Review of Regulation 206/2012 and 626/2011

Air conditioners and comfort fans

Task 5 report

ENVIRONMENT & ECONOMICS

Final version

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Abbreviations

AC	Alternating current
BAT	Best Available Technology
BAU	Business as Usual
BC	Base case
BNAT	Best Not Yet Available Technology
COP	Coefficient of Performance for air conditioners in heating mode
EER	Energy Efficiency Ratio for air conditioners in cooling mode
EoL	End-of-life
Eq	Equivalents
GWP	Global warming potential
LCA	Life cycle assessment
LCC	Life cycle costs
LLCC	Least Life Cycle Costs
PCB	Printed circuit board
PWF	Present worth factor
SCOP	Seasonal Coefficient of Performance for air conditioners, heating mode
SEER	Seasonal Energy Efficiency Ratio for air conditioners, cooling mode
VRF	Variable Refrigerant Flow

Introduction to the task reports

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

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

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

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

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

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

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

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

5 Introduction to Task 5

Task 5 follows the MEErP methodology and aims to identify base cases based on findings from previously performed tasks. The base cases are used to quantify the environmental impacts and the life cycle costs of air conditioners and comfort fans. The base cases will also be used in later tasks to identify the improvement potential. Task 5 includes the following sections:

1. Product-specific inputs: Base cases based on previous tasks.
2. Base-Case Environmental Impact Assessment: Using the EcoReport tool to calculate emission/resource categories
3. Base-Case Life Cycle Costs for consumer: Life Cycle Costs (LCC) of air conditioners and comfort fans
4. EU Totals: Aggregated environmental impacts and Life Cycle Costs
5. Conclusions and recommendations

5.1 Product-specific inputs

In this task, three base cases are defined based on the data and information from Task 4:

- Base case 1: for fixed reversible air conditioners < 6 kW, 3.5 kW wall single split
- Base case 2: for fixed reversible air in range of 6 – 12 kW, 7.1 kW wall single split
- Base case 3: for portable air conditioner, 2.6 kW single duct

The final EcoReport Tool inputs for the base cases built through the work of tasks 1 – 4 are presented in this task.

Task 1 analyses show the relevance of extending the scope to include ventilation exhaust air conditioners in the regulation, however it is not identified as a separate base case due to lack of reliable data for sales and performance.

Base-Case Environmental Impact Assessment and Base-Case Life Cycle Costs for the consumers have been established per base case and aggregated at EU level.

This task summarises the data, assess the environmental and economic impact of the products in scope, and list improvement potentials and barriers for use in Tasks 6-7

Regarding comfort fans no changes have been suggested in the previous tasks, so the base cases and impacts of the base cases are unchanged since the preparatory study. The comfort fans will therefore not be further assessed.

5.1.1 Test standard for performance and consumption data

The most appropriate test standard for performance and consumption have been identified in Task 1.

For other than single duct, double duct and evaporatively cooled air conditioners, the standard EN14825 defines the calculation and testing points to calculate the seasonal energy efficiency (SEER) and seasonal coefficient of performance (SCOP) and completes where required measurement methods defined in standard EN14511.This means for the two base cases of split air conditioners, **EN14825** can be used for measuring performance and consumption data, while keeping the equivalent full load hours in Regulation No 206/2012.

EN14511 defines the rated performance and measurement methods to be used for all air conditioners in cooling and in heating mode, with the exception of air conditioners with evaporatively-cooled condensers whose ratings are defined in EN15218 standard. This means for the single duct portable air conditioner base case, **EN14511** standard, complemented by the proposed equivalent full load hours (Task 3) of 350 hours as well as thermostat off and standby hours and powers, can be used for performance and consumption data.

For ventilation exhaust air conditioners, although it is not established as a separate base case, it is already identified in Task 1 that standard EN14825 for part load can be used for measuring performance and consumption.

5.1.2 Economic data

This subsection presents the EU-27 annual sales and estimated stock in units, purchase price, the installation costs, repair and maintenance costs, unitary rates for energy, discount, inflation, interest and escalation rates to be applied, product service life. These values have been derived and presented in task 2 and task 4.

Table 1: EU 28 annual sales and estimated stock of all air conditioners in scope

	2010	2015	2020	2025	2030	2035	2040	2045	2050
EU28 annual sales, (000) units									
BC 1	2385	1954	2528	3059	3541	4095	4827	5537	6415
BC 2	1482	1473	1648	1898	2142	2403	2711	3022	3381
BC 3	583	557	446	460	474	488	503	518	534
Total	4450	3984	4622	5418	6156	6986	8041	9077	10330
EU28 estimated stock, million units									
BC 1	29.6	29.7	25.5	28.7	34.6	25.8	25.5	56.0	64.9
BC 2	17.7	17.8	16.3	18.1	20.9	16.4	16.3	30.6	34.5
BC 3	4.3	4.4	4.3	4.5	4.6	4.8	4.9	5.0	5.2
Total	51.6	51.9	46.1	51.3	60.1	69.6	80.1	91.7	104.5

EU 28 annual sales and total estimated stock for all air conditioners are presented in Table 1 . Stock estimated for portable air conditioners in 2015 is 4.44 million units, 29.7 million units for > 6 kW split air conditioners, 17.8 million units for 6 – 12 kW split air conditioners. Annual sales for base case 1 and 2 are presented in Table 2 and were already described in Task 4. Base case 3 portable air conditioner annual sales are derived with annual sales for all air conditioners in 2015 and subtracted the annual sales for base case 1 and 2 in 2015.

Table 2: Repartition of split product per class in number and capacity in 2015

	Sales number in 1000 units	Average capacity in kW	Total capacity installed in GW (2015)
0-6 kW	2468	3.5	8.6
6-12 kW	959	7.5	7.2
Totals	3427	NA	15.8
Weighted average	NA	4.6	NA

Product prices for the base cases have been derived in Task 2 and corrected to account for the higher efficiency of base cases in task 4. As seen in Task 2, repair and maintenance costs is derived as 4%/year of the initial investments and in a life time of 12 years for fixed split units. A lifetime of 10 years for portable unit is applied, and no repair and maintenance costs assumed.

The commission have decided to use data from PRIMES[1], and prices and projection are presented in Task 2. The residential electricity rate is 0.204 euro/kWh for households and 0.171 euro/kWh for service sector based on the electricity price in 2021. The distribution of air conditioners installed in households and the service sector are used to calculate the average electricity rate for the different base cases. The distribution of users is:

- For BC 1, the ratio is: 71% households and 29% service premises
    - Resulting average electricity price: 0.195 euro/kWh
- For BC 2, the ratio is: 46% households and 54% service premises
    - Resulting average electricity price: 0.187 euro/kWh
- For BC 3, the ratio is: 79% households and 21% service premises
    - Resulting average electricity price: 0.198 euro/kWh

The distribution between residential and service sectors for air conditioners stock are described in Task 2.

In EcoReport Tool, there is an input for the ratio between average efficiency of the stock and average efficiency of the new sales, this is to account for the difference of average efficiency of the stock and the higher efficiency of the new sales, so the energy consumption calculated would not be underestimated. Since the efficiency is found to be different for residential and service sectors, the ratio is derived using the residential and service sector distribution presented above:

- For BC 1, the average new sales SEER in 2015 is 6.05. The average stock efficiency in 2011 is 3.2 for the residential sector and 2.9 for the service sector, resulting in 3.113 (3.2 x 71% + 2.9 x 29%). SCOP and SEER ratio has not changed since preparatory study so resulting SCOP for new sales 2015 is 5.35 and SCOP for stock 2011 is 2.413.
- For BC 2, the average SEER in 2015 is 5.75. The average stock efficiency in 2011 is 2.9 for the residential sector and 2.5 for the service sector, resulting in 2.684 (2.9 x 46% + 2.5 x 54%). SCOP and SEER ratio has not changed since preparatory study so resulting SCOP for new sales 2015 is 5.15 and SCOP for stock 2011 is 2.084.

