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Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation)

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Policy, Impact and Sensitivity Analysis

CO-ORDINATOR: Philippe RIVIERE, ARMINES, France

PARTICIPANTS

Jérôme ADNOT, Laurent GRIGNON-MASSE, Sébastien LEGENDRE,
Dominique MARCHIO, Guillaume NERMOND,
Sri RAHIM, Philippe RIVIERE
ARMINES, France

Philippe ANDRE, Laurie DETROUX, Jean LEBRUN, Julien L'HOEST, Vladut TEODOROSE
Université de Liège (ULg), Belgium

José Luis ALEXANDRE, Emanuel SA
IDMEC, University of Porto, Faculty of Eng., Portugal.

Georg BENKE, Thomas BOGNER
Austrian Energy Angency, Austria

Amanda CONROY, Roger HITCHIN, Christine POUT, Wendy THORPE
BRE, UK

Stavroula KARATASOU
IASA, Greece

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Introduction

Scope: *This task summarizes and totals the outcomes of all previous tasks. It looks at suitable policy means to achieve the potential e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labelling and promotion. It draws up scenarios 1990 – 2020 quantifying the improvements that can be achieved vs. a Business-as-Usual scenario and compares the outcomes with EU environmental targets, the societal costs if the environmental impact reduction would have to be achieved in another way, etc. It makes an estimate of the impact on consumers (purchasing power, societal costs) and industry (employment, profitability, competitiveness, investment level, etc.) as described in Appendix 2 of the Directive, explicitly describing and taking into account the typical design cycle (platform change) in a product sector. Finally, in a sensitivity analysis of the main parameters it studies the robustness of the outcome.*

8.1 Policy and scenario analysis

8.1.1 Definition of the types of EuPs in the scope of the study

8.1.1.1 Preliminary discussion of the scope of the policy measures

The scope of the proposed measures includes air to air air conditioners and heat pumps for comfort applications with electrically driven compressors and cooling capacity inferior to 12 kW for cooling only and reversible units.

If other units than air conditioners with electrically driven compressors are excluded from the scope of the measures, this is mainly because there is no concurrence by absorption and adsorption cooling and heating air conditioners or heat pumps on this market segment. Available absorption and adsorption air conditioners and heat pumps that could compete thanks to the use made of solar or waste recovered heat are nowadays water based units; their heating function is presently evaluated in Lot 1 and their cooling function could be included in a study on central air conditioning systems. Nevertheless, in order to let the door open for further development of air based products, efficiency targets could be proposed in primary energy using the average conversion factor of 2.5, as in the Ecolabel Decision (CEC, 2007) and the EuP Methodology.

Despite the fact that presently, to our knowledge, heating only air to air heat pumps are not sold on the EU market, measures proposed cover their potential development to avoid market distortion that could occur with policies that would not include them; heating only units are included whether their heating capacity is inferior to 12 kW.

The scope of the measures does not include air to water cooling only, reversible nor heating only products. Reversible products have been treated partially (for their heating function) in Lot 1, while sales of cooling only mini-chillers have been estimated to less than 20 000 units in the EU.

The scope of the measures does not include water cooled cooling only, reversible nor heating only air conditioners. Indeed, most water cooled air conditioners with cooling capacity inferior to 12 kW are part of a larger air conditioning system for commercial centers or large offices called water loop heat pump and implementing measures for Ecodesign should be envisaged in a study dedicated to central air conditioning systems. In addition, only 20 models have been identified on the EU market, which corresponds to sales inferior to 20000 units. Average EER of these products is 3.5 and EER extends to EU energy label grades F to A, one model having a 4.59 EER, above grade A, with grade D as the average. The same observation is valid also for the heating mode. Thus, it appears the labeling directive (CEC, 2002) is still relevant for the few products sold both in cooling and in heating mode.

8.1.1.2 Existing classifications

Existing classification include the following technical types of comfort air conditioners and heat pumps, single split air conditioners, multi-split air conditioners, package air conditioners, package single duct and double duct air conditioners, that can be air cooled or water cooled while operating in cooling mode.

These air conditioners are classified within Prodcom codes 29.23.12.20, 29.23.12.45 for cooling only units and in 29.23.13.73 for reversible units (and heating only units).

Air conditioners (from 2002 onwards)	
29.23.12.20	Window or wall air conditioning systems, self-contained or split-systems
29.23.12.45	Air conditioning machines with refrigeration unit (excluding those used in motor vehicles, self-contained or split-systems machines)

29.23.13.73	Compression type units whose condensers are heat exchangers heat pumps

Table 8-1: Prodcom segmentation for air conditioners, after 2002

As mentioned in the Ecodesign directive, all previous and current technology dependent classifications will not be used for implementing measures, i.e. there is no distinction that can be made for the type of air conditioner, single or multi-split, package window or single duct since they all have the same function. Nevertheless, reference testing conditions for single duct units at full and part load may differ and this has been taken into account in this study.

8.1.1.3 Scope of the study, product definitions and categories

The products covered by the policy measures are comfort air conditioners and heat pumps as defined in the CEN standard EN14511 (2004) with an outdoor heat exchanger to exchange heat between refrigerant and outside or recycled air, and another one to exchange heat with the space to be air conditioned, with cooling capacity inferior to 12 kW[1] for air conditioners and reversible heat pumps, and with heating capacity inferior to 12 kW for heating only heat pumps.

Three main categories of products are defined:
- air conditioner,
- reversible heat pump,
- heat pump,

with the following definitions:

- air conditioner

Encased assembly or assemblies designed as a unit to provide delivery of conditioned air to an enclosed space (room for instance) or zone. It includes an electrically operated refrigeration system for cooling and possibly dehumidifying the air. It can have means for heating, circulating, cleaning and humidifying the air. If the unit provides heating by reversing the refrigerating cycle then it is a heat pump.

- heat pump

Encased assembly or assemblies designed as a unit to provide delivery of heat. It includes an electrically operated refrigeration system for heating. It can have means for cooling, circulating, cleaning and dehumidifying the air. The cooling is by means of reversing the refrigerating cycle.

- Split (package) air conditioner or heat pump

Factory assembly of components of refrigeration system fixed on two mountings or more to form a discrete matched functional unit. This includes split (also called pairs) and multi-split units.

- Package air conditioner

Factory assembly of components of refrigeration system fixed on a common mounting to form a discrete unit. This includes window and through the wall air conditioners.

- Single duct (package) air conditioner

Air conditioner for spot cooling in which the condenser intake air is introduced from the space containing the unit and discharged outside this space

- Indoor heat exchanger

[1] Heating and cooling capacity are to be understood as standard rating heating and cooling capacity as defined in the EN 14511 CEN standard.

Heat exchanger which is designed to transfer heat to the indoor part of the building or to remove heat from it.
NOTE In the case of an air conditioner or heat pump operating in the cooling mode, this is the evaporator. In the case of an air conditioner or heat pump operating in the heating mode, this is the condenser.

- Outdoor heat exchanger
Heat exchanger which is designed to remove heat from the outdoor ambient environment, or any other available heat source, or to transfer heat to it
NOTE In the case of an air conditioner or heat pump operating in the cooling mode, this is the condenser. In the case of a heat pump operating in the heating mode, this is the evaporator.

8.1.2 Energy and refrigerant requirements

8.1.2.1 Portray of the EU industry[2]

As stated in the MEEuP case study report for air conditioners, Prodcom contains no relevant information. Some market research reports give estimates of national imports and exports but do not specify whether these are from or to other Member States.

Information can be found in (IEA, 2007B) and which states that 12 % of Chinese production of air-conditioners and reversible heat pumps with export destination (about 28 M units in 2005 and 2006) is to Europe, meaning about 3 million units in 2005 and 2006.

In 2004, the sum of main countries production in Europe amounted to about 1500000 units (Bsria, 2005), mostly in Italy and Spain. Manufacturers indicate that almost all production has nowadays been relocated in China. It means nowadays most units are produced either in China or in other Asian countries with low labour costs as Thailand or Malaysia.

The total revenues of the sales of products in the scope of the study is estimated to be about 5 billion euros in 2005 for Europe (EU 27).

The dominant brands are Asian. Japanese and Korean brands are thought to represent more than 60 % of market sales of air conditioners and heat pumps.

Hence the market is rather international and not only regional (European), and the same products could possibly be sold anywhere depending on the legislation adopted on the markets where they are sold.

8.1.2.2 European market, energy efficiency, status and trends

8.1.2.2.1 Market structure and growth

The European market for air-conditioning is relatively young and still growing substantially. The installed stock is far from the saturation levels seen in other parts of the world and the sales figures show no signs of approaching market saturation and is estimated to grow from 4.9 million units in 2005 to more than 10 million units in 2030.
Amongst the 4.9 million products, about 75 % are reversible. The proportion of air conditioners is likely to decrease from 25 % to around 20 % in 2020 to the benefit of reversible heat pumps.

The underlying market driver is comfort (and also heat pumping more recently particularly in Central and Northern countries) and is supposed to drive the market expansion now that prices are low enough so that everybody can buy it thanks to manufacture made in low labour cost countries. But demand depends on climate and building design and is constrained by wealth and legislation – all of which vary between countries. So, while the products on the market are essentially the same throughout Europe, the markets themselves are definitely national.

On the whole, the majority of sales is in the commercial sector which concentrated 55 % of the sales in 2005. For air conditioners alone, 55 % of the sales are in the residential sector. Most units are installed in existing buildings with relatively low replacement rates indicating a large potential for this market to grow.

The estimate of the EU 27 market and stock are reported in the table below between 2005 and 2030 every 5 years.

[2] More information is given in the part regarding the impacts of proposed measures on the industry in paragraph 8.2.1.

Nb of units (Million)			2005	2010	2015	2020	2025	2030
Air conditioners	Residential	Sales	0,7	0,7	0,9	1,1	1,2	1,3
		Stock	8,8	11,6	14,0	16,9	20,3	22,7
	Office	Sales	0,4	0,2	0,3	0,3	0,4	0,4
		Stock	5,7	6,4	5,7	5,3	6,0	6,7
	Retail	Sales	0,2	0,2	0,3	0,3	0,4	0,4
		Stock	2,5	3,0	3,2	3,6	4,4	4,9
Reversible heat pumps	Residential	Sales	1,6	2,7	3,0	3,2	3,3	3,3
		Stock	10,6	20,3	29,7	35,6	38,0	39,3
	Office	Sales	1,5	2,5	3,0	3,3	3,5	3,6
		Stock	9,5	18,3	28,1	35,2	39,3	41,9
	Retail	Sales	0,5	0,9	1,1	1,2	1,3	1,4
		Stock	3,3	6,3	9,8	12,6	14,4	15,5
Total	Residential	Sales	2	3	4	4	4	5
		Stock	19	32	44	52	58	62
	Office	Sales	2	3	3	4	4	4
		Stock	15	25	34	40	45	49
	Retail	Sales	1	1	1	2	2	2
		Stock	6	9	13	16	19	20
TOTAL sales			4,9	7,2	8,6	9,5	10,1	10,4
TOTAL stock			40,3	66,0	90,4	109,2	122,4	131,0

Cooling capacity (GW)			2005	2010	2015	2020	2025	2030
Air conditioners	Residential	Sales	2,5	1,8	2,5	3,0	3,3	3,5
		Stock	33,8	41,0	42,4	46,6	55,6	62,2
	Office	Sales	2,0	0,7	0,8	0,9	1,0	1,1
		Stock	26,9	28,5	21,2	15,9	16,9	18,8
	Retail	Sales	0,9	0,6	0,8	1,0	1,1	1,1
		Stock	10,8	12,3	11,0	10,8	12,6	14,3
Reversible heat pumps	Residential	Sales	8,6	14,4	16,2	17,1	17,6	17,9
		Stock	55,9	107,4	157,8	189,7	203,1	210,0
	Office	Sales	7,8	13,8	16,5	18,3	19,3	20,0
		Stock	51,0	98,9	152,1	191,5	214,9	229,2
	Retail	Sales	2,7	4,8	5,9	6,7	7,2	7,5
		Stock	17,6	34,1	53,6	69,0	79,0	85,6
Total	Residential	Sales	11	16	19	20	21	21
		Stock	90	148	200	236	259	272
	Office	Sales	10	14	17	19	20	21
		Stock	78	127	173	207	232	248
	Retail	Sales	4	5	7	8	8	9
		Stock	28	46	65	80	92	100
TOTAL (Sales GW)			25	36	43	47	49	51
TOTAL (Stock GW)			196	322	438	524	582	620

Table 8-2: EU 27 market and stock estimate, million units and GW of cooling capacity installed

8.1.2.2.2 Energy efficiency

EER and COP levels

As explained in previous tasks, the full load performances should not be used to compare the performances of the units but rather part load performances and including the source temperature variations. Nevertheless, these performances are not yet available for all units but only the main energy efficiency indicators, the EER (Energy efficiency ratio in cooling mode) and COP (coefficient of performance in heating mode) rated at full load according to the EN 14511 test standard.

For air conditioners and heat pumps, EER values from 2 to 5.4 are observed on the EU market (2006). For heat pumps, COP values ranged from 2.4 to 5.6 (2006).

The conclusions when observing these figures are:

- the present EU label (31/EC/2002) energy label classes need to be revised,
- there seems to exist a large potential for improvement for all product types in cooling and in heating mode, which is to be made more accurate by including variations of COP and EER with part load, outdoor air temperature, and auxiliary power modes.

EER and COP trends

On a full load basis, there has been little improvement of the average efficiency of the units sold over the period 1996-2006.

Nevertheless, this trend may cover two different thresholds: on one side, manufacturers who also sell more efficient appliances on more efficient markets sell high efficiency products in Europe ; on the other side, there is an increase of direct importation at low cost and low performance.

It should be added that the penetration share of inverter units is already relatively high. From data supplied by the industry for the largest air conditioner and heat pump national markets, it can be ascertained that amongst 45 to 60 % of units were inverter driven in 2005, this proportion having increased to a penetration rate estimated between 55 and 75 % in 2007. Already, some of the more important manufacturers do not sell anymore on-off units in the 0-12 kW range in 2008. Also, low cost units with no brand sold in DIY shops include inverter driven compressors. It appears the movement towards the full penetration of variable speed compressors (and fans) accelerates.

This energy efficiency advantage is not taken into account in the present rating standard despite the fact it represents a real potential to save energy and CO2 emissions. However, since manufacturers are today free to declare the rating frequency they want for inverter driven units, rated performances do not correspond to full capacity but to frequencies around 50 Hz and manufacturers of inverter units may have both gains, more efficient ratings at standard rating condition and publishing in their documentation that thanks to the inverter, capacity can be extended up to X kW. But in those conditions, energy efficiency is not always shown.

Auxiliary power modes

<u>Definitions</u>

When the air conditioner or heat pump compressor is not working, the products can still draw electric power. Despite low electric power values in these modes, energy consumption may not be neglected because of high numbers of operating hours. The functional analysis of these auxiliary power modes led to define the following auxiliary power modes of air conditioners and heat pumps:

- Active mode – thermostat-on
The air conditioner (reversible heat pump) is in operation and the inside temperature is higher (lower in heating mode) than the temperature set point.

- Active mode – thermostat off
The air conditioner is operational in heating or cooling mode but inside temperature is lower (higher in heating mode) than the set point. The impact of thermostat-off mode is included in the cycling degradation for hours of operation with cooling and/or heating requirements and additionally in the thermostat-off consumption corresponding to hours with no cooling or heating load while cooling (or heating) is required.

- Passive mode - standby
The air conditioner is not operational; it can be reactivated either by control device or by timer. This mode corresponds to hours with no occupancy in the building during the cooling or heating season.

- Passive mode – off mode

The air conditioner has been switched off by the user, is not operational and cannot be reactivated nor by control device nor by timer. This mode corresponds to hours outside the cooling and/or heating season.

- Crankcase heater
The crankcase heater operates when the compressor is off and the outdoor temperature is lower than a given value. Other parameters such as the compressor or the heat exchanger temperature may also be included into the control and have an impact on its energy consumption.

Active mode performances are the ones aimed at by the EN14511 standard although part load is not included. Thermostat-off performances will impact the part load performances but there are also thermostat-off hours without cooling nor heating needs and the air conditioner or heat pumps electronics and indoor fan may remain on and draw electric power.

As explained before, main manufacturers who sell units on the EU market are also present on other main international markets. Since no data was presently available in Europe for these auxiliary power modes, data have been retrieved on the Australian market, for standby, off mode and crankcase heater electric power. Australia now requires manufacturers to declare auxiliary power mode values.

Standby and off mode

It has been observed the multiplication of functions offered by the products with some concern regarding standby and off mode power values and this appears clearly in the Australian database of products.

Standby values range from less than 0.3 W to 25 W for products in the scope of the study. In addition, there is in general no difference between standby and off mode power.

It appears there is no relation between off mode power or standby power and cooling capacity or electric power of the unit. Default components and control lead to standard values of 5 and 10 W. For smaller units with more functions, standby and off mode power may increase up to 25 W showing there is no effort made to separate the standby function from other functions not required in these low power modes.

There is a large potential for improvement as far as off mode and standby mode are concerned.

Crankcase heater

Crankcase heaters ensure the compressor's safety. Crankcase heaters are said by stakeholders to be necessary only for reversible heat pumps, whereas according to compressor manufacturers, most split units with scroll compressors should have one (Danfoss, 2008). Crankcase values range from 5 to 70 W for products in the scope of the study. There should be a correlation between cooling capacity and crankcase heater power. This correlation does not appear clearly. For instance, 90 W oil heaters may serve units with cooling capacity from 15 to 60 kW. Default external crankcase heater of scroll compressor as proposed by OEM are adopted.
Little data on control is available despite the fact it could help to save an important part of these losses. Regarding the crankcase heater power, it might lead to important energy consumption yearly whether uncontrolled (about one third of the total unit cooling consumption) while controls do exist to minimize its energy consumption.

Conclusion

Available data indicate that there has been little effort made to decrease the electric power consumption of auxiliary power modes that were presently not considered in testing standards.

8.1.2.3 International legislation

In the benchmark realized on international legislation, it appears that some countries have much more demanding legislation and consequently more efficient markets.
The table below summarizes different aspects of the legislation in main air conditioning countries or zones. The points identified to improve the EU legislation are:

- to require minimum performance thresholds,
- to shift to seasonal performance index to foster the competition on efficient technologies at part load, as inverter compressors: USA adopted seasonal performance indices more than 20 years ago (after the first oil crisis), Japan and Korea in 2004,
- to reduce tolerances: USA has strict minimum performance standards, without tolerances to declare lower performances than required,
- to include auxiliary power modes in legislation (standby, off mode, crankcase heater) – Australia,
- to ban products or to set high financial penalties to manufacturers that do not respect performance requirements (Australia and USA have recent examples).

Region or country	Stand-by	Cooling MEPS	Heating MEPS	Tolerances	Specificity of rating
Australia	Yes (Considered for legislation)	Y	N	10 % EER	Full load
China	No	Y	Y	N/A	Full load
Japan	Yes (0-4 kW) 1 W voluntary agreement	Y	Y	20 % EER and (EER+COP)/2 15 % on the APF (annual performance factor)[3]	Moving to seasonal perf
South Korea	Yes (0-4 kW) 1 W voluntary agreement	Y	N	20 % EER N/A for seasonal performances	Moving to seasonal perf
USA	No	Y	Y	0 %	Seasonal perf
EC	No	N	N	15 % EER & COP	Full load

Table 8-3: Summary of international energy conservation legislation for air conditioners

Regarding full load performances of units on the EU market, they have been compared to the performance requirements in the different countries. Results of the comparison with Japanese requirements are shown hereunder for reversible split units. Around 90 % of the models sold in Europe in 2006 did not comply with the Japanese legislation[4], despite main brands on the EU and on the Japanese market are the same.

[3] Note by JRAIA: "Tolerances in Japan are now +/- 10% capacity and +/- 5% power for residential units. It can reach 86.4% in the worst case (2006). However, the situation is changing (2009). Current APF rating has no tolerance. So, manufacturer has to assure the declared APF value. However, capacity still has tolerance. Current tolerance are as follows; capacity not less than 95%, Input not exceed 110%, APF not less than 100%. Old target had capacity and power input tolerances and resulted in large energy efficiency tolerances. As capacity of air conditioner or heat pump must be declared according to standard sequence of numbers in Japan, capacity tolerance has significant meaning."
[4] 2004 top runner targets, based on full load EER + COP / 2 at that time.

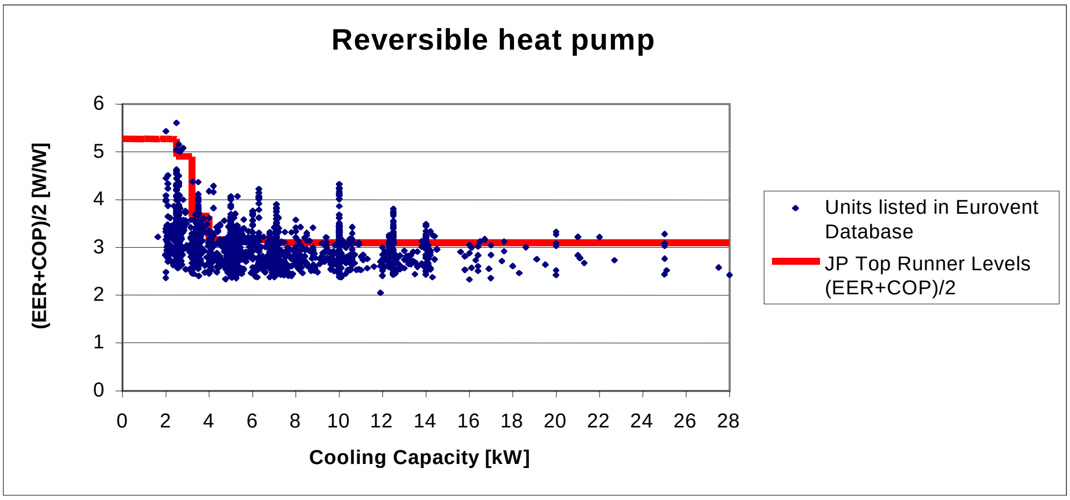


Figure 8-1: Comparison of Japanese MEPS and reversible heat pumps in the Eurovent database products (2006)

The same analysis has been performed for air conditioners and heat pumps EER MEPS levels abroad and the conclusion, illustrated on the graphs below, is the same.

