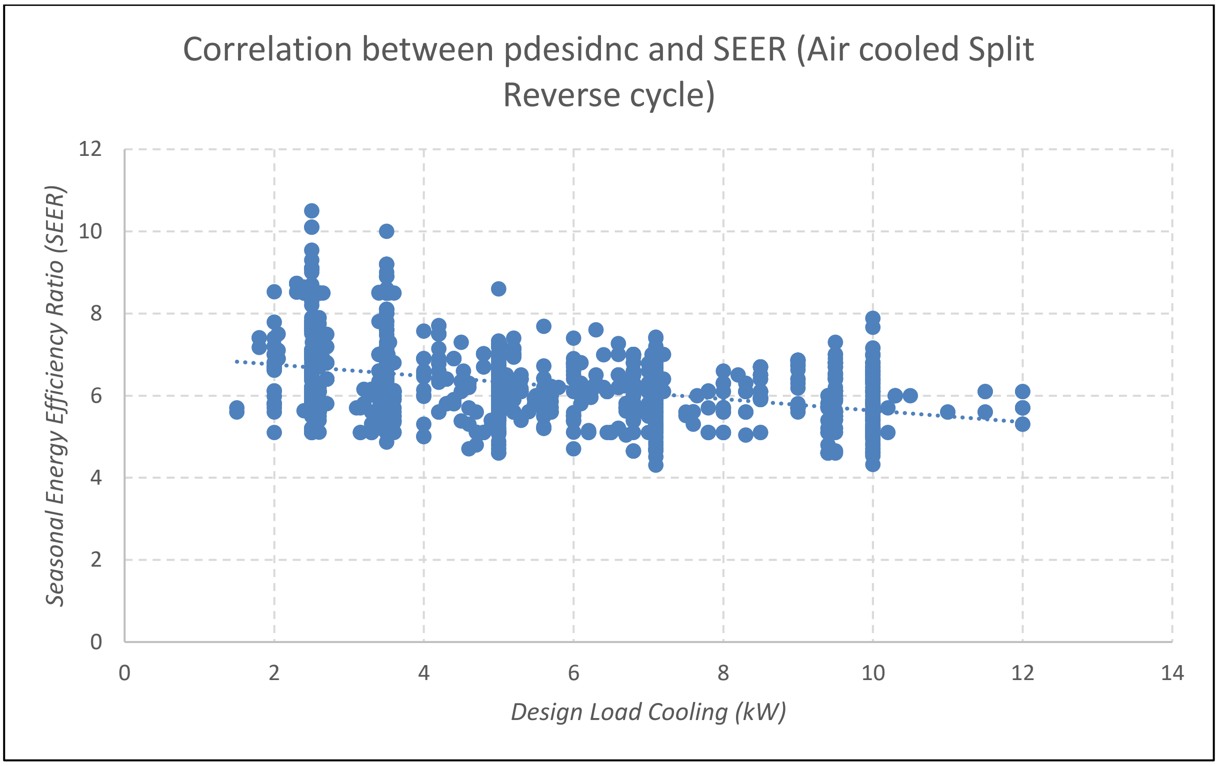


Figure 20: Correlation between Pdesignc and SEER (Air cooled Split Reverse cycle), source ECC

Regarding the change to seasonal performances for fix split conditioners, SEER versus EER and SCOP versus COP are shown respectively in Figure 21 and Figure 22 below using ECC 2016 directory. High dispersion of SEER (resp. SCOP) values for the same EER (resp. COP) shows it is a better way to compare the performances of these products to use seasonal performance indicators (if SEER and EER (resp. SCOP and COP) had been perfectly correlated, the metrics change from full capacity at rating conditions to seasonal performance metrics would have proven useless).

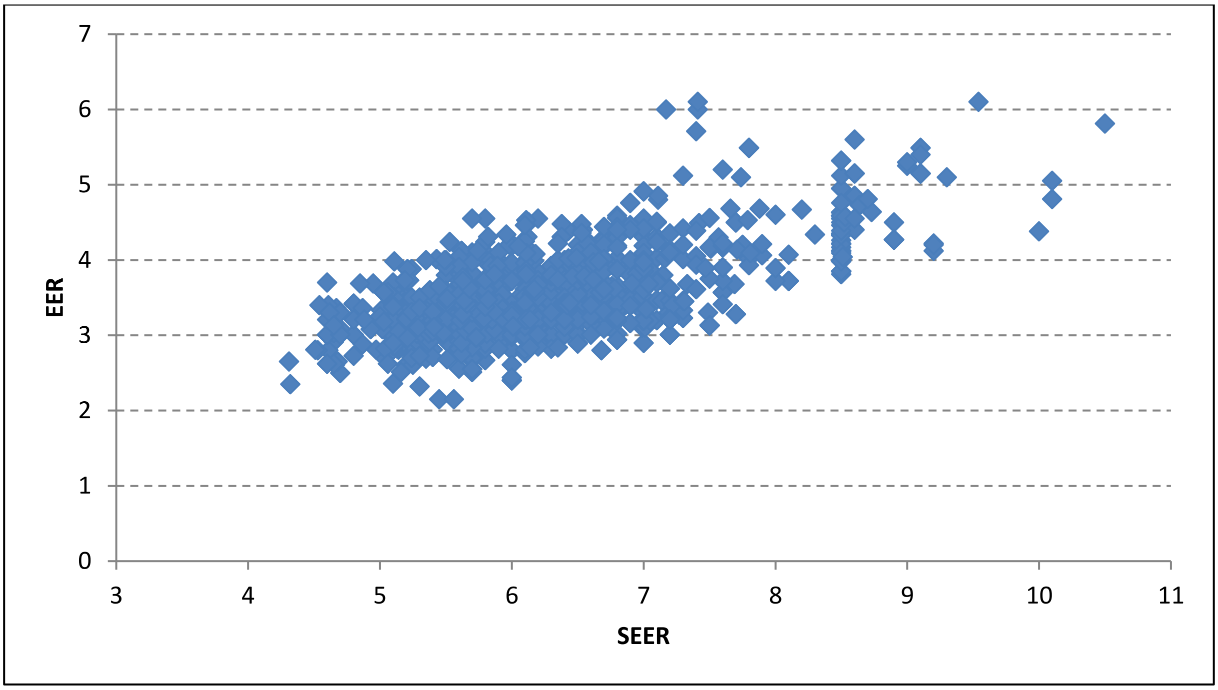


Figure 21: ECC directory 2016, EER Vs SEER

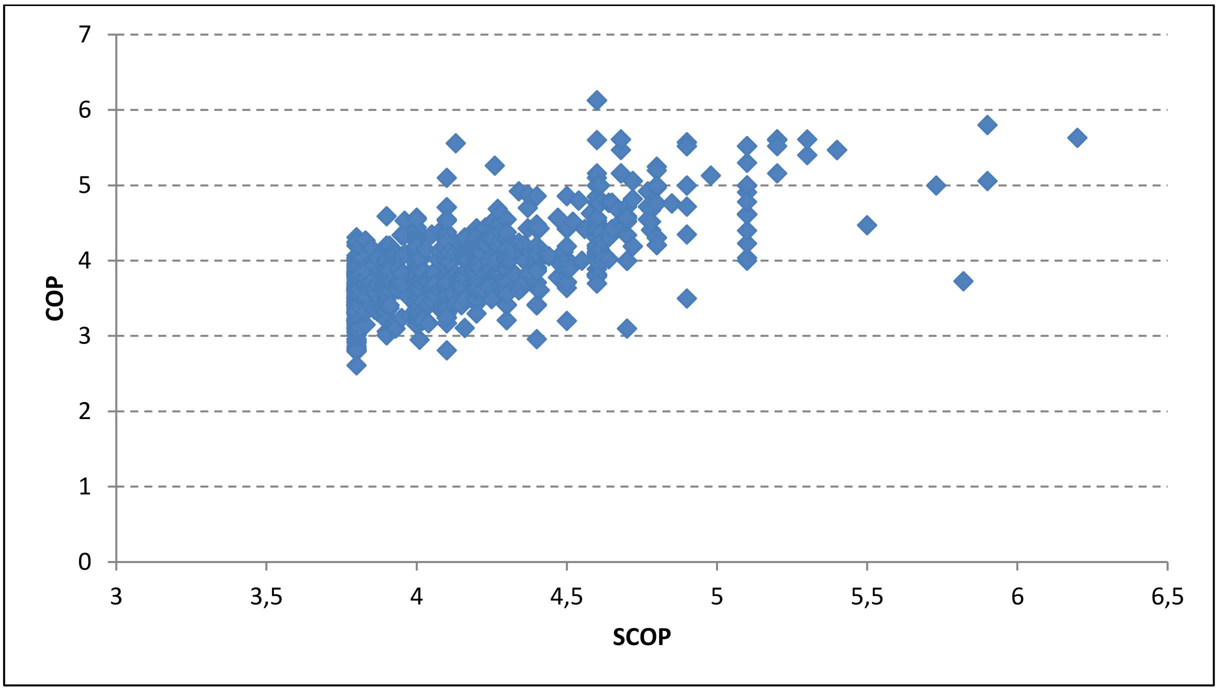


Figure 22: ECC directory 2016, COP Vs SCOP

2.3.2 Market channels and production structure

The European market for split air conditioners is only a small portion of the world market which represented about 90 million units in 2015 according to JRAIA[12], and because of its regulations (on energy efficiency and refrigerants) is also somewhat specific. A minor part

[12] *https://www.jraia.or.jp/english/World_AC_Demand.pdf*

of the production (or assembly) is made in Europe, main countries of production for these products being Czech Republic, Spain, Italy and the UK.

Most of the portable air conditioners are produced in Asia, although there is still a small share of the production made in Europe (Sweden and the Netherlands) according to BSRIA. Main split manufacturers are Japanese, Korean and Chinese brands although US and European brands seem to reinforce their position with more products and models offered. For portable air conditioners, traditional European manufacturers are challenged by retailers (and DIY and other garden or home stores) directly importing from China (and sometimes even specifying the design), direct sales through internet, and Asian new entrant brands from China and Japan mainly.

The standard distribution chain for new construction is shown in Figure 23 below. For replacement and new sales in existing buildings, there is normally no general contractor.

Figure 23: Distribution route for new construction, source US DOE[13]

Distribution routes for portable and split air conditioners in 5 EU countries and the weighted average routes are given in Figure 24 below. As expected, portable, which do not require installation, are mainly sold directly by retailers. For split air conditioners, the proportions of the different routes are more balanced. Note that this is the first point of sales distribution. Products sold to distributor/wholesaler can then be sold via general or specific retailers. When they are sold directly to the customer, most likely the wholesale margin is likely to increase.

