Service Contract to DGTREN

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

Contract TREN/D1/40-2005/LOT10/S07.56606

Final report of Task 5
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DEFINITION OF BASE-CASE: AIR CONDITIONERS

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5 DEFINITION OF BASE-CASE

Introduction

As defined in the MEEuP, one or two average EU product(s) have to be defined. This consists in choosing representative product categories for the whole of the EU-25 and determining typical technical and performance characteristics for each category. On this Base-Case most of the environmental and Life Cycle Cost analyses will be built throughout the rest of the study. These base cases are used to calculate the total environmental impact of products in Europe (Task 5.4 to 5.5), to identify life cycle improvement options (Task 6) and to perform life cycle cost calculation (Task 7). The Base-Case is a conscious abstraction of reality, necessary one for practical reasons (budget, time). Having said that, the question if this abstraction leads to inadmissible conclusions for certain market segments will be addressed in the impact- and sensitivity analysis. The description of the Base-Case is the synthesis of the results of Tasks 1 to 4 and the point-of-reference for tasks 6 and 7 (improvement potential) and 8 (impact analysis).

In this report, it has been considered that the European market of room air conditioners is mainly composed of three main product categories ("reversible" and "cooling only" split air conditioners and moveable air conditioners). According to manufacturers, there are important differences between fixed air conditioners whose capacity is lower than 6 kW and those whose capacity is between 6 and 12 kW. As a result, it was necessary to define two different base cases for both categories of split air conditioners (reversible and cooling only), one representative of the 0-6kW range, another representative of the 6-12 kW range. Finally, five different base cases have been defined in the frame of part 5.1:

- cooling only air conditioner in the [0-6 kW] range
- reversible air conditioner in the [0-6 kW] range
- cooling only air conditioner in the [6-12 kW] range
- reversible air conditioner in the [6-12 kW] range
- moveable air conditioner

In a second step, four parallel studies are performed for each of these base cases. In part 5.2, an environmental impact analysis is carried out. For this purpose, the VHK EuP EcoReport is used along with Bills of Materials (BOM) provided by manufacturers and energy consumption figures calculated within Task 4. In part 5.3, Life Cycle Costs analysis are carried out for every base case. In part 5.4, the total impact of air conditioners installed in 2005 for EU-27 is calculated using stock and market data from Task 2 and environmental impacts of base cases determined in part 5.2. In part 5.5, the total environmental impact of room air conditioners between 2005 and 2030 is assessed assuming no changes in the product and the way in which it is used (Business As Usual scenario).

Thus, this task will concentrate as requested by the MEEuP on assessing the environmental impact of each of the base cases and then explaining how total impact is derived both for the total units sold in 2005 along their life cycle and for the stock of air conditioners from 2005 to 2030.

5.1 Product specific inputs

This part aims at determining the values used as input in the EcoReport tool for the assessment of environmental impact and Life Cycle Costs of the base cases. First it is explained what are the base cases for this study and why they have been chosen. Then for every base case, required data for the eco report are accounted for.
Air conditioner and reversible air conditioner categories are grouped in only one study to avoid useless repetitions.

5.1.1 Determination of base cases

The determination of base cases means that technical features (type of air conditioner, fluid, capacity…) that are the most likely to be found in Europe must be identified. Ideally, the investigation should be based on sales weighted figures. Unfortunately, only air conditioners sales according to market categories and some including cooling capacity are available; there seems to be no database coupling detailed technical information and sales data. For this reason, market data have been used only to define the type of air conditioners to be considered, whereas technical databases have been used to determine technical features.

5.1.1.1 Technical types candidates for base cases

The first step of the base case investigation consists in determining the main types of air conditioner in the European market. In Task 1, it was enlightened that there were two main primary functionalities among the family of air conditioner ("To maintain air temperature inside a room (cooling and heating)" and "To maintain air temperature inside a room (cooling)") leading to two distinct categories (reversible air conditioners and cooling only air conditioners). At least one base case must be determined for every category.

BSRIA provides (Figure 5-1) the number of units sold in 2002 for four types of air conditioners, window and through the wall packages, moveables –single duct, double duct and mobile split-, single split package and multi split package (cooling only and reversible are mixed here). Sales of mini-chillers and central air conditioner sales (US style) are an order of magnitude smaller.

The market study of task 2 mentions that about 40 % of single split package air conditioners were reversible in 2002 (Figure 5-2). The amount of reversible units was similar for packages and multi-split whereas about 25 % of all moveable air conditioner were reversible (20 % of them are single and double duct with electric resistances and 5 % reversible mobile split).

Based on these data, the base case or average model most likely to represent the average environmental impact of cooling only and reversible air conditioners is in both cases a single split package air conditioner.

Figure 5-1: 2002 sales according to the type of air conditioner (BSRIA)

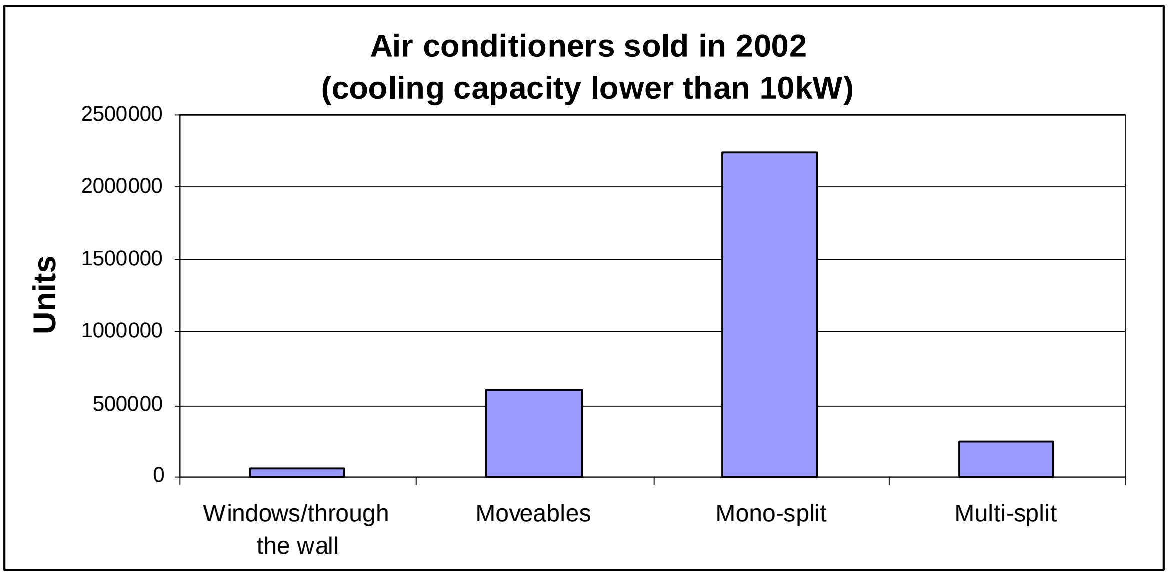
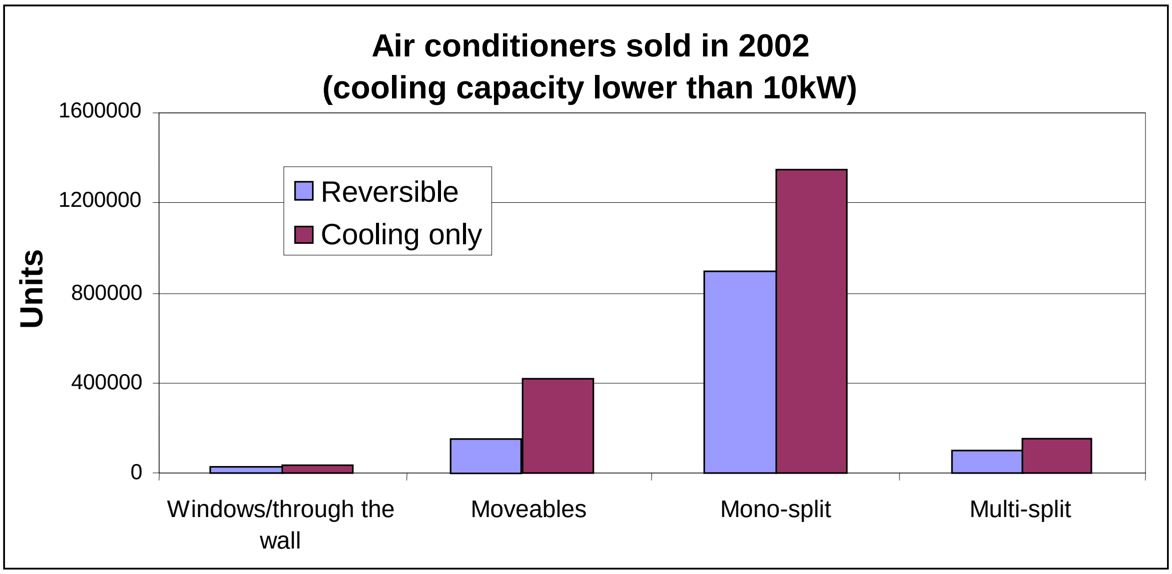


Figure 5-2: 2002 sales according to the type of air conditioner (based on BSRIA data and on the results of the market trend study of Task 2)



Following candidates in terms of sales are multi-split air conditioners and portable air conditioners. Other technical types of air conditioners have very low sales figures. As a consequence, distinctive features will only be considered later on during the sensitivity analysis in task 8 but no base case will be defined to represent these air conditioner types. It would be useful to define average characteristics for window/wall central air conditioners (US style) and mini-chillers to study the possibility to extend conclusions to these specific technical categories.

Regarding multi-split air conditioners, it was shown in Task 4 that they had similar environmental impact as single split air conditioners and that used technologies are similar. As a consequence, it does not seem necessary to have a specific base case for multi-split air conditioners.

On the contrary, moveable air conditioners that regroups single duct air conditioners, double duct air conditioners and mobile split air conditioners should be analyzed in detail in task 5 and in the following tasks. Indeed, given their particular space and noise constraints as well as different average cooling capacities and energy efficiency, environmental impact and potential for improvement will differ from single split ones.

Eventually, three main product categories must be addressed ("reversible" and "cooling only" split air conditioners and moveable air conditioners) and a base case must be determined for each of them. According to manufacturers, there are important differences between fixed air conditioners whose capacity is lower than 6 kW and those whose capacity is between 6 and 12kW. As a result, it was necessary to define two different base cases for both categories of split air conditioners (reversible and cooling only), one representative of the 0-6kW range, another representative of the 6-12 kW range. Finally, five different base cases have been defined in the frame of part 5.1:

- cooling only air conditioner in the [0-6 kW] range
- reversible air conditioner in the [0-6 kW] range
- cooling only air conditioner in the [6-12 kW] range
- reversible air conditioner in the [6-12 kW] range
- moveable air conditioner

5.1.1.2 Single split cooling only and reversible air conditioner base case analysis [0-6 kW]

A few words regarding the method used to define base cases

The method used to determine the base case characteristics both for the reversible mono split within [0-6 kW] category and the cooling only mono split within [0-6 kW] category is explained in details in Annex A. The determination of these base cases is based on two databases from Eurovent (the Eurovent directory and the technical database). The Eurovent directory is used as often as possible since it contains all the products declared by manufacturers. Unfortunately, when it comes to determine accurate technical features, this database is not adequate and then the technical database – with fewer models - is used. From these databases, distributions and regressions have been extracted to determine the characteristics of average models. In a second step, manufacturers were requested to express comments on these base cases. Thus, following their comments, some values and features (notably EER and COP) have been reviewed.

Final base case description

Two typical models have been determined, a single split package cooling only air conditioner and a reversible one. Both models are intended to be representative of the [0-6kW] range. Their characteristics are summarized in Table 5-1 and Table 5-2 hereunder.

Table 5-1: Main technical features of the reversible single split air conditioner representative of the [0-6 kW] range

	Type	**Reversible Single split**
General description	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	3.5 kW
	EER	3.1
Heating performances	Heating capacity	4 kW
	COP	3.4
Fluid	Type	R410A
	Charge	1.2 kg
Indoor coil	Tube type	Grooved
	Fins type	Louvered
	Evaporator surface	8.5 m²
	Fan type	Centrifugal
Outdoor coil	Tube type	Grooved
	Fins type	Louvered
	Condenser surface	14.3 m²

	Fan type	Axial
Compressor	Type	Rotary
	Crank heater	Yes (30W)
Expansion device	Type	Capillary

Table 5-2: Main technical features of the cooling only single split air conditioner representative of the [0-6kW] range

	Type	**Cooling only Single split**
General description	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	3.5 kW
	EER	2.9
Fluid	Type	R410A
	Charge	0.8 kg
Indoor coil	Tube type	Grooved
	Fins type	Louvered
	Evaporator surface	8.5 m²
	Fan type	Centrifugal
Outdoor coil	Tube type	Grooved
	Fin type	Louvered
	Condenser surface	14.3 m²
	Fan type	Axial
Compressor	Type	Rotary
	Crank heater	No
Expansion device	Type	Capillary

Discussion on EER and COP levels of the base cases

Since energy consumption is the most important impact of air conditioners over their lifetime, it is important to enlighten the position of EER and COP of base cases in relation with the actual European market.

The number of listed units in the 2002 and 2006 Eurovent directories have been plotted according to European energy classes. Additional classes have been created in order to show the discrepancy between appliances in terms of energy efficiency (Table 5-3 and Table 5-4).

Table 5-3: Extension of the EER European labelling scale

Energy efficiency class	**Split and multi-split appliances**
A10+	$5.2 < EER \leq 5.4$
A9+	$5 < EER \leq 5.2$
A8+	$4.8 < EER \leq 5$
A7+	$4.6 < EER \leq 4.8$
A6+	$4.4 < EER \leq 4.6$
A5+	$4.2 < EER \leq 4.4$
A++++	$4 < EER \leq 4.2$
A+++	$3.8 < EER \leq 4$
A++	$3.6 < EER \leq 3.8$
A+	$3.4 < EER \leq 3.6$
A	$3.2 < EER \leq 3.4$
B	$3 < EER \leq 3.2$
C	$2.8 < EER \leq 3$
D	$2.6 < EER \leq 2.8$

E	2.4 < EER ≤ 2.6
F	2.2 < EER ≤ 2.4
G	EER ≤ 2.2

Table 5-4: Extension of the COP European labelling scale

Energy efficiency class	Split and multi-split appliances
A8+	5 < COP ≤ 5.2
A7+	4.8 < COP ≤ 5
A6+	4.6 < COP ≤ 4.8
A5+	4.4 < COP ≤ 4.6
A++++	4.2 < COP ≤ 4.4
A+++	4 < COP ≤ 4.2
A++	3.8 < COP ≤ 4
A+	3.6 < COP ≤ 3.8
A	3.4 < COP ≤ 3.6
B	3.2 < COP ≤ 3.4
C	3 < COP ≤ 3.2
D	2.8 < COP ≤ 3
E	2.6 < COP ≤ 2.8
F	2.4 < COP ≤ 2.6
G	COP ≤ 2.4

In Figure 5-3, it appears that the base case for the category of cooling only mono splits (< 6 kW) belongs to Class C which is in the "middle" of the distribution since about 30 % of the listed units are ranked in better classes and 50 % in worse classes. Best products are listed in "Class A4+", which means that there are, in the market, products which are 1.4 time more efficient than the base case.

In Figure 5-4, it appears that the base case for the category of reversible mono splits (< 6 kW) belongs to Class B which is in the "middle" of the distribution since about 43 % of the listed units are ranked in better classes and 43 % in worse classes. Best products are listed in "Class A9+", which means that there are, in the market, products which are 1.65 time more efficient than the base case.

In Figure 5-5 which makes reference to COP labelling, it appears that the base case for the category of reversible mono splits (< 6 kW) belongs to Class B which is in the "middle" of the distribution since about 40% of the listed units are ranked in better classes and 45% in worse classes. Best products are listed in "Class A8+", which means that there are, in the market, products which are 1.6 time more efficient than the base case regarding the COP.

Figure 5-3: Number of listed cooling only mono-split units in the Eurovent directory according to EER energy labelling classes

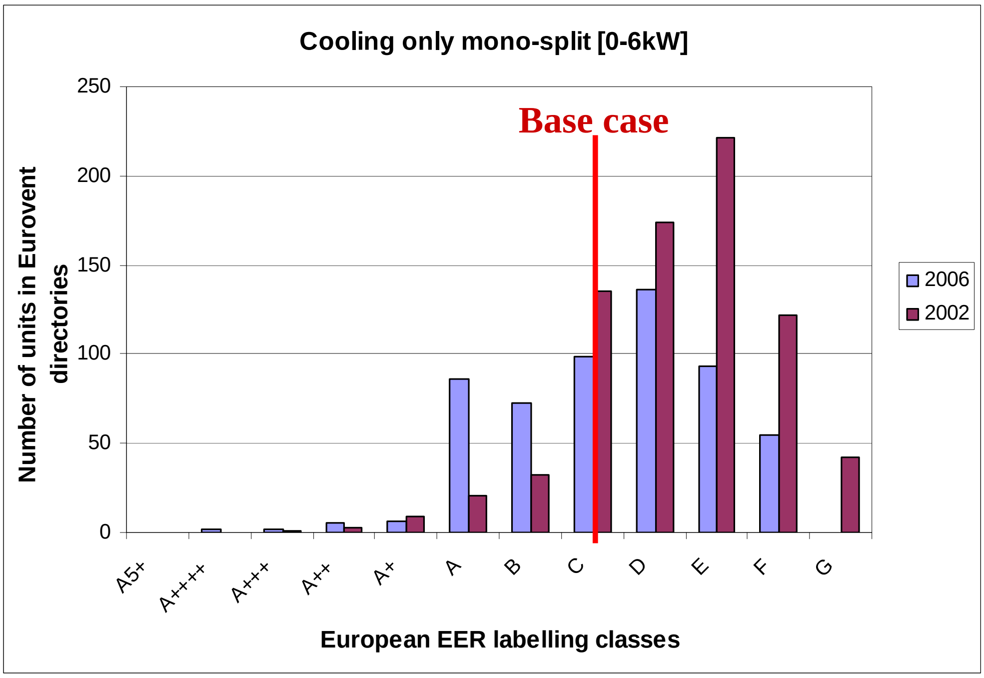


Figure 5-4: Number of listed reversible mono-split units in the Eurovent directory according to EER energy labelling classes

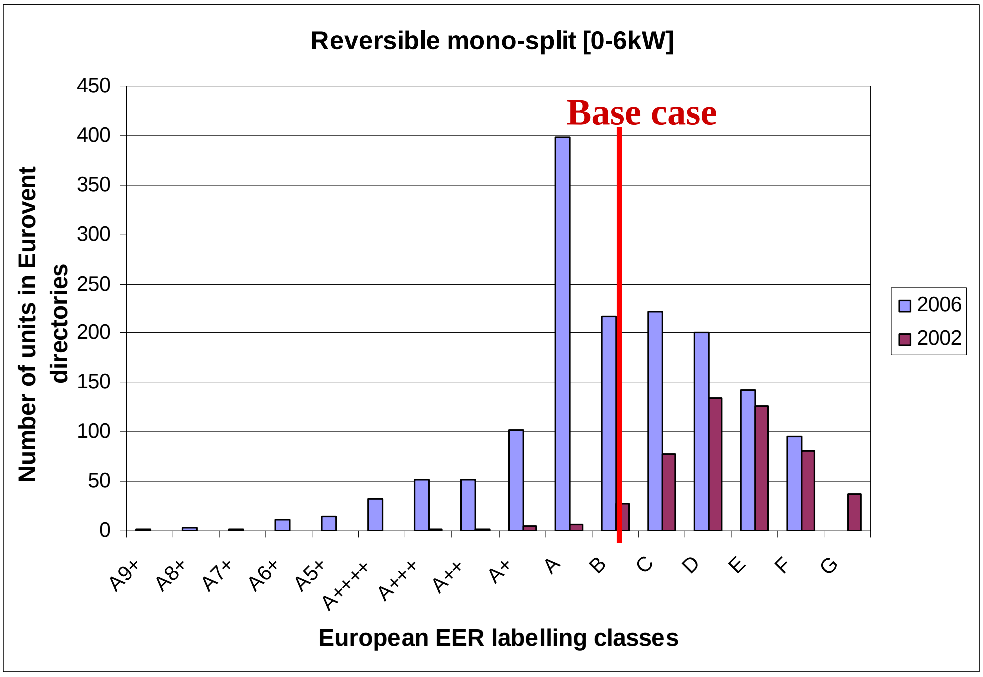
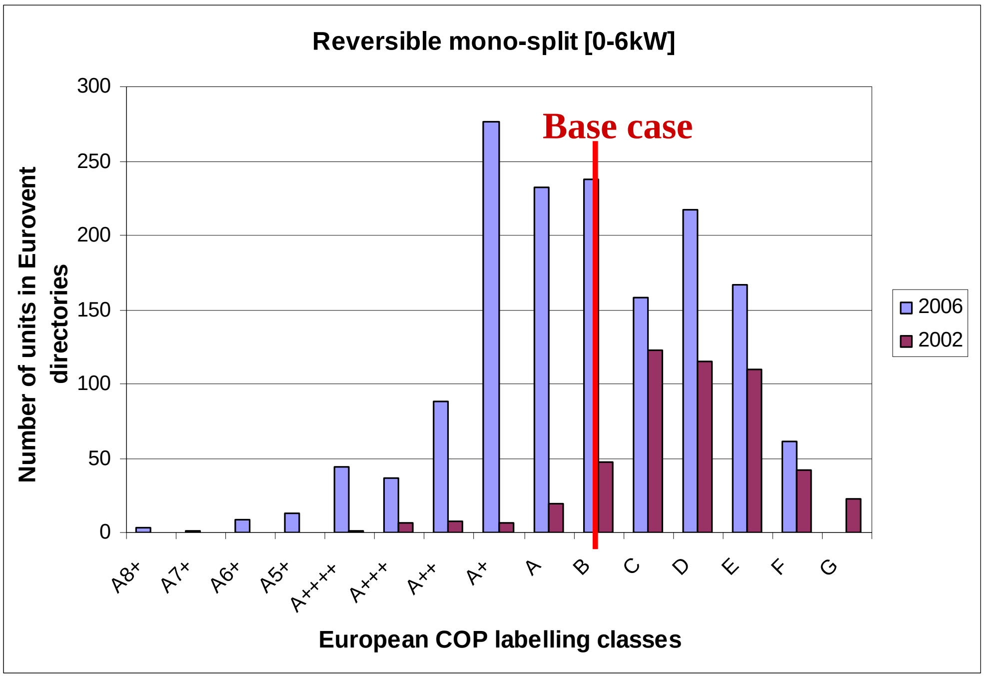


Figure 5-5: Number of listed reversible mono-split units in the Eurovent directory according to COP energy labelling classes



5.1.1.3 Single split cooling only and reversible air conditioner base case analysis [6-12 kW]

A few words regarding the method used to define base cases

The method used to determine the base case characteristics both for the reversible mono split within [6-12 kW] category and the cooling only mono split within [6-12 kW] category is explained in details in Annex B. The determination of these base cases is based on two databases from Eurovent (the Eurovent directory and the technical database). The Eurovent directory is used as often as possible since it contains all the products declared by manufacturers. Unfortunately, when it comes to determine accurate technical features, this database is not adequate and then the technical database – with fewer models - is used. From these databases, distributions and regressions have been extracted to determine the characteristics of average models. In a second step, manufacturers were requested to express comments on these base cases. Thus, following their comments, some values and features (notably EER and COP) have been reviewed.

Final base case description

Two typical models have been determined, a single split package cooling only air conditioner and a reversible one. Both models are intended to be representative of the [6-12 kW] range. Both models characteristics are summarized in Table 5-5 and Table 5-6 hereunder.

Table 5-5: Main technical features of the reversible single split air conditioner

	Type	Reversible Single split
General description	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	7.1 kW
	EER	2.8
Heating performances	Heating capacity	8.1 kW
	COP	3.3
Fluid	Type	R410A
	Charge	2.5 kg
Indoor coil	Tube type	Grooved
	Fins type	Louvered
	Evaporator surface	13 m²
	Fan type	Centrifugal
Outdoor coil	Tube type	Grooved
	Fins type	Louvered
	Condenser surface	28 m²
	Fan type	Axial
Compressor	Type	Rotary
	Crankcase heater	Yes (70W)
Expansion device	Type	Capillary

Table 5-6: Main technical features of the cooling only single split air conditioner

	Type	Reversible Single split
General description	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	7.1 kW
	EER	2.5
Heating performances	Type	R410A
	Charge	2 kg

Fluid	Tube type	Grooved
	Fins type	Louvered
Indoor coil	Evaporator surface	13 m²
	Fan type	Centrifugal
	Tube type	Grooved
	Fin type	Louvered
Outdoor coil	Condenser surface	28 m²
	Fan type	Axial
	Type	Rotary??
	Crank heater	No
Compressor	Type	Capillary??
	Mounting	Wall
Expansion device	Current information	230V-1phase-50Hz

Discussion on EER and COP levels of the base cases

In Figure 5-6, it appears that the base case for the category of cooling only mono splits ([6-12 kW]) belongs to Class E which is in the "middle" of the distribution since about 48 % of the listed units are ranked in better classes and 18 % in worse classes. Best products are listed in "Class A+", which means that there are in the market products 1.5 time more efficient than the base case.

In Figure 5-7, it appears that the base case for the category of cooling only mono splits ([6-12 kW]) belongs to Class D which is in the "middle" of the distribution since about 37% of the listed units are ranked in better classes and 38 % in worse classes. Best products are listed in "Class A4+", which means that there are in the market products 1.5 time more efficient than the base case.

In Figure 5-8, it appears that the base case for the category of cooling only mono splits ([6-12 kW]) belongs to Class B which is in the "middle" of the distribution since about 20 % of the listed units are ranked in better classes and 65 % in worse classes. Best products are listed in "Class A5+", which means that there are in the market products 1.4 time more efficient than the base case.

Figure 5-6: Number of listed cooling only mono-split units in the Eurovent directory according to EER energy labelling classes

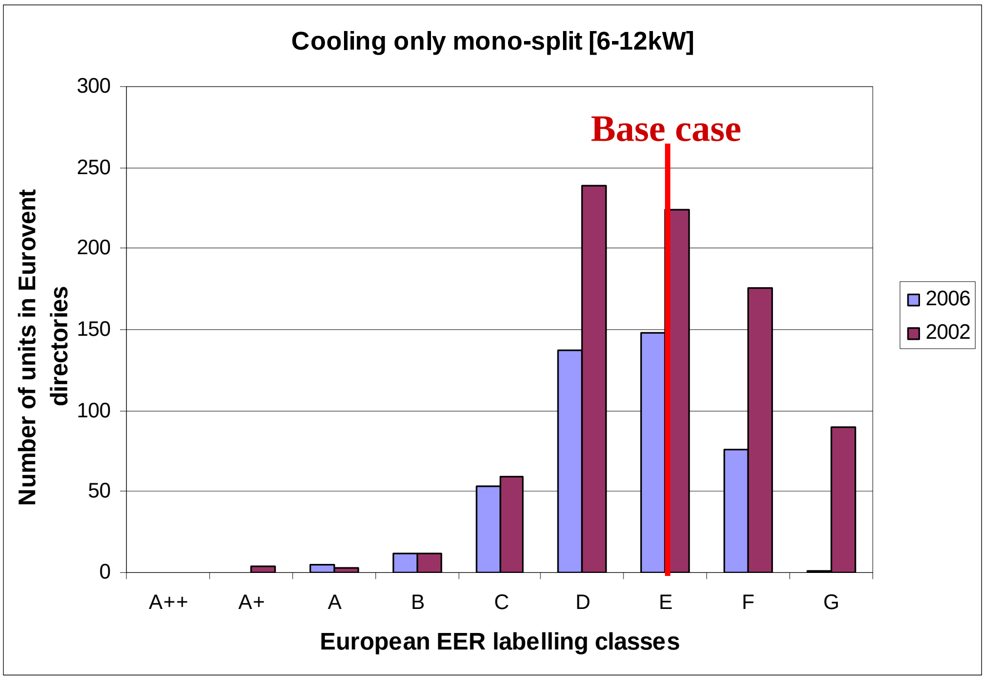


Figure 5-7: Number of listed reversible mono-split units in the Eurovent directory according to EER energy labelling classes

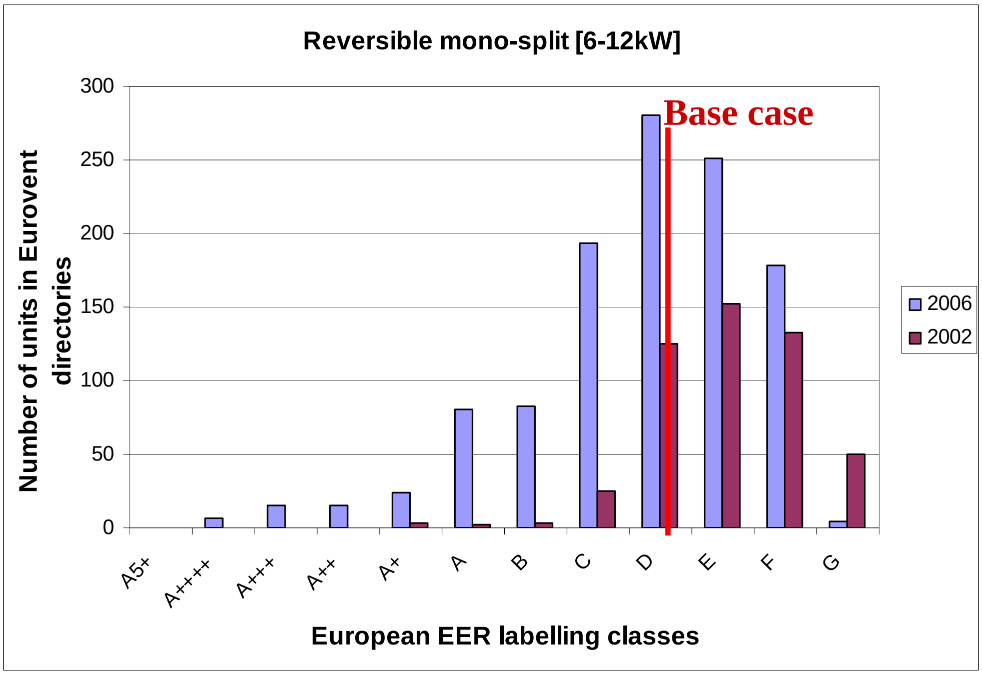
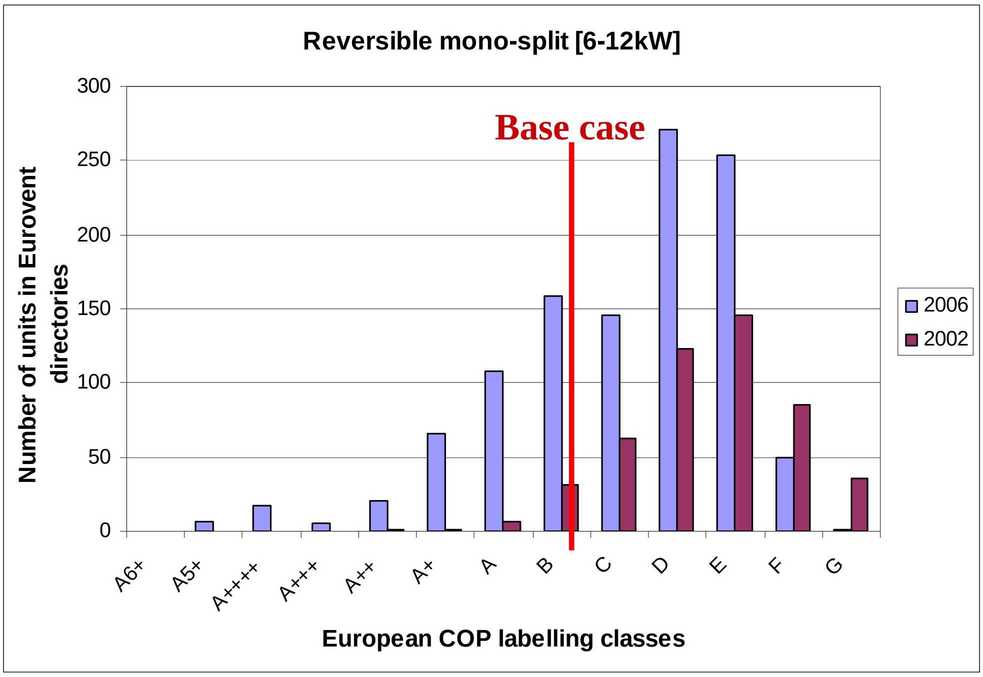


Figure 5-8: Number of listed reversible mono-split units in the Eurovent directory according to COP energy labelling classes



5.1.1.4 Single duct air conditioner base case analysis

The method used to determine the base case characteristics for single duct air conditioners is explained in details in Annex B. The determination of base cases means that technical features (type of air conditioner, fluid, capacity…) that are the most likely to be found in European conditioned rooms must be specified. Ideally, the investigation of the most sold technologies should be based on sales figures. Unfortunately, regarding moveable air conditioners, we have not been provided with any technical data. For this reason, we had to build our own database from manufacturer's catalogues, importers' websites. This database contains performance (declared by manufacturers) of 73 single duct air conditioners along with some technical features when available. However, in a second time, supplementary information supplied by (CECED, 2007) have been taken into account in the base case definition.

Final base case description

A typical model has been determined to represent moveable air conditioners. The main characteristics of this single duct are summarized in Table 5-7. We have striven to gather the greatest number of technical features from retailer websites and catalogues. The features we have not found in the market stem from a detailed technical study of a single duct [EERAC Task 7 (1999)]. This is the case for all detailed characteristics of heat exchangers (Table 5-8 and Table 5-9).

Table 5-7: Main technical features of the single duct air conditioner base case

General description	**Type**	**Cooling only single duct**
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	2.2 kW
	EER	2.3
Fluid	Type	R407C
	Charge	0.5kg
Compressor	Type	Rotary
	Crank heater	No
Expansion device	Type	Capillary (*)

(*) From EERAC study

Table 5-8: Main technical features regarding the evaporator of the single duct air conditioner base case (from EERAC)

Tube type	Smooth
Tube material	Aluminium (stakeholders say that Copper is more common)
Tube outside diameter	8.4 mm
Tube thickness	0.3048 mm
Fin type	Smooth
Fin material	Al
Fin pitch	556 fins/m
Fin thickness	0.2540 mm
Coil frontal area	0.0753 m^2
Tube spacing a	0.025 m
Tube spacing b	0.022 m
No. of rows	2
No. of tubes/row	13
No. of equivalent parallel circuit (2 phase)	1
No. of equivalent parallel circuit (Liquid)	2

Refrigerant Flow Configuration	Cross flow

Table 5-9: Main technical features regarding the condenser of the single duct air conditioner base case (from EERAC)

Tube type	Smooth
Tube material	Aluminium (stakeholders say that Copper is more common)
Tube outside diameter	10 mm
Tube thickness	0.3048 mm
Fin type	Smooth
Fin material	Al
Fin pitch	556 fins/m
Fin thickness	0.127 mm
Coil frontal area	0.040 m^2
Tube spacing a	0.025 m
Tube spacing b	0.022 m
No. of rows	4
No. of tubes/row	23
No. of equivalent parallel circuit (2 phase)	1
No. of equivalent parallel circuit (Liquid)	1
Refrigerant Flow Configuration	Cross flow

5.1.2 Production phase

5.1.2.1 Bill of materials (BOM)

Listing and weight of materials, issued from information supplied by stakeholders and previously analyzed in task 4.2, are reported below.
Since no variation in composition with cooling capacity was detected for split and multi-split appliances, only the 3.5 kW bills of material are shown. For higher capacities, composition is the same with the total mass of the product equal to 14 kg / kW of cooling capacity.
The only difference between reversible and cooling only split lies in the addition of a 4 way valve, a second expansion valve and some copper for tubing these elements in order to enable reverse mode operation.

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Plastics	7669,6	1-BlkPlastics	4-PP
2	Plastics	931,6	2-TecPlastics	11-PA 6
3	Ferrous metals	19821,9	3-Ferro	23-Cast iron
4	Non-ferrous metals	7211,4	4-Non-ferro	30-Cu tube/sheet
5	Non-ferrous metals	3304,9	4-Non-ferro	26-Al sheet/extrusion
6	Coatings	45,9	5-Coating	
7	Electronics	1461,5	6-Electronics	98-controller board
8	Various other materials	5053,3	7-Misc.	

Table 5-10: List of materials of the cooling only split air conditioner base case of 3.5 kW

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Plastics	7669,6	1-BlkPlastics	4-PP
2	Plastics	931,6	2-TecPlastics	11-PA 6
3	Ferrous metals	19821,9	3-Ferro	23-Cast iron
4	Non-ferrous metals	7711,4	4-Non-ferro	30-Cu tube/sheet
5	Non-ferrous metals	3304,9	4-Non-ferro	26-Al sheet/extrusion
6	Coatings	45,9	5-Coating	
7	Electronics	1461,5	6-Electronics	98-controller board
8	Various other materials	5053,3	7-Misc.	

Table 5-11: List of materials of the reversible split air conditioner base case of 3.5 kW

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Plastics	10092,2	1-BlkPlastics	4-PP
2	Plastics	1179,8	2-TecPlastics	11-PA 6
3	Ferrous metals	7668,3	3-Ferro	23-Cast iron
4	Non-ferrous metals	1359,5	4-Non-ferro	30-Cu tube/sheet
5	Non-ferrous metals	1359,5	4-Non-ferro	26-Al sheet/extrusion
6	Coatings		5-Coating	
7	Electronics	682,2	6-Electronics	98-controller board
8	Various other materials	10658,5	7-Misc.	

Table 5-12: List of materials of the moveable air conditioner base case of 2.2 kW

5.1.2.2 Primary scrap

Without further information, the default value of the MEEuP Ecoreport (25 %) is kept for primary scrap.

5.1.3 Distribution phase

The product volume is required in the EcoReport in order to access transportation and warehouse impacts. Transport volume are summarized in Table 5-13, as reported in task 4.3.

Table 5-13: Transportation volumes for the different base cases

Base cases	Cooling only single split 3.5kW	Reversible single split 3.5kW	Cooling only single split 7.1kW	Reversible single split 7.1kW	Single duct
Transport volume [m^3]	0.25	0.25	0.5	0.5	0.25

5.1.4 Use phase

5.1.4.1 Energy consumption

The energy consumption as calculated in task 4 are reported inn the table below.

Table 5-14: Average EU 27 total energy consumption per unit

Energy consumption per unit / year KWh/y		Cooling only single split [3,5kW]	Reversible single split [3,5kW]	Cooling only single split [7,1kW]	Reversible single split [7,1kW]	Single duct [2,2 kW]
Cooling mode	Compressor on	377,5	374,0	882,6	839,7	311,1
	Thermostat off	23,2	18,1	42,5	33,2	47,0
	Stand-by	13,7	13,7	13,7	13,7	13,7
	Off mode	30,5	0,0	30,5	0,0	0,0
Heating mode	Compressor on + electric resistance		957,9		1997,5	
	Thermostat off		100,7		184,6	
	Stand-by		0		0	
	Crankcase heater		34,9		81,4	
TOTAL per unit in kWh/y		445	1499	969	3150	372

5.1.4.2 Other resource consumption

No other resource is used for base cases.

5.1.4.3 Maintenance/repairs

The default value of 1 % as required in the MEEuP is kept.

5.1.5 End-of-Life phase

Regarding the End-of-life phase, default values of the Ecoreport have been adopted. Dumped refrigerant along the life cycle of the product is 1 % for moveables and 3 % for split air conditioners.

5.1.6 LCC inputs

5.1.6.1 Product life

As explained in Task 3 part 3.2.1, the product life is assumed to be **12 years** for all types of air conditioners.

5.1.6.2 Product price

As explained in Task 2, estimated European average price is 177 Euro/kW for moveables and 195 Euro/kW for split systems.

Table 5-15: Average product price per unit for the base cases

Base cases	Cooling only single split 3.5kW	Reversible single split 3.5kW	Cooling only single split 7.1kW	Reversible single split 7.1kW	Single duct
Product prices [€]	682.5	682.5	1384.5	1384.5	389.4

5.1.6.3 Installation costs

As reported in task 2, a value of 1000 € is kept for the installation costs for single split base cases.

Table 5-16: Average installation cost per unit

Base cases	Cooling only single split 3.5kW	Reversible single split 3.5kW	Cooling only single split 7.1kW	Reversible single split 7.1kW	Single duct
Product prices [€]	1000	1000	1000	1000	0

5.1.6.4 Energy prices

As explained in part 2.4.3, an average electricity price of 0.145 euro / kWh is kept for all Europe and all sectors. In order to take into account energy prices evolution, the approach adopted by lot 1 is adopted. This includes a long term electricity price (low) increase of 1.5 % yearly. Over a product life of 12 years, this leads to an average electricity price of **0.158 euro/kWh**.

5.1.6.5 Maintenance/repair costs

According to prEN 15459:2006(E) annual preventative maintenance including operation, **repair and servicing costs for air conditioners are typically 4 % of the initial investment (including installation costs)**.

5.2 Base-Case Environmental Impact Assessment

The base cases are the references for the improvement and are described in terms of financial Life Cycle Costs (LCC) (see part 5.3) but also in terms of environmental impact (see part 5.2) during its life cycle (production, distribution, use, end-of-life), for which the EuP EcoReport is available.

The most important part of environmental impacts occurs during the use phase because of energy consumption. In average, 81 % of GHG emissions are linked to the energy use for moveables, 65 % for cooling only and 89 % for reversible air conditioners. It is to be added that refrigeration leaks are integrated in the end of life phase together with the refrigerant recovery loss. For the single duct, production and distribution have the same emission level as end-of-life. For cooling only split, production and distribution share falls to about one half of the end-od-life share, and one fourth for reversible units.

Hence, these values give also an estimate of the share of GHG direct emissions (refrigerant loss) and indirect emissions. Energy consumption and refrigerant losses appear as the two most significant environmental impacts.

The environmental impact of larger units does not differ much from 3.5 kW units except that, being less efficient, the importance of the use phase is still emphasised.

Table 5-17: Life Cycle Impact (per unit) of average 2.2 kW Single duct

Nr	Life cycle Impact per product:	Date	Author
0	Products Single duct	39239	bre

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**10092**			9083	1009	**10092**	**0**
2	TecPlastics	g			**1180**			1062	118	**1180**	**0**
3	Ferro	g			**7668**			0	7668	**7668**	**0**
4	Non-ferro	g			**2719**			0	2719	**2719**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**682**			682	0	**682**	**0**
7	Misc.	g			**10658**			0	10658	**10658**	**0**
	Total weight	g			**33000**			10827	22173	**33000**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1816	527	**2342**	**932**	**43922**	690	578	**112**	**47307**
9	of which, electricity (in primary MJ)	MJ	487	315	**803**	**1**	**43906**	0	4	**-4**	**44706**
10	Water (process)	ltr	434	5	**439**	**0**	**2931**	0	3	**-3**	**3367**
11	Water (cooling)	ltr	762	147	**909**	**0**	**117071**	0	24	**-24**	**117957**
12	Waste, non-haz./ landfill	g	20280	1747	**22027**	**475**	**51118**	4	17	**-13**	**73607**
13	Waste, hazardous/ incinerated	g	512	0	**512**	**9**	**1017**	10145	3	**10142**	**11681**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	91	29	**120**	**71**	**1917**	297	40	**257**	**2365**
15	Ozone Depletion, emissions	mg R-11 eq.					negligible				
16	Acidification, emissions	g SO2 eq.	602	126	**729**	**239**	**11311**	104	52	**52**	**12331**
17	Volatile Organic Compounds (VOC)	g	6	0	**6**	**11**	**17**	2	1	**1**	**34**
18	Persistent Organic Pollutants (POP)	ng i-Teq	71	7	**78**	**3**	**289**	0	0	**0**	**370**
19	Heavy Metals	mg Ni eq.	115	17	**132**	**24**	**754**	184	0	**184**	**1095**
	PAHs	mg Ni eq.	184	0	**184**	**15**	**88**	0	0	**0**	**288**
20	Particulate Matter (PM, dust)	g	162	19	**181**	**280**	**243**	894	1	**892**	**1597**

Nr	Emissions (Water)	unit	Material	Manuf.	Total	DISTRIBUTION	USE	Disposal	Recycl.	Total	TOTAL
21	Heavy Metals	mg Hg/20	391	0	**391**	**1**	**287**	58	0	**58**	**736**
22	Eutrophication	g PO4	7	0	**8**	**0**	**1**	3	0	**3**	**12**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Table 5-18: Life Cycle Impact (per unit) of average 3.5 kW Split (cooling only)

Nr	Life cycle Impact per product:		Date	Author
0	Products	Average Split (cooling only)	39239	bre

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**7670**			6903	767	**7670**	**0**
2	TecPlastics	g			**932**			838	93	**932**	**0**
3	Ferro	g			**19822**			0	19822	**19822**	**0**
4	Non-ferro	g			**10516**			0	10516	**10516**	**0**
5	Coating	g			**46**			0	46	**46**	**0**
6	Electronics	g			**1462**			1462	0	**1462**	**0**
7	Misc.	g			**5053**			0	5053	**5053**	**0**
	Total weight	g			**45500**			9203	36297	**45500**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	3013	585	**3598**	**870**	**48811**	527	443	**84**	**53363**
9	of which, electricity (in primary MJ)	MJ	919	346	**1266**	**1**	**48787**	0	3	**-3**	**50050**
10	Water (process)	ltr	842	5	**847**	**0**	**3260**	0	2	**-2**	**4105**
11	Water (cooling)	ltr	738	157	**895**	**0**	**130075**	0	18	**-18**	**130952**
12	Waste, non-haz./ landfill	g	79833	2210	**82042**	**425**	**57372**	3	13	**-10**	**139829**
13	Waste, hazardous/ incinerated	g	1005	0	**1005**	**8**	**1134**	7741	2	**7739**	**9887**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	173	33	**206**	**67**	**2131**	928	31	**897**	**3301**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	1457	142	**1598**	**227**	**12575**	79	40	**39**	**14440**
17	Volatile Organic Compounds (VOC)	g	12	0	**12**	**11**	**18**	1	1	**1**	**43**
18	Persistent Organic Pollutants (POP)	ng i-Teq	219	28	**247**	**2**	**322**	0	0	**0**	**572**
19	Heavy Metals	mg Ni eq.	397	66	**464**	**22**	**841**	141	0	**141**	**1467**
	PAHs	mg Ni eq.	449	0	**450**	**15**	**101**	0	0	**0**	**565**
20	Particulate Matter (PM, dust)	g	387	22	**409**	**280**	**272**	682	1	**681**	**1642**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	938	0	**938**	**1**	**324**	44	0	**44**	**1307**
22	Eutrophication	g PO4	11	0	**11**	**0**	**2**	3	0	**2**	**15**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Table 5-19: Life Cycle Impact (per unit) of average 3.5 kW Split (reversible)

Nr	Life cycle Impact per product:		Date	Author
0	Products	Average Split (reversible)	39239	bre

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	

	Materials	unit									
1	Bulk Plastics	g			**7670**			6903	767	**7670**	**0**
2	TecPlastics	g			**932**			838	93	**932**	**0**
3	Ferro	g			**19822**			0	19822	**19822**	**0**
4	Non-ferro	g			**11016**			0	11016	**11016**	**0**
5	Coating	g			**46**			0	46	**46**	**0**
6	Electronics	g			**1462**			1462	0	**1462**	**0**
7	Misc.	g			**5053**			0	5053	**5053**	**0**
	Total weight	g			**46000**			9203	36797	**46000**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	3038	595	**3633**	**870**	**209675**	527	443	**84**	**214262**
9	of which, electricity (in primary MJ)	MJ	919	352	**1271**	**1**	**209652**	0	3	**-3**	**210920**
10	Water (process)	ltr	842	5	**847**	**0**	**13984**	0	2	**-2**	**14830**
11	Water (cooling)	ltr	738	159	**897**	**0**	**559046**	0	18	**-18**	**559925**
12	Waste, non-haz./ landfill	g	83840	2256	**86095**	**425**	**243925**	3	13	**-10**	**330436**
13	Waste, hazardous/ incinerated	g	1005	0	**1005**	**8**	**4841**	7741	2	**7739**	**13594**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	175	33	**208**	**67**	**9151**	928	31	**897**	**10323**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	1488	144	**1632**	**227**	**53998**	79	40	**39**	**55897**
17	Volatile Organic Compounds (VOC)	g	12	0	**12**	**11**	**79**	1	1	**1**	**103**
18	Persistent Organic Pollutants (POP)	ng i-Teq	224	30	**254**	**2**	**1377**	0	0	**0**	**1633**
19	Heavy Metals	mg Ni eq.	414	69	**483**	**22**	**3601**	141	0	**141**	**4247**
	PAHs	mg Ni eq.	452	0	**452**	**15**	**418**	0	0	**0**	**885**
20	Particulate Matter (PM, dust)	g	388	22	**410**	**280**	**1157**	682	1	**681**	**2528**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	957	0	**957**	**1**	**1361**	44	0	**44**	**2363**
22	Eutrophication	g PO4	11	0	**11**	**0**	**7**	3	0	**2**	**20**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

5.3 Base-Case Life Cycle Costs

The base cases are the references for the improvement and are described in terms of environmental impact (see part 5.2) but also in terms of financial Life Cycle Costs (LCC) which includes the appliance purchase price and the running costs (energy, repairs…) discounted over the product life.

Table 5-20: Life Cycle cost of unit base cases

		Single duct Cooling only 2.2 kW	Single split Cooling only 3.5 kW	Single split Reversible 3.5 kW	Single split Cooling only 7.1 kW	Single split Reversible 7.1 kW
Product price	€	389	683	683	1385	1385
Installation/ acquisition costs (if any)	€	0	1000	1000	1000	1000
Electricity	€	582	647	2781	1471	5799
Repair & maintenance costs	€	165	712	712	1009	1009
Total	€	**1136**	**3042**	**5176**	**4865**	**9193**

For reversible split and single duct units, the main cost for the end-user is the energy (electricity) cost that represents between 1 and 4 times the purchase price. For cooling only split units, energy only represents about 30 % of the total life cycle cost.

The standard hypothesis for maintenance (4 % of purchase and installation price) leads also to high maintenance costs to the end user for split units.

5.4 EU totals, impact of new products sold in 2005

This part aims at determining the life cycle environmental impact and total LCC of the new products designed in 2005 which relates to a period starting in 2005 and finishing in 2005 plus the product lifetime or 2017. Another objective consists in assessing the annual (2005) impact of production, use and disposal of the product group, assuming post-WEEE and post-RoHS conditions.

This section presents results for the lifetime environmental impact of all room air conditioners installed in 2005 based on the three standard products defined in part 5.1 of this report.

Total environmental impact regarding materials

The total weight of materials in 2005 room air conditioning products is 372 thousand tons. Figure 5-9 shows the breakdown between material types, whilst Figure 5-10 shows the End of life fate of the materials.

Figure 5-9: Materials in RAC products installed in 2005

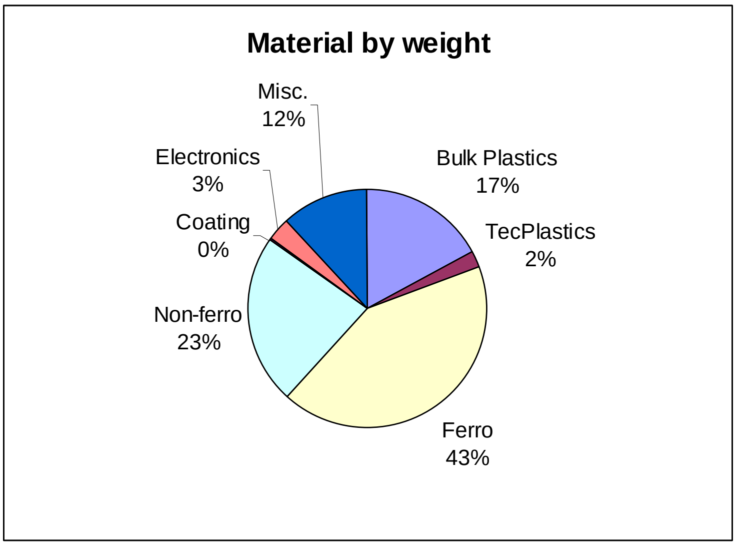
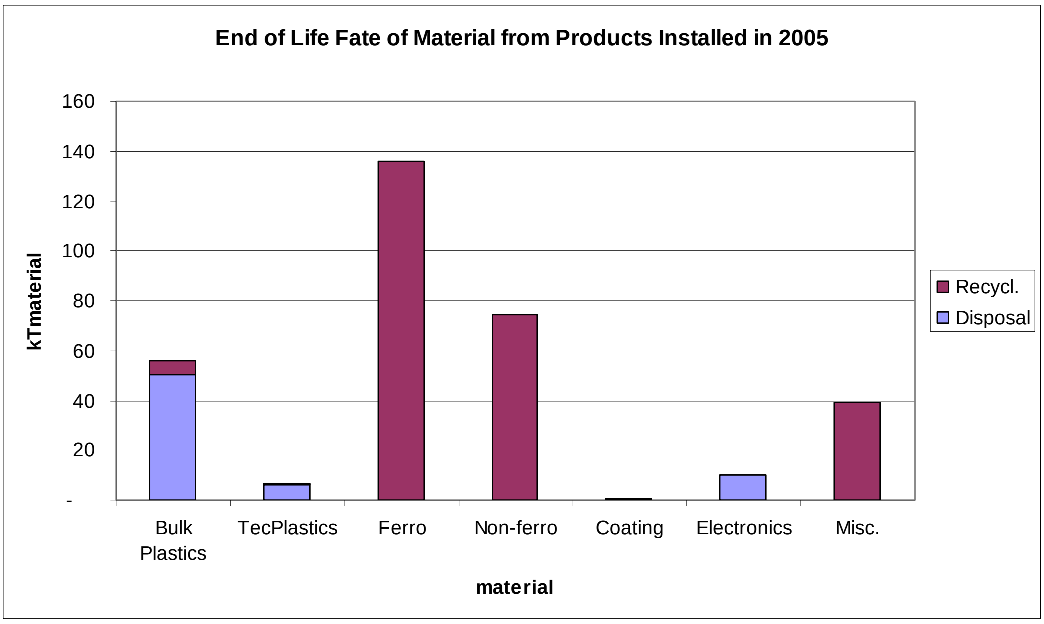


Figure 5-10: End of Life fate of materials for RAC products installed in 2005



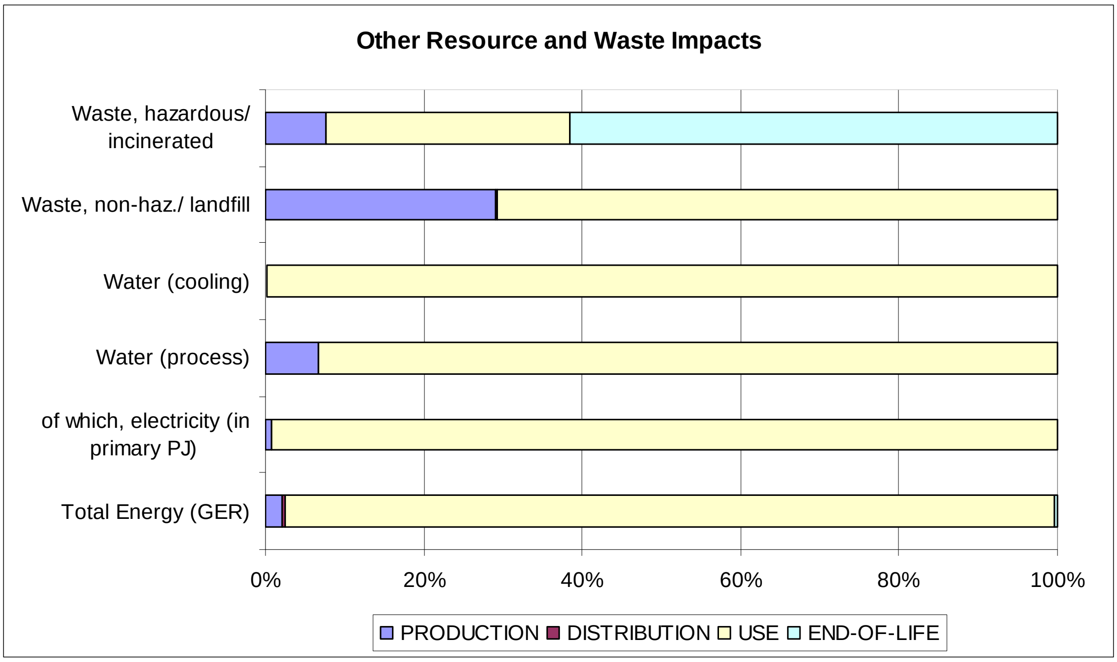
Total environmental impact regarding other resources and wastes

Overall use of other resources and waste impacts for the four life stages are shown in Table 5-21 and Figure 5-11. The use phase accounts for most of the energy consumption and consequently water, required to produce electricity.

Table 5-21: Other resource and waste impacts for all RACs installed in 2005

Other Resources & Waste	Production	Distribution	Use	End of Life	Total
Total Energy [PJ]	25	6	1 222	4	1 258
Of which, electricity (in primary PJ)	9	0	1 222	0	1 231
Water (process) [min.m3]	6	-	82	-	87
Water (cooling) [min.m3]	6	-	3 258	-	3 265
Waste, non haz/landfill [kt]	584	3	1 423	0	2 009
Waste, hazardous/incinerated [kt]	7	0	28	57	92

Figure 5-11: Other resource and waste impacts by phase of lifecycle



Emissions to air

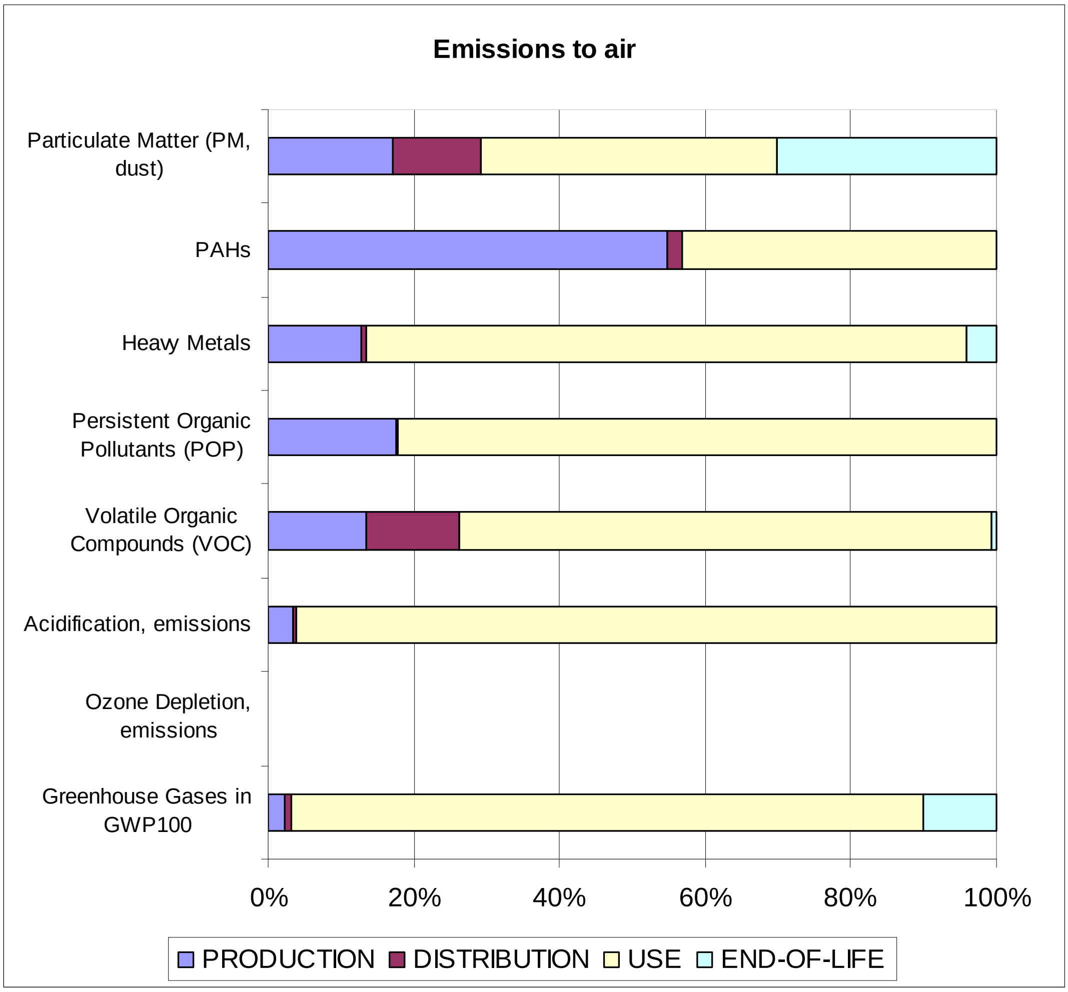
The environmental impact of RAC units installed in 2005 on emissions to air for the four life stages are shown in Table 5-22 and Figure 5-12.

The largest market share is for reversible units and the GHG emissions are mainly concentrated in the use phase. The share linked to direct emissions is in average slightly higher than 10 % and the manufacturing part inferior to 5 %.

Table 5-22: Emission to air for all RACs installed in 2005

Emissions (Air)	Production	Distribution	Use	End of Life	Total
Greenhouse Gases in GWP 100 [Mt CO2eq]	1	0	53	6	62
Ozone depletion, emissions [t R11eq]	-	-	-	-	-
Acidific0ation, emission1s, [kt SO2eq]	11	2	315	1	328
Volatile Organic Compounds (VOC), [kt]	0	0	0	0	1
Persistent Organic Pollutants (POP), [g i-Teq]	2	0	8	0	10
Heavy Metals, [ton Ni eq.]	3	0	21	1	25
PAHs, [ton Ni eq.]	3	0	2	-	6
Particulate Matter (PM, dust) [kt]	3	2	7	5	17

Figure 5-12: Emissions to air by phase of lifecycle



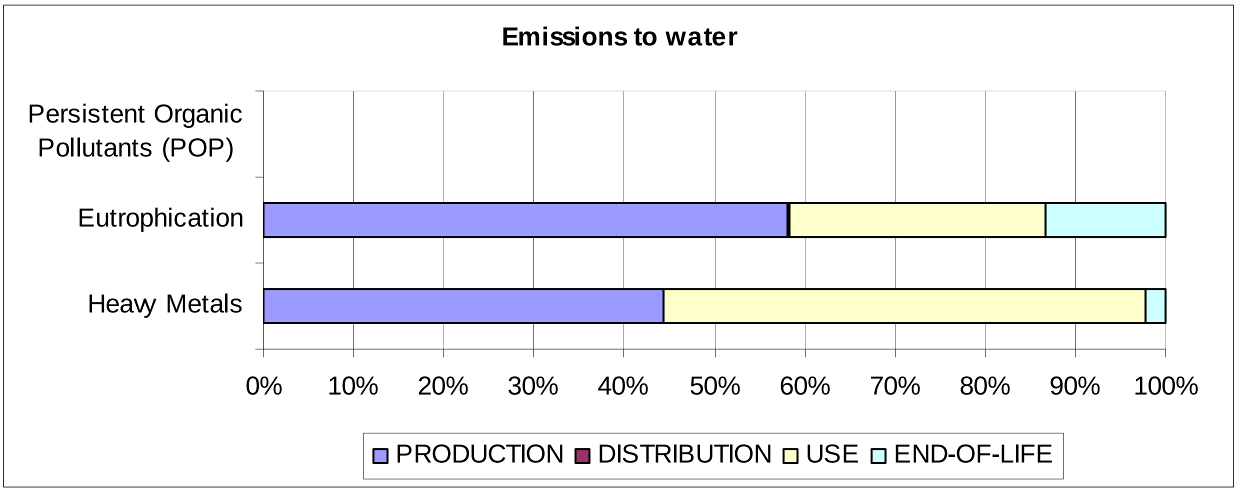
Emissions to water

The environmental impact of RAC units installed in 2005 on emissions to water for the four life stages are shown in Table 5-23 and Figure 5-13. Impacts of the different phases of the life cycle are more equilibrated, with higher production weight.

Table 5-23: Emissions to water for all RACs installed in 2005

Emissions (Air)	Production	Distribution	Use	End of Life	Total
Heavy Metals, [ton Hg/20]	6,6	0,0	7,9	0,3	14,8
Eutrophication, [kt PO4]	0,1	0,0	0,0	0,0	0,1
Persistent Organic Pollutants (POP), [g i-Teq]	-	-	-	-	-

Figure 5-13: Emissions to water by phase of lifecycle



5.5 EU-25 Total System Impact

This part aims at assessing the total environmental impact of Room Air Conditioner between 2005 and 2030 over EU-25.

This is essentially the business as usual case and assumes no changes in the product, or the way in which it is used (e.g., cooling demand which needs to be met). The implicit assumption in the VHK model that “the number of installations = no of retrials” means that the end of use impacts occurring over the period are likely to be overestimated. However, as end of life impacts only make up a small proportion of the total in most instances this approximation is not likely to have a significant effect on the results.

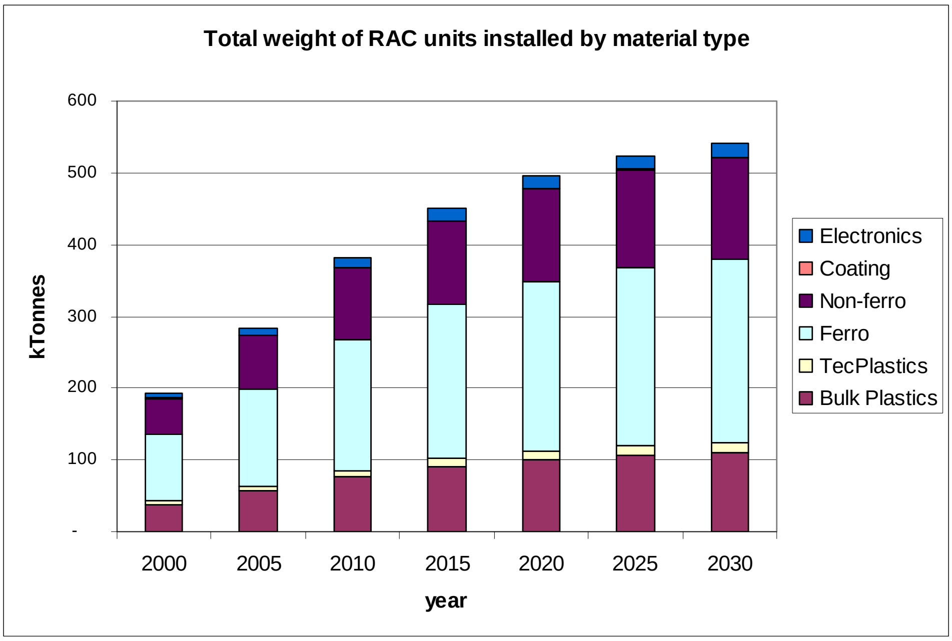
For this baseline scenario the impact has been calculated at 5 year intervals which should be sufficient to provide a robust indication of how impacts change with time.

Table 5.28 and Figure 5-17 show the total weight of materials used across all RAC units installed in each year.

Materials	2000	2005	2010	2015	2020	2025	2030
Bulk plastics [kt]	38	56	76	91	101	107	110
TecPlastics [kt]	5	7	9	11	12	13	13
Ferro [kt]	92	136	182	214	236	249	257
Non-ferro [kt]	51	75	100	117	129	136	140
Coating [kt]	0	0	0	0	1	1	1
Electronics [kt]	7	10	14	16	18	19	19
Misc. [kt]	26	39	53	64	72	76	79
Total weight [kt]	219	323	434	514	568	599	619

Table 5-24: Weight of material contained in all RAC units installed in each year

Figure 5-14: Weight of material in kt contained in all RAC units installed in each year



Total annual use of other resources and waste impacts for RAC units over the whole product lifetime are shown in the table and figure below.

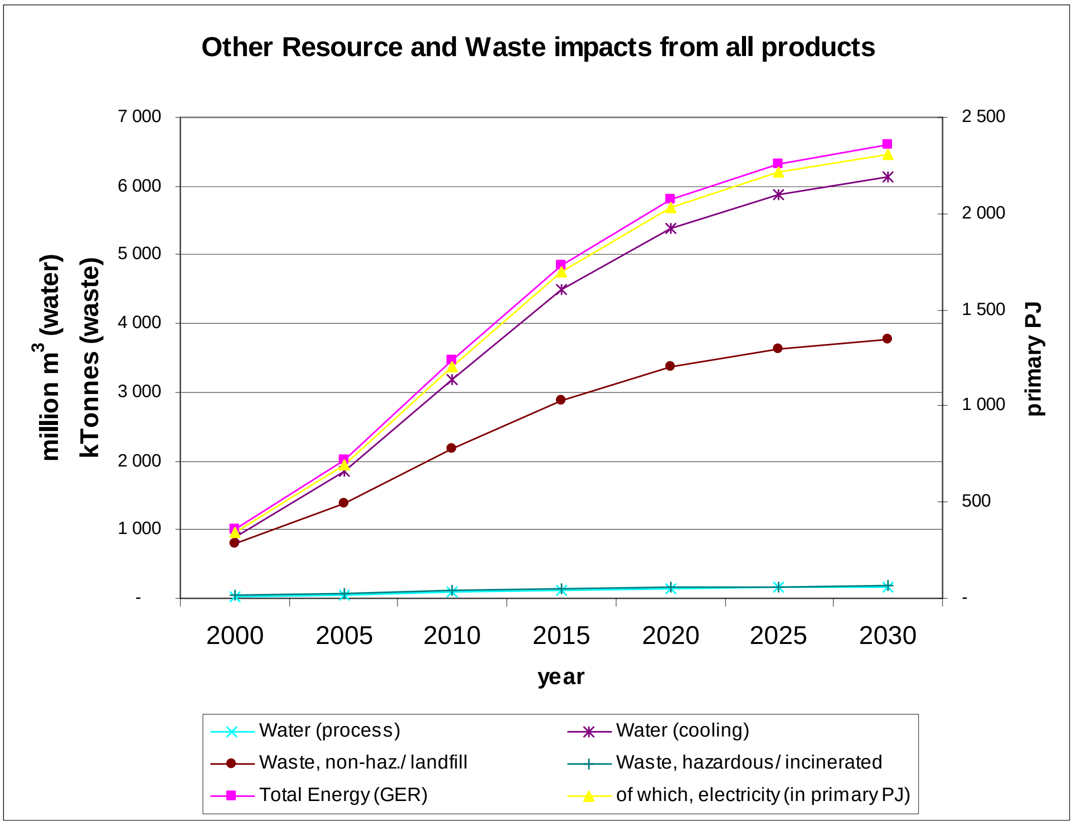
Electricity consumption (use phase) is estimated to grow from approximately 32 TWh to more than 200 TWh. The cooling part is about 30 % of these figures, the heating function being the major contributor.

Total energy consumption of the stock of products increases until 2030 but growth declines after 2020 because of the saturation effect in the market modelling and because of the introduction of new buildings with lower heating energy demand.

Table 5-25: Annual other resource and waste impacts of RAC units

	2000	2005	2010	2015	2020	2025	2030
Total Energy [PJ]	357	721	1 239	1 733	2 071	2 261	2 355
Of which, electricity (in primary PJ)	341	697	1 207	1 696	2 030	2 218	2 310
Water (process) [min.m3]	26	52	88	121	145	158	164
Water (cooling) [min.m3]	897	1 841	3 195	4 494	5 383	5 881	6 127
Waste, non haz/landfill [kt]	790	1 388	2 177	2 880	3 361	3 631	3 774
Waste, hazardous/incinerated [kt]	51	80	114	141	160	171	177

Figure 5-15: Annual other resource and waste impacts of RAC units

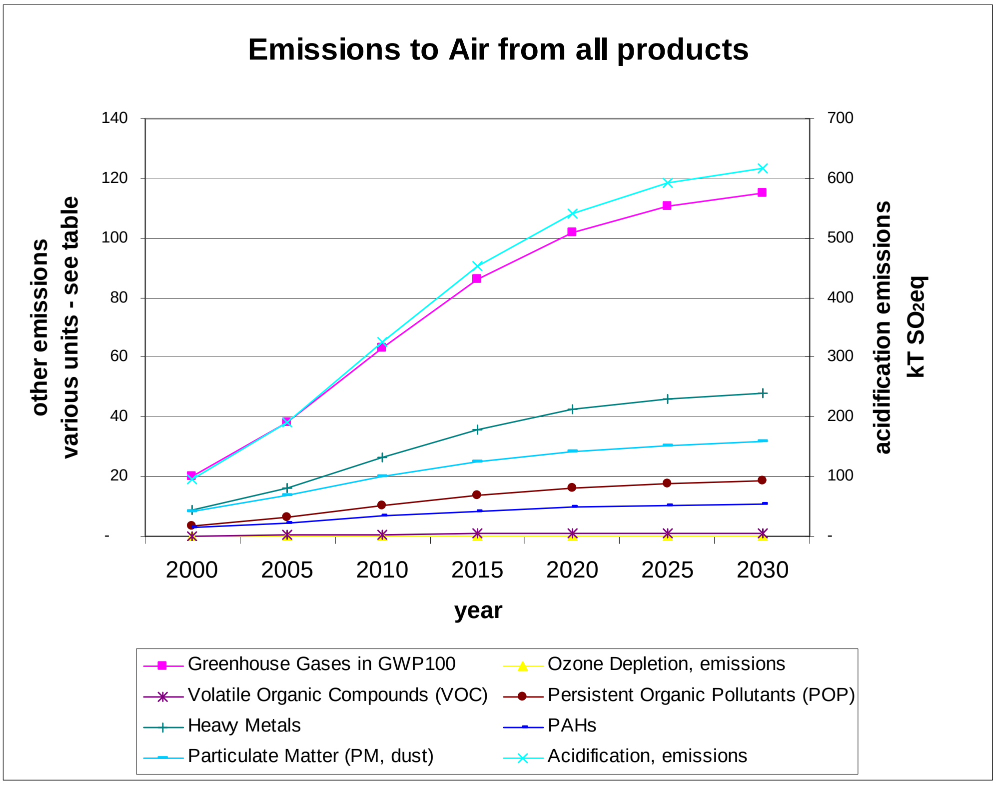


Annual emissions to air arising from all RAC units are shown in Table 5-26 and Figure 5-16.

Table 5-26: Annual emissions to air arising from all RAC units

Emissions to air	2000	2005	2010	2015	2020	2025	2030
Greenhouse Gases in GWP 100 [Mt CO2eq]	20	38	63	86	102	111	115
Ozone depletion, emissions [t R11eq]	-	-	-	-	-	-	-
Acidification, emissions, [kt SO2eq]	95	190	325	454	542	591	616
Volatile Organic Compounds (VOC), [kt]	0	0	1	1	1	1	1
Persistent Organic Pollutants (POP), [g i-Teq]	3	6	10	14	16	18	18
Heavy Metals, [ton Ni eq.]	9	16	27	36	42	46	48
PAHs, [ton Ni eq.]	3	5	7	8	10	10	11
Particulate Matter (PM, dust) [kt]	8	14	20	25	29	31	32

Figure 5-16: Annual emissions to air arising from all RAC units



Annual emissions to water arising from all RAC units are shown in the table and figure herafter.

Figure 5-17: Annual emissions to water arising from all RAC units

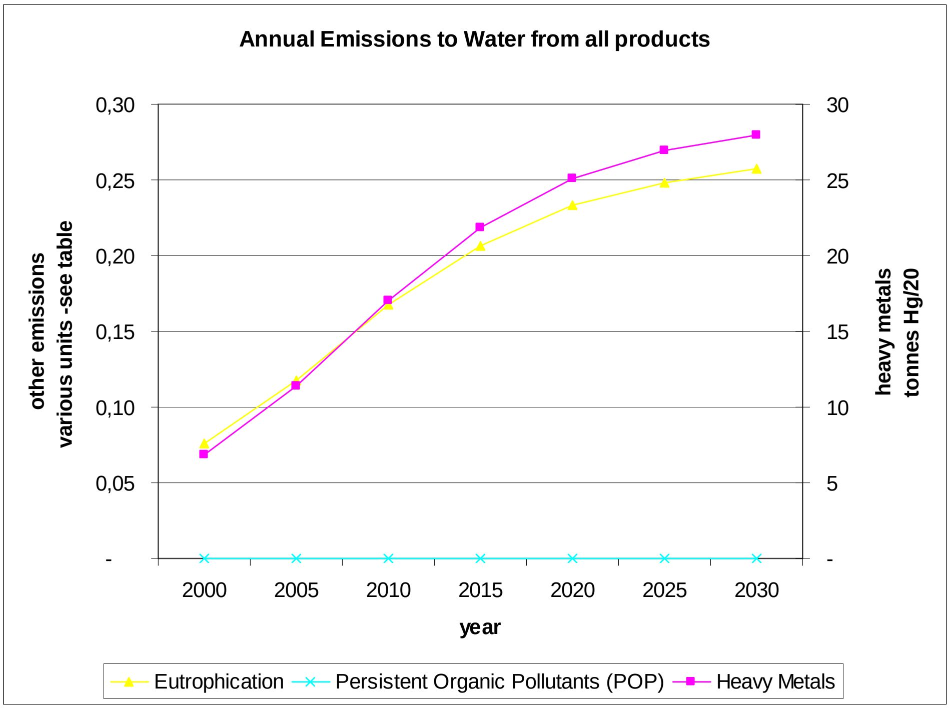


Table 5-27: Annual emissions to water arising from all RAC units

Emissions to water	2000	2005	2010	2015	2020	2025	2030
Heavy Metals, [ton Hg/20]	7	11	17	22	25	27	28
Eutrophication, [kt PO4]	0,08	0,12	0,17	0,21	0,23	0,25	0,26
Persistent Organic Pollutants (POP), [g i-Teq]	-	-	-	-	-	-	-

Finally Table 5-28 shows information about the annual cost of RAC units.

Table 5-28: Annual total costs associated with RAC unit

Costs	2000	2005	2010	2015	2020	2025	2030
Product price	3 355	5 011	6 812	8 118	9 036	9 564	9 909
Installation/acquisition costs	4 540	6 651	8 871	10 386	11 410	11 988	12 377
Fuel (gas, oil, wood)	-	-	-	-	-	-	-
Electricity	4 600	9 576	16 624	23 274	27 743	30 226	31 430
Water	-	-	-	-	-	-	-
Aux. 1: None	-	-	-	-	-	-	-
Aux. 2: None	-	-	-	-	-	-	-
Aux. 3: None	-	-	-	-	-	-	-
Repair & maintenance costs	150	294	467	613	719	798	849
Total	14 645	21 532	32 774	42 390	48 908	52 575	54 564

Conclusion

Amongst the 3 main categories identified, 5 base cases have been defined, one single duct to represent moveable air conditioners, two for cooling only split air conditioners and two for reversible split products with respective sizes of 3.5 and 7.1 kW cooling capacity in order to represent the segments 0 to 6 kW and 6 to 12 kW. Average product characteristics are identified on the basis of a statistic analysis of available technical databases. These characteristics are to be used in the following tasks to study the potential for improvement.

The energy efficiency of these products are defined as follows :

- single duct unit: EER 2.3
- reversible split 3.5 kW: EER 3.1, COP 3.4
- cooling only split 3.5 kW: EER 2.9
- reversible split 7.1 kW: EER 2.8, COP 3.3
- cooling only split 7.1 kW: EER 2.5

The most important part of environmental impacts occurs during the use phase because of energy consumption. In average, 81 % of CO2 emissions are linked to the energy use for moveables, 65 % for cooling only and 89 % for reversible air conditioners. Refrigerant losses account for non negligible part of the total impact concerning CO2 emissions.

The total impact of the stock of installed products is increasing rapidly. Electricity consumption (use phase) is estimated to grow from approximately 32 TWh to more than 200 TWh. The cooling part is about 30 % of these figures, the heating function being the major contributor.

Total energy consumption of the stock of products increases until 2030 but growth declines after 2020 because of the saturation effect in the market modelling and because of the introduction of new buildings with lower heating energy demand.

Appendix A: Base case determination for cooling only and reversible Single split [0-6kW]

Data sources

The Eurovent-Certification programme is a trans-national AC energy performance-certification programme. The managing body, Eurovent Certification, is a business association created specifically for the purpose. This is a branch of the manufacturers association Eurovent-Cecomaf, which covers the following types of air conditioners (single split package, multi split package and window/wall units). By participating in the Eurovent-Certification scheme and allowing their products to be independently tested, manufacturers are allowed to use the Eurovent Certification label and they have also the right to include their products in the annual Eurovent product directory, which is published online for consultants and installers. This directory constitutes the first database; it contains all the declared products. The participation of EU brands to this program is generally relatively high, around 90 % as an average (EECCAC, 2003). However, this figure may vary according to the programs and also to the National markets. For products certified by Eurovent and then published in the Eurovent directory, every model is not tested. Equipment to be tested is independently selected by Eurovent Certification (not by the manufacturer) and then tested independently. In order to ensure true comparability and reproducibility of the test results all equipment are tested in a single designated test centre. Because, there is always a risk that some manufacturers certify only their best equipment, Eurovent has moved, following a similar move by their American counterpart, ARI, to a "Certify All" policy wherein a manufacturer can only report performance data of equipment BEING ALL certified (in a given certification program) if he wants to claim the benefits of its participation to the Eurovent scheme. The technical features of the models tested by Eurovent Certification are gathered in the technical database. Of course, this second database contains less models than the Eurovent directory but information is very detailed on the characteristics of each model.

Thus, the determination of the single split package model base cases is based on two databases from Eurovent (the Eurovent directory and the technical database). The Eurovent directory is used as often as possible since it contains all the products declared by manufacturers. Unfortunately, when it comes to determine accurate technical features, this database is not adequate and then the technical database – with fewer models - is used. Table 1 summarizes available information in both Eurovent databases.

Table 1: Comparison between contained information in Eurovent databases

Technical characteristics	Eurovent directory	Technical database
Cooling capacity	X	X
EER	X	X
Heating capacity	X	X
COP	X	X
Air or water cooled	X	X
Current information (Voltage, Frequency, phase)	X	X
Refrigerant weight		X
Refrigerant weight (refrigerant link)		X
Weight of the indoor and outdoor units		X
A weighted power sound	X	X
Fan type (indoor and outdoor coils)		X
Row pitch (indoor and outdoor coils)		X
Tube pitch (indoor and outdoor coils)		X
Fin spacing (indoor and outdoor coils)		X
Tube outside diameter (indoor and outdoor coils)		X
Type of tube (indoor and outdoor coils)		X
Type of fins (indoor and outdoor coils)		X
Dimensions of the indoor and outdoor coils		X
Number of circuits (indoor and outdoor coils)		X

Indoor air flow rate		X
Compressor model number and manufacturer		X
Type of expansion valve		X

From these databases, distributions and regressions have been extracted to determine the characteristics of an average model.

When using distributions, the “modes” are selected and not the average values because they represent types that are the most likely to be found on the European market.

Determination of cooling capacities

Based on BSRIA figures, it appears that 38.5% of the mono-split units sold in 2002 have a cooling capacity between 0 and 3.5 kW and 64% between 0 and 5kW (see Figure 3). It is concluded that the most common cooling capacities in Europe are within this last range (0-5kW) which should be accurately studied to determine the features of an average mono-split model. On the other hand it is admitted that regarding room air conditioners, the actual trend benefits the small capacity models (Figure 4). It is furthermore assumed that in 2006, an even more important part of sold conditioners has a cooling capacity lower than 5kW.

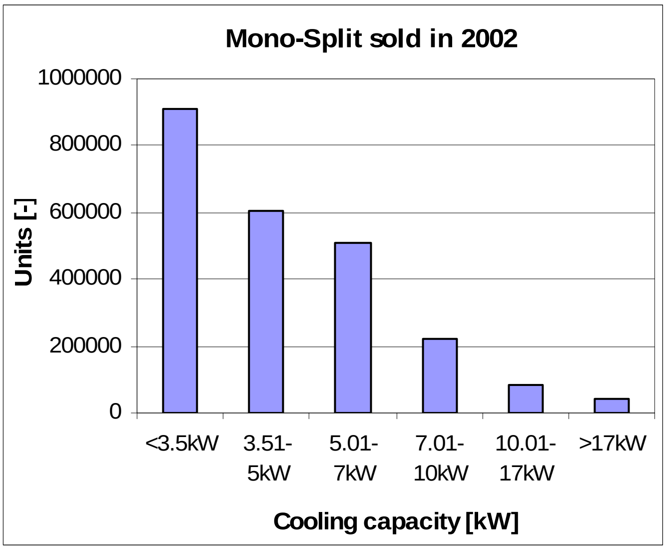


Figure 3. 2002 sales according to the cooling capacity (BSRIA)

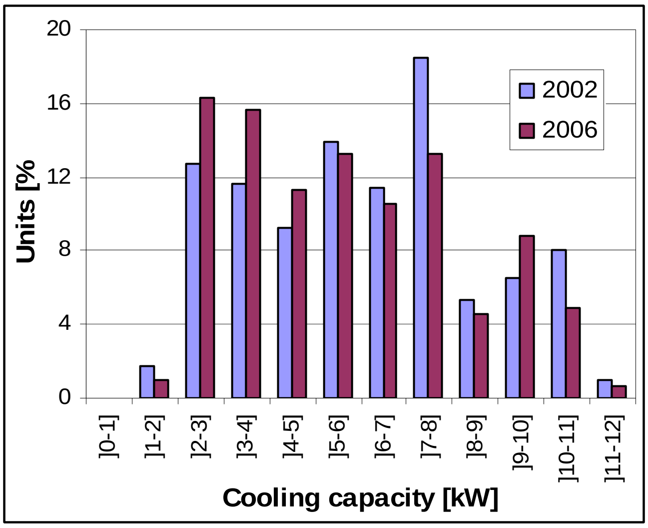


Figure 4. Comparison between listed mono-split units in the 2002 and 2006 Eurovent directories [0-12kW].

From the 2006 directory, more accurate distributions are figured out in terms of cooling capacity both for reversible and cooling only mono-splits (Figure 5 and 6). It appears that both for reversible and cooling only units, the "mode" is in the interval: [3.4kW-3.6kW[. Thus, only this interval has been studied hereafter and the following values are assumed to be characteristic of both average models:

$$Pc_{cooling\_only} = 3.5kW$$
$$Pc_{reversible} = 3.5kW$$

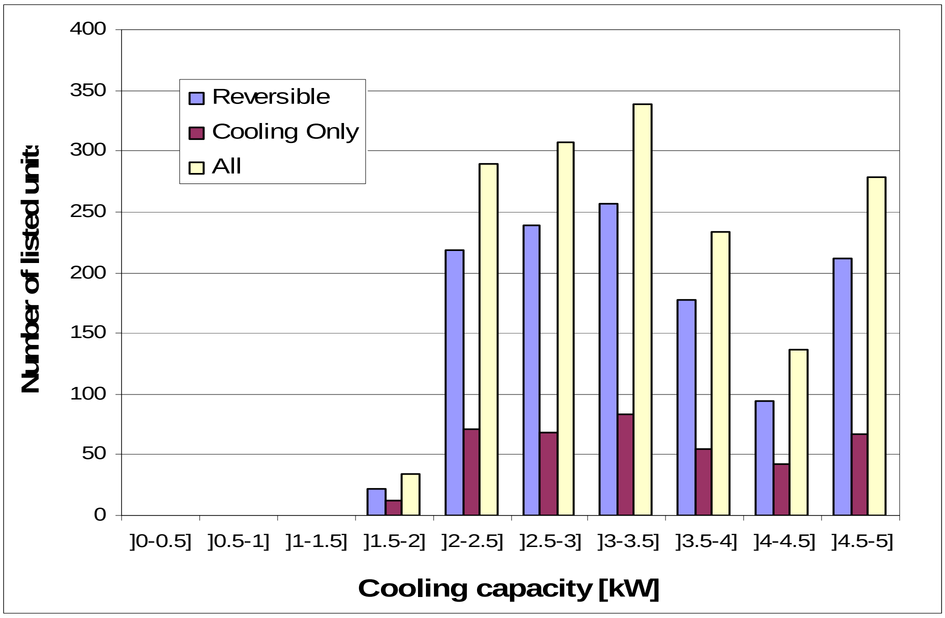


Figure 5. Number of listed mono-splits in the 2006 Eurovent directory according to their cooling capacity

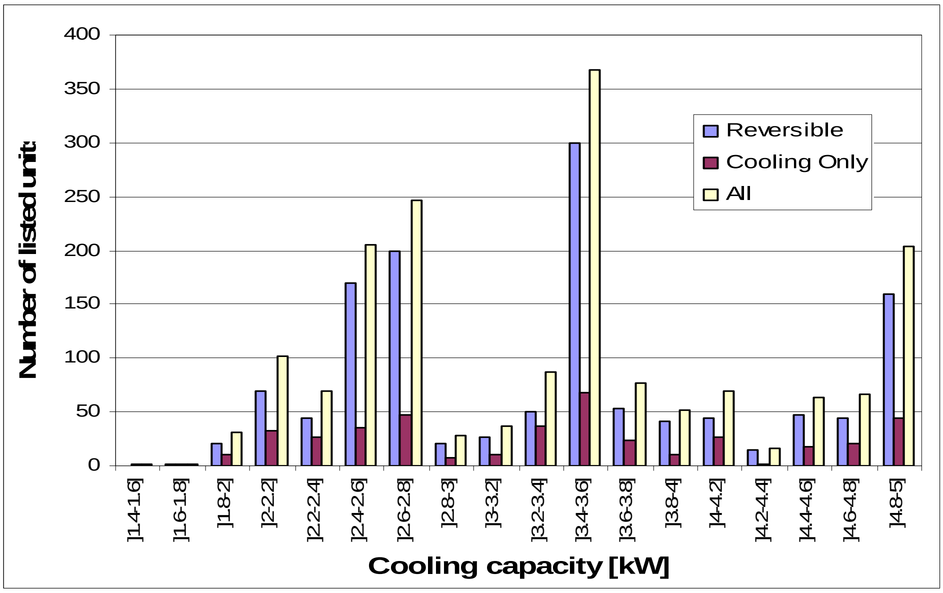


Figure 6. Number of listed mono-splits in the 2006 Eurovent directory according to their cooling capacity

Determination of Energy Efficiency Ratios

From the 2006 directory, a distribution is figured out according to the Energy Efficiency Ratio both for reversible and cooling only mono-splits whose cooling capacity is between 3.4 and 3.6kW (Figure 7). It appears that the mode differs between reversible (EER within]3.2-3.4]) and cooling only units(EER within]2.8-3]).Thus, the following values are assumed to be characteristic of both average models:

$$EER_{cooling\_only} = 2.9$$
$$EER_{reversible} = 3.3$$

According to manufacturers, the energy efficiency ratio (EER) was too high and did not match with the real market. They claimed the sales would be much larger on low EER (class C for example) than on high EER because of higher purchase costs even if less types of models are proposed by manufacturers.

Taking into account the comments of manufacturers of the second stakeholder meeting and trying to achieve a compromise, we propose to determine the efficiency ratios based on models whose cooling capacity is between 3 and 4 kW. In this way, the average of EER on the [3kW-4kW] range has been figured out and the following value is kept for the reversible base case:

$$EER_{reversible} = 3.1$$

Several companies participating to the Eurovent program are intended to provide us with sale figures. This will enable to compare sales weighted average to our figures that are based on the number of different models declared by manufacturers to Eurovent.

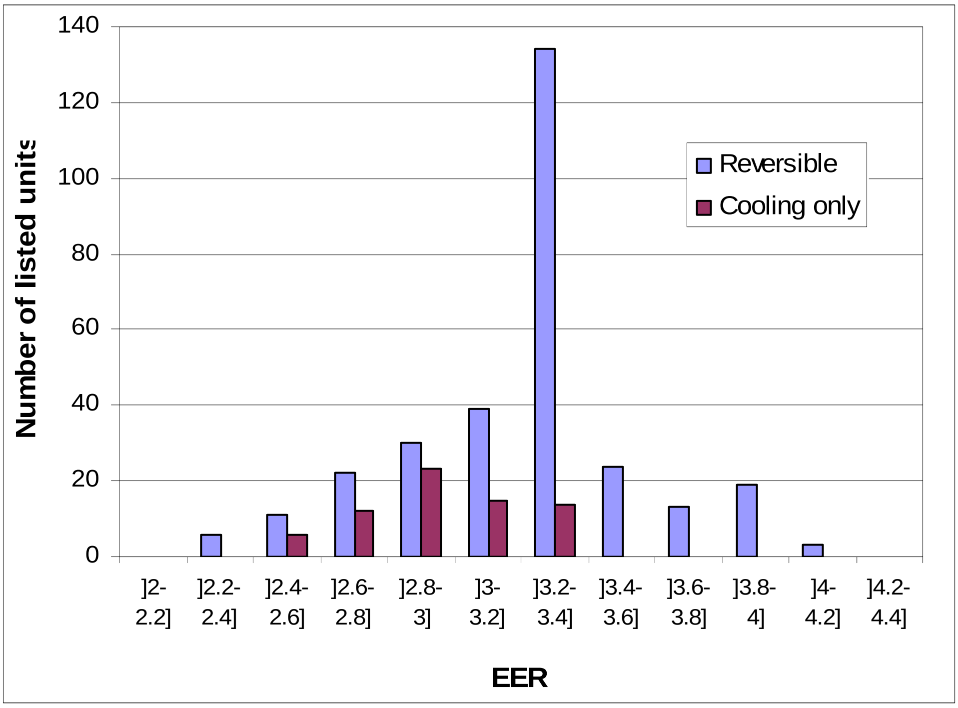


Figure 7. Number of listed units (whose cooling capacity is between 3.4 and 3.6 kW) in the Eurovent 2006 directory according to the EER

Determination of heating performances of the average reversible mono-split unit

Regarding reversible mono-split units, distributions according to COP and heating capacity have been plotted (Figure 8a) and 8b)). The following values are kept as representative of European reversible mono-split:

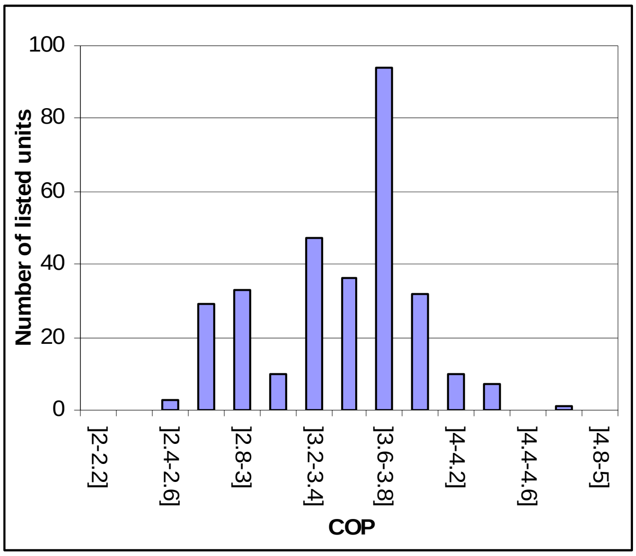
$$Ph_{reversible} = 4kW$$
$$COP = 3.7$$

According to manufacturers, the COP was too high and did not match with the real market. They claimed the sales would be much larger on low COP (class C for example) than on high COP because of higher purchase costs even if less types of models are proposed by manufacturers.

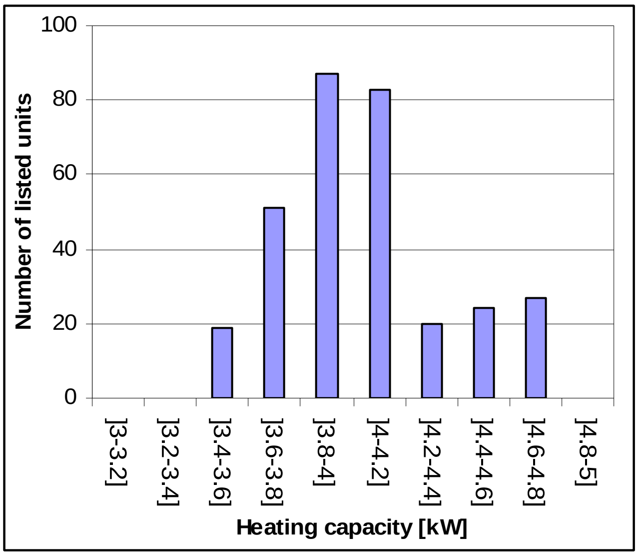
Taking into account the comments of manufacturers of the second stakeholder meeting and trying to achieve a compromise, we propose to determine the efficiency ratios based on models whose cooling capacity is between 3 and 4 kW. In this way, the average of COP on the [3kW-4kW] range has been figured out and the following value is kept for the reversible base case:

$$COP = 3.4$$

Several companies participating to the Eurovent program are intended to provide us with sale figures. This will enable to compare sales weighted average to our figures that are based on the number of different models declared by manufacturers to Eurovent.



a)



b)

Figure 8. Number of listed units (whose cooling capacity is between 3.4 and 3.6 kW) in the Eurovent 2006 directory according to the COP (a) and heating capacity (b).

Condensation type

The average models are **air-cooled** since no other type of model has been found in the Eurovent database. Regarding current information, more than 98% of the models included in the Eurovent database have the following characteristics:

$$\begin{aligned} &Voltage = 230\,V \\ &1\,phase \\ &Frequency = 50\,Hz \end{aligned}$$

Refrigerant fluids

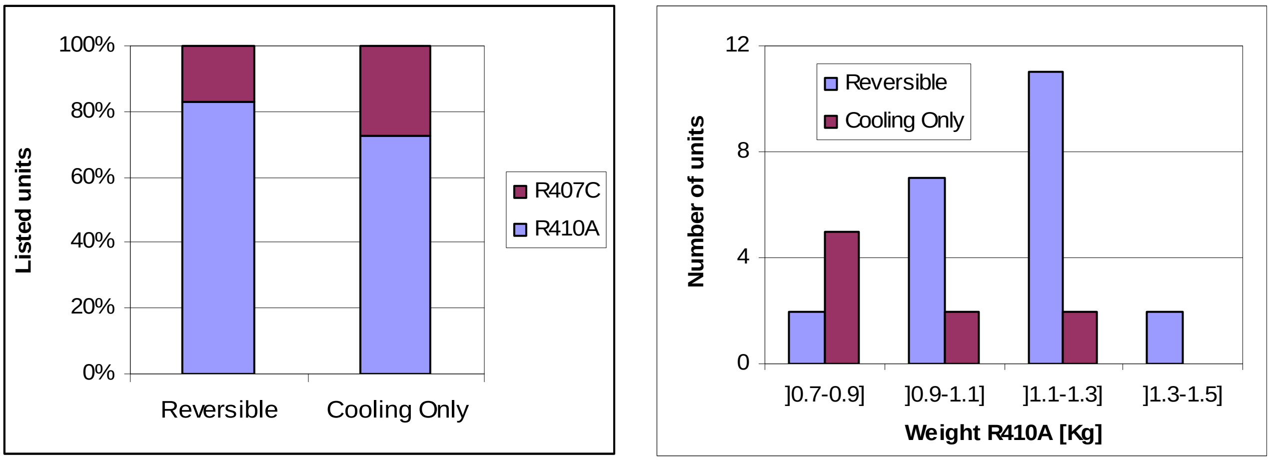
Within the category of mono-split whose cooling capacities are between 3.4 and 3.6 kW, the most common refrigerant is R410A both for reversible and cooling only units (Figure9a)). Regarding the weight of refrigerant, the technical database is analyzed. The analysis is based on 16 cooling only units and 29 reversible ones whose cooling capacity is comprised between 3 and 4kW (Figure9b)). It is not possible to focus only on the 3.4-3.6kW range because of the lack of data. Eventually, two different values are kept for reversible and cooling only appliances:

$$\begin{aligned} &Weight_{reversible\_R410A} = 1.2kg \\ &Weight_{cooling\_only\_R410A} = 0.8kg \end{aligned}$$

It is noticeable in Figure 8 that both values are representative for mono split systems both for cooling only and reversible.

Regarding the length of the refrigerant line, two values can be found on the Eurovent technical database: 5m and 7.5m. About 90% of the reversible units and 93% of the cooling only ones have a refrigerant line of 7.5m. As a result this value is kept for the average models.

$$Lenght_{refrigerant\_line} = 7.5m$$



a) b)

Figure 9. a) R410A and R407C shares in mono-split units [3.4-3.6] kW (Eurovent directory)

b) Distribution of mono-split units whose cooling capacity is within 3 and 4 kW in terms of weight of R410A (Eurovent technical database)

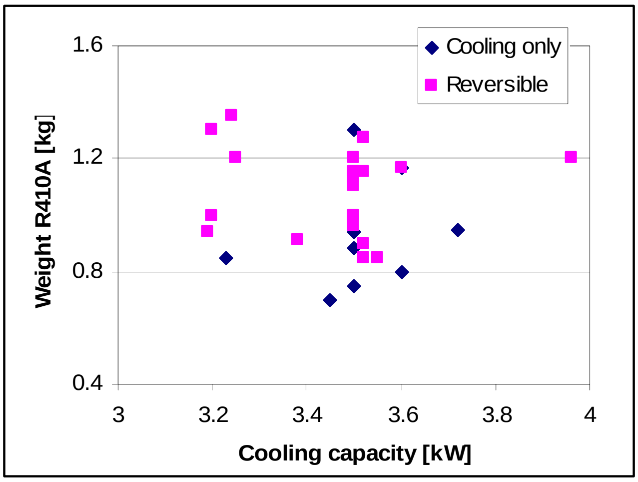


Figure 10. Weight of R410A in mono-split units according to their cooling capacity

Indoor unit characteristics

First of all, in the 3-4kW range, about 70% of the mono-split listed in the Eurovent directory are equipped with **wall mounted indoor units** (Figure 11). It is therefore assumed that both average models are equipped with this kind of indoor unit.

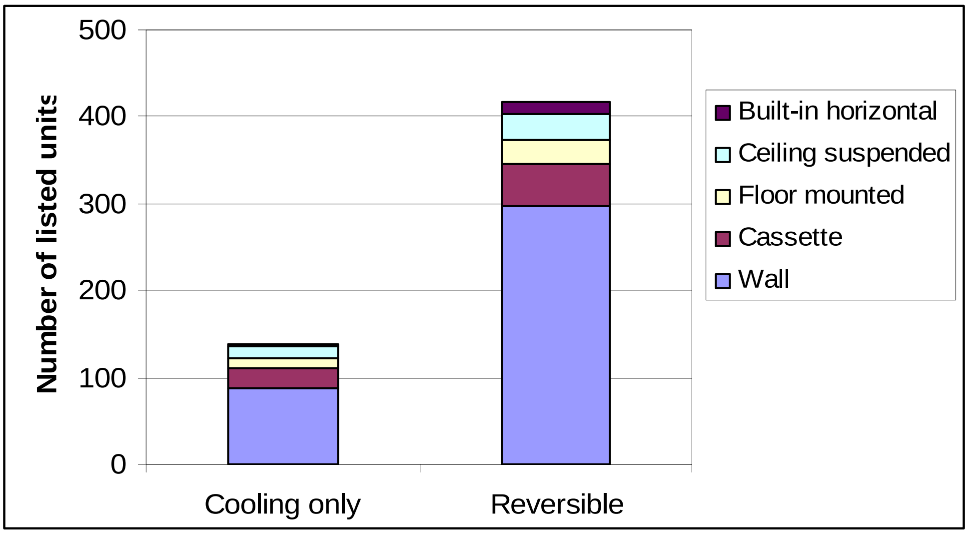


Figure 11 Types of indoor unit for mono-split models whose cooling capacity is within 3 and 4 kW (Eurovent 2006)

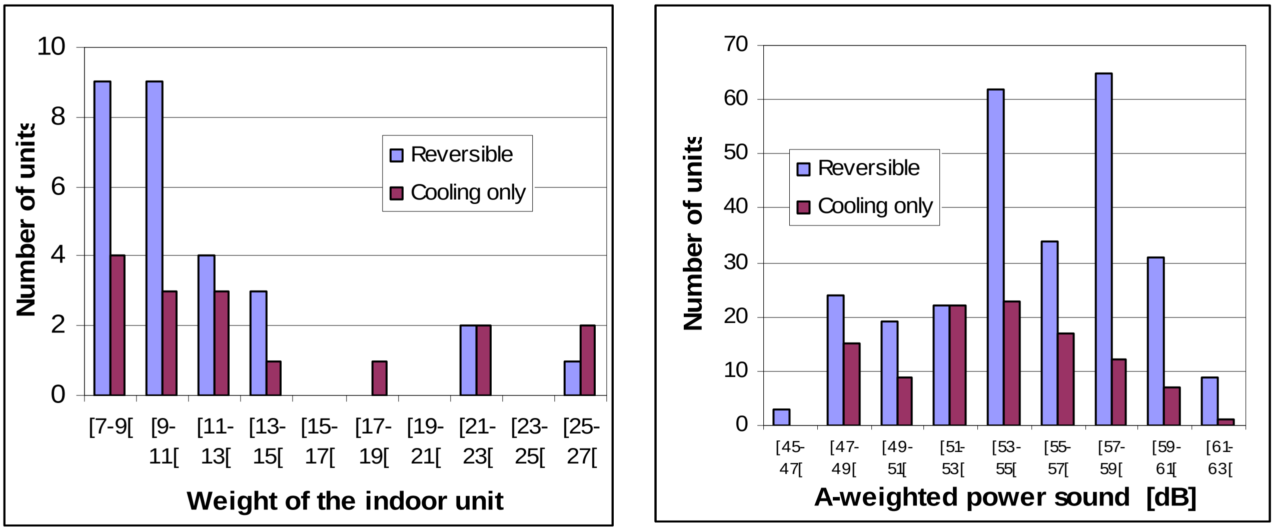
The distribution of the indoor unit weight has been plotted from the Eurovent technical database (Figure 12a)) for mono-split whose cooling capacity is within 3 and 4 kW. A value of 9 kg seems reliable to characterize both average models.

$$\boxed{Weight_{indoor} = 9\,kg}$$

In the Eurovent technical database all the mono split whose cooling capacity is within 3 and 4 kW have a non ducted indoor unit, as a result **both average systems will not be indoor ducted**.

Regarding the sound generated by the indoor unit, the Eurovent directory has been used. Finally the distribution according to the A-weighted power sound has been plotted (Figure 12b)) and it appears that 53 dB can be kept as a typical value for cooling only units and 55 dB for reversible ones.

$$\boxed{\begin{array}{l} A - weighted\_power\_sound_{reversible\_indoor\_unit} = 55\,dB \\ A - weighted\_power\_sound_{cooling-only\_indoor\_unit} = 53\,dB \end{array}}$$



a) b)

Figure 12 a) Distribution of mono-split units whose cooling capacity is within 3 and 4 kW according to the weight of the indoor unit (Eurovent 2006)
b) Distribution of mono-split units whose cooling capacity is within 3 and 4 kW according to the A-weighted sound power (Eurovent 2006)

In the Eurovent technical database most of the mono split that are equipped with a wall mounted unit and whose cooling capacity is within 3 and 4 kW blow the air thanks to a **centrifugal fan**. This type of device is kept for both reversible and cooling only average models.

Regarding more accurately the indoor coil, 87% of the cooling only listed models and 90% of the reversible ones have **two rows.**

$$Number_{rows} = 2$$

Tube pitch, row pitch, tube outside diameter and fin spacing do not depend on the capacity neither on the EER. All these features are presented on Figure 11 and their values according to cooling capacity and EER on Figure 14 and 15. The following values are considered as representative of the low capacity mono splits:

$$Pitch_{row} = 13.2mm$$
$$Pitch_{tube} = 20.5mm$$
$$Spacing_{fin} = 1.37mm$$
$$Outside\_Diameter_{tube} = 7mm$$

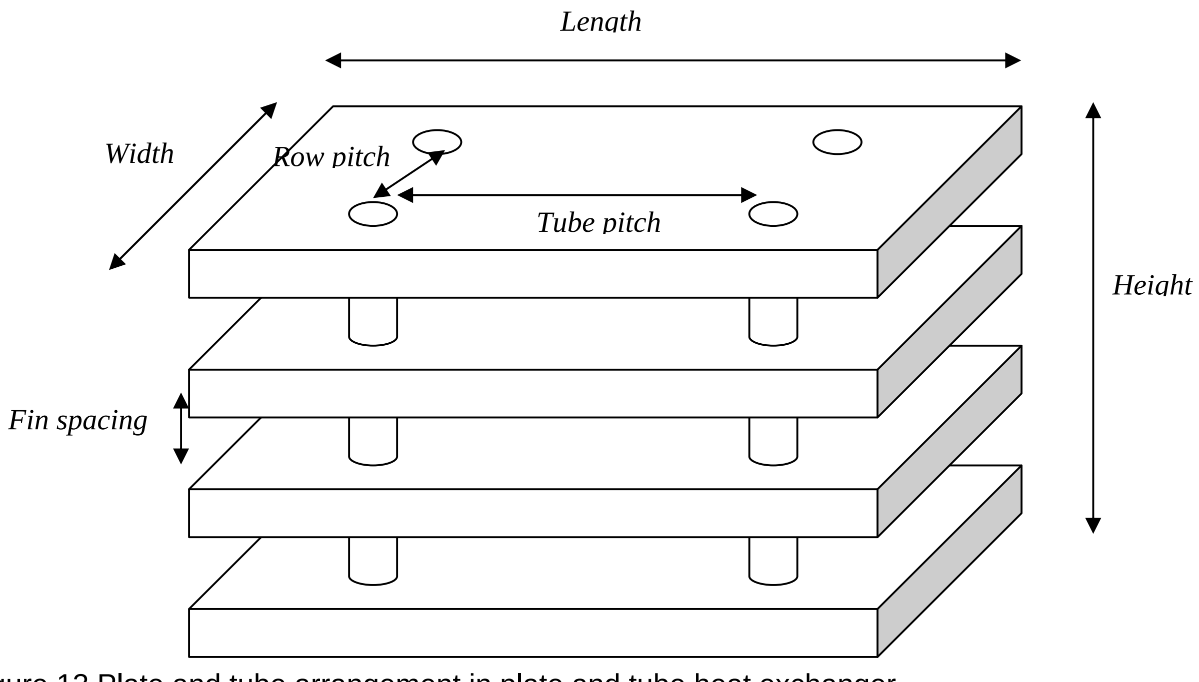


Figure 13 Plate and tube arrangement in plate and tube heat exchanger

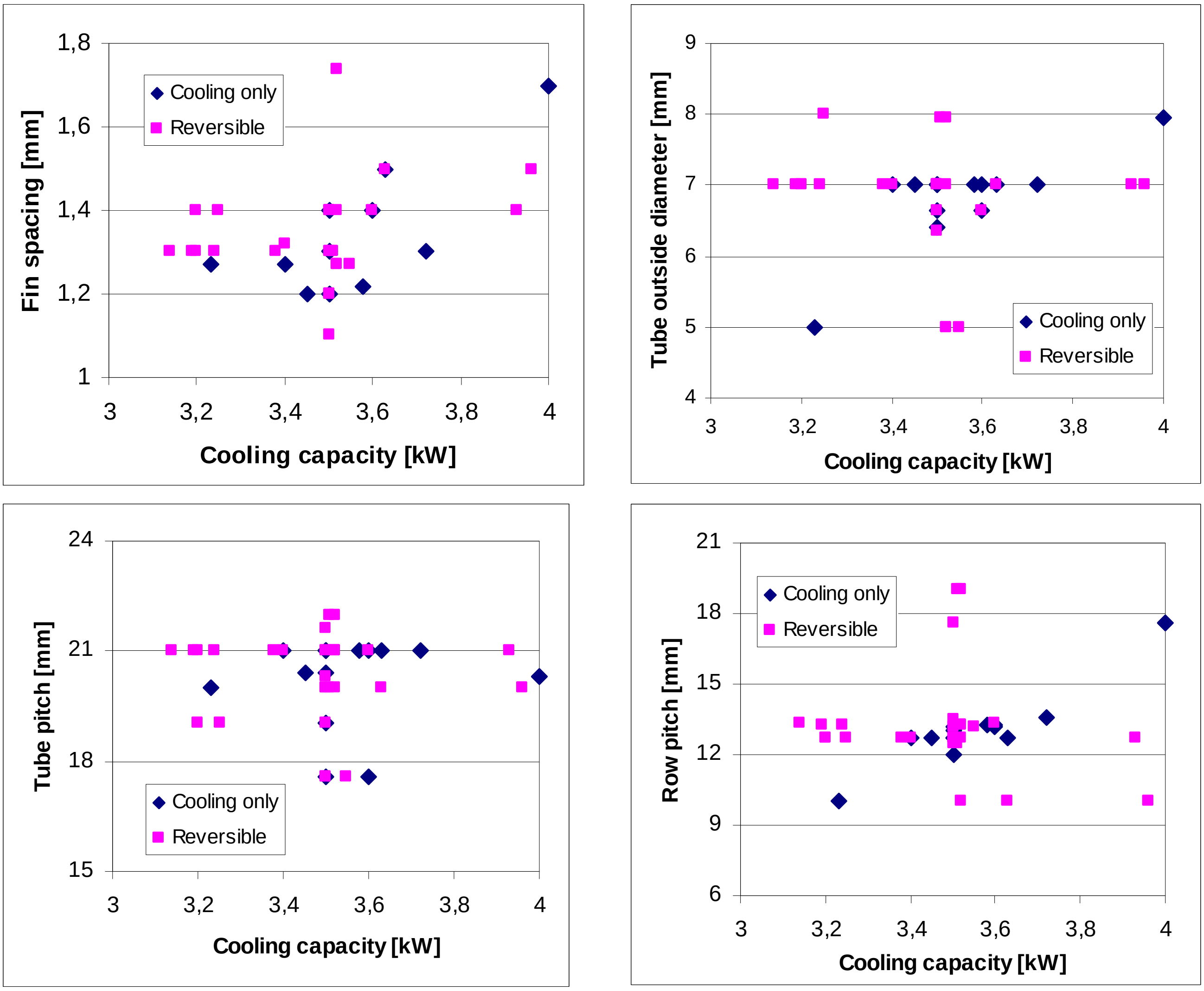
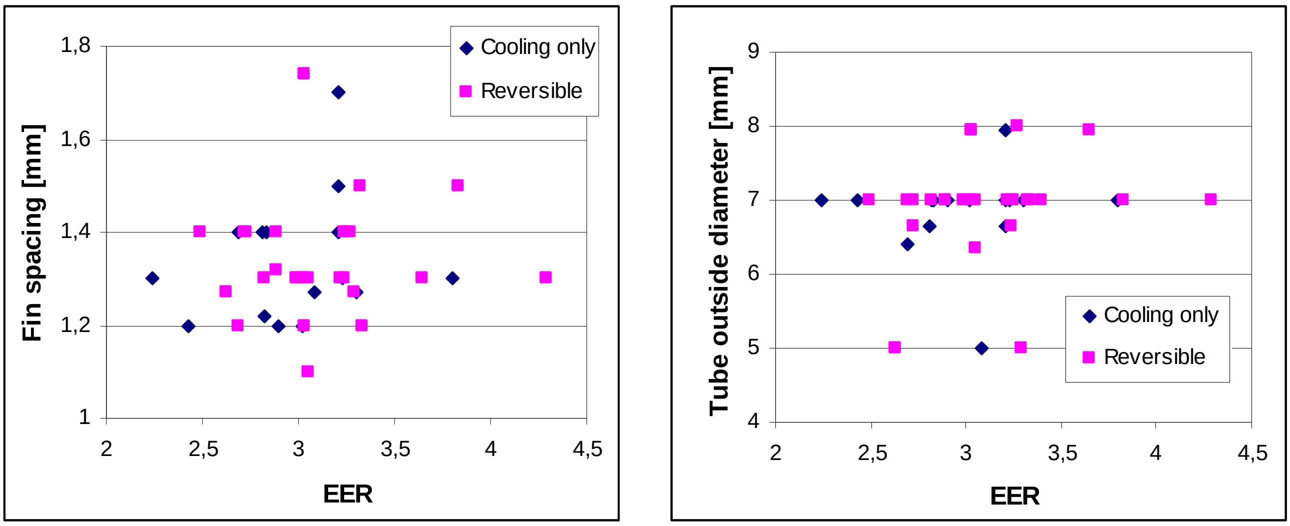
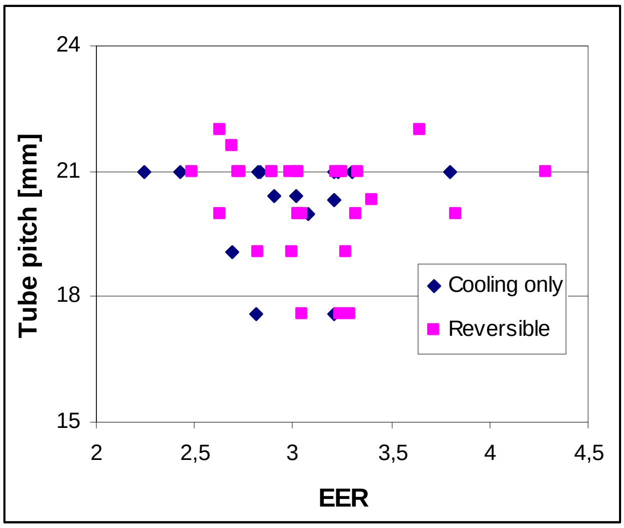


Figure 14 Fin spacing, tube outside diameter, tube pitch and row pitch of mono-split units' indoor coil according to the cooling capacity (Eurovent 2006)





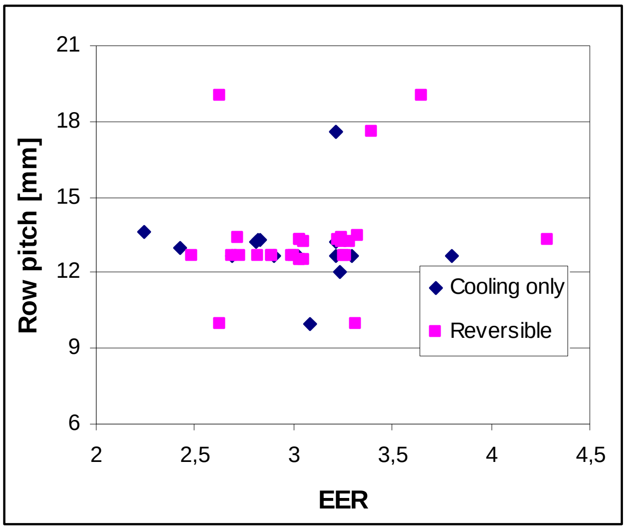


Figure 15 Fin spacing, tube outside diameter, tube pitch and row pitch of mono-split units' indoor coil according to the EER (Eurovent 2006)

In the Eurovent technical database, most of the mono-splits (reversible or cooling only) with a cooling capacity between 3 and 4 kW are equipped with **louvered fins** (indoor coil) and with **grooved tubes** (see Table 2 and 3). As a result these two characteristics are kept for the average model.

Type of fins	Cooling only [3kW-4kW] (number of listed units in the technical database)	Reversible [3kW-4kW] (number of listed units in the technical database)
Louvered	13	23
Corrugated	2	1
Flat	1	1
Louvered-Wavy	0	3
Louvered-Corrugated	0	1

Table 2 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of fins in the indoor coil

Type of tube	Cooling only [3kW-4kW] (number of listed units in the technical database)	Reversible [3kW-4kW] (number of listed units in the technical database)
Grooved	18	29
Not indicated	1	0

Table 3 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of tube in the indoor coil

Regarding dimensions, indoor coils are very similar whatever the capacity between 3 and 4kW (Figure 16), the following values are considered as representative ones both for reversible and cooling only units:

$$Length_{Plate} = 290\ mm$$
$$Heigth_{Coil} = 660\ mm$$
$$Width_{Plate} = 31\ mm$$

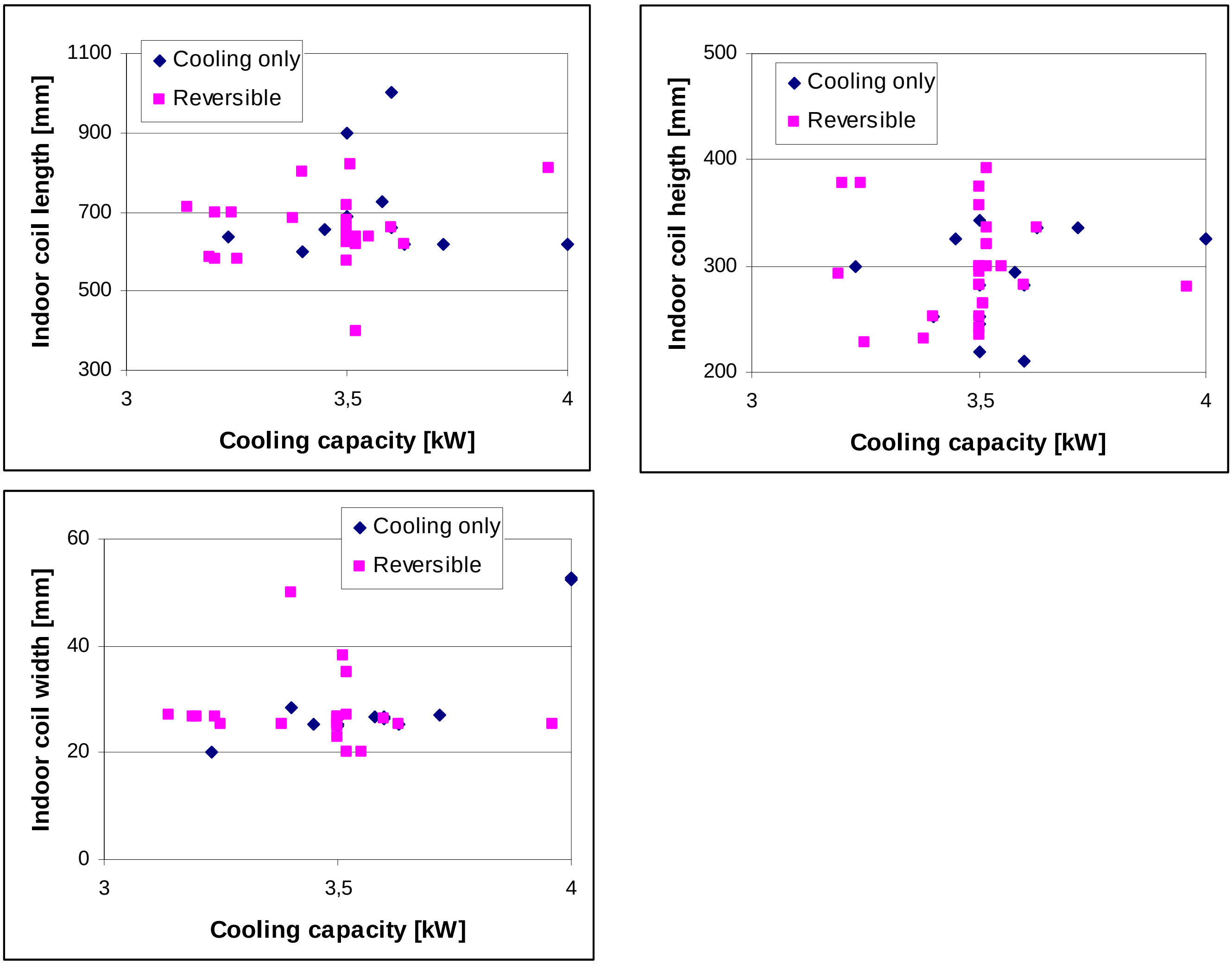


Figure 16 Dimensions of mono-split units' indoor coil according to the cooling capacity (Eurovent 2006)

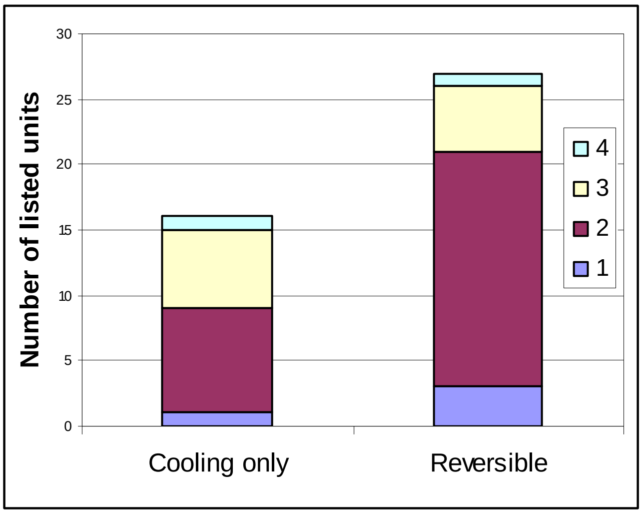


Figure 17 Number of circuits (indoor coil) of mono-split units according to the cooling capacity (Eurovent 2006)

The number of circuits for the indoor coil is set to 2, which is considered as a representative value for this range of capacity (Figure 17).

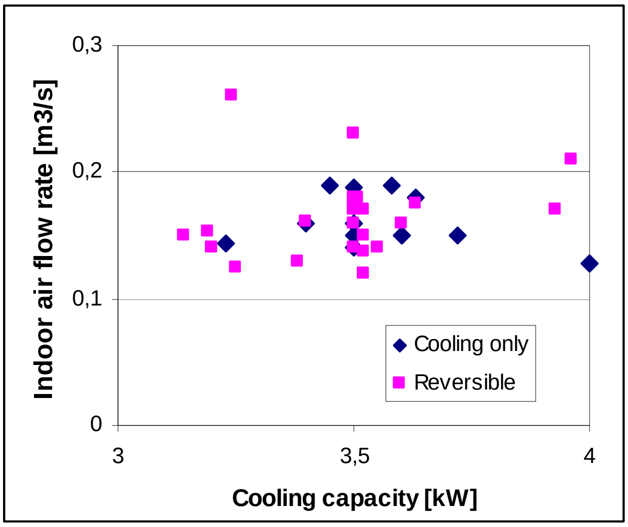


Figure 18 Indoor air flow rate (indoor coil) of mono-split units according to the cooling capacity (Eurovent 2006)

The indoor air flow rate depends on the capacity (Figure 18). For a 3kW capacity, a value of $0.15m^3/s$ is considered as representative.

$$Airflow_{indoor} = 0.15 m^3 / s$$

All the indoor coil characteristics have been determined and it became possible to define the evaporator surface. Equation 1 is used to roughly calculate the evaporator surface from the technical values previously defined.

$$Surface_{exchanger} = 2n.Length_{Plate}.Width_{Plate} - n\pi T \frac{Diameter_{Tube}^{2}}{2} \quad (1)$$

Where T is the number of tubes:

$$T = \frac{Length_{Plate}}{Pitch_{Tube}} \cdot Number_{rows} \quad (2)$$

and n the number of plates:

$$n = \frac{Height_{Coil}}{Spacing_{Fin}} \quad (3)$$

Finally, by using the values already defined:

$$Surface_{evaporator} = 8.6 m^2$$

This is a representative value for mono split systems both for cooling only and reversible (Figure 19 and 20). Outliers (surface higher than 14 m^2) are due to values that have been probably wrongly filled in the database. For example there is a model whose evaporator surface is about 17 m^2. This value is very uncommon, compared with other studied mono-split, and can be explained by the fact that the plate width is 144 mm whereas common values are about 20-40 mm. As a result, mistakes are probably present in the Eurovent databases and results must be cautiously taken into consideration.

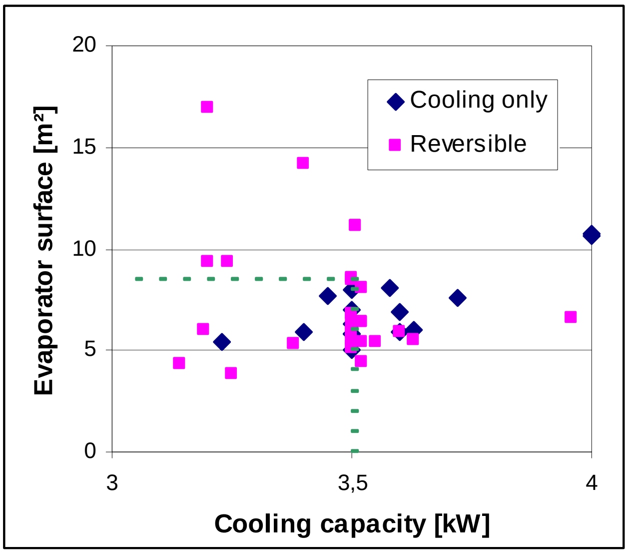


Figure 19 Evaporator surface (indoor coil) of mono-split units according to the cooling capacity

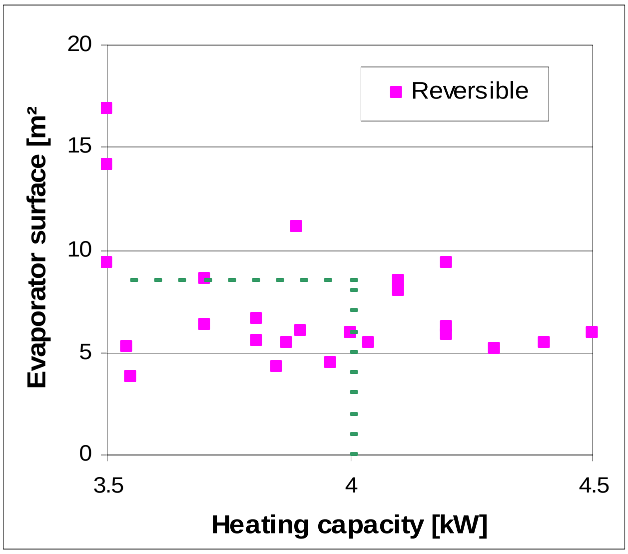


Figure 20 Evaporator surface (indoor coil) of mono-split units according to the heating capacity

Outdoor unit characteristics

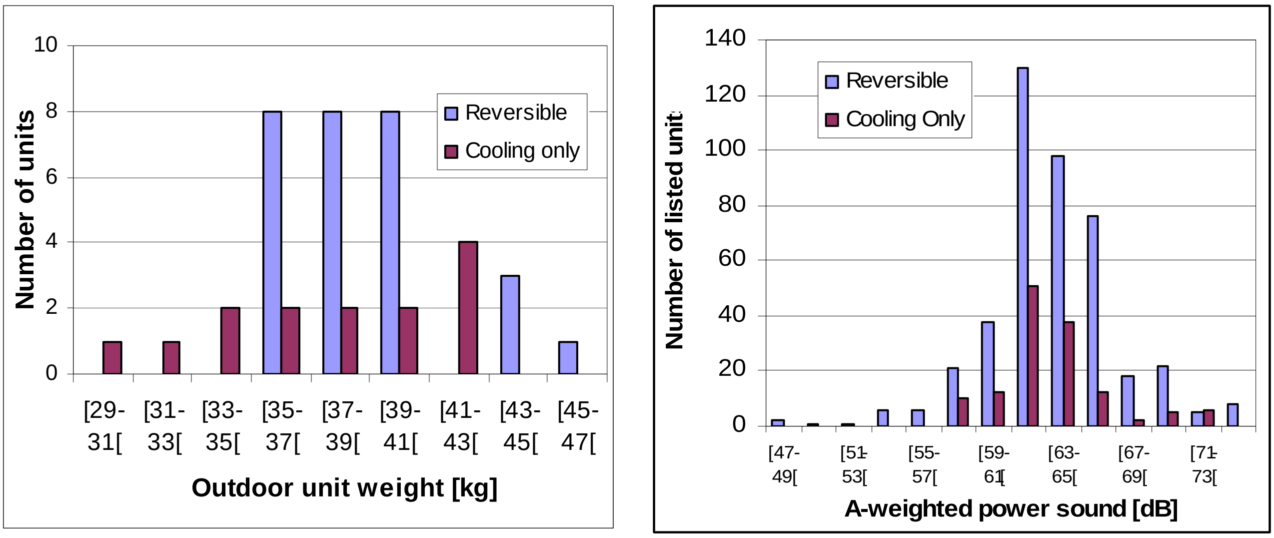
The distribution of the outdoor unit weight has been plotted from the Eurovent technical database (Figure 21) for mono-split whose cooling capacity is within 3 and 4 kW. A value of 9 kg seems reliable to characterize both average models.

$$Weight_{outdoor} = 37\,kg$$

In the Eurovent technical database all the mono split whose cooling capacity is within 3 and 4 kW have a non ducted outdoor unit, as a result **both average systems will not be outdoor ducted**.

Regarding the sound generated by the outdoor unit, the Eurovent directory has been used. Finally the distribution according to the A-weighted power sound has been plotted (Figure21b)) and it appears that 62 dB can be kept as a typical value for cooling only units and reversible ones.

$$A-weighted\_power\_sound_{reversible\_indoor\_unit} = 62\,dB$$
$$A-weighted\_power\_sound_{cooling-only\_indoor\_unit} = 62\,dB$$



a) b)

Figure 21 a) Distribution of mono-split units whose cooling capacity is within 3 and 4 kW according to the weight of the outdoor unit (Eurovent 2006)
b) Distribution of mono-split units whose cooling capacity is within 3 and 4 kW according to the A-weighted sound power (Eurovent 2006)

In the Eurovent technical database most of the mono split whose cooling capacity is within 3 and 4 kW have an **axial fan** (also named **propeller fan**). This type of device is kept for both reversible and cooling only average models.

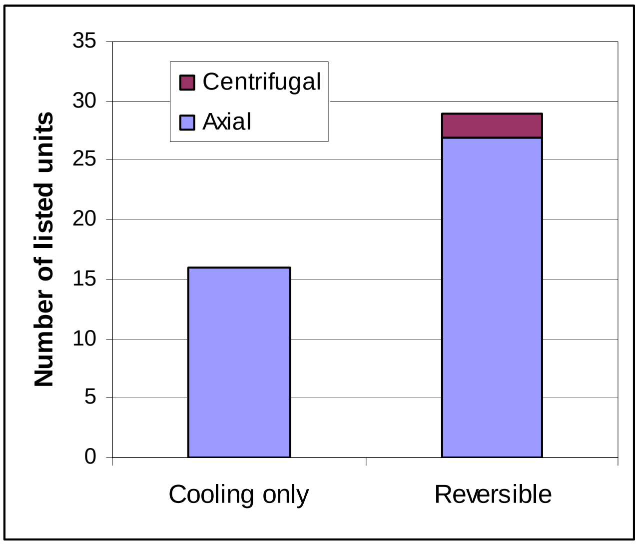


Figure 22 Kind of outdoor fans for mono-split units [3-4kW] (Eurovent 2006)

Regarding more accurately the indoor coil, 80% of the cooling only listed models and 100% of the reversible ones have **two rows.**

Tube pitch, row pitch, tube outside diameter and fin spacing do not depend on the capacity neither on the EER. All these features are presented on Figure 10 and their values according to cooling capacity and EER on Figure 23. The following values are considered as representative of the low capacity mono split:

$$
\begin{aligned}
Pitch_{row} &= 25\,mm \\
Pitch_{tube} &= 18\,mm \\
Spacing_{fin} &= 1.5\,mm \\
Outside\_Diameter_{tube} &= 7\,mm
\end{aligned}
$$

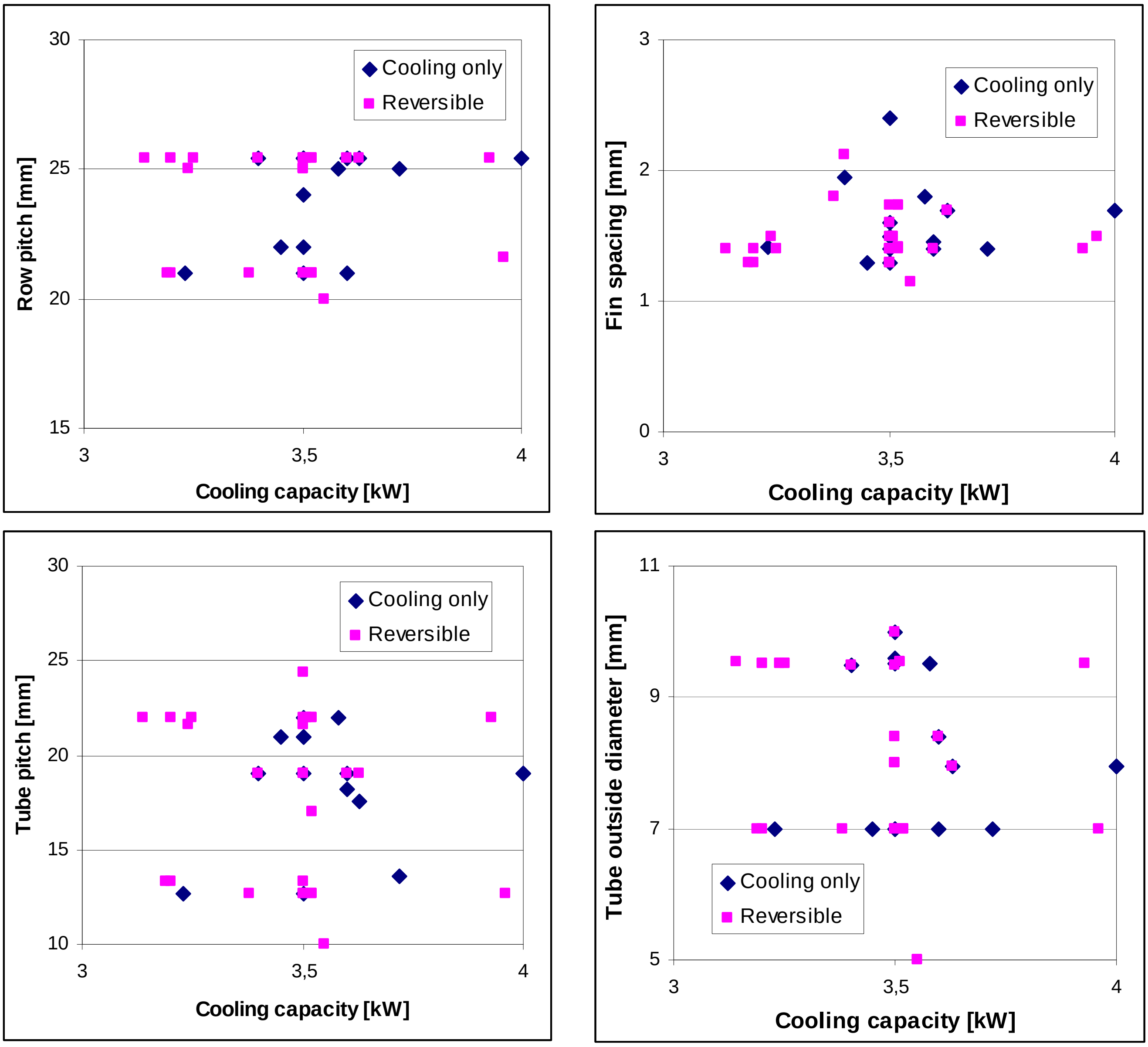


Figure 23 Fin spacing, tube outside diameter, tube pitch and row pitch of mono-split units' outdoor coil according to the cooling capacity (Eurovent 2006)

In the Eurovent technical database, most of the mono-splits (reversible or cooling only) with a cooling capacity between 3 and 4 kW are equipped with **louvered fins** (indoor coil) and with **grooved tubes** (see Table 4 and 5). As a result these two characteristics are kept for the average model.

Type of fins	Cooling only [3kW-4kW] (number of listed units in the technical database)	Reversible [3kW-4kW] (number of listed units in the technical database)
Louvered	10	14
Corrugated	3	3
Flat	3	9
Louvered-Wavy	0	3
Louvered-Corrugated	0	1

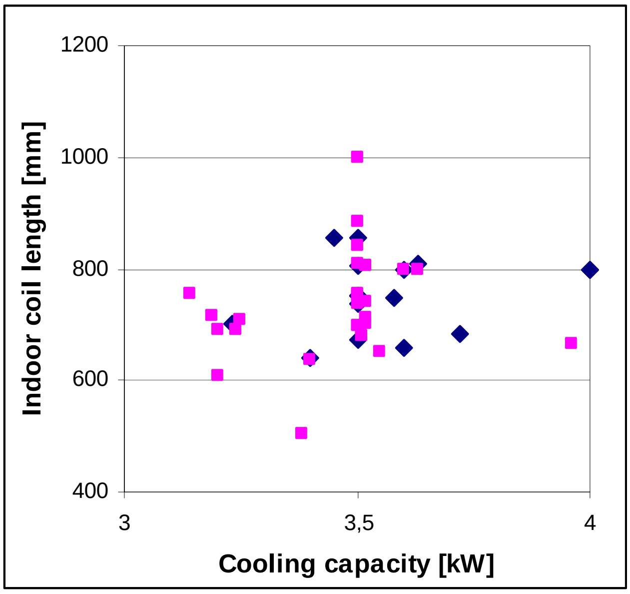
Table 4 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of fins in the outdoor coil

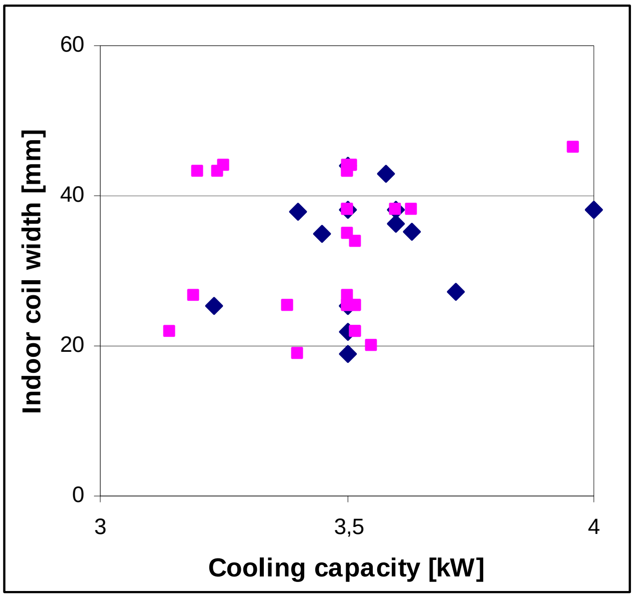
Type of tube	Cooling only [3kW-4kW] (number of listed units in the technical database)	Reversible [3kW-4kW] (number of listed units in the technical database)
Grooved	14	28
Smooth	1	1
Not indicated	1	0

Table 5 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of tube in the outdoor coil

Regarding dimensions, outdoor coils are very similar whatever the capacity (between 3 and 4kW), the following values are considered as representative ones both for reversible and cooling only units:

$$Length_{Plate} = 530\ mm$$
$$Heigth_{Coil} = 750\ mm$$
$$Width_{Plate} = 30\ mm$$





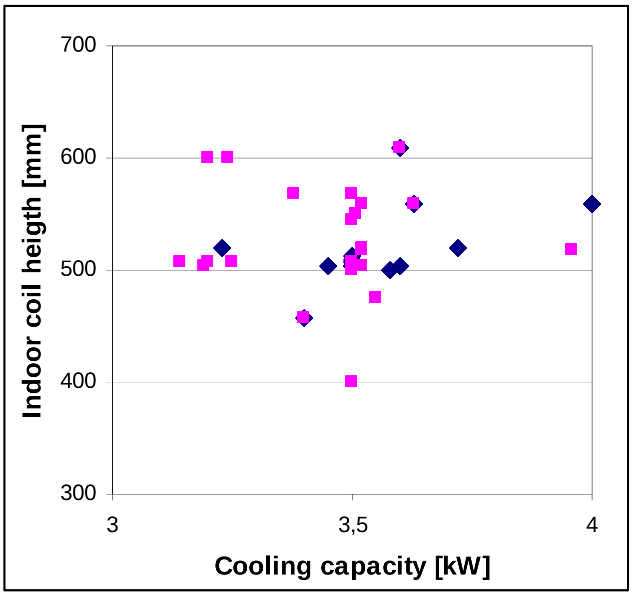


Figure 23 Dimensions of mono-split units' outdoor coil according to the cooling capacity (Eurovent 2006)

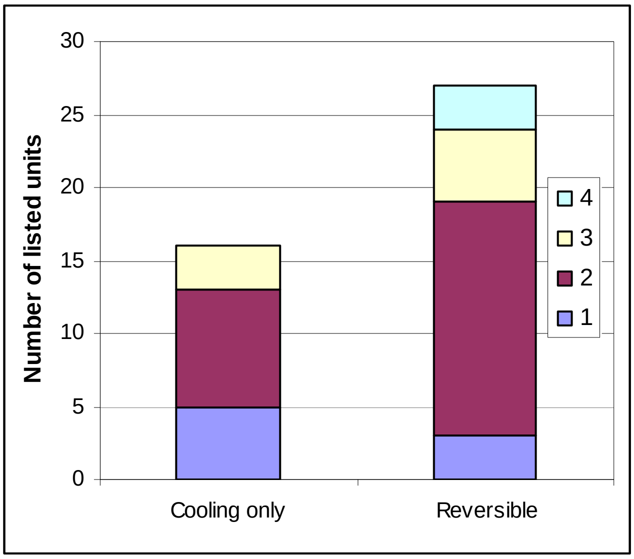


Figure 24 Number of circuits (outdoor coil) of mono-split units according to the cooling capacity (Eurovent 2006)

The number of circuits for the outdoor coil is set to 2, which is considered as a representative value for this range of capacity (Figure 24).

All the outdoor coil characteristics have been determined; based on Equation 1 it became possible to define the condenser surface:

$$Surface_{evaporator} = 14.3 m^2$$

This is a representative of an average mono split model (Figure 25 and 26).

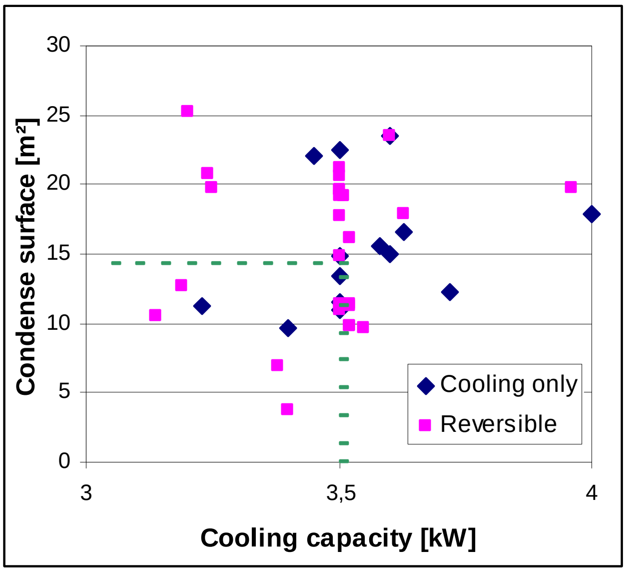


Figure 25 Condenser surface (outdoor coil) of mono-split units according to the cooling capacity

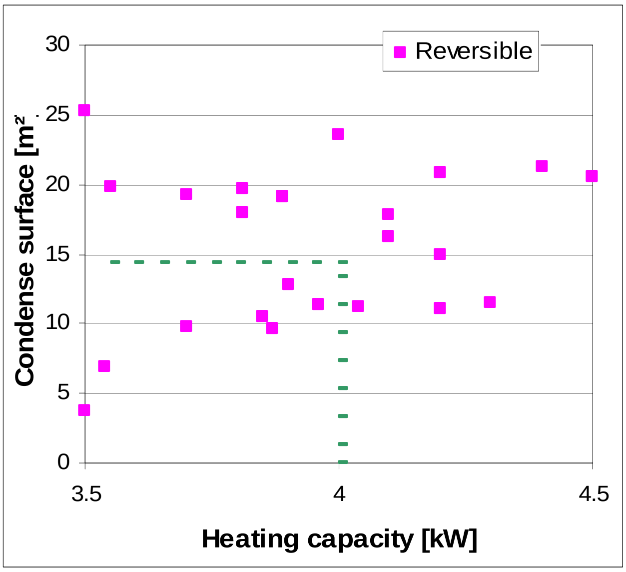


Figure 26 Condenser surface (outdoor coil) of mono-split units according to the heating capacity

Compressor characteristics

The Eurovent database only includes the compressor model numbers. More information regarding performances, crank heaters has been looked for but few information has been found. In this interval of capacity (3-4kW), it seems that **rotary** are the only compressors used. For low capacity, crankcase heaters seem very present, both average models are fit up with a crankcase heater of **70W**.

Expansion valve characteristics

According to the technical Eurovent database (Figure 27), the **capillary expansion valve** is the most frequently used. Our average model is supposed to be equipped with this.

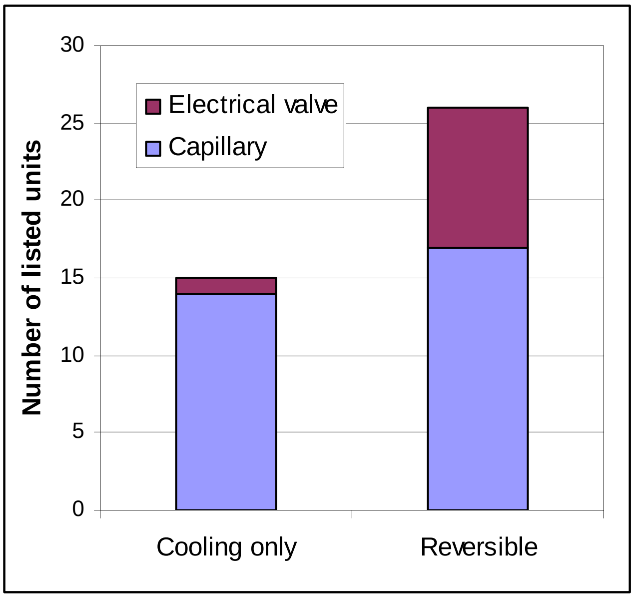


Figure 27. Type of expansion valve for Mono-Split whose cooling capacity is within 3 and 4 kW (Eurovent 2006)

Final base case description

Two typical models have been determined, a single split package cooling only air conditioner and a reversible one. Both models characteristics are summarized in Table 6 and 7 hereunder. Manufacturers are invited to comment these results.

General description	Type	Reversible Mono-Split
	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	3.5 kW
	EER	3.1
Heating performances	Heating capacity	4 kW
	COP	3.4
Fluid	Type	R410A
	Charge	1.2 kg
Indoor coil	Tube type	Grooved
	Fins type	Louvered
	Evaporator surface	8.5 m²
	Fan type	Centrifugal
Outdoor coil	Tube type	Grooved
	Fins type	Louvered
	Condenser surface	14.3 m²
	Fan type	Axial
Compressor	Type	Rotary
	Crank heater	Yes (70W)
Expansion device	Type	Capillary

Table 6 Main technical features of the reversible single split air conditioner

General description	Type	Cooling only Mono-Split
	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	3.5 kW
	EER	2.9
Fluid	Type	R410A
	Charge	0.8 kg
Indoor coil	Tube type	Grooved
	Fins type	Louvered
	Evaporator surface	8.5 m²
	Fan type	Centrifugal
Outdoor coil	Tube type	Grooved
	Fin type	Louvered
	Condenser surface	14.3 m²
	Fan type	Axial
Compressor	Type	Rotary
	Crank heater	Yes (70W)
Expansion device	Type	Capillary

Table 7 Main technical features of the cooling only single split air conditioner

Appendix B: Definition of base case models for "cooling only" and "reversible" single split air conditioners of the 6-12kW range

Data sources

The Eurovent-Certification programme is a trans-national AC energy performance-certification programme. The managing body, Eurovent Certification, is a business association created specifically for the purpose. This is a branch of the manufacturers association Eurovent-Cecomaf, which covers the following types of air conditioners (single split package, multi split package and window/wall units). By participating in the Eurovent-Certification scheme and allowing their products to be independently tested, manufacturers are allowed to use the Eurovent Certification label and they have also the right to include their products in the annual Eurovent product directory, which is published online for consultants and installers. This directory constitutes the first database; it contains all the declared products. The participation of EU brands to this program is generally relatively high, around 90 % as an average (EECCAC, 2003). However, this figure may vary according to the programs and also to the National markets. For products certified by Eurovent and then published in the Eurovent directory, every model is not tested. Equipment to be tested is independently selected by Eurovent Certification (not by the manufacturer) and then tested independently. In order to ensure true comparability and reproducibility of the test results all equipment are tested in a single designated test centre. Because, there is always a risk that some manufacturers certify only their best equipment, Eurovent has moved, following a similar move by their American counterpart, ARI, to a "Certify All" policy wherein a manufacturer can only report performance data of equipment BEING ALL certified (in a given certification program) if he wants to claim the benefits of its participation to the Eurovent scheme. The technical features of the models tested by Eurovent Certification are gathered in the technical database. Of course, this second database contains less models than the Eurovent directory but information is very detailed on the characteristics of each model.

Thus, the determination of the single split package model base cases is based on two databases from Eurovent (the Eurovent directory and the technical database). The Eurovent directory is used as often as possible since it contains all the products declared by manufacturers. Unfortunately, when it comes to determine accurate technical features, this database is not adequate and then the technical database – with fewer models - is used. Table 1 summarizes available information in both Eurovent databases.

Table1: Comparison between contained information in Eurovent databases

Technical characteristics	Eurovent directory	Technical database
Cooling capacity	X	X
EER	X	X
Heating capacity	X	X
COP	X	X
Air or water cooled	X	X
Current information (Voltage, Frequency, phase)	X	X
Refrigerant weight		X
Refrigerant weight (refrigerant link)		X
Weight of the indoor and outdoor units		X
A weighted power sound	X	X
Fan type (indoor and outdoor coils)		X
Row pitch (indoor and outdoor coils)		X
Tube pitch (indoor and outdoor coils)		X
Fin spacing (indoor and outdoor coils)		X
Tube outside diameter (indoor and outdoor coils)		X
Type of tube (indoor and outdoor coils)		X
Type of fins (indoor and outdoor coils)		X
Dimensions of the indoor and outdoor coils		X

Number of circuits (indoor and outdoor coils)		X
Indoor air flow rate		X
Compressor model number and manufacturer		X
Type of expansion valve		X

From these databases, distributions and regressions have been extracted to determine the characteristics of an average model.

When using distributions, the “modes” are selected and not the average values because they represent types that are the most likely to be found on the European market.

Determination of cooling capacities

From the 2006 Eurovent directory, distributions of the standard cooling capacity in the new range, both for reversible and cooling only single splits (Figure 1) are extracted. It appears that for both reversible and cooling only units, the “mode” is in the interval: [7 kW-7.2 kW[. Thus, attention is focused hereafter on the air conditioners with cooling capacity within this interval and the following values are proven to be characteristic the new base cases:

$$Pc_{reversible} = 7.1kW$$

$$Pc_{cooling\_only} = 7.1kW$$

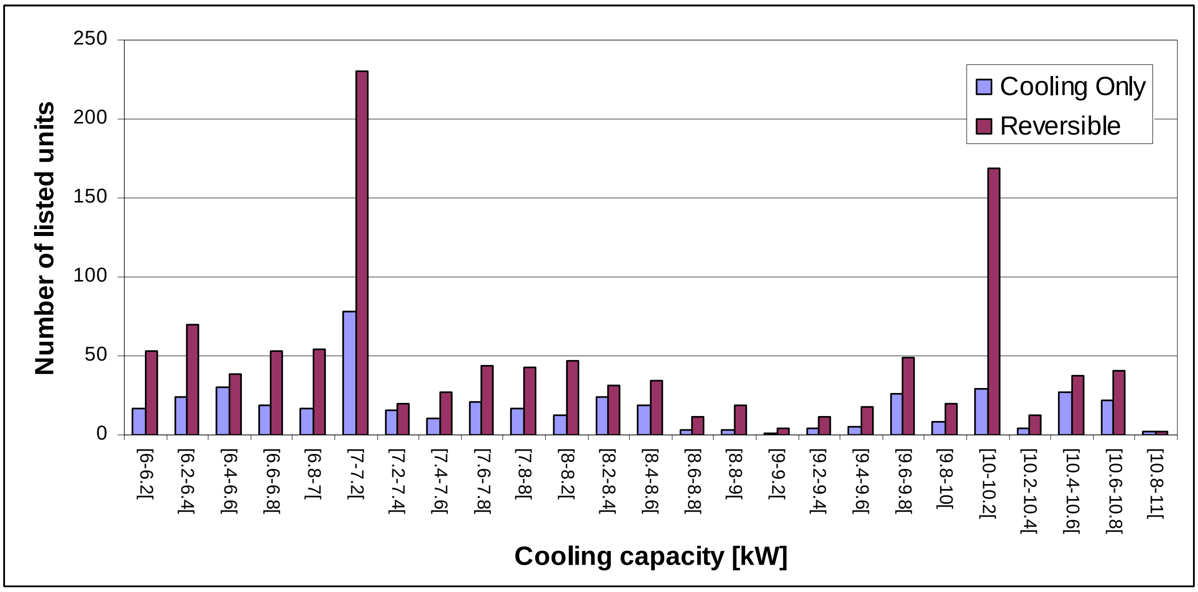


Figure 1: Number of listed single splits in the 2006 Eurovent directory according to their cooling capacity

Determination of EER (Energy Efficiency Ratio)

From the 2006 directory, the distribution of the Energy Efficiency Ratio in standard conditions both for reversible and cooling only single splits whose cooling capacity lies between 7 and 7.2 kW is shown in Figure 2. It appears that the mode differs between reversible having their EER within the interval]2.6-3] and cooling only units having their EER within the range]2.4-2.6].Thus, the following values are assumed to be characteristic of the two average models:

$$EER_{reversible} = 2.8$$
$$EER_{cooling\_only} = 2.5$$

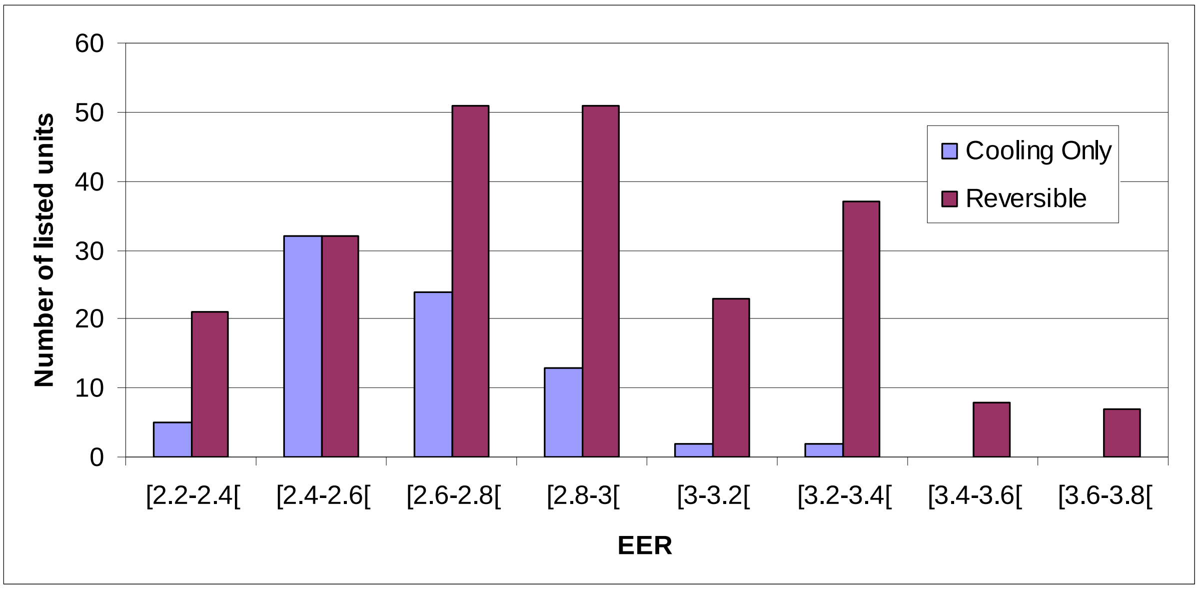


Figure 2: EER of listed units with cooling capacity lying between 7 and 7.2 kW in the Eurovent 2006 directory.

Determination of heating performance of the average reversible single split unit

Regarding reversible single split units, distributions according to COP and heating capacity have been plotted in Figure 3 left and right. The following values are kept as representative of European reversible single split air conditioner:

$$COP_{reversible} = 3.3$$

$$Ph_{reversible} = 8.1 kW$$

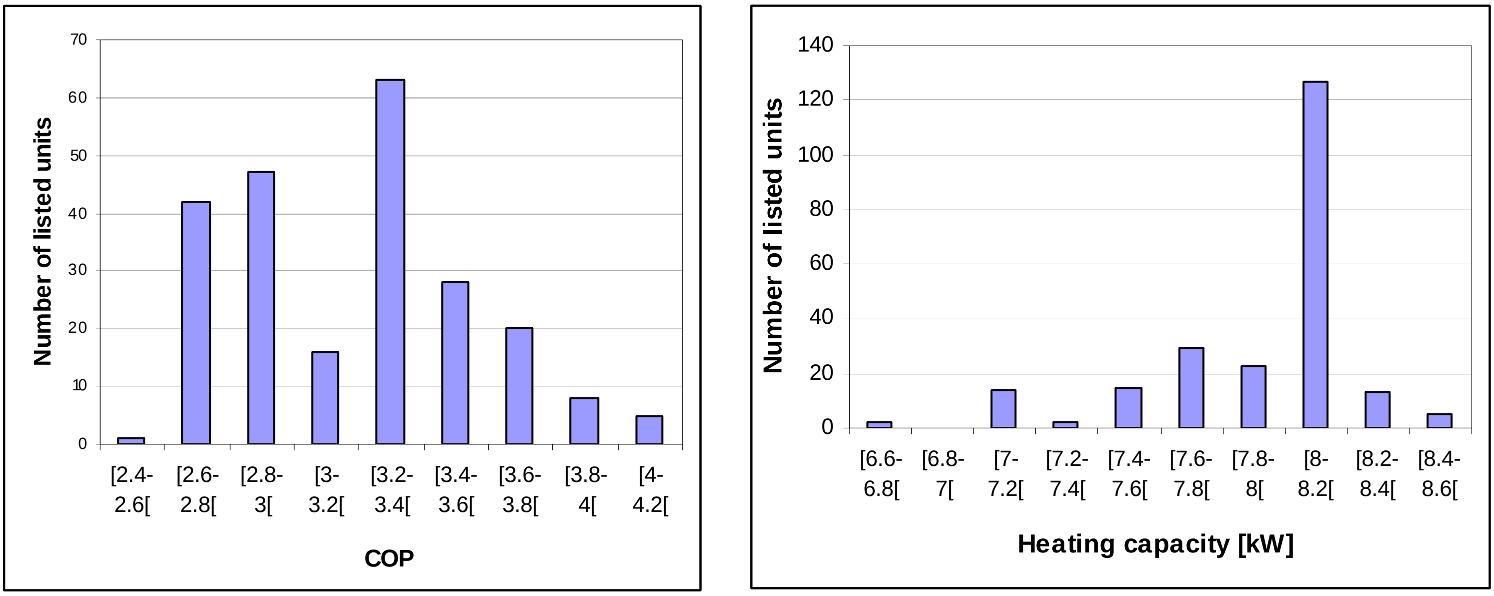


Figure 3: COP (left) and heating capacity (right) with cooling capacity lying between 7 and 7.2 kW in the Eurovent 2006 directory.

Condenser outside fluid type

The average models is **air cooled** since no other type of model has been found in the technical database. As previously mentioned in the market analysis, water cooled air conditioners are a limited segment mostly used in some specific central air conditioning systems as water loop heat pumps. There is no doubt about the predominance of air cooled air conditioner.

Electrical characteristics

Regarding that information, most of the models included in the Eurovent database have the following characteristics:

$$
\begin{array}{|l|}
\hline
Voltage = 230\,V \\
1\,phase \\
Frequency = 50\,Hz \\
\hline
\end{array}
$$

Refrigerant fluid type and weight

Within the category of single split whose cooling capacities are between 7 and 7.2 kW, the most common refrigerant is R410A both for reversible and cooling only units - Figure 4. The refrigerant charge of air conditioners with cooling capacity between 6 and 8 kW is plotted according to cooling capacities in Figure 5. It is not possible to focus only on the 7-7.2 kW range because of the insufficient number of units. Eventually, two different values are kept for reversible and cooling only appliances:

$$
\begin{array}{|l|}
\hline
Weight_{reversible\_R410A} = 2.5\,kg \\
Weight_{cooling\_only\_R410A} = 2\,kg \\
\hline
\end{array}
$$

Regarding the length of the refrigerant line, two values can be found in the Eurovent technical database: 5 m and 7.5 m. About 90% of the reversible units and 90 % of the cooling only ones have a refrigerant line of 7.5 m. As a result this value is kept for the average models.

$$Lenght_{refrigerant\_line} = 7.5m$$

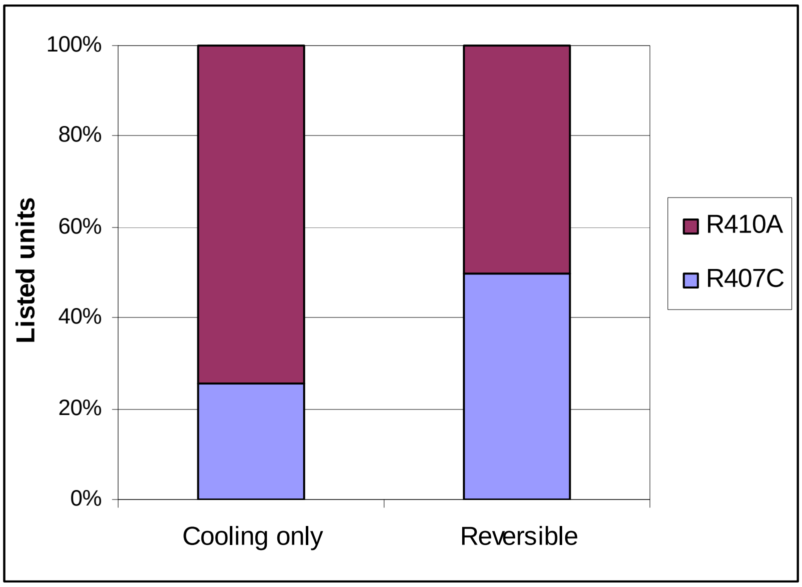


Figure 4: R410A and R407C shares in single split units between 6 and 8 kW (Eurovent directory)

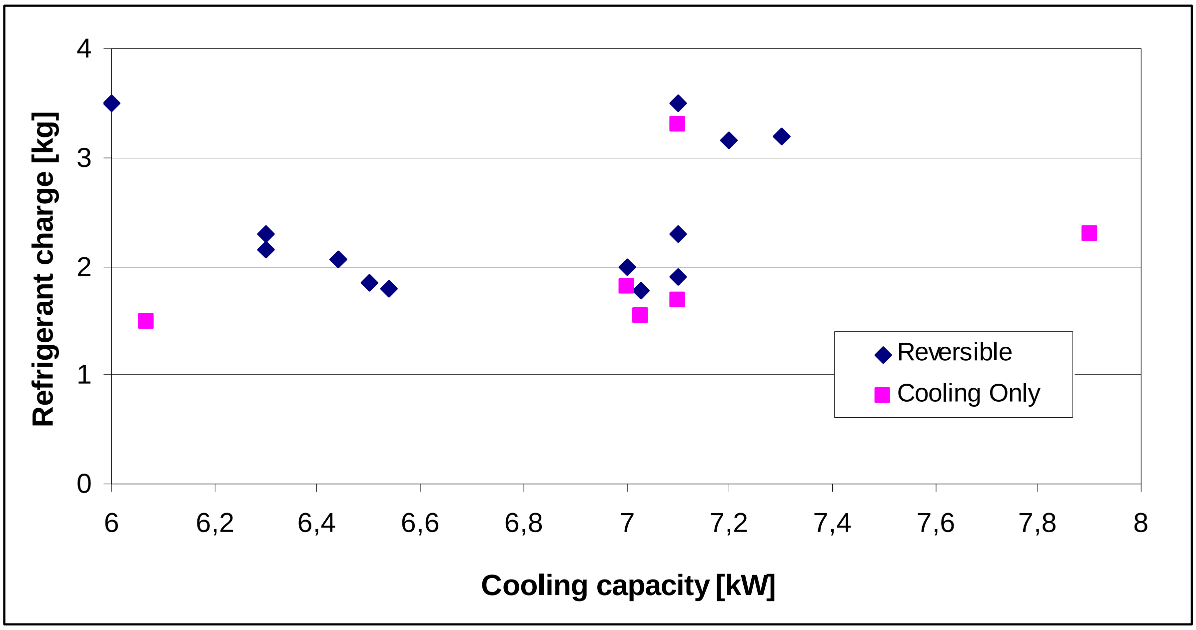


Figure 5. Weight of R410A in mono-split units according to their cooling capacity

Indoor unit characteristics

First of all, in the 7-8 kW range, the most common indoor unit of single splits listed in the Eurovent directory is the wall mounted indoor one (Figure 6). It is therefore assumed that both average models are equipped with this kind of indoor unit.

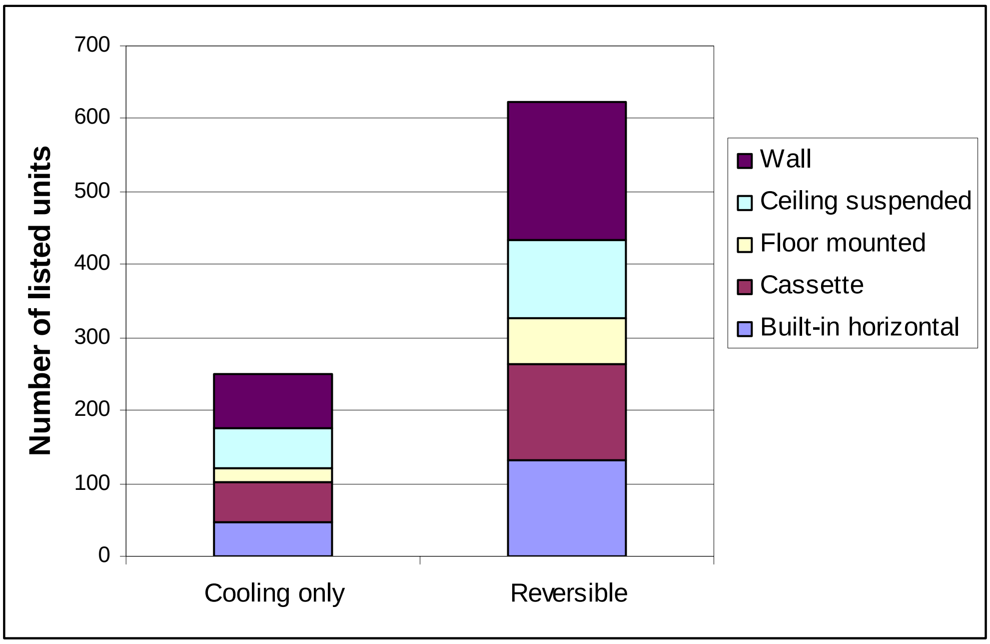


Figure 6: Types of indoor unit for single split models whose cooling capacity is within 6 and 8 kW (Eurovent 2006)

The indoor unit weights have been plotted from the Eurovent technical database on Figure 7 for single split with cooling capacity within 6 and 8 kW. A value of 30 kg seems reliable to characterize both average models.

$$Weight_{indoor} = 30\,kg$$

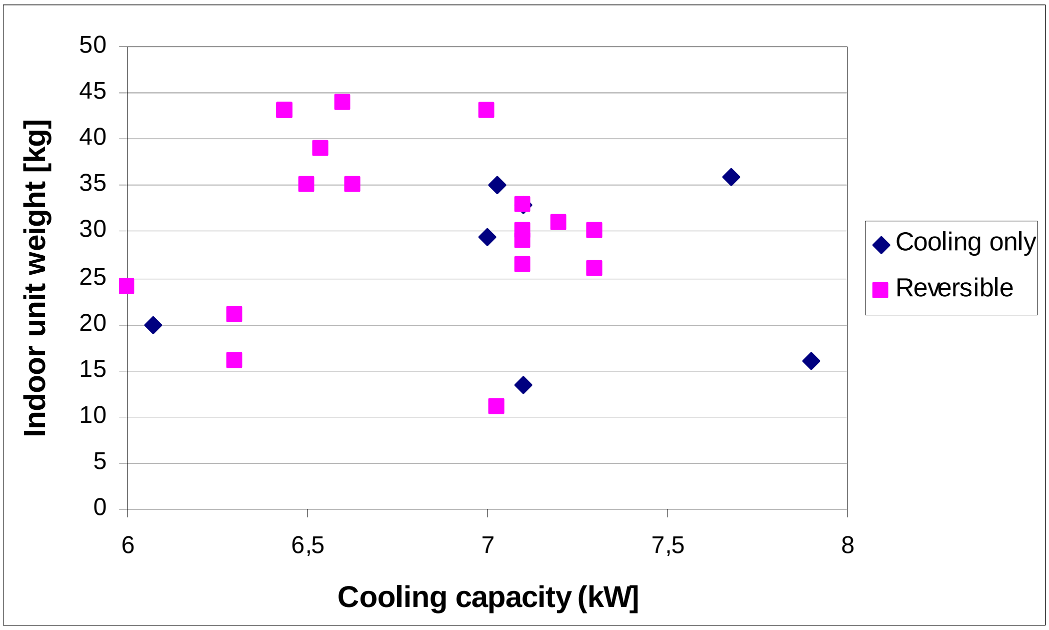


Figure 7: Weight of indoor unit for single split models whose cooling capacity is within 6 and 8 kW (Eurovent 2006)

In the Eurovent technical database all the single split with cooling capacity between 6 and 8 kW have a non ducted indoor unit, as a result **both average systems will not be indoor ducted**.

Regarding the sound generated by the indoor unit, the Eurovent directory has been used. Finally the distribution according to the A-weighted power sound has been plotted (Figure 8) and it appears that 60 dB can be kept as a typical value for cooling only units and for reversible ones. Moreover, no correlation has been found between produced sound and EER (Figure 9).

$$A-weight\_power\_sound_{indoor\_unit} = 60\,dB$$

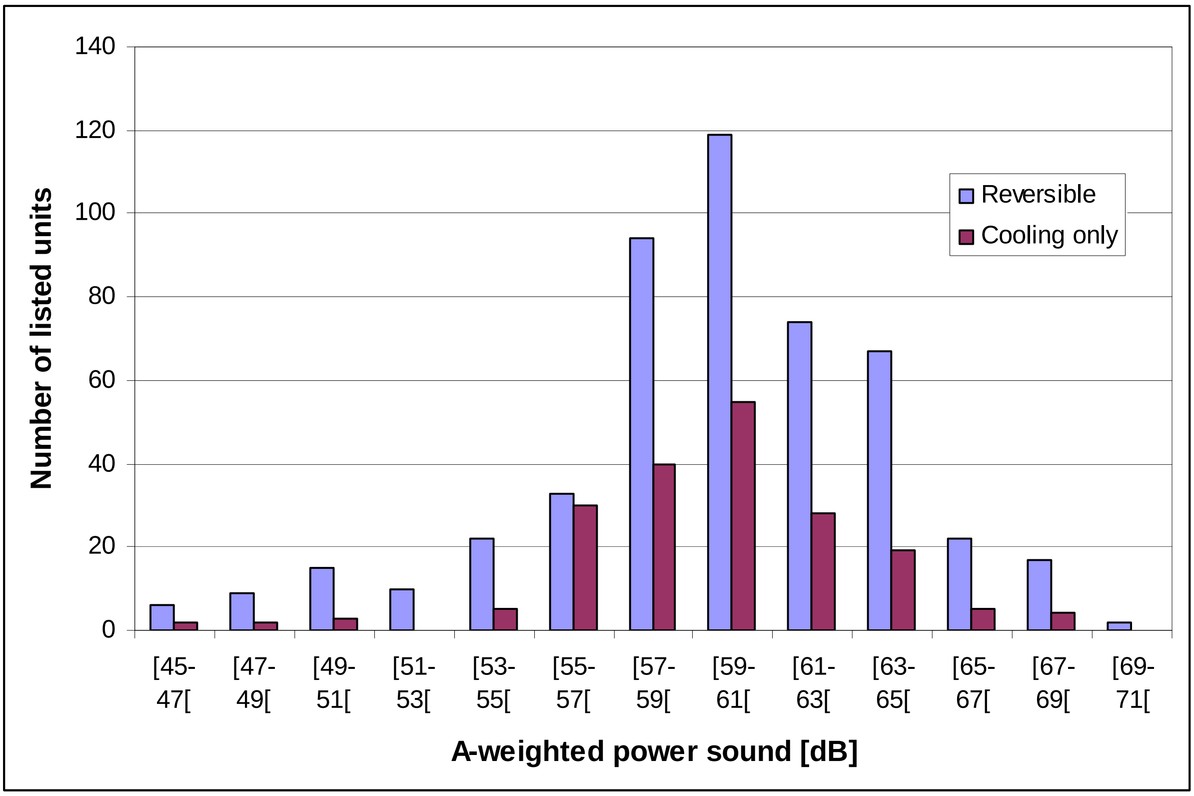


Figure 8 Distribution of mono-split units whose cooling capacity is within 6 and 8 kW according to the A-weighted sound power (Eurovent 2006)

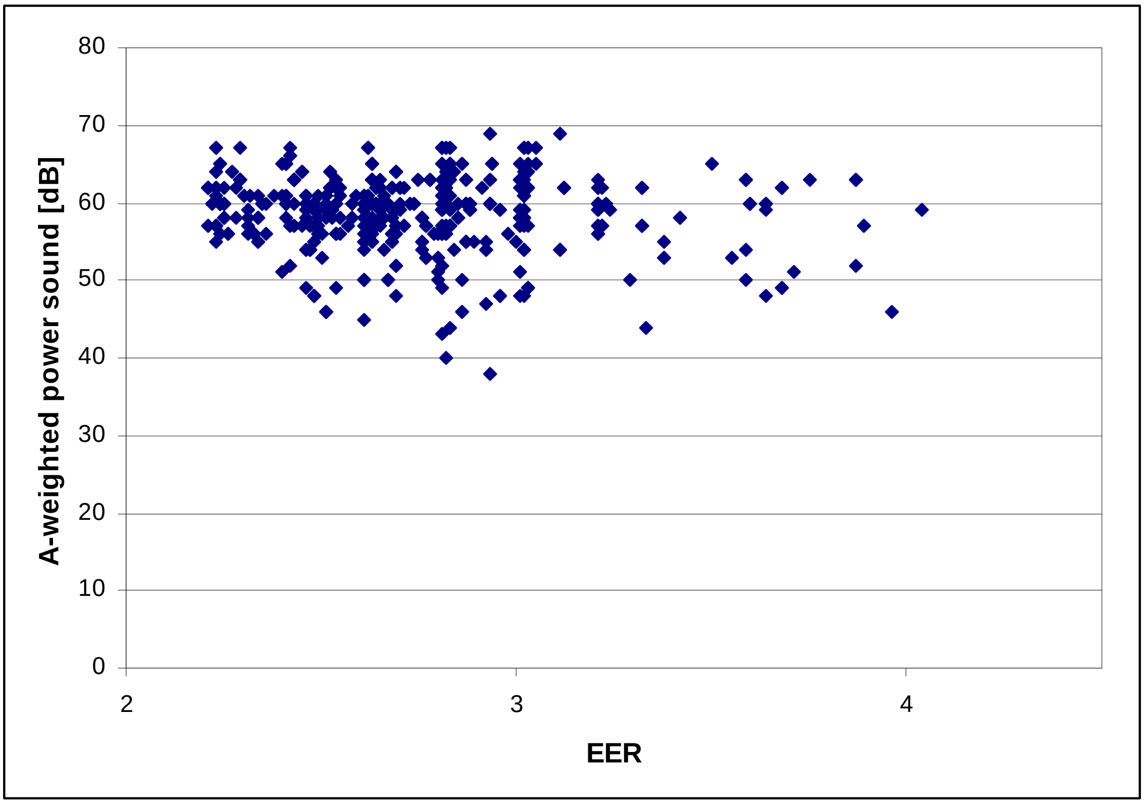


Figure 9 A-weighted sound power according to the EER for mono-split units whose cooling capacity is within 6 and 8 kW (Eurovent 2006)

In the Eurovent technical database most of the mono split that are equipped with a wall mounted unit and whose cooling capacity is between 6 and 8 kW blow the air thanks to a **centrifugal fan**. This type of device is kept for both reversible and cooling only average models.

Regarding more accurately the indoor coil, 87% of the cooling only listed models and 90% of the reversible ones have two rows.

$$Number_{rows} = 2$$

Tube pitch, row pitch, tube outside diameter and fin spacing do not depend on the capacity neither on the EER. All these features are presented on Figure 5-13 and their values according to cooling capacity and EER on Figure 10. The following values are considered as representative of the low capacity single splits:

$$\begin{aligned} Pitch_{row} &= 13.2mm \\ Pitch_{tube} &= 20.5mm \\ Spacing_{fin} &= 1.5mm \\ Outside\_Diameter_{tube} &= 7mm \end{aligned}$$

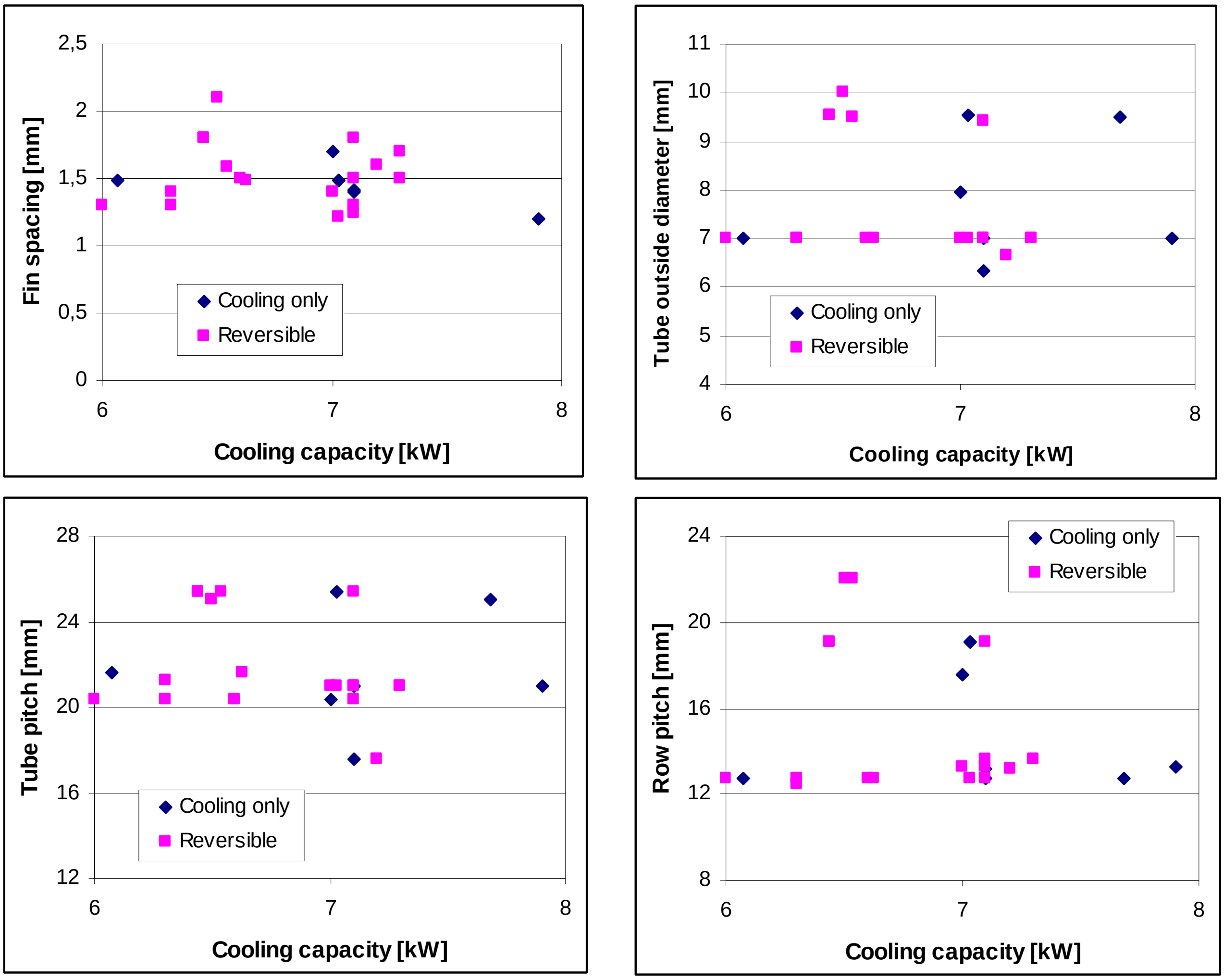


Figure 10 Fin spacing, tube outside diameter, tube pitch and row pitch of mono-split units' indoor coil according to the cooling capacity (Eurovent 2006)

In the Eurovent technical database, most of the mono-splits (reversible or cooling only) with a cooling capacity between 6 and 8 kW are equipped with **louvered fins** (indoor coil) and with **grooved tubes** (see Table 2 and 3). As a result these two characteristics are kept for the average model.

Type of fins	Cooling only [6kW-8kW] (number of listed units in the technical database)	Reversible [6kW-8kW] (number of listed units in the technical database)
Louvered	8	15
Corrugated	0	2
Flat	0	0
Louvered-Wavy	0	0
Louvered-Corrugated	0	2

Table 2 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of fins in the indoor coil

Type of tube	Cooling only [6kW-8kW] (number of listed units in the technical database)	Reversible [6kW-8kW] (number of listed units in the technical database)

Grooved	8	15
Smooth	0	2
Not indicated	1	2

Table 3 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of tube in the indoor coil

Regarding dimensions, indoor coils are very similar whatever the capacity between 6 and 8 kW (Figure 11), the following values are considered as the representative ones both for reversible and cooling only units:

$$Length_{Plate} = 1000\ mm$$
$$Heigth_{Coil} = 280\ mm$$
$$Width_{Plate} = 40\ mm$$

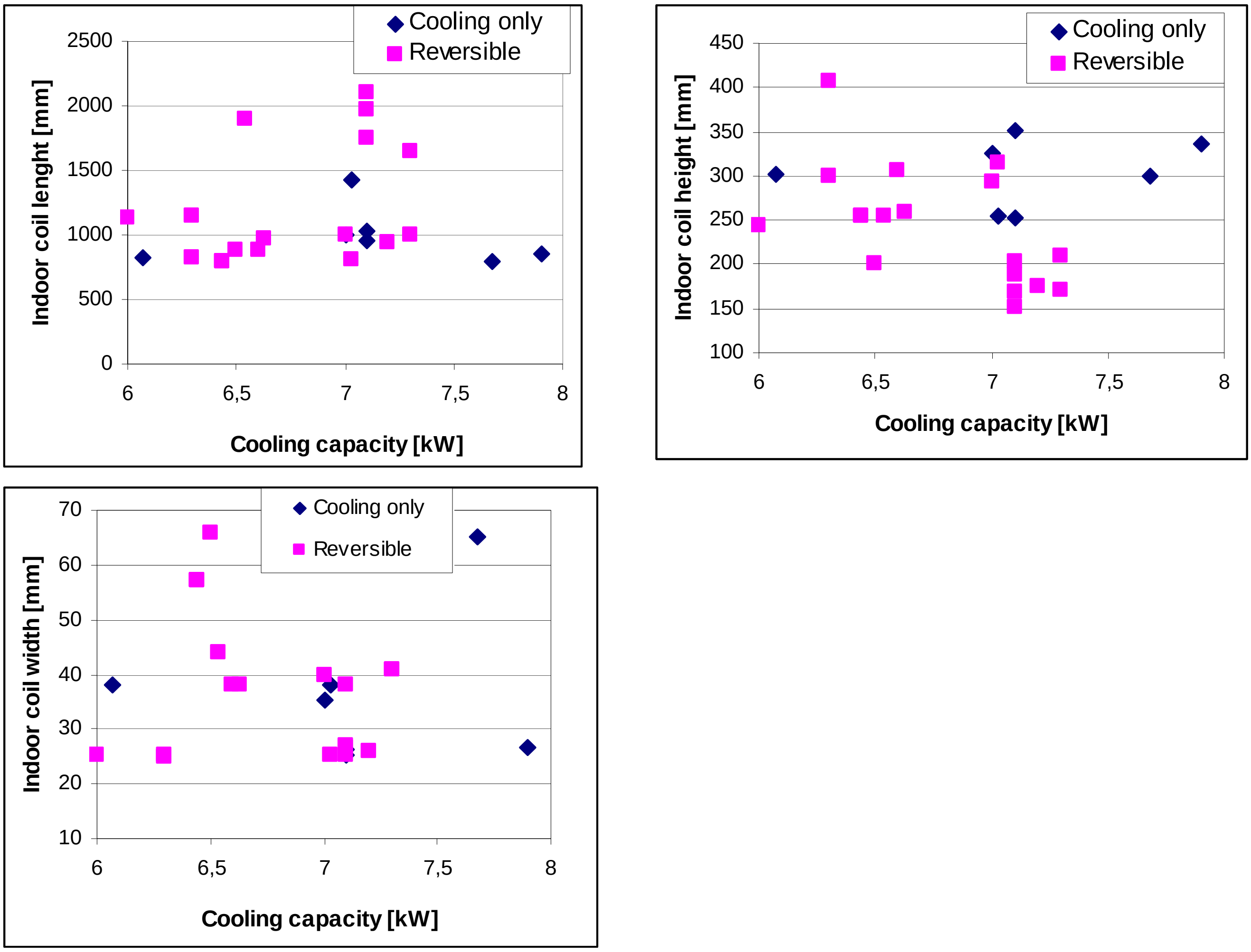


Figure 11 Dimensions of mono-split units' indoor coil according to the cooling capacity (Eurovent 2006)

The number of circuits for the indoor coil is set to 1, which is considered as a representative value for this range of capacity (Figure 12).

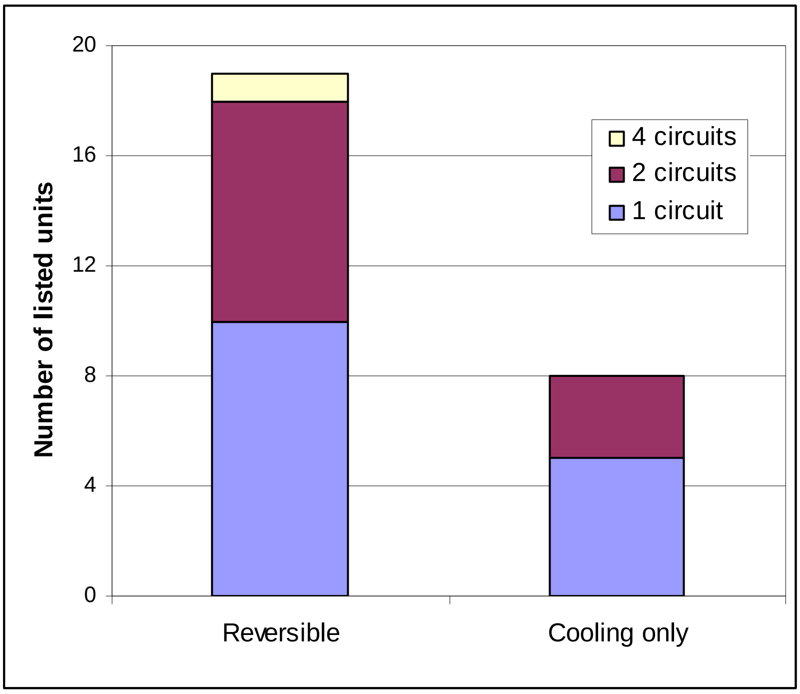


Figure 12 Number of circuits (indoor coil) of mono-split units according to the cooling capacity (Eurovent 2006)

The indoor air flow rate depends on the capacity (Figure 13). For a 7.1kW capacity, a value of 0.3m³/s is considered as representative.

$$Airflow_{indoor} = 0.3 m^3 / s$$

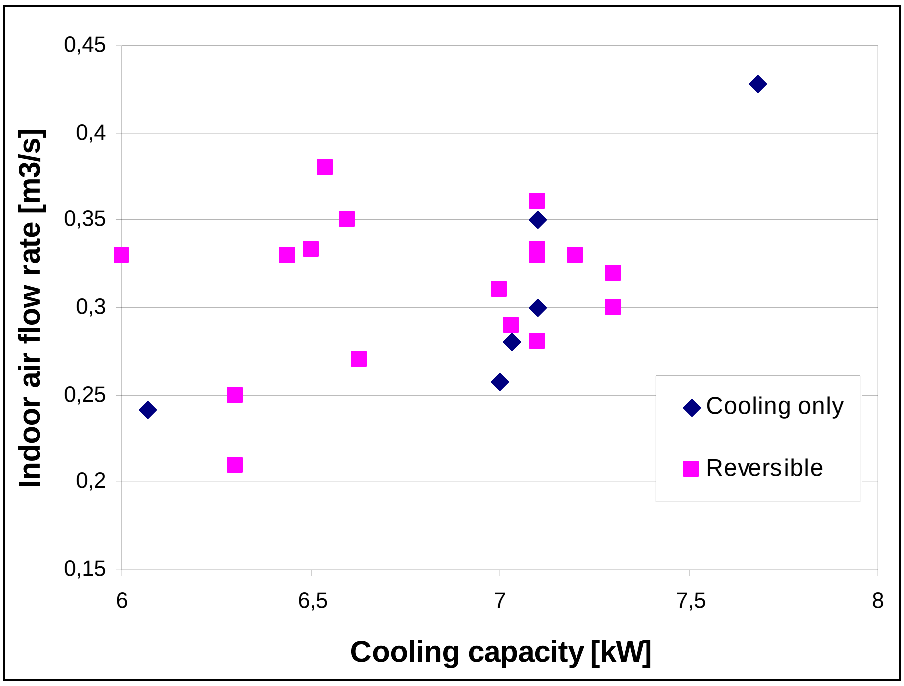


Figure 13 Indoor air flow rate of mono-split units according to the cooling capacity (Eurovent 2006)

All the indoor coil characteristics have been determined and it became possible to define the evaporator surface. Equation 1 is used to roughly calculate the evaporator surface from the technical values previously defined.

Finally, by using the values already defined:

$$\boxed{Surface_{\ indoor} = 13\, m^2}$$

This is a representative value for mono split systems both for cooling only and reversible (Figure 14 and 15).

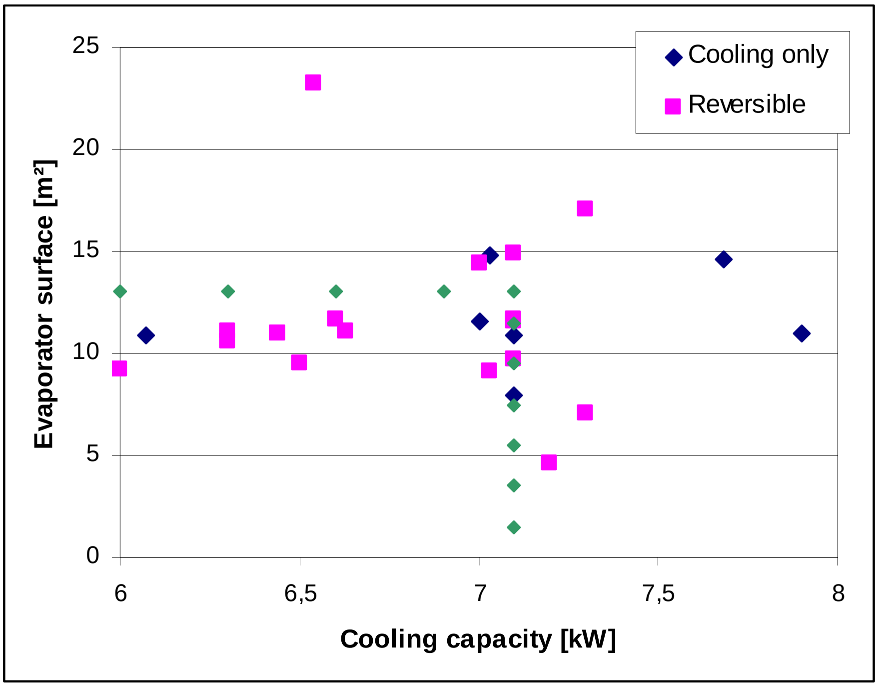


Figure 14 Evaporator surface (indoor coil) of mono-split units according to the cooling capacity

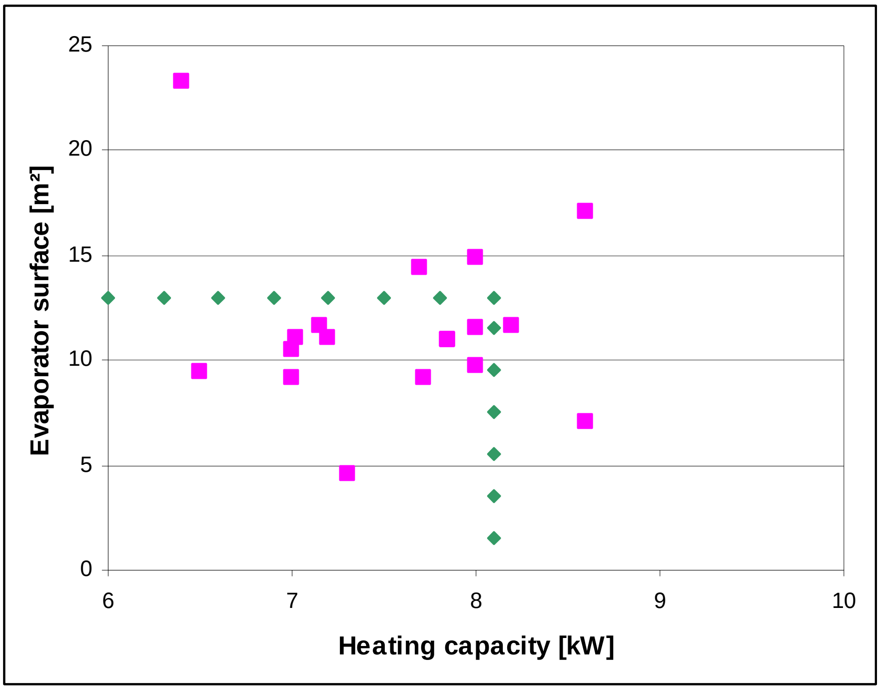


Figure 15 Evaporator surface (indoor coil) of mono-split units according to the heating capacity

Outdoor unit characteristics

The distribution of the outdoor unit weight has been plotted from the Eurovent technical database (Figure 16) for mono-split whose cooling capacity is within 3 and 4 kW. A value of 9 kg seems reliable to characterize both average models.

$$Weight_{outdoor} = 70\,kg$$

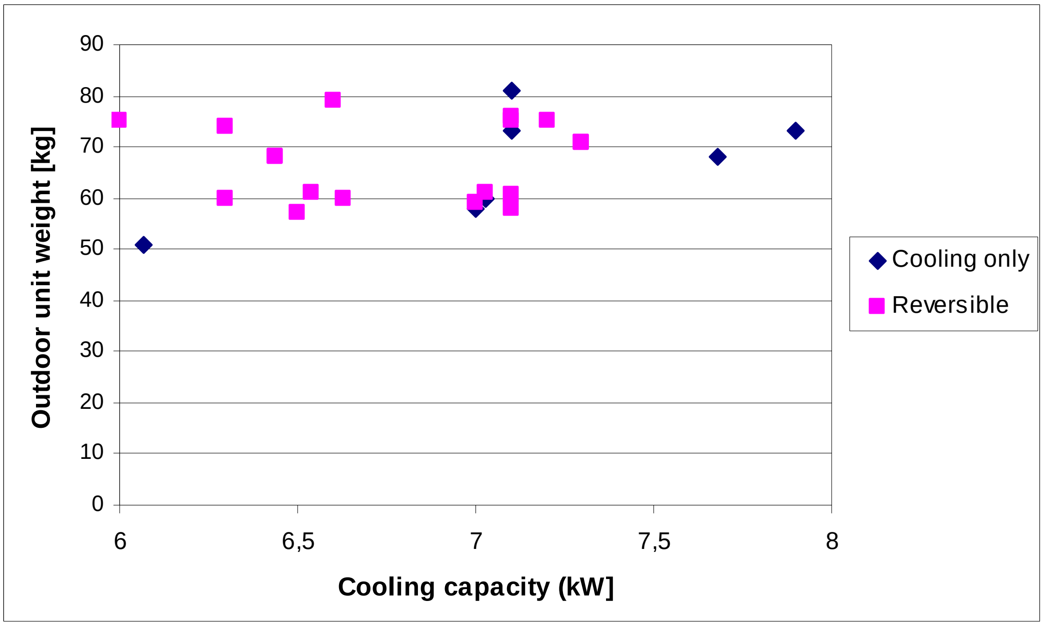


Figure 16: Weight of outdoor unit for single split models whose cooling capacity is within 6 and 8 kW (Eurovent 2006)

In the Eurovent technical database all the mono split whose cooling capacity is within 6 and 8 kW have a non ducted outdoor unit, as a result **both average systems will not be outdoor ducted**.

Regarding the sound generated by the outdoor unit, the Eurovent directory has been used. Finally the distribution according to the A-weighted power sound has been plotted (Figure17) and it appears that 66 dB can be kept as a typical value for cooling only units and reversible ones. Moreover, no correlation has been found between produced sound and EER (Figure 18).

$$A-weight\_power\_sound_{outdoor\_unit} = 66\,dB$$

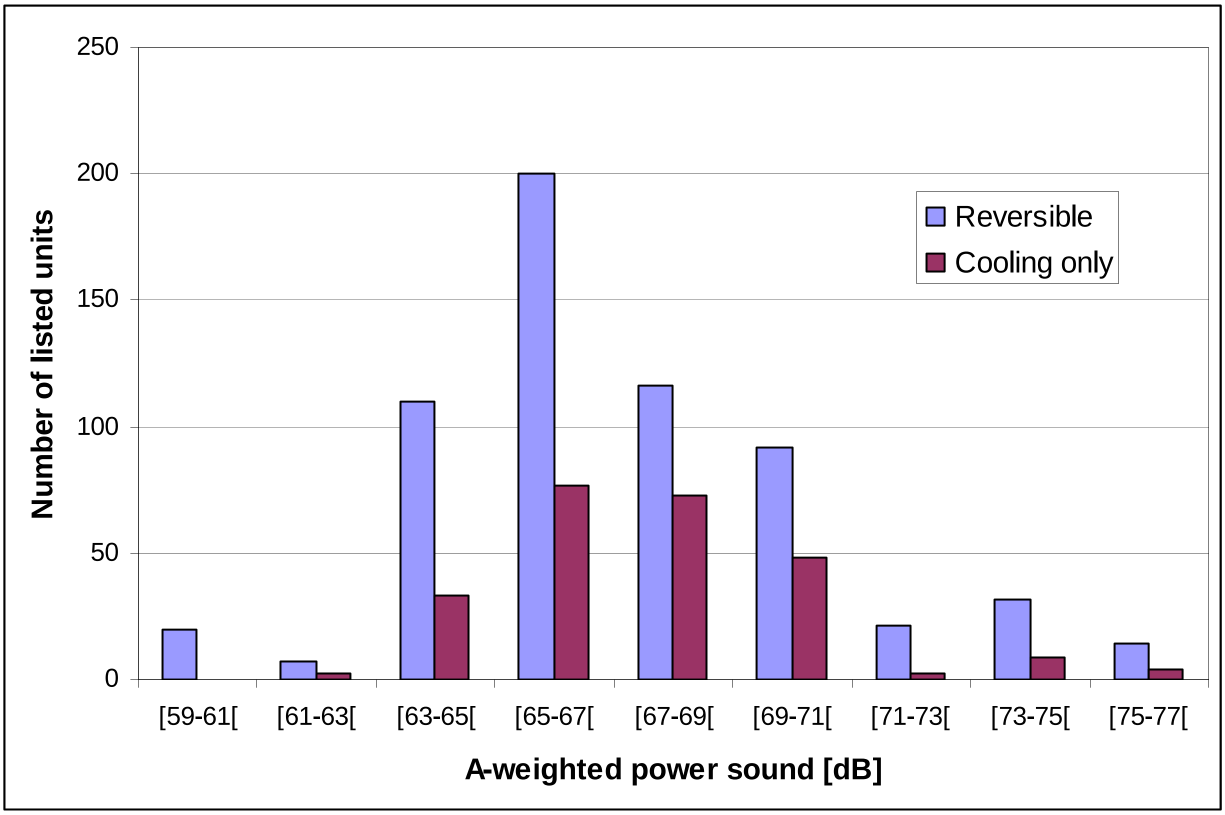


Figure 17 Distribution of mono-split units whose cooling capacity is within 6 and 8 kW according to the A-weighted sound power (Eurovent 2006)

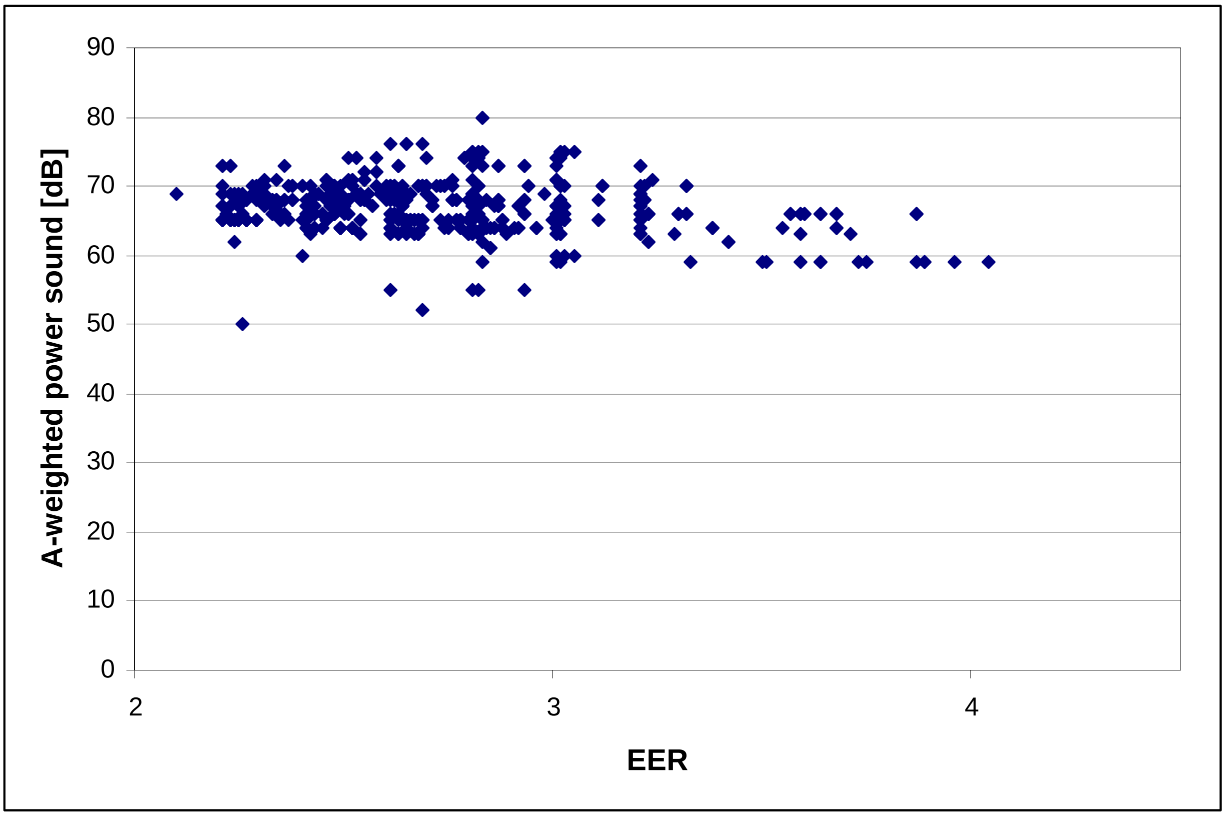


Figure 18 Distribution of mono-split units whose cooling capacity is within 6 and 8 kW according to the A-weighted sound power (Eurovent 2006)

In the Eurovent technical database most of the mono split whose cooling capacity is within 6 and 8 kW have an **axial fan** (also named **propeller fan**). This type of device is kept for both reversible and cooling only average models.

Regarding more accurately the indoor coil, 100% of the cooling only listed models and 88% of the reversible ones have **two rows.**

Tube pitch, row pitch, tube outside diameter and fin spacing do not depend on the capacity neither on the EER. All these features are presented on Figure 5-3 and their values according to cooling capacity and EER on Figure 19. The following values are considered as representative of the low capacity mono split:

$$Pitch_{Row} = 20\,mm$$

$$Pitch_{Tube} = 25\,mm$$

$$Spacing_{Fin} = 1.5\,mm$$

$$Outside\_Diameter_{Tube} = 7\,mm$$

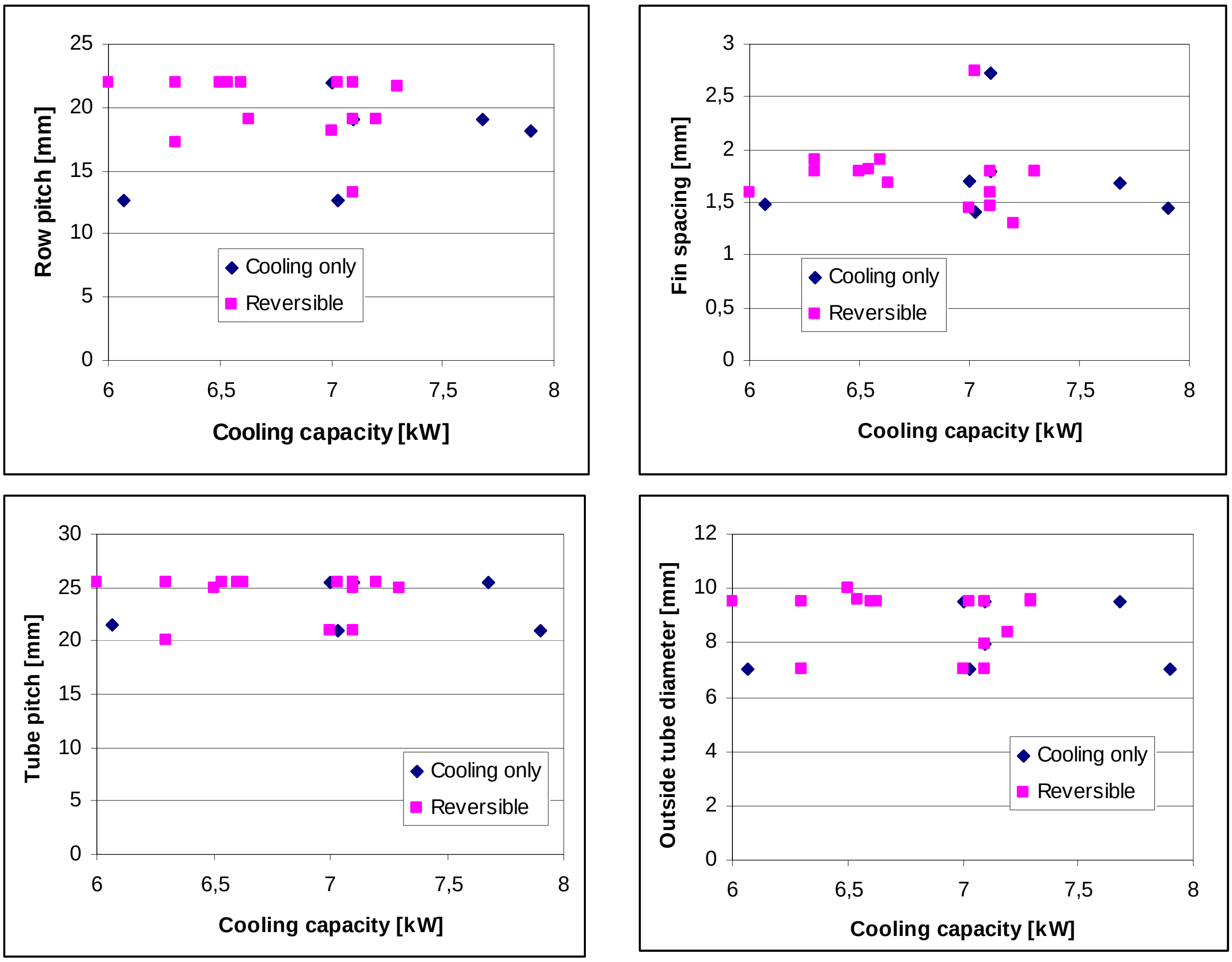


Figure 19 Fin spacing, tube outside diameter, tube pitch and row pitch of mono-split units' outdoor coil according to the cooling capacity (Eurovent 2006)

In the Eurovent technical database, most of the mono-splits (reversible or cooling only) with a cooling capacity between 6 and 8 kW are equipped with **louvered fins** (outdoor coil) and with **grooved tubes** (see Table 4 and 5). As a result these two characteristics are kept for the average model.

Type of fins	Cooling only [6kW-8kW] (number of listed units in the technical database)	Reversible [6kW-8kW] (number of listed units in the technical database)
Louvered	8	6
Corrugated	1	5
Flat	0	1
Louvered-Wavy	0	0
Louvered-Corrugated	0	2

Table 4 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of fins in the outdoor coil

Type of tube	Cooling only [6kW-8kW] (number of listed units in the technical database)	Reversible [6kW-8kW] (number of listed units in the technical database)
Grooved	7	16
Smooth	0	1

Not indicated	2	2

Table 5 Number of listed mono-split units in the 2006 technical database of Eurovent according to the type of tube in the outdoor coil

Regarding dimensions, outdoor coils are very similar whatever the capacity (between 6 and 8kW), the following values are considered as representative ones both for reversible and cooling only units:

$$Length_{Plate} = 830\ mm$$

$$Height_{Coil} = 700\ mm$$

$$Width_{Plate} = 40\ mm$$

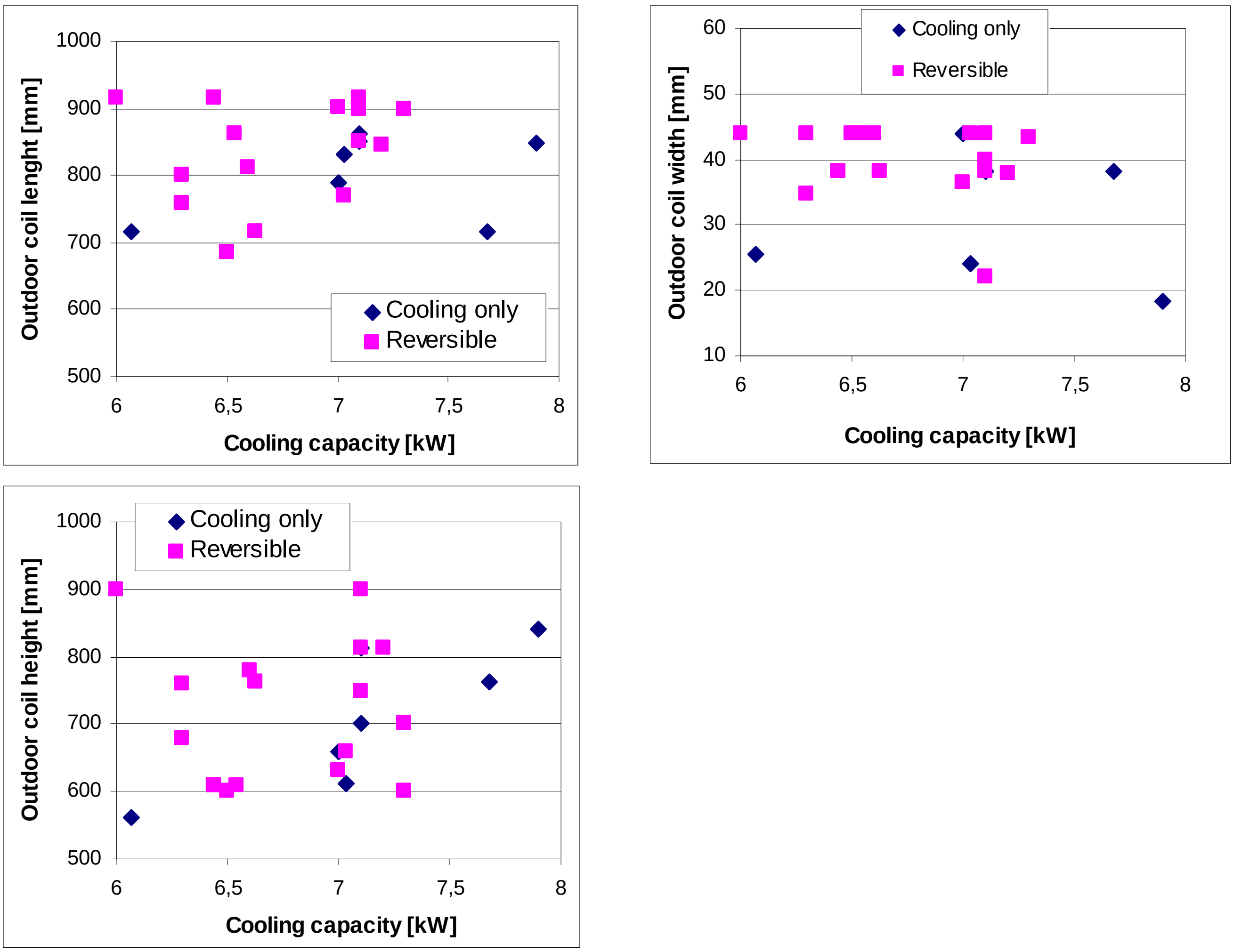


Figure 20 Dimensions of mono-split units' outdoor coil according to the cooling capacity (Eurovent 2006)

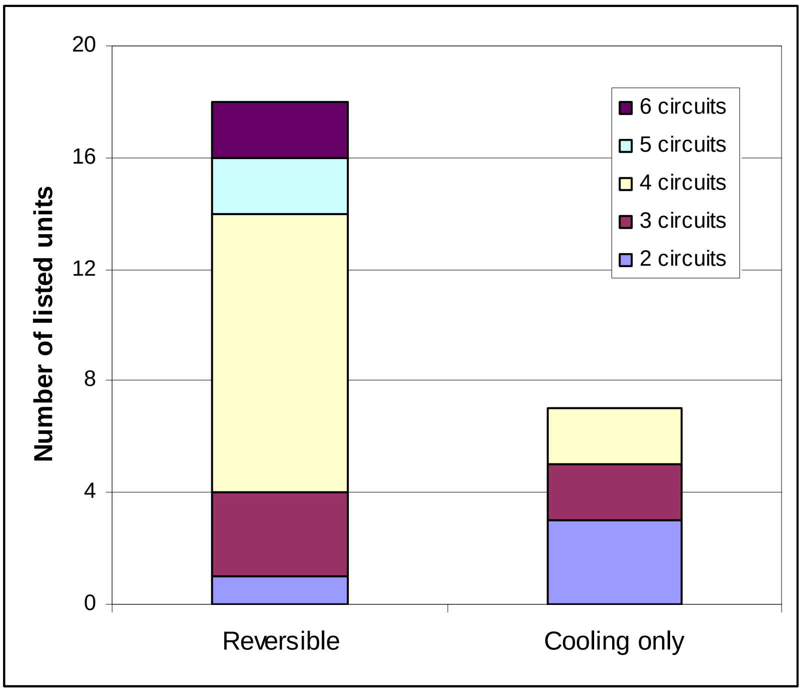


Figure 21 Number of circuits (outdoor coil) of mono-split units within [6-8kW] (Eurovent 2006)

The number of circuits for the outdoor coil is set to 2 for cooling only units and 4 for reversible ones, which are considered as representative values for this range of capacity (Figure 21).

All the outdoor coil characteristics have been determined; based on Equation 1 it became possible to define the condenser surface:

$$Surface_{evaporator} = 28\,m^2$$

This is a representative of an average mono split model (Figure 20 and 21).

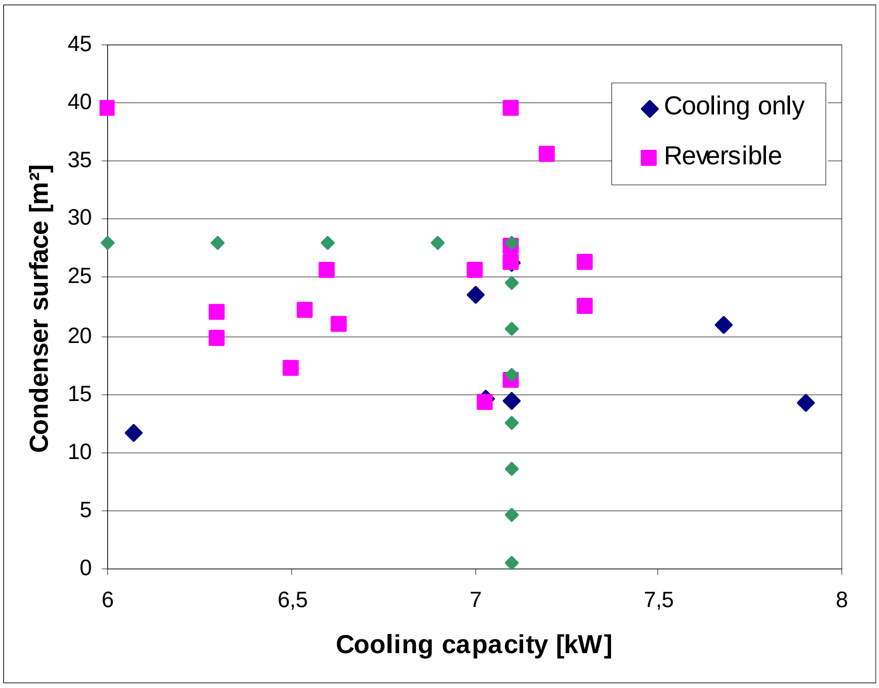


Figure 22 Condenser surface (outdoor coil) of mono-split units according to the cooling capacity

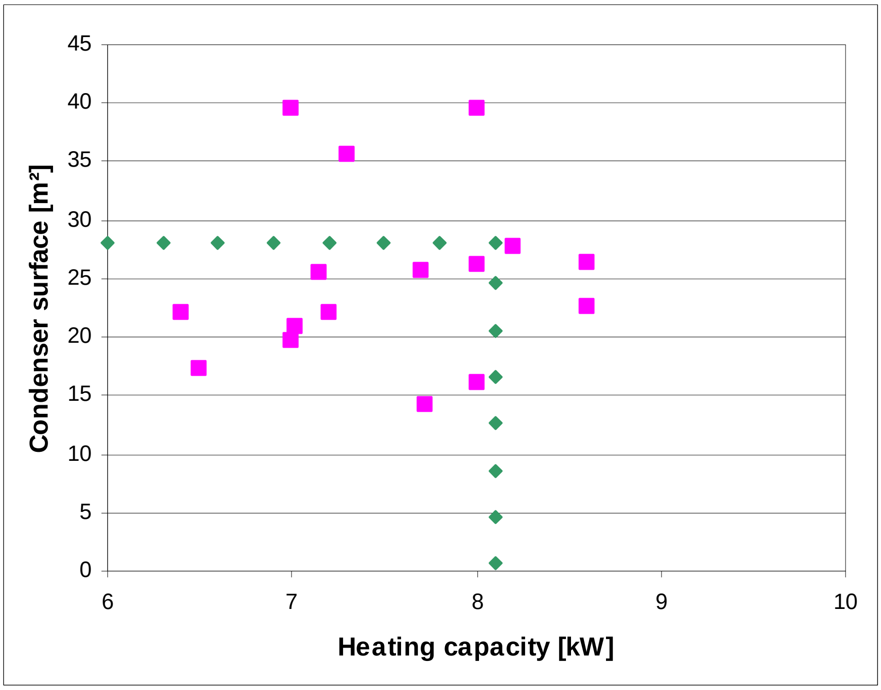


Figure 23 Condenser surface (outdoor coil) of mono-split units according to the heating capacity

Compressor technical characteristics

The Eurovent database only includes the compressor model numbers. More information regarding performances, crank heaters has been looked for but few information has been found. In this interval of capacity (6-8kW), it seems that **rotary and scroll** compressors are used. For low capacity, crankcase heaters seem very present, both average models are fit up with a crankcase heater of **70W**.

Which compressor? scroll or rotary

Expansion valve characteristics

According to the technical Eurovent database (Figure 24), the **capillary expansion valve** is the most frequently used for cooling only units. Regarding reversible air conditioners, capillary and electrical expansion valves seem to share the market in equity. Our average model is supposed to be equipped with a capillary expansion valve.

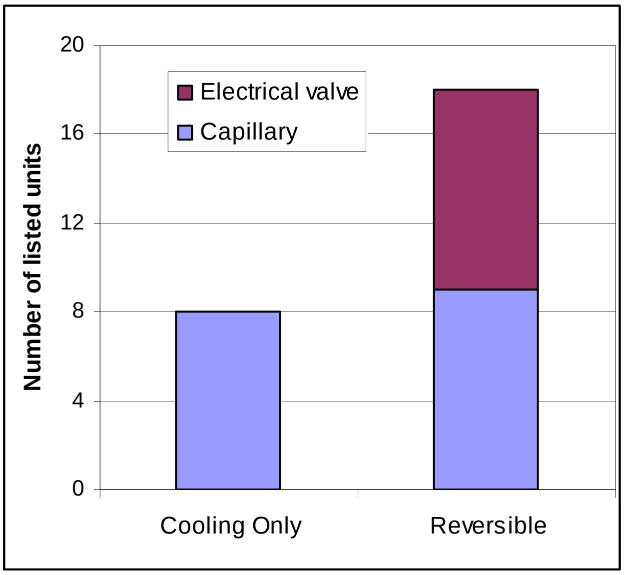


Figure 24. Type of expansion valve for Mono-Split whose cooling capacity is within 6 and 8 kW (Eurovent 2006)

Final base case description

Two additional typical models have been determined, a single split package cooling only air conditioner and a reversible one. Both models characteristics are summarized in Table 6 and 7 hereunder. Manufacturers are invited to comment these results.

General description	Type	Reversible Mono-Split
	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	7.1 kW
	EER	2.8
Heating performances	Heating capacity	8.1 kW
	COP	3.3
Fluid	Type	R410A
	Charge	2.5 kg
Indoor coil	Tube type	Grooved
	Fins type	Louvered
	Evaporator surface	13 m²
	Fan type	Centrifugal
Outdoor coil	Tube type	Grooved
	Fins type	Louvered
	Condenser surface	28 m²
	Fan type	Axial
Compressor	Type	Rotary??
	Crank heater	Yes (30W)??
Expansion device	Type	Capillary??

Table 6 Main technical features of the reversible single split air conditioner

General description	Type	Cooling only Mono-Split
	Mounting	Wall
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	7.1 kW
	EER	2.5
Fluid	Type	R410A
	Charge	2 kg
Indoor coil	Tube type	Grooved
	Fins type	Louvered
	Evaporator surface	13 m²
	Fan type	Centrifugal
Outdoor coil	Tube type	Grooved
	Fin type	Louvered
	Condenser surface	28 m²
	Fan type	Axial
Compressor	Type	Rotary??
	Crank heater	Yes (30W)??
Expansion device	Type	Capillary??

Table 7 Main technical features of the cooling only single split air conditioner

Appendix C: Determination of a base case model for "cooling only" moveable air conditioner

Data sources

The determination of base cases means that technical features (type of air conditioner, fluid, capacity…) that are the most likely to be found in European conditioned rooms must be specified. Ideally, the investigation of the most sold technologies should be based on sales figures. Unfortunately, regarding moveable air conditioners, we have not been provided with any technical data. For this reason, we had to build our own database from manufacturer's catalogues, importers' websites. This database contains performance (declared by manufacturers) of moveable air conditioners along with some technical features when available. The numbers of different models in the database are given hereunder in Table1.

Type	Single Duct	Mobile Split	Double Duct
Number of models	73	39	11

Table 1 Number of models in the database according to the different types of moveable air conditioners.

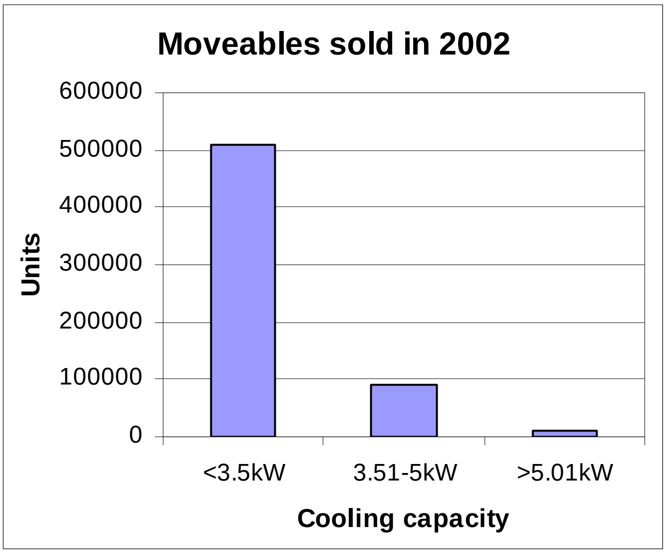


Figure 1. Number of moveable air conditioners sold in Europe over 2002 (BSRIA)

Type of air conditioner kept for the base case

The first step of the base case investigation consists in determining the type of air conditioner. Based on our database, it appears that Single Ducts are the most common products among moveable air conditioners (60%).
According to [BSRIA, 2002], only 25 % of all moveable air conditioner were reversible (20 % of them being single and double duct with electric resistances and 5 % reversible mobile split). This trend is visible in our database where 21% of moveable air conditioners are really reversible and 11% are equipped with electric resistances.
In consequence, the base case must be a "cooling only single duct" air conditioner.
Then, the remaining part of this document defines the detailed characteristics of a typical single duct air conditioner in Europe.

Determination of the reference cooling capacity

From our database, the distribution of single duct air conditioners capacities is figured out in terms of cooling capacity (Figure 2). It appears that the “mode” is in the interval: [2kW-2.4kW[. Thus, the following value is assumed to be characteristic of the average model:

$$Pc_{cooling\_only} = 2.2kW$$

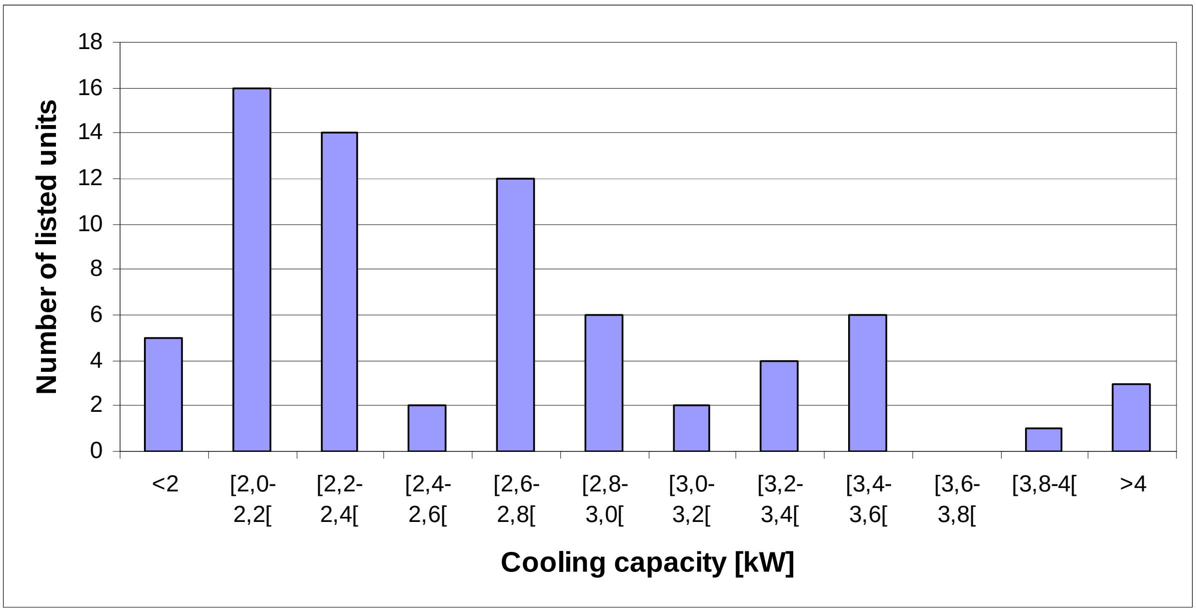


Figure 2. Number of Single Ducts listed in our database according to the cooling capacity

Determination of the reference Energy Efficiency Ratio

From our database, the distribution of single duct air conditioners EER is figured out in terms of EER (Figure 3). It appears that the “mode” is in the interval: [2.4-2.6[. However, supplementary information supplied by (CECED, 2007) indicates that sales weighted average EER is rather 2.3 for moveable air conditioners. It is kept as the average EER for the base case.
Thus, the following value is assumed to be characteristic of the average model:

$$\mathrm{EER}_{\mathrm{cooling\_only}} = 2.3$$

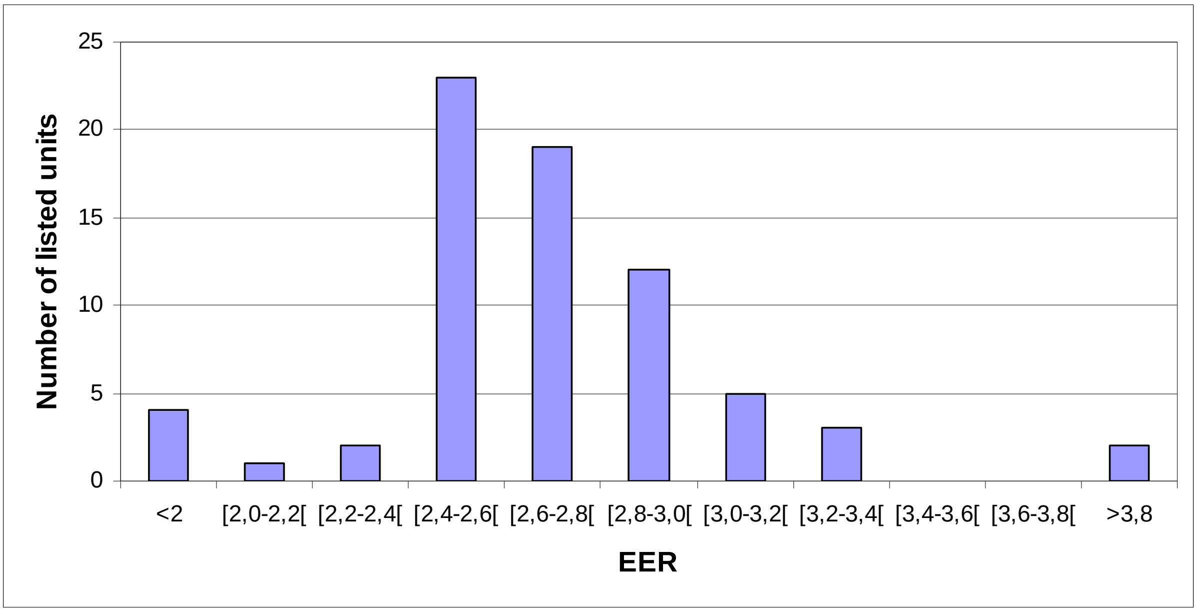


Figure 3. Number of Single Ducts listed in our database according to EER

Electrical information

Regarding electrical information, we observe that the moveable base case has the following characteristics:

$$\begin{array}{|l|}\hline Voltage \ = 230\,V \\ 1\,phase \\ Frequency \ = 50\,Hz \\ \hline \end{array}$$

Working fluid

According to our database, the most common working fluid in single duct units is R407C (Figure 4). Unfortunately, only a few values have been found regarding the refrigerant charge contained in single duct units. They have been plotted according to the cooling capacity (Figure 5) displaying no dependence and one value is finally kept for the base case:

$$\boxed{Weight_{R407c} = 0.5kg}$$

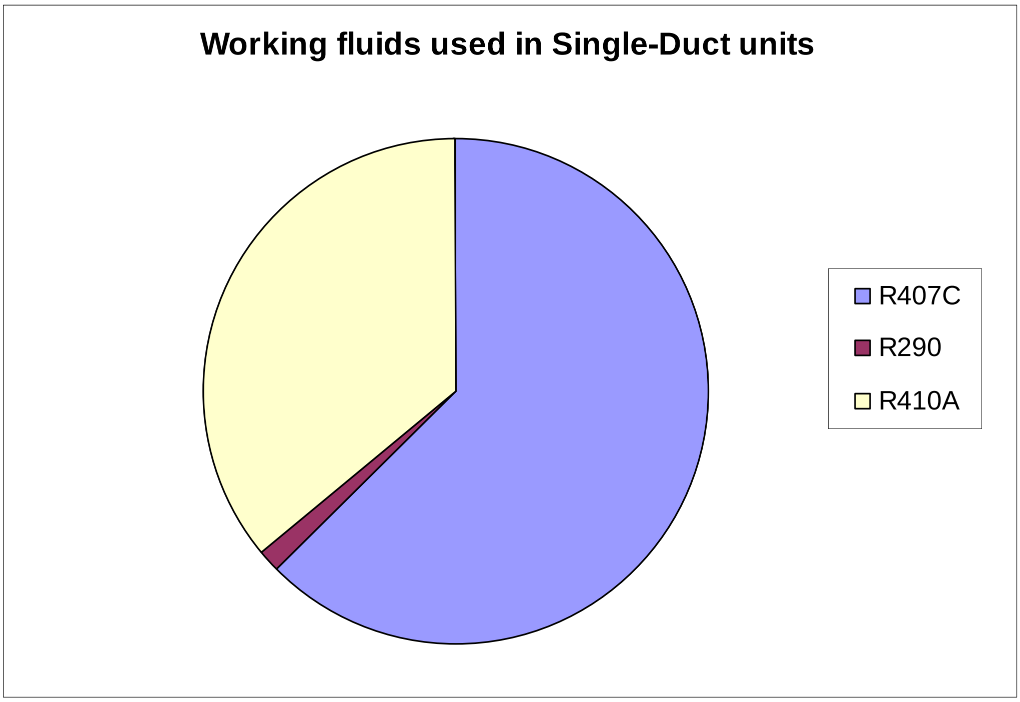


Figure 4. R410A, R290 and R407C shares in single-duct units

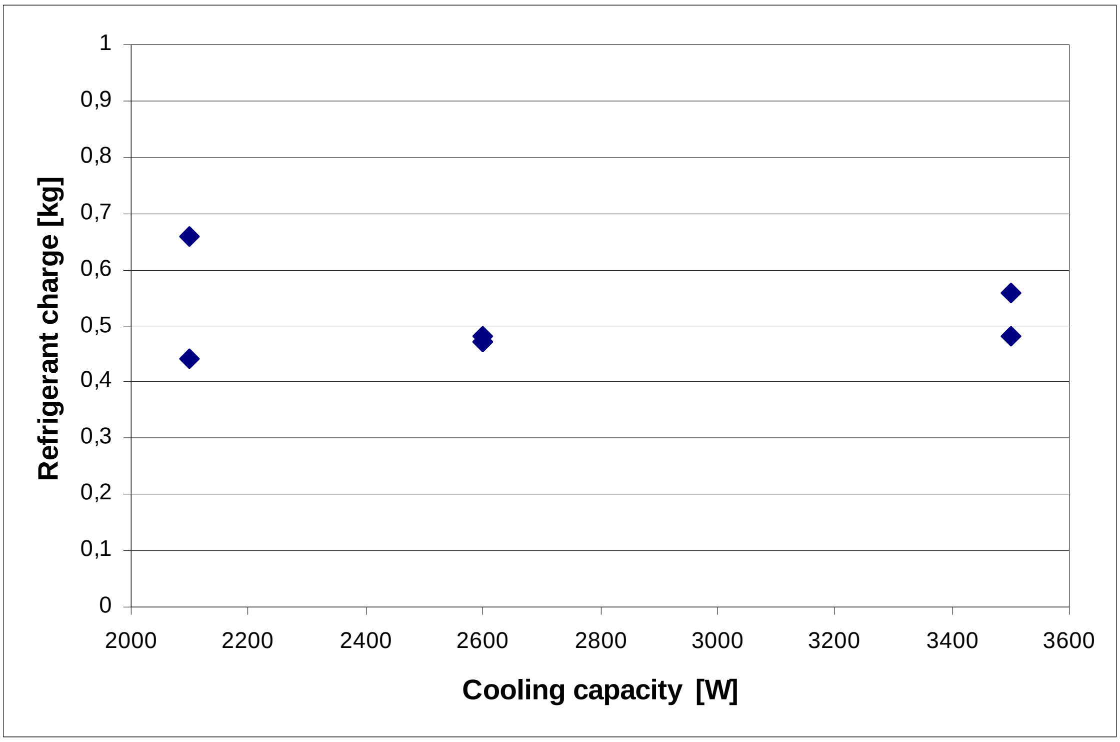


Figure 5. Refrigerant charge of some single duct units according to the cooling capacity

Noise intensity

Noise intensities declared on websites or catalogues have been plotted according to the cooling capacity (Figure 6) and no correlation has been found. Finally, the following value is assumed to be relevant for the base case:

$$A - weighted\_power\_sound_{single\_ductt} = 50\,dB$$

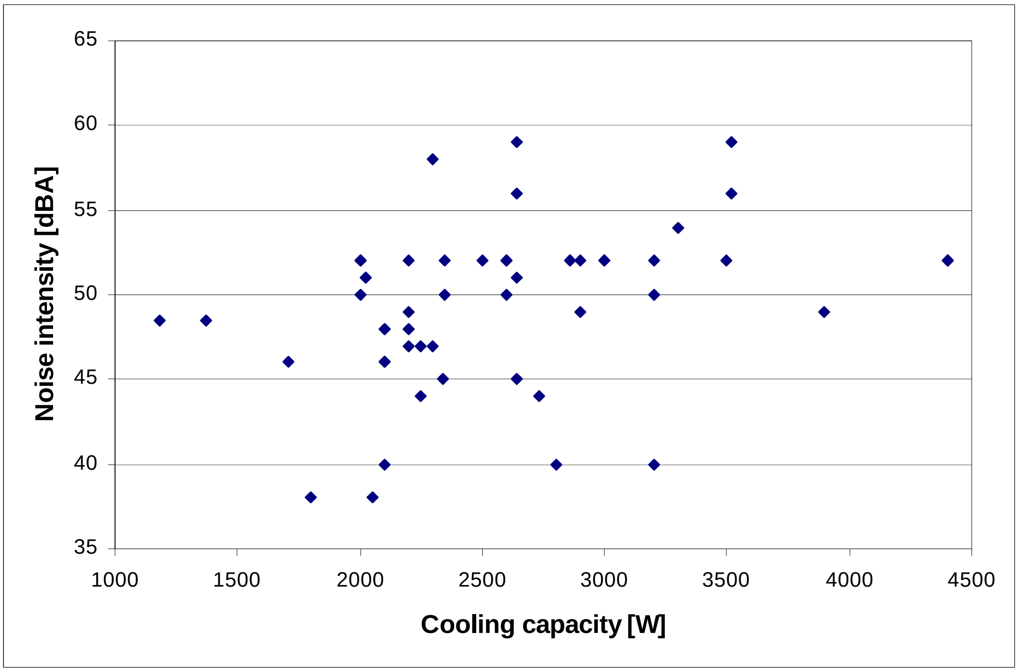


Figure 6. Noise intensity of some single duct units according to the cooling capacity

Air flow rate:

The indoor air flow rate slightly depends on the capacity (Figure 7). For a 2.2kW capacity, a value of 0.09m³/s is considered as representative.

$$Airflow_{indoor} = 0.09\, m^3/s$$

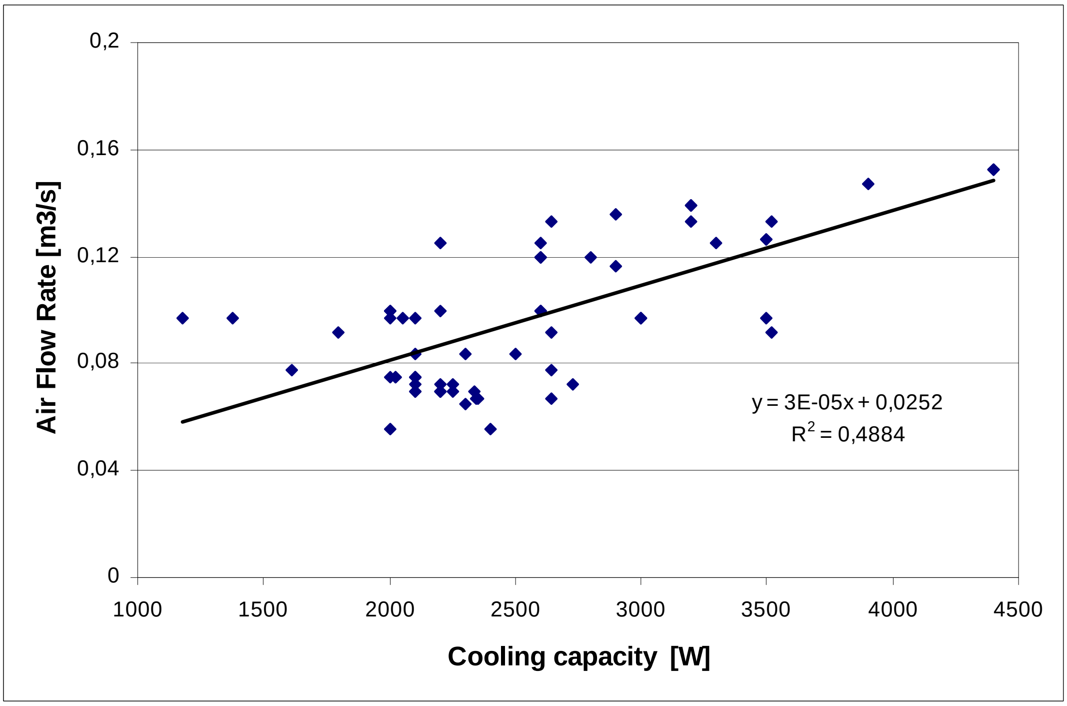


Figure 7. Air flow rate of some single duct units according to the cooling capacity

Total weight

The total weight of single duct units slightly depends on the capacity (Figure 8). For a 2.2kW capacity, a value of 33kg is considered as representative.

$$Weight_{unit} = 33\,kg$$

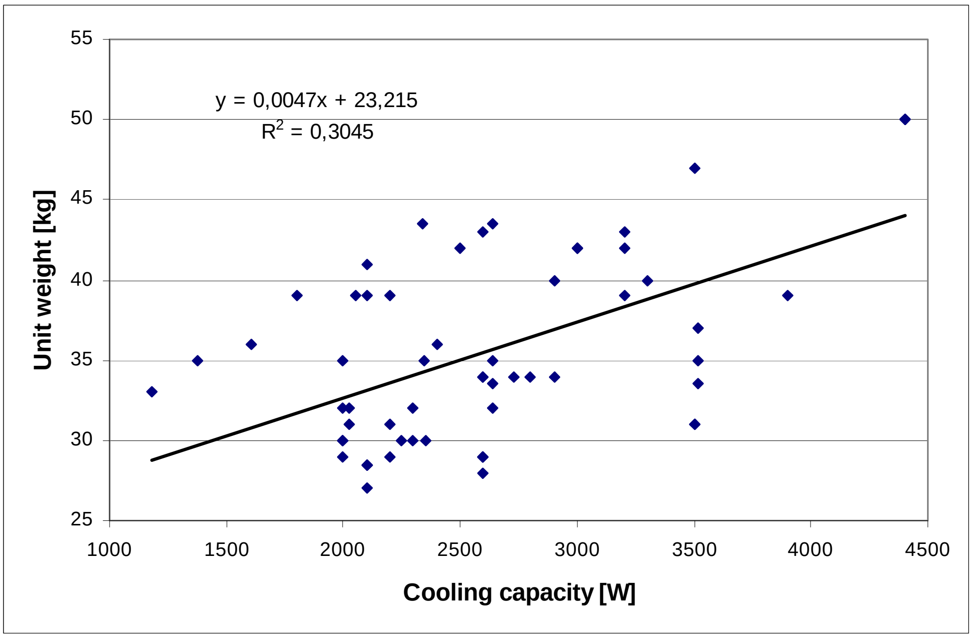


Figure 8. Total weight of some single duct units according to the cooling capacity

Compressor data

Information on compressor is very uncommon on websites and catalogues. In our database, the type of compressor is mentioned for only 14% of the units. For all of them, the compressor is **a rotary one**, which is kept for the base case.

Final base case description

A typical model has been determined to represent moveable air conditioners. The characteristics of this single duct are summarized in Table 2. We have striven to gather the greatest number of technical features from retailer websites and catalogues. The features we have not found in the market stem from a detailed technical study of a single duct [EERAC Task 7 (1999)]. Manufacturers are invited to comment these results.

General description	Type	Cooling only single duct
	Current information	230V-1phase-50Hz
	Air or water cooled	Air cooled
	Ducted (Y/N)	N
Cooling performances	Cooling capacity	2.2 kW
	EER	2.3
Fluid	Type	R407C
	Charge	0.5kg
Compressor	Type	Rotary
	Crank heater	?
Expansion device	Type	Capillary (*)

(*) From EERAC study

Table 2 Main technical features of the single duct air conditioner

Tube type	Smooth
Tube material	Al
Tube outside diameter	8.4 mm
Tube thickness	0.3048 mm
Fin type	Smooth
Fin material	Al
Fin pitch	556 fins/m
Fin thickness	0.2540 mm
Coil frontal area	0.0753 m^2
Tube spacing a	0.025 m
Tube spacing b	0.022 m
No. of rows	2
No. of tubes/row	13
No. of equivalent parallel circuit (2 phase)	1
No. of equivalent parallel circuit (Liquid)	2
Refrigerant Flow Configuration	Cross flow

Table 3 Main technical features regarding the evaporator of the single duct air conditioner (from EERAC)

Tube type	Smooth
Tube material	Al
Tube outside diameter	10 mm
Tube thickness	0.3048 mm
Fin type	Smooth
Fin material	Al
Fin pitch	556 fins/m
Fin thickness	0.127 mm
Coil frontal area	0.040 m^2
Tube spacing a	0.025 m
Tube spacing b	0.022 m
No. of rows	4
No. of tubes/row	23
No. of equivalent parallel circuit (2 phase)	1
No. of equivalent parallel circuit (Liquid)	1
Refrigerant Flow Configuration	Cross flow

Table 4 Main technical features regarding the condenser of the single duct air conditioner (from EERAC)

REFERENCES

R5-Definition of Base-Case

Eurovent-Certification, 2006, Directory of certified products, http://www.eurovent-certification.com

Eurovent-Certification, 2006, Technical data of tested products