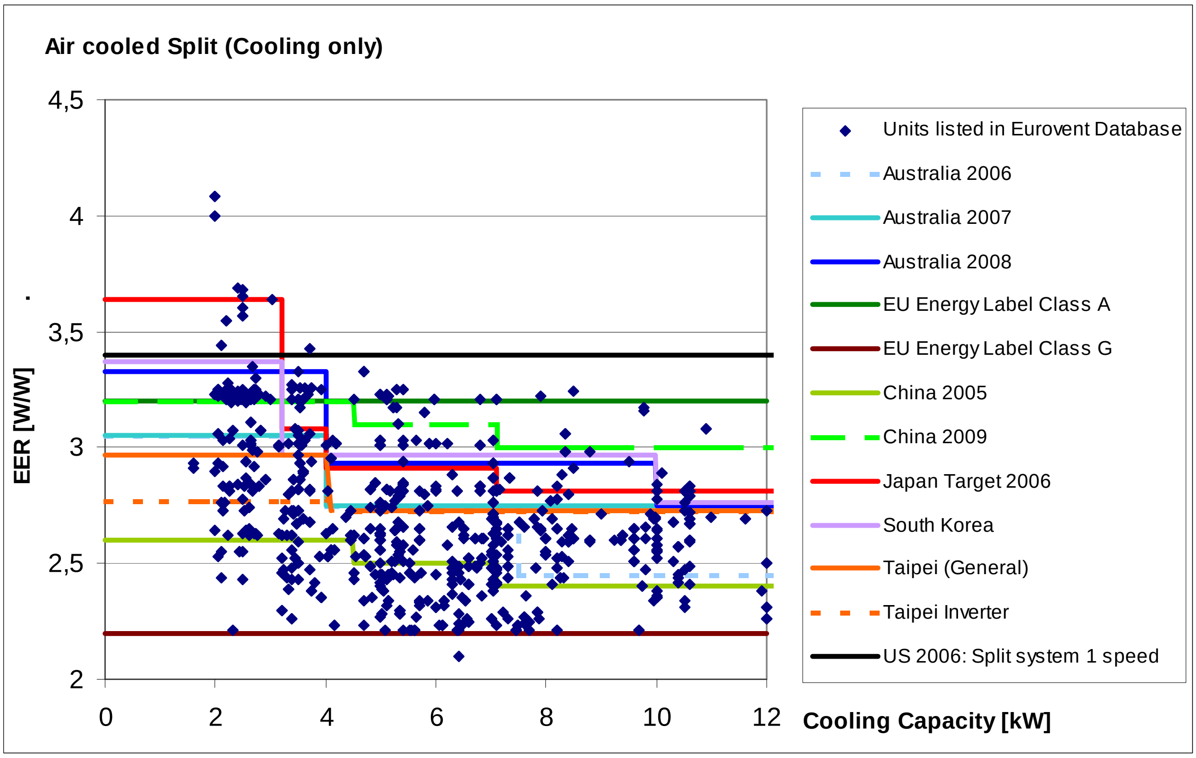


Figure 8-2: International comparison of air conditioner EER MEPS

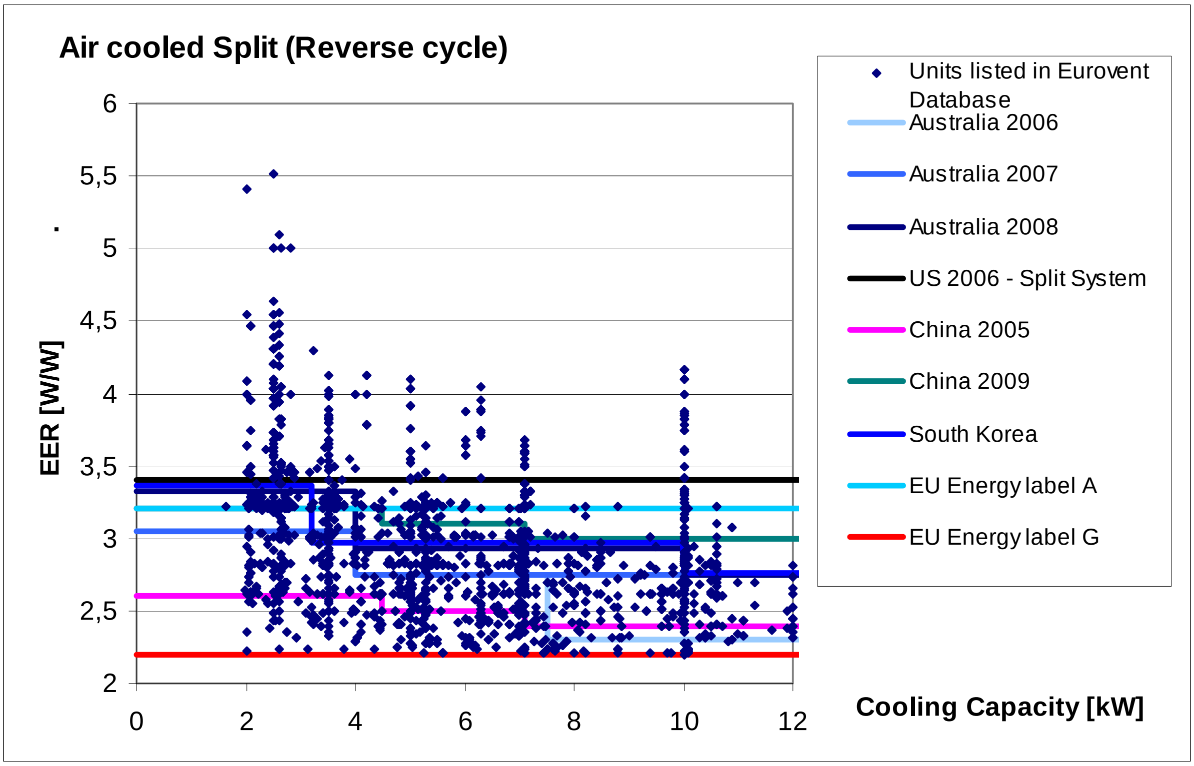


Figure 8-3: International comparison of heat pumps EER MEPS

8.1.2.4 EU voluntary agreements

Eurovent Certification: Voluntary MEPS program for air conditioners

Eurovent has implemented minimum energy efficiency thresholds for air conditioners up to 12 kW cooling capacity in 2004. Starting at January 1st 2004, Class G, as defined in the Labelling Directive 31/EC/2002, was eliminated from the Eurovent Certification.
According to a position paper from the Eurovent working group 6B "Air Conditioners" (dated from July 2005), Eurovent intended to pursue the same kind of actions and eliminate Classes E and F in the near future. It had been proposed to split air conditioners in two parts:

- up to 4 kW cooling capacity,
- from 4 to 12 kW cooling capacity,

and to apply different schedules for each part.
Thus, starting at January 1st 2008, Eurovent WG 6B proposed to eliminate from Certification:

- classes E and F for air conditioners with less than 4 kW cooling capacity
- class F for air conditioners with cooling capacity from 4 to 12 kW

And from January 1st 2010, Eurovent WG 6B proposes to eliminate from Certification:

- classes C and D for air conditioners with less than 4 kW cooling capacity
- class E for air conditioners with cooling capacity from 4 to 12 kW

By this measure no Manufacturers would have been allowed to participate to the Eurovent Certification Programme for Air Conditioners if their products did not comply with the minimum Energy Efficiency requirements.

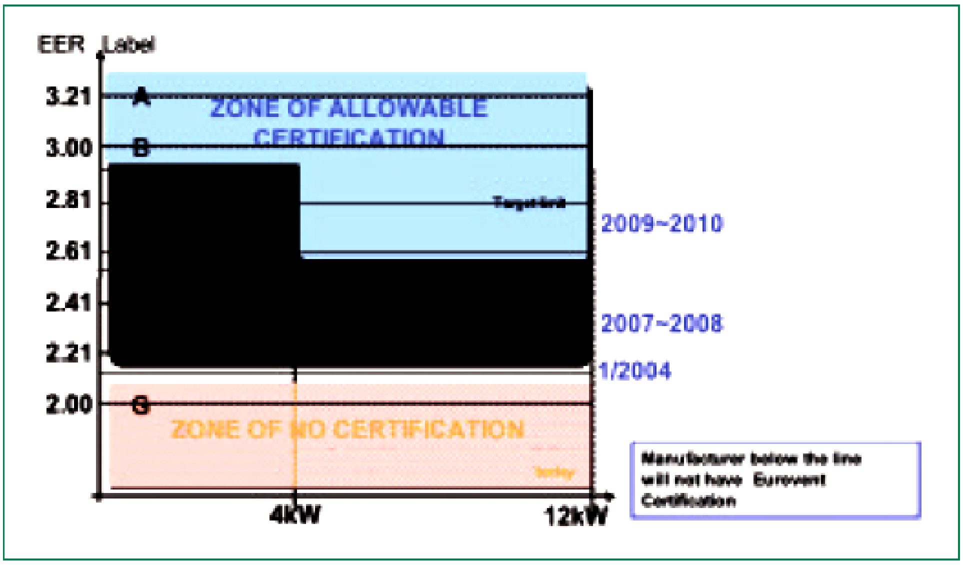


Figure 8-4: Eurovent's time schedule for energy efficiency deployment

The effect of the ban of class G has been reported in (Saheb, 2006): from 2003 to 2005, the average EER of all certified air conditioners increased from 2.58 to 2.87, i.e. 11%.

However, the further steps of the program remained a proposal .

As a conclusion, Eurovent being the only industry association to our knowledge to have led voluntary actions for products in the scope, and that no other action has been programmed since 2005 , we believe there is no planned voluntary agreement to be considered in the frame of this study.

8.1.2.5 Environmental impact and life cycle cost at LLCC and BAT levels

8.1.2.5.1 Energy consumption

Seasonal cooling and heating energy efficiency indicators

The standard rating conditions of the EN14511 standard cannot translate properly the energy efficiency of the products. With the fast penetration of inverter driven air conditioners and heat pumps, seasonal performance indicators have been developed and proposed for the revision of the part load CEN TS 14825 technical standard. Following stakeholders' comments, a revised version is proposed. It is fully described in paragraph 8.4.

Energy consumption at LLCC and BAT levels

The improvement study has been led using seasonal performance indicators: SEER is the seasonal performance index for air conditioners and reversible heat pumps and HSPF is the Heating Seasonal Performance Factor for heat pumps. These indices include auxiliary power modes whose energy consumption cannot be neglected.

The LCC analysis was led for 5 base cases, 3 for air conditioners and 2 for reversible heat pumps. The reason to have 2 base cases in heating mode was to have a better representation of the 0 – 12 kW capacity range for reversible heat pumps and also for air conditioners to include a single duct air conditioner, that, as mentioned before, has the specificity to use recycled air at its condenser. This sensitivity analysis showed that improving these different air conditioner and heat pump products led to compatible LLCC levels in terms of seasonal indicators.

- The same **SEER target** can be kept for the 3 base case air conditioners with **SEER[5] equal to 4.3**. Full load standard rating EER values vary between 2.8 and 3.2 with the optimisation paths identified for the base cases.
- The same **energy efficiency target** can be kept with the 2 reversible heat pump base cases with a value of **HSPF equal to 3.9**, with SEER 5.6.. Full load standard rating EER values vary between 3.9 and 4.3, full load COP between 4.3 and 4.5.

Regarding **BAT levels**, they are as follows:
- air conditioners: SEER between 6.1 and 7.1,
- reversible heat pumps: SEER about 7.0, HSPF of 4.8.

For air conditioners:
- LLCC levels enable to cut energy consumption by 40 to 60 % as compared to the base case,
- BAT levels enable to cut energy consumption by 60 to 70 % as compared to the base case.

For reversible heat pumps:
- LLCC levels enable to cut energy consumption by 40 to 45 % as compared to the base case,
- BAT levels enable to cut energy consumption by 55 % as compared to the base case.

Energy consumption results are synthesized in the following table.

Air conditioners								
	BASE CASE		LLCC			BAT		
				Saving versus			Saving versus	
	kWh	SEER	kWh	base case	SEER	kWh	base case	SEER
3.5 kW	445	2,8	273	39%	4,4	179	60%	6,6
7.1 kW	969	2,5	562	42%	4,3	342	65%	6,8
Single duct 2.2 kW	394[6]	1,9	171	57%	4,3	122,7	69%	6,1

Reversible heat pumps											
	BASE CASE			LLCC				BAT			
					Saving versus				Saving versus		
	kWh	SEER	HSPF	kWh	base case	SEER	HSPF	kWh	base case	SEER	HSPF
3.5 kW	1472	3,0	2,3	816	45%	5,9	4,2	653	56%	7,1	4,8
7.1 kW	3084	2,8	2,2	1778	42%	5,9	3,9	1356	56%	7,0	4,8

Table 8-4: Air conditioner and heat pumps base cases, LLCC and BAT levels - energy consumption

SEER values reached at LLCC level for reversible heat pumps are higher than for air conditioners since the energy consumption for LLCC analysis includes heating and cooling. However, both types of products may still be in competition and the end-user at the time of purchase must be able to compare

[5] The SEER value used here corresponds to the SEER2 in Task 7: Table 7.42 page 50 gives the translation with the previous indice used.

[6] This value takes into account the fact the base case is only equipped is one fan, as explained in task 7.

products with the same scale for both air conditioners and heat pumps, reversible heat pumps representing in addition the largest share of the sales.

Additionally, the LLCC levels above have been compared with requirements in heating mode for other heating systems as set in the EuP study Lot 1[7]. The scale for comparison is shown hereunder. Requirements based on the yearly consumption of air air heat pumps would lead to requirements higher by more than 2 classes than Lot 1 requirements.

However, when comparing the HSPF values of reversible units for cooling mode LLCC improvement, it appears that both sets of requirements would be compatible. This is shown in the table hereunder.

Lot 1 heating system label		Air air heat pump
Grade	**Net efficiency**	**HSPF**
A3	120%	4,6
A2 LLCC LOT 10 for yearly consumption	104%	4,0
A1	88%	3,4
A	80%	3,1
LLCC LOT 10 for cooling consumption	77%	3,0
MEPS	76%	2,9
B	72%	2,8
C	64%	2,5
D	56%	2,2
E	48%	1,9
F	40%	1,5
G	40%	1,5

Table 8-5: Comparison of Lot 1 requirements and Lot 10 LLCC results

For these two reasons, SEER and HSPF targets based on the LLCC analysis are taken lower than suggested by the LLCC analysis :

- When performing the life cycle cost analysis of reversible unit over the cooling season, SEER of reversible units is between 4.1 and 4.2,
- Corresponding HSPF would be between 3.1 and 3.2.

8.1.2.5.2 CO2 emissions

Energy consumption gain does not lead to similar gains in terms of CO_2 emissions. The two reasons are: with lower energy consumption, the share of direct emissions linked to refrigerant becomes more important in relative terms ; in addition, increasing the energy efficiency above LLCC levels means more heat exchanger surface and consequently more refrigerant fluid if strategies to reduce direct emissions are not associated to energy efficiency improvements.

Hypothesis to compute CO2 emissions

The following standardized values are used to assess the CO_2 emissions of the products (all details can be found in Task 6):

- Emissions linked to electricity consumption: 430 gCO_2 / kWh (electric) (EuP methodology)

[7] Task 7, paragraph 7.4.10.

- Leak rate of split products: 3 % of nominal refrigerant fluid mass yearly
- Leak rate of package products: 1 % of nominal refrigerant fluid mass yearly
- End-of-life recovery losses: 5 % of nominal refrigerant fluid mass

CO2 emissions at LLCC and BAT levels

Regarding split products, it appears CO2 could be used as an alternative refrigerant. But in the absence of products on the market, there are large differences in the estimate of the energy efficiency the products could reach. Other alternative refrigerant blends, based on propane or propylene, are being investigated but with no concrete outcome at the moment for market application.
For R410A products, there are technologies that could be implemented to cut refrigerant charge by 20 to 50 % according to manufacturers. Manufacturers also report technologies to reduce leak levels down to 1 % for split products but there is no test standard to check these values.
Regarding package products, the rebound effect might be less important because leakage rates are estimated to be lower (factory sealed products) and moreover, it is possible to adopt propane with nearly zero GWP value within the limits of the EN378 safety requirements regarding flammable refrigerants.
With energy consumption levels shown in table 8.8, CO2 emissions at LLCC and BAT levels with and without strategies to cut direct emissions are presented in the table below.

Air conditioners									
	BASE CASE	LLCC (refrigerant mass increases)		LLCC (with strategy to cut refrigerant mass or GWP)		BAT (refrigerant mass increases)		BAT (with strategy to cut refrigerant mass or GWP)	
	kg eq / y	kg eq / y	Savings	kg eq / y	Savings	kg eq / y	Savings	kg eq / y	Savings
3.5 kW R410A	262	196	25%	161	39%	219	17%	155	41%
7.1 kW R410A	561	426	24%	343	39%	434	22%	305	46%
Single duct 2.2 kW	188 R410A	100 R410A	47%	73 Propane	61%	93 R410A	51%	53 Propane	72%
Reversible heat pumps									
	BASE CASE	LLCC (refrigerant mass increases)		LLCC (with strategy to cut refrigerant mass)		BAT (refrigerant mass increases)		BAT (with strategy to cut refrigerant mass)	
	kg eq / year	kg eq / y	Savings	kg eq / y	Savings	kg eq / y	Savings	kg eq / y	Savings
3.5 kW R410A	704	449	36%	405	42%	422	40%	359	49%
7.1 kW R410A	1470	921	37%	831	43%	871	41%	741	50%

Table 8-6: Air conditioner and heat pumps base cases, LLCC and BAT levels – CO2 emissions

For air conditioners:
- At LLCC levels for split air conditioners, a 40 % energy consumption gain translates into a 25 % CO2 emissions cut without refrigerant charge reduction and with a 45 % charge reduction, a 40 % gain can be reached,
- At LLCC levels for single duct air conditioners, the unit is supposed to use propane so that a 57 % energy gain gives a 61 % CO2 emissions cut.
- At BAT levels for split air conditioners, 60 to 65 % energy consumption gain translates into a 17 to 22 % CO2 emissions cut without refrigerant charge reduction and with charge reduction, a 40 % to 45 % gain can be reached,

- At BAT levels for single duct air conditioners, the unit is supposed to use propane so that a 69 % energy gain gives a 72 % CO2 emissions cut.

For reversible heat pumps:
- At LLCC levels for split air conditioners, a 42 to 45 % energy consumption gain translates into a 36 - 37 % CO2 emissions cut without refrigerant charge reduction and with charge reduction, a 42 to 43 % gain can be reached,
- At BAT levels for split air conditioners, a 56 % energy consumption gain translates into a 40 % CO2 emissions cut without refrigerant charge reduction and with charge reduction, about 50 % gain can be reached.

8.1.2.5.3 Life cycle cost

Economic gain at LLCC level ranges extends from 6 % to 19 %. At BAT level, there are still savings for reversible heat pumps thanks to the larger energy consumption due to heating and cooling energy consumption. For air conditioners, with smaller energy consumption, losses from 2 to 23 % occur.

Air conditioners										
	BASE CASE		LLCC				BAT			
	LCC (Euros)	Purchase price (Euros)	LCC (Euros)	Savings (%)	Purchase price (Euros)	Overcost (%)	LCC (Euros)	Savings (%)	Purchase price (Euros)	Overcost (%)
3.5 kW	3166,7	683	2983,7	6%	792	16%	3413,3	-8%	1 383	103%
7.1 kW	5065,4	1 385	4617,8	9%	1 631	18%	6224,6	-23%	3 613	161%
Moveable 2.2 kW	1195,6	389,4	974,0	19%	529,8	36%	1224,7	-2%	858,1	120%
Reversible heat pumps										
	BASE CASE		LLCC				BAT			
	LCC (Euros)	Purchase price (Euros)	LCC (Euros)	Savings (%)	Purchase price (Euros)	Overcost (%)	LCC (Euros)	Savings (%)	Purchase price (Euros)	Overcost (%)
3.5 kW	4918,0	683	4 329	12%	1 035	52%	4374,5	11%	1 536	125%
7.1 kW	8668,8	1 385	7364,8	15%	2 084	51%	7692,1	11%	3 351	142%

Table 8-7: Air conditioner and heat pumps base cases, LLCC and BAT levels – Life cycle costs

8.1.2.6 Energy label update

Two ways can be used to include **auxiliary power modes**, either to have specific requirements on each one of these modes separately or to set targets on the total energy consumption. The comparison of the improvement of the energy consumption of the units has been done by power mode, cooling, heating and auxiliary power modes. Depending on the type of unit, climate and building, it appears that decreasing the standby and off mode power, may be or not amongst the options that lead to the LLCC optimum. As a conclusion, the approach chosen here is to include those power modes in the evaluation of the performances of the units and not to ask for specific requirements.
To adopt total energy consumption targets offers more flexibility to the manufacturers to improve the units while minimizing the overcost of the unit and then should also be profitable in average to the end-user.

For reversible heat pumps in the same way, EU targeted efficiency levels based on the total consumption including heating and cooling enables manufacturers to design differently units for Northern or Southern countries while maintaining a single EU index. Consequently, and in line with manufacturer recommendations, we adopt indices fixed in terms of total energy consumption, i.e including auxiliary consumptions.

8.1.2.6.1 Energy efficiency scales

Grades set for heating systems in Lot 1 are compatible to the high end with HSPF levels identified with BAT levels.

However, on the low end side of the scale, thanks to the ban of class G products in the present EU labeling system by Eurovent, the G class should be empty for air air heat pumps. Opening a G class for air air heat pumps would then be a regression as compared to the present situation and consequently the scale stops at grade F.

The efficiency scale in cooling mode is based upon the SEER indice in order to get compatible values between SEER and HSPF for reversible units.

Minimum class width has been can reach 10 % for the A class.

	HSPF	SEER		Class width heating	Class width cooling
A3	4,6	6,8		-	-
A2	4,0	5,7		15%	19%
A1	3,4	4,6		18%	24%
A	3,1	4,0		10%	15%
B	2,8	3,4		11%	18%
C	2,5	2,8		12%	21%
D	2,2	2,4		14%	17%
E	1,9	2,0		16%	20%
F	1,9	2,0		-	-

Table 8-8: Classes of the EU energy label

Regarding the energy label, in order to compare all heating systems with the same type of label, a design as close as possible to the Lot 1 label should be adopted. This leads to separated cooling and heating labels.

An indication of HSPF grade variation with climate is necessary for heat pumps and other heating systems whose performance are climate sensitive.

Regarding the indication of the heating capacity, the first possibility would be to declare “freely” the design heating requirements the unit has been designed for. It is another way for saying that the heat pump covers only a part of the heating requirements, the other part being supplied by a complementary heating means (resistive heater for air air heat pumps). This would enable manufacturers to optimize their ratings (higher profiles, lower performance because of more resistive heating).