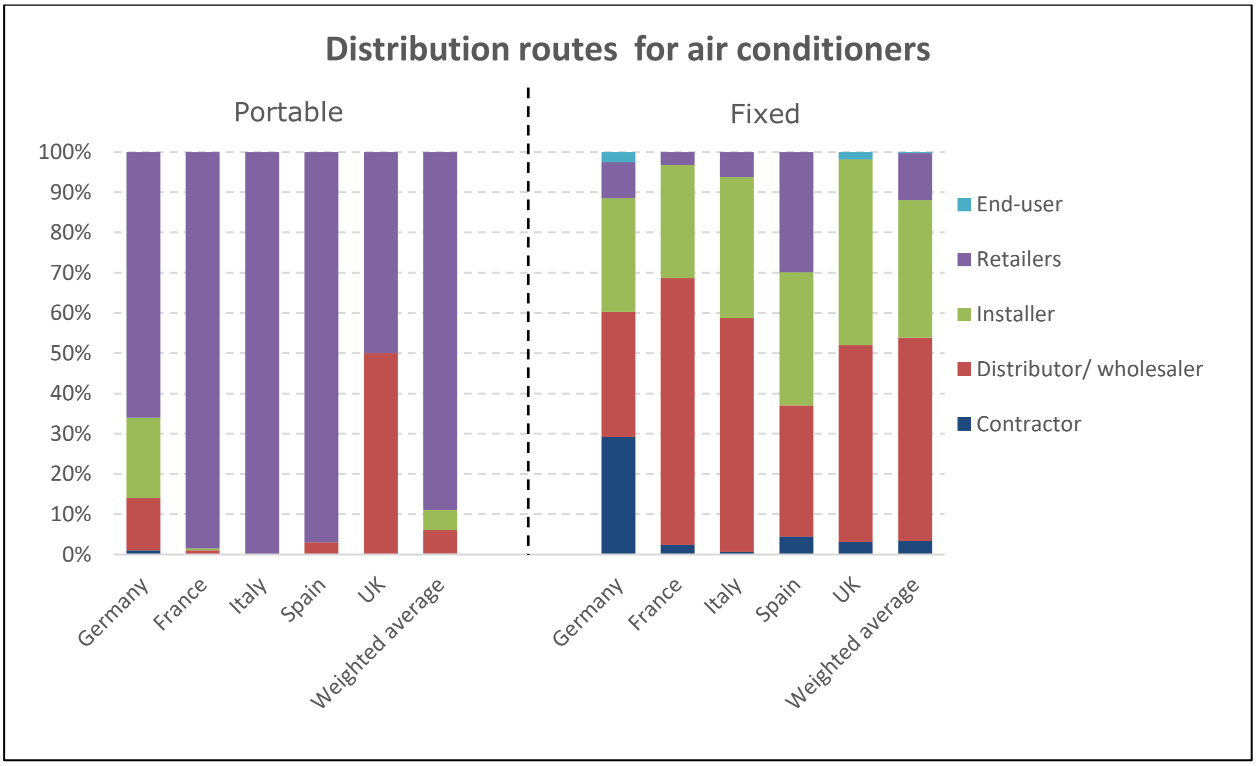


Figure 24: Distribution routes for portable and split air conditioners, source BSRIA

[13] *https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0098*

2.3.3 Trends in product design and features

Beside energy efficiency, the trends in product design identified mainly regard alternative refrigerants, sound power (driven by Regulation (EU) No 206/2012) and "smart" functions. The trend to include more air treatment functions observed in EuP Lot 10 study is more or less generalised, such as dehumidification, fan only, cooling, heating and air purification.

2.3.3.1 Low GWP refrigerant

The planned ban of certain refrigerants by F-gas Regulation (EU) No 517/2014 with higher than 750 values for split air conditioners in 2025 (resp. 150 for portable in 2020) is an important motivation to adopt compatible refrigerant fluids. However, the answer is different in both product segments.

In the split segment, there seems to be a clear trend. Daikin first, and now other Japanese manufacturers are progressively converting their R410A split product range to R32 (it can be noticed that not only single split products are proposed with R32 but also multisplit, despite the ban only regards single split products). It is still the beginning of the conversion however. In 2016, sales of R32 split are estimated to about 5 %, which is also the proportion of models declared with R32 in the ECC[14] directory. Basing on the ECC product database, it seems there is no product using the GWP bonus (allowing an 8 % lower SEER for split air conditioners) to enter the market with alternative refrigerant fluids. Instead, R32 products are put on the market at the same capacity, efficiency and price as middle efficiency or premium R410A units. It thus seems that the impact of the GWP bonus has been null or negligible.

In the portable segment, one company already proposed propane products in 2006 and still does[15]. But there does not seem to be other competitor using alternative refrigerants compatible with the 2020 ban (GWP lower than 150) yet. Information on refrigerant in portable air conditioners is surprising (Table 9) for several reasons. First, not all refrigerants are known, while a refrigerant information label is required by Regulation (EU) 517/2014 for fluorinated gases. Secondly, it is prohibited to sell R22 products in Europe. Third, there are R32 products being sold also for the portable segment although this is not a viable option for the 2020 ban; this is probably a product developed for other markets and imported (Japan for instance). Above that, the share of post ban compatible refrigerant (propane here) is also about 5 % as for split air conditioners. This market is then late for its conversion (because the ban is already in 2020 versus 2025 for split air conditioners). According to experience from a company, it may prove difficult to find reasonably expensive propane compressor manufacturers as at the moment demand volumes are very limited (when compared to global sales)[16]. Thus, the portable air conditioning is likely to adopt other than propane solutions for its conversion, most likely pure HFO or HFC/HFO mixtures with high HFO proportions.

[14] *www.eurovent-certification.com*
[15] Consultation with Delonghi, April 2017
[16] Consultation with Delonghi, April 2017

Table 9: Distribution of refrigerants in air conditioners sold, source GfK

Refrigerant	Fixed average share 2015/2016 %	Portable average share 2015/2016 %
R 407 C	-	2.8%
R 410 A	96.3%	74.8%
R 290	-	5.5%
R 22	-	0.04%
R 32	0.4%	0.4%
<Others>	3.4%	16.4%

With the implementation of the F-gas regulation and the suggested removal of the bonus systems, the only incitement to promote refrigerants with very low GWP i.e. < 150 is the phase down schedule.

It can be discussed if this is sufficient and whether the GWP of the refrigerant should be included with a different approach. A possible solution could be the Total Equivalent Warming Impact methodology (TEWI)[17]. This methodology compares the impact of the refrigerant leakage and the electricity used. In this matter, the equipment is rated according to its total environmental impact and promotes low GWP refrigerants and efficient equipment. The TEWI is calculated by the below equation (defined in Europe in Standard EN378-1):

$$TEWI = GWP \times L \times n + GWP \times m \times (1 - \alpha) + n \times E \times \beta$$

Where:

- GWP is the refrigerant Global Warming Potential (kg CO2/kg refrigerant)
- L is the annual leakage rate [kg/year]
- n is the systems operating lifetime [years]
- m is the refrigerant charge [kg]
- α is the recycling factor [%]
- E is the annual energy consumption [kWh/year]
- β is CO2 emissions on energy generation [kg CO2/kWh]

2.3.3.2 Noise

Ecodesign Regulation (EU) No 206/2012 on air conditioners also has requirement regarding maximum sound power level of indoor (60 dB(A) for ≤ 6 kW and 65 dB(A) for > 6 kW) and outdoor units (65 dB(A) for ≤ 6 kW, 70 dB(A) for >6 kW). The reduction in noise level due to ecodesign is visible when comparing 2006 and 2016 data for both outdoor (Figure 25) and indoor units (*Figure 26*).

[17] http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1708&context=iracc

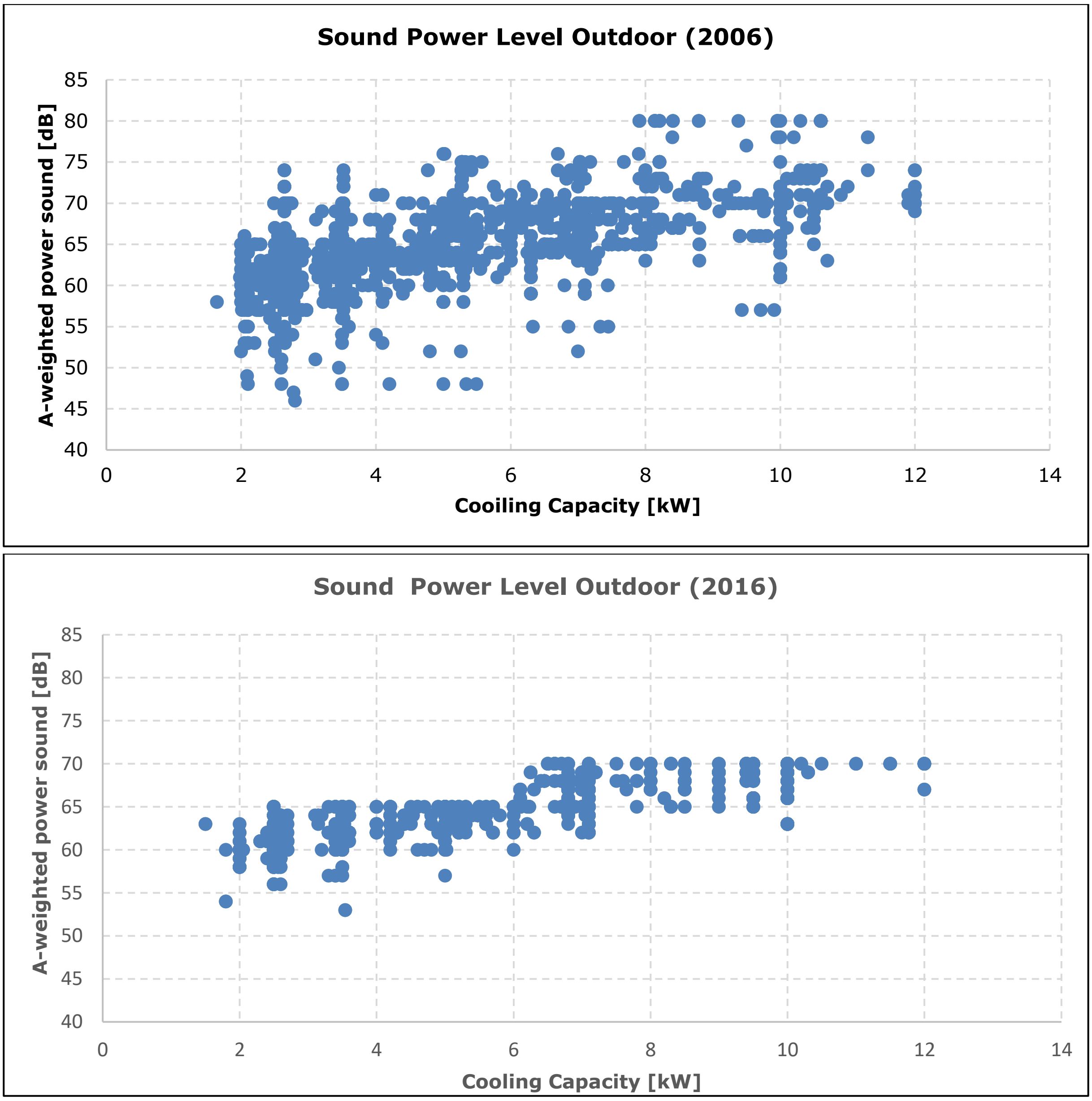
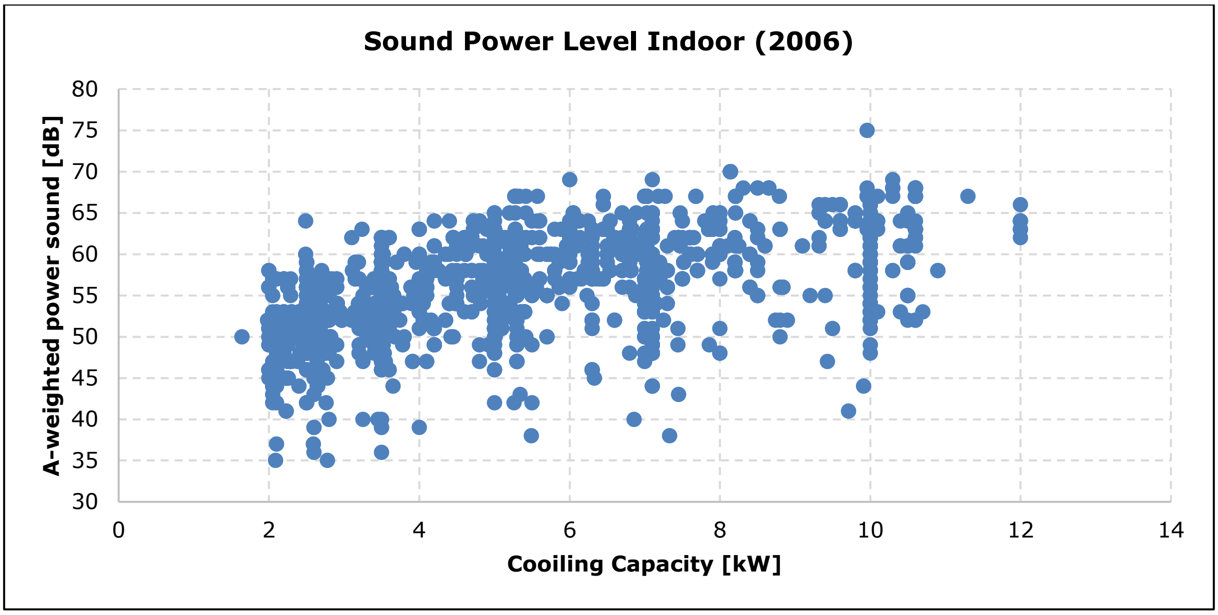