[1] PRIMES 2016

- For BC 3, the average EER 2015 is 2.6. The average stock efficiency 2011 is 2.3 for the residential sector and 2.2 for the service sector, resulting in 2.279 (2.3 x 79% + 2.2 x 21%).

The average stock efficiency for 2011 should be then corrected with a consumption ratio[2] of new sales and stock, as it is assumed that stock is used for 30% heating hours and new sales are used for 50% heating hours:

  - For BC1, resulting SEER ratio: 0.781, resulting SCOP ratio: 0.685
  - For BC2, resulting SEER ratio: 0.787, resulting SCOP ratio: 0.683
  - Resulting EER ratio for BC3: 0.877

Note the ratio for BC 1 and BC 2 split air conditioners is low, because the regulation led to the change from single speed compressor and fan to DC inverter compressor and fan.

All economic inputs for EcoReport Tool are presented in Table 3.

Table 3: Input economic data for EcoReport tool

Description	Unit	BC 1	BC 2	BC 3
Product Life	years	12	12	10
Annual sales	mln. Units/year	2.468	0.959	0.557
EU Stock	mln. Units	29.7	17.8	4.44
Product price	Euro/unit	743	1992	386
Installation/acquisition costs (if any)	Euro/ unit	800	800	N/A
Electricity rate	Euro/kWh	0.195	0.187	0.198
Repair & maintenance costs	Euro/ unit	741	1310	N/A
Discount rate (interest minus inflation)	%	4%	4%	4%
Escalation rate (project annual growth of running costs)	%	1%	1%	1%
Present Worth Factor (PWF)	(years)	9.97	9.97	8.54
Ratio efficiency STOCK: efficiency NEW, in Use Phase		0.733	0.735	0.877

5.1.3 Annual resources consumption (energy)

The annual energy consumption in the use phase are calculated for each of the base cases and presented in the following section. Based on inputs from previous tasks it is possible to calculate the energy consumption in the use phase for fixed air conditioners and portable air conditioners.

The energy consumption for fixed air conditioners can be calculated based on the values presented in Table 4. The table presents the full load hours in heating and cooling mode and some main characteristics such as capacity, SEER and SCOP.

[2] Consumption ration is found as follows: (Pc*Hc/SEER2011+Ph*0.5*Hh/SCOP2011) / (Pc*Hc/SEER2016+Ph*0.3*Hh/SCOP2016)

Table 4: An extract of information from task 3 and 4 to calculate the energy consumption

Type	Reversible split [0-6kW]	Reversible split [6-12kW]
Pdesignc kW	3.5 kW	7.1 kW
SEER	6	5.8
Hours (cooling full load)	350	350
Pdesignh kW	3.1 kW (-7°C)	6 kW (-10°C)
SCOP	4	4
Hours (heating)	1400	1400

The full load hours are essential to evaluate the energy consumption of products as the energy consumption of the unit is proportional to the equivalent full load hours.

The equivalent full load hours for cooling can be established by weighting the simulated cooling load by country (in kWh/m^2) by the share of the total installed cooling capacity (in % of kW) per sector and per country (stock weighted average). The equivalent full load hours are 350 hours for cooling and are discussed in task 3, section 3.1.2.3.

The equivalent full load hours for heating are established upon heating load and sizing estimates for the 3 climates which are warmer, average, and colder. Previously it was decided to use the heating needs estimated in the preparatory study on space heating. The rationale is that reversible air conditioners installed for heating do compete with other heating means and should then be compared with the same heating loads. The equivalent full load hours are 1400 hours for heating and are discussed in task 3, section 3.1.3.2. Though, the impact of air conditioners should be calculated based on real-life conditions where the hours in heating mode on average are lower than 1400 hours.

In Commission decision 2013/114/EU, it is supposed that 10 % of the reversible air to air conditioners are used for heating in warm climates, 40 % in average climates and 100 % in Northern climates. This amounts to about 25 % (weighting by 2015 stock numbers and 28 % weighting by capacity) reversible units used for heating. This is close to the value declared for Italy for 2015 in the Energy Efficiency Directive[3]. Furthermore, in the Impact assessment for Regulations (EU) 626/2011 and 206/2012[4], a value of 33 % was assumed.

However, stakeholders of the current review study suggest that the present rates of reversible units used for heating are higher, with residential rates between 20 % (only heating) and 60 % (used in addition, partial replacement or replacement of an existing central systems) and commercial rates around 85 %. Using 20 % for residential and 85 % for services, this leads to about 50 % reversibility use with 2015 sales.

Hence, it is assumed that only 30 % of the fixed air conditioners currently are used for heating purposes, but this number is expected to increase to 50 % from now and over the next 12 years. This means that the hours of use in heating mode are corrected to 50 % of the full load hours presented in Table 4 for new units and 30 % for the EU stock.

The average capacities are estimated based on the sales/stock model. This model is built on the 0-5 kW and 5-12 kW capacity intervals. These numbers are then adjusted to fit the capacity categories in the regulation which are 0-6 kW and 6-12 kW. This is done by shifting

[3] http://ec.europa.eu/eurostat/web/energy/data/shares

[4] Impact Assessment of Commission Regulation (EU) No 206/2012 of 6 March 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for air conditioners and comfort fans (OJ L 72, 10.3.2012, p. 7)

about 15 % of total sales from "> 5 kW" class to "< 5 kW" class as this gives comparable weighted average kW to BSRIA sales data. The BSRIA data indicates weighted average capacities of 3.8 kW in the 0-6 kW interval and of 7.8 kW in the 6-12 kW interval. For air conditioners equal to or below 6 kW the most common type of air conditioner is the 3.5 kW according to the Eurovent. This value is adopted as the reference value. Above 6 kW the most common product capacities are 6.8, 7.1 and 10 kW. The 7.1 kW model is the closest to the weighted average value and is adopted as the reference value. The cooling capacities of the base cases for fixed air conditioners are discussed in Task 4 section 4.1.1.1.

The heating capacity, SEER and SCOP are then derived from the base cases as the median product characteristics of products around the base case (cooling) capacities in the ECC database.

- Reversible 3.5 kW wall single split base case: SEER 6.00, SCOP 4.0, Pdesignh= 3.1 kW
- Reversible 7.1 kW wall single split base case: SEER 5.80, SCOP 4.0, Pdesignh= 5.6 kW

These values are extracted from Task 4 section 4.1.1.2.

The data presented in Table 4 can then be used to calculate the annual energy consumption by the following equation:

$$Energy\ consumption_{annual} = \frac{Pdesignc \times H_{CE}}{SEER} + \frac{Pdesignh \times H_{HE} \times 50\ \%}{SCOP}$$

Where:

- *Pdesignc = the maximum building cooling needs in kW, which is equal to the maximum cooling capacity of the unit*
- *H_{CE}: the equivalent number of full load cooling hours*
- *Pdesignh = the maximum building heating needs in kW, which is equal to the maximum heating capacity of the unit*
- *H_{CE}: the equivalent number of full load heating hours*

The annual energy consumption for fixed split air conditioners equal to or below 6 kW (BC1) is then calculated to:

$$Energy\ consumption_{annual} = \frac{3.5\ kW \times 350h}{6} \times \frac{3.1\ kW \times 1400h\ \times 50\ \%}{4.1} = 747\ kWh$$

The annual energy consumption for fixed split air conditioners above 6 kW (BC 2) is then calculated to:

$$Energy\ consumption_{annual} = \frac{7.1\ kW \times 350h}{5.8} + \frac{6\ kW \times 1400h\ \times 50\ \%}{4} = 1478\ kWh$$

These values are used in the EcoReport tool.