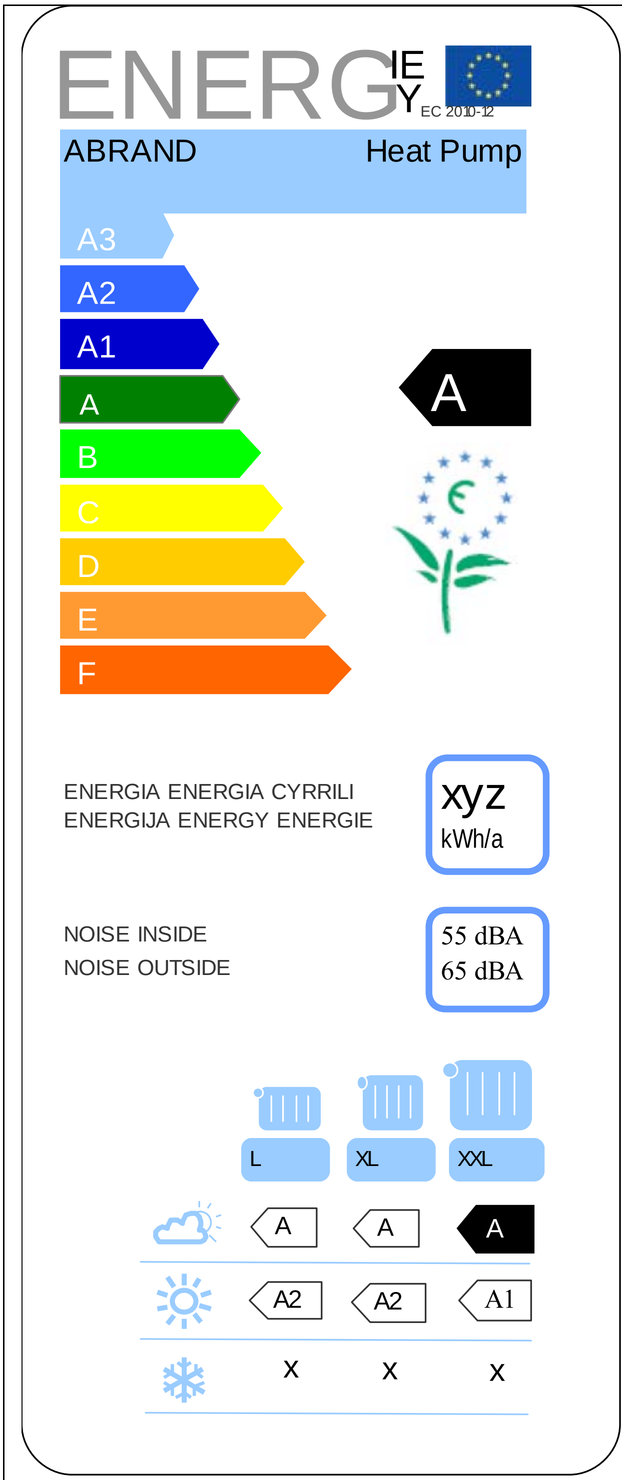
This is also the approach adopted on the US market for reversible air air heat pumps. The corresponding possible profiles for products in this lot would be:

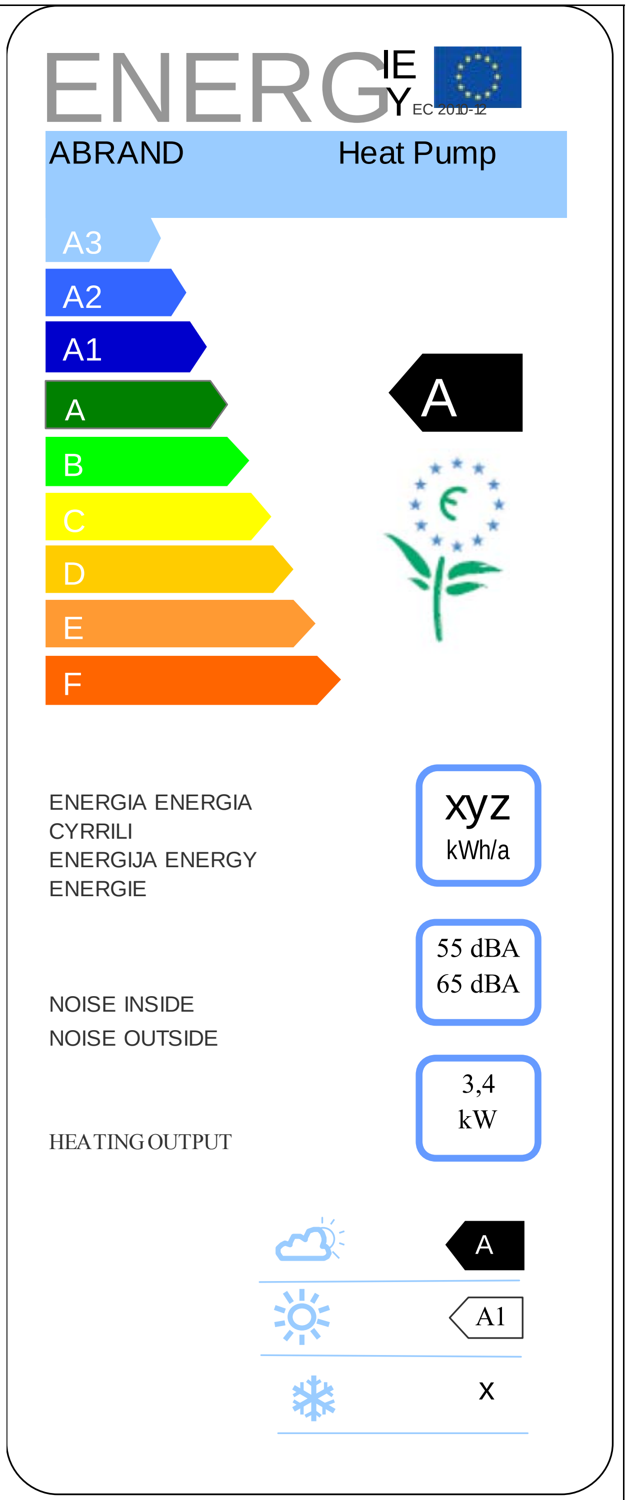
Profile size	Design heating requirement (kW)
4XS	0,75
3XS	1,1
XXS	1,7
XS	2,5
S	3,8
M	5,8
L	8,7
XL	13,0
XXL	19,6

Table 8-9: Standardized heating design requirements @ -10 °C

However, it is possible than the free declaration of this maximum heating requirement at –10°C might be a problem for testing the performances of the heat pump. In that case, the heat pump capacity at 7 °C could be kept (that corresponds to sizing the heat pump at –2 °C, a likely situation for the Strasbourg climate). But the capacity at 7°C is not directly related to the HSPF value. Consequently, the capacity at 2 °C is kept in this second option.

This leads to two possible labels, hereafter.





Label with free declaration of Pdesign	Label with fixed Pdesign

Table 8-10: Possible labels of air air heat pumps in heating mode

In cooling mode, it was not found that a climatic indication was worth doing it so that only one scale is kept. The information to be put on the energy label is shown hereunder for the cooling mode.

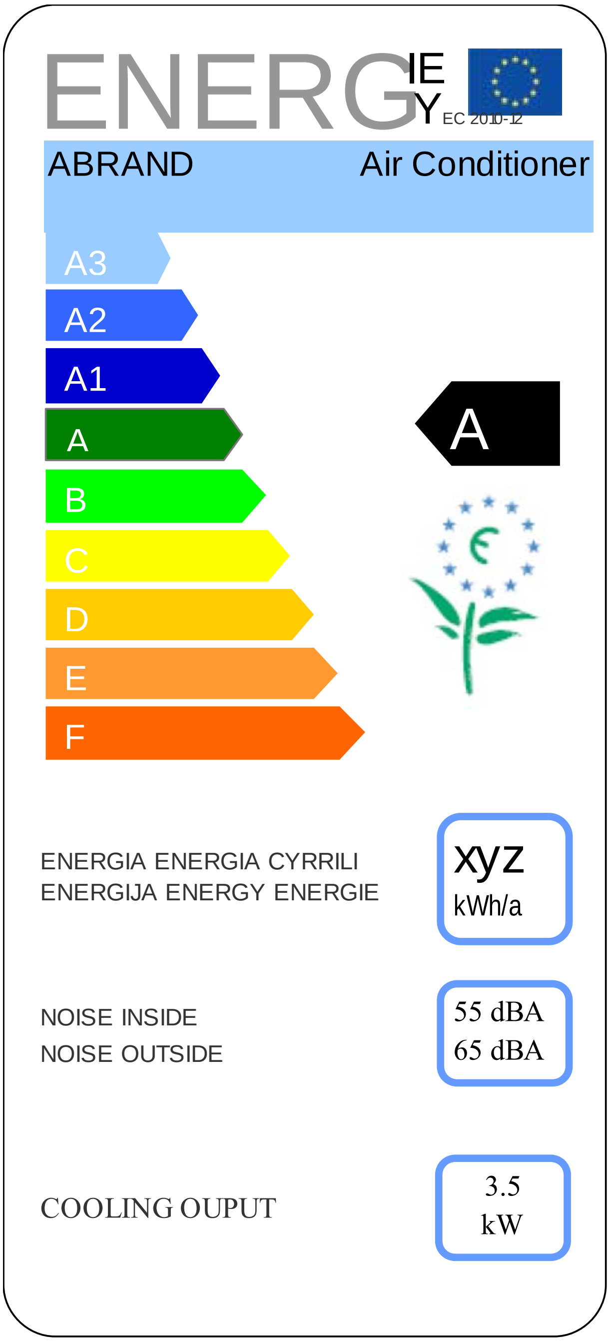

ENERG
IE
Y
EC 2010-12
ABRAND
Air Conditioner
A3
A2
A1
A
B
C
D
E
F
A
ENERGIA ENERGIA CYRRILI
ENERGIJA ENERGY ENERGIE
xyz
kWh/a
NOISE INSIDE
NOISE OUTSIDE
55 dBA
65 dBA
COOLING OUPUT
3.5
kW

Figure 8-5: Energy label layout

8.1.2.6.2 Tolerances

Tolerance level of 15 % makes that the EU labeling classes (that are between 6 and 14 % depending on the product categories and classes) are shorter than the tolerances, enabling manufacturers to declare EER and COP values up to 2 classes above the real EER values (Saheb, 2006). An enquiry led in the UK by the Market Transformation Program shows that consumers are very concerned by such a situation, and majoritarily by the fact that it would affect their energy bill. This is a very risky situation for the EU labeling scale that could end up with a global failure of the labeling system. It is both necessary to increase the size of the intervals between classes and to reduce the tolerance levels to solve the issue.

Tolerance for market surveillance

In the few countries (to our knowledge: Italy, Spain, UK) where market control was led, tests have shown that low price products with false declarations was a common situation with some units declared in class A or B and rated in class E or F. In these countries where units were tested, no measure was taken towards the manufacturers or importers responsible of the infringement.

This quasi absence of market control cannot be addressed with the EuP directive but it is crucial for the implementing measures adopted under the application of this directive to reach their full potential.

To our knowledge, two round Robin Tests were led in the recent years, one by Eurovent-Certification and the other one by CECED. The final conclusion is that energy labelling of the units and market control should be achieved only in laboratories certified according to the ISO 17025 laboratory accreditation standard for testing according to the EN 14511 standard. In those conditions, it has been found tolerances could be reduced down to 5 % and 8 % was kept for Eurovent following the tests, including deviations between laboratories.

Uncertainty of measurement has been treated by the CEN TC113 WG7 when revising the Technical Standard CEN/TS/14825. Uncertainty of measurement for capacity measurement should be inferior to 5 % when capacity measured is superior to 2 kW and inferior to 10 % below 2 kW. Also, and as in the EN 14511 test standard, uncertainty of measurement up to 10 % is allowed for capacity measured under frost conditions. It means that uncertainty of measurement will lie between 5 and 10 % depending on capacity. With 1 % uncertainty of measurement for electric intensity, it means that the uncertainty of measurement of SEER and HSPF will lie between 5.1 % and 10.1 %.

Tolerances should be reduced to compatible levels with rating the performances of the units. 10 % is the maximum value that could be admitted for the label to keep its plain value.

8.1.2.6.3 Credit to units using a low GWP refrigerant

The increase in energy performance with the adoption of the precedent measures leads to important energy savings. Nevertheless, with no measure targeted on direct emissions (linked to refrigerant loss), energy efficiency increase is likely to induce a refrigerant charge increase, as has been reported previously for the Japanese market in Task 6. In addition, there is presently no specific incitation to foster the development of low GWP refrigerants.

In the EU Decision regarding Ecolabel criteria for heat pumps (CEC, 2007), energy efficiency targets are lowered by 15 % for units using low GWP (<150) refrigerants.

The only existing competitor to R410A identified is propane for package units, which is authorized with specific safety installation requirements (standard EN 60335 – 2 – 40), because of its flammability properties.

For single duct, using propane as the refrigerant has been defined as one of the options leading to the LLCC product since performance are superior to the ones of R410A by 0 to 10 %. In the previous analysis in task 6, it has been shown that using propane instead of R410A in a single duct unit could enable to save between 10 % and 20 % of the total emissions depending on the efficiency of the unit, in addition of the energy efficiency gain linked to the refrigerant itself.

In the other hand, there is today no competitor to R410A for split units, at least with products sold on the EU market.
The share of direct CO2 equivalent emissions linked to the refrigerant fluid has been estimated to lie between 20 and 50 % for split air conditioners and between 10 and 20 % for reversible split depending on the energy efficiency of the unit. Highest figures, 20 %, already includes micro channel heat exchanger technology that has been supposed to reduce the charge amount by 45 % when used in both heat exchangers. It means that once best available technology has been used to improve energy efficiency and without specific measure on refrigerant charge or leaks, the share of direct emissions in the total CO2 equivalent emissions of the heat pumps is likely to rise to more than 40 %.

Without any specific measures on these small units, manufacturers have little incitation to adopt the most promising technologies to cut CO2 direct emissions.

It could be computed a standardized global CO2 equivalent emission value over the whole life cycle of the product, on a kWh basis (gCO2/kWh), tailored on the label for cars in gCO2/km. Nevertheless, with separate heating and cooling labels, it seems difficult to use it.

Then, the only approach left would be to use the same approach as in the Ecolabel and to give a credit to units using low GWP refrigerant fluids.

8.1.2.7 Benchmark for public procurement or fiscal incentives

In order to support the energy efficiency increase and CO2 direct emission decrease, public procurement should be based on upper values of the grading scale. Given that LLCC levels are above SEER 4.0 and HSPF 3.1 (class A products), incentives by member states should be based on this grades as a minimum in the first place and values updated in case of the adoption of MEPS levels. Nevertheless, for these products, it has been shown that the LCC curve was very flat around the LLCC value. Consequently, in order to push the market forward in creating demand on more efficient appliances which then will experience lowered prices due to higher sales/production volumes, it would make sense to push higher than the LLCC levels as energy grades higher than A1.
This targets could also be decreased for products using low GWP values.

8.1.2.8 Minimum energy performance requirements

8.1.2.8.1 Scenarios: general description

The heating and cooling need trends are taken into account: change in heating and cooling needs are considered only as far as the evolution of the building stock is concerned: new buildings (to be understood here as building constructed after 2005) enter the stock progressively ; the refurbishment rate is of 2 % yearly for commercial buildings (office and trade) and of 1 % in the residential sector.

Whereas in task 5 the design of the base cases was conserved up to 2030, the **BAU scenario** includes the energy efficient improvements observed up to now , and the continuous penetration of inverter driven air conditioners - up to 70 % penetration ratio in 2009. Since the label leaves some place for non inverter units and has a large spread in SEER values, efficiency evolves little after 2010. Refrigerant charge of the units increases following the trends observed in Task 6 for more efficient units. Propane unit's market share grows linearly up to 25 % in 2025 amongst cooling only units.

In the **"2015" scenario**, the MEPS levels are set to ensure the complete transition of the sales towards inverter driven units ; this scenario is seen as an accompanying measure of an already observed trend. Energy efficiency classes C-F in cooling and in heating mode are banned from the market in 2015.

In the **"LLCC" scenario**, the MEPS levels are set to LLCC levels. Classes B-F for heating and cooling are banned from the market in 2013.

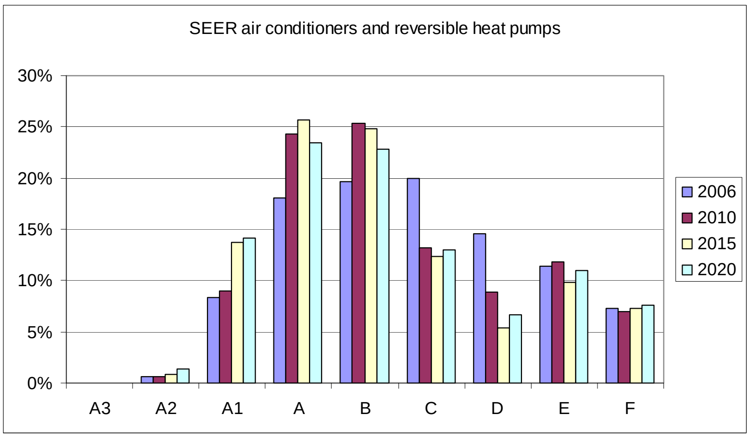
The **"2012" scenario** is made of two steps:
- MEPS are applied in 2012,
- and additionally, a second set of MEPS enters in 2018.

As shown previously in task 7, the LCC curves are very flat around the LLCC optimum: it means that the LLCC energy efficiency levels are likely to move upward rapidly whether adequate public procurement and other incentive schemes are put in place at Member State level. That is the reason to build a scenario with higher targets than the LLCC optimums as minimum requirements.

8.1.2.8.2 Scenarios: parameters

The **BAU scenario** leads to the following repartition of products by efficiency classes as defined for the labeling scale update. Both in cooling and heating distribution, a change in distribution occurs between 2006 and 2015 thanks to the penetration of inverter in the split product range. For the cooling mode, this leads to an important spread of units' performances because of the persistence of on-off controlled package units. In heating mode, the efficiency scale, compatible with other heating systems is favorable to heat pumps.

SEER and HSPF of the products sold are shown in the table below.



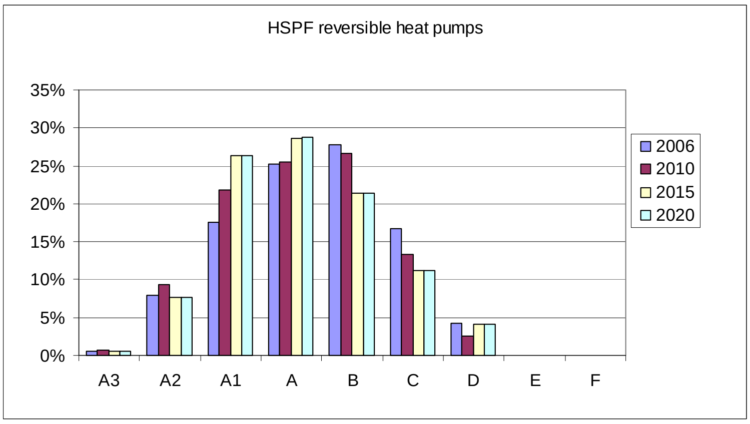
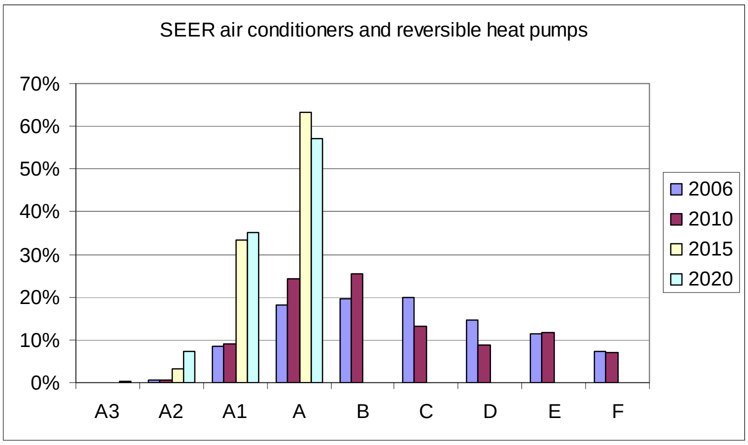


Figure 8-6: Energy classes repartition of SEER and HSPF – "BAU scenario"

In the **"MEPS 2015"**, class B to F air conditioners and heat pumps are removed from the market in 2014.. In 2014, it is estimated that the share of compliant units before the MEPS application would be of 40 % in cooling mode and 65 % in heating mode .



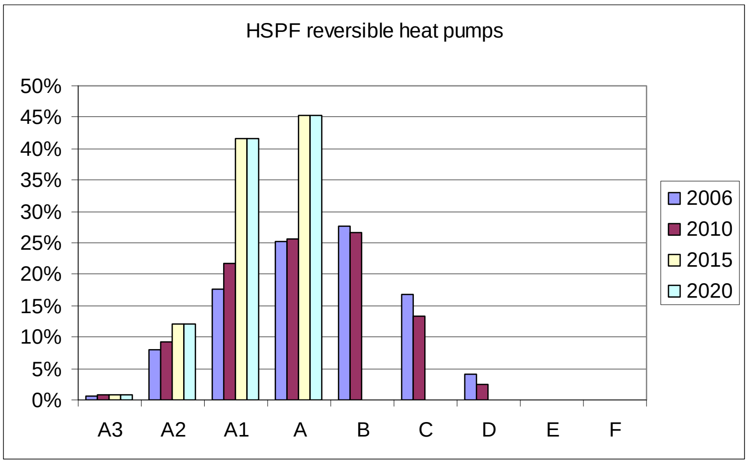
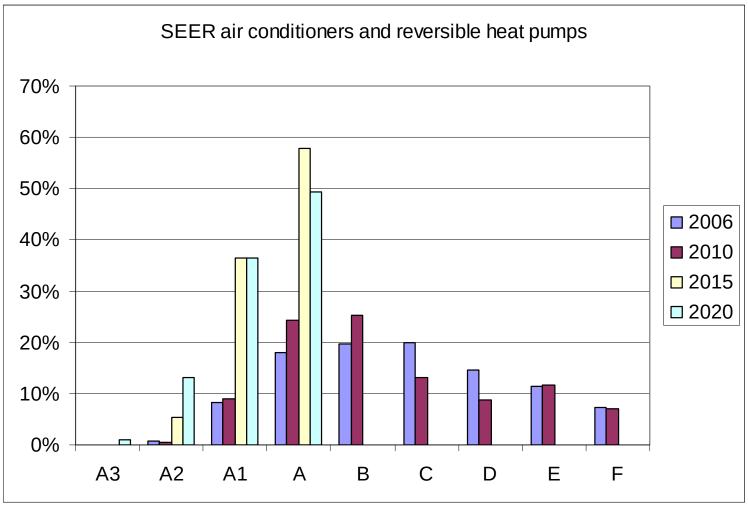


Figure 8-7: Energy classes repartition of SEER and HSPF – "MEPS 2015 scenario"

In the **"LLCC"** scenario, 2 years are gained over the MEPS 2015 scenario: this scenario satisfies the requirements of the EuP directive. In 2013, it is estimated that the share of compliant units before the MEPS application would be of 30 % for the SEER threshold and of 60 % for the HSPF.



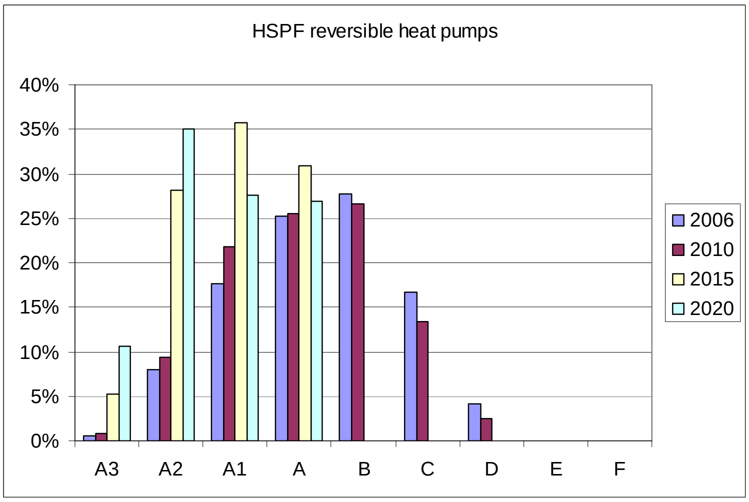
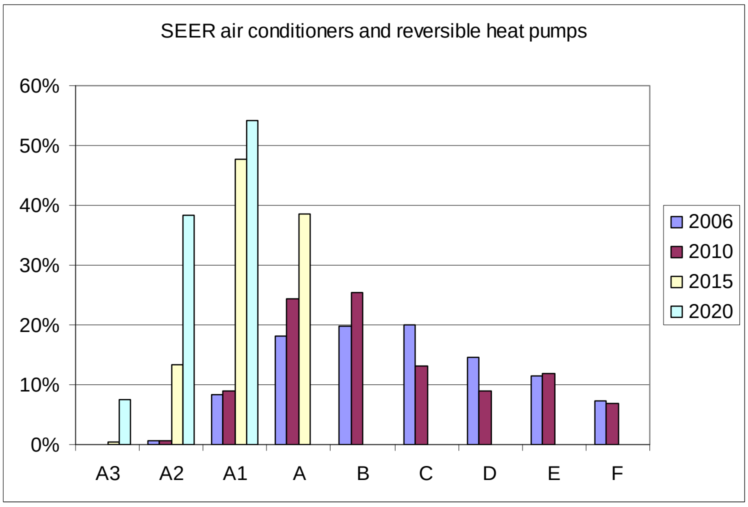


Figure 8-8: Energy classes repartition of SEER and HSPF – "LLCC scenario"

In the MEPS 2012 scenario, MEPS are applied in 2012 and a second set of requirements is taken in 2018 (simulated here by removing class A products). In 2012, it is estimated that the share of compliant units before the MEPS application would be of 30 % for the SEER threshold and 60 % for the HSPF one.



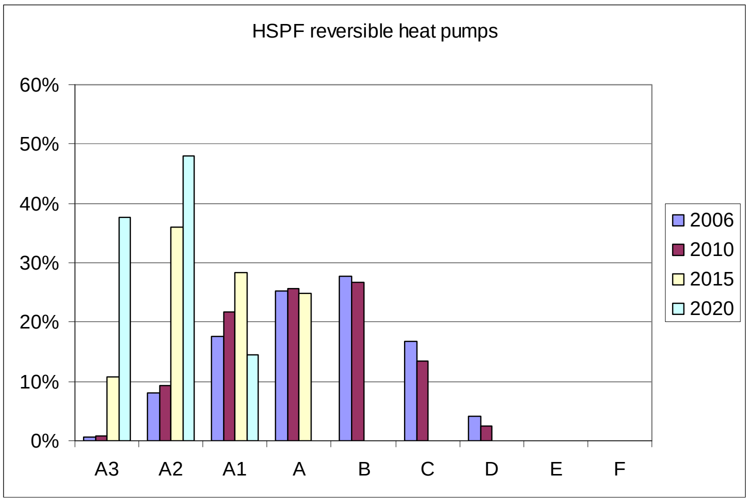


Figure 8-9: Energy classes repartition of SEER and HSPF – "MEPS 2012"

Evolution of energy efficiency of all products in use in a given year according to these different scenarios is summarized below. In the BAU scenario, a significant improvement is already reached with the increasing share of inverter products.