Figure 25: ECC directory 2006 and 2016, air conditioners below 12 kW, sound power level of outdoor unit in cooling mode



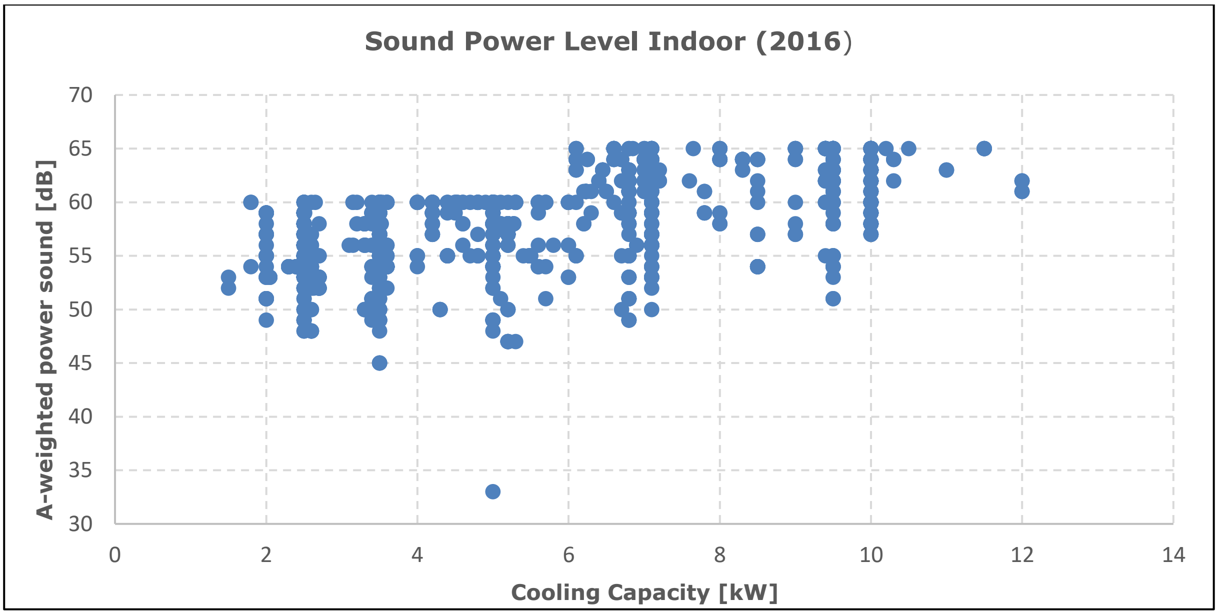


Figure 26: ECC directory 2006 and 2016, air conditioners below 12 kW, sound power level of indoor unit in cooling mode

Today the average indoor sound power level of fixed split air conditioners (≤6 kW) is 56.3 dB(A) while the average outdoor sound power level is 62.3 dB(A). For larger air conditioners (>6 kW) the average indoor sound power level is 61 dB(A) while the average outdoor sound power level is 67.6 dB(A).

From a consumer perspective, the sound power level is less relevant than the sound pressure level. The sound power level is representing the sound directly emitted by the equipment while the sound pressure level is the sound reaches a person's ear (certain measure point from the unit). However, unlike sound power level, the sound pressure level cannot be regulated for products placed on the market as it can depend on the distance of measurement and installation on site. To enable comparison, it can roughly be estimated that the sound pressure level equals the sound power level minus subtracted 8-12 (dB). This means that the average indoor sound power level of fixed split air conditioners (≤6 kW) corresponds to a sound pressure level of 44.3 to 48.3 (dB)

As a comparison, for most concentrated office work, the corresponding Standard EN ISO 11690, Acoustics: Recommended practice for the design of low-noise workplaces containing machinery recommends sound pressure levels of no more than 35-45 dB(A). It should also be noted that the sound power level is a more robust indicator for sound emitted by air conditioners, albeit more difficult to measure, because it is not room dependent nor distance dependent but reflects the total sound power emitted by the unit in all directions. It is thus preferred for rating air conditioner noise emission, even if sound pressure is an interesting reference to compare with requirements in building and other international standards and regulations.

It will be investigated in later tasks how much the requirements for sound power level can be reduced without compromising the efficiency.

2.3.3.3 Network capabilities

Functionalities such as app-controlled functions are more common today than a few years ago. It is assumed that all new air conditioners are ready to be connected to the internet but only a few of the models include this feature directly out of the box. For the majority of the air conditioners sold, these functions are supplementary equipment one has to buy. The share of air conditioners sold with the ability to connect to a network directly out-of-the-box is presented in Figure 27.

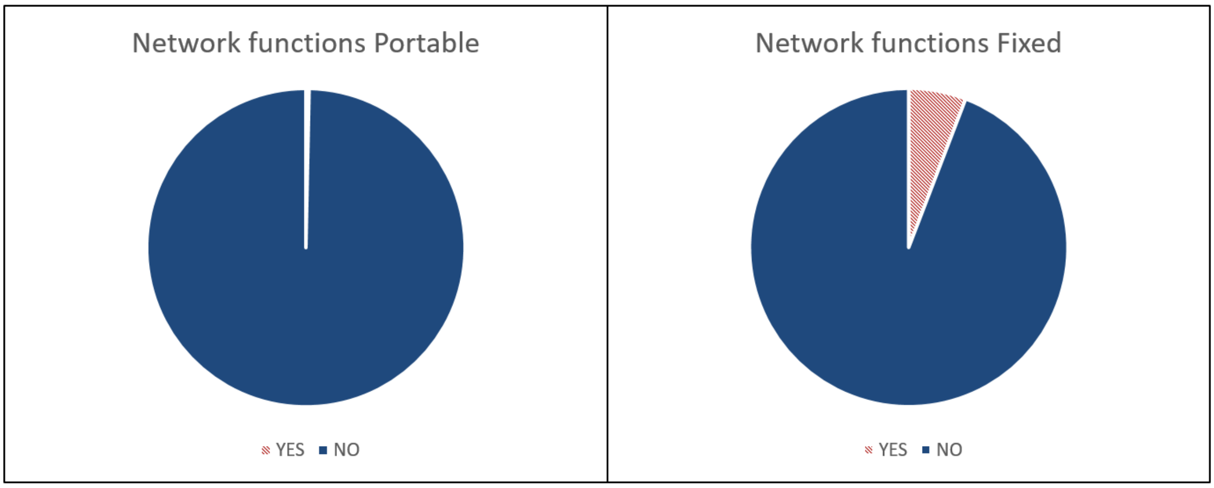


Figure 27: Share of air conditioners sold with network functions

2.4 Consumer expenditure base data

2.4.1 Average EU consumer prices

Manufacturer selling price and final product prices are described below for portable and split air conditioners.

BSRIA data consists of total sales values (manufacturer selling prices, MSP) for 18 EU countries and detailed information on 5 countries.

From GfK, there are weighted average final price of units sold in 10 EU countries (including BSRIA countries) for products sold directly to the customer through retailers.

In BSRIA data for **portable air conditioners**, there appears large variations in manufacturing selling price depending on countries, average MSP for Germany is 393 euros, France 201 euros, 276 for Italy, 338 for Spain and 490 for the UK. Similar trends have been found via online research of various online retail platforms from different countries, the UK seems to have higher prices for portable air conditioners in general. This probably reflects to a certain extent the different types of products sold in each country (whether more or less capacity or higher or lower efficiency) and brands' market shares.

The weighted average manufacturer selling price across 18 EU countries according BSRIA is 342 euros (Table 10), however, the average product size of product sold is not known for all 18 EU countries, therefore the MSP or final product price ratio per kW is not derived. It can be noticed in BSRIA data, prices are starting to increase again after a large drop from 2005 to 2014.

GfK data for average final product price including VAT and retailer margin is 355 euros; with an average size of 2.6 kW this corresponds to about 135 euros /kW (Table 10). Note that GfK values correspond to much lower values than BSRIA estimates: removing 20 % VAT and a typical 40 % retailer margin (see mark-up analysis hereafter at the end of paragraph 2.4.1), the manufacturer selling price corresponds to 210 euros, versus 342 euros for BSRIA. Online research based on various retail platform from 7 countries[18] show also deviations from GfK data, with an average of 460 euros. Datasets on portable air conditioners prices seems to deviate from each other.

BSRIA dataset contains likely more than only residential air conditioners and may be missing a part of the low-cost market available through retailers. On the other hand, GfK prices may underestimate the average price as other distribution routes apart from retails are significant in Germany and in the UK for instance. It seems however more reasonable to use the GfK estimate in the rest of the studies as residential air conditioners bought via retailers is the most current situation, and the average capacity is known for the derived prices. The final manufacturer selling price of 81 Euros per kW is coherent with the 82 Euros per kW (Price sold: 162 USD/kW, corrected for change rate USD/Euro 2014 of 1.33, US retailer margin 1.39 and sales taxes of 1.07) hypothesis of the US DOE in the technical support document of the final ruling proposal of portable air conditioners (based on 2014 price and mark-up information)[19]. It can also be noticed that according this same study, the price per kW of double duct products is similar to the one of single duct air conditioners (74 Euros/kW against 82 Euros/kW for single duct), with only slightly higher average cooling capacity (3.4 kW against 2.8 kW).

Table 10: Estimated manufacturer selling price and final product price of portable air conditioners, based on data from BSRIA and GfK

	BSRIA data	GfK data
Manufacturer selling price weighted average (Euros)	342	210 (2.6 kW)
Manufacturer selling price ratio (Euros per kW)	-	81
Average final product price (Euros)	-	355 (2.6 kW)
Final product price ratio (Euros per kW)	-	135

[18] Spain, Italy, the UK, Netherlands, France, Germany, Denmark
[19] https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=65

Regarding the prices of **fixed split air conditioners**, according to BSRIA data, there are also important price variations, with the same countries exhibiting high prices and low prices as for portable. An average fixed split air conditioner costs 1181 euros in Germany, 746 in France, 719 in Italy, 548 in Spain and 1264 in the UK. The weighted average manufacturer selling price across 18 EU countries is of 704 euros (Table 11), or 154 Euros/ kW with the average unit size of 4.6 kW (weighting sales below 5 kW with anaverage size of 3.5 kW unit and sales above 5 kW with an average size of 7.5 kW unit). This was 195 euros / kW in EuP Lot 10 study. This represents a 21 % price decrease in 10 years. However, BSRIA expects the price to increase in the coming years with the renewed growth of the construction sector. The product category has much influence on the price per kW. According BSRIA, smaller split units have lower price per kW. With an average size of split below 5 kW, e.g. a 3.5 kW unit, the manufacturer selling price is 138 euros/kW. Above 5 kW, using a 7.1 kW average product, the ratio is 165 euros/kW.