The energy consumption for portable air conditioners (BC 3) can be calculated based on the values presented in Table 5. The table presents the hours in cooling (full load), thermostat-off mode and in standby and the energy consumption in these modes. The energy consumption in cooling mode is determined by the cooling capacity and the EER which also are presented in the table below.

Table 5: An extract of information from task 3 and 4 to calculate the energy consumption

Type	Portable
Cooling capacity kW	2.6 kW
EER	2.65

The hours of use are established by using Regulation (EU) 206/2012 and taking the cooling season (above 23 °C), which leads to 1289 hours. As for fixed installations, they are supposed to be used only 10 hours over 24, or about 58 % of the time, which leads to 750 hours in standby mode and leaves 549 hours for hours when the unit is on.

Using these figures and the standard SEERon simulation presented in Task 3, section 3.1.5.4 the cooling capacity is 2.6 kW unit with EER 2.65 (air flow at condenser of 520 m^3/h), which leads to the following figures:

- cooling energy supplied: 365 kWh/a

- electricity consumption (cooling mode only): 172 kWh/a

It is clear that integrating standby power consumption makes no difference; with 1 W power, standby power consumption is 0.75 kWh or 0.4 % or yearly electricity consumption for cooling. So further progress on standby power consumption cannot be expected from including standby in seasonal performance metrics.

These values are used in the EcoReport tool.

The lifetime of fixed and portable air conditioners is also of great importance regarding the energy consumption over the lifetime as it defines how many years air conditioners with the current efficiency are in use. The average lifetime of air conditioners for the three base cases are presented in Table 3. The technical product life is described in task 3.

5.1.4 Resources and End-of-Life

Besides the energy consumption during the use phase, the materials in the product itself contain a considerable amount of embedded energy e.g. calorific value but also the energy used to mine the raw materials and produce the finished materials. Some of this energy can be recovered at End-of-Life when products are either reused, recycled, or burned. When products are landfilled this energy is lost. It is therefore important to describe the most likely End-of-Life scenario to quantify the impact of the material consumption.

The material composition and weight of air conditioners are expected to be very similar to the values presented in the preparatory study. The preparatory study assumed an average weight of 14 kg/kW. These numbers cover an indoor unit of 4 kg/kW and an outdoor unit of 10 kg/kW. These values seem a little high compared to the values presented in Table 6.

Table 6: The weight to size ratio of air conditioners (base cases)

	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable
Size (kW)	3.5	7.1	2.6
Weight (kg)	41	96	32
Weight to size ratio (kg/kW)	11.8	13.5	12.3

The material composition of air conditioners is expected to be unchanged since the preparatory study, therefore the same assumptions are adopted to the current review study. The assumed average material composition of air conditioners is presented Table 7 and are discussed in detail in Task 4.

Table 7: Average material composition of air conditioners

Material Type	Monosplit
	Average %
Bulk Plastics	16
TecPlastics	2
Ferrous	45
Non-ferrous	24
Coating	0
Electronics	3
Misc.	11

The average material composition and weight of the different air conditioners are used to calculate the material composition of the base cases. Note that the values in Table 7 for the non-ferrous are divided into a copper and aluminium fraction. It is estimated that air conditioners contain of 17 % copper and 7 % aluminium.
Based on these inputs the material composition of each of the base cases are calculated in Table 8.

Table 8: The calculated material composition

Description	Share	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable	Material group	Material
		Weight (g)				
Plastics	16%	6355	14880	4960	1-BlkPlastics	4 -PP
Plastics	2%	615	1440	480	2-TecPlastics	12 -PA 6
Ferrous metals	45%	18450	43200	14400	3-Ferro	24 -Cast iron
Non-ferrous metals	17%	6970	16320	5440	4-Non-ferro	31 -Cu tube/sheet
Non-ferrous metals	7%	2870	6720	2240	4-Non-ferro	27 -Al sheet/extrusion
Coatings	0%	0	0	0	5-Coating	
Electronics	3%	1230	2880	960	6-Electronics	98 -controller board
Various other materials	11%	4510	10560	3520	7-Misc.	
Total		**41**	**96**	**32**		

It should be noted that the weight of the refrigerant in the base cases is included in the category "various other materials", however EcoReport Tool cannot properly calculate the impacts of refrigerants (or the impacts of leakage), therefore the impact of refrigerant and leakage are then calculated separately and incorporated back to the EcoReport result in this review study. See more details about the method in Annex 1: Impact of refrigerant.

The primary scrap production is set to 25 % which is the default value in the EcoReport tool.

The distribution phase is included in the calculations but have a very limited impact on the overall analysis. The transport volume is previously discussed in Task 4, and the volume of the package for the three base cases are:

- Fixed reversible split [0-6kW]: 0.25 m^2
- Fixed reversible split [6-12kW]: 0.50 m^2
- Portable: 0.25 m^2

These values have been used for EcoReport Tool.

The recycling rate depends on how the air conditioners are treated End-of-Life. As presented in Task 4, the collection rate for EU was just below 40 % in 2014 which could pose a challenge for the resource efficiency. After collection, the air conditioners are handled together with other appliances containing refrigerants such as refrigerators. These appliances are treated at specialised shredders which can handle the refrigerants and are discussed in Task 4.4.1.
The effectiveness or recycling rate of the shredder (the share of recovered, recycled, and reused materials) is based on the default values in EcoReport tool[5] but updated regarding plastics[6]. The values used in the current study are presented in Table 9.

Table 9: Recycling rates from EcoReport Tool adopted in the current study

	Bulk Plastics TecPlastics	Ferro Non-ferro Coating	Electronics	Misc.	refrigerant
EoL mass fraction to re-use, in %	1%*	1%	1%	1%	1%
EoL mass fraction to (materials) recycling, in %	29%*	94%	50%	64%	30%
EoL mass fraction to (heat) recovery, in %	40%*	0%	0%	1%	0%
EoL mass fraction to non-recov. incineration, in %	0%*	0%	30%	5%	5%
EoL mass fraction to landfill/missing/fugitive, in %	31%*	5%	19%	29%	64%
TOTAL	100%*	100%	100%	100%	100%

**Adjusted values compared to the default values in EcoReport tool[7]*

The consumption on critical raw materials are mainly focusing on copper in the heat exchanger and the gold in the printed circuit boards (PCBs). The copper is included in the calculated material composition in Table 8 and in the recycling rates in Table 9. The amount of e.g. gold in the printed circuit boards is included in the "electronics" fraction. Based in

[5] http://ec.europa.eu/growth/industry/sustainability/ecodesign_da
[6] Plastic Europe, Available at: http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf
[7] Plastic Europe, Available at: http://www.plasticseurope.org/documents/document/20161014113313-plastics_the_facts_2016_final_version.pdf

stakeholder inputs[8] there are 2 printed circuits boards in an average air conditioner and has a combined weight of 428 grams in air conditioners below 6 kW. For large air conditioners the combined weight of the PCBs amounts to 1392 grams. No information on portable air conditioners was provided so it is assumed that the weight of PCBs is 50 % of the PCBs in small air conditioners.

The average composition of a printed circuit board is assumed as follows[9]:

- 70% - non-metallic e.g. glass-reinforced polymer
- 16% - Copper
- 4% - Solder (containing tin)
- 3% - iron, ferrite (from transformer cores)
- 2% - Nickel
- 0.05% - Silver
- 0.03% - Gold
- 0.01% - Palladium
- <0.01% - other (bismuth, antimony, tantalum etc.)

This means that air conditioners contain gold in the range of 0.06 grams to 0.4 grams which originates from the printed circuit boards. The grade[10] of printed circuit boards in air conditioners can be discussed, but the complexity of the air conditioners is increasing which imposes higher grades of printed circuit boards to be used. In general, there are many different grades for PCBs for different electronic or electrical products depending on the level of complexity of the purposes and tasks.

The environmental impacts and commodity prices of gold and copper are:

- Gold – 250 GJ/kg, 22500 CO_2-eq/kg[11] and 35150 euro/kg[12]
- Copper – 50.9 MJ/kg, 2.7 CO_2-eq/kg[13] and 5.9 euro/kg[14]

The recycling rate of copper and electronics are presented in Table 9 and is estimated to 94 % for non-ferrous (copper) and 50% for electronics (including the gold in printed circuit boards). However, if printed circuit boards are removed before shredding the recycling rate of gold is assumed to be above 90 %. According to stakeholders the design of air conditioners is already in favour of easy removal of printed circuit boards, as they consider southern EU countries where manual labour cost is low, the air conditioners with faulty PCBs would be repaired and therefore the PCBs need to be easily accessible for the repairer.

5.2 Base-Case Environmental Impact Assessment

The impacts of the three base cases are presented and discussed in this section. The following impacts are generated by the EcoReport tool and based on the data inputs previous presented:

[8] Data collection questionaire on resource efficiency from stakeholders, November 2017
[9]http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf
[10] The grade of PCBs is dependent on the amount of precious metals (e.g. gold and silver), which can vary between the category of WEEE and its age.
[11] http://ec.europa.eu/environment/integration/research/newsalert/pdf/302na5_en.pdf
[12] Price assessed in November 2017 at: http://www.infomine.com/investment/metal-prices/gold/1-day-spot/
[13] EcoReport tool
[14]Price assessed in November 2017 at: http://www.infomine.com/investment/metal-prices/copper/1-year/

- Other Resources & Waste
    - Total Energy (MJ)
    - of which, electricity (MJ)
    - Water – process (litre)
    - Water – cooling (litre)
    - Waste, non-hazardous/ landfill (g)
    - Waste, hazardous/ incinerated (g)
- Emissions (air)
    - GWP100 (kg CO_2-eq.)
    - Acidification (g SO_2-eq.)
    - Volatile Organic Compounds (VOC) (g)
    - Persistent Organic Pollutants (ng i-Teq)
    - Heavy Metals (mg Ni eq.)
    - PAHs (mg Ni eq.)
    - Particulate Matter (g)
- Emissions (Water)
    - Heavy Metals (mg Hg/20)
    - Eutrophication (g PO_4)

All impacts are further divided in the different life phases of the units which are the material phase, manufacturing phase, distribution phase, use phase, disposal phase and the recycling phase. The different phases are shortly described below:

- **The material phase**: In this phase the weight of the materials is multiplied with the LCA Unit Indicators[15] so the impacts of using the different materials can be calculated.
- **The manufacturing phase**: The manufacturing phase describes the (OEM) manufacturing of metals and plastics materials. The specific weights per process are calculated automatically from the material phase.
- **The distribution phase**: This phase covers all distributing activities from OEM components to the final customer.
- **The use phase**: For the use phase, the average product life in years and annual energy consumption are multiplied together to calculate the energy consumption during the whole lifetime.
- **The disposal and recycling phase**: These phases deal with the impacts End-of-Life. In the recycling phase, the recycling of the different materials is credited, and a negative value can appear (due to avoiding the production of new materials).

In recent year, the dominant impact category has been CO2-emission due to an increased focus on global warming, therefore the energy consumption and Global Warming Potential (GWP) expressed in kg CO_2-eq in the different life phases for the base cases are presented in the below figures:

[15] see MEErP 2011 Methodology, Part 2

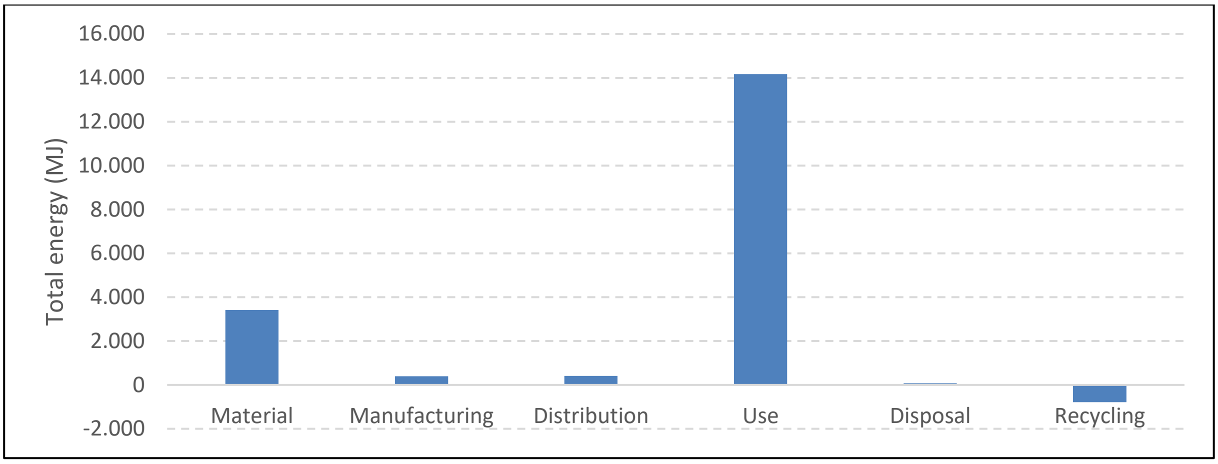

Figure 1: Total energy consumption BC 1 Reversible split [0-6kW]

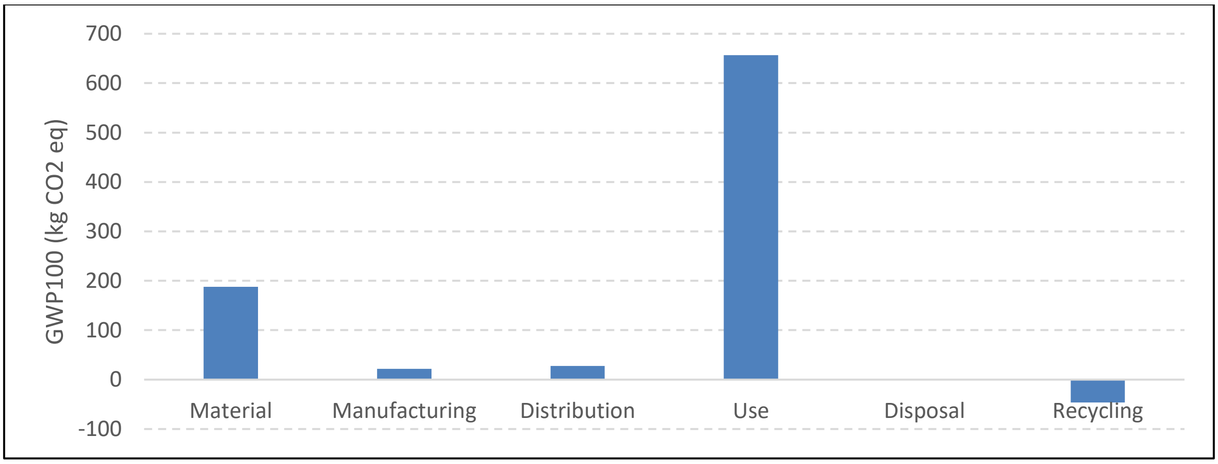

Figure 2: Global warming potential BC 1 Reversible split [0-6kW]

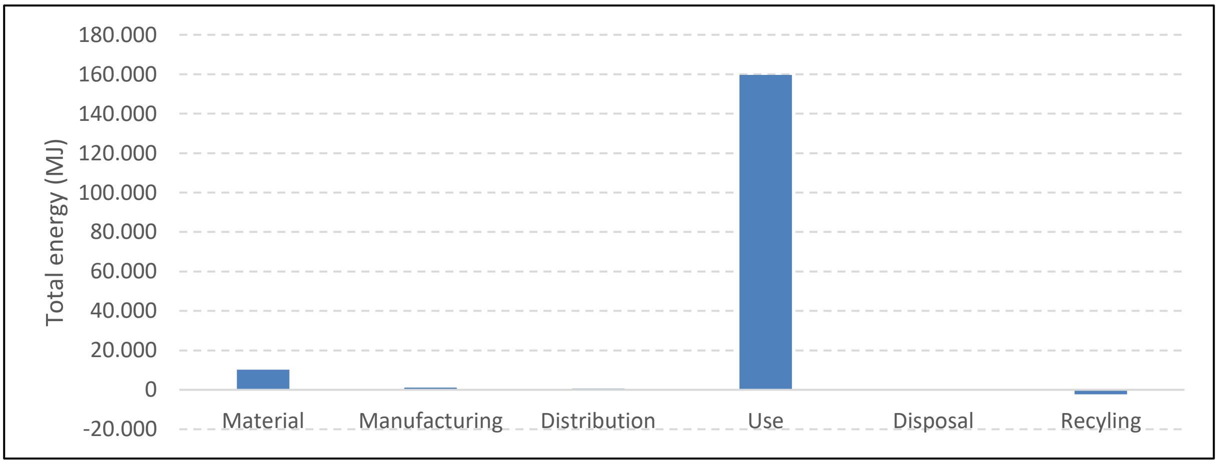

Figure 3: Total energy consumption – BC 2 Reversible split [6-12kW]

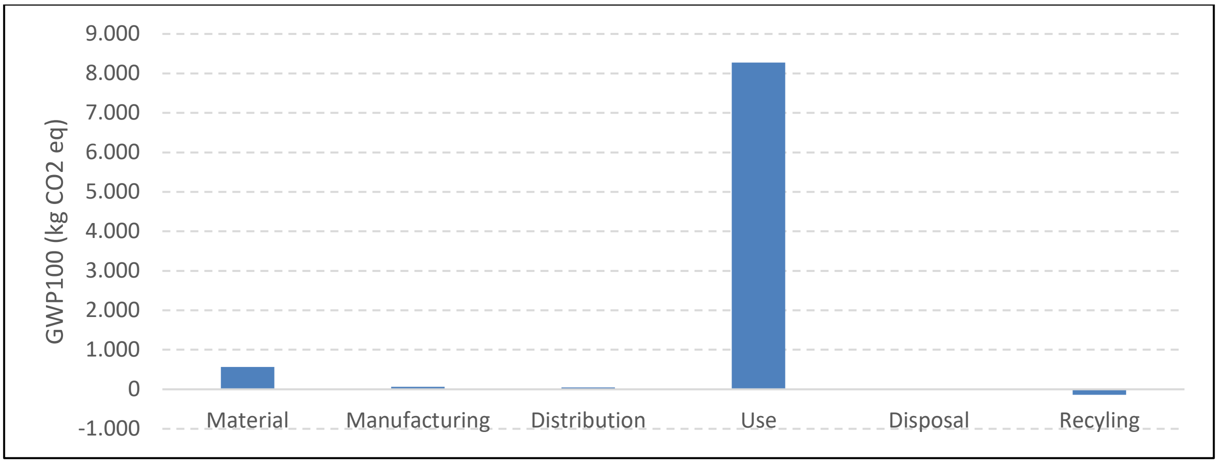

Figure 4: Global warming potential – BC 2 Reversible split [6-12kW]

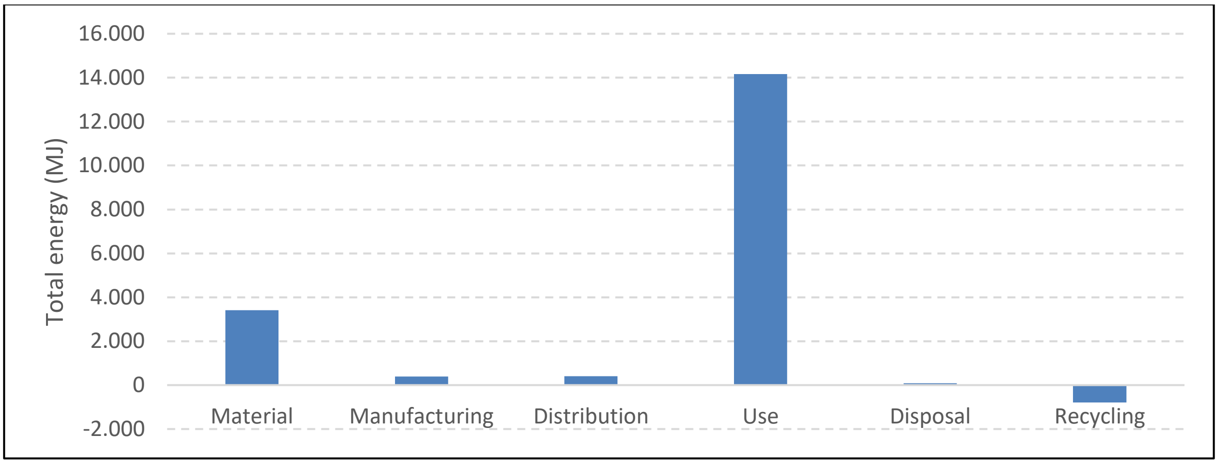

Figure 5: Total energy consumption – BC 3 Portable air conditioner

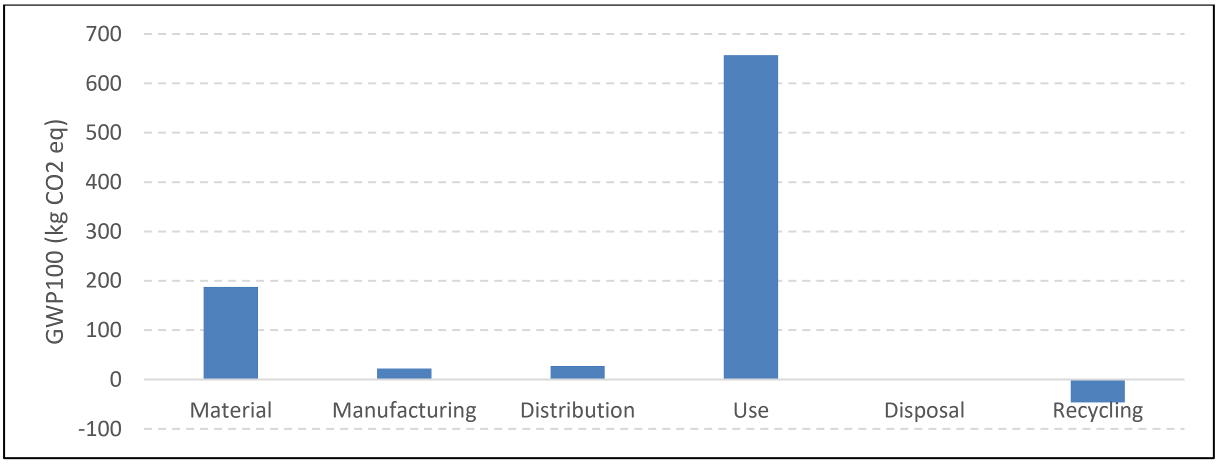

Figure 6: Global warming potential – BC 3 Portable air conditioner

The energy consumption and the emission of CO_2-eq are closely connected and there is a high correlation between the figures. In all base cases the highest energy consumptions are related to the use phase independently on the type of air conditioner. In all cases, above 90 % of the energy consumption and above 88 % of the CO_2-eq emissions appears in the use phase. The share is presented in the below tables.

Table 10: Impacts BC 1 Reversible split [0-6 kW]

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Total Energy share	5%	1%	0%	95%	0%	-1%	100%
GWP100 share	6%	1%	1%	95%	0%	-1%	100%

Table 11: Impacts BC 2 Reversible split [6-12 kW]

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Total Energy share	6%	1%	0%	94%	0%	-1%	100%
GWP100 share	6%	1%	1%	94%	0%	-2%	100%

Table 12: Impacts – BC 3 Portable air conditioner

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Total Energy share	19%	2%	2%	80%	0%	-4%	100%
GWP100 share	24%	3%	3%	76%	0%	-6%	100%

In general, the use phase is responsible for the highest impacts for most categories calculated in the EcoReport tool. All impact categories are presented in the below tables and for each of the categories is the life cycle phase with the highest impact highlighted with red text. The leakage of refrigerants is not assumed to have any impacts on the energy consumption, but only on the emission of CO_2-eq.

- BC 1: 671 kg CO_2-eq, responsible for 15 % of the emitted CO_2-eq
- BC 2: 1451 kg CO_2-eq, responsible for 16 % of the emitted CO_2-eq
- BC 3: 0.08 kg CO_2-eq, responsible for < 1 % of the emitted CO_2-eq

The leakage rate is included in all tables below, and the shares presented above are representative in all scenarios.

Table 13: All impact categories for BC 1- Reversible split [0-6 kW]. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Total Energy (MJ)	4,379	504	410	80,720	106	-1,009	**85,110**
of which, electricity (MJ)	2,289	298	1	80,699	0	-466	**82,820**
Water – process (litre)	583	4	0	6	0	-119	**474**
Water – cooling (litre)	499	135	0	3,591	0	-68	**4,155**
Waste, non-haz./landfill (g)	9,799	1,929	256	41,673	208	-3,224	**50,641**
Waste, hazardous/ incinerated (g)	160	0	5	1,274	0	-28	**1,412**
Emissions (Air)							
GWP100 (kg CO_2-eq)	240	28	28	4,073	0	-59	4,310
Acidification (g SO_2-eq.)	1,971	122	83	15,259	6	-524	16,918
VOC (g)	8	0	5	1,802	0	-2	1,813
Persistent Organic Pollutants (ng i-Teq)	210	26	1	190	0	-78	350
Heavy Metals (mg Ni eq.)	803	62	13	824	5	-216	1,491
PAHs (mg Ni eq.)	380	0	14	192	0	-134	453
Particulate Matter (g)	1,335	19	855	336	44	-332	2,258
Emissions (Water)							
Heavy Metals (mg Hg/20)	541	2	0	353	1	-180	716
Eutrophication (g PO_4)	6	0	0	15	1	-1	21

Table 14: All impact categories for BC 2 Reversible split [6-12kW]. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Total Energy (MJ)	10,253	1,179	710	159,727	248	-2,362	169,755
of which, electricity (MJ)	5,360	697	1	159,678	0	-1,092	164,644
Water – process (litre)	1,366	10	0	14	0	-280	1,110
Water – cooling (litre)	1,167	315	0	7,106	0	-160	8,429
Waste, non-haz./ landfill (g)	22,945	4,516	406	82,489	487	-7,548	103,294
Waste, hazardous/ incinerated (g)	374	0	8	2,522	0	-65	2,840
Emissions (Air)							
GWP100 (kg CO_2-eq)	563	66	47	8,104	1	-139	8,641
Acidification (g SO_2-eq.)	4,616	286	142	30,197	15	-1,227	34,030
VOC (g)	19	1	10	3,565	0	-5	3,590
Persistent Organic Pollutants (ng i-Teq)	492	62	2	377	0	-183	751
Heavy Metals (mg Ni eq.)	1,881	144	21	1,633	12	-505	3,185
PAHs (mg Ni eq.)	891	0	25	381	0	-313	984
Particulate Matter (g)	3,127	44	1,710	670	104	-777	4,877
Emissions (Water)							
Heavy Metals (mg Hg/20)	1,266	5	1	700	1	-422	1,551
Eutrophication (g PO_4)	13	1	0	30	1	-3	43

Table 15: All impact categories for BC 3 Portable air conditioner. The life cycle phase with the highest impact for each of the categories is highlighted with red text.

	Material	Manufacturing	Distribution	Use	Disposal	Recycling	Total
Other Resources & Waste							
Total Energy (MJ)	3418	393	410	14,164	83	-787	17,681
of which, electricity (MJ)	1787	232	1	14,148	0	-364	15,804
Water – process (litre)	455	3	0	5	0	-93	370
Water – cooling (litre)	389	105	0	632	0	-53	1,073
Waste, non-haz./ landfill (g)	7648	1505	256	7,358	162	-2,516	14,414
Waste, hazardous/ incinerated (g)	125	0	5	224	0	-22	332
Emissions (Air)							
GWP100 (kg CO_2-eq)	188	22	28	605	0	-46	796
Acidification (g SO_2-eq.)	1539	95	83	2,684	5	-409	3,998
VOC (g)	6	0	5	316	0	-2	326
Persistent Organic Pollutants (ng i-Teq)	164	21	1	35	0	-61	160
Heavy Metals (mg Ni eq.)	627	48	13	149	4	-168	673
PAHs (mg Ni eq.)	297	0	14	36	0	-104	242
Particulate Matter (g)	1042	15	855	67	35	-259	1,755
Emissions (Water)							
Heavy Metals (mg Hg/20)	422	2	0	65	0	-141	349
Eutrophication (g PO_4)	4	0	0	3	0	-1	7

The same pattern is visible for fixed air conditioners where the use phase has the highest impact in 9 out of the 15 impact categories, and the material phase has the highest impact in the remaining 6 categories. For portable air conditioners the use phase has the highest impact in 7 out of the 15 impact categories, and the material phase has the highest impact in the remaining 8 categories. Regarding the impacts of the heating and cooling mode of reversible air conditioners, approximately 30 % of the energy and thereby 30 % of the impacts in the use phase are related to the cooling mode. This share is lowered in the future as more people are expected to use their reversible air conditioner for heating purposes.

In the above tables it is also visible that air conditioners above 6 kW have the highest impact in all categories compared with the other base cases. This is due to the size of the equipment and the higher energy consumption. Though, it should be noted that they are not used at the same premises and are not fully comparable. To make a fully comparable analysis between the 3 base cases, the same functional unit shall be defined. The purpose of the base cases is not to compare the different air conditioners but to determine the impact of each of them individually.

The impacts of each base case per product have been presented above, in section 5.4, the total EU impact of air conditioners are presented.

The consumption of critical raw materials is also determined for the base cases per product. For each of the base case, the amount of gold and copper calculated and the derived impacts regarding energy, emission of CO_2-eq and market value in euros.

- For BC 1:
  - 0.128 grams of gold, 32.1 MJ, 2.9 kg CO_2-eq. and 4.5 euros
  - 6970 grams of copper, 355 MJ, 21 kg CO_2-eq. and 41 euros
- For BC 2:
  - 0.4176 grams of gold, 104.4 MJ, 9.4 kg CO_2-eq. and 14.7 euros
  - 16320 grams of copper, 831 MJ, 49 kg CO_2-eq. and 96 euros
- For BC 3:
  - 0.0642 grams of gold, 16.1 MJ, 1.4 kg CO_2-eq. and 2.3 euros
  - 5440 grams of copper, 277 MJ, 16 kg CO_2-eq. and 32 euros

Both copper and gold have limited impacts compared with the impacts of the use phase. Copper is responsible for less than 1 % of the emission of CO_2-eq over the lifetime and gold has an even lower impact.

5.3 Base-Case Life Cycle Costs for consumer

The base-case life cycle costs for the consumer are calculated based on the data presented in section 5.1.2. The life cycle costs for consumers are calculated by the following equation:

$$LCC = PP + PWF \times OE + EoL$$

Where:

- LCC is Life Cycle Costs
- PP is the purchase price
- OE is the operating expense
- PWF (Present Worth Factor)
- EoL is End-of-life costs (disposal costs, recycling charge) or benefit (resale).

The present worth factor is automatically calculated in the EcoReport tool. The formula to calculate the present worth factor is:

$$PWF = \{1 - 1/(1 + r)^N\}/r$$

Where:

- N is the product life
- r is the discount rate minus the growth rate of running cost components (e.g. energy, water rates)

The discount rate is assumed to be 4 % and the escalation rate (annual growth rate of running costs) are assumed to be approximately 1% and the resulting values for the different base cases are:

- BC 1 – 9.97
- BC 2 – 9.97
- BC 3 – 8.54

The life cycle costs of the three different base cases calculated in the EcoReport tool are presented in Table 16.

Table 16: Life cycle cost of the three base cases

	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable
Product price (€)	743	1929	386
Installation/ acquisition costs (€)	800	800	0
Electricity (€)	1238	2350	367
Repair & maintenance costs (€)	741	1310	0
Total (€)	3521	6389	692

For fixed air conditioners the highest expenses are related to the use phase and the electricity consumption. For portable air conditioners the highest expenses are related to the purchase due to low hours of use assumed. Note, that the cost of electricity in the three base cases varies, because the electricity price for each base case is derived based on the share of residential users and service sector users as described above on section 5.1.2.

5.4 EU Totals

The EU totals are the environmental impacts and the life cycle costs aggregated to EU-27 level. For the EU totals the following is calculated:

- **Environmental impacts during the entire lifetime of air conditioner sold in 2015** is calculated by multiplying the annual sales with the impacts of each of the base cases and presented in Table 17.
- **Environmental impacts of air conditioner (EU-27 stock)** is calculated by multiplying the current stock with the impacts of each of the base cases and presented in Table 18.
- **Environmental impacts of air conditioners as a share of EU total impacts** is calculated as the ratio of impacts from air conditioners compared to EU totals (total impacts of all energy-related products in 2011) and presented in Table 19.
- **Annual consumer expenditure in EU27** is calculated based on the life cycle costs per product multiplied by the annual sales and presented in Table 20.
- **The EU consumption of critical raw materials in air conditioners** is calculated by multiplying the current stock with the amount of gold and copper in each of the base cases.

Table 17: Environmental impacts during the entire lifetime of air conditioner sold in 2015

Materials	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable	Total
Bulk Plastics (kt)	5	4	1	10
TecPlastics (kt)	0	0	0	0
Ferro (kt)	2	2	0	4
Non-ferro (kt)	1	1	0	2
Electronics (kt)	2	1	0	3
Misc. (kt)	4	3	1	8
Total weight (kt)	**14**	**13**	**2**	**29**
Other resources & waste				
Total Energy (PJ)	210	163	10	383
of which, electricity (PJ)	204	158	9	371
Water (process) (mln.m^3)	1	1	0	2
Water (cooling) (mln.m^3)	10	8	1	19
Waste, non-haz./ landfill* (kt)	125	99	8	232
Waste, hazardous/ incinerated* (kt)	3	3	0	6
Emissions (Air)				
GWP100 (mt CO_2-eq.)	10	8	0	18
Acidifying agents (AP) (kt SO_2-eq.)	42	33	2	77
Volatile Org. Compounds (kt)	4	3	0	7
Persistent Org. Pollutants (g i-Teq.)	1	1	0	2
Heavy Metals (ton Ni eq.)	4	3	0	7
PAHs (ton Ni eq.)	1	1	0	2
Particulate Matter (kt)	6	5	1	12
Emissions (Water)				
Heavy Metals (ton Hg/20)	2	1	0	3
Eutrophication (kt PO_4)	0	0	0	0

The combined energy consumption during of all air conditioners sold will account to 383 PJ during their lifetime resulting in 18 mt CO_2-eq. emitted. The highest impacts are connected with small fixed air conditioners as the have the highest annual sales.

In Table 18 the annual impact of all air conditioners (stock) is calculated which allows for comparison with the EU totals from all energy-related products. The share of impacts originating from air conditioners are calculated in Table 19.

Table 18: Environmental impacts of air conditioner (EU-27 stock)

Materials	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable	EU totals
Plastics (Mt)	0.017	0.016	0.003	48
Ferrous metals (Mt)	0.046	0.042	0.008	206
Non-ferrous metals (Mt)	0.025	0.022	0.004	20
Other resources & waste				
Total Energy (PJ)	286	359	10	75697
of which, electricity (TWh)	31	39	1	2800
Water (process)* (mln.m^3)	1	1	0	247000
Waste, non-haz./ landfill* (Mt)	0.17	0.21	0.01	2947
Waste, hazardous/ incinerated* (kton)	0.00	0.01	0.00	89
Emissions (Air)				
GWP100 (mt CO2-eq.)	14	18	0	5054
Acidifying agents (AP) (kt SO2eq.)	57	70	2	22432
Volatile Org. Compounds (kt)	6	8	0	8951
Persistent Org. Pollutants (g i-Teq.)	1	1	0	2212
Heavy Metals (ton Ni eq.)	5	6	0	5903
PAHs (ton Ni eq.)	2	2	0	1369
Particulate Matter (kt)	7	6	1	3522
Emissions (Water)				
Heavy Metals (ton Hg/20)	3	3	0	12853
Eutrophication (kt PO_4)	0	0	0	900

Table 19: Environmental impact share of EU total impacts (EU-27 stock)

Materials	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable	Total
Plastics (Mt)	0.036%	0.033%	0.006%	0.075%
Ferrous metals (Mt)	0.022%	0.020%	0.004%	0.046%
Non-ferrous metals (Mt)	0.123%	0.112%	0.022%	0.257%
Other resources & waste				
Total Energy (PJ)	0.377%	0.474%	0.013%	0.864%
of which, electricity (TWh)	1.107%	1.399%	0.033%	2.539%
Water (process)* (mln.m^3)	0.001%	0.001%	0.000%	0.002%
Waste, non-haz./ landfill* (Mt)	0.006%	0.007%	0.000%	0.013%
Waste, hazardous/ incinerated* (kton)	0.005%	0.007%	0.000%	0.012%
Emissions (Air)				
GWP100 (mt CO_2-eq.)	0.29%	0.36%	0.01%	0.660%
Acidifying agents (AP) (kt SO_2-eq.)	0.25%	0.31%	0.01%	0.570%
Volatile Org. Compounds (kt)	0.07%	0.09%	0.00%	0.160%
Persistent Org. Pollutants (g i-Teq.)	0.06%	0.06%	0.01%	0.130%
Heavy Metals (ton Ni eq.)	0.08%	0.09%	0.01%	0.180%
PAHs (ton Ni eq.)	0.12%	0.12%	0.01%	0.250%
Particulate Matter (kt)	0.19%	0.17%	0.03%	0.390%
Emissions (Water)				
Heavy Metals (ton Hg/20)	0.02%	0.02%	0.00%	0.040%
Eutrophication (kt PO_4)	0.01%	0.01%	0.00%	0.020%

The annual energy consumption of all air conditioners in Europe is calculated to 655 PJ which leads to 32 mt CO_2-eq released to the atmosphere. This means that air conditioners are responsible for 0.86 % of the energy consumption (2.5 % of the electricity consumption) in the EU and 0.66 % of the CO_2-eq. Air conditioners are also responsible for 0.57 % of the acidifying agents released within EU. The remaining impact categories are all below 0.5 % of the EU totals.

The annual consumer expenditures in EU-27 of the average air conditioners are presented in Table 20. The product price and installation costs per product is multiplied by annual EU sales to arrive at the annual consumer expenditure for EU27. The lifetime electricity costs per product multiplied by the annual EU stock and divided by the lifetime to arrive at the annual consumer expenditures for electricity in the EU-27, the same is done for repair & maintenance costs.

Table 20: Annual consumer expenditure in EU27

	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable	Total
Product price (mln. €)	1834	1910	215	3959
Installation/ acquisition costs (mln. €)	1974	767	0	2741
Electricity (mln. €)	4326	3920	138	8384
Repair & maintenance costs (mln. €)	1834	1943	0	3777
Total (mln. €)	9968	9540	353	19861

The highest costs are related to fixed air conditioners which have the highest annual sales. As the table above shows, every year EU consumers are spending 19.7 billion euros in the purchase and operation of their air conditioners. Approximately 42 % (8.4 billion euros) are related to electricity expenses.

The EU consumption of critical raw materials is also determined for the base cases for the EU stock. For each of the base cases the amount of gold and copper is calculated and the derived impacts regarding energy, emission of CO_2-eq and value are presented below.

- For BC 1
    - 3.8 tonnes of gold, 0.95 PJ, 85803 tonne CO_2-eq. and 134 million euros
    - 207009 tonnes of copper, 11 PJ, 564716 tonne CO_2-eq. and 1221 million euros
- BC 2
    - 7.4 tonnes of gold, 1.86 PJ, 167249 tonne CO_2-eq. and 261 million euros
    - 290496 tonnes of copper, 15 PJ, 792467 tonne CO_2-eq. and 1714 million euros
- BC 3
    - 0.3 tonnes of gold, 0.07 PJ, 167249 tonne CO_2-eq. and 10 million euros
    - 24154 tonnes of copper, 1 PJ, 65891 tonne CO_2-eq. and 143 million euros

The impacts of the raw materials are limited[16] compared with the other impacts imposed by air conditioners in the use phase. The value for the amount of gold and copper present in the EU stock are significant. The combined impact and value of gold and copper in all air conditioners (stock) are presented in Table 21.

[16] Taking environmental impacts beyond energy and GWP into account, raw materials are connected to very severe environmental and health issues (gold: use of mercury; copper: acid mine drainage, water contamination in mining etc.) though these aspects are difficult to assess with MEErP methodology.

Table 21: The combined impact and value of gold and copper in all air conditioners (stock)

	Total Energy (PJ)	GWP100 (mt CO_2-eq.)	Total (mln. €)
Gold	2.88	0.26	405
Copper	26.56	1.42	3078
Total	**29.44**	**1.68**	**3483**

Gold and copper are accountable for an energy consumption of 29.44 PJ and an emission of 1.68 million tonne of CO2-eq. The combined value of copper and gold in the EU stock amounts to more than 3 billion euros. Based on stakeholder inputs the PCBs are located easily available for repair which also implies that the PCBs can be easily removed at End-of-Life. This means that most of the critical raw materials are recycled and the value is recovered. To make the critical raw materials easier to remove at End-of-Life could also impose a safety risk (e.g. risk of electric shock) for the consumers, if they believe they can repair the air conditioners by them self as the components are easy to remove.

5.5 Conclusions and recommendations

For fixed air conditioners, the use phase has the highest impacts for 9 out of the 15 investigated impact categories including electricity consumption and the derived CO_2-eq emission. For portable air conditioners the highest impacts for 7 out of the 15 investigated impact categories including electricity consumption and the derived CO_2-eq emission are also related to the use phase. The material phase has the highest impact in the remaining 6 impact categories. The energy consumption, emission of CO_2-eq and emission of SO_2-eq for the different base cases are:

- BC 1: Energy consumption - 85,110 MJ, emission of CO_2-eq - 4,310 kg, emission of SO_2-eq - 16,918 g.
- BC 2: Energy consumption - 169,755 MJ, emission of CO_2-eq - 8,641 kg, emission of SO_2-eq – 34,030 g
- BC 3: Energy consumption - 17,681 MJ, emission of CO_2-eq - 796 kg, emission of SO_2-eq – 3,998 g

The life cycle impacts of the base cases will serve as a baseline or reference for the improvement options and policy scenarios assessment in Task 6 and 7. The comparison between the annual impacts of all air conditioners and the EU total impacts (from all energy-related products) reveals that air conditioners are responsible for 2.5 % of the total EU electricity consumption, 0.66 % of the total EU emitted CO_2-eq and 0.57 % the emitted acidifying agents within the EU. These are the categories with the highest share and are mostly related to the electricity consumption in the use phase. In total, all EU air conditioners over a lifetime account for 655 PJ of energy consumption, which leads to 32 mt CO2-eq released to the atmosphere. When more air conditioners are used for heating mode, this energy consumption and CO_2-eq emission will also increase.

The life cycle costs for air conditioners reveal that the highest expenses are related to the use phase as well. Within the EU, all consumers are spending 19.7 billion euros annually in the purchase and operation of their products. Approximately 42 % (8.4 billion euros) are related to electricity expenses.

The critical raw materials consumed during production have limited impacts and constitutes below 1 % of the impacts imposed by air conditioners over a lifetime. In the EU stock, the raw materials (gold and copper) embedded account for an energy consumption of 29.44 PJ and an emission of 1.68 million tonnes of CO2-eq. The combined value of copper and gold in the stock amounts to more than 3 billion euros. The majority of these raw materials are considered to be recycled at End-of-Life as most air conditioners already are facilitating easy dismantling and repair.

Annex 1: Impact of refrigerant

In the EcoReport Tool inputs, the refrigerant weight is included in the category "various other materials". However, it cannot properly calculate the impacts of refrigerants (or the impacts of leaking). The impact of the refrigerant and leakage are then calculated separately in this review study. The yearly leakage is presented in Table 22.

Table 22: Calculated leakage of refrigerants per year

	Reversible split [0-6kW]	Reversible split [6-12kW]	Portable
Refrigerant charge	0.98 kg	2.01 kg	0.26 kg
Annual leakage rate	3 %	3 %	1 %
GWP	R410A (GWP 2088)	R410A (GWP 2088)	R290 (GWP 3.3)
Average Leakage kg/year	0.027 kg/year	0.058 kg/year	0.0025 kg/year

The leakage of refrigerants during the lifetime of the air conditioners is included directly in the EcoReport tool manually, as kg CO_2-eq in the use phase, in the result sheet under the "Life cycle Impact per product". This includes the impact of leakage in all of the results by the EcoReport tool.

Regarding the EU stock, as the leakage rate of older air conditioners in the stock are difficult to determine, the values presented in Table 22 are used for calculating the emission of CO_2-eq of stock as well.