		1990	2000	2005	2010	2015	2020	2025
BAU	**SEER**	2,1	2,6	3,0	3,2	3,4	3,3	3,3
	HSPF	2,4	2,5	2,8	2,9	3,1	3,1	3,1
MEPS 2015	**SEER**	2,1	2,6	3,0	3,2	4,3	4,3	4,3
	HSPF	2,4	2,5	2,8	2,9	3,3	3,3	3,3
LLCC	**SEER**	2,1	2,6	3,0	3,2	4,3	4,5	4,5
	HSPF	2,4	2,5	2,8	2,9	3,5	3,6	3,6
MEPS 2012	**SEER**	2,1	2,6	3,0	3,2	4,5	5,2	5,2
	HSPF	2,4	2,5	2,8	2,9	3,7	4,1	4,1

Table 8-11: Planned evolution of the average sales SEER and HSPF for the different MEPS scenarios

8.1.2.8.3 Scenarios: environmental impact

The energy consumption of the stock of air conditioners and heat pumps following the different scenarios is presented in the following figures.

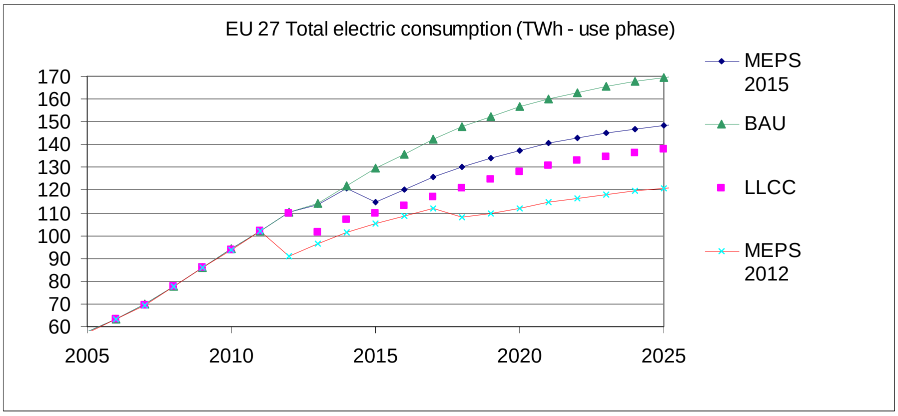


Figure 8-10: Yearly energy consumption of all products in use in TWh for the different scenarios

The CO2 emissions of the stock of air conditioners and heat pumps following the different scenarios are presented in the following figure.

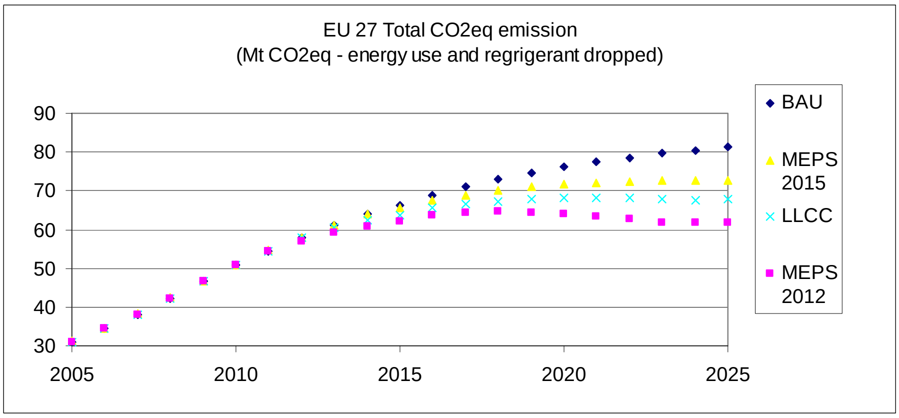


Figure 8-11: Yearly CO2 emissions of all products in use in million ton CO2eq for the different scenarios

Results are summarized in the table below.

Energy consumption and CO2 emissions are mainly the consequence of energy consumed for heating, 65 TWh over 94 TWh in 2010. Gains with specific measures on efficiency in 2020 amount to 21 TWh for the 2015 MEPS, to 32 TWh in the "LLCC" scenario and to 49 TWh in the case of the 2012 MEPS scenario. Regarding GHG emissions, this translates in respectively 9 MtCO2eq, 1 MtCO2eq and 20 MtCO2eq.

BAU	YEAR	1990	2005	2010	2015	2020	2025
Total Consumption	TWh	8	58	94	129	156	170
CONS Stock Heating	TWh	5	36	65	92	111	118
CONS Stock Cooling	TWh	3	22	29	38	46	52
Total GHG emission	MtCO2eq	4	31	51	66	76	81
Part CO2 direct emissions	MtCO2eq	0	5	8	7	5	4
MEPS 2015	**YEAR**	**1990**	**2005**	**2010**	**2015**	**2020**	**2025**
Total Consumption	TWh	8	58	94	115	138	149
CONS Stock Heating	TWh	5	36	65	85	102	109
CONS Stock Cooling	TWh	3	22	29	30	35	40
Total GHG emission	MtCO2eq	4	31	51	65	72	73
Part CO2 direct emissions	MtCO2eq	0	5	8	13	9	5
GAIN Electricity consumption	TWh	0	0	0	15	19	21
Gain GHG emissions	MtCO2eq	0	0	0	1	5	9
LLCC	**YEAR**	**1990**	**2005**	**2010**	**2015**	**2020**	**2025**
Total Consumption	TWh	8	57	94	110	128	138
CONS Stock Heating	TWh	5	36	65	80	93	100
CONS Stock Cooling	TWh	3	22	29	30	34	38
Total GHG emission	MtCO2eq	4	31	51	64	68	68
Part CO2 direct emissions	MtCO2eq	0	5	8	14	10	5
GAIN Electricity consumption	TWh	0	0	0	20	29	32
Gain GHG emissions	MtCO2eq	0	0	0	2	8	14
MEPS 2012	**YEAR**	**1990**	**2005**	**2010**	**2015**	**2020**	**2025**
Total Consumption	TWh	8	57	94	106	112	121

CONS Stock Heating	TWh	5	36	65	77	83	88
CONS Stock Cooling	TWh	3	22	29	28	30	33
Total GHG emission	MtCO2eq	4	31	51	62	64	62
Part CO2 direct emissions	MtCO2eq	0	5	8	14	13	6
GAIN Electricity consumption	TWh	0	0	0	24	44	49
Gain GHG emissions	MtCO2eq	0	0	0	4	12	20

Table 8-12: Scenarios - environmental impact

8.1.2.8.4 Scenarios: economic impact

The evolution of the average purchase price for air conditioners and heat pumps in each scenario and of the LLCC gains is reported in the table below. Electricity price increases 1.5 % / y as explained previously in task 2. LCC values refers to a 3.5 kW unit for heat pumps and to an average of 3.5 kW and 2.2 kW units for air conditioners. Regarding air conditioners, after 2010, the LCC mainly translates the situation of the 2.2 kW products when including the reversibility trends explained before.

In the BAU scenario, the price already increases because of the increasing share of inverter driven units and given the fact that the correlations established in task 7 between energy efficiency improvement and purchase price are used to assess the average purchase price for a given year.

Regarding heat pumps, every scenario gives benefits on a LCC basis. This is because the potential for improvement has been limited to levels established for other heating systems. Largest gains are expected in the LLCC scenario since the fleet efficiency after the MEPS is close to LLCC levels. “2012 scenario”.

For air conditioners (mainly single duct), it is supposed that all products just pass the threshold MEPS. Consequently, the gains are similar in the different scenarios. The lower LCC values are reached for the two first scenarios as in the the “MEPS 2012” scenario, the second set of requirements leads to fleet average efficiencies higher than the LLCC.

Economic impact		1990	2005	2010	2015	2020	2025
BAU							
Price Heat pumps	Euros/kW	195	192	197	206	206	206
Price Air conditioners	Euros/kW	193	194	184	183	183	183
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3991	4124	4251
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1757	1010	980	1030	1088
MEPS 2015							
Price Heat pumps	Euros/kW	195	192	197	221	221	221
Price Air conditioners	Euros/kW	193	194	184	233	233	233
Price increase Heat pumps	%	0%	0%	0%	8%	8%	8%
Price increase Air conditioners	%	0%	0%	0%	27%	27%	27%
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3826	3929	4042
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1757	1010	770	794	819
Gain LCC heat pumps	%	0%	0%	0%	4%	5%	5%
Gain LCC air conditioners	%	0%	0%	0%	21%	23%	25%

LCC							
MEPS 2012	Euros/kW	195	192	197	235	245	244
Price Air conditioners	Euros/kW	193	194	184	233	233	233
Price increase Heat pumps	%	0%	0%	0%	14%	19%	18%
Price increase Air conditioners	%	0%	0%	0%	27%	27%	27%
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3782	3856	3956
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1736	973	770	794	819
Gain LCC heat pumps	%	0%	0%	0%	5%	6%	7%
Gain LCC air conditioners	%	0%	1%	4%	21%	23%	25%
MEPS 2012							
Price Heat pumps	Euros/kW	195	192	197	246	292	292
Price Air conditioners	Euros/kW	193	194	184	247	267	267
Price increase Heat pumps	%	0%	0%	0%	19%	42%	42%
Price increase Air conditioners	%	0%	0%	0%	35%	46%	46%
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3745	3776	3864
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1736	973	785	833	854
Gain LCC heat pumps	%	0%	0%	0%	6%	8%	9%
Gain LCC air conditioners	%	0%	1%	4%	20%	19%	22%

Table 8-13: Economic impact of scenarios

8.1.2.8.5 Scenarios: summary

The summary of the energy efficiency targets adopted in each scenario is shown in the table below.

Measures	MEPS 2015	LLCC	MEPS 2012
Label	2010	2010	2010
MEPS B-F	2015	2013	2012
Supplementary measure (MEPS - A)	-	-	2018

Table 8-14: Summary of energy efficiency levels in the different scenarios and of introductory dates

A summary of the environmental and economic impacts is shown in the table below.

BAU	YEAR	1990	2005	2010	2015	2020	2025
Total Consumption	TWh	8	58	94	129	156	170
Total GHG emission	MtCO2eq	4	31	51	66	76	81
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3991	4124	4251
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1757	1010	980	1030	1088
MEPS 2015	YEAR	1990	2005	2010	2015	2020	2025
GAIN Electricity consumption	TWh	0	0	0	-15	-19	-21
Gain GHG emissions	MtCO2eq	0	0	0	-1	-5	-9
Gain LCC heat pumps	%	0%	0%	0%	4%	5%	5%
Gain LCC air conditioners	%	0%	0%	0%	21%	23%	25%
LLCC	YEAR	1990	2005	2010	2015	2020	2025
GAIN Electricity consumption	TWh	0	0	0	-20	-29	-32
Gain GHG emissions	MtCO2eq	0	0	0	-2	-8	-14
Gain LCC heat pumps	%	0%	0%	0%	5%	6%	7%
Gain LCC air conditioners	%	0%	1%	4%	21%	23%	25%
MEPS 2012	YEAR	1990	2005	2010	2015	2020	2025

GAIN Electricity consumption	**TWh**	0	0	0	-24	-44	-49
Gain GHG emissions	**MtCO2eq**	0	0	0	-4	-12	-20
Gain LCC heat pumps	**%**	0%	0%	0%	6%	8%	9%
Gain LCC air conditioners	**%**	0%	1%	4%	20%	19%	22%

Table 8-15: Summary of environmental and economic impact of scenarios

8.1.2.9 Auto mode function redesign

Regarding the design of the units, the “auto” mode has been found as a source of highly inefficient operation. In the “auto” mode, the user adjusts one single set point temperature and the unit provides either cooling or heating depending on the temperature inside. This option is likely to be used for intermediary outside temperature conditions, in late spring or in early autumn, leading to important energy waste. Such unit should be designed with a large default interval for set point values, that might be adjusted by the end-user afterwards.

Hence, for products in the scope that propose a function to automatically switch from cooling to heating or from heating to cooling, this function shall integrate two different set points for heating and cooling. Default temperature set point settings should be inferior or equal to 21 °C in heating mode and superior or equal to 25 °C in cooling mode.

8.1.3 Link with existing EU legislation

The link with the **labelling directive 2002/31/EC** has been established with a proposal for revised labelling scales and information to be supplied on the energy label previously.

Regarding the **proposal for a directive on the promotion of the use of energy from renewable sources (CEC, 2008)**, the thermal energy for reversible and heating only heat pumps should be computed on the basis of the SCOP indice, including part load, outside temperature variation and auxiliary power modes.

Regarding the **Energy Performance of Building Directive 2002/91/EC**, the application of the directive is made very difficult for reversible heat pumps and air conditioners since their performances at other than standard rating conditions according to EN14511 standard are not published. Member States, in order to evaluate the energy consumption of these products for a given project, adopt default factors to correct the performances of the units with outside and inside temperature and with load ratio ; these corrections are different for each Member States. With the fast penetration of inverter driven units and the design freedom manufacturers have regarding the declaration of rating frequencies, correction factors have little chance to capture the differences between two units.

As a first measure, it is then required, in the section 8.1.9 regarding “information to be supplied by manufacturers”, that all test results required to compute the seasonal performance indices are added in the technical documentation of the unit. But the only way to enable a true comparison between air conditioners or reversible heat pumps and also with other heating and cooling products / systems, is to require manufacturers to publish a standardized map of the performances of their products (at given outside temperature, inside temperature and load ratio). This performance map is to be standardized and energy efficiency declared by manufacturers in those conditions should be superior to the declared value minus the uncertainty of measurement as specified in the technical annex in section 8.4.1. This work should be mandated to CEN with a specific mention that a coordination between TC228 and TC113 is required within the frame of the application of the EPB directive.

In order to avoid the checking of too many test points on air conditioners and reversible heat pumps, the Eurovent-Certification scheme, where a few points are chosen randomly in the performance map, could serve as a basis. Alternatively, this performance map could be based on default modelling hypothesis as can be found in the Japanese (JRA, 4046) and American (ARI 210/240) standards, but should, in any case, be shared by all the Member States in order to avoid market distortion at national level.

The article 9 regarding the inspection of air conditioning system sets the following requirements:
“- With regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall lay down the necessary measures to establish a regular inspection of air-conditioning systems of an effective rated output of more than 12 kW.
- This inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. Appropriate advice shall be provided to the users on possible improvement or replacement of the air-conditioning system and on alternative solutions.”

As reported in task 1, it is not clear whether air conditioners and reversible heat pumps with a cooling output below 12 kW whether several products should be considered as an air conditioning system or not. Whether those products are included, then “To assess the air conditioning efficiency and the sizing compared to the cooling requirement” could be made much easier by requiring manufacturers to include on-board systems that evaluate the cooling capacity of the equipment as a function of the operating conditions (temperatures, humidity indoor, frequency speeds of compressor and fans, refrigerant temperatures and pressures, …). In that case indeed, the inspector could simply check the maximum capacity seen by the unit for instance over one year and thus check the real sizing of the unit. He could also access the field performances of the unit and benchmark these performances against the performances that the unit should have according to its performance map and with other units. This would enable to give an accurate diagnosis regarding maintenance and replacement economic impacts for the end-user.

A first mandate to CEN should aim at defining a standardized performance map for which manufacturers should give the performances of their units and also define the assessment procedure to check the performance map exactness.

In order to enable the application of the inspection article, a second mandate to CEN could require air conditioners and heat pumps to be equipped with systems able to record and to edit the performances of the units (capacity, electricity consumption and EER or COP), for instance with an hourly time step and the possibility to store data over one year.

8.1.4 Noise requirements

In the labeling directive 2002/31/EC, noise indication on the label is only voluntary and it is up to the appreciation of the Member States to add noise intensity: "Where applicable, noise during standard function, determined in accordance with Directive 86/594/EEC".
Noise of the product is one of the more important criteria for end-users to select a unit. Moreover, increasing the competition on energy efficiency without fixing noise constraints could lead to increased noise levels to the detriment of the end-user. Hence, it is necessary that the noise levels become mandatory on the label to avoid improving efficiency to the cost of noise increase:

The analysis of noise sound power (measured according to standard EN12102) in task 2, 3 and 4, has shown that there had been no improvement in the average levels of sound power between 1996 and 2006.
The analysis of best available products on the Japanese and European market shows it is possible to reach highest efficiency levels with equal or lower noise levels indoor and outdoor[8]. Setting maximum values for sound power will avoid that energy efficiency improvement may be detrimental to sound emissions. In order not to limit energy efficiency improvement, noise limits are fixed at the level of most energy efficient units, as follows:

Sound power threshold	Split 0-6 kW range		Split 6-12 kW range	
	Indoor	Outdoor	Indoor	Outdoor
DBA (ENV 12102)	60	65	65	70

Table 8-16: Maximum sound power values

For package units, the same requirements as the outdoor limitation of split units should be kept depending on the capacity of the unit.

8.1.5 Ecodesign parameters referred to in Annex I, Part 1 relating to which no ecodesign requirement is necessary

The study investigated in a quantitative manner all phases of the lifecycle of the products -materials use, manufacturing, transport, distribution, installation and maintenance, use, end of life- taking into account the potential ecodesign parameters mentioned in the Annex I, section I.3 of the EuP directive.

The environmental impact of air conditioners and heat pumps products is largely dominated by energy consumption and refrigerant loss.

The most important part of environmental impacts occurs during the use phase because of energy consumption. In average, between 65 % and 80 % of CO_2 emissions are linked to the energy use for

[8] Figures 4.33 to 4.35, task 4.

air conditioners and 89 % for reversible heat pumps. Refrigerant losses thus accounts for a non negligible part of the total CO2 emissions.

The stock of products in use in 2005 has been estimated to consume 58 TWh amongst which 36 TWh for heating and 22 for cooling. This amounts to about 31 million tCO2eq.

At the end of the product's life, the fact that the refrigerant is recovered or not makes a large difference in terms of CO2 emissions, however, this point is already covered by the WEEE directive and by the EC Regulation 842/2006 on fluorinated gases.

8.1.6 Requirements on installation and maintenance of the EuP with direct relevance to the EuP's environmental impact

The installation and maintenance requirements are explicitly covered in the CEN EN14511 and EN 378 standard. Qualification of people regarding refrigerant management at the time of installation and use of the products in the scope is required by the Regulation 2006/842/EC regarding fluorinated gases and covered by the EN 13133 standard. Hence, with the two main environmental impacts being already covered, it is thought there is no specific requirements needed regarding installation and maintenance.

8.1.7 Measurement standards and/or measurement methods to be used

8.1.7.1 Energy performance

Because of the large penetration of inverter technology and of the potential energy efficiency gains associated, the CEN EN14511 testing standard is to be completed with a part load standard to define testing and calculation of seasonal performance indicators. This work is in progress and coordination with the CEN TC113 WG7, the group in charge of the revision of the part load Technical Standard CEN TS 14825 has been ensured. The draft standard is at the enquiry stage. A technical addendum has been developed in paragraph 8.4 of this report that is to become part of any implementing measure based on seasonal performance indices, as energy efficiency measures proposed in the frame of this study.

8.1.7.2 Noise

The sound intensity values should be measured in agreement with the EN 12102 CEN standard.

8.1.8 Conformity assessment under Decision 93/465/EEC

It is advised to require Modules B and C for conformity assessment. Three main reasons justify this necessity:
- All stakeholders have underlined how frequent was false declaration regarding energy efficiency of the products in the scope and other parameters such as capacity. The important impact of false declaration on the EU labelling scheme has been underlined.
- For very few products in the scope, performances of the products have been checked in the frame of the market surveillance by Member States. This is also because tests are quite expensive for those products. Supplementary tests required in order to assess the seasonal and/or yearly performances of the units will make testing again more expensive limiting the possible increase in the number of models checked within the frame of market surveillance by Member States.
- Finally, requiring Module B and C will enable to reinforce the quality of testing, by stabilizing the market offer for testing products in the scope of the study.

8.1.9 Requirements on information to be provided by manufacturers

8.1.9.1 Programmable thermostat

The cooling load and air conditioner energy efficiency (the heating load and COP of a heat pump) is very sensitive to the indoor set point temperature. Energy consumption of heat pumps have been computed including a setback of the indoor temperature during unoccupied periods. This simple measure (using setback) leads to cut heating energy consumption up to a factor two depending on the set point at night or during inoccupation, on climate, on building characteristics and occupancy, without accounting further gains on the COP of the unit because of more favorable operating conditions.

The best reference identified in that field is the EERE consumer guide regarding the use of programmable thermostat that is based on requirements from the US ENERGY STAR® label for programmable thermostats. The following information should be added in the technical documentation of the products (in SI units).
- “You can easily save energy in the winter by setting the thermostat to 68°F (20 °C) while you're awake and setting it lower while you're asleep or away from home. By turning your thermostat back 10°–15° (5 to 8 °C) for 8 hours, you can save about 5%–15% a year on your heating bill—a savings of as much as 1% for each degree (for each two Celsius degrees) if the setback period is eight hours long. The percentage of savings from setback is greater for buildings in milder climates than for those in more severe climates.”
- “In the summer, you can follow the same strategy with central air conditioning (your air conditioner), too, by keeping your house warmer than normal when you are away, and lowering the thermostat setting to 78°F (26°C) only when you are at home and need cooling. Although thermostats can be adjusted manually, programmable thermostats will avoid any discomfort by returning temperatures to normal as you wake or return home.”

One of the problem with heat pumps and thermostat is that heat pumps may not cover all heating needs. In case two heating systems are installed, care should be given so that reducing the heat supplied by the heat pump may not be compensated by the other heating system in place, with subsequent energy efficiency loss.
There is some place here for manufacturers of programmable thermostats to propose solutions to optimize the performance of bivalent systems, depending on the characteristics of the heat pump and of the complementary heating system. This optimization requires the knowledge of the heat pump performances in non standard rating conditions and gives a supplementary reason to require the performance map described above.

8.1.9.2 Energy performance information

Every product in the scope of the study shall bear on its plate and in all document describing the performances of the unit the following values:

- SEER value for both cooling only and reversible air conditioners,
- HSPF value for both reversible heat pumps and heating only heat pumps,

All the test results required to determine the SEER and HSPF should be made available in the technical documentation supplied with the product.

This measure is applicable at year Yo and should be revised at year Yo + 6.

8.1.9.3 Dehumidifying capability

Increasing energy efficiency can be done while maintaining the evaporating temperature low enough in order to ensure dehumidification capability is maintained or without this constraint ; the first option is typical in the USA and the second one in Japan. For Japanese best available products, dehumidification now appears as a separate option. Since dehumidification requires lower evaporating temperatures than necessary for sensible cooling and that consequently cooling and dehumidifying at the same time leads to less efficient cooling performance, manufacturers now propose intermittent operation in a dehumidifying mode operating with very low evaporating temperature for a short time period.

Dehumidification being an important function of the products in the scope for the end-user, manufacturers should indicate the dehumidification capability and efficiency of air conditioners and reversible heat pumps. The definition of test conditions and measurement to be done is to be mandated to CEN and should be added to the tests defined in the CEN 14511 standard. It should enable the comparison of the dehumidification capability and energy efficiency of the products in the scope with dehumidifiers, e.g. having the same ambient test conditions as defined in the EN 810 test standard for dehumidifiers.

8.1.9.4 Information enabling independent testing

Problems found

For inverter driven units, manufacturers design their product to work at given frequencies of rotation of the compressor(s) and fan(s) in specific conditions. To test products in standardized conditions, generally manufacturers pre-program the frequencies under which the units have to operate for the standard tests and communicate directly to the laboratory in charge of the testing how to set the unit in such conditions.
It is also reported by laboratories that some units may automatically detect that they are being tested (for instance by detecting that indoor air temperature is being constant for an unusual long time) and adapt consequently the operating conditions.