GfK data indicates final price values of about 180 euros/kW through retailer channel. When removing 20% VAT and retailer margin (36 % value used here), this results only 110 euros/ kW as manufacturer selling price (Table 11).

The difference between the prices derived from BSRIA and GfK data is likely due to the difference in product type (GfK distribution gives more weight to smaller products with higher share of single split wall units), but also due to the difference in product distribution types as manufacturer selling price varies depending on the distribution routes.

Table 11: Estimated manufacturer selling price of fix (split and multi-split) air conditioners, based on data from BSRIA and GfK

	BSRIA data	GfK data
Manufacturer selling price weighted average (Euros)	704 (4.6 kW)	375(3.5kW)
Manufacturer selling price ratio (Euros per kW)	154	110
Average final product price (Euros)	-	630 (3.5kW)
Final product price ratio (Euros per kW)	-	180

We attempted above to compare manufacturer selling price seen as a constant value above which a variable margin applied depending on destination. This is the US model developed right after. However, BSRIA statistics does not give this value, but the compound value of the product sold to its first buyer (that can be retail, wholesaler, installer, contractor or end-user). For a manufacturer, selling directly to an installer enables to increase its margin of the money given to the wholesaler in the complete value chain. We evaluated this maximum gain based on mark-up values indicated in Table 12 and the product distribution routes in Figure 24: this leads to a 20 % increase in manufacturer selling price (18 % below 5 kW and 25 % above, when specifying the different distribution channels by size). Hence, the weighted average BSRIA manufacturer selling price is now close to 128 (117 for less than 5 kW units and 132 for higher than 5 kW units) and thus closer to the estimate from GfK value.

However, there is still some differences to be explained: GfK retail final price for single split wall unit is 512 euros, however, the unit size is not known. Using again average BSRIA product size and GfK product type distribution, the average wall unit type product size in GfK data is probably about 3.4 kW, which gives when accounting for 36% retailer markup and taxes about 92 Euros per kW. Hence using 117 euros per kW seems exaggerated. As a consequence, the study team made an estimate of the likely EU average price per size and category (trying to be coherent with BSRIA data as a whole and using GfK information price information via internet search). The estimated manufacturer selling prices by unit type are presented below in Table 12.

This representation, combined with the sales per product type given in Table 3, allows to have the same weighted average as derived from BSRIA (117 for less than 5 kW units and 132 for higher than 5 kW units) and to be compatible with the estimate for single split wall unit derived from GfK data (95 euros / kW for base unit versus estimated 92 from GfK). A few remarks should be added:

- the ratio multi-split / split has been derived from 18 countries (about 1.9), but has been corrected accounting for internet price survey for larger units (where prices are lower); multi-split indoor units are mainly of wall type and it was not possible to disaggregate by the prices per type because of the difficulty to find prices for these products.
- largest uncertainties are for non wall product types as there sales are lower (errors have less impact on the weighted average final price).

Table 12: Estimated manufacturer selling price by product type, adapted from GfK and BSRIA source

	Single split					Multisplit
	Wall	**Ceiling type**	**Floor/vertical or consoles**	**Cassette**	**Ducted**	**All (mainly wall)**
< 5 kW	95	171	190	171	171	181
>5 kW	124	137	137	137	127	153

Above manufacturer selling price, the final price paid for the unit also depends on the distribution route. Often the more players involved, the more expensive the unit.

Typical mark-ups from a recent US regulatory text on central air conditioners (which includes part of EU type split systems) is shown in Table 13.

Table 13: Example of mark-up multipliers depending on distribution routes for central air conditioners, source US DOE[20]

	Replacement		New Construction	
	Baseline Mark-up	**Incremental Mark-up**	**Baseline Mark-up**	**Incremental Mark-up**
Manufacturer	1.34		1.34	
Wholesaler	1.36	1.10	1.36	1.10
Mechanical Contractor	1.53	1.23	1.43	1.14
General Contractor	-		1.46	1.33
Sales Tax	1.07		-	
Total Mark-up	3.00	1.95	3.80	2.24

For a limited number of products, it was possible to compare manufacturer selling prices and installer + wholesale margin + VAT in Europe. For average efficiency products, the result is close to 2.2, which is in line with US values (2.2 using a 7 % VAT). However, with

[20] https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0098

the 20 % VAT in Europe, the mark-up comes to 2.5 (in Table 13, 1.36 x 1.53 x 1.2=2.5). We keep in what follows this detrimental value of 2.5.

Table 14 shows the extract of the US regulatory text regarding mark-up multipliers for portable air conditioners. Retailer mark-up in Europe for portable air conditioners, starting from manufacturer selling price and including 20 % VAT (instead of 7% in the USA) is thought to be close to 1.7 for first time installation and replacement. This is based on US values with adapted taxes (in Table 14, 1.39 x 1. 2=1.67). This is a useful input to compare manufacturer selling prices and street prices of best products in further tasks.

Note that the incremental mark-up multipliers are to be applied to the manufacturer selling price increase due to more efficient and thus more expensive product. Mark-up thus decrease for more efficient products, from 2.5 to 1.6 for fixed air conditioners, and from 1.67 to 1.36 for portable air conditioners.

Table 14: Example of mark-up multipliers depending on distribution routes for portable air conditioners, source US DOE[21]

	Replacement		New Construction	
	Baseline Mark-up	Incremental Mark-up	Baseline Mark-up	Incremental Mark-up
Manufacturer	1.42		1.42	
Retailer	1.39	1.13	1.36	1.13
Sales Tax	1.071		1.071	
Total Mark-up	2.11	1.72	2.11	1.72

Distribution routes for portable and split air conditioners in 5 EU countries and the weighted average routes are given in Figure 24 in section 2.3.2 above.

As expected, portable, which do not require installation, are mainly sold directly by retailers. Only about 5 % are surely sold via installers according to BSRIA: using the mark-up chain of split air conditioners sold via installers (2.5) and the retail mark-up of 1.67 (1.39 * 1.2), the total markup is then about 1.7 (1.72), while it could be reduced to about 1.35 for premium efficiency products.

For split air conditioners, the proportions of the different routes are more balanced, and comparing with GfK total B2C sales, it can be assessed this share is larger than just the retailer share in BSRIA statistics on first point of sales, higher than 40 %. According to BSRIA it should also be lower than about 60 % (as installers and contractors represent about 60 % of the total). Assuming a 50/50 sharing between final B2C retail and sales via installers, this leads to a total markup of 2.1 (50% * 1.36 * 1.2 + 50% * 1.36 * 1.53 * 1.2 = 2.1). The mark-up is probably higher when there is a contractor; according to BSRIA statistics, it is at least 5 % and could go up to 15 % (considering all new built need a contractor). Considering 10 % and using the USA mark-up hypothesis for the additional general contractor of 1.46, the total average mark-up for split air conditioners increases up to 2.2 (2.22), while it could be reduced to about 1.65 for premium efficiency products.

A summary of average manufacturer selling prices and of final prices is given in Table 15 below. Manufacturer selling price differences for less than 5 and more than 5 kW seem to be correctly explained by the change of the mix of product type (less wall indoor units and more cassettes and other types) so that in practice, the prices per kW are thought to be

[21] https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0098

relatively flat for the same type of unit. For multisplit air conditioners, the price ratio to wall single split would vary depending on the type of indoor unit; the price given is an average over the 0-12 kW range.

For split air conditioners, a sensitivity analysis of at least +/- 10 % is to be performed on the results of the study given the differences in prices for both datasets used to derive the prices.

Table 15: Average product price

Air conditioner type	Portable	Single split							Multisplit
	Single duct	Size / type	Wall	Suspended ceiling	Floor/vertical or consoles	Cas-sette	Ducted		all mounting types
Manufacturer selling price (Euros / kW)	81	< 5 kW	95	171	190	171	171		181
		>5 kW	124	137	137	137	127		153
Mark-up (incl. VAT)	1,7	< 5 kW	2,2	2,2	2,2	2,2	2,2		2,2
		>5 kW							
Final price to customer (Euros / kW)	138	< 5 kW	209	368	490	399	418		418
		>5 kW	272	301	301	301	278		338

Price premium indications have been supplied by several stakeholders for split air conditioners (variations of manufacturer selling prices) for different levels of efficiency. The result of the analysis is shown in Figure 28. In that figure, the 100 % price has been aligned to the product type efficiency using the ECC directory (1st quartile, see comparison of average SEER between GfK and ECC directory in section 2.3.1). This SEER value matches with the average price indicated in Table 15 for corresponding product type. The maximum SEER value drawn on the graph is also extracted from ECC directory.

For wall units, for which many price information are available via internet, efficiency cost increments (or price/cost depending on data supplied) were compared with market values from internet search. The overcost curve built compares well to the information received from stakeholders and to the internet search results. SEER values above 8.5 are prospective indications supplied by manufacturers. Note that R32 units have not been considered here because of the different manufacturer policies regarding the prices of these units; there are in some cases relatively high overcost at equal efficiency (mainly for high class products) and in other cases (mainly lower end products) lower prices, while the bulk of average products exhibit similar or slightly lower prices. Hence, there is no clear signal of a higher price for R32 units versus R410A units in general and the study team thinks these differences are not meaningful and cannot represent the mid-term evolution of R32 unit prices. For larger units, the price increase curve is similar, and the same curve can be used, although the base price per kW is higher and the maximum efficiency reached is lower.

For cassettes and ducted type units, information on 3.5 kW units were too limited so that only 7.1 units could be assessed. For these categories, the study mixed stakeholder information and its own price information research because of limited information. It can be seen that the slope of the overcost curves increases from wall to cassette and ducted units in relation to the maximum SEER value that can be reached in the specific category.

Note that these price curves are to be considered carefully. Indeed, there may be other functionalities / features added in premium products that are also included in the price (to be investigated in Task 4). It is also important to state that this is not forcedly the price signal seen by the end-user, because of the pricing policy of the different actors in the distribution routes (for instance retailers may take larger mark-ups on low efficiency ranges or adapt those in order to maximise their sales or profit or to empty the stocks), and of the different possible distribution routes.

It is interesting to notice that overall, the price relationship to efficiency for split products mainly depends on SEER values (despite a limited number of manufacturers may have different policies). If using it also systematically for heating and rationale, the customers should rather look at SCOP values, which makes most of the consumption (QHE=1400 and QCE=350).

