Service Contract to DGTREN

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

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Air conditioners
Final report of Task 3
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CONSUMER BEHAVIOUR AND LOCAL INFRASTRUCTURE

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http://www.ecoaircon.eu

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Final version of task 2 is available on the website study:
http://www.ecoaircon.eu

3 CONSUMER BEHAVIOUR AND LOCAL INFRASTRUCTURE

This part should identify consumer behaviors likely to influence the assessment of the environmental impact and the life cycle cost of the product. It should also identify barriers and restrictions to possible eco-design measures, due to social, cultural or infra-structural factors. At last, it should also quantify relevant user-parameters that influence the environmental impact during product-life and that are different from the Standard test conditions.

Real Life Efficiency
For air conditioners, the total energy consumption is generally understood as the product of the cooling (and heating for reversible units) energy needed multiplied by the energy efficiency. Because energy efficiency is measured nowadays on a single design conditions (35 °C outdoor for air to air conditioners) and at full load[1] it is not a useful indicator of average energy efficiency. However, this operating conditions, likely temperature of operation and average load, are mainly a function of the climate, and this will be characterized in task 4. Nevertheless, the cooling set point fixed by the user directly affects the cooling energy needed, extends the cooling period and finally may have an important impact on the total cooling energy required. Our goal here is to focus on user parameters, options proposed to the end-user or again installation and maintenance problems that are likely to modify the environmental impact of the product.

End-of-Life behaviour
Because it is a rapidly increasing market still relatively new, very few data have been identified in Europe concerning the end of life of air conditioners. Main output needed for later tasks of this study regarding the following items are proposed:
- Economical product life (=actual time to disposal);
- Repair- and maintenance practice (frequency, spare parts, transportation and other impact parameters);
- Present fractions to recycling, re-use and disposal;
- Estimated second hand use, fraction of total and estimated second product life (in practice);
- Best Practice in sustainable product use, amongst others regarding the items above.

Local Infra-structure
This part should describe and identify the barriers and opportunities relating to the local infra-structure. Considering the specificity of air conditioners, the following plan has been followed and is thought to cover main problems related with local infrastructure:
- Urban and social context of air conditioning and ventilating
- Limitations to natural cooling (access to ground and natural coolth, access to fresh air)
- Influence of past heat waves
- Electricity reliability
- Electricity tariffs influence on consumer behaviour
- Selection and Installation guides for good practice

[1] Please refer to CEN standard EN14511, in task 1 of this study.

3.1 Real Life Efficiency

3.1.1 Purchase and installation

In the market analysis, it has been acknowledged that there were two different main destinations for air conditioners, residential and tertiary sectors, with then two distinct types of decision circuits.

Concerning households (about one third of the installed cooling capacity), they have only access to limited information: they cannot study all passive cooling options, forecast the effect of envelope measures, predict discomfort duration and depth. Then, in the context of heat waves and increasing comfort demand, they select an air conditioner to avoid a situation that they don't want, without enough information.

According to (VHK, 2005), around two thirds of European citizens are renting their dwelling. Hence, for one third of the EU dwellings, the decision to purchase an air conditioner may not be the one of the end-user. In countries with warm climates and in high standing dwellings, owners may choose to install an air conditioners to increase the renting value. In that case, first cost may be the key factor.

With the decreasing average prices of air conditioners, the part of renters purchasing an air conditioner may have increased. Then, installation cost may be a barrier for the installation of a split fix air conditioner and a portable equipment may be preferred.

For installations in new buildings, the cost is certainly less important because of the relative very small part of the total costs as compared to the price of the house. However a large majority of installations are made in existing buildings. In that case, either a previous system was already used: for window units, the modification of the building envelope may lead the purchase of a similar type of window type air conditioner.

For customers that decided to buy an air conditioning system, the enquiry led by ENEA (ENEA, 1999) on a sample of Italian and Spanish households shows that about one third let the decision on the type of equipment to be installed to the installer. Amongst the ones that chose by themselves the type of air conditioner, advice from relatives, performance characteristics, economic factors and marketing factors were primarily quoted.

Concerning tertiary sales (about two thirds of the installed cooling capacity), the owner or the manager of a building should be more rational. Rationality of the owner may be to lower first costs depending on the final use of the building (its own use or renting). For the building manager, even if he should think in Euros per functional unit (it would be in that case comfortable square meters), and compare solutions, he cannot usually reconstitute the cost of various possible decisions.

If not already required by other standards, the EN 14511 standard forces the manufacturer to provide very complete information inside the product documentation of the unit to ensure complete information of the installer and/or end-user. This information is likely to be enough to ensure a proper installation of the unit.

Nevertheless, the decision of the consumer may interact at different levels as follows.

Sizing the cooling (heating) capacity of the air conditioner

Concerning installation, **portable appliances** differ from fix installations since no installer can help in choosing the right capacity to be installed. Wholesalers generally use ratios as available in manufacturers brochures that give the size of the room the air conditioner can cool. Manufacturers[2] generally advise sizing ratio superior to **100 W/m2** of **coolin**g capacity.

[2] See for instance Carrier (www.carrier.fr) and Delonghi (www.delonghi.fr)

For **fix installed units**, window/wall, single and multi split, central air conditioners and mini chillers, **sizing of the cooling/heating capacity** of the unit is generally done by a professional. Since each capacity sizing is site dependant, manufacturers generally do not indicate sizing rules. Installers may either use simplified methods that are part of the formation they received (see part 3.1.3.6) or rules of thumb. Oversizing may occur at that time because of split incentives or because of the inadequacy of the simplified rules. There is not in Europe general sizing rules as there may be in the United States (ASHRAE, 2004). EPBD standards at the moment only indicate the parameters that should be taken into account but this generally has not been transposed in national building codes that mostly do not consider individual air conditioners.
More and more direct sales are registered, even for fix installations. This means that the end-user may be the one to choose the capacity of its system. Very little help is available in that case. A few free and immediate online services are provided by installers with sometimes very strange (high) cooling capacity results. More serious methods on demand capacity evaluations are available free of charge from installers' websites. Some energy agency may also provide useful and accurate simplified guides, see for instance the energy guide for room air conditioners in Canada (OEE, 2005).

We have highlighted in task 2 the market trend of **overcapacity** introduced by manufacturers selling inverters and advertised as a way to reach indoor comfort conditions more rapidly. There is a risk the competition may lead the consumer to require higher cooling capacity than needed. As will be detailed in the technical analysis of existing products (in task 4), it may lead to an increased energy consumption depending to the type of part load control. The other way round, performances of inverter driven units when operating above the rated capacity (in conditions of overcapacity) are likely to decrease importantly. Generally, the time of operation in those conditions is limited to 20 minutes or half an hour by factory settings but it is not always the case. The lack of information supplied on the consequences of the sizing on the overall performance of the unit is seen as a possible barrier for ecodesign. For instance, inverter manufacturers generally provide the limits of operation of their air conditioner with minimum value – nominal value (test standard) – maximum value, but without giving additional information on efficiency above or beyond the standard performance that can let the end-user believe energy efficiency will not vary (there are exceptions). Moreover, this overcapacity trend can conduct people to buy oversized air conditioning units that would not propose the fast cooling option.

Indoor and outdoor positions

For **split air conditioners**, the more popular inside unit type, if we refer to the number of models in the Eurovent catalogue is the **wall type**. Also the position (and thereby the effectiveness) of the indoor-part (evaporator + fan) of the RAC unit is very much determined by the available space and the economics of realizing the connections. As cold air is heavier than warm air it tends to drop. The best position for the evaporator is high-up in a room, as close as possible to the places where people actually dwell and as far away from (natural) ventilation outlets (doors, not well-insulated windows, etc.) as possible.
This requires only moderate fan action (less drafts, less noise, less energy) and gives the highest effectiveness and comfort. Of course –as is the case e.g. with window units—the evaporator can also be placed at a lower level, but this would require much more fan action (more drafts, noise, energy) and also a lower evaporator temperature to satisfy the consumer needs. The same goes for situations where the unit is placed next to ventilation outlets, which would create a shortcut of cold air going out of the room before it "reaches" its occupants. It is the most favourable type for cooling purpose but not for heating. Hence, for Northern countries, installation of floor mounted or built-in vertical would be more sensible.
Technically, the position of the condenser in practice is important, because of the exposure to direct sunlight and wind, the possibility of freezing in the winter, natural convection etc..

For **mini-chillers**, floor cooling sometimes may be chosen. Water temperature regimes are higher than for fan coil terminal units to avoid the condensation on the soil. This system will then only be able to provide partial cooling requirements.

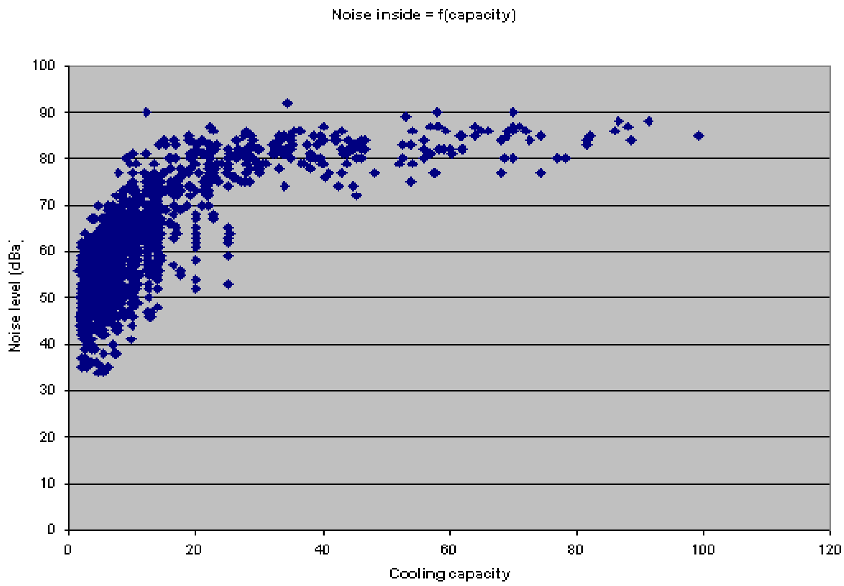
Secondary functions

All air conditioners in the scope provide secondary functions as highlighted in task 1.They may all provide heating and uncontrolled dehumidification when cooling. Some will provide in addition controlled dehumidification and air purifying functions.
The effects of these secondary functions (except for heating since it is required in the EN 14511 test standard) on energy consumption are not known by the end-user, whereas the function is generally well described. For instance, for units that can be used as dehumidifiers, their dehumidification capacity, measured in standard conditions for dehumidifiers is generally published whereas the related energy consumption in that mode is not known, making it impossible to compare the energy consumption of this function with the same function provided by classical dehumidifiers. Thus, generally, the user has only partial information on the variation in energy consumption when using different functions, which limits its ability to choose the unit in function of its own use.
Concerning the heating function, as mentioned in the market analysis, most reversible portable units use an electric resistance to supply heat. This is not always clearly indicated on the manufacturer documentation of the product where sometimes appear an indication of the heating capacity with no more information. On the contrary, whether it is a truly reversible air conditioner, the coefficient of performance is generally presented as well as the word heat pump.

Noise

At the time of purchase, noise is of primary importance for the choice of an air conditioner. On Figure 3-1, the correlation between cooling capacity and standard noise level is shown for AC products in the Eurovent-Certification directory. Noise limitation is then a real constraint to be taken into consideration for eco-design options. For instance, it will limit the maximum air flow rate admissible how high may be the energy efficiency advantage.
Manufacturers have to indicate the standard noise level (sound power) measured at maximum cooling operation and rating fan speed. But manufacturers also present noise intensities of reduced fan speed modes (silent mode, low speed …) for marketing purposes. The impact of these modes is on the contrary never explained to the user and anyway not straightforward. Indeed, a reduction in fan speed will increase the latent capacity of the air conditioner (increase in dehumidification capacity) and decrease the sensible capacity. A consumer test review (Which, 2007) reports a testimony of end users (in the UK) complaining of noise levels in bedrooms and of dry air resulting of the air conditioner operation.

Figure 3-1: Internal noise of air conditioners as a function of capacity



Warm air drawn inside for portable appliances

As previously mentioned in task 1 when presenting the different technical types of air conditioners, single duct draws air from outside or from another room of the building. First an opening is necessary for the condenser duct: generally the end-user opens a window or a door. This also applies to split mobile air conditioners. Second, the single duct takes air inside the room to cool the condenser and rejects it outside.

In case the temperature of the air drawn in is higher than the inside air temperature (cooling in that case is required because of climate conditions outside) and as reported in the MEEuP base case report, it is then possible that the user sits in an air-conditioned environment whereas another part of the room may heat up because of warm air entering. The warm air entering increases the actual heat load of the room, making it more difficult for the unit to attain and maintain the desired temperature in the whole room. The consequences of this ventilation effect in terms of annual consumption are to be considered in task 4. It also explains why it is not really a priority to prevent warm air entering the room around the duct, manufacturers offering for instance to open the window to pass the air duct.

Split mobile or double duct portable air conditioners may be a solution to this problem. Nevertheless, mobile split air conditioners are supplied with a flat tube flexible refrigerant line to rely outdoor and indoor units. Then, best practice for warm air entering may lead to perform a hole through the building envelope to ensure air tightness.
However, once connected, the unit cannot be moved any longer. Some manufacturers then explain that it is possible to connect and disconnect the refrigerant link between outdoor and indoor unit (with the indication it should be done by qualified personal from the own manufacturer’s Technical Assistance or by a professional installer) several times (until 6 times). Impact (refrigerant leakage) may be high or low according to the design of the flat tube connections.

3.1.2 Consumer behaviour during use phase

Hours of use

For air conditioners to supply cooling or heating, the number of hours of use – selected by the end-user (manual activation, timer control) - is of primary importance to calculate the energy consumption of the appliance. Nevertheless, because when it is put on, air conditioners are generally controlled by a thermostat, the final energy consumption (when the unit supplies heating or cooling) is not forcedly mainly defined by the end-user but by the required cooling and heating needs of the room and then will vary with the thermal characteristics of the building/room (internal loads, insulation, shading, air infiltration, ventilation practice …), with the climate, the settings of the user (temperature set point) and the way the unit is installed.
Then, we have to distinguish the pattern of use of the end-user: “I use my air conditioner 8 hours a day” means he will put on the cooling mode of the air conditioner for 8 hours, and the related effective working time: over these 8 hours, cooling the room (with compressor input) may only be needed for 4 hours.
The pattern of use is dependent on the user behaviour as opposite to the real “working time” that is related to climate, building characteristics, sun radiation, internal loads … and that is generally called the thermal load.
Meanwhile, the thermal load (or rather the ratio between the thermal capacity of the unit and the required thermal load at a given instant) itself, the climate conditions, the settings of the user also influence the energy consumption of the unit to perform its function, in addition to the design of the unit, its installation and maintenance.

In the labelling directive 2002/31/EC, energy consumption is calculated by the product of the standard full load electricity consumption by an equivalent full load hours. This equivalent number of full load hours is in fact the ratio of the total yearly consumption to the electric full load power, where the total yearly consumption takes into account real yearly load, specific sizing of the cooling capacity, variation in performance of the unit with load, outdoor and indoor temperature and the impact of maintenance lack. The complexity of these interactions can only be calculated using building and equipment simulation codes in which modelling of real life conditions can be taken into account and this technical analysis will be fully undertaken in task 4.
At the moment, we will only mention that standard energy efficiency in cooling mode is measured at high outdoor temperatures 35 °C and at full load operation while actual average outdoor temperature and average cooling load may be substantially lower, depending on climate and building characteristics. In heating mode, the same rational occurs for load, while the outdoor temperature of 7 °C would certainly be higher than the average temperature of use. This is likely to result in increased average energy efficiency for cooling and lower for heating as compared to the standard test performances. The reason for these specific rating conditions is first to be able to compare units’ cooling capacity and energy efficiency on an equal basis (and international). In cooling mode, this point defines the likely maximum cooling capacity at higher (design) outdoor temperature conditions. In heating mode, 7 °C may be high. But lower outdoor temperatures would make the tests more time consuming because of frost / defrosting cycles.

Boundary conditions are still useful, e.g the periods of time the end-users (in residences and small tertiary buildings) will use their air conditioner.
In that direction, an enquiry on the number of hours of use of air conditioners in **dwellings** was led in Spain and in Italy (ENEA, 1999). Results are figures for average use during the day, hours per day and months per year. Air conditioner categories in table 3.1 are single duct (SD), Window/wall air conditioners (PA), mobile split air conditioner (Spm), single split package air conditioner (Spf) and multi-split package air conditioner (MS).

Table 3-1: air conditioners use in residential area in Italy and in Spain (ENEA, 1999)

ITALY		RAC categories				
RAC use (months/year)	Average (%)	SD (%)	PA (%)	Spm (%)	Spf (%)	MS (%)
1-2	59	68,2	68,4	75	48,2	44,4
3-4	29	25,8	10,5	16,7	38,6	33,3
5-6	5,7	3	0	8,3	7,2	11,1
7-8	1,9	1,5	0	0	1,2	11,1
9-10	1	1,5	0	0	1,2	0
11-12	1,4	0	10,5	0	1,2	0
Don't know	1,9	0	10,5	0	2,4	0
TOTAL	100	100	100	100	100	100
Average (months/year)	2,8	2,3	3,1	2,1	3,1	3,5

ITALY		RAC categories				
RAC use (hours/day)	Average (%)	SD (%)	PA (%)	Spm (%)	Spf (%)	MS (%)
1-3	30,5	37,9	42,1	37,5	22,9	16,7
4-6	31	30,3	26,3	8,3	36,1	44,4
7-9	14,3	18,2	15,8	25	6	22,2
10-12	15,7	9,1	5,3	25	21,7	11,1
13-15	1,4	1,5	0	0	2,4	0
16-18	0,5	0	0	0	1,2	0
19-21	0,5	0	0	0	1,2	0
22-24	0,5	1,5	0	0	0	0
Don't know	5,7	1,5	10,5	4,2	8,4	5,6
TOTAL	100	100	100	100	100	100
Average (hours/day)	6,1	5,7	4,8	6,2	6,7	6
Average use (hours/year)	512	393	446	391	623	630

SPAIN		RAC categories				
RAC use (months/year)	Average (%)	SD (%)	PA (%)	Spm (%)	Spf (%)	MS (%)
1-2	59	68,2	68,4	75	48,2	44,4
3-4	29	25,8	10,5	16,7	38,6	33,3
5-6	5,7	3	0	8,3	7,2	11,1
7-8	1,9	1,5	0	0	1,2	11,1
9-10	1	1,5	0	0	1,2	0
11-12	1,4	0	10,5	0	1,2	0
Don't know	1,9	0	10,5	0	2,4	0
TOTAL	100	100	100	100	100	100
Average (months/year)	3,2	3,4	2,9	3,5	3,2	3,3

SPAIN		RAC categories				
RAC use (hours/day)	**Average (%)**	**SD (%)**	**PA (%)**	**Spm (%)**	**Spf (%)**	**MS (%)**
1-3	30,5	37,9	42,1	37,5	22,9	16,7
4-6	31	30,3	26,3	8,3	36,1	44,4
7-9	14,3	18,2	15,8	25	6	22,2
10-12	15,7	9,1	5,3	25	21,7	11,1
13-15	1,4	1,5	0	0	2,4	0
16-18	0,5	0	0	0	1,2	0
19-21	0,5	0	0	0	1,2	0
22-24	0,5	1,5	0	0	0	0
Don't know	5,7	1,5	10,5	4,2	8,4	5,6
TOTAL	100	100	100	100	100	100
Average (hours/day)	5,2	4,6	4,9	4,4	5,8	5,2
Average use (hours/year)	499	469	426	462	557	515

A few conclusions that will be useful to assess quantitative estimates in task 4, or during the sensitivity analysis afterwards, are:

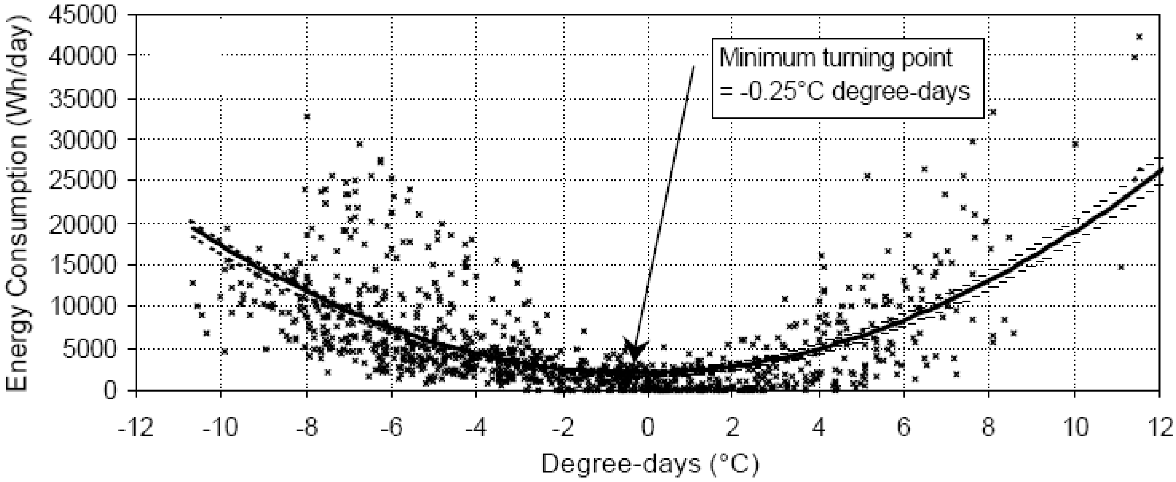
- in warm countries (Italy and Spain), the number of use is about identical; thus, it can be inferred that residential use is directed mainly by climate,
- moveable units have lower hours of use than fix installations in Italy but about identical in Spain. These results do not enable to conclude on a lower use that would be made of moveable air conditioners as compared to fix ones; in addition, sales of single duct have developed significantly in the UK, Germany and France where no information is available.
- Average annual hours of use for cooling was about 500 hours in warm climates at the time of the study in residences, and the same number of hours was adopted for moveable and fix products.

In the **tertiary** sector, cooling and heating hours of operation are closely linked to the occupation of the building, which is standardized by working hours, that is kept for further evaluation of cooling and heating needs in task 4.

Air conditioning use is spreading all over Europe in the residential area. However, there is no existing survey of air conditioning use in Central and Northern climates in residential area.

Given the general spread of air conditioning, in cars, in offices, in public transportation systems, the end-user is getting used to live in artificial ambient conditions. This is observed by energy regulating authorities that observe that the range of "non cooling - non heating" operations reduces. It is also one of the findings in the survey of energy consumption of residential reversible air conditioners (De Dear, 2002). The figure below shows that hours of use are lowered when outdoor temperature is around the required indoor temperature; the end-users still require heating and cooling operation. This general trend is likely to lead to more hours of operations, people loosing progressively their ability to adapt to more extreme climates, by clothes, protection against sun …

Figure 3-2: Survey of the yearly energy consumption of a reversible air conditioner (De Dear, 2002)



User settings

This change in thermal comfort habits could induce higher cooling requirements during summertime (lower temperature setting) and also higher heating requirements (higher temperature setting) in wintertime. Some reversible units may propose **automatic change-over** as an option. It means that the user adjusts one set point temperature with the unit providing either cooling or heating depending on the day. This option is likely to be used for intermediary conditions, in late spring or in early autumn. Best practice for this option would be to fix two different set points, one for heating and another one for cooling to create a dead-band for the controller. This best practice has not been identified amongst existing products proposing the change-over option. The over-consumption of automatic changeover with only one set point needs further calculations to be undertaken in task 4.

The tendency to higher heating set point and lower cooling set point can be balanced by best practice programs. For instance, Energy guides in the USA and in Canada clearly explicit the direct impact of temperature setting on the energy consumption. Japanese authorities also recommend to residential end-users not to cool before 27 or 28 °C, while France have forbidden the use of air conditioning in state owned buildings below 26 °C. Manufacturers could have an important active role in this matter with adjustment of default factory values and by indicating figured over consumption related to lower temperature set points (for cooling in summer). Standard indoor temperatures are of 27 °C (and around 50 % relative humidity) indoor in cooling mode and 20 °C in heating mode. In both cases, real life temperatures may be quite different.

As stated in the MEEuP base case analysis for air conditioners, most units, even simple and cheap ones, allow the setting of the desired room temperature through thermostat control. The simplest thermostat controls have only indicative settings (e.g. position "1 to 8", indicating progressive lower temperatures) and are not calibrated to degree celsius. The consequence is that with such simple settings consumers have difficulty achieving consistent and optimal temperature settings under varying circumstances. For most units nevertheless, a thermostat in degrees Celsius with digital setting is proposed so that best practice on that point already seems to be the standard case.

As stated in the MEEuP base case analysis for air conditioners, many models also allow the temperature regime to be time-dependent e.g. in function of the expected occupancy of the room(s). On that point, however, we have no information on whether this is used indeed by end-users. If most unit are programmable indeed, we have not identified any units that enable the user to program set back temperatures as for boilers. In Nordic countries, IVT proposes a 10 °C mode to maintain minimum temperature level in the house when it is not occupied, but it is not coupled to the programmer.

A number of manufacturers propose energy efficient or low energy modes, not always associated with energy savings but also with limited power that would be necessary on a short period to run other equipment in case of limited subscripted power level. Their real impact is to be figured out in task 4. No unit on the market propose adaptive control, e.g with indoor temperature that would vary as a function of outdoor climate (a constant 7 °C difference for instance).

As stated in the MEEuP base case analysis for air conditioners, additional functions such as high-low air flow settings, additional air purifying or odorizing systems, air flow louver motion control, and condensate pumps can raise energy consumption depending on how they are used.
Common options that are certainly used are low noise operations (again called silent or night modes), low noise or silent or night modes low energy modes (the air conditioner is let free to operate as efficiently as possible in function of the conditions of the room and the conditions required), fast cooling operation over a limited time period, adjustable air flow direction manual or automatic.
The impact of the indoor unit air flow reduction[3] is evaluated in task 4 and has been found to be relatively low, about 5 % reduction in energy efficiency in cooling mode for the unit tested for a cut of indoor air flow rate by a factor 2; it is in good agreement with results of (Bory, 2007) presented in the maintenance part. Consequently, the likely difference between test standard EN14511 that tests energy performance of units at maximum flow rate and the real life energy efficiency at varied air flow is likely to be low.

Stand-by energy consumption

Concerning Lot 6 study - Standby and off-mode losses of EuP, the CEN (CEN, 2007b) notes the following: “Problem is to define off-mode, standby and low power functions. There are many existing standards which are not consistent and it seems likely that either horizontal or vertical standards are required. »

Power modes of air conditioners

Accordingly, we are to define the different power modes of air conditioners in order to include them in the energy consumption calculation of the following tasks.

Fortunately, a standby portraying of air conditioners was already undertaken by Australia (AGO, 2004). Main findings are reported in the frame below.

Air conditioners have several operational modes:
• **On mode** – the air conditioner is operating (performing a heating or cooling function as applicable). This mode is not relevant for this standby profile.
• **Passive standby mode** – where the air conditioner is not operational but where it has a remote control and is monitoring for a signal from the remote control unit or where there is a timer with some programming capability (eg timed or delay start). This mode includes those with remote communications capability.
• **Off mode** – where the air conditioner is not operational and where the air conditioner has no remote control or automatic program functions or these are inoperative.
There are sometimes transition modes during startup and shutdown of the air conditioner (eg inverter soft start), but these are not considered relevant for this profile. The above modes are described in more detail below.
On mode is where the air conditioner is performing its primary function of cooling or heating as applicable. During this mode fans are operational and where there is a compressor, the compressor is either on or cycling on and off according to thermostat requirements.
Passive standby mode is present on all air conditioners that use a remote control or where there is remote communication capability. It also applies to air conditioners which may not have a remote

[3] Task 4 - Annex A

control but where there may be a control system on the air conditioner that can provide some programming capacity such as delay start or timer operation. In this mode the cooling or heating system (where applicable) is not operating. This mode includes any sump (crankcase) heaters or other forms of heating in or on the compressor where applicable (see below for further details). Air conditioners with a passive standby mode may or may not have an off mode. Typical power levels in passive standby mode are **0.2 W to 10 W without a sump heater**.

Off mode is present on all air conditioners that do not have passive standby mode. In this mode the cooling or heating system (where applicable) is not operating and the unit can only be turned on by direct intervention by the user, using controls attached to the air conditioner. This mode includes any sump (crankcase) heaters or other forms of heating in or on the compressor where applicable (see below for further details). Some air conditioners may have both off mode and passive standby modes, but in off mode remote controls and remote communication are not able to control the unit. Typical power levels in off mode are **0.0 W to 5 W without a sump heater**.

Thus, there are three modes to be considered: active mode, standby mode and off mode. (Delonghi, 2007) also reports the existence of a mode “transition to stand-by and off-mode”. Despite, the electric power in this mode is the same as for the stand-by mode.

Additional findings from (AGO, 2004) are reported concerning sump (or crankcase heaters) in the frame below.

Sump heaters: some air conditioners have small resistive heaters attached to the compressor sump or crankcase (the sump is where oil and some refrigerant collects when the unit is not operating). Sometimes other means of warming the crankcase or compressor are used such as immersion heaters within the sump itself (more common in very large compressors) or providing some current through motor windings.
The purpose of these heaters is to limit that amount of refrigerant that condenses and mixes with the oil in the compressor while the air conditioner is not operating. In some situations where there is excessive refrigerant in the sump, when the compressor starts the rapid reduction of pressure can cause the refrigerant to boil and disperse the oil, which can result in excessive compressor wear during each start, which will reduce compressor life. The issue of sump heaters and their associated energy is a substantial one.

They appear to be present on some small air conditioners (as many as one in 10) and are even more common on larger models. **The typical power draw of a sump heater is between 30 W and 90 W and these appear to run continuously on all models examined (except when the air conditioner is actually running)**. Some models have the capability of adjusting the power of the heater in response to changes in ambient temperature (so called positive temperature coefficient controls), although the heating power can remain significant even in warmer ambient temperatures.

In the case of an **uncontrolled sump heater** where the air conditioner is not used at all, the energy consumption equates **to between 250 and 720 kWh/year** for the examples above, **equivalent to a typical refrigerator**.

The curious thing is that many air conditioners do not require sump heaters. There appear to be a number of reasons why this is the case. Some compressors appear to have designs to limit refrigerant accumulation when the unit is off. Some refrigerants appear to be more problematic than others (eg R22) and the amount of refrigerant in the system also is an important issue. Other designs to overcome these problems include slow starting options on variable speed drive units where the compressor is rotated slowly during startup (sometimes with auxiliary heating) which generates slow pressure changes and limits any refrigerant phase change. Traditional sump heaters are likely to be very inefficient in that they typically heat the outer crankcase in order to warm liquids inside the sump itself. It is likely that 90% or more of the heat does not contribute to the task. Whatever the reason for their use, those models with sump heaters consume large amounts of energy while the unit is not in use, in many cases they probably use as much energy as when the air conditioner is operating (in milder climates).

The consumer is unlikely to be aware of this power consumption as most of the models with sump heaters are hard wired. While most hard wired units have to have a "hard" off switch, this is unlikely to be used by consumers, nor should be expected to have to operate this when the unit is not being used. The modes of interest for the "One Watt" Power Plan are passive standby mode and off mode. Sump heaters are included within these two modes in this profile. The term standby power in this profile is intended to cover both passive standby mode and off mode. Other modes are related to the provision of a specific energy service (heating or cooling modes) and are not relevant to this standby profile.

Since crankcase heater energy consumption is not measured very few efforts have been done to reduce this energy consumption so far. While its use is generally controlled in function of outdoor temperature (Henderson, 2000), this temperature control may have disappeared sometimes leading to a constant base electric consumption when the compressor is off. Crankcase heater resistance typically amounts to 0.5 % to 3 % of the electric power of the compressor. For a reversible air conditioner with a cooling season of 500 equivalent full load hours and 1000 equivalent full load hours, this can represent until 15 % of the annual consumption. Interestingly, when the user uses the hard switch of its indoor unit of a split air conditioner (when available), the crankcase heater resistance will remain in operation (either controlled in function of temperature or not). (Floyd, 1998) also underlines "some control strategies leave the heater connected when it is not needed, namely during the cooling season. One design only activates the heater when the compressor discharge line temperature falls below 21 °C. With that control, the crankcase heater was on only for 15 % of the time where ambient temperatures varied between 11.5 °C and 34 °C. Another design had the crankcase heater energized continuously."
With improper control, the crankcase heater energy consumption alone can represent until 25 % (500 hours of operation in cooling mode) of the yearly consumption of cooling only air conditioners and 15 % for reversible units (500 hours of operation in cooling mode and 1000 in heating mode). For cooling only operation in Moderate or Northern countries, the relative weight could be worse.

Since January 2007, Australia requires sump heaters to be controlled in function of the outdoor air temperature.

(Danfoss, 2008) advises a preheating function be installed not only for reversible split but for any air conditioner whose installed refrigerant charge is higher than the one advised for the specific compressor, which is said to be the case of all split units. However, (CECED, 2007) reported that oil heater was not to be considered for cooling only air conditioners (either split or single duct) and was common for reversible split, and although that it was not common for reversible split sold in Southern Europe. It was added that no crankcase heater was used in almost any imported splits with no brand that use new lubricants - synthetic oil instead of mineral oil - with less lubrication problem and no need for crankcase heater.

Despite, the question was raised to Eurovent (Eurovent, 2007) whether manufacturers had several products for different markets in Europe and the answer was not clear; manufacturer proposed to gather information on the use of oil heaters and to look for the existence of different design options of reversible split according to climate but no information was made available finally on this matter.

Definition of the power management modes, compatibility with the EuP lot 6 definitions

Following information by (AGO, 2004), air conditioners power management modes seem to be compatible with the lot 6 study on stand by definitions. These definitions are recalled hereunder:

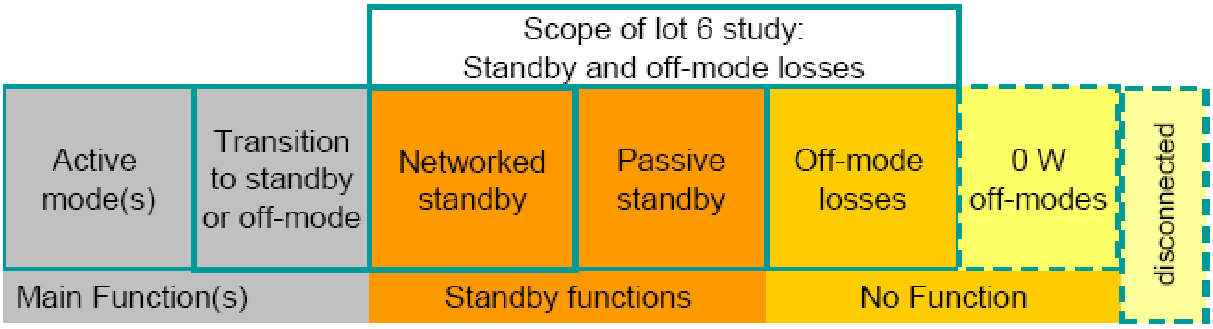


Figure 3-3: Stand by modes as defined in Lot 6 study

Main functions are already covered in specific test standards: for cooling and heating, stationary active modes are covered by the EN14511 standard and performance in part load (that may include cycling, ie the compressor is off but the unit still has the function to maintain the temperature of a room at a certain level; CEN TC 113 WG 7 proposed to call this state "thermostat-off") is covered by the CEN TS 14825 standard.
Passive standby is almost universal for air conditioners that about all have remote control, this mode enables to reactivate the equipment with the remote control. (Delonghi, 2007) also indicates networking is rather uncommon. A large majority of air conditioners have a hard switch on the panel control of the unit. It is not to be completely excluded however that some units may in addition have an off mode and still draw power, even without a sump heater.
- For moveable units, either with the hard switch (that leaves the unit connected but in 0 Watt off mode by galvanic switch) or because it is simply physically unplugged when it is not used, no power is likely to be drawn in addition of the standby energy consumption, that should be accounted for a cooling season (months with apparition of a cooling need – building and site dependant), and also for the heating season for reversible units.
- For split units and more generally for fix installations, there may be or not a hard switch off on the panel control. Nevertheless, since most units are hardwired, the unit will pass to off-mode but will almost never be disconnected. In addition, even when the indoor unit has been hard switch off in possible in 0W off mode by the end user, it remains possible that the outdoor unit still draws energy consumption for the sump heater and for the communication line between the two units. The sump heater has a function, to increase the reliability and then the life of the compressor, and that can be qualified as a continuity function even if it is controlled as a function of outdoor air temperature and/or other parameters. Because it has a clear function for the product, and can even be a gage of quality to enable proper operation in cold climates with compressors located outdoor, the corresponding function should be considered separately: energy consumption cannot be accounted as for other standby modes. In any case, power values and control should be declared by manufacturers and this should be asked for in the EN 14511 standard. However, present values declared by manufacturers in off mode and standby mode do not differ (see Appendix A, part 2). Thus, it appears that even without a sump heater, a hard wired split air conditioner is likely to draw the same power in off mode and in standby.

<u>Power values of the different modes</u>

(Delonghi, 2007) reports stand-by values between 1.24 and 2.37 W for moveable units, the back-lighted LCD screen function represents 1.05 W alone to be added when the end user modifies the control of the unit. It is also specified that some units use that backlight function only when the end-user activates the control so that this over-consumption should not be accounted for. Some units may not have a remote control and then do not have a standby mode but only an off mode. (Delonghi, 2007) reports 0 W consumption e.g no off mode for moveable units. In any case, it still may be relevant to consider both modes for some units.

In a survey led on the stand-by energy consumption of appliances in Australia, (AGO, 2006) found that the average "passive standby mode" without sump heaters of split system air conditioners was

10.7 Watts, while the average off mode was found to be 1.9 Watts. (AGO, 2006 also notes that these average power consumptions should be interpreted with caution due to the sample size of the units able to be measured (four and one unit for passive and off mode respectively), since most split systems were hardwired and thus energy consumption measurement not accessible.
From our own experience (data gathered within the frame of this study), standby power may range from 0.2 W (Australia), 0.6 W (best practice example is the case of the Japanese program to reduce stand-by losses of air conditioners) to a few watts (6 W for the model tested in task 4) and a maximum of 10.7 W in Australia. Data declared by manufacturers in Australia (Appendix A, part 2) shows much higher standby and off mode values (up to 25 W) and the same values in both modes confirming hardwired units, which represents the majority of fix installation in the EU still draws important electric current when the indoor unit has been hard switched off by the end user.

The crankcase heater electric input can range from 10 to 90 W for fix air conditioners in the scope.

More recent data as declared by manufacturers in the frame of the Australian standby programs are gathered in Annex 1. Main conclusions are reported hereafter by equipment category. No supplementary data were available in addition to the ones presented before.

- Window/wall (cooling capacity ranges between 1.5 and 6 kW)

Stand-by and off mode power ranges from 0.1 W or less until 5 W. Forces of the market failed to reach the Australian voluntary target of 2007: 8 % of products pass the off mode 2007 threshold (1 W), 3 % of products pass the standby 2007 threshold (2 W). One unit over 135 reversible with low mode power values available is declared with a crankcase heater of 35 W.

- Split / Multi-split (cooling capacity ranges between 1.5 and 60 kW)

There is no relationship between off mode power or standby power and cooling capacity or electric phase of the unit. Default components and control lead to standard value of 5 and 10 W. For smaller units with more functions, standby power may increase until 25 W showing there is no effort made to separate the standby function of the reactivation functions that are not required in these low power modes. For crankcase heater power, there should be a correlation with cooling capacity. This correlation does not appear clearly. Default external crankcase heater of scroll compressor as proposed by OEM (90 W) serve units with cooling capacity from 5 to 60 kW. Electric power of the crankcase heater for 6 kW units ranges from 5 W to 90 W showing a great margin for improvement. For most units, it is not possible to know whether the crankcase heater is controlled as a function of outdoor air temperature because standby measurement is made at the rating H1 test conditions. However, since in Japan, measurement in made in cooling mode T1 conditions, a few manufacturers may indicate standby power separately from crankcase heater power.

<u>Hours of operation of the different power modes</u>

In order to compute the energy consumption related to standby power of the different modes, it is necessary to establish patterns of use. Given that most of the time, standby power consumption is constant in a specific mode, it is enough to fix a number of hours of operation.

Basically, over the 8760 hours, it simply means to discount the cooling season (and the heating season for reversible units) to find the off-mode period (for moveable, units are likely to be disconnected, while for split it should be in off-mode, and crankcase heater be added if present).
Then standby hours are the difference between the total number of hours of the cooling season and the hours with cooling operation that is demanded (to be added to winter operation for reversible units).
Then, when the end-user has put the unit in active mode, the unit may be in the “thermostat-off” state. We will compute these hours of thermostat-off as the difference between cooling operation required by the end-users following the timetables of simulations in task 4 and the cooling hours (hours with operation required, at reduced or full capacity).

Following (Karlsson, 2006), we will conclude that oil heaters are certainly a quality mark that will ensure a longer life of the compressor and that is then unlikely to be found in cheaper reversible units. It is certainly absent from cooling only units. The reversible split unit tested in part 4 was equipped with a temperature controller and the oil heater was stopped above 7 °C that seems to be the best available option. It is not known whether this temperature control is general or not for units that have a sump heater. What is sure is that the heater is off when compressor is on. It means that for inverter controlled units, the maximum hours of operation is 8760 hours minus cooling + heating hours of operation. For ON-OFF control units, because of cycling, more hours should be accounted for, nevertheless, this is to be taken into account in the cycling performance (thermostat off) in the part load standard. Then, it enables to compute the same number of hours whatever is the technology.

Taking into account standby energy consumption

At the moment, EN14511 only covers the electricity consumption of the air conditioners when performing their cooling or heating duty, including auxiliary consumption. However, no attention is paid to other power modes. Definitions of these modes should be added and measurement methods included in the standard. A yearly index, as requested by (CECED, 2007), taking into account the different modes would enable to compare air conditioners on a fairer basis and give a better information to the end-users. Nevertheless, it does not entail the added value of the Australian approach of stating the energy consumption in the different modes, that has the advantage to warn specifically the end-user on standby energy consumption, likely to represent about 10 % of world electricity consumption. Both approaches should be kept to get optimal results, particularly since the total weight of standby energy modes on the total yearly consumption may be very low in absence of an inefficient sump heater.

A summary is proposed in the table hereunder.

Category	Product type	Reversible Or cooling only	Mode characteristics	Passive standby	Off-mode with losses	Off-mode (0 W) or Disconnected	Crankcase heater
Fix air conditioners	**Split, multi-split, window/wall, double duct (fix installation)**	**Cooling only**	**Function**	Remote control, reactivation function, timer	No	Plugged units only	Prevent compressor failure
			Power value	6 W Plugged units: 0.2 to 10.7 W Hard wired units: up to 25 W	6 W plugged units: 0.0 to 4 W hard wired units: up to 25 W for	0 W	10 to 90 W 30 W (unit with Pc < 6 kW) 70 W (unit with Pc > 6 kW)
			Hours of operation	Cool. Season minus active period	Plugged units: Cool. Season minus active period Hard wired units: 8760 hours minus active period	Plugged units: 8760 hours minus cool. Season Hard wired units: never	Depends on control
			Comment	Majority of products	Majority of products	A minority	No heater is the general rule (most equipment in Southern countries)
		Reversible	**Function**	Remote control, reactivation function, timer	No	Plugged units only	Prevent compressor failure
			Power value	6 W Plugged units: 0.2 to 10.7 W Hard wired units: up to 25 W	6 W plugged units: 0.0 to 4 W hard wired units: up to 25 W for	0 W	10 to 90 W 30 W (unit with Pc < 6 kW) 70 W (unit with Pc > 6 kW)
			Hours of operation	Cool. Season minus active period	Plugged units: Cool. Season minus active period Hard wired units: 8760 hours minus active period	Plugged units: 8760 hours minus cool. Season Hard wired units: never	Depends on control
			Comment	Majority of products	Majority of products	A minority	May not be common for the cheapest equipment
Moveable	**Mobile split, Single duct, double duct (mobile)**	**Cooling only**	**Function**	Remote control, reactivation function, timer	No	No	No
			Power value	6 W (0.2 to 10.7 W)	0.5 W (0.0 to 4 W)	0 W	N/A
			Hours of operation	Cool. Season minus active period	Cool. Season minus active period	8760 hours minus cool. season	N/A
			Comment	Majority of products	For products without remote control	Majority of products	No heater (compressor indoor)

		Reversible	**Function**	Remote control, reactivation function, timer	No	No	No
			Power value	6 W (0.2 to 10.7 W)	0.5 W (0.0 to 4 W)	0 W	N/A
			Hours of operation (*)	Cool. and heat. seasons minus active period	8760 hours minus cool. + heat. season	8760 hours minus (cool. + heat.) season	N/A
			Comment	Majority of products	For products without remote control	Majority of products	No heater (compressor indoor)

Window opening

Consumer behaviour as regards opening of windows and doors during use remains relevant, since it should be avoided that warm air continuously enters the room when the unit is on (as already mentioned, it cannot be avoided for single duct air conditioners). On the contrary, window opening can enable to decrease indoor temperature when load is first linked to internal gains, which is the general situation in offices and shops. A summer survey of air-conditioned shops in the UK found that 36 % had their doors open, 25 % had air curtains but did not have them operating, 2 % had operating air curtains and the rest had closed doors (Brown, 2006). Hence the general advise for door opening when outdoor air temperature is for instance below 25 and 26 °C with the air conditioner off and in any case to close the openings when the air conditioner is on and the outdoor temperature is higher that the one required indoor that should be made available to the end-user.

3.1.3 Maintenance

In this part, we are mainly interested in the impact on real life efficiency of the maintenance that has to be done on air conditioners while in the subtask 3.2, maintenance is regarded for its consequences on the product life of the unit (possible stop or breakdown in case of lack of proper maintenance) and we attempt to answer the following questions:

1. Is maintenance a common practice, under what form? And how far mandatory European specific measures (EPBD and F gas) can interact?
2. What is the impact on the real life efficiency of the unit?

Is maintenance a common practice?

Households sign maintenance contracts relatively seldom. The only identified source concerns the French market in 1999 and 2000: an enquiry addressed to installers of air conditioners in France shows that about 30 % of air conditioners were sold with a “maintenance” contract by the installer (Batim Etudes, 2000). This figure is applicable only to fix installation, and not to portable air conditioners for which maintenance occurrence should be quite lower since the appliance is more similar to other households white goods. This type of “maintenance” is called business “repair” and households call in case of failure. Electrical installers often take care of air conditioners purchased by households, not being real air conditioners’ installers.

Owners and managers with expertise in air conditioning are very few. However an owner or a manager will rely on some real professionals : maintainers, consultants, operators, who earn their living from the relationship with him. Maintenance will take place on a regular basis and/or after a breakdown, and aims at availability, not usually thermodynamic performance.

If not already required by other standards, the EN 14511 test standard for air conditioners forces the manufacturers to provide supplementary information with among others, maintenance practice advices:

- advice for maintaining cleanliness of heat exchange surfaces; some manufacturers also develop easy access filters to enable end-users to take care themselves of preventive maintenance; this can be seen as a best practice design option;
- content and frequency of routine maintenance operations to be performed by the user;
- content and frequency of maintenance and inspection operations which shall be performed by a specialist.

Manufacturer’s regularly scheduled maintenance program guidelines are thus supplied when purchasing an air conditioner. It is of course greatly advised to follow these guidelines whose main points are presented hereafter. The recommended frequencies of maintenance and inspection depend on manufacturers and the frequencies that we report only aim at giving orders of magnitude.

Split/Multi split units

Regarding the indoor unit, the air filter must be clean every month. A vacuum cleaner can be use to remove dust, the filter can also be washed with water and dried afterwards. Indoor and outdoor coils must be regularly cleaned paying particular attention to avoid any obstruction to the airflow. If the refrigerant charge is higher than 3 kg (2 kg in France) it is compulsory to check the installation for refrigerant leakage. Since the scope is [0-12] kW and that average refrigerant charge value of 0.3 kg / kW of cooling capacity is an accepted common value, it simply means that most air conditioners in the scope will not be subjected to this regular inspection.

For higher capacity products [10-12] kW or for tighter regulation (as in France), the inspection can only be carried out by certified companies. This annual control can come with a non-compulsory comprehensive maintenance that consists in duct, compressor, filter inspection and in airflow rate measurements. Possible practice is summarized hereunder for Split and Multi-Split systems based on operation manuals.

Table 3-2: Maintenance tasks of split/ multi-split air conditioners

Period	**Measure**	**Who?**	**Compulsory?**
Every month	Clean or replace the AC filters (indoor unit)	Owner	N
Every six months	Clean the coils	Owner	N
	Clean landscaping (grass, debris) ahead the outdoor unit	Owner	N
Every year	- If Fluid mass > 3 kg (2kg for France); Fluid containment, fluid leaks control	Certified companies	Y
	Clean and inspect the motor, compressor, air handler, ducts, coils and air filter	Certified companies	N
	Measure the airflow over the air conditioner's cooling coils	Certified companies	N

Movable air conditioners

Mobile air conditioners require a minimal maintenance. Filters and fans must be regularly cleaned the water tank must be sometimes emptied.

Table 3-3: Maintenance tasks of single duct air conditioners

Period	**Measure**	**Who?**	**Compulsory?**
Every month	Clean AC filters (vacuum cleaner, rinse, dry)	Owner	N
For a long stop	Clean the filters	Owner	N
	Remove the water of “condensates”	Owner	N

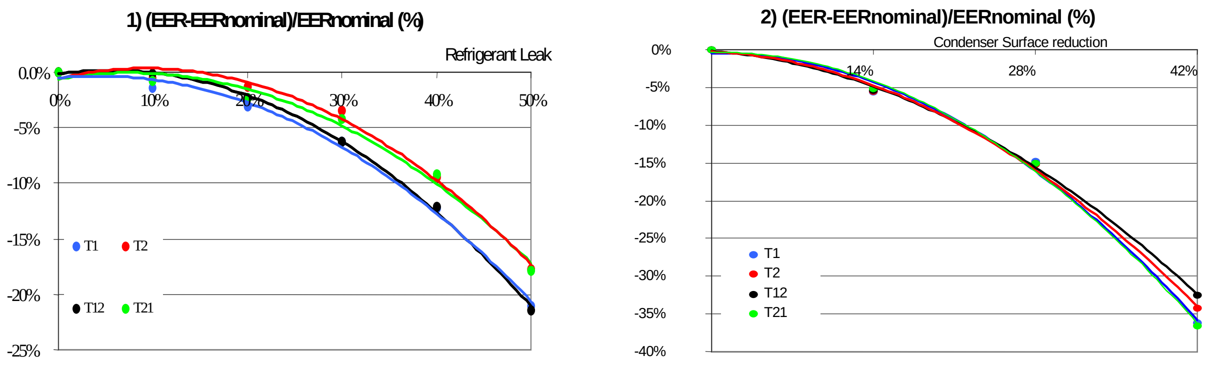
Options to ease maintenance have been developed by manufacturers such as auto-cleaning air filters and easy cleaning options. As for an increasing number of white goods, some manufacturers propose options that relate to the auto-diagnosis of operation faults of the unit and that propose in consequence solutions to the end-user. These integrated features may be seen as best practices concerning maintenance.

Impact on energy efficiency

Energy efficiency of air conditioners depends directly on the maintenance practices.

Results have been adapted by (Bory, 2007) to an average split unit (representative of the stock of air conditioner, with R22 refrigerant). The different curves represent different operating conditions indoor and outdoor, ISO 5151 T1 conditions, T2 conditions, and reversed indoor and outdoor conditions for these two conditions.
More significant impacts of energy efficiency are for refrigerant leak and condenser (outdoor heat exchanger, cooling mode) fouling.

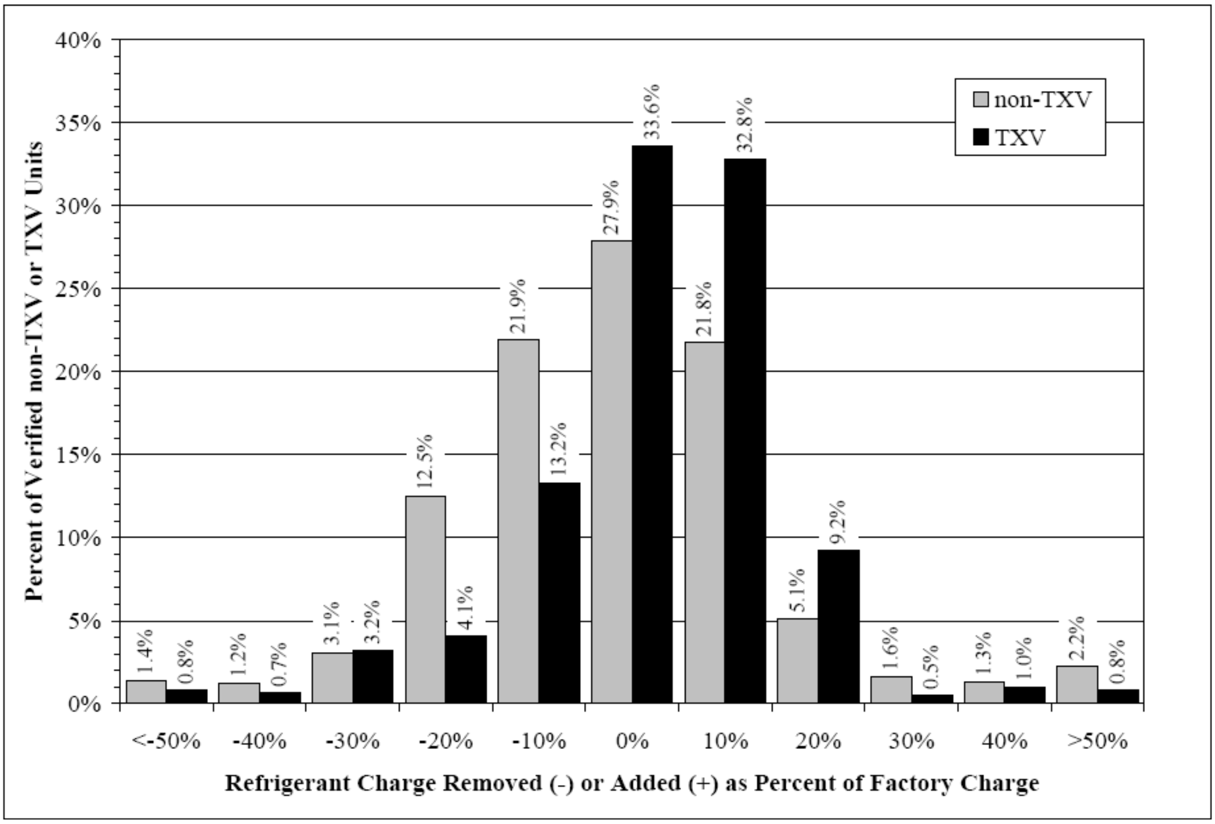
Figure 3-4: Simulation of default impact on air conditioner performance from (Bory, 2007)



For large air to air conditioners (roof-tops), (Breuker, 1998) indicated a maximum 20 % decrease in energy efficiency because of condenser fooling in real life. This corresponds to a 30 % decrease in the heat exchanger surface of the outdoor unit. The **impact of indoor heat exchanger fouling** is also calculated and gives lower values (4 to 6 % energy efficiency decrease for a 50 % air flow reduction). Nevertheless, these values are very much dependant upon the repartition of the thermal resistance between air and refrigerant and are likely to be higher for more efficient units.

Concerning **refrigerant leakage** impact on energy efficiency is in good agreement with other simulation results and laboratory tests (Farzad, 1993) that also stress little performance drop with over or under refrigerant charge. Noticeably, thermostatic expansion valves could in theory help to decrease the consequences of too low refrigerant charge.
However, (Mowris, 2004) led a large campaign of charge verification and found much higher figures than predicted by simulation tools. Over the more than 4000 central air conditioners units checked about 2/3 were not properly charged. The distribution of the factory charge as compared to the charge figuring on the plate of the appliance is shown in the figure below.

Figure 3-5: Results of the campaign of charge verification, source (Mowris, 2004)



Findings by (Mowris, 2004) show that after proper charging, energy efficiency gain could be much higher than expected in simulations: a 21 % efficiency gain was obtained in average after charge correction for those equipped of thermostatic expansion valve and undercharged by 25 %. This is an interesting point for the Ecodesign of air conditioners because most units are already charged when installed on field but it is never checked nowadays, except if refill is needed or in case of refrigerant inspection but that only applies to larger capacity units.
However, the variation of energy efficiency with refrigerant charge may differ for other products (and also in heating mode) in the scope and this is still to be figured out. At the moment, we have a scale of possible degradation with refrigerant leakage as large as 5 to 20 % for 25 % under charged units.

It can be concluded that the lack of appropriate maintenance has to be taken into account as far as energy efficiency degradation is concerned, including reduced heat transfer areas outdoor and reduced refrigerant charge because of leakage.

3.2 End-of-Life behaviour

3.2.1 Economical product life

First of all, it is important to remind that there are many definitions of lifetime as it was explained in the CEN Workshop Agreement (CEN WS 27, 2007) concerning lifespan of appliances for energy saving calculation. The **design lifetime** here is the intended lifespan, in terms of functioning time, number of functioning cycles, etc, foreseen by the manufacturer when he designs the product, provided that it is used and maintained by the user as intended by the manufacturer. The design lifetime must not be confused with the guarantee period of products, which is a service offered by the manufacturer and fulfills other constraints, namely commercial. The **behavioral (or social) lifetime** is defined as the number of years until the device is replaced for other reasons than technical failure or economic unattractiveness. This generally regards social and consumption trends, a product including new feature has been released and is preferred, a more powerful computer ...

In this study, the term "lifetime" or "Economic product life" must be understood as the period (ie the number of years) during which the appliance is used and consumes electricity ("actual time to disposal"). It is therefore a value included between the social lifetime and the design lifetime. It is also an abstraction of reality since, for a given product, a single value is investigated for all Europe whereas lifetime depends on location, marine climate for example, or more operating hours in cooling for Southern Europe ...

The question of the evaluation of the total lifetime of room air conditioners was raised at the stakeholder meeting of September 8, 2006. JRAIA and CECED have been the only organizations to answer and have proposed similar values. For CECED that mainly represents manufacturers of moveable air conditioners (single duct, double duct and mobile split), a typical product life is about 12 years. They also added that premature replacement sometimes might occur as switch from portable air conditioners to fixed split systems. This observation is in good agreement with the fact that moveable air conditioners, that have the compressor located inside the room whose air is to be cooled, are more noisy for the end-user that other air conditioner types. Many other causes can justify this willingness to change as being forced to install the air conditioner when it is to be used, having the indoor unit inside the room if space is constrained …

Lifetime values are also in line with the results of the (ENEA, 1999) survey reported in the table below. It was also found that the average life span of the four main air conditioner types in Spain and Italy was largely due to the desire for a new unit rather than equipment failure, due to good reliability and low annual usage. The values identified at that time are reported in the table below.

Table 3-4: Average life expectancy for different kinds of air conditioners (ENEA, 1999) used in the (EERAC, 1999) study

Category	Average life expectancy (years)
Window/wall package air conditioner	12.6
Multi split package air conditioner	12.6
Single split package air conditioner	12.5
Single-duct package air conditioner	10.3

According to JRAIA, product life for residential units in Japan is estimated to be about 12 years based on the analysis of recycled products and for commercial units it is thought to be between 10 and 15 years. They guess it could be longer in Europe than in Japan because of less hours of usage in average, especially since a large part of the products are not reversible or not used as such, whereas in Japan residential air conditioners are used in winter and summer time. JRAIA have also provided us with the main causes of replacement decision by order of importance:

- breakdown,
- drop in performance,
- rise in sound noise,
- replacement by more energy efficient models,
- building renovation,
- the end-user is moving.

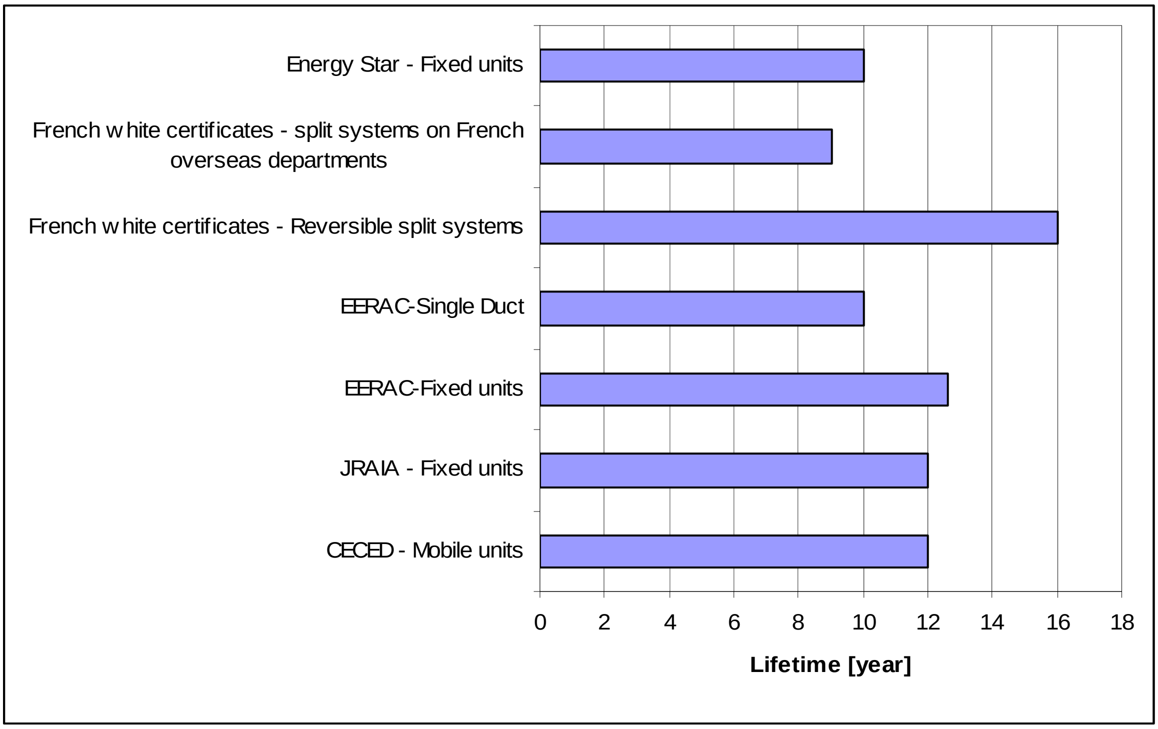
From a meeting with JRAIA on 6 December 2006, accurate figures were obtained regarding end-of-life causes for fixed air conditioners in Japan. Official statistics presented show that 62% of replacement purchases are the result of breakdown, 13% as upgrades, 16% because of moving house and 10% other reasons. The breakdown major cause is the compressor failure.

In Europe end-of-life causes are similar but no study has been carried out to assess their importance even in country where the market is mature. The WEEE frame could enable to establish reliable statistics on this matter once it has entered into force. Some data may already exist for some countries in which this directive already applies.

In the frame of the implementation of white certificates, the French State has estimated the lifetime of air conditioners (only single split package and multi split package air conditioners) that are used in French overseas departments and territories at 9 years. However, conditions of use are more intensive: climate is generally hot and air is charged in salt leading to the accelerated corrosion of heat exchange areas of outdoor unit. The lifetime of reversible air conditioners (only single split package and multi split package air conditioners) used in France is estimated to 16 years.

Regarding third countries, in the ENERGY STAR brochure about room air conditioners (Energy star, 2007), it is written that according to the "28th Annual Portrait of the U.S. Appliance Industry, *Appliance Magazine*, September 2005" (Appliance, 2005), the typical product life for RAC is ten years. Furthermore, because models that are at least 10-years old use 20% more energy than a new ENERGY STAR model, ENERGY STAR advocates consumers to replace 10-year-old room air conditioner with a new ENERGY STAR qualified model.

Figure 3-6: Air conditioners' lifetimes, from different sources and for different types



Lifetime values identified lie between 10 and 16 years for air conditioners. Japan estimate of 12 years for residential and commercial products are certainly the more reliable because based on a broad statistical analysis.

In Japan, 62 % of the replacements correspond to failure, 12 years may be considered as an upper limit for reversible units for a typical use. If we consider the Tokyo climate as the average Japanese climate as in the APF standard (JRAIA 4046, 2004), then it means around 3000 hours when the unit is working in heating mode and 1500 in cooling mode. Considering an average load rate of 50 %, this leads to 2250 hours a year and in a time period of 12 years to around 25 000 to 30 000 hours of operation of the compressor before breakdown. This figure then gives an idea of the maximum hours of operation.

There is not enough evidence to conclude on the lifetime of the different types of air conditioners. Certainly, there may be reasons for shorter average life expectancy of single duct units because of replacement by single split units, as explained by CECED. Life expectancy of products in Europe, especially cooling only units may be longer than in Japan – 12 years. At the same time, (ENEA, 1999) found that people changed their units in Italy and Spain not because of failure but rather because of the will to buy a new one. In absence of further data, we will then keep the values of **12 years for all types of air conditioners**. A sensitivity analysis will be performed in order to establish the impact of a longer or shorter life.

3.2.2 Repair - and maintenance practice

Regarding repair and maintenance actions that are usually performed by professionals, two points must be raised: fluid refill and additional material of spare parts.

Refrigerant fluid leakage

Refrigerant fluid leakage rate represents the amount of rejected fluid according to the initial charge. A French study, (Barrault, 2004) proposed different values for average yearly emission rates reported in Table 3-5. The values used for life expectancy of the units are the ones reported here above.

Table 3-5: Leak rates for different types of room air conditioners (Barrault, 2004)

	Single and double duct	Window/Wall	Split	Multi split (<17,5kW)
Nominal charge [kg]	0.5	0.5	1	1.5
Lifetime [years]	10	10	15	15
Leak rate	2 %	2 %	5 %	15 %

For compact units (by opposition to split units), 2 % annual leakage is a common value previously used in the TEWI 3 (DOE, 1997) reference study. However, stakeholders have indicated that since they were filled and hermetically sealed in factory, single duct leak rates were lower and comparable to leak rates for fridges, or 1 % of yearly leakage, including the refrigerant recovery loss and the refrigerant leakage during the life of the product.

Concerning split and multi-split systems, annual emission values are higher with 5 % and 15 % respectively. A field study of leakage rates on air conditioning and refrigerating equipment was led in France (CETIM, 2004); estimates of 3.8 % were found in situ for two split units working with R22. The same order of magnitude was identified for small air to water heat pumps and then may be adopted for mini-chillers. According to (CETIM, 2004), leaks are localized at connection of supplementary components (valves, pressure gauges, potential intrusive temperature measurements …). As a consequence, the value of 15 % for multi-split units seems high for multi-split of the [0-12] kW range that are mostly made of two indoor units, whereas the value seems to be set up for a multi split with 3 indoor units. 10 % is seen as an upper value. These values are also the ones adopted by the International Governemental Panel on climate Change (IPCC/TEAP, 2005).

Results of the STEK study (STEK, 2001) indicate a global leak rate (leakage and recovery at the end of life) inferior to 3 %. Results are based on statistics of the refill made by installers. It includes the end of life losses. This values includes the leaks during the life of the products and the part of the refrigerant dumped at the end of life. It seems to be the more statistically significant study for leak rates in Europe but also in an advanced country for end-of-life recovery. In the EUP Methodology study, in the Product case report study, (product case 2: room air conditioners, chapter 4.3.2 refrigerant losses), it is stated that for leakage 4 % per year is considered average, including end-of-life and that “refrigerant losses of the base case during its whole lifetime (including end-of-life) are estimated at 35% following the results of a study presented on the 2004 Earth Technologies Forum."

This evolution in figures between these latest values and the (IPCC/TEAP, 2005) values seem to translate a progress between the stock of air conditioners, older units, and the current situation, that apparently has been improved. In absence of statistically significant data, it is difficult to make a correct assessment, valid for all EU products.

In conclusion, the yearly leakage rates in operation seem to be as low as 1 % for single package air conditioners and 3 % for split air conditioners over a 12 years average period, including end of life recovery losses.
Final values kept within the study are of 1 % yearly leakage rate for package units in operation and 3 % for split with 5 to 10 % refrigerant loss at the end of life.
It means that the average operating charge is of 94 % for package units and of 82 % for split units. Then, we assume that no fluid reloading is carried out and also that refrigerant leakage does not imply any significant energy efficiency loss.

The end-of-life hypothesis is to be understood in the terms of the MEEuP methodology as a post WEEE condition. In case the unit would not be treated following the WEEE directive, all the refrigerant fluid would be lost at the end-of-life.

Component changes

On some websites (DELMO for example), available spare parts and proposed and prices are given. It seems that all components (compressor, exchanger, tubes) can be bought individually by repair companies. In any case, repair should be performed by a professional which would add to the costs of the pieces. Important technical problems like a compressor breakdown may occur when the appliance is old. Since the lifetime of a compressor is estimated around 12 years (EECCAC, 2003), it is very unlikely that a compressor change would occur during the lifetime of the air conditioner: if it has to happen after 10 or 12 years, certainly the end-user would change the complete unit given the cost of the intervention. It is not known if repair actions are often carried out neither which ones and consequently, it is not possible to estimate additional material for repair.

Normal maintenance like cleanliness of the filters, emptying and cleaning the condensate container requires no additional material. Manufacturers now propose washable filters. In general for products in the scope, there is no maintenance contract. As a consequence, no additional material would have to accounted for during the life cycle. In case of maintenance contract, we have not identified any data concerning usual maintenance practice and consequently have no information concerning possible additional material to be added to the raw input to compute the environmental impact of the product.

3.2.3 Present fractions to recycling, re-use and disposal

Nowadays, insignificant values for recycling and disposal are expected, as the air conditioner market is only emerging in most of EU member states.

For mobile units, there are two alternatives:
- in countries with no WEEE scheme already in place, they may either be collected with fridges and freezers (the end of life should be the same that when a WEEE scheme is already in place, (CECED, 2007)) or collected in the same stream as brown goods like TV or washing machines. In that latest situation, according to the country, appliances are disposed in landfill or treated, metals ferrous and non-ferrous (copper, aluminium…) are in general retrieved after being grinded but refrigerant circuits are likely to be destroyed and then refrigerant vented to the atmosphere. This means at the moment all the refrigerant charge originally in the air conditioner or added during the life cycle is likely to contribute to global warming.
- in countries with WEEE scheme established, they should be collected in a particular stream with refrigerators and freezers. Fluids should then be recovered before air conditioners are sent to grinding

centers. Metals ferrous and non-ferrous (copper, aluminium…) are in general retrieved after being grinded whereas recovered fluids are burned.

For fix units, according to UNICLIMA, there is an existing "end-of-life scheme" for most of the air conditioners since local scrap merchants are aware of the values of these units (copper, aluminium) and recover them to dismantle and sell materials. According to Gifam, installers remove the air conditioners and bill it as "disposal and end of life treatment". Then the air conditioner is sold to scrap merchants or "solidarity based economy" associations. Fix units are therefore dismantled, valuable wastes (copper…) are sold and last wastes (materials that cannot be sold) are grinded. In that latest hypothesis, a part of the refrigerant could be recovered. But fix appliances may also be included in the national WEEE scope (since there is an uncertainty on the WEEE scope directive regarding installed fix air conditioners, it may differ from one country to another). In that case, refrigerant is likely to be recovered.

Recovering the refrigerant of a fix unit (Split…) requires a consequent amount of money (bottle rental, specialist…) and time. According to manufacturers, extraction and collection of refrigerant cost between 4 and 7 euros per unit. When split appliances are not included in the WEEE national scope, it is assumed that users or operators choose to release the fluid in the air rather than confine it. For the time being, there is no legal mean to check that the refrigerants of fix units is recovered. For portable units, the same recovery rates as for refrigerators can be assumed. This is of importance for systems using hydrocarbons with low-GWP since their flammability may pose a risk.

The end of life behaviour regarding room air conditioner will be partly influenced by the WEEE directive, as room air conditioner, if they are not a fixed installation, fall under the scope of the WEEE directive (category 1 "Large household appliances") which puts the responsibility on the producer: referring to the scope of this study this will apply to non-ducted split-packaged unit with mobile indoor unit (mobile split) and single duct air conditioner only.

If one adopts the position to be in the frame of the WEEE directive, the rate of recovery shall be increased to a minimum of 80 % by an average weight per appliance, and component, material and substance reuse and recycling shall be increased to a minimum of 75% by an average weight per appliance. Beyond this there is an obligation to remove refrigerants from any separately collected WEEE: this obligation applies to "ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits: the gases must be properly extracted and properly treated. Ozone-depleting gases must be treated in accordance with Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer (4)". Hence, HC 290 with no ODP and a GWP of 11 (EIA, 2007) is not concerned by this obligation. These substances, respective preparations and components shall be disposed of or recovered in compliance with Article 4 of Directive 75/442/EEC.

Following the F-gas regulation 2006/842/EC on "fluorinated greenhouse gases" recovery for the purpose of recycling, reclamation or destruction shall take place before the final disposal of the equipment and when appropriate, during its servicing and maintenance for the case of stationary equipment, applying to the air conditioner products listed in the scope excluding the above mentioned and provided refrigerants containing fluorinated greenhouse gases are in use.

3.2.4 Estimated second hand use, fraction of total and estimated second product life

Statement from UNICLIMA stresses there is rather no incentive or economic justification for refurbishment or second hand use of fix appliances since reinstall a fixed air conditioner and fill it with a new fluid costs more money than a new product.
Regarding moveable units, a second hand use market exists. The situation may change but there is at the moment very little second hand use of the products. It was confirmed by a survey led on Ebay in the frame of this project where very few products are available, despite of direct imports from China

of new products. Main second hand market is thought to relate to people buying a portable air conditioner before the summer in case of heat wave and willing to recover the money once the summer has ended. This market can be neglected here.

3.2.5 Best practice in sustainable product use, amongst others regarding the items above

The first step toward the best practice in sustainable product use, regarding the items above rely on the application of WEEE. Regarding air conditioners, there are many negotiations and both the scope and the suitability of treatment capacities remain unclear. Let's mention that specific fees for disposal and treatment for air conditioners are shown in the price band of approximately € 13 per appliance in the EU. As a comparison the framework conditions in Japan regarding the implementation of the Home Appliance Recycling law shows a very different situation: the fee for air-conditioning equipment amounts to YEN 3.500 in 2005 (approx. € 25) according to (DTI, 2005).
Aiming at a fully environmental sound product use, including the end of product life aspects, user should be aware of all related aspects. This is required by the WEEE directive, article 10. Here again, the WEEE scope appears to be of primary importance.

Among others, two existing examples are presented that can be considered as "best practices" for Europe regarding air conditioner end-of-life.
In Canada, the Clean Air Foundation (http://www.cleanairfoundation.org/) implemented in 2002 the keep Cool program that aims at reducing the number of old room air conditioners. A $25 in-store coupon to be used at participating retailers is offered when people turn in their old conditioner.
The Clean Air Foundation has then to deal with the old and inefficient collected appliances. It puts in place a network that is presented as "ensuring that old room air conditioners are handled in the most environmentally appropriate manner. This not only includes adhering to all regulations governing refrigerants, but also making sure oils, capacitors, recyclable metals and plastic are taken care of." It is mentioned on its website that RAC are treated in 5 steps:
Step 1: The air conditioners are palletized at The Home Depot and Home Hardware locations and shipped to their main distribution centre. Plugs are cut and units are tagged for tracking purposes and to ensure the units are not sold for re-use.
Step 2: Once consolidated, the units are shipped to Total Home Comfort Recycling site for processing.
Step 3: Total Home Comfort will safely handle the refrigerants from the donated air conditioners. Using the latest technology, refrigerants (likely R12 or R22) are extracted into containers that safely capture the refrigerants.
Step 4: After taking down information on the unit, the hulk and shell of the unit are sent through a metal and plastics recycling program. The refrigerant containers are then sent through the Refrigeration Management Canada (RMC) program. All refrigerants are sent for re-use or proper disposal by one of Canada's certified refrigerant management companies.
Interestingly, people are invited to turn in their old and energy inefficient air conditioners. The purpose is to reduce the number of old air conditioners by inciting people to buy a new one and in this way to ease the burden on the power grid in summer among with ensuring a suitable end-of-life treatment.

3.3 Local Infra-structure

There are several important points concerning the influence of the infrastructure on the potential growth of air conditioners (reasons why other cooling means cannot develop), the influence of local infrastructure on their energy consumption (heat island effect for instance) but also the influence of air conditioners on their environment (increase peak demand and possible related problems on the electric grid). These problems, that are to be included in the study at different stages, either in the market modeling or in the study of impacts (either as supplementary impacts or parameters for different scenarios) are gathered hereafter.

3.3.1 Urban and social context of air conditioning and ventilating

The national, regional or municipal authorities may be interested in promoting the lowest life-cycle cost solutions for consumers, and at the same time, as urban planners are interested in promoting local development, improving visual comfort, architectural aesthetics etc.

The choice of the type of cooling system escapes to local authorities, except for the aesthetics part (the outside aspect of buildings is very often regulated) or in case of creation of a district cooling system. Such authorities may integrate in their development projects local impacts (negative): noise, power plants, works, aesthetics; external costs ; or (positive): job creation, services to citizens and companies. Regarding district cooling, the conditions necessary, or that justify its construction, are even more site dependent. As an illustration, the first district cooling networks appeared in Northern European cities (e.g. Stockholm) where cooling demand is very low but where other networks were being installed, thus permitting the installation of a cooling network at low marginal cost. Others appeared due to a circumstantial overcapacity (Climespace in Paris), or in new urban areas where they were bundled with other developments (e.g. Lisbon World Exposition Expo'98 site).

Air temperatures in densely built urban areas are higher than the temperatures of the surrounding areas. The phenomenon is known as the “heat island” effect and is the most obvious climatic manifestation of urbanisation. It can be defined as a "reverse oasis" - a urban area that is hotter than the surrounding countryside due to a lack of trees and vegetation, and use of dark surfaces like roofs and pavements that absorb and retain the sun's heat and less ventilated.
The net balance between the solar gains and the heat loss by emitted long wave radiation determines the thermal balance of urban areas. Because the radiant heat loss is slower in urban areas, the net balance is higher than in the surrounding rural areas, and thus temperatures are higher. Effective design of passively cooled urban buildings requires a good understanding of the urban climate characteristics, in particular of the temperature and wind distribution.
Most European studies concentrate on night heat islands during the winter period, but few studies analyse the day-period and summer heat islands. Naturally, in cold climates, the urban heat island effect can be positive in terms of energy consumption as it reduces heating needs. Conversely, the heat island effect in warm to hot climates exacerbates cooling energy use in summer. In-depth measurements have been made in Athens, where thirty automatic temperature and humidity stations have been installed giving hourly data during more than 3 years (Santamouris, 2004). The main objective of the project was to study various urban micro-climatic conditions. The following conclusions were drawn:

- Cooling degree hours in the central area of the city is about 350% higher than in the suburban areas;
- Maximum heat island intensity (the difference between the maximum urban temperature and the background rural temperature) in the very central area is close to 16 °C, while a mean value for the major central area of Athens is close to 12 °C;
- The Western Athens area, characterised by scarce vegetation, high building density and a high anthropogenic emission rate, presents twice as many cooling degree-days than the Northern or Southern Athens area. The heat island intensity in the central Park is close to 6.1 °C, compared to

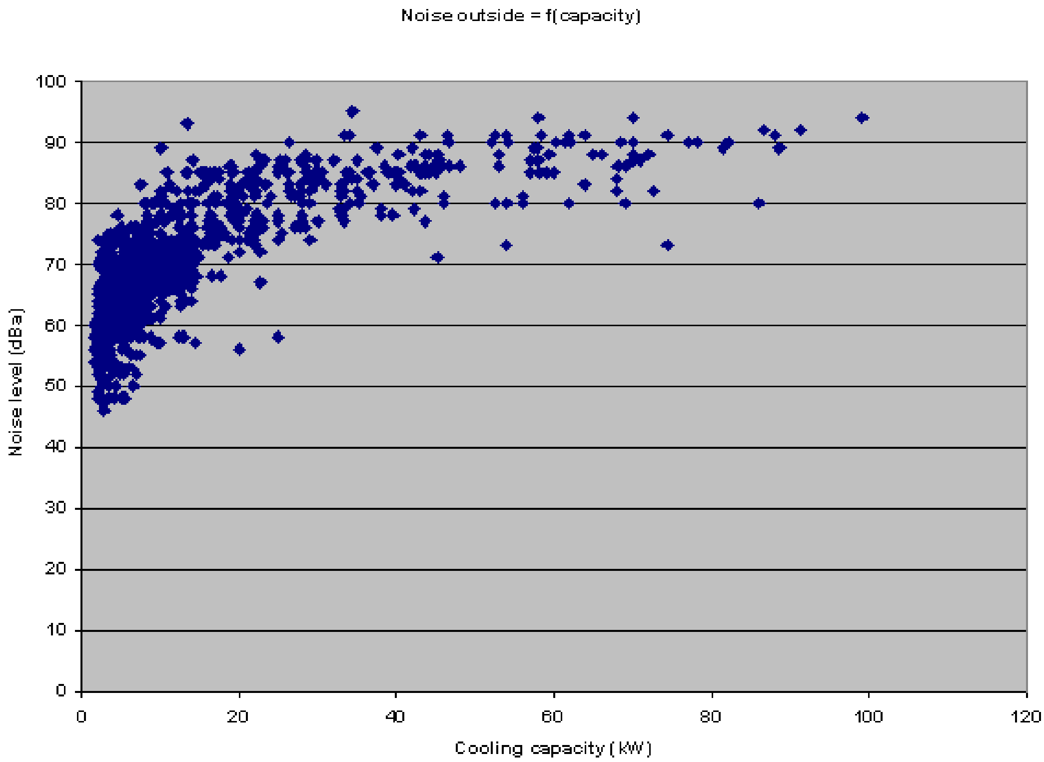
10 °C in stations located nearly. The park further presents almost 40 % less cooling degree-hours than the other urban surrounding stations;
- Heating degree-hours in the very central area of Athens are about 40-60 % lower than in the surrounding suburban areas.

The London heat island has been studied quite extensively recently. The urban cooling load is up to 25% higher than the rural load over the year and the annual heating load is reduced by 22% (Koloktroni, 2005).

Zoning of housing and activities has a social dimension. In many cities noisy and older construction zones, with more heat island and pollution, are occupied by poorer people who cannot afford climatic protection for their dwelling. Some products under consideration in this report are largely affected by the urban context :
- Split air conditioners may experience hotter outside temperatures.
- Single Ducts may become difficult to use (because if you open the window you have the noise).
- Comfort fans do not bring enough benefit and, on the opposite, heat the room.
- Ventilation would require filtering of the hot and polluted external air to bring a real benefit.

There is contribution of outside units of air conditioners to external noise levels. Environmental noise can negatively affect people’s health and quality of life as it interferes with basic activities such as sleeping, resting, studying, and communicating. Noise has an important cost for society. Some European countries estimate that the social cost of road noise pollution is about 1% of their GDP. The possible effects of noise depend not only on the physical characteristics of the noise itself (sound pressure level, temporal evolution, frequency spectrum, etc.), but also on subjective parameters inherent to each person. Having its own frequencies and a non negligible sound level the outside units of air conditioners (for those having outside units) may be important for some citizens. For air conditioners, external noise is “correlated” to capacity in a non linear way and scattered. The graph below shows this relation for window air conditioners, single and multi split package air conditioners (Eurovent-Certification, 2006).

Figure 3-7: External noise level (dBa) of air conditioners as a function of capacity, source Eurovent-Certification directory (Eurovent, 2006)



So we can say that the noise impact of air conditioners (split systems more precisely) varies a lot from one to another and cannot be neglected as one of the important factors for the end-user to compare the units.

3.3.2 Limitations to natural cooling

Different competitors of air conditioning and artificial ventilation exist, e.g natural cooling and ventilation. Potentially negative conditions for the development of these alternative solutions are:

- The sharp price decrease of air conditioners.
- No external shading.
- Higher Sun exposure (South West for instance).
- Rooms not on ground floor (no close and direct connection to the ground, to caves or other sources of natural coolth).
- No aquifer, no natural cold water available.
- Rooms on top floor, even worse than average floor, due to solar exposition of roof.
- Lack of insulation of roof (this is particularly dangerous in combination with rooms on top floor).
- Noise outdoors (e.g. traffic noise): reduces air circulation because people do not open windows enough.
- Security concerns: reduces air circulation because people do not open windows enough.
- Lack of adequate thermal mass. (no agreement among the experts had been reached as to what extent thermal mass is beneficial during heat-waves).
- Lack of cross ventilation (e.g. because windows on only one side of the room/building).
- Low albedo of building surface: outdoor surfaces with low infra-red reflection.
- Restrictive building legislation: potentially beneficial façade changes are delayed or even prohibited by law (e.g. due to protection of historic buildings).
- Thermal design only focuses on winter time heating and does not take summer time conditions into consideration (e.g. air tightness).
- Lack of evaporation potential (low convection, high humidity).
- Building located in Urban Heat Island.
- Increased internal loads (no real cut of TV set, high cooking energy, etc.).

- High(er) risk of electrical power outages, preventing fans to operate.

All these limitations are likely to increase the development of the air conditioner market and then to increase the total environmental impacts generated during their life cycle.

3.3.3 Influence of past heat waves

The behaviour of end users, and the decision to purchase an airco, and which airco, or to withstand discomfort with ventilation or comfort fans depends largely of the experience the EU populations have had with heat waves and associated casualties.

More than 35,000 excess deaths were reported in Europe during the summer of 2003. Europe has experienced an unprecedented rate of warming in recent decades. It is predicted that the current increasing instability of the climate system will lead to increased weather variability and an increase in the frequency and intensity of extreme temperatures. Adaptation strategies focus on improving urban planning and reducing urban heat islands, reduction of indoor heat stress (by passive or active (air conditioning) means), heat plans, heat health warning systems, rapid surveillance, care of the elderly, information and awareness raising.

In quantitative terms, the overall health impacts of heat-waves depend upon the level of exposure (the frequency, severity and duration of high temperatures); the size of the exposed population; and the sensitivity or “dose-response” relationships between climate variables (temperature, humidity, air quality) and the relevant health outcomes (mortality, morbidity, hospital admissions). Conceptually, adverse health impacts could be minimised by reducing the level of exposure, the size of the exposed population, and/or the sensitivity of the population.

Independently from long term improvements, populations and governments have little remedies on short term. They can rely on artificial air conditioning to decrease the heat stress on the most affected populations (children, elderly, ill people) either by offering temporary access to places with centralized air conditioning (movie theaters, supermarkets) or by relying on small air conditioners. In this last case, the purchase takes usually place in an emergency situation, that leads to the choice of an appliance not needing an installer, and later movable. Renting schemes of movable air conditioners are being proposed by local authorities or by private companies, whereas the cost of renting a unit for a summer in case of private companies can be as high as the price of a new unit (Which, 2007).

This element is taken into account into the projection of the growth rate of the air conditioner market.

3.3.4 Electricity reliability

Summer blackouts have become a more frequent occurrence, even in Europe, not only in the USA. In 2000, Southern Europe became Summer peaking while all European countries were before winter peaking (SAMELEC, 2000). Heat waves and demand for Summer comfort induce a rapid change of the seasonality of the electric load curves of European countries (which is the contribution of air conditioning).

Heat waves as the one of 2003 have surprised the national electric grid utilities with the occurrence of an unusually hot anticyclonic event over a long period of time. Electricity shortages in France forced the power generating company to revise the maintenance plan of nuclear power plants. Condensing units were normally maintained during the summer, which may not be the case in the future.

However, in most recent blackout experimented in recent years in developed countries, in the US (2003, East cost) (US, 2003), in Portugal (Algarve, 2003), in Italy (2004) (UCTE, 2004), the total capacity available was never the first cause of the blackout. Local or regional transmission problems temperatures (air conditioning use, transmission lines loss capacity with higher temperatures) were found to be the direct cause, not lack of power plants.

The increased use of air-conditioning in central London is thought to have been one factor contributing to a blackout in July 2006. In hot weather UK demand increases by up to 1GW.

All this becomes more stringent in Islands belonging to EU : more expensive peak electricity, less reliability (except at the price of a large overcost).

This direct impact of air conditioners on the electricity grids reliability will be evaluated as one of the impact in task 8. Ecodesign measures could increase the energy efficiency of the products at the time of electric grid peak, saving supplementary power plant installation in summer peaking countries and increasing the grid reliability.

3.3.5 Electricity tariffs influence on consumer behaviour

On the short term, and admitting that there is a perfect regulation, there is a separate capacity payment associated with power demand and an energy charge, proportional to energy use. The cost of air conditioning is proportional to its use because it does not alterate the capacity demand at individual level (sized by other uses like ovens). The marginal kWh may seem less expensive than the first ones because capacity charge is spread over more kWh. However if air conditioning affects the peaking condition of the grid, this approximation may become unjustified. New kW should be made available in transmission and distribution capacities to meet the demand of air conditioning. When the regulatory framework gives energy companies the possibility to recover through tariffs the additional investments to satisfy all the increasing cooling needs, energy companies do not receive the right incentive to engage in demand-side management activities and might over-invest in infrastructures, with small duration of use in the year, so difficult to recover from sales. It is then very likely that the electricity price in summer increases for countries that are already or are likely to become summer peaking.

A study carried out by INESTENE (Samelec, 2000) for France, Greece, Italy, Portugal and Spain indicates that summer peaking is likely to develop in the EU (see table below). If we except the French case pushed by the electric space heating in winter and Greece, already summer peaking, the simulations show a possible transfer of the annual extreme peak hours from the winter to the summer in the three other countries studied. Furthermore, these peaks were determined in a national perspective and would certainly be worse in some regions, particularly in local urban environments.

Table 3-6: Annual electricity system peak in 5 EU countries - 1995-2020 – peak electricity demand and month of occurence (Source: Inestene). Unit: GW

	France	**Greece**	**Italy**	**Portugal**	**Spain**
1995	62.4 January	6.0 July	44.2 December	4.7 January	25.8 December
2020 BAU [1]	90.0 +44% January	9.4 +57% July	64.0 +45% July	8.9 +89% September	42.1 +63% September
2020 DSM [2]	74.0 January	8.1 July	55.0 July	7.4 September	35.0 September
Net gains	16.0	1.2	9.0	1.4	7.0

[1] *BAU - Business as usual scenario*
[2] *DSM - Demand-Side Management: scenario considering the adoption of energy efficiency policies and measures.*

Moreover, heat island effect in warm to hot climates exacerbates cooling energy use in summer. As reported by Akbari, for US cities with population larger than 100 000 the summer peak electricity demand will increase 1.5 to 2 percent for every 1 F (0.55 °C) increase in temperature. Taking into account that urban temperatures during summer afternoons in US have increased by 2 to 4 F (1.1 to 2.2 °C) during the last forty years, it can be assumed that 3 to 8 percent of the current urban electricity demand in the US is used to compensate for the heat island effect alone. Detailed comparisons of high ambient temperatures to utility loads for the Los Angeles area have shown that an important correlation exists. It is found that the net rate of increase of the electricity demand is almost 300 MW per F (0.55 °C). Taking into account that there is a 5 F (2.8 °C) increase of the peaks temperature in Los Angeles since 1940 this is translated into an added electricity demand of 1.5 GW due to heat island effect.

3.3.6 Selection and Installation guides for good practice

We found evidence of some existing “best practice guide” published by EDF, some for mainland France in the nineties, some for overseas departments in this century. Those guides cover sizing and installation.

In parallel it would be very useful that efforts be made to define best practice in operation and maintenance so that best practice guidelines can be issued against which existing contracts would be compared at the time of inspection and/or on an autonomous basis.

All the professions mentioned have societies trying to raise the technical level of the members. Some are EU wide, others are limited to one country.

AREA is a federation of **installers’ associations in refrigeration**. It has presently 21 Member Associations from 19 European countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Slovakia, Spain, Sweden, Turkey, United Kingdom.

There is a group about training and technical level of staff. In a survey reported by AREA in Europe, the people in charge of ozone depletion substances or F gases have generally less than one year of training in air conditioning but most of them are “engineers” (50 to 80 % except Germany and France, two countries having diplomas of “higher technician” comparable to some other countries “engineers”).

HVAC Designers societies have either a purely intellectual role (like AICVF in France, AICARR in Italy, etc.) or a certain regulatory power about qualification (like CIBSE in the UK, “Ordem dos Engenheiros” in Portugal, etc.). They are all gathered in REHVA at EU level. REHVA has members in Austria, Belgium, Bosnia, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia Spain, Sweden, Switzerland, Turkey, United Kingdom, Yugoslavia.

Manufacturers of HVAC equipment are gathered both nationally and at (more and more) at EU level. The European Association of Air Handling and Refrigerating Equipment Manufacturers “Eurovent-Cecomaf” includes fifteen National Associations from eleven countries : Belgium Finland France Germany Italy Netherlands Norway Spain Sweden Turkey

Households appliances manufacturers are gathered within CECED, the European body that regroups national representations: Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom.

HVAC installers have specific techniques and specific societies, not only the refrigeration aspect (like AREA members). Some installers provide maintenance as well as some manufacturers. However in many countries there are also independent maintainers. Traditionally there are two links between HVAC installers **that tackle also some maintenance issues** : CEEBTP (COMITE EUROPEEN DES EQUIPEMENTS TECHNIQUES DU BATIMENT) and GCI (Génie Climatique International), association created in 1937.

A **new link among operators** is the recent federation called EFIEES. EFIEES purpose is to promote the activities of Energy Efficiency Service Companies (EESC) in the European Union. These are companies that implement programs to improve energy efficiency in the frame of a maintenance activity, in the wide sense.

Some national professional associations are trying to introduce local quality labels that the households and even the professional managers could recognize or request. Let’s take the example of France. The most important organisation for accreditation in France is the COFRAC (Comité Français d’Accreditation). It accredited Qualibat and Qualiclima and labeling qualified companies and this label is used frequently in commercial relations. Qualibat is a label for qualification for professionals of construction, and between the qualifications released, a qualification for management and **maintenance of heating and A/C equipments** exists. Qualiclima is a qualification label of **installers of A/C equipments** under the label Qualiclima and for chiller equipments under the label Qualifroid. For some levels of qualification and certification of the companies, the staff has also to be qualified. Between the activities of the organisation, the most interesting for our study, is the qualification in “Management and maintenance of heating and air-conditioning plants (certification number 5522) which applies to room systems with cooling capacity lower than 12 kW”.

Qualiclimafroid is another association of qualification and of classification of the companies of **installation of refrigerating materials, ventilation, treatment of the air and air conditioning** and delivers the qualifications. These qualifications have been, on the request of the trade associations representing the refrigeration companies, of equipment of professional kitchens and of the air conditioning, integrated as a requirement for enabling to handle the fluids, by the Ministry of environment, agriculture, economy and industry and the Ministry for the equipment. Qualiclimafroid is the only organization exclusively specialized in refrigeration and air-conditioning to deliver qualifications in conformity, according to the decree of February 10, 1993, to standards NF –EN 45012 (attestation of quality system and environmental management).

Qualifelec is a similar association for **electrical installations**. But it certifies installers for **air conditioning** also with three levels Th1, Th2, Th3.

Conclusion

Several important consequences arise from the task 3 analysis that will be considered in the following tasks of the study. Main findings are summarized hereafter, including potential restrictions and barriers to Ecodesign.

Concerning real life efficiency, it is to be noticed that EN 14511 performances are judged only on the full load performances at a given temperature. Impact of load and temperature will be studied in task 4 because they are not dependent on the end-user behaviour but on the climate and building characteristics. Because the air conditioner are mostly installed in existing buildings, split incentive situation is likely to occur, the end-user paying the bill not being the one that chose the air conditioner; the end-user may not even be the one paying the bill in tertiary buildings.
Over or under sizing may be a cause of over-consumption and/or discomfort. There is no accepted general method of sizing in Europe. The lack of information related to part load and sizing may be a barrier for the improvement of the sizing situation since the end-user cannot evaluate the consequences of this factor. Generally speaking, the user has only partial information on the variation of energy consumption when using different functions (dehumidification, economic mode, fast cooling mode …), which limits its ability to choose the unit in function of its own use. In that direction, the distinction between real reversible and electric resistance units is not always clear to the end user.
The analysis of user parameters have shown that temperature controls could largely be improved. For instance, reversible units propose automatic changeover modes (cooling or heating) with a single temperature set point. As opposed to boilers, no set back function is available, reversible air conditioners in heating mode cannot be used with reduced temperatures at night for instance.
It has been found that stand-by losses may be quite important for air conditioners. Main side consumption is the crankcase heater. It fulfils an important function. However, since it is not measured in standards, no effort have been made until now to reduce its consumption, by technical improvement or better control. Important over-consumption may arise in real life due to outdoor unit fooling, improper unit refrigerant charge and leakage. Real life performance check is not available for small capacity air conditioners and the unitary cooling capacity of units is too low to fall under the requirements of mandatory charge verification. It will then be difficult both to improve and to check the effects of potential Ecodesign measures in that field.

Concerning end of life, it appears that units' lifetime may not be linked to breakdown but rather to the willingness of the end-user to buy a new one. End-of-life national schemes efficiency as compared to WEEE objectives is still to be evaluated.

Concerning local infrastructure, noise is to be taken into account in the following tasks as a constraint to potential for improvement. In the context of heat waves and heat island effect, the growth of air conditioner ownership rates is likely to increase. The supplementary sales and energy impact is to be considered in this study. Air conditioners also have an important impact on the electric grid. However, since the electricity tariffs do not reflect its consequences, there is little incentive to improve this situation.

Appendix A: Current power mode values for air conditioners sold in Australia

1. Air conditioner profile, source (AGO, 2004)

1.a Window wall air conditioners and portable

Table 3-7: Off mode power of window wall and portable air conditioners, field survey

TABLE 1: VALUES FOR WINDOW WALL AND PORTABLE AIR CONDITIONERS: OFF MODE

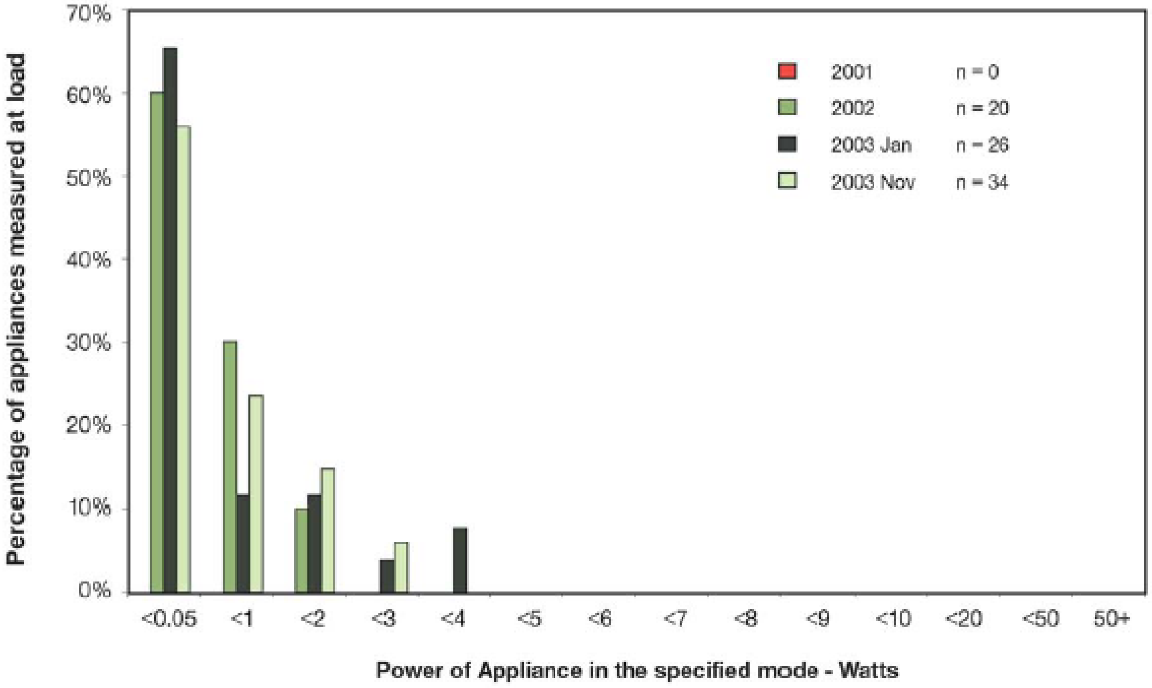
Survey Date	Number Models	Average Off Mode W	Maximum Off Mode W
Jan 2002	20	0.4	1.9
Jan 2003	26	0.6	4.0
Nov 2003	34	0.5	2.5

Source: Energy Efficient Strategies and EnergyConsult 2003 and field data.

Note: Some models may have passive standby mode.

Figure 3-8: Passive standby mode of wall and portable air conditioners, field survey

FIGURE 5: VALUES FOR WINDOW WALL AND PORTABLE AIR CONDITIONERS: OFF MODE



None of these models had crankcase heaters.

1.b Split and multi-split units

Since measurement of hardwired units was not made during field survey, there is a limited set of data because tests were made in laboratory when checking the cooling and heating performances of the units.

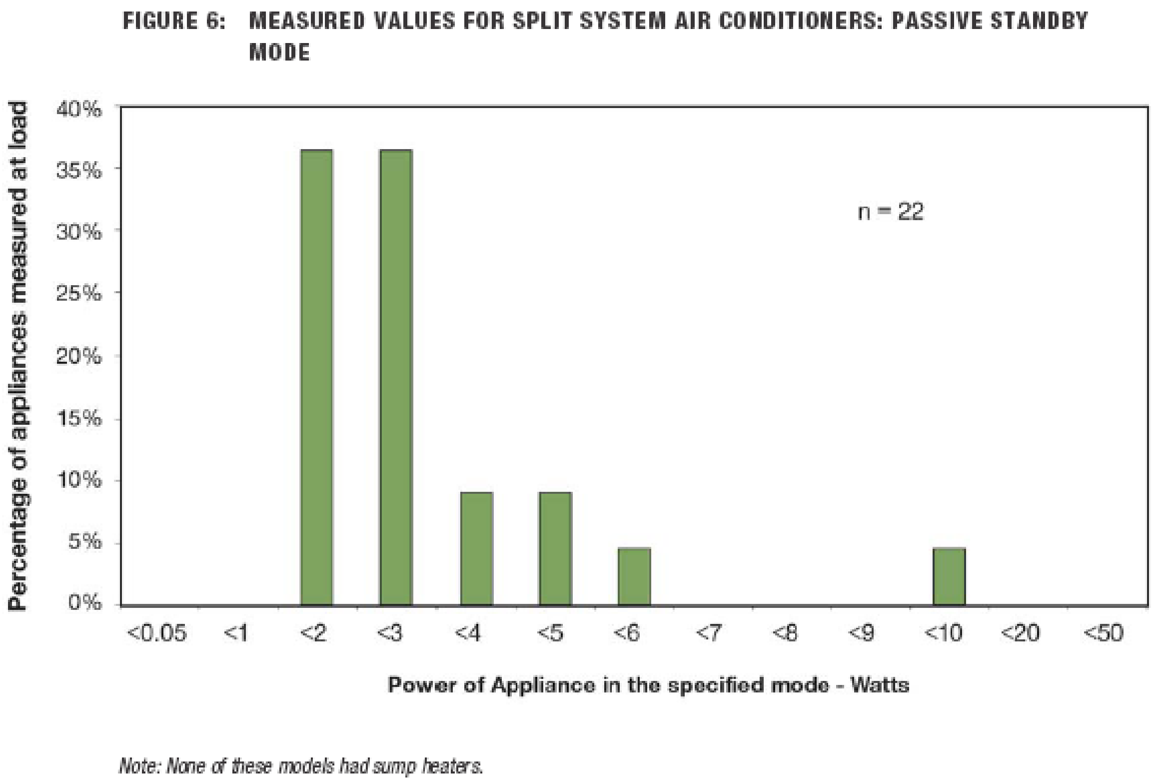


Figure 3-9: Passive standby mode of split air conditioners, field survey

1.c Crankcase heaters

For split units, whereas some window units may have a crankcase heater, “A total of 5 units with sump heaters were measured. The values recorded ranged from 30 to 79 W with an average of 53 W for the five models measured.” (AGO, 2004).

2. Air conditioner database of products, source www.energyrating.gov.au

Since April 2006, manufacturers have to state off mode power, standby power and crankcase heater power for air conditioners sold in Australia. A database of products is now available online. Power values as declared by the manufacturers are reported hereafter.
General description of products in database follows. The file treated was downloaded from www.energyrating.gov.au on October, 19 2007.

Table 3-8: Treatment of public Australian database of air conditioners power mode consumption, as declared by manufacturers (10/2007)

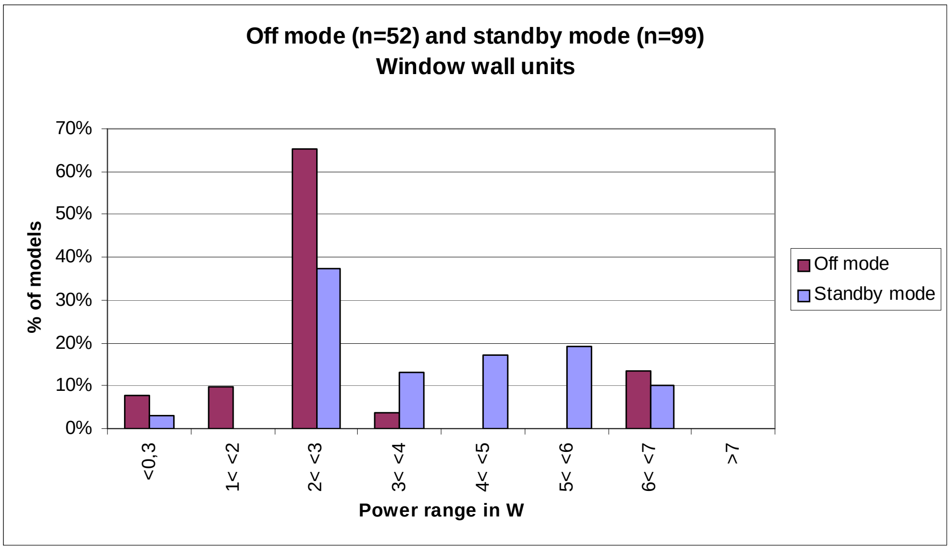
Type	Portable	Window / wall	Split and MS	Package	TOTAL
Models	15	569	5088	424	6112 (2 unknown)
Cooling only	8	294	671	49	1022
Reversible	7	275	4417	375	5074
Rev. Share (%)	47%	48%	87%	88%	83%
Information on low power modes	0	134	1486	101	1621
Information on crankcase	0	134	1488	101	1623

When controlled as a function of outdoor air temperature, temperature control of the crankcase heater lies generally around 10 °C. The Australian standard (AS, 2005) requires measurement of standby and off mode power at 7 °C. Consequently, most units with crankcase heaters have large standby and off mode power. In that case, standby and off mode power were calculated by subtracting the power of the crankcase, when declared by manufacturers. Some Japanese units, in which country standby power is measured at 35 °C outdoor may indicate separate values for standby power that could not be measured with the Australian standard.

2.a Window / wall

Off mode and standby

Figure 3-10: Off mode and standby power of window / wall air conditioners, AU air conditioner database



Forces of the market failed to reach the voluntary target of 2007. Consequently, Australia is likely to introduce mandatory thresholds, as explained in the general policy lines concerning standby.

- 8 % of products pass the off mode 2012 threshold (1 W)
- 3 % of products pass the standby 2007 threshold (2 W)

Figure 3-11: Off mode of window / wall air conditioners, AU air conditioner database

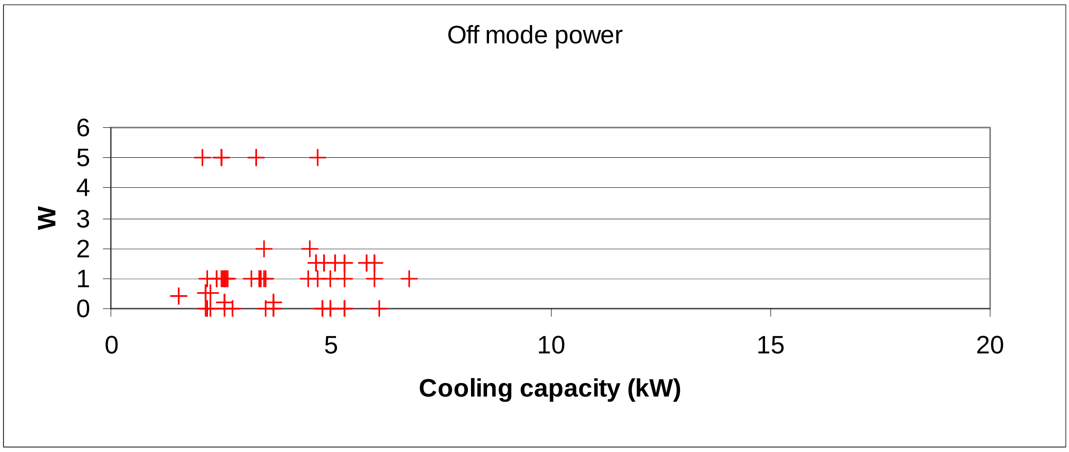
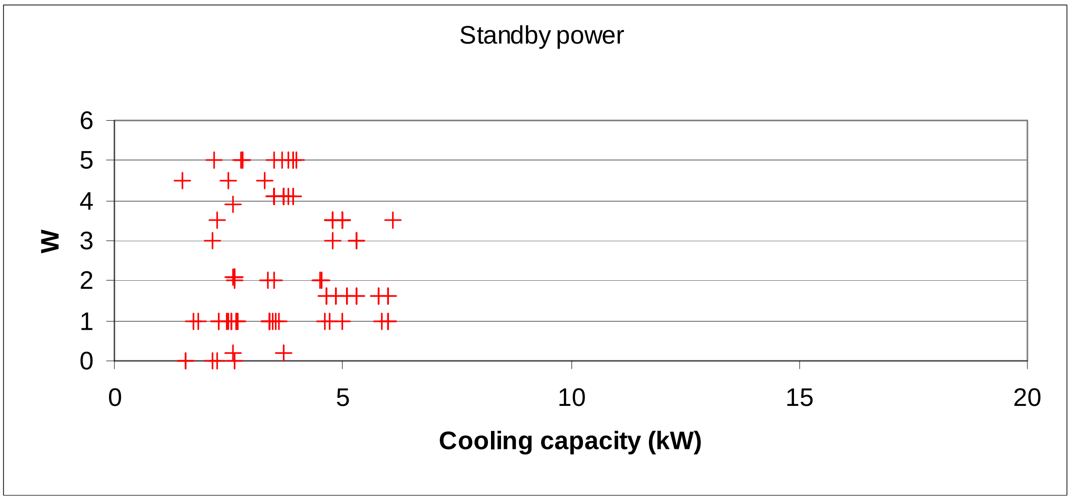


Figure 3-12: Standby power of window / wall air conditioners, AU air conditioner database



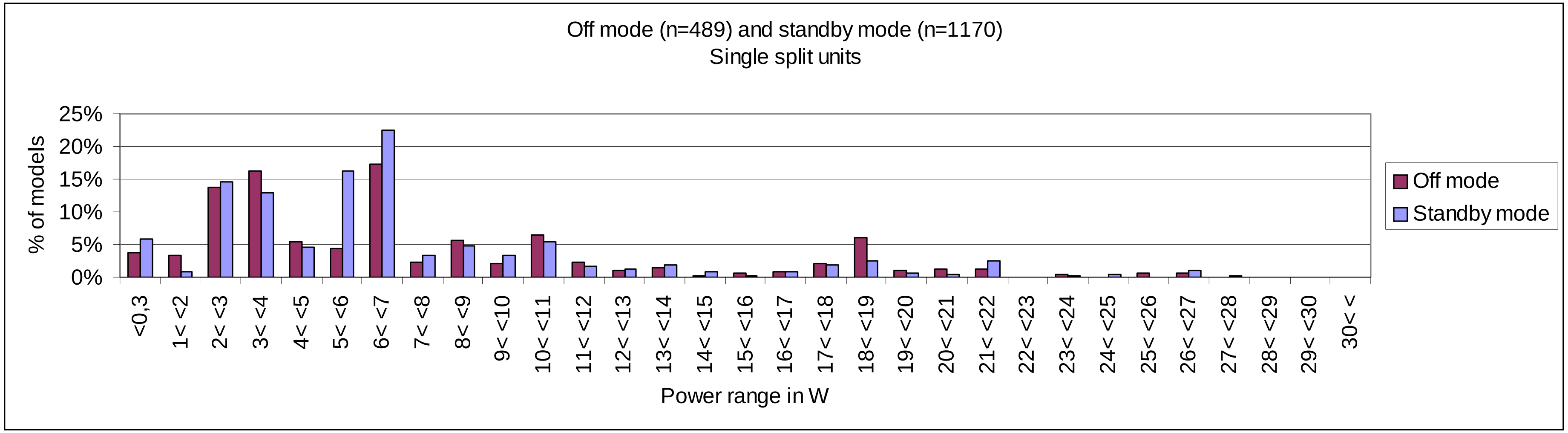
Crankcase

1 unit with a crankcase heater with a 35 W value.

2.b Split and multi-split

Off mode and standby

Figure 3-13: Off mode and standby power of split air conditioners, AU air conditioner database



Forces of the market failed to reach the voluntary target of 2007. Consequently, Australia is likely to introduce mandatory thresholds.

– 4 % of products pass the off mode 2012 threshold (1 W)
– 7 % of products pass the standby 2007 threshold (2 W)

Figure 3-14: Off mode of split air conditioners, AU air conditioner database

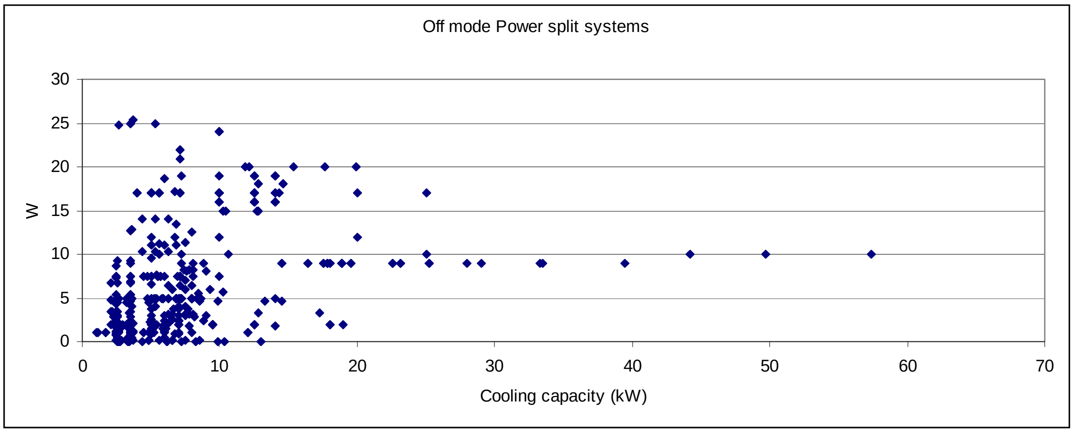
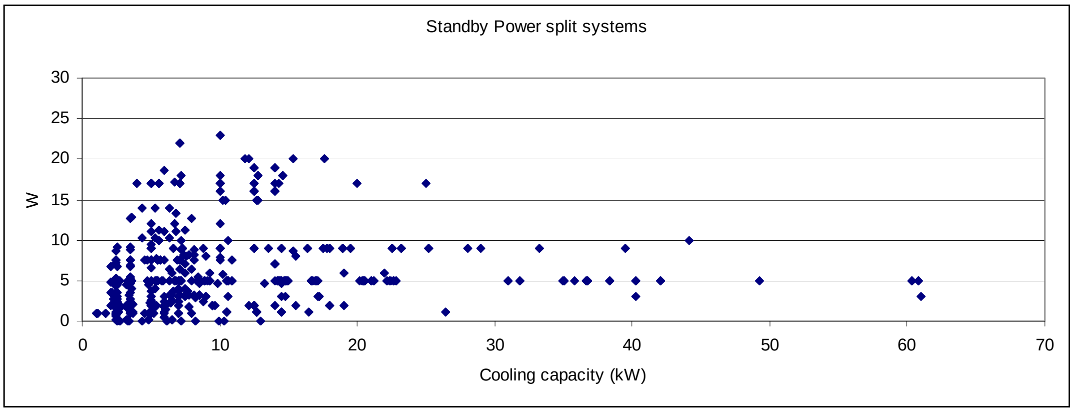


Figure 3-15: Standby power of split air conditioners, AU air conditioner database



There is no relationship between off mode power or standby power and cooling capacity or electric phase of the unit.

Default components and control lead to standard value of 5 and 10 W.

For smaller units with more functions, standby and off mode powers may increase until 25 W showing there is no effort made to separate the standby function and reactivation functions that are not required in these low power modes.

<u>Crankcase</u>

Figure 3-16: Crankcase heater power of split units, AU air conditioner database

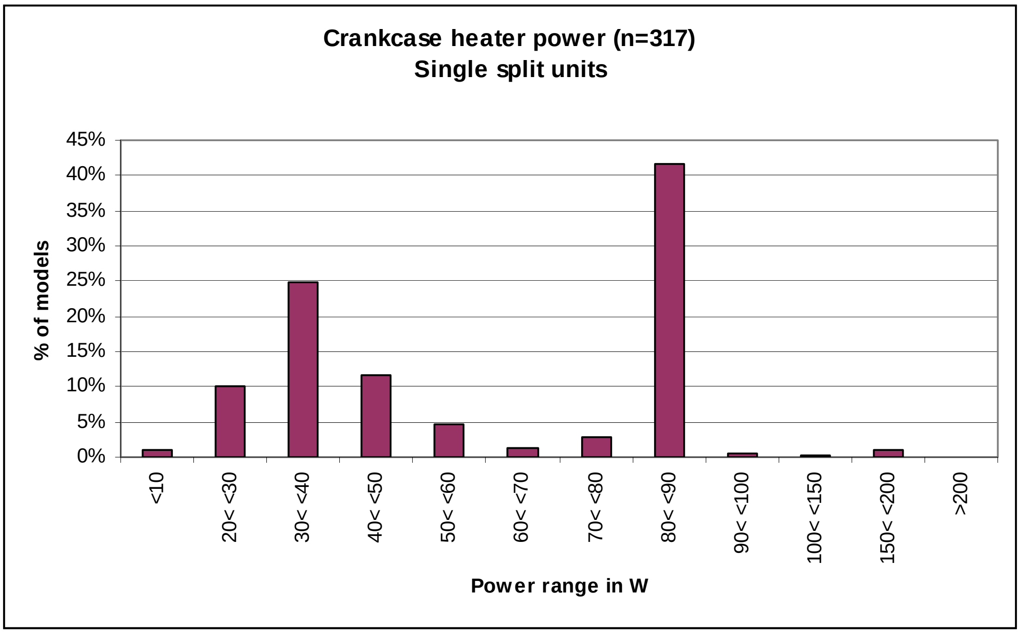
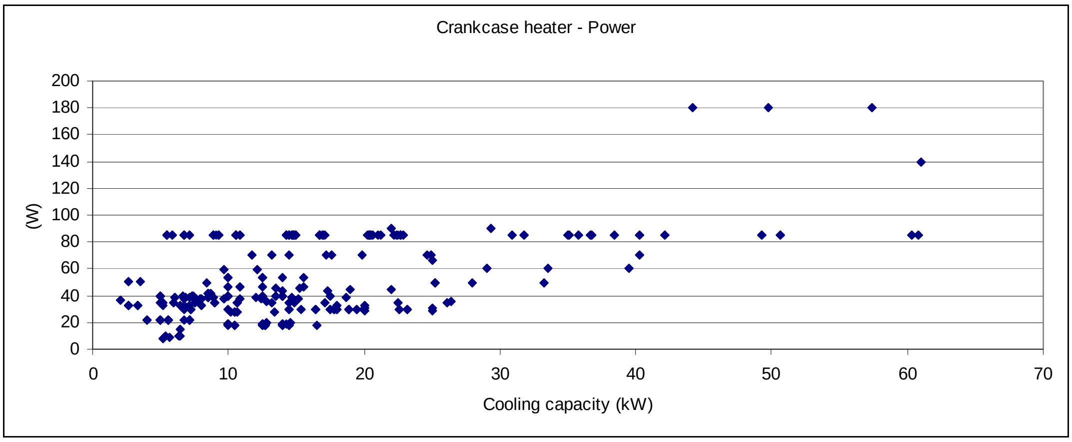


Figure 3-17: Crankcase heater power of split units, AU air conditioner database



There should be a correlation between cooling capacity and crankcase heater power.

This correlation does not appear clearly. Default external crankcase heater of scroll compressor as proposed by OEM (90 W) serve units with cooling capacity from 5 to 60 kW. Efficiency of the crankcase heater for 6 kW units is likely to range from 5 % to 95 % showing a great margin for improvement.

For most units, it is not possible to know whether the crankcase heater is controlled as function of outdoor air temperature.

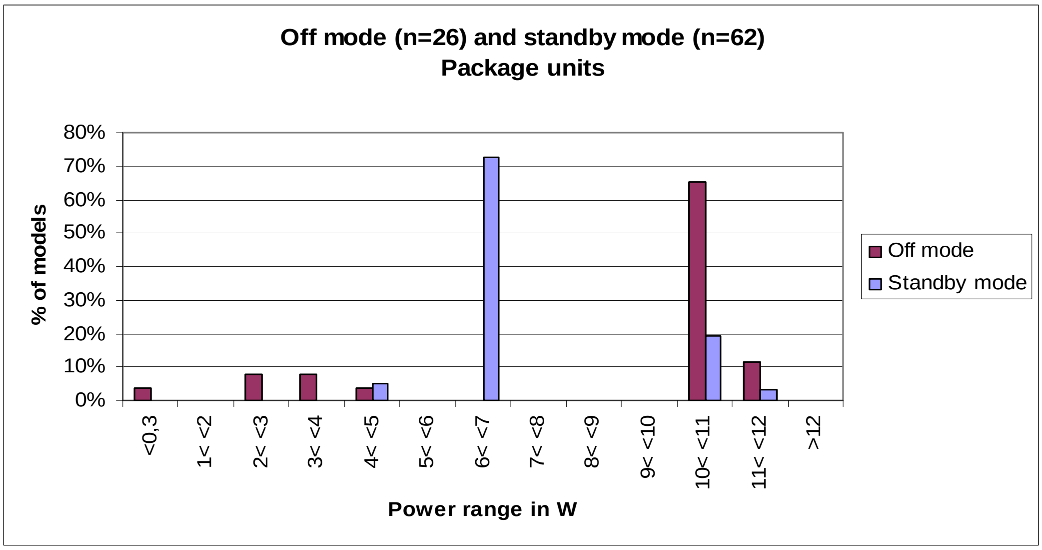
Among the units whose information on crankcase heater is supplied, 15 units have a control temperature that enables its standby or off mode measurement in H1 rating temperature conditions.

74 units are declared reversible without a crankcase heater. It is not known whether there it is a BAT option or simply a mistake in the declaration.

2.c Package

Off mode and standby

Figure 3-18: Off mode and standby power of package air conditioners, AU air conditioner database



Forces of the market failed to reach the voluntary target of 2007. Consequently, Australia is likely to introduce mandatory thresholds.

- 3 % of products pass the off mode 2012 threshold (1 W)
- no product pass the standby 2007 threshold (2 W)

Figure 3-19: Off mode of package air conditioners, AU air conditioner database

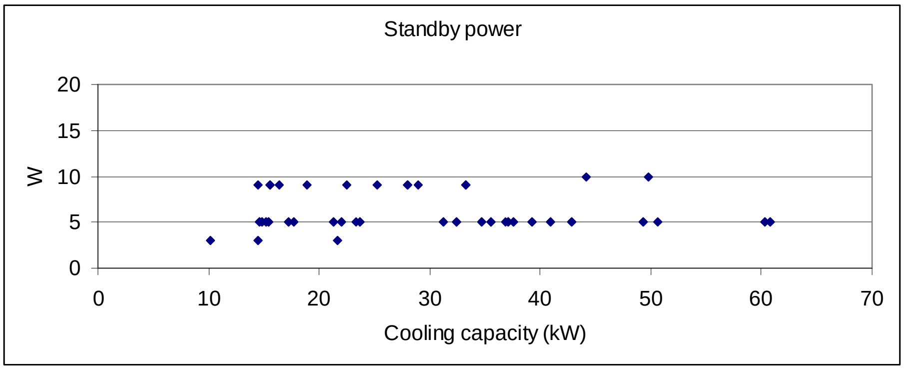
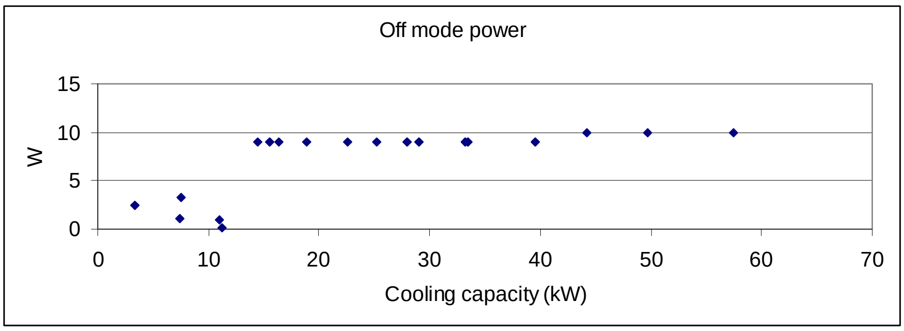


Figure 3-20: Standby power of package air conditioners, AU air conditioner database



<u>Crankcase</u>

Figure 3-21: Crankcase heater power of package units, AU air conditioner database

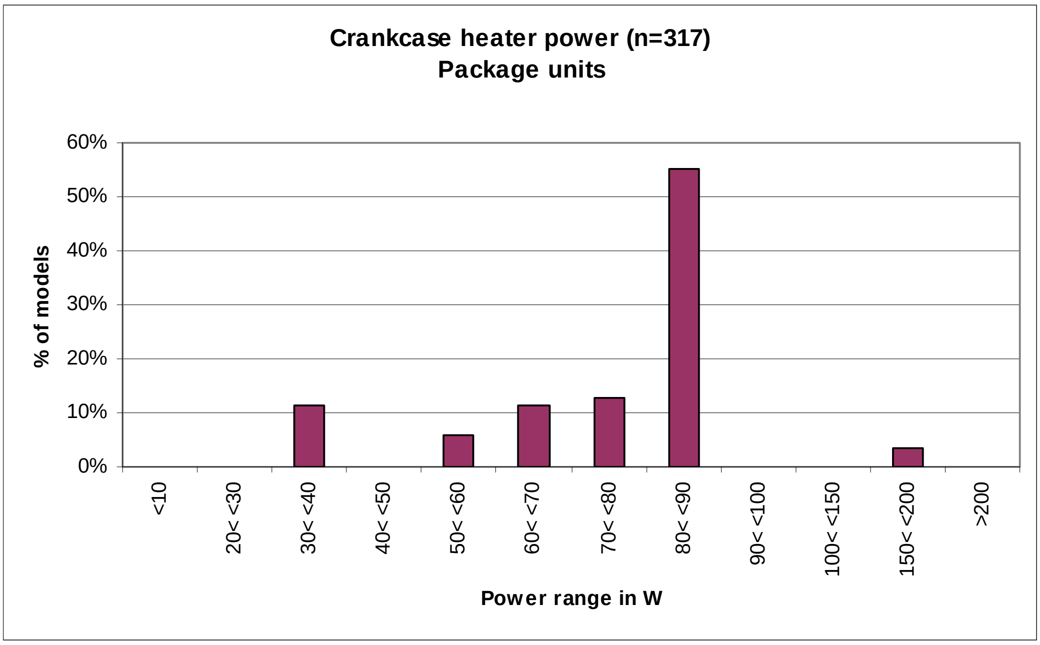
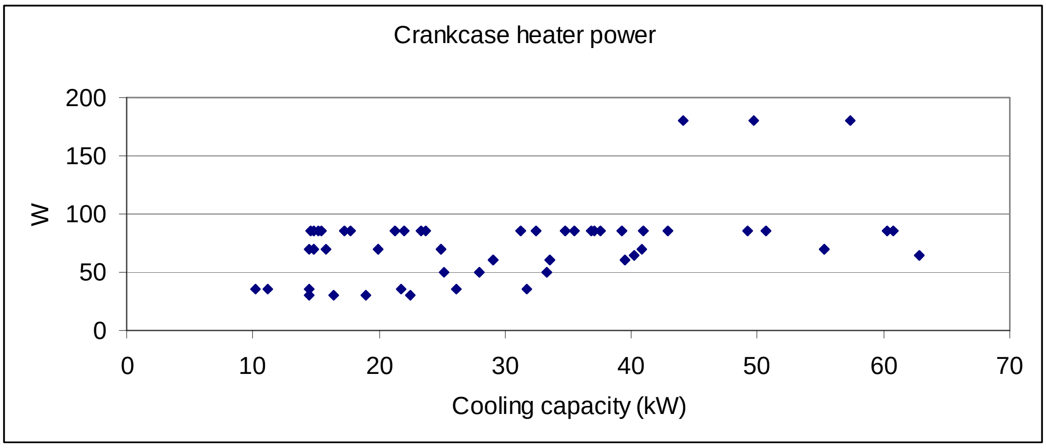


Figure 3-22: Crankcase heater power of package units, AU air conditioner database



There should be a correlation between cooling capacity and crankcase heater power.

This correlation does not appear clearly. Default external crankcase heater of scroll compressor as proposed by OEM (90 W) serve units with cooling capacity from 15 to 60 kW.

For all units, it is not possible to know whether the crankcase heater is controlled as function of outdoor air temperature.

Among the units whose information on crankcase heater is supplied, no unit has a control temperature lower than 7 °C.

0 units are declared reversible without a crankcase heater.

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