Both situations are equivalent: there is no insurance that the unit performs on field with performances measured according to the stationary performance standard. This a worrying situation since the implementing measures for label and minimum energy performance are likely to accelerate the full penetration of inverter driven units on the EU market.

As it has been shown previously, inverter driven units are becoming the common standard and this is justified by better performances in laboratory conditions, with specific settings that might not be the ones of the control on field. Laboratories report that when they cannot join the manufacturer or importer of the unit they have to test, it is very difficult to test the unit (getting stable conditions in the rooms) and that in this situation, performances are not always the ones promised because testing frequency of the inverter of the fans or of the compressor is (are) different of the one(s) planned.

On the EU market based on performance declaration, the only means available to check the compliance of the products is to pick a sample of units and to have them tested in an independent laboratory. The present situation in which the laboratory has to contact (phone call, email) the manufacturer to know which “code” (in the sense of a combination of sometimes more than 20 keys) should be entered via the remote controller to fix the frequency does not enable a true independent testing of the unit.

Solutions

Consequently, for capacity controlled units and for inverter driven units, there should be either a programmed mode to fix the capacity steps or frequencies of operation of the units as declared, or information required on how to set the units for the different tests given in the technical documentation of the unit. This requirement appears in the section on information to be supplied by manufacturers.

This requirement however solves only a part of the problem: it is still not sure that units will perform on the field the same way as in laboratory conditions. With an unchanged product, the only foreseen solution would be to envisage dynamic testing, which would require all testing laboratories to be exactly identical or alternatively to have only one testing laboratory for the whole Europe for matters of accuracy, and that goes well behind product design and the frame of this study.

8.1.9.5 Noise information at low outside and inside fan speeds

A problem reported in task 3 is that air conditioner and heat pump performances are very sensitive to the inside noise level due to different fan speeds. Typically, manufacturers publish sound pressure levels at the different fan speeds of the indoor units. However, since the end-user does not know the performances of the units in these non-standard performances, he cannot make an advised choice if he wants to use the unit at low speed. Conclusively, any information on noise in conditions different to the ones specified in EN 12102 and EN 14511 should be completed with information on the performances of the units, EER or COP, in those conditions.

8.1.10 Duration of transitional periods

The complete redesign cycle is estimated to be of 3 years for smaller units in the [0-6 kW] range and longer than 5 years for larger units in the [6-12 kW], what is explained by manufacturers by the lower sales in the higher capacity segment. With this preparatory study ending in 2008, it seems reasonable to adopt 5 years to adapt to specific requirements. For other requirements, mainly information to be supplied by stakeholders, the time required between the end of the preparatory study and the date of entry into force of the measures is thought to be long enough for manufacturers to adapt.

8.1.11 Date for the evaluation and possible revision of policy measures

Policy measures are planned for two design cycles following the publication date for the smaller capacity range and one for larger products. Revision of these implementing measures should intervene to deliver updated requirements in 2015.

8.2 Impact analysis industry, consumers

8.2.1 Impact analysis: industry

Two main markets have been previously identified in the scope of the study, split air conditioners and moveable air conditioners (single duct, double duct and mobile split) that compose the main products in the two categories kept in the study, air conditioners (cooling only) and heat pumps (reversible air conditioners). It is to be noticed that these two markets are not completely hermetic to each other. In one hand, some manufacturers sell split units to install yourself in order to cut the expenses of the installation. In the other hand, the development of urban constraints either aesthetic or regarding noise outside favors the development of single duct and other moveable units in replacement of fix installation because of the absence of the outside unit (or non permanent use for moveable split units).

Measures proposed and employment loss

The portray of the industry has been addressed in this task report in the introduction to policy measures. Manufacture of air conditioners and heat pumps in the scope of the study is almost completely made in low labor cost countries, mainly in China but also in other Asian countries. The only known exception is Daikin who settled three facilities in Eastern Europe, to assemble the products, for heat exchangers production and for compressor production, decision taken after the product supply shortage in 2003 during the heat wave. Despite some brands are originally European, almost all manufacturers are rather multinational companies with production in low labor cost countries. Mainly sales department and sometimes R&D departments for brands that originally produced in Europe (Delonghi, Bosch-Siemens, Carrier ..) are settled in Europe. Hence, even if massive investment was made necessary by the measures, which is not likely to happen as shown hereafter, consequences on employment in Europe would be negligible.

What is the likely impact of the proposed policy measures on products?

The table below summarizes the energy efficiency of products on the EU and Japanese markets on a single scale.

For reversible heat pumps, LLCC level considering heating and cooling consumption is comparable to the minimum Top Runner energy efficiency requirements for reversible heat pumps set for 2010 in the 0-4 kW[9] range. With main players on the EU market being also present on the Japanese market, products to be sold in the EU with the adoption of MEPS levels are already produced massively for the Japanese market (which is about the same size as the EU market in number of units sold). Consequently, impact on the industry is thought to be very low in the 0-6 kW capacity range.
Regarding the 6-12 kW capacity range that represents around 15 % of the sales of air conditioners and heat pumps in Europe, there is presently no requirements in terms of APF in Japan and energy efficiency levels are lower than for the 0-6 kW capacity range in Japan. For multi-split units which make use of the same indoor and outdoor units as for smaller capacity products[10], there is no reason to have different requirements than for smaller capacity units. For single split units, best energy efficiency levels reached are similar to the ones of multi-split products so that there seems to be no specific constraints neither. In any case, because of the presence of multi-split air conditioners on the 6-12 kW range and of the likely competition between the two capacity ranges, it would be difficult to maintain low efficiency products on the 6-12 kW range, which most likely would affect negatively the sales of larger capacity units. The impact on industry of measures differentiated by capacity ranges would most likely be worst than the impact of improving the products to the same levels as smaller capacity products.

[9] Japanese APF of 4.9 is the lowest requirement for size constrained split air conditioners in the 3.2 to 4 kW range, highest value is 6.6 under 3.2 kW and with free dimensions.
[10] It is common for instance that bi-split units use the same indoor units as single split of the same product range, and that outside unit be made of two outside units superposed.

Regarding single duct and other moveable units, it might be argued that improving the performance might be at the cost of reducing the essential characteristic of moveability (which is not a function in the sense of the EuP directive) by increased heat exchanger areas and air flow rates. Nevertheless, it has been shown in task 7 that improving the unit at the LLCC level could be done without significant size increase but with part load and auxiliary modes improvement. Also, the penetration of micro-channel heat exchangers in moveable products could enable to gain some space while maintaining or even improving the performance. With the labeling scale and minimum performance thresholds of the policy measures, the whole market transformation towards inverter driven compressors and other efficient capacity control means should come faster.

For split units, it will primarily accelerate an already fast trend in the EU as mentioned previously in this report. Inverter compressor penetration will also be encouraged for single duct and other moveable products as one of the less costly option to reach SEER 4 and to fill the existing gap in efficiency with split products.

	HSPF	**Product**
A3	**>4,6**	0 - 6 kW, Japan top runners
A2	**4**	Best available split 0 - 6 kW, EU Best available split 6 - 12 kW, Japan
A1	**3,4**	Best 6 - 12 kW EU market
A	**3,1**	EU split with inverter, high performance
B	**2,8**	
C	**2,5**	
D	**2,2**	EU split with inverter, very low performance
E	**1,9**	
F	**<1,9**	Very low performance ON-OFF

	SEER	**Product**
A3	**>6,8**	0 - 6 kW, Japan top runners
A2	**5,7**	BAT single duct T7 0 - 6 kW best EU market Best available split 6 - 12 kW, Japan
A1	**4,6**	Best 6 - 12 kW EU market
A	**4**	EU split with inverter, high performance
B	**3,4**	
C	**2,8**	
D	**2,4**	EU split with inverter, very low performance
E	**2**	Best single duct, EU (EER=2.4 to 2.6)
F	**<2**	Low performance ON-OFF

Table 8-17: SEER and HSPF values of EU air conditioners and heat pumps and of best available products in Japan

The policy measures could be expected to ban window / wall air conditioners and reversible heat pumps: because of geometry constraints, these units are structurally less efficient than split products when compared to other products with full load EER and COP values. However, when comparing the performances on a seasonal basis, the gain linked to the adoption of an inverter driven compressor is likely to be higher than for more efficient products at full load conditions. Hence, whether these products are upgraded with options for part load and efforts are made to reduce auxiliary power modes, they can still outreach the LLCC targets for both air conditioners and reversible heat pumps.

It should be added that this market is rather small (below 100000 pieces) and decreasing, being mainly a replacement market (since there is already a hole in the wall to put a unit). With less demand, manufacturers have also less invested in these products ; for instance, the share of newly designed products with refrigerant fluid R410A is rather small as compared to the situation of split units for the same year. Also, replacement of the unit is done more and more with more efficient split units whose outdoor unit is typically put ahead of the trace of the hole let by the window unit in the building envelope. Consequently, the disappearance of this type of units could be accelerated by the measures taken, even if improvement potential exists to reach the required MEPS levels.

Consequently, the impact on the industry of setting minimum requirements at LLCC level or just above for air conditioners and heat pumps is estimated to be very low.

Price and efficiency

Within these products manufactured mostly abroad there is a competition between efficient and relatively expensive units in one side and less efficient and cheap units in the other side.

The market share estimates seem to indicate that this competition has turned out in favor of more efficient units on the split market with most famous air conditioning brands well established on this segment as Daikin, Mitsubishi, Hitachi, Fujitsu, LG and with the entrance of new players from China who target efficiency as Haier (this last manufacturer sells the more efficient product presently in Europe if we refer to the EER and COP values). The signal is less clear on the moveable (mainly single duct) market where penetration of cheap and inefficient products gains important shares. Also, in order to increase their benefits, even manufacturers marketing quality and efficiency have kept lower cost (and price) units to increase their competitiveness with cheap products.

EU market

Some data made available on the UK market shows that the correlation between purchase price and energy efficiency is weak both for split air conditioners (Figure 8-12) or even apparently null for single duct air conditioners (Figure 8-13), despite the fact that average prices on this market are amongst the lower ones in Europe (suggesting by this remark that there is more competition than in other countries where prices may be higher because of a lower demand).

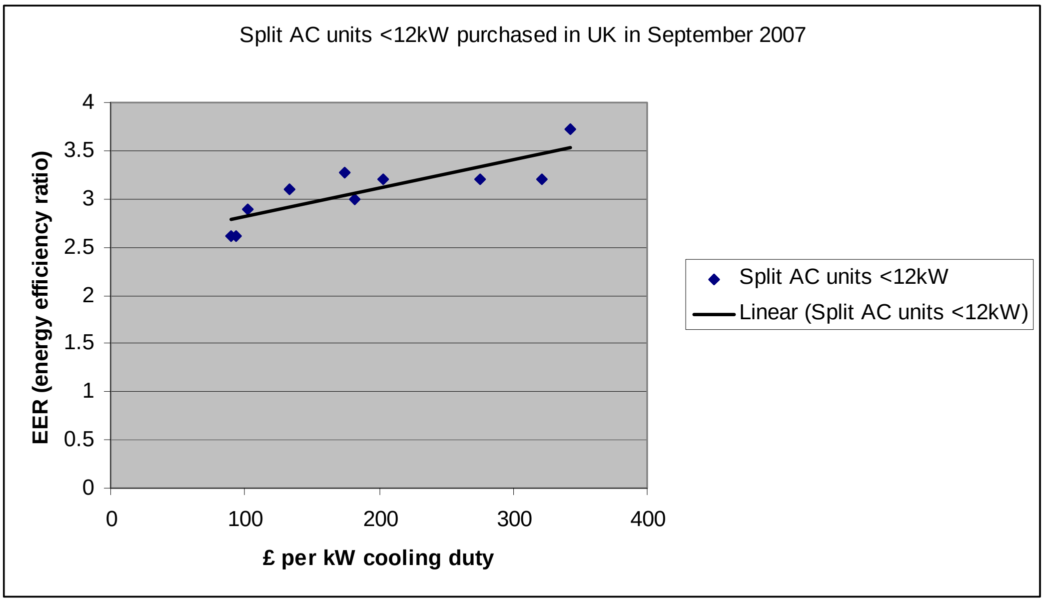


Figure 8-12: Premium for energy efficiency in the UK – split air conditioners, (MTP, 2007)

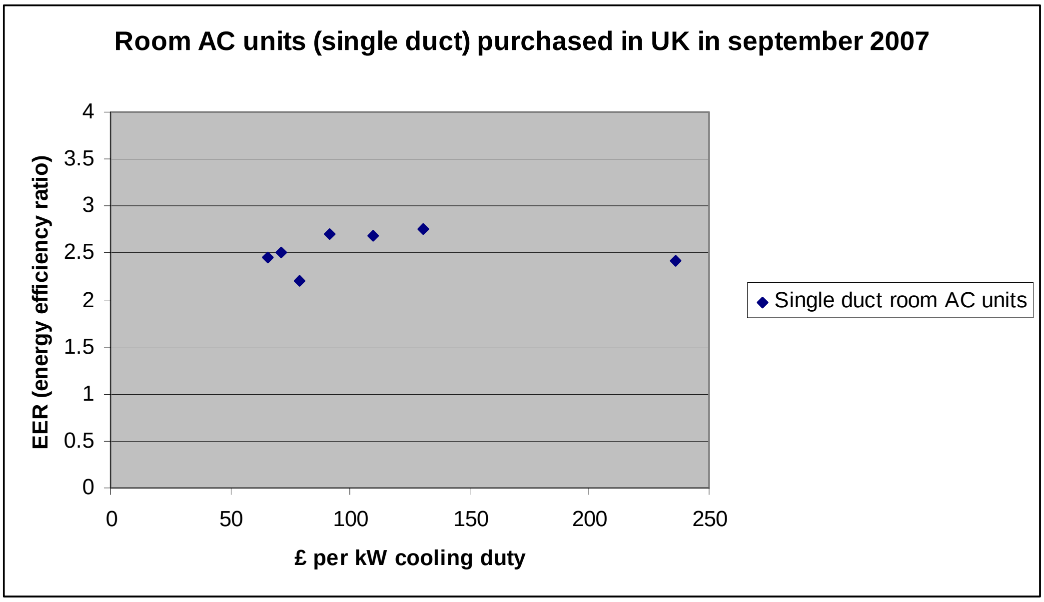


Figure 8-13: Premium for energy efficiency in the UK – single duct air conditioners, (MTP, 2007)

<u>Chinese and Japanese markets</u>

Several sources have been gathered on the prices of air conditioners in Japan and South-East Asia. (IEA, 2007B) looking for roads to diffuse energy efficient technologies around the world analyses the prices of air conditioners in China and in Japan. “For Japanese air conditioners, the information is collected by POS (Point of Selling) system which cover 35-40 % of total air conditioner sales in Japan (ECCJ 2006b). For Chinese air conditioners, the information was collected from internet shopping sites.” Results are shown in the graph below.

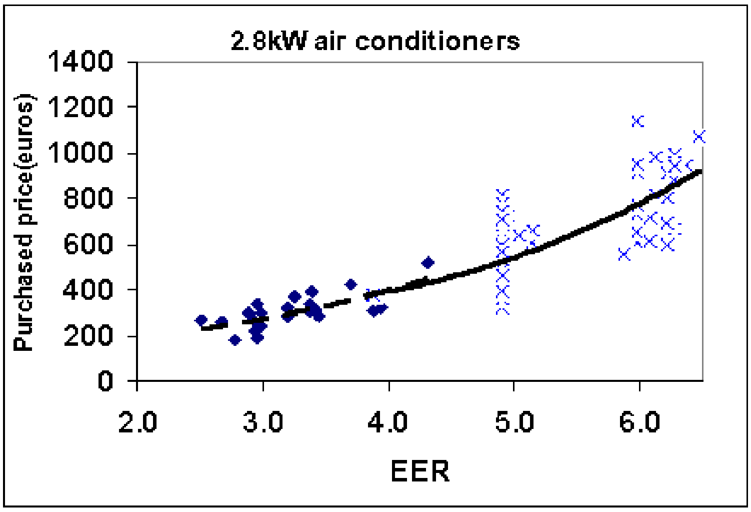
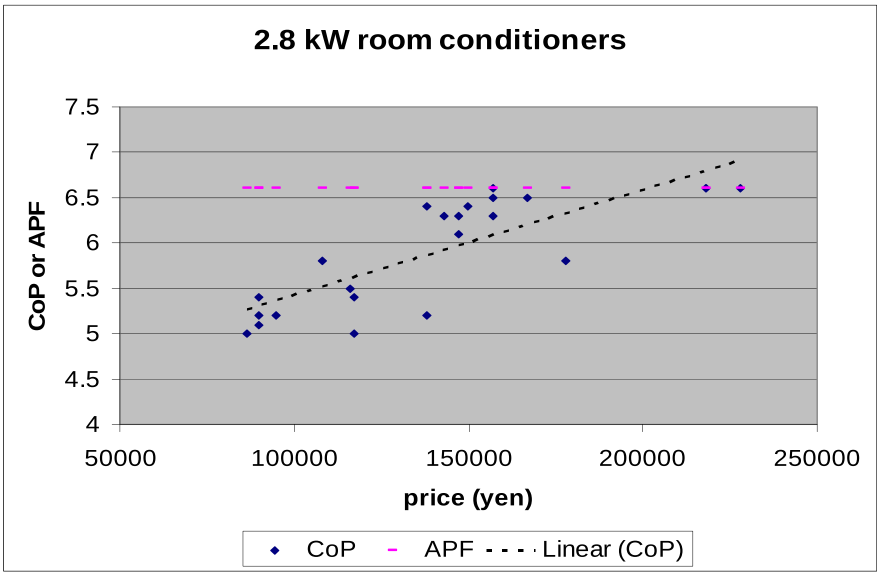


Figure 8-14: Purchase prices of Chinese and Japanese air conditioner versus EER – source (IEA, 2007B)

Previous prices of Japanese products were also gathered in shops within the frame of this study in December 2006 and presented in task 2 versus (COP+EER)/2, higher than EER by only 0-5 % for these highly efficient products. Figure 8-15 shows that the price differential with the energy efficiency index in Japan, that we noted on the basis of shop prices, are general and have been in place since at least 2001, year of the first Top Runner target.

Figure 8-15: Purchase prices of Chinese and Japanese air conditioner versus performance – source (EuP Lot 10, Task 2, 2006), COP stands for (EER + COP) / 2



Additional information on the Japanese market can be found in (IEA, 2007B). Higher energy efficient air conditioners are also sold at higher prices because of having more options. According to the authors the average difference between 6.5 EER units is in average 20 % between "all options" appliances and efficient units with less extra functions. This tendency increases with higher efficiency levels.

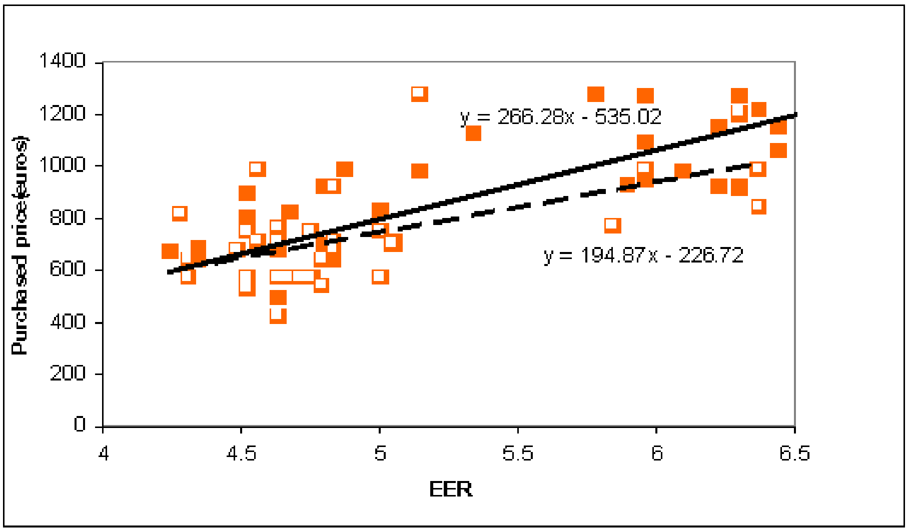


Figure 8-16 suggests that about 20 to 25 % of the extra price is associated with additional features – so 75% - 80% is supposed to reflect the "cost" (or market value) of better efficiency.

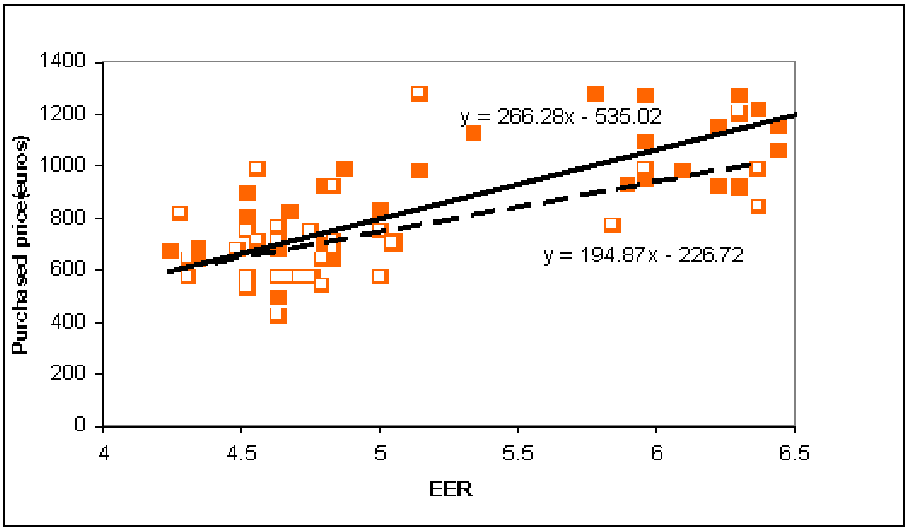


Figure 8-16: Decrease in purchase cost by the reduction of functions – source (IEA, 2007B)

These tendencies can be translated into the following exponential trends of efficiency versus purchase price where the 5 and 7 EER points are the correlation issued from Figure 8-15 (there is still presently no EER 7 unit on the Japanese market, best value is 6.6). The higher values (blue curve) is the aggregate of prices in (IEA, 2007B), and prices issued from task 2. The second and lower price curve shows these same values but corrected by the purchase decrease because of less additional functions, more likely to capture the cost of energy efficiency.

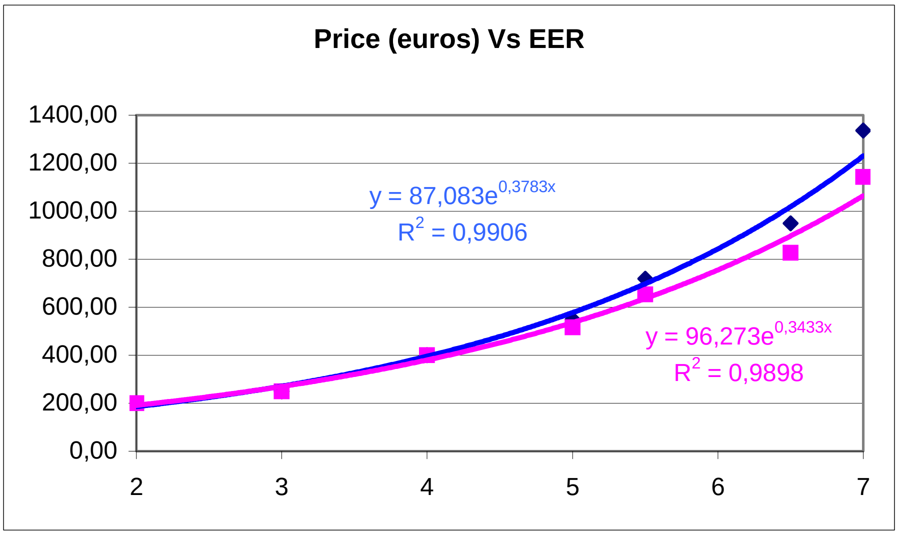


Figure 8-17: Purchase prices of Chinese and Japanese air conditioner versus EER – miscellaneous sources

Hence, a correlation appears clearly between energy efficiency and price on Chinese and Japanese markets. In addition, this correlation is in good agreement between both countries.

Possible evolution of prices on the EU market

The prices of split air conditioners as found in 2007 on the EU market (UK transformation program completed with internet offers for higher efficiency products) have been estimated and added on the following graph to ease the comparison. The EuP base case EER for 195 euro/kW is also reported on the same graph with the price increase linked to the improvement of task 7 of the comparable 3.5 kW units (cost increase reported with constant margin on purchase price).

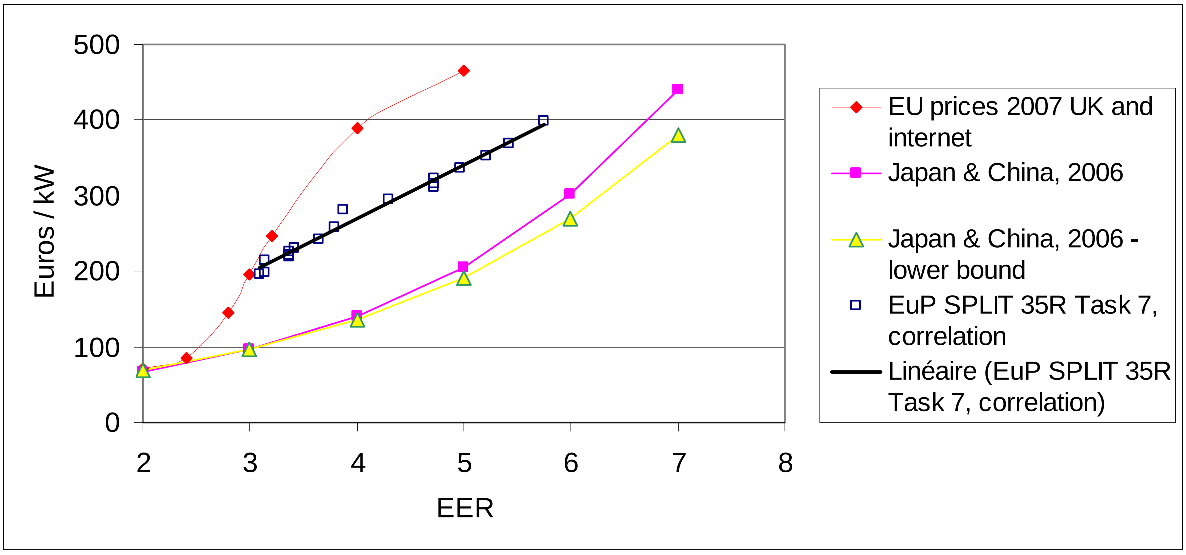


Figure 8-18: Purchase prices of EU, Chinese, Japanese and task 7 improved 3.5 kW reversible split versus EER

It appears that the improvement led in task 7 regarding cost of options leads to comparable shape as the reconstructed curve of energy efficiency price premium in China and Japan.

In average, low efficient cheap products are introduced on the EU market at similar prices than in China and high efficient products are rather more expensive than in Japan. The gap in purchase prices begins with EU label B and A units (2002/31/EC). For models in EU class A, there is a price increase over 100 % and more for the end-user in Europe.

With higher energy performance standards in Europe, the price premium for energy efficiency is likely to decrease, with the red curve overtaking Asian countries price efficiency curves by the lowest efficiency end.

For manufacturers presently established on the EU market, ambitious efficiency standards will enable to limit the competition on low price and efficiency products and to concentrate the sales on more efficient products they already know how to manufacture, putting them ahead of competition by a few years, typically between one or two design cycles depending on the evolution of the energy efficiency run in China and in Japan.

For the end user, this evolution is likely to end up with a double gain, maintained or lower product prices and higher energy efficiency levels.

Limited price increase and higher energy efficiency levels: cost reduction to maintain margin

The present EU situation and the comparison with China and Japan lets us think that the EU consumer is ready to pay for energy efficiency and that major established brands make much profit on air conditioners and heat pumps sales which might be difficult to maintain in a more efficient market.

(Ellis, 2007) reports that: "recent data from **Japan**, collected between 2001 and 2005, shows that the efficiency of room air conditioners has increased by 15 % during this period, while the real average price has decreased by 17 % (ECCJ, 2006)." The conclusion, following several other studies, is that the real price of air conditioners is more likely linked to an industry progress ratio that has been found to be between 10 and 17 % price decrease after a doubling of cumulative sales. Setting requirements at the LLCC level will about double the sales of more efficient units (the EU and Japanese markets being about the same size in terms of units old per year), and prices are likely to decrease by 10 – 17 %, to less than 300 euros / kW for A grade levels.

Technology may play an important part in this cost reduction. According to (USDOE, 2001), the emerging technologies reported in the table below had the potential (in 2001) to decrease cost productions when US SEER levels would increase. This probably extends today to DC technologies that are presently available technologies in Europe.

Efficiency Level SEER (US index) (W/W)	VS compressor	Advanced Modulating compressors	Microchannel Heat Exchanger	Next generation VS Fan Motors
2.9	increases production costs	increases production costs	increases production costs	increases production costs
3.2	increases production costs	increases production costs	-5%	increases production costs
3.5	increases production costs	increases production costs	-2%	increases production costs
3.8	increases production costs	increases production costs	-1%	0%
4.1	increases production costs	-22%	-17%	-7%
4.4	increases production costs	-23%	-21%	-5%
4.7	-6%	-27%	--	--
5.0	-6%	--	--	--

Table 8.18 : Options for a cost effective SEER (US index) increase, from (USDOE, 2001)

Fostering competition to introduce technologies to cut refrigerant charge should lead to technologies that help to reduce the cost of production as micro-channel heat exchangers which enable to replace high quality copper (which is expensive and whose price is increasing) by aluminum. Although developments of compact aluminum heat exchangers for the HVAC industry is mainly led by the USA, the market size increase of air conditioners and heat pumps should incite other suppliers of car manufacturers to diversify, increasing concurrence and lowering the prices.

8.2.2 Impact analysis: consumers

Comfort

Comfort of the end-users should not be negatively affected by the energy efficiency increase and consequent lower dehumidification capability since it has been required air conditioner’s capability to dehumidify and energy efficiency in this mode to be measured and added in the technical documentation.

Noise

In order to avoid energy efficiency increase at the cost of more noisy units, the labeling update does include the mandatory publication of noise inside (and outside for split products). In addition, minimum requirements on noise are proposed. These requirements are not set at minimum levels in order to enable an energy efficiency increase but have been set up on the basis of best available products regarding energy efficiency and low noise emission. Also, since the noise sound power is measured only at standard rating conditions, recommendations have been formulated to study the energy efficiency and the noise levels at lower fan speeds, the ones that are the most likely to be used by the end users.

Better information received by the end-user

The information to be supplied within the technical documentation of products regarding possible means to cut energy consumption with setback options and means to reduce cooling needs in summer time will help the end-user to save energy when using the products.

The update of the labeling system with seasonal performance indices will help the end-user to make a better choice regarding energy efficiency of the products. Indeed, energy information of the units sold may be more representative of the real consumption of the unit or at least it will give him a better tool to compare products since the new indices include:

- temperature variation and part load,
- and auxiliary power modes (thermostat-off, standby, off mode and crankcase heater).

With the reduction of tolerances, the information received will help the consumer to make a better estimate of the energy bill, element that is highlighted in the results of the enquiry on tolerances led in the UK in the frame of the Market Transformation Program (see task 2 for more details).

The LCCP labeling scale will contribute to satisfy EU citizens aiming at "responsible" purchase in addition to help reducing the total emissions of GHG, by setting CO2 indicators, as was done previously for cars.

Affordability

Regarding the benefit the end user can hope from the measures, it has been shown in task 7 that improvements are cost effective on average and this is also studied by type of end-user in the different countries in the sensitivity analysis in part 8.3.
As explained previously in task 2, the market for air conditioners and reversible heat pumps – as for any product - is determined by desire and affordability. Desire is influenced amongst other things by climate; affordability by income.
According to (Macneil and Letschert, 2007), air-conditioning ownership stays at around 5% to 10% of households (irrespective of climate) until average GDP per household reaches about $12,000 per annum (not PPP corrected). Between household income levels of about $12,000pa and $30,000pa, market penetration starts to rise rapidly and this accelerates above $30,000pa until it reaches a climate-dependent saturation level. All European countries are above the lower threshold, and most are above the upper one – they are in the rapid market expansion phase. Only Bulgaria and Romania are currently below this second threshold, though Latvia, Lithuania, Estonia and Poland are only slightly above it. However, with present higher GDP growth rates in Eastern Europe countries, it can be ascertained that within a decade, GDP levels will become more homogeneous so that all countries will be closer of the first GDP threshold.

The table 8.16 previously shown is reported hereunder ; it represents the economic impact of the different MEPS scenarios. Prices in the BAU scenario increases since the correlations established in task 7 have been used. Nevertheless, following what has been show before regarding the comparison of prices in the EU and in Asia, the increased share of inverter units in the BAU scenario, most likely, will not increase the prices but will help them not to fall.
For the end-user, the purchase price increase due to the measures is planned to be of +27 % for air conditioners and +14 % for heat pumps in the "LLCC" scenario. The 14 % increase in purchase price for reversible heat pumps would only translate in a 10 % total cost increase (installation + purchase price).

Over this price increase, two main trends will tend to lower the increase in total cost and/or purchase price increase:

- Manufacturers now develop products to install yourself in order to entail the installation costs. It is the common situation now for products sold in large retail and DIY shops but other well known manufacturers have developed solutions, as for instance DeLonghi.
- Following (IEA, 2007a), a 10 to 17 % price decrease (for doubling of the cumulated sales) can be hoped with scenarios that enable to transform the whole market to more efficient units thanks to higher sales' volume. So in the "LLCC" scenario, the end-user overcost at the time of purchase would only be of 5 to 10 % of the total installation cost (as compared to 2006 total installation cost) for both air conditioners and heat pumps.

All these elements show that there should not be affordability issue with the measures proposed. So the implementing measures may not be as costly as computed and will most probably become very profitable already from its application date.

Economic impact		1990	2005	2010	2015	2020	2025
BAU							
Price Heat pumps	Euros/kW	195	192	197	206	206	206
Price Air conditioners	Euros/kW	193	194	184	183	183	183
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3991	4124	4251
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1757	1010	980	1030	1088
MEPS 2015							
Price Heat pumps	Euros/kW	195	192	197	221	221	221
Price Air conditioners	Euros/kW	193	194	184	233	233	233
Price increase Heat pumps	%	0%	0%	0%	8%	8%	8%
Price increase Air conditioners	%	0%	0%	0%	27%	27%	27%
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3826	3929	4042
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1757	1010	770	794	819
Gain LCC heat pumps	%	0%	0%	0%	4%	5%	5%
Gain LCC air conditioners	%	0%	0%	0%	21%	23%	25%
LCC							
Price Heat pumps	Euros/kW	195	192	197	235	245	244
Price Air conditioners	Euros/kW	193	194	184	233	233	233
Price increase Heat pumps	%	0%	0%	0%	14%	19%	18%
Price increase Air conditioners	%	0%	0%	0%	27%	27%	27%
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3782	3856	3956
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1736	973	770	794	819
Gain LCC heat pumps	%	0%	0%	0%	5%	6%	7%
Gain LCC air conditioners	%	0%	1%	4%	21%	23%	25%
MEPS 2012							
Price Heat pumps	Euros/kW	195	192	197	246	292	292
Price Air conditioners	Euros/kW	193	194	184	247	267	267
Price increase Heat pumps	%	0%	0%	0%	19%	42%	42%
Price increase Air conditioners	%	0%	0%	0%	35%	46%	46%
LCC Heat pumps (equiv. 3.5 kW unit)	Euros	3911	3963	3947	3745	3776	3864
LCC Air conditioners (Average 3.5 and 2.2 units)	Euros	2080	1736	973	785	833	854
Gain LCC heat pumps	%	0%	0%	0%	6%	8%	9%
Gain LCC air conditioners	%	0%	1%	4%	20%	19%	22%

Table 8-19: Economic impact of scenarios (id. Table 8.16)

8.2.3 Impact analysis: utilities

The growth of air conditioners and heat pumps is likely to put pressure on electric utilities in the summer and in the winter. The EU electricity grid is now fully interconnected and this means that not only countries with large penetration of air conditioners and heat pumps may suffer electricity shortage due to peak power demand in extreme cold or warm conditions.

For electric utilities, the adoption of seasonal performance indicators may hide the behaviour of the units in extreme conditions; for instance EDF in France always promoted the use of the COP of heat pumps at –7 °C in addition to the performance at 7 °C to judge the efficiency of these products at peak time. On the USA market, where air conditioners must have a 13 SEER (3.8 SI), some units are rated below SEER 8 (2.35 SI) and the Energy Star program promotes units with full load EER of 11 (3.2 SI) in order to ensure energy gains also in peak conditions when utilities most require it. Nevertheless, we believe, following the observation of the long term trends on the Japanese market, that SEER and SCOP increase will also imply EER and COP improvements.

In order to assess the potential impact of air conditioners and heat pumps in the scope of this study on utilities, we have extracted the capacity installed in heating and in cooling mode and the likely impact of the measures. To that extent, total installed capacity in both modes was computed. Although the scenarios were studied in terms of seasonal performance indices, it was possible to estimate fleet average EER and COP on the basis of the average characteristics of the distribution of EER and COP shown previously in Task 5 for the base scenario and with the use of correlations between EER and SEER and between COP and SCOP obtained in task 7.

Results are shown in the table below. GW installed are to be understood at standard rating conditions, full load 35 °C in cooling mode and full load 7 °C in heating mode. In heating mode in peak conditions, the COP is likely to decrease with lower ambient and potential complementary heater ; this is not taken into account here and heating GW might then underestimate the grid power demand in winter for heating with heat pump.

BAU	**YEAR**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Total Consumption	TWh	58	94	129	156	170	175
Aver EER	-	2,7	3,2	3,2	3,1	3,1	3,1
Aver COP	-	3,0	3,1	3,3	3,3	3,3	3,3
Total capacity summer	**GW**	**69**	**98**	**131**	**158**	**177**	**189**
Total capacity winter	**GW**	**48**	**87**	**126**	**157**	**173**	**182**
MEPS 2015	**YEAR**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Energy consumption gain	TWh	58	94	115	138	149	153
Loss on energy bill	Meuros	0	0	-2477	-3430	-4112	-4686
Aver EER	-	2,7	3,1	3,8	3,8	3,8	3,7
Aver COP	-	3,0	3,1	3,6	3,6	3,6	3,6
Power gain summer	GW	0	-1	20	27	30	33
power gain winter	GW	0	0	10	12	13	14
Gain on power investment	Meuros	-246	-326	12743	17326	19670	21170
Balance	**Meuros**	**-246**	**-326**	**10266**	**13896**	**15559**	**16483**
LLCC	**YEAR**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Energy consumption gain	TWh	57	94	110	128	138	142
Loss on energy bill	Meuros	-26	-32	-3324	-5192	-6171	-6998
Aver EER	-	2,72	3,16	3,81	3,87	3,87	3,89
Aver COP	-	2,99	3,15	3,78	3,90	3,89	3,89
Power gain summer	GW	0	0	21	30	35	39

power gain winter	GW	0	0	16	24	27	28
Gain on power investment	Meuros	0	0	13556	19342	22685	25197
Balance	**Meuros**	**-26**	**-32**	**10232**	**14150**	**16514**	**18199**
MEPS 2012	**YEAR**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Energy consumption gain	TWh	57	94	106	112	121	124
Loss on energy bill	Meuros	-26	-32	-4025	-8034	-9510	-10712
Aver EER	-	2,7	3,2	3,9	4,4	4,3	4,35
Aver COP	-	3,0	3,1	3,9	4,4	4,4	4,43
Power gain summer	GW	0	0	25	44	50	55
power gain winter	GW	0	0	20	40	44	46
Gain on power investment	Meuros	0	0	15965	28572	32684	35515
Balance	**Meuros**	**-26**	**-32**	**11940**	**20538**	**23175**	**24802**
Electricity price	**Euros/kWh**	0,145	0,156	0,168	0,181	0,195	0,210

Table 8-20: Electric and economic impact of scenarios on utilities

The power investment required for cooling dominates the heating capacity in the BAU scenario despite the rapid growth of reversible heat pump segment.

In order to get an idea of the importance of the development of these products on utility, it is useful to give a few figures of the total installed power in Europe. (Bower, 2007) reports the declared installed electric capacity by the 20 larger electricity suppliers in the EU: this amounts to 635 GW. The 100 GW addition in the BAU scenario in heating mode represent a 15 % increase in power installed (since the products are spread all over Europe and thanks to the EU grid, the simultaneous capacity required in peak conditions may be less). On the basis of a new gas-fired CCGT plant or about € 650 per kW (DTI), 100 GW gives about 65 billion euros, a figure of the same order of magnitude as the yearly margin of EU electricity producers on one year (3000 TWh EU 27 energy consumption at 0,1 euro/kWh with 0,02 euro/kWh margin).

In the table above, we extracted electricity sales income linked to the electricity consumption of products in the scope. Revenues for utilities were estimated on the basis of the EU average electricity price of 0.145 euro/kWh kept in the study and with 1.5 % long term increase. In order to study the possible gain or loss in utility revenues of the different measures affecting electricity consumption and energy efficiency of the products, the estimated investment in capacity required to supply electricity in peak conditions has been estimated on the basis of a new gas-fired CCGT plant or about € 650 per kW (DTI).

All scenarios are largely beneficial to utilities. Yearly gains amount to 20 billion euros in 2020 and still increase in 2025.

Even if the measures applied contribute greatly to lower the peak demand in summer time -25 % of the power to be installed in cooling mode and also about 25 % in cold conditions-, the penetration of these products still represents a challenge for the European electricity supply. In that context, technologies that are not presently economically viable as air conditioner coupled with solar photovoltaic panel, should gain some interest from utilities, as well as peak shaving technologies built in appliances. Also electricity price in peak conditions is bound to increase, and cost of inefficiency is likely to become much higher for end-users.

8.3 Sensitivity analysis

Being climate dependant, the LLCC analysis is to be led at country level. Even if the main countries for air conditioners and heat pumps use are Southern countries, reversible air conditioners are clearly a growing end-use in Northern and Central countries and three different types of climates are used to perform this analysis, Northern, Central and Southern climates. In each case, 2 countries are kept with low and high electricity prices, electricity rates being the second most important parameter after energy consumption: Denmark and Estonia for northern Europe, France and Germany for central Europe and Italy (with Rome climate) and Greece for southern Europe.

The analysis is led by product type hereafter.

8.3.1 LLCC variations by country

8.3.1.1 Cooling only air conditioner

In the near future, we made the hypothesis that current trends regarding reversibility are continued so that the cooling only market would be under the large domination of single duct air conditioners. In addition, single duct units exhibit comparable LLCC levels as split cooling only units and thus the product is kept for this analysis.

The parameters for the comparison are reported in the table below. Electricity prices are as reported in task 2 (without the 1.5 % long term increase). Results are presented hereafter by sector - dwellings, offices and shops for existing buildings.

<u>Residential sector</u>

	Estonia	Denmark	France	Germany	Italy	Greece
	Existing dwelling					
COOLING NEEDS						
kWh/m2/y	6,2	1,5	10,2	3,2	21,2	51,6
W/m2	63,6	46,7	88,2	78,2	104,5	136,8
kWh/unit/year	216	70	255	90	447	830
Average load ratio	31%	23%	51%	29%	45%	47%
Thermostat off (hours)	1173	1348	1148	1346	972,5	680
Standby (hours)	2183	2183	2183	2183	2183	2183
Elec price	0,07	0,26	0,13	0,20	0,23	0,08
Discount rate	-0,2%	1,9%	1,9%	2,0%	1,9%	0,8%
Simple payback time of LLCC options (years)	6,9	5,9	8,2	7	5	6,6
Options that decrease the LCC	INVAC Sb CP1 F1 F2	INVAC Sb CP1 F1 F2	INVAC Sb CP1 F1 F2	INVAC Sb CP1 F1 F2	INVAC Sb CP1 F1 F2	INVAC Sb CP1 F1 F2

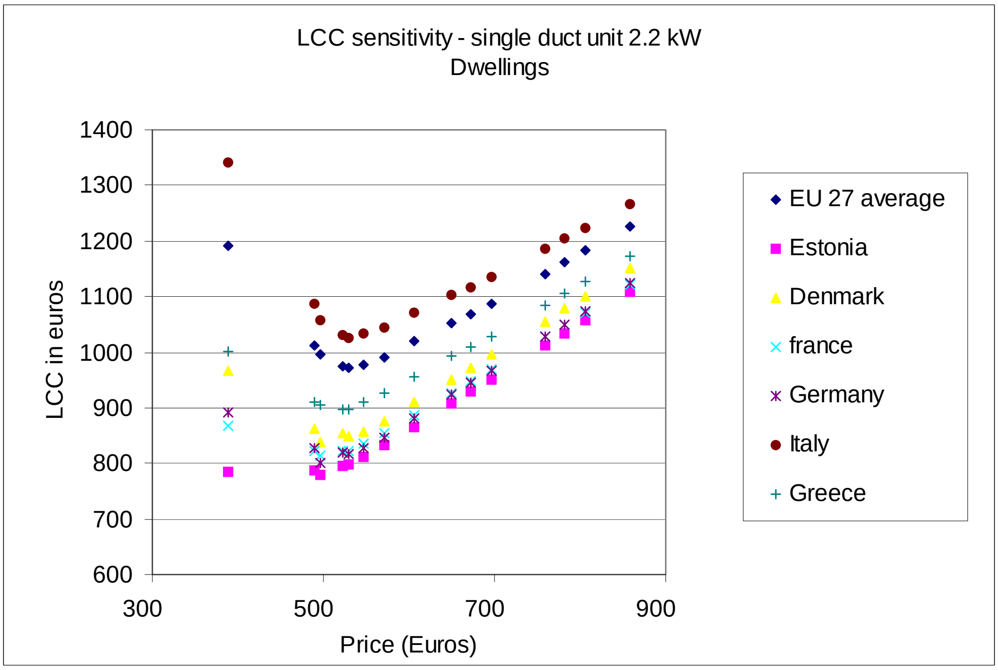
Table 8-21: LLCC sensitivity analysis – single duct unit – existing dwelling

In the residential sector, only 3 of the four options leading to LLCC level would be optimal for all countries, INV AC, standby and improved fan, compressor option CP1 lowering the LCC value only in Southern countries with higher cooling loads. The target EU SEER value would then lay between 3.5 and 3.9 instead of 4 for cooling only units with R410A.

However, in all situations, the improvement options required to reach the LLCC level in the EU average conditions lead to simple payback time largely inferior to the lifetime of the unit, between 5 and 8.2 years, despite very low cooling loads in Northern countries.

The figure below presents the LCC curves in the residential area for the different national situations and for the base case.

Figure 8-19: LCC curves versus product price, single duct air conditioners in dwellings



When improvement leads to units with higher life cycle cost values than the optimal combinations, improvement to the EU average LLCC level would increase the LCC by less than 2 % in the worst case. In addition, for all countries, the LCC value exhibits a zone of nearly constant LLCC with +/- 2 options as compared to the average EU 27 optimum.

<u>Retail sector</u>

The same analysis led for single duct units installed in retails shows that whatever the climate and the specific national parameters, all the improvements of the base case product for EU average conditions are below or equal to the optimum LLCC. The LLCC would be higher in warmer climates because of higher loads.

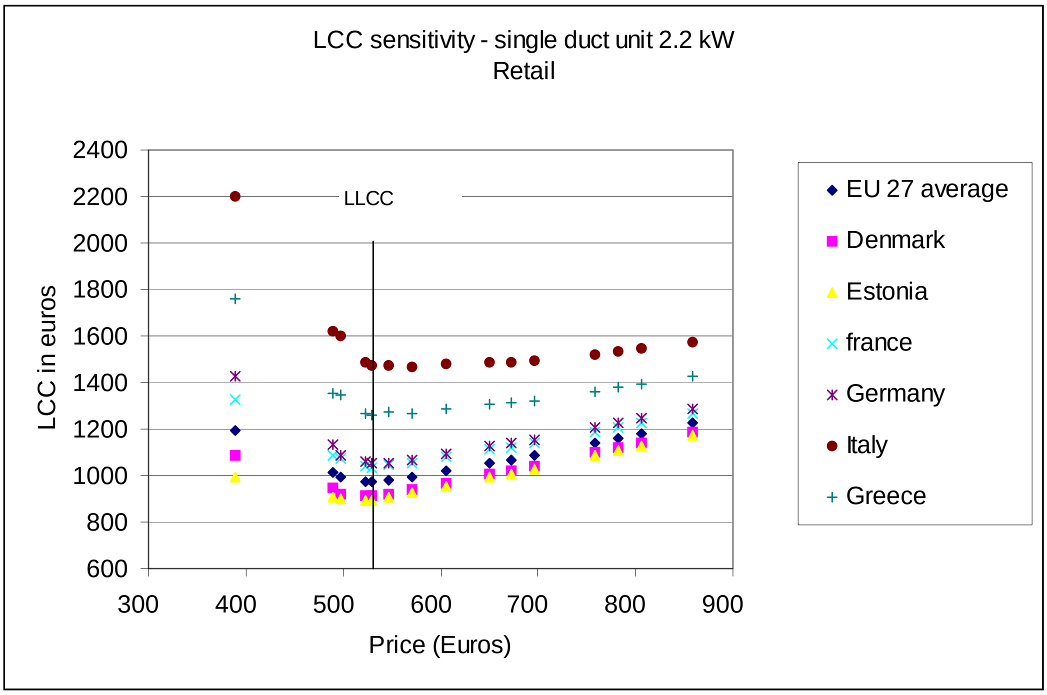
	Estonia	Denmark	France	Germany	Italy	Greece
	RETAIL					
COOLING NEEDS						
kWh/m2/y	7,8	13,6	26,2	10,2	46,6	87,8
W/m2	66,7	65,5	97,8	89,0	113,4	136,3
kWh/unit/year	256	458	588	253	904	1417
Average load ratio	31%	40%	44%	33%	60%	55%
Thermostat off (hours)	1027	920	652	1069	458	289
Standby (hours)	1988	1988	1988	1988	1988	1988
Elec price	0,14	0,08	0,12	0,24	0,18	0,12
Discount rate	1,9%	-0,2%	1,9%	2,0%	1,9%	0,8%
Simple payback time of LLCC options (years)	4,8	7,1	3,5	2,9	1,8	2,5

Options that decrease the LCC (in red)						
	INVAC	INVAC	INVAC	INVAC	INVAC	INVAC
	Sb	Sb	Sb	Sb	Sb	Sb
	CP1	CP1	CP1	CP1	CP1	CP1
	F1	*F1*	*F1*	*F1*	*F1*	*F1*
	F2	F2	F2	F2	F2	F2
	HE1	HE1	HE1	HE1	HE1	HE1
	EXV	EXV	EXV	EXV	EXV	EXV
	CP2	CP2	CP2	CP2	CP2	CP2
	HE2	HE2	HE2	HE2	HE2	HE2

Table 8-22: LLCC sensitivity analysis – single duct unit – existing retail

In all situations, the improvement options required to reach the LLCC level in the EU average conditions lead to simple payback time inferior to the lifetime of the unit.

Figure 8-20: LCC curves versus product price, single duct air conditioners in retail



Office sector

The same analysis led for single duct units installed in offices shows intermediate results between residence and commercial shops, because of intermediate cooling energy consumption. The LLCC options are in average beneficial, but in Northern countries, the LLCC level would require less options. In all situations, however, the improvement options required to reach the LLCC level in the EU average conditions lead to simple payback time inferior to the lifetime of the unit – between 2.6 and 10, despite very low cooling loads in Northern countries.

	Estonia	Denmark	France	Germany	Italy	Greece
	OFFICES					
COOLING NEEDS						
kWh/m2/y	7,8	13,6	26,2	10,2	46,6	87,8
W/m2	66,7	65,5	97,8	89,0	113,4	136,3
kWh/unit/year	256	458	588	253	904	1417
Average load ratio	27%	33%	34%	29%	39%	60%

Thermostat off (hours) **Standby (hours)**	769 2472	459 2472	487 2472	801 2472	299,5 2472	118 2472
Elec price **Discount rate**	0,14 1,9%	0,08 -0,2%	0,12 1,9%	0,24 2,0%	0,18 1,9%	0,12 0,8%
Simple payback time of LLCC options (years)	7,3	9,8	5,2	3,5	2,6	3,7
Options that decrease the LCC (in red)	INVAC Sb CP1 *F1* F2	INVAC Sb CP1 *F1* F2	INVAC Sb CP1 *F1* F2	INVAC Sb CP1 *F1* F2	INVAC Sb CP1 *F1* F2 HE1 EXV CP2	INVAC Sb CP1 *F1* F2 HE1 EXV CP2

Table 8-23: LLCC sensitivity analysis – single duct unit – existing office

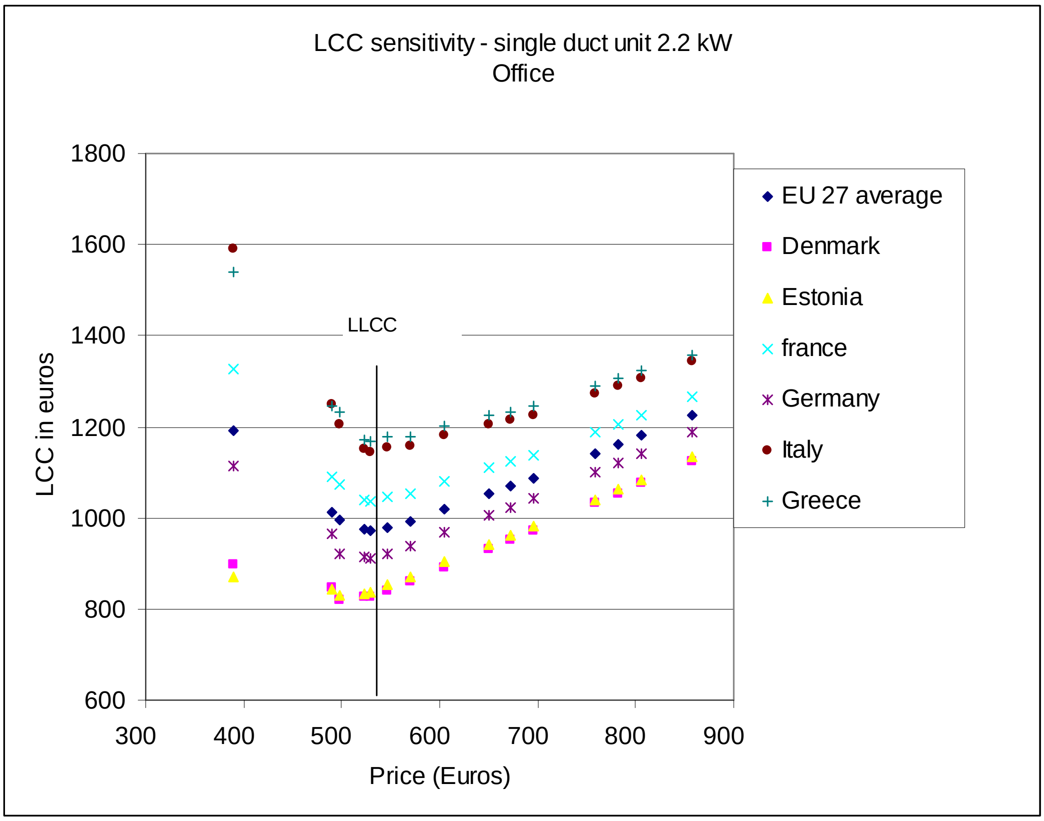


Figure 8-21: LCC curves versus product price, single duct air conditioners in offices

When improvement leads to units with higher life cycle cost values than the optimal combinations, improvement to the EU average LLCC level would increase the LCC by less than 2 % in the worst case.

8.3.1.2 Reversible air conditioners

Regarding LLCC analysis of reversible split air conditioners, LLCC levels of 3.5 and 7.1 kW units are also comparable so that the analysis is led for the more popular 3.5 kW unit. As compared to 7.1 kW units, 3.5 kW units also have less electric consumption linked to auxiliary power modes and consequently, the LCC analysis is more sensitive to climate.

Since for reversible heat pumps, the heating needs area added to the cooling needs, the largest energy consumption is observed in residences and the lowest one in offices. The results are shown under the same format as for cooling only units above.

For residences, electricity tariffs Dd (see Task 2 for more details) are used, which are more likely for dwellings heated by heat pumps. For offices and commercial, tariff 1a is kept.

Residential sector

RESIDENTIAL	Denmark	France	Germany	Greece	Estonia	Italy-Rome
Cooling needs (kWh/unit)	101	547	172	1783	246	1580
Heating needs (kWh/unit)	4465	3788	3676	464	4417	1923
Res. Heat (kWh/unit)	19	35	9	0	440	7
Electricity rate	0,24	0,13	0,18	0,09	0,08	0,22
Discount rate	1,9%	1,9%	2,0%	0,8%	-0,2%	1,9%
Simple payback time of LLCC options (years)	1,4	3,0	2,2	7,8	4,9	2,4
Options that decrease the LCC (in red)	**Base case**	**Base case**	**Base case**	**Base case**	**Base case**	**Base case**
	TXV	**TXV**	**TXV**	**TXV**	**TXV**	**TXV**
	INV AC	**INV AC**	**INV AC**	**INV AC**	**INV AC**	**INV AC**
	CP1	**CP1**	**CP1**	**CP1**	**CP1**	**CP1**
	DEF	**DEF**	**DEF**	DEF	**DEF**	**DEF**
	CK2	**CK2**	**CK2**	**CK2**	**CK2**	**CK2**
	EXV	**EXV**	**EXV**	**EXV**	**EXV**	**EXV**
	CP2	**CP2**	**CP2**	CP2	**CP2**	**CP2**
	INV DC	**INV DC**	**INV DC**	INV DC	**INV DC**	**INV DC**
	ALL DC	**ALL DC**	**ALL DC**	**ALL DC**	**ALL DC**	**ALL DC**
	HE1	HE1	**HE1**	HE1	HE1	**HE1**
	HE2	HE2	HE2	HE2	HE2	**HE2**
	CK1	CK1	CK1	CK1	CK1	CK1
	Sb	Sb	**Sb**	Sb	Sb	**Sb**
	HE3	HE3	HE3	HE3	HE3	HE3
	HE4	HE4	HE4	HE4	HE4	HE4
	HE5	HE5	HE5	HE5	HE5	HE5
	CP3	CP3	CP3	CP3	CP3	CP3

Table 8-24: LLCC sensitivity analysis – split reversible heat pump – residential

The average LLCC product would benefit all specific countries since the minimum improvement proposed leads to simple payback time (even when considering the actualised payback time) inferior to the life time. Greece, with low heating needs and electricity price and Denmark with high heating needs and electricity prices are the two extremes and payback time extends from 2.3 to 10.9.

However, the LLC curves are very flat around the LLCC set of options. For Greece the optimal combination of option would lead to a value only 1 % lower than the LLCC.

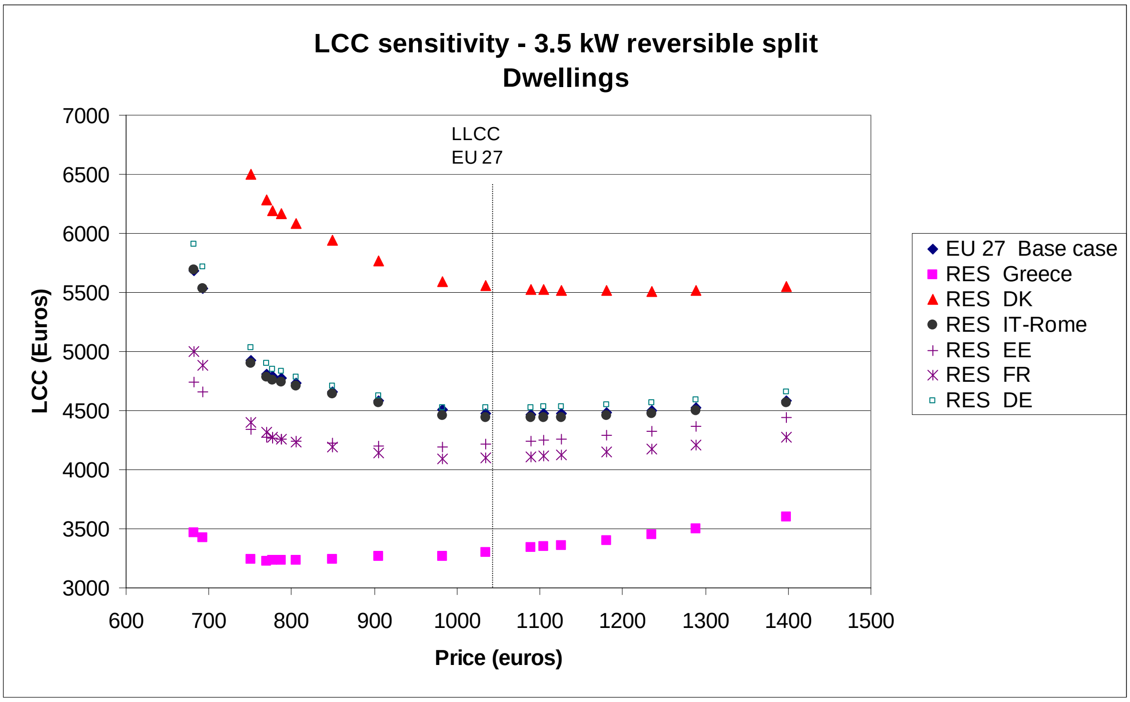


Figure 8-22: LCC curves versus product price, split reversible heat pump in residences

<u>Retail sector</u>

For the retail sector, in all cases, the LLCC product is very close to the local optimums in the worst case, and with relatively high energy prices as in Germany and Italy, the optimum would be quite higher, close to the BAT level in the case of Germany. Because of higher energy consumption, simple payback time decreases.

RETAIL	Denmark	France	Germany	Greece	Estonia	Italy-Rome
Cooling needs (kWh/unit)	580	1589	612	2856	530	2634
Heating needs (kWh/unit)	4396	3869	3602	1442	3808	2047
Res. Heat (kWh/unit)	48	115	33	1	377	8
Electricity rate	0,14	0,12	0,24	0,12	0,08	0,18
Discount rate	1,9%	1,9%	2,0%	0,8%	-0,2%	1,9%
Simple payback time of LLCC options (years)	2,4	2,8	1,7	3,9	5,1	5,3
Options that decrease the LCC (in red)	Base case	Base case	Base case	Base case	Base case	Base case
	TXV	TXV	TXV	TXV	TXV	TXV
	INV AC	INV AC	INV AC	INV AC	INV AC	INV AC
	CP1	CP1	CP1	CP1	CP1	CP1
	DEF	DEF	DEF	DEF	DEF	DEF
	CK2	CK2	CK2	CK2	CK2	CK2
	EXV	EXV	EXV	EXV	EXV	EXV
	CP2	CP2	CP2	CP2	CP2	CP2
	INV DC	INV DC	INV DC	INV DC	INV DC	INV DC
	ALL DC	ALL DC	ALL DC	ALL DC	ALL DC	ALL DC
	HE1	HE1	HE1	HE1	HE1	HE1
	HE2	HE2	HE2	HE2	HE2	HE2
	CK1	CK1	CK1	CK1	CK1	CK1

	Sb	Sb	Sb	Sb	Sb	Sb
	HE3	HE3	HE3	HE3	HE3	HE3
	HE4	HE4	HE4	HE4	HE4	HE4
	HE5	HE5	HE5	HE5	HE5	HE5
	CP3	CP3	CP3	CP3	CP3	CP3

Table 8-25: LLCC sensitivity analysis – split reversible heat pump – retail

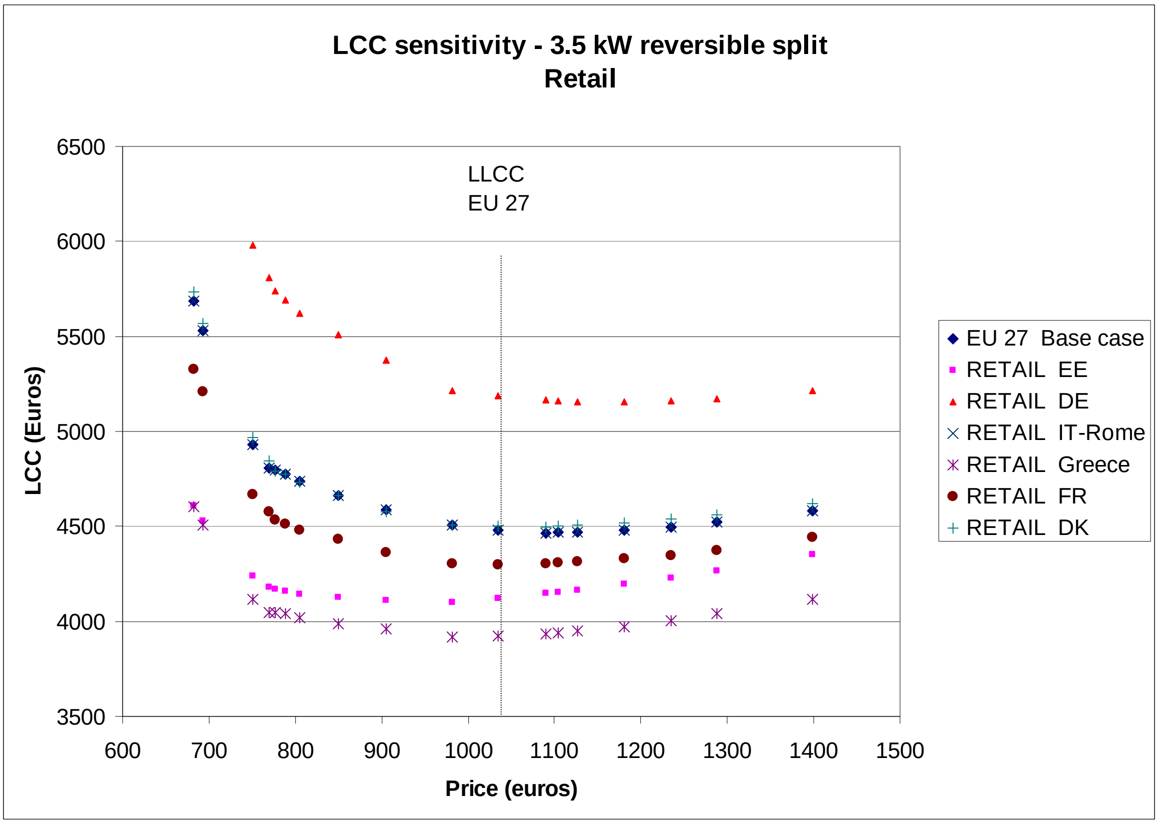


Figure 8-23: LCC curves versus product price, split reversible heat pump in retail

<u>Office sector</u>

Here again, LLCC product would be beneficial in all situations with payback ranging from 2.7 to 7.5.

OFFICE	Denmark	France	Germany	Greece	Estonia	Italy-Rome
Cooling needs (kWh/unit)	405	1075	491	1767	465	1590
Heating needs (kWh/unit)	3431	2746	3124	778	3139	1181
Resist. Heat (kWh/unit)	29	29	46	0	326	0
Electricity rate	0,14	0,12	0,24	0,12	0,08	0,18
Discount rate	1,9%	1,9%	2,0%	0,8%	-0,2%	1,9%
Simple payback time of LLCC options (years)	1,8	3,7	1,9	5,6	5,9	3,5
Options that decrease the LCC	Base case	Base case	Base case	Base case	Base case	Base case
	TXV	TXV	TXV	TXV	TXV	TXV
	INV AC	INV AC	INV AC	INV AC	INV AC	INV AC
	CP1	CP1	CP1	CP1	CP1	CP1
	DEF	DEF	DEF	DEF	DEF	DEF
	CK2	CK2	CK2	CK2	CK2	CK2

	EXV	EXV	EXV	EXV	EXV	EXV
	CP2	CP2	CP2	CP2	CP2	CP2
	INV DC	INV DC	INV DC	INV DC	INV DC	INV DC
	ALL DC	ALL DC	ALL DC	ALL DC	ALL DC	ALL DC
	HE1	HE1	HE1	HE1	HE1	HE1
	HE2	HE2	HE2	HE2	HE2	HE2
	CK1	CK1	CK1	CK1	CK1	CK1
	Sb	Sb	Sb	Sb	Sb	Sb
	HE3	HE3	HE3	HE3	HE3	HE3
	HE4	HE4	HE4	HE4	HE4	HE4
	HE5	HE5	HE5	HE5	HE5	HE5
	CP3	CP3	CP3	CP3	CP3	CP3

Table 8-26: LLCC sensitivity analysis – split reversible heat pump – office

In average one less option would be more profitable that the LLCC combination but the difference in terms of LCC is very low, always lower than 1 % and LCC curves below appear very flat around the LLCC value.

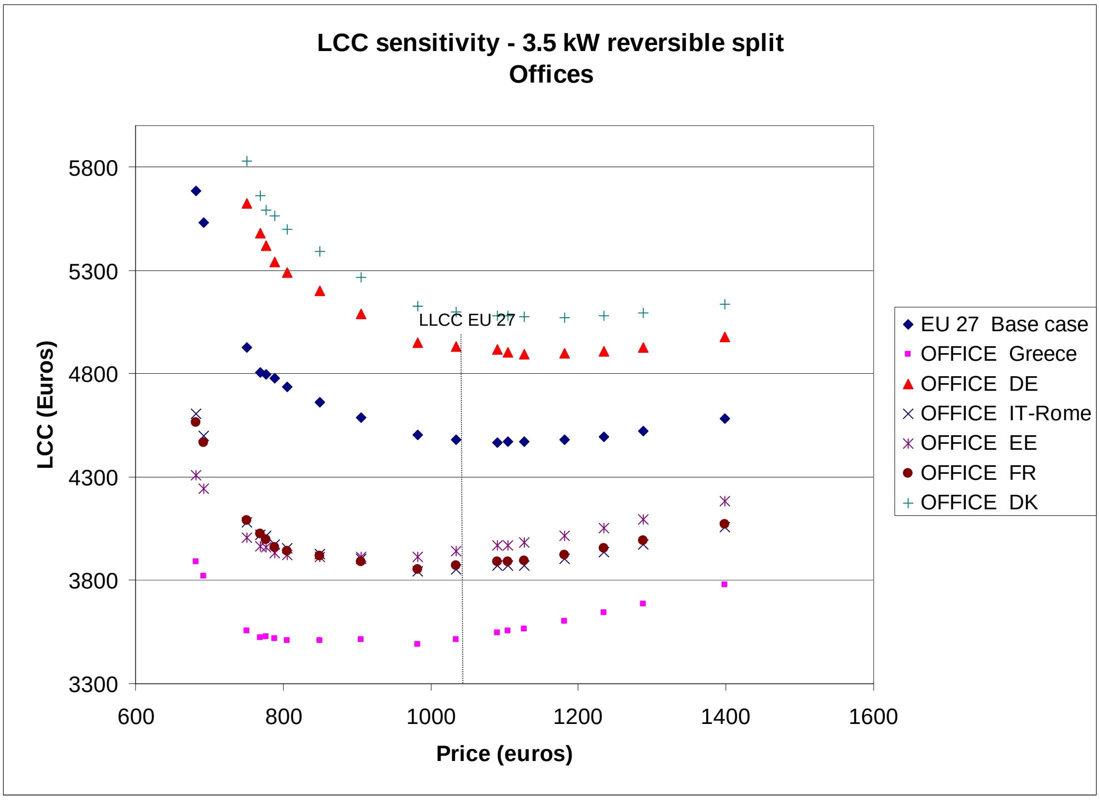


Figure 8-24: LCC curves versus product price, split reversible heat pump in office

8.3.2 Discussion of the LLCC targets

The outcomes of the country's specific analysis is that both LLCC combinations of options would be profitable for products installed in the three types of buildings simulated and for the different national situations. Even if the average combination would not be the optimum of all situations, it would be nevertheless beneficial in all cases. For countries in which the combination of options led to LCC values higher than would have been the optimum, the difference in LCC values was found to be very low, below 2 % of the total LCC value for single duct products, and 1 % for reversible split air conditioners.

Other elements should also be considered:
- Electricity prices could increase much more than forecasted here (1.5 % / y), especially given the fast increase of the price of gas and the pressure put on the utilities with the required installation of large power capacities needed to satisfy the demand of peak conditions for air conditioners and heat pumps,
- EPEE mentions that product life could be larger than 12 years ; in Japan, more efficient (and expensive) reversible heat pumps seem to have a larger life time 13 to 14 years. This also means that refrigerant leak rates could gain in importance and increase energy consumption, as well as the impact of the lack of proper maintenance reported in Task 3. These two last points have not been considered in this analysis and the lack of proper maintenance could tend to increase energy consumption as much as 20 % (EERAC, 1999).
- Warmer temperatures are already observed throughout Europe and a reference scenario (IPCC, 2007) shows a 2 °C yearly average temperature increase by 2050 for Europe. The analysis led by (Jakob, 2008) on the consequences of such a temperature change on energy consumption in buildings shows that in average heating degree days will decrease less (between 30 % in EU Southern countries and 20 % in Northern countries) than will increase cooling degree days (from 40 % increase in Southern Europe up to more than 300 % in Scandinavia). Hence energy consumption is likely to increase for both product types, air conditioner and heat pumps, as well as LLCC targets.

In conclusion, it appears that the LLCC values can be kept as minimum targets and also that they should be revised regularly within the coming years to translate the evolution of electricity prices, energy consumption and energy efficiency premium.

8.4 Technical annex (to become a technical annex of any IM)

8.4.1 Performance testing leading to seasonal performance indices (to become a technical annex of any IM)

Most of the work presented here is based on the work led by CEN TC113/WG7 in order to enable the development of a standard to rate seasonal performance indices. Also, the draft standard PrEN14825 incorporates all HVAC equipment, the scope of this annex is limited to products in the scope of this study, air to air air conditioners and heat pumps, including single duct products, with cooling capacity inferior to 12 kW.

Modifications include the following points:

- the computation is now based on a simplified bin method.
- Being still requiring four temperature conditions in both modes, calculation rules have been set up to enable energy consumption computation for different application climatic conditions.

In heating mode, PdesignH is computed for sizing of the unit at 2 °C. Whether it is thought feasible to make tests in the zone with frost and part load conditions, this PdesignH value could then be a declaration of the manufacturer, with limitations for instance between a sizing condition at 2 °C and a sizing condition at – 7 ° C.

PART 1: TERMS AND DEFINITIONS

Reference cooling capacity
Rated capacity as defined by the standard rating conditions given in EN 14511.

Reference heating capacity
Rated capacity as measured at „A“ temperature conditions as defined in EN 14511 (standard rating or application rating conditions as applicable).

Part load capacity
A capacity which is lower than the reference cooling or heating capacity.

Part load ratio
Ratio of the capacity at any temperature conditions of the tables of this standard for a defined type of unit and the capacity measured in the “A” temperature conditions of the considered table.

EERx%
The EER of a unit operating at x% of part load ratio.

COPx%
The COP of a unit operating at x% of part load ratio.

Fixed capacity unit
Air conditioner or heat pump, which does not have the possibility to change automatically (in minimum two steps or continuously) the amount of refrigerant flowing through the system.
Note: Where no refrigerant is flowing through the indoor side (or one of the indoor units) it is not considered a capacity step.

Variable capacity unit
Air conditioner or heat pump, where the capacity is varied or changed in a series of steps or increments. This variation can be achieved by off loading the compressor(s), by a number of compressors operating in sequence, by varying the speed of the compressor(s), normally by inverter control or by other means.

Reference SEERon (HSPFon)

The $SEER_{on}$ ($HSPF_{on}$) determined from mandatory conditions
Note : These mandatory conditions represent the average conditions of use for Europe.

Reference SEER (HSPF)
The SEER (SCOP) determined using the reference SEERon (SCOPon) and including the power consumption in thermostat off mode, standby mode, off mode (and crankcase heater consumption), that is used for marking, comparison and certification purposes.

Application SEERon (HSPFon)
The $SEER_{on}$ ($HSPF_{on}$) that takes into account the specific application and the specific location of the system, which are different from the ones used for determining the reference $SEER_{on}$ ($HSPF_{on}$) given in this standard.

Design temperature
The temperature of the maximum thermal requirements for cooling or heating. It is noticed Tdesign hereafter.

Design thermal requirements
Maximum heating and cooling requirements the unit is rated for. It is noticed PdesignH in heating and PdesignC in cooling, that takes different values for heating and for cooling. Building load is computed as a function of outdoor temperature Ti.

Bin interval, Ti, nj
Ti is the average outdoor temperature in bin interval I and nj the number of operating hours at this outdoor temperature.

Building load
The heating and cooling requirements the air conditioner or heat pump has to fulfill.

Thermostat-off mode
The air conditioner is operational in heating or cooling mode but inside temperature is lower (higher in heating mode) than the set point. The impact of thermostat-off mode is included in the cycling low and additionally in the thermostat-off consumption corresponding to hours with no cooling or heating load while cooling (or heating) is required by the user. Average electric power in this mode is noted P_{TO} and hours of operation in this mode are noted H_{TO}.

Passive standby mode
The air conditioner is not operational; it can be reactivated either by control device or by timer. This mode corresponds to hours with no occupancy in the building during the cooling or heating season. Average electric power in this mode is noted P_{SB} and hours of operation in this mode are noted H_{SB}.

Off mode
The air conditioner has been switched off by the user, is not operational and cannot be reactivated neither by control device nor timer. This mode corresponds to hours outside the cooling and/or heating season. Average electric power in this mode is noted P_{OFF} and hours of operation in this mode are noted H_{OFF}.

Crank heater operation
The crankcase heater operates when the compressor is off and the outdoor temperature is lower than a given value. Other parameters such as the compressor or the heat exchanger temperature may also be included into the control and have an impact on its energy consumption. Average electric power in this mode is noted P_{CK} and hours of operation in this mode are noted H_{CK}. The crankcase heater may be controlled as a function of the outdoor temperature; the set point temperature is called T_{CK}. The values of T_{CK} and H_{CK} in table 5 should be used to assess the number of hours as a function of outside temperature in that case.

T_{MIN}
The minimum outside air temperature of operation in heating mode as declared by the manufacturer or importer and stipulated in the technical documentation of the equipment, as required in EN 14511-4.

PART 2: SEASONAL ENERGY EFFICIENCY RATIO (SEER)

2.1 General formula

The calculation of the SEER that applies to all types of units is given by the formula Eq.1:
[Eq.1]

$$SEER = \frac{H_{CE}.PdesignC}{\frac{H_{CE}.PdesignC}{SEER_{on}} + H_{TO}.P_{TO} + H_{SB}.P_{SB} + H_{CK}.P_{CK} + H_{OFF}.P_{OFF}}$$

The values for H_{TO}, H_{SB}, $H_{OFF,}$ H_{CK} are given in table 5.

2.2 SEERon formula

The calculation of the $SEER_{on}$ that applies to all types of units except for single duct units is given by the following formula:

[Eq.2] $$SEER_{on} = \frac{\sum_{j=1}^{n} n_j BL(T_j)}{\sum_{j=1}^{n} n_j.(BL(T_j)/EER(T_j))}$$

Whether Tj≤TdesignC,
$BL(T_j) = (T_j-16)/(Tdesign-16)*PdesignC$

Whether Tj>TdesignC,
$BL(T_j) = PdesignC$

Where
- $1 \leq j \leq 24$
-PdesignC is defined as the maximum capacity of the heat pump at the temperature TdesignC for a specific location.
-Design temperatures is 35 °C in the case of the reference EU climate.

Nj and Tj to compute the reference SEERon value are reported in the table below.

Cooling capacity is interpolated linearly for bin temperatures between measurements A, B, C and D.

Above 35 °C, the cooling capacity remains constant and its value equals the cooling capacity measured in the A test conditions.

Below 20 °C, the cooling capacity remains constant and its value equals the cooling capacity measured in the D test conditions.

The electric power consumption should be estimated assuming linear correlation between outdoor temperature and EER as in the heating mode (part 3) for bin temperatures between measurements A, B, C and D.

Above 35 °C, the EER remains constant and its value equals the EER measured in the A test conditions.

Below 20 °C, the EER remains constant and its value equals the EER measured in the D test conditions.

Table 1 – Operating binned hours to compute the reference SEER

		Reference EU conditions
Bin interval number j	**Outdoor temperature °C Tj**	**Operating hours nj**
1	17	205
2	18	227
3	19	225
4	20	225
5	21	216
6	22	215
7	23	218
8	24	197
9	25	178
10	26	158
11	27	137
12	28	109
13	29	88
14	30	63
15	31	39
16	32	31
17	33	24
18	34	17
19	35	13
20	36	9
21	37	4
22	38	3
23	39	1
24	40	0

The temperature conditions for determining the four part load EER values to be used in the general formula [Eq.2] are given in table 2.

Table 2 - Temperature conditions for $SEER_{on}$ calculation of air-to-air units (except single duct air conditioners)

	Part load	Outdoor air dry bulb (wet bulb) temperatures (°C)	Indoor air dry bulb (wet bulb) temperature (°C)
A	$(T_j\text{-}16)/(TdesignC\text{-}16)$	*35*	*27 (19)*
B	$(T_j\text{-}16)/(TdesignC\text{-}16)$	*30*	*27 (19)*
C	$(T_j\text{-}16)/(TdesignC\text{-}16)$	*25*	*27 (19)*
D	$(T_j\text{-}16)/(TdesignC\text{-}16)$	*20*	*27 (19)*

For single duct air conditioner only, SEERon is equal to the EER of the unit in application environmental conditions 27(19) as defined in EN 14511-2 with a part load ratio of 50 %.

2.3 Calculation procedure for fixed capacity units

For each part load ratio A, B, C and D, the EER is calculated as follows :

$$EER_{part\ load} = EER_{minload} *(load / (Cc * load + (1 - Cc))) * (1 - Cd*(1-load)) \quad \text{[Eq.3]}$$

Where
$EER_{part\ load}$: EER when the unit operates at the considered part load ratio
$EER_{min\ load}$: EER at the considered minimum part load temperature conditions when the unit is operating steady state continuously

Cd : degradation factor for pressure equalization when unit cycles off (default value 0.2, see below).
Cc : degradation factor for thermostat off power

load : ratio between PdesignC multiplied by the part load ratio, and the capacity when the unit is operating continuously (and in steady state) at the considered part load temperature conditions

In absence of measurement of the Cd value, Eq 2 should be used with a default Cd value of 0.2 that accounts only for thermodynamic losses when cycling.

In case of measurement, Cd and Cc should be computed separately (respectively degradation of average capacity, and average power increase).

All tests with a continuous and steady state operation of the unit shall be conducted according to EN 14511-3 procedure.

2.4 Calculation procedure for staged capacity control units

Determine the part load capacity and EER at each step of capacity control of the unit. If the steps do not allow to reach the required part load ratio within ± 3 % (e.g. between 22 % and 28 % for a required part load ratio of 25 %), determine the capacity and EER at the defined part load temperatures for the steps on either side of the control step of the unit.

The part load capacity and the EER at the required part load ratio are then determined by interpolation between the results obtained from these two steps.

If the smallest control step of the unit is higher than the required part load ratio (D and/or C and/or B), then the EER at the required part load ratio is calculated using Equation [Eq.3] as for fixed capacity units.

All the tests shall be conducted according to EN 14511-3 procedure.

2.5 Calculation procedure for continuous variable capacity control units

Perform the tests at the required part load ratios with the corresponding setting of the capacity control of the unit.
If the electronic control of the unit does not allow to obtain the required part load ratio, the calculation procedure given for staged capacity in 2.4 shall be applied.
If the smallest setting of the capacity control does not allow reaching one or several part load ratios, then the EER at the required part load ratio(s) shall be calculated using [Eq.3] as for fixed capacity units in 2.3.
All the tests shall be conducted according to EN 14511-3 procedure.

PART 3: HEATING SEASONAL PERFORMANCE FACTOR (HSPF)

3.1 HSPF formula

The calculation of the SCOP that applies to all types of units is given by the formula Eq.4:

[Eq.4]
$$HSPF = \frac{H_E . PdesignH}{\frac{H_E . PdesignH}{HSPF_{on}} + H_{TO}.P_{TO} + H_{CK}.P_{CK} + H_{OFF}.T_{OFF}}$$

The values for H_{TO}, H_{CK} and H_{OFF} are given in table 5.

3.2 HSPFon formula

$BL(T_j) = PdesignH.(T_j-16)/(TdesignH-16)$

$$HSPF_{on} = \frac{\sum_{j=1}^{n} n_j BL(T_j)}{\sum_{j=1}^{n} n_j.((BL(T_j)-R_H(T_j))/COP(T_j)+R_H(T_j))} \quad \text{[Eq 5]}$$

Notations :
n_j : Frequency of hours of operation at the outdoor temperature of bin j
$BL(T_j)$: Building load ratio at the outdoor temperature of bin j
$R_H(T_j)$: Required additional resistive heating at the outdoor temperature of bin j
COP(Tj) : Coefficient of performance of the heat pump at the outdoor temperature of bin j

Building heat load ratio : $BL(T_j)$

$BL(T_j) = (T_j-16)/(TdesignH-16)*PdesignH$

Where
- $1 \leq j \leq 46$
- PdesignH is the maximum heating requirement and TdesignH is the design temperature for a specific location. PdesignH is 186 % of the rated capacity at 2 °C for the reference EU climate.

Heating capacity of the heat pump

$P_H(T_j)$ is the capacity of the heat pump at the outdoor temperature of bin j.

- Whether $12 \leq Tj$
$P_H (T_j)=P_H (D)$

- Whether $7 < Tj < 12$
$P_H(T_j)= P_H (C)+(7- T_j)/(7-12)* (P_H (D)- P_H (C))$

- Whether $2 \leq Tj < 7$
$P_H(T_j)= P_H (B)+(2- T_j)/(2-7)* (P_H (C)- P_H (B))$

- Whether $-7 \leq Tj < 2$

Case 1: $T_j \geq Tmin$
$P_H(T_j)= P_H (A)+(-7- T_j)/(-7-2)* (P_H (B)- P_H (A))$

Case 2 : $T_j < Tmin$
$P_H(T_j)=0$

- Whether $-7 > Tj$
$P_H(T_j)=0$

Resistive heat output : $R_H(T_j)$

For each temperature T_j, the complementary heating is computed as follows :
$R_H(T_j)=max (0, BL(T_j)-P_H(T_j))$.

Electric power of the heat pump

$P_E(T_j)$ is the electric power absorbed by the heat pump at the outdoor temperature of bin j.

- Whether $12 \leq Tj$
$P_E (T_j)=P_E (D)$

- Whether $7 \leq Tj < 12$
$P_E(T_j)= P_E (C)+(7- T_j)/(7-12)* (P_E (D)- P_E (C))$

- Whether $2 \leq Tj < 7$
$P_E(T_j)= P_E (B)+(2- T_j)/(2-7)* (P_E (C)- P_E (B))$

- Whether $-7 \leq Tj < 2$

Case 1: $T_j \geq Tmin$
$P_E(T_j)= P_E (A)+(-7- T_j)/(-7-2)* (P_E (B)- P_E (A))$

Case 2 : $T_j < Tmin$
$P_E(T_j)=0$

- Whether $-7 > T_j$
$P_E(T_j)=0$

Coefficient of performance of the heat pump : $COP(T_j)$

- Whether $T_j < -7$
$COP(T_j)=1$

- Whether $-7 \leq T_j < 2$

Case 1: $T_j \geq T_{min}$
$COP(T_j)= P_H(T_j)/P_E(T_j)$

Case 2 : $T_j < T_{min}$
$COP(T_j)=1$
- Whether $2 \leq T_j < 12$
$COP(T_j)= P_H(T_j)/P_E(T_j)$

- Whether $12 < T_j$
The coefficient of performance of the heat pump is computed with the cycling formula defined in Eq 3 with the heating capacity and COP of measured point D as a reference for COPmin and load.

Table 3 – Operating binned hours to compute the reference SEER

		Reference EU conditions
Bin interval number j	**Outdoor temperature °C Tj**	**Operating hours nj**
1	**-30**	0
2	**-29**	0
3	**-28**	0
4	**-27**	0
5	**-26**	0
6	**-25**	0
7	**-24**	0
8	**-23**	0
9	**-22**	0
10	**-21**	0
11	**-20**	0
12	**-19**	0
13	**-18**	0
14	**-17**	0
15	**-16**	0
16	**-15**	0
17	**-14**	0
18	**-13**	0
19	**-12**	0
20	**-11**	0
21	**-10**	1
22	**-9**	25

23	**-8**	23
24	**-7**	24
25	**-6**	27
26	**-5**	68
27	**-4**	91
28	**-3**	89
29	**-2**	165
30	**-1**	173
31	**0**	240
32	**1**	280
33	**2**	320
34	**3**	357
35	**4**	356
36	**5**	303
37	**6**	330
38	**7**	326
39	**8**	348
40	**9**	335
41	**10**	315
42	**11**	215
43	**12**	169
44	**13**	151
45	**14**	105
46	**15**	74

The temperature conditions to determine the four COP part load values to be used in the general formula are given in the following table :

Table 4 - Temperature conditions for HSPFon calculation of air-to-air units

	Part load	Outdoor air dry bulb (wet bulb) temperatures (°C)	Indoor air dry bulb temperature (°C)
A	$(T_j-16)/(TdesignH-16)$	*-7(-8)*	*20*
B	$(T_j-16)/(TdesignH-16)$	*2(1)*	*20*
C	$(T_j-16)/(TdesignH-16)$	*7(6)*	*20*
D	$(T_j-16)/(TdesignH-16)$	*12(11)*	*20*

3.4 Calculation procedure

The calculation procedure described from 2.3 to 2.5 for the determination of the EER part load values in cooling mode also applies for the determination of the part load COP values.

PART 4: HOURS OF OPERATION

4.1 Cooling mode

Hours to be used in the calculation of the SEER can be found in the table 5.

Table 5 – Time spent in the different power modes to be used to calculate reference SEER values

	Reversible heat pump	Cooling only air conditioner
Equivalent Hours Cooling	350	350
Cooling Thermo-off	221	221
Cooling Standby	2142	2142
Crankcase heater	2672	7760
Off mode	0	5088

4.2 Heating mode

Hours to be used in the calculation of the HSPF can be found in the table 6.

Table 6 – Time spent in the different power modes to be used to calculate reference HSPF values

HOURS	Reversible heat pump	Heating only heat pump
Equivalent Hours heating	**1400**	1400
Heating Thermo-off	179	179
Crankcase heater	179	3851
Off mode	0	3672

PART 5: PART LOAD CAPACITY TESTS - COOLING AND HEATING MODE

5.1 General

See PrEN 14825.

5.2 Basic principles

See PrEN 14825.

5.3 Uncertainties of measurement

See PrEN 14825.

5.4 Test procedures for units with fixed capacity

See PrEN 14825.

Unchanged except :

The part load test to be performed is to determine the degradation factor Cd. If the default value of 0.2 is used than the Cc coefficient is to be determined.

During this cyclic test, the delivered cooling (heating) capacity is integrated over the on/off interval. The electric energy used is integrated over the period when the compressor is on. Then the cyclic EER (COP) is obtained by dividing the integrated cooling (heating) capacity (Wh) by the electrical energy used by the unit over the same on/off interval.

The part load ratio is calculated by dividing the same integrated cooling (heating) capacity (Wh) by the cooling (heating) energy (Wh) that would have been delivered by the unit running continuously for the same time interval (i.e. 30 minutes).

The part load factor is calculated as the ratio of the cyclic EER (COP) to the steady-state EER (COP) (for the same ambient test conditions).

The plot of part load factor as a function of part load ratio can then be generated from the results of the cyclic test and the full load test and the slope represents the Cd degradation factor.

Air-to-air units (other than single duct units) - Cooling mode
- One test at 100% at an outdoor dry bulb temperature of 35 °C with dry indoor coil
- One cyclic test at the same dry bulb temperature conditions, with dry indoor coil.

Single duct units - Cooling mode
- One test at 100% at an outdoor dry bulb temperature of 27 °C with dry indoor coil
- One cyclic test at the same dry bulb temperature conditions, with dry indoor coil.

Air-to-air units - Heating mode
- One test at 100% at an outdoor dry bulb temperature of 7 or 12 °C and corresponding wet bulb temperature.
- One cyclic test at the same dry bulb and wet bulb temperature conditions, so that no frost occurs during the full load and cyclic tests

PART 6: SUPPLEMENTARY TESTS

6.1 Standby mode power

After the “A” test condition in cooling mode and C condition in heating mode for reversible heat pumps (standard rating condition for single duct unit), the unit is stopped and put in standby mode. After 10 minutes, the residual energy power is measured and assumed to be the standby mode consumption. Required uncertainty of measurement shall follow the requirements of the “IEC 62301 Measurement of standby power" standard.
In case of multi-split units, all the indoor units shall be stopped with the control device.

6.2 Off mode power

Following the standby mode power test, the unit should be switched in off mode while remaining plugged. After 10 minutes, the residual energy power is measured and assumed to be the off mode consumption. Test method and uncertainty of measurement shall follow the requirements of the “IEC 62301 Measurement of standby power" standard, with exception of the ambient temperature of the test. In case no off mode switch is available on the unit (on the indoor unit(s) for split units), the standby mode power is supposed equal to the standby mode power.

6.3 Crankcase heater operation power

The energy consumption of the unit shall be measured after the compressor reached stable temperature for the “B” temperature conditions test in heating mode and stopped with the control device. Ambient temperature of compressor unit shall be maintained at 2 ± 2 K for at least 8 hours. During this 8 hours period from stop of the compressor, the power input for crankcase heater shall be measured and averaged. The standby power consumption is deducted from this measured total energy consumption of the unit to determine the crankcase heater power.

6.4 Thermostat-off mode power

When there is a cooling/heating demand, the compressor is on and the total power consumption includes all electrical auxiliary devices. Once the set point is reached, the cooling/heating demand is satisfied. The compressor is then off but there is still a remaining power consumption due to the other auxiliary devices (electronics, fans, …). This state of the unit is called "thermostat off" state.
If a cyclic test is made to determine the Cd coefficient, the "thermostat-off" power shall be measured during this test. In case two cycling tests are realized, in cooling and in heating mode, the two different results can be used shall be used.
If no cyclic test is performed, after the "D" test condition, in cooling mode for reversible air conditioner (standard rating condition for single duct unit), the thermostat set point is increased until the compressor stops. The standby power consumption is deducted from the measured total energy consumption of the unit to determine the thermostat off power on a time period not inferior to one hour.

PART 7: TEST REPORT

The test report shall contain general and additional information specified in EN 14511-3.
It shall also include the results of the part load test(s) and the calculation of $EER_{X\%}$ or $COP_{X\%}$, where applicable.

PART 8: TECHNICAL DATA SHEET

In addition to the data specified in EN 14511-4 the $EER_{rc\%}$ or $COP_{rc\%}$ may be indicated in the manufacturers data sheet. If so the corresponding test conditions shall be indicated with a clear reference to this European standard. Power measured in tests 6.1 to 6.4 shall be supplied in the technical documentation of the unit.

8.4.2 Energy consumption for labelling purpose

With the same notations as in section 8.4.1, the energy consumption of air conditioners is computed with equation [6] and the figure rounded down to the closest figure multiple of 10 kWh.

[Eq.6] $$\text{Econs(kWh)} = \frac{H_E.PdesignC}{SEER}$$

With the same notations as in section 8.4.1, the energy consumption of heating only heat pumps is computed with equation [10] and the figure rounded down to the closest figure multiple of 10 kWh.

[Eq.7] $$\text{Econs(kWh)} = \frac{H_E.PdesignH}{HSPF}$$

R8-Scenario-, policy-, impact- and sensitivity analysis

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