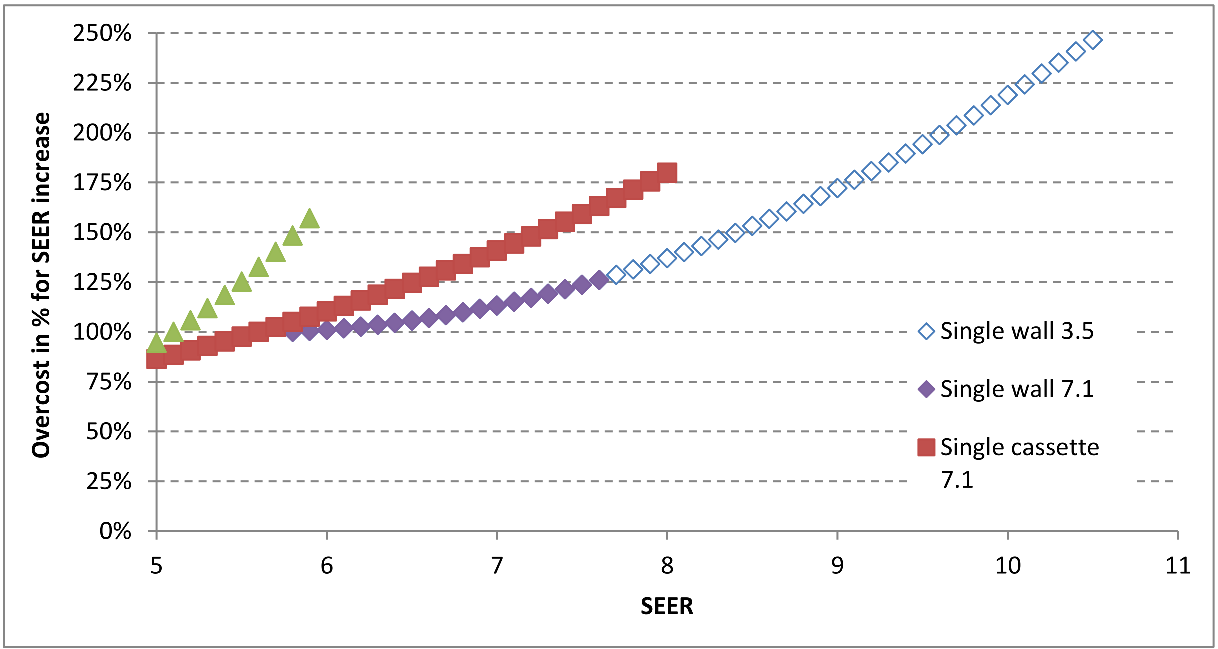


Figure 28: Price premium for some of the split air conditioners

For portable air conditioners, prices were derived based on GfK data. However, the information is averaged at EU level and price signal between classes are thus difficult to interpret. The average final product price (355€ presented in Table 10) also equals the price of an energy class A product. However, the change from class A to class A+ leads to much higher prices, 650 to 700€, resp. about 80% and 100% product price increase. This is probably because A+ models are sold only by EU manufacturers whose models are usually more expensive.

2.4.2 Installations costs

Installation costs in EuP Lot 10 study were evaluated to be of 1000 Euro (Incl. VAT) per fix single split unit, independently of the unit size. Industry stakeholders have indicated that the installation costs for split units vary a lot depending on the country and to some extent the size of the air conditioner. The price of a similar sized unit can be above 1500 in one country and as low as 350-700[22] Euro/unit in another country. Based on inputs from the stakeholders the suggested installation costs is reduced to 800 Euro/unit independently of the unit size. It should be noted that the installation costs have no impact on the efficiency of the LLCC.

[22] Data collection from industry stakeholders, June 2017.

2.4.3 Repair and maintenance costs

For split air conditioners, as in EuP Lot 10 study, repair and maintenance are based on prEN 15459:2006(E) and are estimated to be of 4 % of the initial investment (including installation costs) per year. This includes annual preventative maintenance and repair and servicing costs. Using the weighted average manufacturer selling prices of 128 euros / kW, this leads to:

$$Average\ maintenance\ annual\ cost:\ 4\%\ \times (800\ Euros\ + (128\ \times 2.2\ \times 4.6\ \mathrm{kW}) \approx\ 85\ euros$$

Stakeholders have indicated varying cost of repair and maintenance depending on the country and the unit size. The 85 Euro/year in this example seems reasonable based on the inputs from the stakeholders. An average repair and maintenance cost of 4 % on initial investment will be used.

There is no maintenance cost for portable air conditioners as in most cases end-users maintain themselves their units following manual instructions.

2.4.4 Disposal costs

The disposal costs are paid by the end-user buying the products under the form of the Eco tax under the WEEE directive. For an air conditioner, this corresponds nowadays to a fee of 80 to 120 euros/tonne. This fee is adjusted on a country basis and by product category depending on recycling costs. The fee is not always included in the final product price, and even if it is, it is not always allowed to be visible at the point of sale. Stakeholders have also indicated that the removal of air conditioners can cost up to 850 euro for a multi-split system including recovery of the refrigerant and removal of units, refrigerant pipe, drain pipe and electric wires. The disposal costs are estimated to 500 Euro/unit independently of the unit size.

2.4.5 Interest, inflation and discount rates

The generic interest and inflation rates in the EU-28 are presented in Table 16. The European Commission recommends a discount rate of 4%[23].

Table 16. Generic interest and inflation rates in the EU-28[24].

	Domestic	Non-domestic
Interest rate (%)	7.7	6.5
Inflation rate (%)	2.1	
Discount rate (%)	4	

2.4.6 Electricity prices

Electricity prices are presented in the MEErP methodology. Recent updated average household and industry prices were found for 2015 S1 (first half of the year) including average annual price increase based on EUROSTAT[25], and are presented in Table 17.

From the first half of 2014 to the first half of 2015 the electricity prices have increased by 2 % for household consumers. For industrial consumers, there have been a 2 % percent decrease in the same period. The electricity prices are subject to yearly fluctuations but in the long-term the electricity prices are expected to increase. The development in electricity prices from 2008 to 2016 are presented in Annex 6: Electricity prices

[23] http://ec.europa.eu/smart-regulation/guidelines/tool_54_en.htm
[24] VHK(2011), MEErP 2011 METHODOLOGY PART 1.
[25] Source: Eurostat, assessed April 2017

Table 17. Household and industry electricity costs and annual increase from 2014 S1 to 2015 S1 (first half of the year).

EU country	Household electricity price 2015 S1, €/kWh	Annual household price increase 2014 S1 to 2015 S1, %/a	Industry electricity price 2015 S1, €/kWh	Annual industry price increase 2014 S1 to 2015 S1, %/a
Belgium	0.2126	1%	0.11	1%
Bulgaria	0.0942	13%	0.0692	-7%
Czech Republic	0.1385	0%	0.0772	-7%
Denmark	0.3068	1%	0.0899	-4%
Germany	0.2951	-1%	0.1509	-5%
Estonia	0.1302	0%	0.0889	-3%
Ireland	0.2426	1%	0.1417	4%
Greece	0.1767	0%	0.1292	-3%
Spain	0.2309	7%	0.1173	-6%
France	0.1624	2%	0.1008	2%
Croatia	0.1317	0%	0.092	-4%
Italy	0.245	0%	0.1608	-7%
Cyprus	0.1957	-15%	0.1393	-20%
Latvia	0.1635	20%	0.1178	1%
Lithuania	0.1256	-6%	0.0989	-15%
Luxembourg	0.1767	2%	0.0928	-8%
Hungary	0.1127	-6%	0.0867	-5%
Malta	0.1257	-15%	0.1599	-10%
Netherlands	0.1986	8%	0.0902	-3%
Austria	0.2009	-1%	0.1039	-5%
Poland	0.1444	2%	0.0882	7%
Portugal	0.2279	5%	0.114	-2%
Romania	0.1303	1%	0.083	-5%
Slovenia	0.1589	-3%	0.0827	-5%
Slovakia	0.1506	0%	0.1126	-2%
Finland	0.1552	-1%	0.0707	-4%
Sweden	0.1851	-6%	0.0622	-12%
United Kingdom	0.2125	11%	0.1489	16%
EU (28 countries)	**0.2085**	**2%**	**0.1206**	**-2%**
Norway	0.1614	-2%	0.077	-4%

Electricity prices from EUROSTAT presents the past and current electricity prices but does not suggest any projections for the future. Standardised projections are suggested in the Ecodesign impact accounting[26] The impact accounting study use updated electricity price for 2013 (0.189) and then escalate with 4 % pa (MEERP). The suggested electricity prices are presented in the below table.

Table 18: Real rates electricity prices from 1990 to 2030. Based on the Ecodesign impact accounting

Real rates electricity prices from Ecodesign impact accounting*						
	1990	2000	2010	2015	2020	2030
Residential €/kwh elec*	0.178	0.162	0.170	0.205	0.249	0.369
Industry €/kwh elec*	0.119	0.084	0.105	0.122	0.149	0.220

** Inflation index (2010=1, inflation 2%)*

***Residential (incl. VAT); Industry (excl. VAT, tariff Ie)*

The electricity prices from the ecodesing impact accounting seems a little high and the commission have discussed how to apply more realistic projections of the electricity prices.

[26] Van Holsteijn en Kemna B.V. (VHK), ECODESIGN IMPACT ACCOUNTING Part 1 – Status Nov. 2013, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf

The commission have decided to use data from PRIMES[27]. The suggested electricity prices are presented in Table 19.

Table 19: Electricity priced suggested by the commission[28].

Electricity	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Average €/kwh	0.117	0.136	0.144	0.153	0.157	0.161	0.165	0.165	0.163	0.163
Industry €/kwh	0.084	0.097	0.097	0.098	0.099	0.100	0.101	0.102	0.101	0.101
Households €/kwh	0.156	0.172	0.190	0.203	0.209	0.212	0.217	0.215	0.211	0.209
Services €/kwh	0.127	0.148	0.157	0.171	0.176	0.179	0.184	0.182	0.180	0.178

In real life air conditioners are used in households and in the service sector. Hence, the electricity price to be used in EcoReport Tool (Task 5) for the average air conditioner in EU consists of both the residential and industry rate. The share of residential consumers is presented in Figure 29.

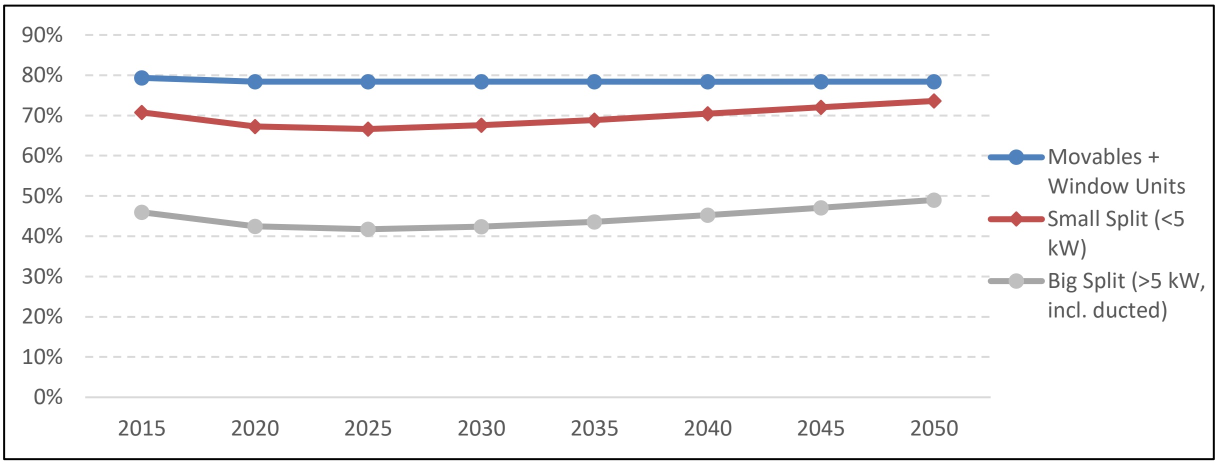


Figure 29: Share of residential users for portable air conditioners and fixed air conditioners

2.5 Conclusions and recommendations

There have been important changes in the market structure since the preparatory study completed in 2009. Mobile split and window/wall air conditioners have almost completely disappeared from the EU market. Regarding fixed air conditioners, they are now nearly all reversible (> 99%).

Since the preparatory study the development in sales of air conditioners have been almost flat (comparing 2005 and 2015 markets) which is widely due to the financial crisis (sales increased to very high levels in 2007, dropped until 2013-2014 and started to grow again in 2015-2016 depending on the country). Even though the trend has been flat it is expected that the sales will increase over the next decades. It has been shown based on US and world air conditioning development that sales and stock could be increased by fourfold from 2015 to 2050. The comfort decision to install air conditioning is influenced by climate (and global warming will increase air conditioning penetration), building regulations and affordability, the increasing gross national income (GNI) per capita will increase the consumers' willingness to buy air conditioners. In 2015 the sales were approximately 4

[27] PRIMES 2016
[28] PRIMES 2016

million units and the stock were 53.7 million units. The sales and stocks are expected to increase and reach above 10 million units in sales and 98.5 million units in stock by 2030.

The market is dominated by air conditioners with R 410A refrigerant, but this is expected to change soon to refrigerants with much lower Global Warming Potential (GWP) due to the F-gas regulation.

According to the market data of fixed air conditioners, A++ is well populated and the A+++ category is already populated before the regulation (EU) No 626/2011 introduces the A+++ class. It should be noted that it is not lawful to use A+++ class indication before 2019. For portable air conditioners, only a few of them can reach an A++ mark currently.

Based on Eurovent Certita Certification data, it is clear to see the increasing trend of air conditioners efficiency, median EER increased from 2.9 to 3.4 from 2006 to 2016, and COP increased from 3.2 to 3.7 from 2006 to 2016. Sales weighted efficiency is calculated based on available data; for portable air conditioner EER = 2.65, and COP = 2.53, for fixed split air conditioners, SEER = 5.7, split SCOP = 4.0.

Today the average sound power levels of air conditioners are well below the ecodesign requirements. For small fixed split air conditioners (≤6 kW), average indoor sound power level is 56.5 dB(A) while the average outdoor sound power level is 62.4 dB(A). For larger air conditioners (>6 kW) the average indoor sound power level is 61.1 dB(A) while the average outdoor sound power level is 67.6 dB(A).

The average price of air conditioners decreased since the preparatory study due to the financial crisis but started to increase again as observed recently. The average final product price for portable air conditioners is found approx. 135 EUR/kW, while the manufacturer selling price is approx. 80 EUR/kW. The average manufacturer selling price for fixed split air conditioners is found approx. 130 EUR/kW and while the final product price is approx. 285 EUR/kW. The mark-up factor for split systems starting from manufacturer selling price is approx. 2.2, and the mark-up for portable unit is approx. 1.7. Price increase for wall split units, large cassettes and ducted units were identified and will be used in later tasks for life cycle cost analysis.

Annex 1: Test conditions for SEER and SCOP determination of exhaust air-to-outdoor air heat pumps and air conditioners

SEER calculation: for exhaust air/outdoor air units, the part load conditions for determining the declared capacity and the declared energy efficiency ratio are given in Table 20.

Table 20: Conditions for determining $EER_{A,B,C,D}$ values in SEER calculation

Test condition	Part load ratio		Outdoor heat exchanger: exhaust air dry bulb (wet bulb) temperatures	Indoor heat exchanger: outdoor air dry bulb (wet bulb) temperatures
	%	%	°C	°C
A	(35–16)/(Tdesignc–16)	100	27(19)	35(24)
B	(30–16)/(Tdesignc −16)	74	27(19)	30(21)
C	(25–16)/(Tdesignc −16)	47	27(19)	25(18)
D	(20–16)/(Tdesignc −16)	21	27 (19)	20(15)

SCOP calculation: for exhaust air/outdoor air units, the part load conditions for determining the declared capacity and the declared coefficient of performance are given in Table 21.

Table 21: Conditions for determining $COP_{A,B,C,D,E,F,G}$ values in SCOP calculation

Test condition	Part load ratio				Outdoor heat exchanger	Indoor heat exchanger
	Formula	A	W	C	Exhaust air dry (wet) bulb temperatures	Outdoor air dry (wet) bulb temperatures
	%	%	%	%	°C	°C
A	(-7–16)/(Tdesignh −16)	88	n/a	61	20(12)	-7(-8)
B	(+2–16)/(Tdesignh −16)	54	100	37	20(12)	2(1)
C	(+7–16)/(Tdesignh −16)	35	64	24	20(12)	7(6)
D	(+12–16)/(Tdesignh −16)	15	29	11	20(12)	12(11)
E	(TOL–16)/(Tdesignh −16)				20(12)	TOL
F	(Tbiv–16)/(Tdesignh −16)				20(12)	Tbiv
G	(-15–16)/(Tdesignh −16)	n/a	n/a	82	20(12)	-15

Annex 2: Estimating 2015 stock for countries with insufficient sales data

For the 12 EU countries which there is not enough sales data available (Bulgaria, Croatia, Cyprus, Denmark, Estonia, Ireland, Latvia, Lithuania, Luxembourg, Malta, Slovakia, Slovenia), the following procedure in 6 steps is used to estimate the 2015 stock. Note: these 12 countries represent about 7% of the total EU population.

STEP 1: The total installed rated cooling power in 2015 in the first 16 EU countries is estimated using the average power of units sold (Table 22) and the lifetime (Table 23) of the technology.

Table 22: Average power of units installed per product type

Technology	Average rated capacity (kW)
Movables + Window Units	2.5
Small Split (<5 kW)	3.5
Big Split (>5 kW, incl. ducted)	7.5
VRF	25
Rooftop + Packaged	65
Chillers (A/W) < 400 kW	81
Chillers (A/W) > 400 kW	616
Chillers (W/W) < 400 kW	114
Chillers (W/W) > 400 kW	755

Regarding average rated capacities per unit type, country specific values is used when data is available. The average (Table 22) is used for the remaining countries.

Table 23: Average lifetime of units per product type

Technology	Average lifetime (years)
Movables + Window Units	10
Small Split (<5 kW)	12
Big Split (>5 kW, incl. ducted)	12
VRF	15
Rooftop + Packaged	15
Chillers (A/W) < 400 kW	15
Chillers (A/W) > 400 kW	20
Chillers (W/W) < 400 kW	15
Chillers (W/W) > 400 kW	20

STEP 2: Dividing the installed power by the average power installed per unit of indoor floor area (equipment sizing in W/m^2) gives the total cooled floor area.

Sizing values of EuP Lot 10 study for the residential and service sectors were used. These are results of dynamic building demand simulations for a number of locations in Europe which were fitted to CDDs to deduce all countries and were then corrected by a 20% oversizing estimate based on limited evidence of real life sizing.

Installation (W/m²)	RES	SER
Austria	108	134
Belgium	85	110
Bulgaria	122	151
Croatia	123	152
Cyprus	181	349
Czech Rep.	90	115
Denmark	76	101
Estonia	74	99
Finland	73	98
France	110	136
Germany	90	115
Greece	177	254
Hungary	113	140
Ireland	69	95
Italy	157	203
Latvia	76	101
Lithuania	82	107
Luxembourg	89	114
Malta	185	320
Netherlands	76	101
Poland	88	113
Portugal	135	169
Romania	138	172
Slovakia	98	124
Slovenia	111	137
Spain	153	196
Sweden	71	97
UK	72	98

STEP 3: A matrix of repartition of sales (Table 24) into the different sectors is used to separate residential and tertiary cooled floor area. Penetration levels of cooling in the building stock are then computed, for residential and tertiary sectors separately.

Table 24: Share of sales in the residential sector by country (years 2011-2015)

Country	movable	Split <5kW	Split >5kW	VRF	Chiller air <400kW	Chiller water <400kW
Austria	82%	28%	18%	6%	28%	28%
Belgium	80%	9%	6%	6%	4%	3%
Bulgaria	89%	62%	37%	5%	22%	22%
Croatia	92%	77%	55%	7%	27%	28%
Cyprus	67%	88%	80%	3%	13%	21%
Czech Rep.	84%	17%	11%	7%	29%	29%
Denmark	95%	32%	10%	0%	0%	0%
Estonia	90%	75%	11%	0%	0%	0%
Finland	73%	3%	2%	6%	2%	2%
France	97%	62%	26%	6%	47%	49%
Germany	30%	8%	7%	5%	5%	3%
Greece	98%	94%	85%	4%	48%	48%
Hungary	83%	39%	25%	6%	28%	29%
Ireland	56%	9%	0%	21%	5%	5%
Italy	95%	84%	68%	5%	28%	28%
Latvia	90%	73%	10%	0%	0%	0%
Lithuania	90%	67%	9%	0%	0%	0%
Luxembourg	95%	55%	19%	2%	21%	23%
Malta	97%	89%	76%	7%	36%	36%
Netherlands	68%	4%	2%	5%	3%	2%
Poland	75%	13%	8%	6%	3%	2%
Portugal	87%	14%	4%	1%	5%	5%
Romania	91%	68%	43%	7%	27%	28%
Slovakia	88%	32%	18%	3%	13%	14%
Slovenia	91%	62%	45%	9%	35%	35%
Spain	90%	78%	57%	9%	25%	24%
Sweden	83%	2%	1%	7%	4%	3%
UK	35%	2%	0%	10%	2%	2%

All Rooftop systems as well as all chillers>400kW are assumed to be sold in the service sector.

For country with available information, this is based on years 2011-2015 depending on the product and country. For missing countries and/or product types, neighbouring countries were used as model.

STEP 4: For each sector, a correlation between AC penetration and cooling degree days is established for year 2015 (Figure 30).

The total cooled floor area is an input from the EU buildings database[29].

[29] https://ec.europa.eu/energy/en/eu-buildings-database

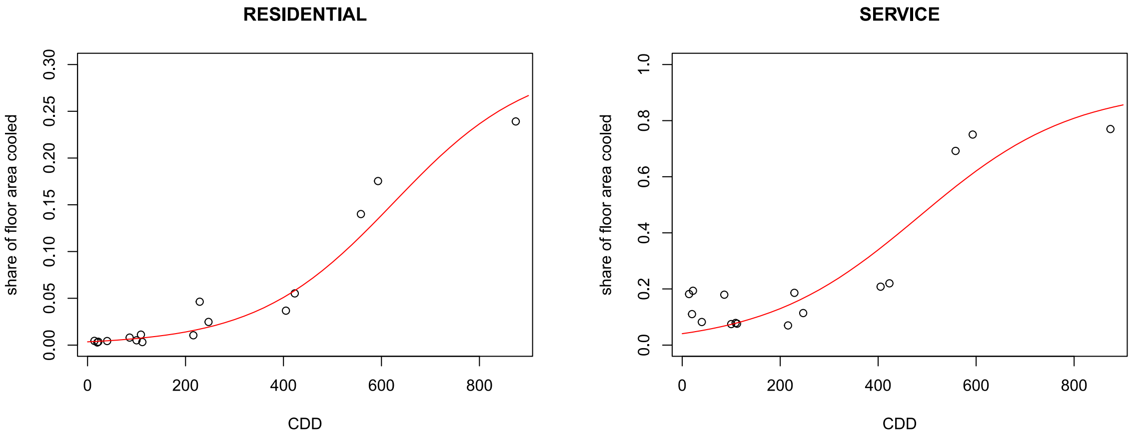


Figure 30: Cooled area penetration in % of total floor area by sector in 16 EU countries (black circles) and correlations (red circles) for other 12 EU countries; left - residential (Penres - Residential penetration); right - services (Penser - Services penetration).

STEP 5: These two correlations are finally used to estimate the penetration of air conditioning cooled floor of the remaining 12 minor countries in both countries (in addition for the residential sector, the GNI per household is used as a limiting factor as indicated in section 2.2.2.4 hereafter)

Estimated penetrations of cooled floor area for the 28 EU countries in 2015 by sector are reported in Table 25. More information on the coiling degree days' estimate is given in part 2.2.2.4.

Table 25: Estimated penetration of cooled area by sector in 28 EU countries

	Cooled floor area penetration in % of total floor area		Est. Cooling degree days in 2015
Country	**Residential**	**Services**	**base 18 °C**
Austria	1.2%	13.5%	226
Belgium	1.7%	41.2%	89
Bulgaria	4.2%	26.2%	317
Croatia	5.8%	27.3%	325
Cyprus	35.0%	84.7%	1417
Czech Republic	1.5%	18.1%	117
Denmark	0.6%	6.6%	43
Estonia	0.4%	6.1%	30
Finland	0.3%	16.8%	24
France	5.1%	33.1%	236
Germany	0.5%	15.6%	118
Greece	18.1%	76.3%	889
Hungary	2.4%	17.2%	259
Ireland	0.3%	4.9%	6
Italy	13.2%	79.1%	607
Latvia	0.5%	6.6%	42
Lithuania	0.9%	8.0%	76
Luxembourg	1.8%	10.1%	115

Malta	31.0%	84.7%	1258
Netherlands	0.8%	17.1%	42
Poland	0.9%	19.5%	109
Portugal	3.2%	31.0%	418
Romania	6.0%	45.8%	437
Slovakia	2.3%	13.1%	168
Slovenia	3.9%	19.0%	243
Spain	10.8%	79.8%	569
Sweden	0.8%	31.0%	18
United Kingdom	0.9%	48.4%	23

According to available penetration information in terms of equipped households[30], considering that in average only one room per dwelling is equipped nowadays and that these statistics do not account for portable air conditioners in general, penetration levels appear compatible, except for Bulgaria, Croatia and Slovakia, whose residential penetration appears to be underestimated by a factor 2 to 3.

STEP 6: Air conditioning product types are disaggregated by product type using the repartition of products by sectors.

For country with available information, this is based on years 2011-2015 depending on the product and country. For missing countries and/or product types, neighbouring countries were used as model. Values are given below for residential (Table 26) and service (Table 27).

Table 26: Share of the residential stock by product type and country

Country	Portable	Small Split (<5 kW)	Big Split (>5 kW, incl. ducted)	VRF	Rooftop + Packaged	Chillers (A/W) < 400 kW	Chillers (A/W) > 400 kW	Chillers (W/W) < 400 kW	Chillers (W/W) > 400 kW
AT	10%	13%	13%	7%	0%	34%	0%	23%	0%
BE	33%	23%	19%	18%	0%	3%	0%	5%	0%
BG	3%	60%	30%	4%	0%	1%	0%	2%	0%
HR	3%	60%	30%	4%	0%	1%	0%	2%	0%
CY	54%	43%	0%	0%	2%	0%	0%	0%	0%
CZ	17%	23%	21%	11%	0%	19%	0%	9%	0%
DK	58%	17%	5%	2%	0%	11%	0%	7%	0%
EE	67%	3%	3%	10%	0%	10%	0%	8%	0%
FI	67%	3%	3%	10%	0%	10%	0%	8%	0%
FR	12%	29%	25%	3%	0%	25%	0%	6%	0%
DE	27%	9%	26%	22%	0%	11%	0%	5%	0%
EL	54%	43%	0%	0%	2%	0%	0%	0%	0%
HU	9%	53%	24%	0%	0%	10%	0%	4%	0%
IE	20%	3%	1%	72%	0%	4%	0%	1%	0%
IT	5%	55%	32%	1%	0%	6%	0%	1%	0%
LV	67%	3%	3%	10%	0%	10%	0%	8%	0%
LT	67%	3%	3%	10%	0%	10%	0%	8%	0%
LU	12%	29%	25%	3%	0%	25%	0%	6%	0%

[30] https://ec.europa.eu/energy/en/eu-buildings-database

MT	5%	55%	32%	1%	0%	6%	0%	1%	0%
NL	53%	9%	8%	15%	0%	11%	0%	2%	0%
PL	6%	42%	32%	15%	0%	4%	0%	1%	0%
PT	5%	44%	37%	5%	0%	8%	0%	1%	0%
RO	3%	60%	30%	4%	0%	1%	0%	2%	0%
SK	17%	23%	21%	11%	0%	19%	0%	9%	0%
SI	9%	53%	24%	0%	0%	10%	0%	4%	0%
ES	2%	40%	51%	2%	0%	4%	0%	0%	0%
SE	58%	17%	5%	2%	0%	11%	0%	7%	0%
UK	20%	3%	1%	72%	0%	4%	0%	1%	0%

Table 27: Share of the service sector stock by product type and country

Country	Portable	Small Split (<5 kW)	Big Split (>5 kW, incl. ducted)	VRF	Rooftop + Packaged	Chillers (A/W) < 400 kW	Chillers (A/W) > 400 kW	Chillers (W/W) < 400 kW	Chillers (W/W) > 400 kW
AT	0%	4%	8%	13%	1%	12%	26%	8%	27%
BE	1%	15%	20%	17%	0%	5%	12%	11%	19%
BG	0%	17%	24%	33%	1%	2%	5%	3%	15%
HR	0%	17%	24%	33%	1%	2%	5%	3%	15%
CY	12%	18%	15%	5%	18%	21%	2%	9%	0%
CZ	0%	17%	25%	22%	1%	7%	12%	3%	12%
DK	0%	32%	15%	1%	0%	11%	16%	9%	15%
EE	1%	4%	6%	6%	0%	17%	13%	14%	39%
FI	1%	4%	6%	6%	0%	17%	13%	14%	39%
FR	0%	8%	29%	22%	7%	12%	12%	2%	8%
DE	3%	6%	18%	23%	0%	12%	14%	9%	15%
EL	6%	18%	23%	0%	12%	14%	9%	15%	0%
HU	1%	30%	26%	1%	2%	9%	17%	3%	11%
IE	2%	6%	31%	30%	1%	7%	16%	1%	6%
IT	0%	12%	18%	15%	5%	18%	21%	2%	9%
LV	1%	4%	6%	6%	0%	17%	13%	14%	39%
LT	1%	4%	6%	6%	0%	17%	13%	14%	39%
LU	0%	8%	29%	22%	7%	12%	12%	2%	8%
MT	0%	12%	18%	15%	5%	18%	21%	2%	9%
NL	1%	13%	18%	14%	1%	19%	13%	6%	16%
PL	0%	21%	26%	18%	1%	8%	13%	3%	9%
PT	0%	9%	31%	28%	6%	8%	10%	1%	6%
RO	0%	17%	24%	33%	1%	2%	5%	3%	15%
SK	0%	17%	25%	22%	1%	7%	12%	3%	12%
SI	1%	30%	26%	1%	2%	9%	17%	3%	11%
ES	0%	9%	30%	17%	15%	10%	14%	1%	4%
SE	0%	32%	15%	1%	0%	11%	16%	9%	15%
UK	2%	6%	31%	30%	1%	7%	16%	1%	6%

Annex 3: Cities by country to compute national average CDD from CNRM model

Note that population associated to a city corresponds to the population located inside the geographic coordinates of the grid cell of the meteorological model, and for that reason may only cover a share of large metropole population. It is however a useful indicator of climate weighting coefficients for large countries.

Table 28: Cities by country to compute national average CDD from CNRM model

City	Population associated	Country
Vienna	2 065 500	Austria
Brussels	1 381 011	Belgium
Sofia	1 029 913	Bulgaria
Plovdiv	319 089	Bulgaria
Zagreb	710 746	Croatia
Nicosia	212 376	Cyprus
Prague	582 043	Czech Republic
Ostrava	396 025	Czech Republic
Kobenhavn	1 085 000	Denmark
Tallinn	367 025	Estonia
Helsinki	836 728	Finland
Tampere	230 983	Finland
Paris	4 957 588	France
Marseille	1 097 405	France
Lyon	947 658	France
Toulouse	640 027	France
Lille	636 164	France
Berlin	3 250 007	Germany
Frankfurt	1 787 332	Germany
Stuttgart	1 775 644	Germany
Hamburg	1 748 058	Germany
Mannheim	1 337 587	Germany
Munich	1 267 695	Germany
Essen	1 157 801	Germany
Cologne	983 697	Germany
Athens	1 985 568	Greece
Budapest	1 679 000	Hungary
Dublin	1 013 988	Ireland
Milan	2 125 830	Italy

Rome	1 687 226	Italy
Naples	1 619 486	Italy
Turin	1 258 631	Italy
Florence	935 758	Italy
Riga	723 802	Latvia
Vilnius	524 697	Lithuania
Luxembourg	91 972	Luxembourg
Valletta	187 608	Malta
The Hague	953 862	Netherlands
Amsterdam	886 318	Netherlands
Warsaw	1 704 569	Poland
Katowice	1 527 362	Poland
Lodz	758 000	Poland
Krakow	755 525	Poland
Lisbon	1 664 901	Portugal
Bucharest	1 842 097	Romania
Iasi	325 914	Romania
Timisoara	309 575	Romania
Galati	302 621	Romania
Craiova	301 143	Romania
Cluj-Napoca	299 444	Romania
Brasov	293 566	Romania
Bratislava	398 712	Slovakia
Ljubljana	284 961	Slovenia
Barcelona	3 250 797	Spain
Madrid	2 808 718	Spain
Seville	957 533	Spain
Valencia	806 652	Spain
Bilbao	614 369	Spain
Stockholm	1 258 654	Sweden
Goteborg	520 940	Sweden
London	7 994 104	United Kingdom
Birmingham	1 634 666	United Kingdom
Manchester	1 312 757	United Kingdom
Leeds	992 061	United Kingdom

Annex 4: CDD evolution and GNI per capita

Figure 31 shows the projection of CDD according to the CNRM model and RCP4.5 scenario for six specific countries (All the modelled countries are shown in Annex 4: CDD evolution and GNI per capita). Yearly variability has been erased to exhibit climate evolution trends.

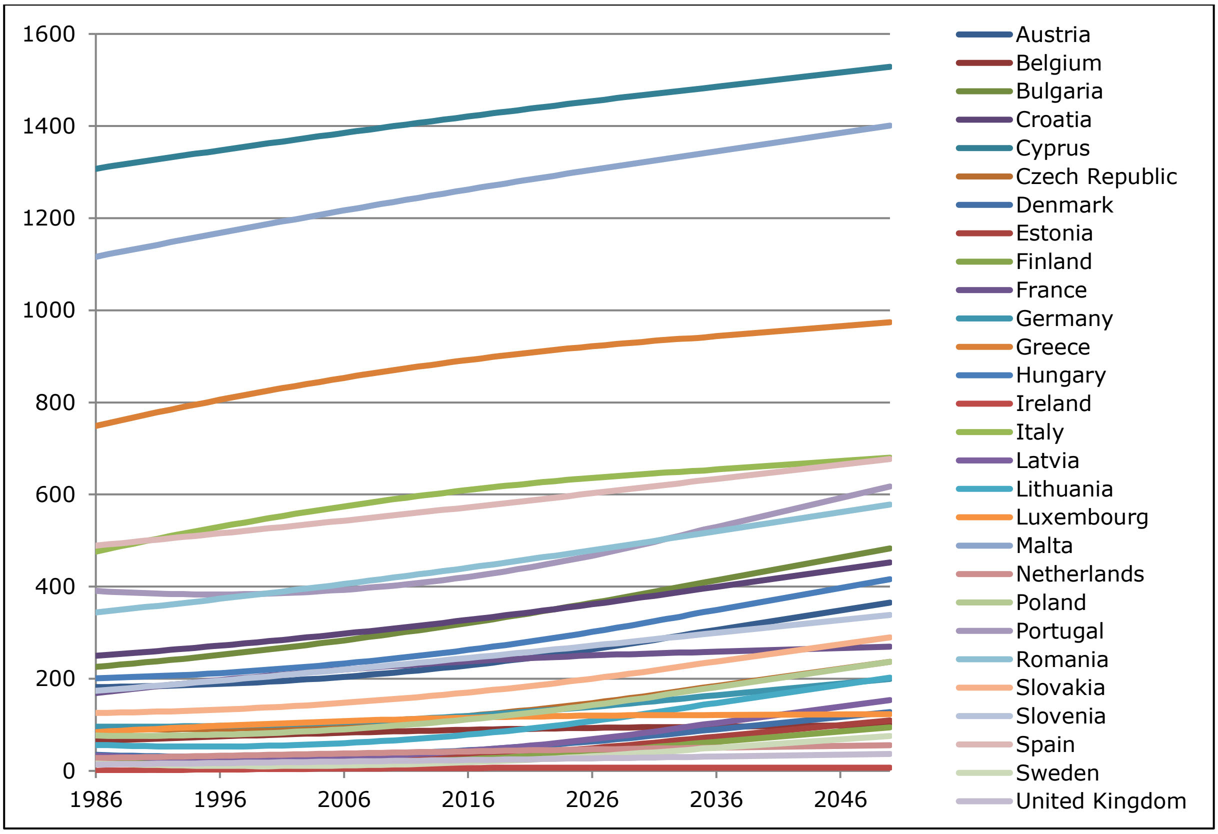


Figure 31: CDD evolution following climate change impact according to CNRM model, scenario RCP4.5, and country model according this report

GNI ppp (Purchasing Power Parity) per capita are available from the World Bank. Number of people per household are available from Eurostat. GNI ppp per capita and linear projections to 2030 are shown on Figure 32 below.

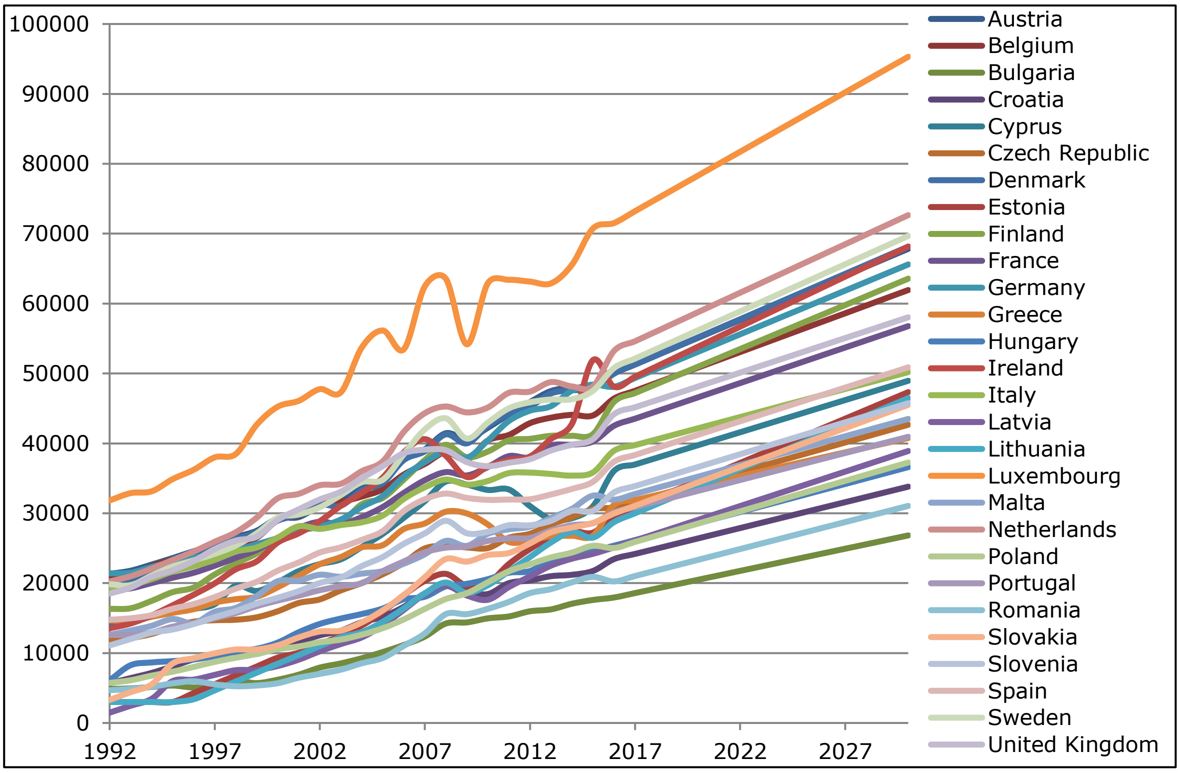


Figure 32: GNI per capita in US$(2015), source World Bank, and linear projections to 2030

Annex 5: Changes in split air conditioner efficiency in Europe from 2006 to 2016

The ECC[31] database has been used to identify changes in split air conditioner efficiency in Europe from 2006 to 2016, for EER and COP

Table 29:Eurovent Certita Certification split air conditioners below 12 kW certified products, EER evolution 2006/2016

EER	2006	2016
2	0.03%	0.00%
2.4	8.52%	0.63%
2.8	29.83%	4.13%
3.2	28.82%	26.35%
3.6	24.31%	55.07%
4	5.71%	25.03%
4.4	2.16%	11.64%
4.8	0.44%	6.51%
5.2	0.14%	1.75%
5.6	0.05%	0.69%
6	0.00%	0.25%
6.4	0.00%	0.44%

Table 30:Eurovent Certita Certification split air conditioners below 12 kW certified products, COP evolution 2006/2016

COP	2006	2016
2	0.00%	0.00%
2.4	0.03%	0.00%
2.8	16.93%	0.19%
3.2	26.93%	7.20%
3.6	31.72%	29.16%
4	17.98%	55.01%
4.4	4.57%	26.66%
4.8	1.65%	8.82%
5.2	0.11%	3.57%
5.6	0.06%	1.19%
6	0.03%	0.50%
6.4	0.00%	0.19%

[31] http://www.eurovent-certification.com/

Annex 6: Electricity prices

The development of electricity prices for household consumers and industrial consumers are shown in the below figures.

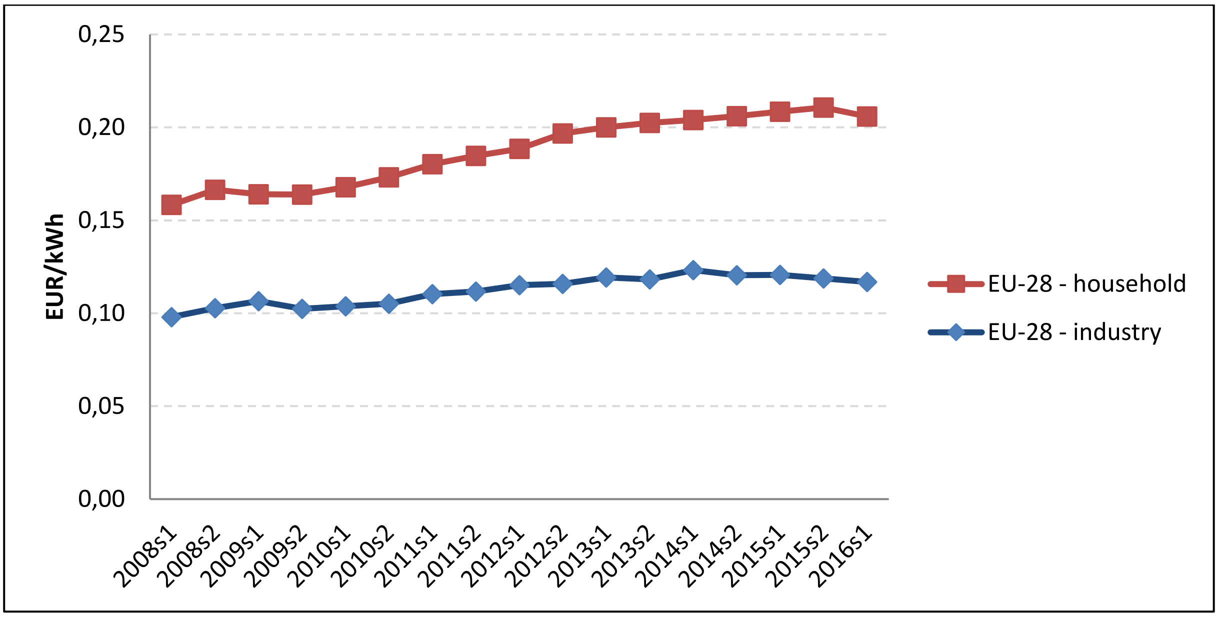


Figure 33: Development of electricity prices from first half of 2008 to first half of 2016 (based on EUROSTAT)

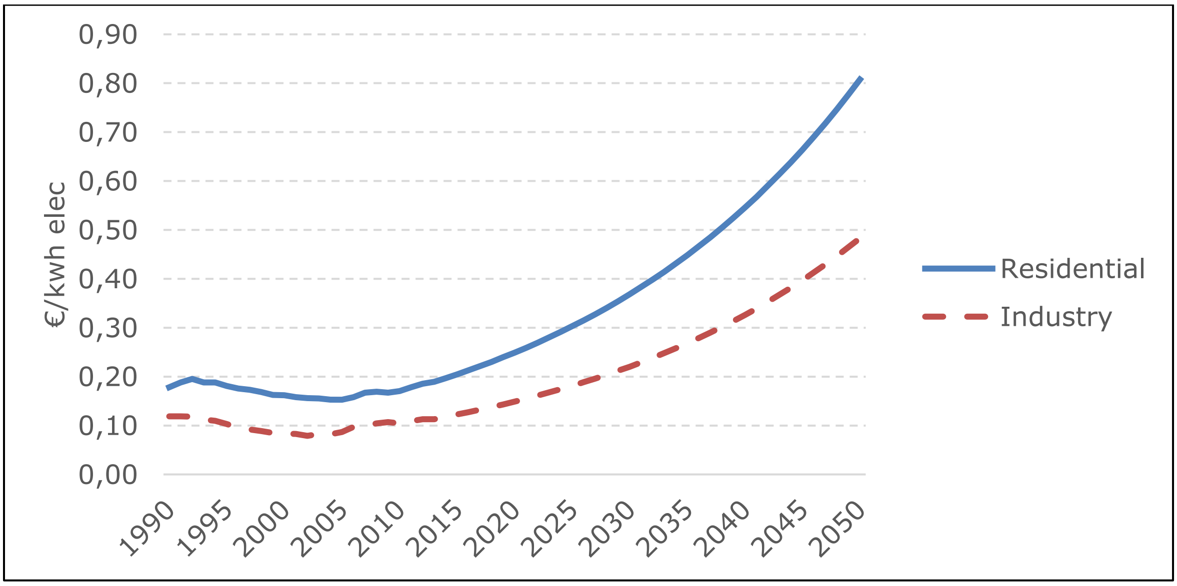


Figure 34:Development of electricity prices from 1990 to 2050 (based on Ecodesign impact accounting[32])

[32] Van Holsteijn en Kemna B.V. (VHK), ECODESIGN IMPACT ACCOUNTING Part 1 – Status Nov. 2013, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf