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Lot 6: Air-conditioning and ventilation systems

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Air conditioning systems

Final report of Task 7

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TASK 7 – POLICY AND IMPACT ANALYSIS

INTRODUCTION

This is the draft report for Task 7 on the Air Conditioning Systems, as part of the preparatory study on Air Conditioning and Ventilation Systems in the context of the Ecodesign Directive: '**ENTR Lot 6 – Air Conditioning and Ventilation Systems'.** This study is being carried out for the European Commission (DG ENTR). The consortium responsible for the study is Armines (lead contractor), BRE and VHK. The underlying report has been written by Armines.

PURPOSE OF THIS REPORT

As laid out in previous Task reports, this product group is eligible for Ecodesign measures as it complies with the criteria of Art. 15 of the 2009/125/EC directive. It is economically and environmentally significant. There is a significant cost-effective saving potential that is not captured. The general objective is to develop a policy which corrects the market and regulatory failures following the task 7 description as given in the methodology and reproduced below.

SCOPE: *This task looks at suitable policy means to achieve the potential improvement, e.g. implementing LLCC as a minimum requirement, the environmental performance of BAT or BNAT as a benchmark, using dynamic aspects, legislative or voluntary agreements, standards, labelling or incentives, relating to public procurement or direct and indirect fiscal instruments.*
It draws up scenarios 1990–2025 quantifying the improvements that can be achieved versus a Business-as-Usual scenario and compares the outcomes with EU environmental targets, the societal costs if the environmental impact reduction would have to be achieved in another way, etc.

It makes an estimate of the impact on users (purchasing power, societal costs) and industry (employment, profitability, competitiveness, investment level, etc.), explicitly describing and taking into account the typical design cycle (platform change) in a product sector.
In addition the contractor should provide an analysis of which significant impacts may have to be measured under possible implementing measures, and what measurement methods would need to be developed or adapted.

Subtask 7.1 - Policy Analysis
The policy analysis should identify policy options considering the outcomes of all previous tasks, notably the options should:
- Be based on the exact definition of the products, according to subtask 1.1 and modified/ confirmed by the other tasks;
- Provide ecodesign requirements, such as minimum (or maximum) requirements[1], considering the sensitivity analysis carried out in subtask 6.4;
- Be complemented, where appropriate, with (dynamic) labelling and benchmark categories linked to possible incentives, relating to public procurement or direct and indirect fiscal instruments;
- Where appropriate, apply existing standards or propose needs/ generic requirements for harmonised standards to be developed;
- Provide measurement requirements, including measurement standards and/or methods;
- Consider possible self-regulation, such as voluntary agreement or sectoral benchmarks initiatives;
- Provide requirements on installation of the product or on user information.

Subtask 7.2 - Impact Analysis
For each of the policy options defined in subtask 7.1, the costs and benefits should be assessed. In particular, the ecodesign requirements should not entail excessive costs nor undermine the competitiveness of European enterprises and should not have a significant negative impact on consumers or other users. This encompasses the assessment of the following impacts:

[1] Ecodesign requirements should always address improvements in terms of environmental performance, not in terms of technologies.

- Monetary impacts for categories of users in particular as regards affordability and life cycle cost of the product (confirming or modifying the results obtained in subtask 6.1);
- Impacts on the functionality of the product, from the perspective of the user;
- Monetary impacts on the manufacturer regarding redesign, testing, investment and/or production costs (confirming or modifying the results obtained in subtask 6.1);
- Further impacts on manufacturers, such as imposed proprietary technology or administrative burdens;
- Impact on the competitive situation of the market; such as market share of products already complying with the envisaged minimum requirement, market shares of remaining models after the minimum requirement is introduced, competitive advantage or negative impacts on the competitive situation of some market players (e.g. SMEs, regional players) or reduction in user choice;
- Impacts on EU firms' competitiveness outside the EU and on importers;
- Impact on innovation or research and development;
- Any significant social impact, such as impacts on employment and labour conditions, health and safety or equality of treatment and opportunities.

REPORT ORGANISATION

The report follows the task structure outlined in the methodology and reported above.

In the task 7.1, the scope and definitions are reviewed. The performance indicators proposed and standardization requirement are discussed. On this basis, policy options regarding the main environmental impacts of these products are proposed, as well as complementary measures regarding information requirements and other environmental impacts.

In the task 7.2, the hypothesis of the scenarios are described and their impact are evaluated. As regards the operational objectives it is clear that the 2020 time horizon, used in several overarching policy objectives for energy security of supply and environment, is very important. Savings in 2020, with respect to the reference year 1990, indicate the relative contribution of measures, although these impacts are computed up to 2025. In addition, likely impacts on the product functionality, on the users, manufacturers and utilities are described.

7.1. POLICY OPTIONS

INTRODUCTION

The table below gives the list of all possible combinations by main product type (chiller, air conditioner …), packaging (package, split, VRF, …), principle of operation (electric vapor compression type, absorption …) and sink type of products in the scope of the ENTR Lot 6 study and proposed measures.

Table 7 - 1 . Summary of the scope and analysis performed in the previous tasks

Description of products in the scope of ENTR Lot 6 study				Evaluation of the improvement potential	
Product category	Packaging	Cooling principle	Sink type	Base cases in Task 4	LLCC BAT
Air conditioning chillers	Package, split	Electric	Air-cooled	Yes	Yes
			Evaporatively-cooled	No	No
			Water-cooled	Yes	Yes
	Package		Condenserless	No	No
	Package, split	Gas engine vapor compression	Air-cooled	No	No
			Water-cooled	No	No
	Package	Absorption / adsorption	Air-cooled	No	No
			Water-cooled	No	No
Air conditioners	Split, multi-split	Electric	Air-cooled	Yes	Yes
			Water-cooled	No	No
	Split, multi-split	Gas engine vapor compression	Air-cooled	No	No
			Water-cooled	No	No
	VRF	Electric	Air-cooled	Yes	Yes
			Water-cooled	No	No
	VRF	Gas engine vapor compression	Air-cooled	No	No
			Water-cooled	No	No
	Package (incl. Rooftop)	Electric	Air-cooled	Yes	Yes
			Water-cooled	No	No
Air conditioning condensing unit	Package	Electric	Air-cooled	No	No
			Water-cooled	No	No
	Package	Gas engine vapor compression	Air-cooled	No	No
			Water-cooled	No	No
Heat rejection units	Dry-cooler	Electric	N/A	Yes	No
	Evaporatively-cooled liquid cooler	Electric	N/A	No	No
	Open cooling tower	Electric	N/A	No	No
Fan coil units	N/A	Electric	N/A	Yes	No

N/A: not applicable

This table is limited to products thought to be presently available on the EU market. However, some of the combinations for which there is no available products (evaporatively-cooled electric air conditioner for instance) could be populated in the short term and should be considered at least for standardization purpose.

Given the very high number of products in scope, the study focused its efforts on the modeling of a very limited number of base cases, which are thought to represent more than 95 % of the total environmental impacts of ErP products in comfort air conditioning systems in Europe (out of the scope of the 2012/206/EC regulation ie only accounting air-to-air conditioners above 12 kW).
These base cases are:
- Air conditioning chillers
1. An air cooled electric chiller of 100 kW cooling output,
2. An air cooled electric chiller of 400 kW cooling output,
3. A water-cooled electric chiller of 100 kW cooling output,
4. A water-cooled electric chiller of 1000 kW cooling output,
- Air conditioners
5. An electric split air conditioner of 14 kW cooling output,
6. An elecric VRF air conditioner of 50 kW cooling output,
7. An electric rooftop package air conditioner of 80 kW cooling output,
- Air conditioning condensing unit
- Terminal units
8. A fan coil unit of 3 kW cooling output
- Heat rejection units
9. A dry-cooler of 200 kW cooling output
10. Cooling tower of 1000 kW cooling ouput (representative of the stock of cooling towers installed, no base case made for the sales)

Cooling generators

An economic optimization was performed in task 6 for the seven base cases representing the cooling generators, ie the first five base cases above. Altogether they are believed to represent more than 90 % of the total environmental impact of ErP products in comfort air conditioning systems in Europe (out of the scope of the 2012/206/EC regulation).

For these base cases, the LLCC and BAT were determined in view of requiring specific energy efficiency and TEWI minimum performance values following Task 6 results. In part 7.1.3, the possible targets regarding energy efficiency and equivalent CO_2 emissions minimum requirements are discussed for electric air conditioning chillers (air-cooled and water-cooled) and electric air conditioners (air-to-air above 12 kW).

It is clear that when having in view a regulation for the whole sector, it is not possible to exclude from possible measures, products that represent even a very low market share as it could lead to biaise the market. Hence, all cooling generators in scope should be included in the scope of the measures.

However, the environmental impact of the other cooling generators than electric air conditioning chillers (air-cooled and water-cooled) and electric air conditioners (air-to-air above 12 kW) is estimated to be very low because of low sales. This regards mainly water-cooled air conditioners, gas-engine air conditioners and absorption chillers.

In addition, water-cooled air conditioners, which could be in competition with air-to-air air conditioners, are inherently more efficient, because of more favorable temperature levels at the condenser, and are also structurally more expensive, as they need a cooling tower, or a geothermal/acquifer heat exchanger. Hence, a major market change does not seem likely. The same rationale applies to absorption chillers, which correspond to a niche market.

Thus, for other cooling generators than the electric or gas engine air-cooled and water-cooled chillers and air-to-air air conditioners, it is proposed to include them in the scope of the measures, to require standards to be developed, to add also the same other requirements, regarding sound power maximum levels, resource efficiency and information requirements but not to ask for specific requirements. This is the case of water-cooled air conditioners and absorption chillers.

Heat rejection and terminal units

The study team did not proceed with the economic optimization of terminal and heat rejection units. The main reason for that choice is that more efficient system designs do not match with the choice of more efficient products in that case: for instance, the gain in the fan power consumption of using a highly efficient dry cooler would still lead to higher energy consumptions at system level than choosing a cooling tower. The reason is that the cooling tower would lead to 20 K lower condensing temperature at the condenser of the water cooled chiller, which makes much more gains on the energy consumption of the cooling generator than the potential fan motor consumption reduction.

Nevertheless, it is proposed to include heat rejection units and terminal units in the scope of a possible implementing measure, to improve the standards and ask for the other than specific requirements, regarding sound power maximum levels, resource efficiency and information requirements

7.1.1. DEFINITION OF PRODUCTS AND SCOPE

Scope overview

The study scope has been defined in Task 1 of this study as follows.

The focus is on air conditioning systems in human occupied buildings to ensure comfort air conditioning. The Energy Related Products in this preparatory study are themselves a complete air conditioning system that ensures a cooling function for comfort purposes, or are part of air conditioning systems that supply this function.

The cooling products that ensure this main function are cooling cycles that can extract heat directly from a room and reject it directly to the outside of the building. In that case, they are called air-to-air air conditioners, on the basis of the names of the sink (outside air) and source (indoor air) they use. Whether the heat is still directly extracted from the room but then rejected at the condenser by other means, these products can be called water-to-air or evaporatively-cooled-to-air air conditioners, depending thus on the sink type.

Whether the heat extraction is made by an intermediary water-to-air heat exchanger, the heat is then rejected outside by a chiller. As for air conditioners, a chiller can be air-cooled, water-cooled or evaporatively-cooled.

Consequently, all the sink-source combinations are included in the study:

- air-to-air air conditioner,
- water-to-air air conditioner
- evaporatively-cooled-to-air air conditioner,
- air-to-water chiller,
- water-to-water chiller
- evaporatively-cooled-to-water chiller,

Concerning air conditioners, in some cases, a unit can be sold without the indoor refrigerant-to-air cooling coil (and its associated indoor fan), in which case it is called a condensing unit (in other terms, a condensing unit contains the condenser heat exchanger and its fans, the compressor(s) and the expansion valve that any air conditioner is equipped with, the only difference being that it does not contain the indoor heat exchanger). The fitting with the refrigerant coil must therefore be made on site. As for other air conditioners, a condensing unit can be air cooled, water cooled or evaporatively-cooled. In larger capacity ranges, these air conditioning condensing units are adapted from chillers (sold without the refrigerant to water heat exchangers).

Note : to avoid any confusion, the term "coil" is a synonym of "heat exchanger"

In the same way, chillers may be sold without a condenser (outdoor heat exchanger with its fans if it is of an air-cooled type, and without fans if it is of another sink type and are then logically called condenserless products.

Each air conditioning system type is composed of a large number of components. Nevertheless, the number of energy using products in these systems is limited. Hence, the Lot 6 scope can be summarized by main energy using product type as follows:

1. Air conditioners
- Package air conditioner [air-to-air > 12 kW, water-to-air, evaporatively cooled] and
- Split and multi split air conditioners [air-to-air > 12 kW, water-to-air, evaporatively cooled]
- VRF systems (a split system where the expansion of the refrigeration occurs in the indoor units and not in the outdoor unit) [air-to-air > 12 kW, water-to-air, evaporatively cooled]

2. Chillers for air conditioning applications [air-to-water, water-to-water, evaporatively-cooled, condenserless]

3. Air conditioning condensing units [air-to-water, water-to-water, evaporatively-cooled]

4. Terminal units to extract heat from the space to be conditioned
- Fan coils

5. Heat rejection units means from the cooling system
- Cooling towers
- Evaporatively-cooled liquid cooler
- Dry coolers

Product definitions

The definitions of the products in the scope of Lot 6 study are given below.

Air conditioner

An ‘air conditioner’ means a device capable of cooling or heating, or both, conditioned air for human comfort, using a vapour compression cycle driven by an electric compressor or by an engine driven compressor, including air conditioners that provide additional functionalities such as dehumidification, air-purification, ventilation or supplemental air-heating by means of electric resistance heating or by the combustion of gaseous or liquid fossil fuel. An air conditioner releases the heat extracted from the conditioned air to ambient air, water or ground source; this definition also includes appliances that may use water for evaporation on the condenser (either condensate that is formed on the evaporator side or externally added water), as well as appliances that may use water (either condensate water that is formed on the evaporator side or externally added water) for evaporation on the condenser.

The definition in the regulation EC 206/2012 is reproduced below :

‘air conditioner’ means a device capable of cooling or heating, or both, indoor air, using a vapour compression cycle driven by an electric compressor, including air conditioners that provide additional functionalities such as dehumidification, air-purification, ventilation or supplemental air-heating by means of electric resistance heating, as well as appliances that may use water (either condensate water that is formed on the evaporator side or externally added water) for evaporation on the condenser, provided that the device is also able to function without the use of additional water, using air only;

Several differences are to be noted:
- “indoor” has been replaced with “conditioned air” as the air treated by air conditioners may also be partly fresh air,
- it is also proposed to limit the definition to comfort application as specific air conditioners for other purpose have not been studied here, ie to exclude close control air conditioners,
- gas engine air conditioners are included,
- other than electric complementary heating means are integrated,

- the sentence “provided that the device is also able to function without the use of additional water, using air only” has been removed as there is no reason this should not be the case.

Additionally, only air-to-air air conditioners with a design cooling capacity greater than 12 kW are included in the study.

<u>Note</u> : nothing prevents that air conditioners may be based on absorption/adsorption cycles except there is presently no such unit on the market nor being developed to the knowledge of the study team. If necessary, the definition could be extended to cover these products.

Air conditioning chiller

A “chiller” means a device which meets all of the following criteria:
- it extracts heat from a water-based central cooling system in order to reach and maintain the indoor temperature of an enclosed space such as a building, a dwelling, or a room, at a desired level;
- it uses a cooling generator based on one of the following processes:
  - a vapour compression cycle driven by an electric compressor
  - a vapour compression cycle with a compressor driven by a motor engine
  - an absorption cycle whose heat is supplied by the combustion of gaseous or liquid fossil fuels or by waste heat;
- it releases the heat extracted from the enclosed space to ambient air, water or ground source; this definition also includes appliances that may use water for evaporation on the condenser and condenserless units.

It can also supply heating as a “boiler” and in that case is called a reversible chiller/heat pump.

Regarding boiler, the provisional definition of the draft boiler regulation is used here:

(1) “boiler” means a device which meets all of the following criteria:
- *it provides heat to a water-based central heating system in order to reach and maintain the indoor temperature of an enclosed space such as a building, a dwelling, or a room, at a desired level;*
- *it uses a heat generator using the processes listed in point (2);*

(2) “heat generator” means the part of a boiler that generates the heat using the following processes:
- *combustion of gaseous or liquid fossil fuels;*
- *use of the Joule effect in electric resistance heating elements;*
- *capture of ambient heat from air, water or ground source, and/or waste heat;*

(3) “water-based central heating system” means a system using water as heat transfer medium to distribute centrally generated heat to heat emitters for space heating of buildings, or parts thereof.

Air conditioning condensing unit

An air conditioning condensing unit means a device designed to provide refrigerant to a cooling coil which ensures the delivery of conditioned air to an enclosed space (room for instance), enabling the coil of cooling and/or heating this air, and which is based on the vapour compression cycle. It is driven by an electric compressor or by an engine driven compressor.
An air conditioning condensing unit releases the heat extracted from the conditioned air to ambient air, water or ground source; this definition also includes appliances that may use water for evaporation on the condensor (either condensate that is formed on the evaporator side or externally added water.

Terminal units

Room fan-coil unit
A factory-made assembly which provides one or more of the functions of forced circulation of air, heating, cooling, dehumidification and filtering of air, but which does not include the source of cooling or heating. This device is normally designed for free intake of air from a room and delivery of air into the same room, but may be applied with minimal ductwork. This device may be designed for built in application, or with an enclosure for application within the conditioned space.

Heat rejection units

Heat rejection unit
A self contained system that cools a single phase liquid by rejecting sensible and/or latent heat via a water to air heat exchanger, the air being mechanically circulated by one or several fans.

Scope limitations due to other ecodesign studies and regulations

Air-to-air air conditioners below 12 kW cooling capacity are included in the ENER Lot 10 study and are covered by the regulation EC/206/2012. Hence, air-to-air air conditioners with cooling capacity below 12 kW are not included here. In addition, this regulation gives a reference in order to propose requirements above 12 kW, regarding minimum energy efficiency requirements, performance indicators used and tolerances, as well as regarding noise. These references will be discussed hereafter.

For chillers, they were not included in the ENER Lot 10 preparatory study, and consequently there is no lower capacity limit.
Chillers for other purpose than (comfort) air conditioning, meaning refrigeration and process cooling, are already included in the ENTR Lot 1 preparatory study and the consequently planned measures. Hence, other than air conditioning chillers are not concerned by the measures here.

Part of the cooling generators, which term encompasses air conditioners and chillers, are reversible.

For reversible air-to-air conditioners below 12 kW, their heating function is included in the regulation EC/206/2012. Above 12 kW, the heating function has been the subject of the ENER Lot 21 preparatory study on central heating products using hot air to distribute heat (other than CHP).

Both ENTR Lot 6 and ENER Lot 21 preparatory studies have been led in parallel. The main reason to treat separately the heating function is that there are other central heating solutions using hot air than just reversible air conditioners. Hence, it was decided all heating products should be compared regarding their heating function in ENER lot 21 and that the cooling function of reversible products should be studied in the air conditioning ENTR Lot 6 study.

The ENER Lot 21 builds upon the regulation 2012/206/EC on smaller than 12 kW air conditioners in order to define a seasonal coefficient of performance (SCOP) and eventually proposes SCOP specific requirements. In ENTR Lot 6, specific requirements are based on the seasonal energy efficiency ratio in cooling mode. For reversible products however, a matching SCOP value is indicated (with bivalent point at – 7 °C, as for the ENER Lot 10 study).

As the energy consumption for cooling is lower than the one for heating, the ambition of the cooling requirements (and corresponding heating SCOP values) is likely to be lower than the heating requirements set in ENER lot 21. However, at the end, a single measure is planned for air conditioners, whether reversible or not, and the final implementing measure (if any) should set harmonized requirements from these two studies.

For reversible water/brine-to-air air conditioners below 12 kW, the products were included in the ENER Lot 20 study. The same rationale as for ENER Lot 21 applies.

For reversible chillers, their heating function has been included into the ENER lot 1 study on water based heating systems. The planned energy efficiency minimum requirements apply up to 400 kW rated capacity in standard rating conditions, both for floor and radiator based applications (which would result in different cooling capacities for the same chiller). It should be noticed that part of the reversible chillers may have a much higher heating capacity (up to 800 kW for air cooled chillers, and higher than 1500 kW for water cooled chillers). The planned measures on water based heating systems also contain noise requirements up to 70 kW heating capacity, to be discussed hereafter for Lot 6 products.

Screening of the environmental impacts of products in scope

Global environmental impact

The environmental impacts of air conditioning products in the scope of ENTR Lot 6 have been computed in Task 4, taking into account their conditions of installation (system/building/climate) and all their life cycle phases.

Energy consumption constitutes the greatest part of the environmental impacts of air conditioning products, the second largest impact being the direct equivalent CO_2 emissions due to the losses of refrigerant fluids of electrically driven vapour compression cycles.

For 2010, which is taken as a reference year, the stock of products in scope is estimated to consume 97 TWh/y, including the heating function of reversible air conditioners, and probably a little more than 110 TWh/y if the heating function of reversible chillers is also included. This electricity consumption corresponds respectively to about 40 MtCO2eq/y and 45 MtCO2eq/y.

In addition, it is estimated that between 4 and 17 MtCO2eq/y correspond to the direct equivalent emissions due to the losses of the HCFC-22 refrigerant for old products, and of HFC refrigerants for more recently installed products. The large uncertainty on this figure comes from the uncertainty regarding refrigerant losses all along the product life cycle. Using estimates available in France by product type, the direct emissions should be about 8 to 10 MtCO2eq.

Hence, it appears that the environmental impact of products in scope is significant and mainly relates to their energy consumption and refrigerant losses.

In addition, the analysis led in Task 2 has shown that the market is still continuously growing. With the present growth rates, it has been estimated (Task 1) that the overall energy consumption of products in use would be multiplied by 1.5 between 2010 and 2020 and probably by a factor 2 between 2020 and 2030. Thus, these products are clearly relevant for Ecodesign measures regarding their main environmental impact, energy consumption during the use phase and refrigerant losses during the use phase and at end-of-life.

The case of terminal units

Amongst the products in scope, the contribution of terminal units is relatively low, about 2 TWh for fan coils. Consequently, it is proposed to limit the requirements for these products to an information request, whose content is described hereafter in paragraph 7.1.4. In addition, it has been shown that it may be more energy efficient to move to higher temperature emitters than fan coils. In that direction, it is thought to be more useful to require more information on the likely SEER gains for chillers at higher chilled water temperature levels than to put relatively high efficiency requirements on the fan coil product itself, which would not lead to substantial energy savings with regards to the energy that can be saved at the level of the chiller when combined with higher temperature emitters.

The case of heat rejection units

Amongst the products in scope, the contribution of heat rejection units is relatively low. It has been estimated in Task 4 that these products represent around 1 TWh of electricity consumption over a year at the EU level. The issue is that there is a clear lack of information today on heat rejection units : it is difficult to evaluate the energy consumption of these products with the present standard and information, all the more since there is very little information on their market shares by country, which is a key information. The study team proposes to correct this lack of information with improved standards and information request.

In any case, at the end, what makes a water-cooled chiller based air conditioning system efficient is rather the water temperature at the inlet of the condenser of the chiller than the energy efficiency of the heat rejection unit. Note also that asking too high efficiency requirements for the heat rejection unit itself can lead to higher water temperatures at the inlet of the chiller condenser, and so decrease the efficiency of the chiller : the energy gain at the level of the heat rejection unit can be offset by a more important increase in the energy consumption of the chiller. In that direction, information is also required from chiller manufacturers on the impact the choice of different condensing temperatures has on the chiller's performance.

Other products not fully covered in the study

Because of limited resources, it has not been possible to study in depth absorption chillers, gas engine air conditioners and chillers and water cooled air conditioners. In order to ensure a common level playing field for all cooling products on the market, this should be corrected when planning measures for the products that fall within the scope of Lot 6. Stakeholder inputs regarding the performances (at full-load and part-load) of these products is thus required.

Existing European legislation for products in scope

The European legislation which constrains the main environmental impacts of Lot 6 products, meaning energy efficiency and direct emissions linked to the use of HFC refrigerants, have been identified and discussed in Task 1. The main conclusion regarding their likely impact on the proposed measures for the products in scope is summarized here.

Ecodesign regulations

Main energy consumers in air conditioning products are compressor motors and to a lower extent fan motors.

Regarding compressors, motors of hermetic compressors are not included in the Commission Regulation (EC) No 640/2009, for semi-hermetic it depends whether the motor can be tested independently or not, and for open compressors the motor efficiency is regulated for AC induction motors (2, 4 and 6 poles) between 750W and 375kW. So part of the compressor motors of air conditioning products are regulated by this measure.

However, this is thought to have little effect on the consumption of Lot 6 products as most of them are already equipped with very efficient motors and that in addition, the highest gains that can be hoped are rather due to other types of improvement options like the use of oversized heat exchangers.

The Regulation on motors and the Regulation on fans proposed on the basis of ENER Lot 11 preparatory study could slightly improve the performance of fans in air conditioning products. But the share of their energy consumption is low in the total energy consumption of Lot 6 cooling generators, added to the fact that in the product ranges in scope, it is common to use very efficient EC motors. Therefore, the contribution of motors and fans regulations to the improved performance of cooling generators is thought to be limited.

Energy Performance of Buildings Directive 2010/31/EU (recast) and Member States associated national requirements

The recast of the Energy Performance of Buildings Directive confirms the importance of its effective implementation at the Member States level, the importance of Community-wide co-operation and the strong long-term commitment and role of the Commission itself to support such an effective implementation.

As the November 2008 Commission Communication for the original proposal states, buildings have significant untapped potentials for cost effective energy savings "which, if realized, would mean that in 2020 the EU will consume 11 % less final energy." The magnitude of the potential savings is such that every effort must be made to achieve it.

In the highlights, it is mentioned that :

- Minimum requirements for components are introduced for all replacements and renovations, although for major renovations, the holistic calculation methodology is the preferred method with performance calculations based on component requirements allowed as a complement

- A harmonised calculation methodology to push-up Member States' minimum energy performance requirements towards a cost-optimal level is set out in the Directive in a definition and an annex, and will also be refined in a comitology process. Member States will have to justify to the Commission if the gap between current requirements and cost optimal requirements is more than 15 %

In addition, the Recital 12. mentions that :

"When setting energy performance requirements for technical building systems, Member States should use, where available and appropriate, harmonised instruments, in particular testing and calculation methods and energy efficiency classes developed under measures implementing Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products and Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy- related products, with a view to ensuring coherence with related initiatives and minimise, to the extent possible, potential fragmentation of the market."

Regarding requirements for air conditioning products, articles 8 and 15 do apply:

Article 8 Technical building systems

System requirements shall be set for new, replacement and upgrading of technical building systems and shall be applied in so far as they are technically, economically and functionally feasible.

The system requirements shall cover at least the following:

(a) heating systems;
(b) hot water systems;
(c) air-conditioning systems;
(d) large ventilation systems;
or a combination of such systems.

Article 15 Inspection of air-conditioning systems

Article 15 sets an obligation of inspection for air-conditioning systems >12 kW rated output regarding efficiency and sizing.

Summary of the findings regarding air conditiong product requirements at Member State Level :

Only a few national legislations have adopted specific requirements on the energy efficiency of cooling products, even if a growing number includes cooling in the energy consumption calculations. One of the main reasons is that energy performance requirements are rather set at the level of the building performance and not on specific subsystems.

In a small number of countries (France, UK), minimum performance requirements for cooling generators constrain the energy efficiency of products to be installed in buildings. Most of the time, they are based on the full-load performance of the products in standard rating conditions, in cooling and in heating mode. Portugal has specific requirements regarding the minimum number of capacity steps available and Spain is requiring mode information on part load performances. In the UK, seasonal performance requirements in addition to full load requirements are also used for chillers and based upon available performance data.

It should be added that the different calculation methods use different input data (and so ratings) and models to compute the energy consumption of products in scope.

Conclusion for Ecodesign measures on these products

Both the different requirements by country and the different input data and calculation methods can be seen as market barriers on the European market. As mentioned in the Recital 12, “Member States should use, where available and appropriate, harmonised instruments, in particular testing and calculation methods and energy efficiency classes developed under measures implementing Directive 2009/125/EC”.

There is then a place for the Ecodesign Directive to help harmonizing input data, calculation methods and minimum performance requirements in the EPBD process. Performance information required on products, input data and calculation methods, should be generic enough so that they can be used in all EU members for their national legislations.

Existing measures regarding refrigerant fluids

Ozone Depleting Substances (ODS) REGULATION (EC) No 1005/2009

This regulation covers production, importation, exportation, placing on the market, use, recovery, recycling and destruction of chlorofluorocarbons, other fully halogenated chlorofluorocarbons, halons, carbon tetrachloride, 1,1,1-trichloroethane, methyl bromide hydrobromofluorocarbons and hydrochlorofluorocarbons as defined in Annex I. The regulation also imposes the reporting of information on these substances.

This regulation also applies to importation, production, placing on the market, use of new substances enumerated in Annex II of the regulation.

Production and placing on the market of Annex I molecules is prohibited, except for specific uses (e.g. for laboratory use). This regulation doesn’t concern HFC.

The enforcement of the complete interdiction of HCFC will accelerate the retrofit of a large number of cooling generators still operating with R22 (former HCFC dominant refrigerant). The transition from R22 to HFC refrigerants in new products occurred between 2000 and 2003 depending on the product types and sizes.

Regarding existing products, servicing of already installed products is still possible until 31 December 2014. After that date, it can be estimated that no more cooling products will be charge with R-22.

Regulation 2006/842/EC on fluorinated greenhouse gases

The objective of this regulation is to reduce the emissions of the fluorinates greenhouse gases covered by the Kyoto Protocol. It shall apply to the fluorinated greenhouse gases listed in Annex 1 of the regulation.

The main HFC for ENTR Lot 6 products are the refrigerant mixture R-410A (50 % by mass of HFC-32 and 50 % HFC-125) and R-407C (23 % by mass of HFC-32, 25 % of HFC-125 and 52 % of HFC-134a) and the HFC-R134a. So, all HFC used for cooling generators in ENTR Lot 6 are covered by the regulation.

This Regulation addresses:

- The containment, the use, the recovery and the destruction of the fluorinated greenhouse gases
- The labelling and disposal of products and equipment containing those gases; the reporting of information on those gases
- The control of uses
- The placing on the market prohibitions of certain products and equipment
- The training and certification of personnel and companies involved in activities provided for by this regulation

A certain schedule for the prohibition of products and equipments containing fluorinated greenhouse gases is listed in the Annex II of the regulation. This schedule is not affecting common refrigerants used in ENTR Lot 6 cooling generators for the European market.

Containment (Art. 3) is performed by inspection and reparation, whose frequency depends upon the charge and type of unit. “Applications containing 3 kg or more of fluorinated greenhouse gases shall be checked for leakage at least once every 12 months; this shall not apply to equipment with hermetically sealed systems, which are labelled as such and contain less than 6 kg of fluorinated greenhouse gases; […]”
This means that inspection does not apply to about any product in the scope of this study that contains less than 3 kg (equivalent to more than 10 kW of cooling capacity), and possibly 20 kW for hermetically sealed unit (these could be package air conditioners and package chillers).

Regarding fluid recovery (Art. 4), it is the responsibility of the operators ; the fluid should be recovered and the fluids shall be recovered “before the disposal of the equipment and, when appropriate, during its servicing and maintenance”.

Supplementary requirements regard training programmes and certification for companies and personnel involved are of the Member States responsibility.

Additional warning labelling requirements (Art. 7) for the products are formulated. This label “shall clearly indicate that the product or equipment contains fluorinated greenhouse gases covered by the Kyoto Protocol and their quantity, and this shall be clearly and indelibly stated on the product or equipment, adjacent to the service points for charging or recovering the fluorinated greenhouse gas, or on that part of the product or equipment which contains the fluorinated greenhouse gas. Hermetically sealed systems shall be labelled as such.”

These requirements have been completed by the labelling requirements under Regulation 2007/1494/EC. This later label is affixed on all ENTR Lot 6 cooling generators using HFC refrigerants : “Where fluorinated greenhouse gases may be added outside the manufacturing site and the resulting total quantity is not defined by the manufacturer, the label shall contain the quantity charged in the manufacturing plant and shall provide space on the label for the quantity to be added outside the manufacturing plant as well as for the resulting total quantity of fluorinated greenhouse gases.” “For air conditioning products and equipment as well as heat pumps with separate indoor and outdoor sections connected by refrigerant piping, the label information shall be placed on that part of the equipment which is initially charged with the refrigerant.” Regulation 2007/1516/EC defines standard leakage checking requirements.

Preparatory study on the F-gas revision

Under the “Service contract to provide technical support for conducting a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases”, policy options to revise the 842/2006 regulation were proposed and assessed. The findings are now discussed by main sector concerned by the results of the study in order to identify the best possible policy option for each sector situation.

The results of this study were integrated in Tasks 5 and 6 of this report in order to study more in-depth the proposed alternative refrigerant fluids for products in the scope of ENTR Lot 6. Both studies share the fact that the direct emissions are a non negligible part of the total equivalent warming impact (TEWI) of the products. In the Preparatory study on the F-gas revision, all the options available to manufacturers were not studied, including R-32 (to replace the R410A) and R-1234ze, one of the possible candidates to replace R-134a.

Safety and national legislations

At European level, the EN378 standard gives the safety rules to design air conditioning equipment depending on the fluid which is used. Reducing the GWP of refrigerant fluids using HFO increases the refrigerant flammability and the risk for the end user. Regarding flammability, standards have been revised to introduce a new safety classification for “moderately” flammable refrigerants, including R32, R1234yf and R1234ze (Flammability class A2L in the ASHRAE standard 34, not yet passed to the EN378 standard but already included in ISO draft standards). The new safety category aims to differentiate and favor the refrigerants in the group over other flammable refrigerants A2, creating a less stringent safety requirement group. This ,and the fact the HFO1234yf, a A2L fluid, has already been approved for cars, leads the study team to think that the A2L class should also be included in the EN378 standard later on.

It should also be noticed that in some countries, as in France, the regulation might limit the use of flammable refrigerants (natural and HFCs) because these are flammable or toxic or corrosive, in addition to the existing EN378 standard described in Task 1.

It should be noticed that additionally, some further regulations do constrain the use of HFC in Europe. A ban on HFC for refrigeration (including air conditioning) products with a refrigerant charge above 10 kg has been in effect in Denmark since January 2007. Additionally, some countries do raise taxes or have added other requirements, as maximum leak rates by product category.

Regulation 2012/206/EC, regarding air conditioners below 12 kW

In this regulation, products using refrigerant fluids with GWP lower than 150 benefit from a bonus: there energy efficiency limit is set 10 % below the target of the one of fluids with a GWP superior to 150.

Conclusion for Ecodesign measures on these products

Ozone Depletion Potential of refrigerant has already been addressed in the EU.
Regarding the global warming potential, the manipulation and end-of-life fate of HFC gases in ENTR Lot 6 products are covered by the regulation 2006/842/EC. This regulation is being revised and a preparatory study just finished proposing different policy options for the future of these gases and consultations with the different sectors are on-going. The possible measures could be a reinforcement of the present legislation, but could also lead to the ban of certain refrigerant fluids in some areas where replacement solutions are available.
Other options do exist as the one proposed in the Ecodesign regulation 2012/206/EC, in which a 10 % bonus has been designed to favour the development of alternative refrigerants for air conditioners below 12 kW.

As explained in Tasks 5 and 6, energy consumption and refrigerant fluids are clearly linked. Consequently, several alternative policies including refrigerant fluids are discussed in paragraph 7.1.3. The study team conclusions base upon the evolution of the EN378 standard to include a A2L class as in the ASHRAE and international standards, what would allow to design products with middle GWP fluid and efficiencies and costs comparable to the ones of the products sold today.

International legislation for products in scope

The international legislation regarding products in scope have been reviewed and synthetized in Task 1. Numerous countries require minimum performance requirements for these products at full-load and increasingly under part-load conditions, using seasonal performance requirements.

The comparison of the ambition of these minimum energy performance requirements with the present product efficiencies in the EU market differ depending on the market segments. All in all, the application of the most severe requirements by product category would imply severe cuts in the products allowed to be put on the EU market. This is in line with the findings of Task 6 where a significant saving potential has been identified above the median products.

Suitability of the products in scope of the study for Ecodesign measures

The main findings from the previous tasks for the products in the scope of the study are summarized below :

- Products in scope of the study do represent significant sales in number in the EU

- They have a significant environmental impact at EU scale, mainly related to the energy consumption during the use phase and the refrigerant direct emissions. As more efficient products might often lead to higher refrigerant charges and so refrigerant losses, this environmental impact is foreseen to grow significantly over the coming years if not appropriate measures to mitigate it are taken.

- The improvement potential has been established in Task 6 ; it shows that significant cost effective savings could be achieved thanks to Ecodesign implementing measures and that solutions exist to limit both the energy consumption and the CO2eq emissions of the products. Nevertheless, very high efficiency products have been put on the market for a few years now, and it did not trigger any movement on the market, which still seems to be dominated by first cost approach.

- This is in line with the observation of the installation and operation decision chain of air conditioning systems in buildings in Task 3, which shows that without strong measures, the split incentives will continue limiting the efficiency of products sold.

- The legislation in force in Europe and the market forces do not suffice to tap this potential. Regarding energy efficiency, the main contributing directive is the Energy Performance of Building Directive. However, it has been shown in Task 1 that the integration of the cooling consumption was not yet acquired for all countries. It was found that some countries had put minimum performance requirements, more to limit the risk of very inefficient products than to select most efficient products.

- There is room for the Ecodesign Directive to help harmonizing input data, calculation methods and minimum performance requirements in the EPBD process. Performance information required on products, input data and calculation methods, should be generic enough so that they can be used in all EU Member States within their national legislations.

As a conclusion, and for all these reasons, it seems necessary for the EU to act in order to reduce the environmental impact of air conditioning products.

7.1.2. PERFORMANCE INDICATORS AND EXISTING STANDARDS

Summary regarding performance indicators and existing standards for products in scope

The proposed performance indicators and the different needs for standardization are described hereafter by main product category. The initial table with the product scope is simplified as the packaging does not in general change the requirements for standardization. The only exception is VRF air conditioners, for which test requirements should specify the type of part load method used and the piping length. These specific standard requirements and others are discussed in more details in the following paragraphs.

Specific energy and refrigerant requirements in part 7.1.3 are only proposed for air conditioning electric chillers and air-to-air air conditioners. They are based upon a SEER index (seasonal performance index), an EER index (full load index) and possibly a TEWI indicator. These are basically the required performance indicators regarding energy efficiency and equivalent CO_2 emissions.

Regarding sound emission, the sound power level is proposed as the performance indicator for all products in scope.

Air emission and refrigerant standards are also discussed.

Table 7 - 2 . Summary of table regarding performance indicators and standardization requirements for energy efficiency and sound emission

Description of products in the scope of ENTR Lot 6 study			Energy Performance Indicator			Sound emission indicator		
Product category	Cooling principle	Sink type	Type	EN reference	Standard need	Type	Standard reference	Standard need
Air conditioning chillers	Electric	Air-cooled	SEER, EER, TEWI	14511, 14825, 378	Adapt.	Lw(A)	EN 12102	No
		Evaporatively-cooled	SEER, EER, TEWI	14511, 14825, 378	Adapt.	Lw(A)	EN 12102	No
		Water-cooled	SEER, EER, TEWI	14511, 14825, 378	Adapt.	Lw(A)	EN 12102	No
		Condenserless	SEER, EER, TEWI	14511, 14825, 378	Adapt.	Lw(A)	EN 12102	No
	Gas engine vapor compression	Air-cooled	SEER (PE), TEWI	Not yet & Not yet, 378	New	Lw(A)	Not yet	New
		Water-cooled	SEER (PE), TEWI	Not yet & Not yet, 378	New	Lw(A)	Not yet	New
	Absorption / adsorption	Air-cooled	SEER (PE)	12309	Adapt.	Lw(A)	Not yet	New
		Water-cooled	SEER (PE)	12309	Adapt.	Lw(A)	Not yet	New
Air conditioners	Electric	Air-cooled > 12 kW	SEER, EER, TEWI	14511, 14825, 378	Adapt.	Lw(A)	EN 12102	No
		Water-cooled	SEER, EER, TEWI	14511, 14825, 378	Adapt.	Lw(A)	EN 12102	No
	Gas engine vapor compression	Air-cooled	SEER (PE), TEWI	Not yet & Not yet, 378	New	Lw(A)	Not yet	New
		Water-cooled	SEER (PE), TEWI	Not yet & Not yet, 378	New	Lw(A)	Not yet	New
Air conditioning condensing unit	Electric	Air-cooled	SEER, EER, TEWI	Not yet	New	Lw(A)	EN 12102	No
		Water-cooled	SEER, EER, TEWI	Not yet	New	Lw(A)	EN 12102	No

	Gas engine vapor compression	Air-cooled	SEER (PE), TEWI	Not yet	New	Lw(A)	Not yet	New
		Water-cooled	SEER (PE), TEWI	Not yet	New	Lw(A)	Not yet	New
Heat rejection units	Electric	N/A	EER	1048	Adapt.	Lw(A)	Not yet	New
	Electric	N/A	EER	Not yet	Yes	Lw(A)	Not yet	New
	Electric	N/A	EER	14705	Adapt.	Lw(A)	Not yet	New
Fan coil units	Electric		FCEER, FCCOP	1397	Adapt.	Lw(A)	Not yet	New

N/A: not applicable | (PE): in primary energy |
Adapt.: adaptation required

Electric cooling generators

Part load energy performance indicator (SEER)

The regulation 2012/206/EC and the ENER Lot 1 study established seasonal performance indicators for heating (SCOP) and cooling mode (SEER) of air-to-air air conditioners and for reversible chillers used for heating. Commission mandates should enable to align the present prEN14825 standard with these performance indicators, in heating mode for reversible chillers and for air-to-air air conditioners below 12 kW, and in cooling mode for air-to-air air conditioners below 12 kW.

The ENTR Lot 6 study builds its SEER performance indicators on the reference regulation 2012/206/EC for the electric cooling generators in the scope of the study with two main modifications :
- Modification of the hours in cooling mode for all cooling generators in the scope of ENTR Lot 6,
- Addition of two climates (warm, cold) for the cooling mode of ENTR Lot 6 products.

Equivalent active hours have been defined in the Lot 10 study for the buildings in which small air conditioners below 12 kW are installed, with a large part of residences. For ENTR Lot 6 air conditioners and chillers, the number of hours differs as products are preferentially installed in commercial buildings in which the cooling requirements have been estimated as being much higher. Consequently, the number of equivalent hours needs to be modified and so the number of hours the units operate in the other modes (thermostat off, standby and off mode).

The second proposed modification regards the addition of two climates for the cooling mode, which has been agreed with stakeholders. This aims at a better evaluation of cooling performances whose climate does not correspond to the average climate presently in use.

The full description of these two proposed modifications of the metrics defined in the regulation 2012/206/EC for ENTR Lot 6, can be found in Task 6.

SEER values for chillers are to be understood as net values. Gross SEER values computed in Task 6 are given here as an indication. SEER values thus include the impact of the circulator electricity consumption required to circulate water through the heat exchangers of the chillers. This correction should also be included for other gas engine and absorption chillers so that values may be comparable.

In addition, regarding VRF systems, the test method should clearly specify that all the indoor units remain connected during the part load test in order to establish the part load ratings. In this way, it makes the VRF ratings comparable to the ones of split air conditioners and of package air conditioners.
For the same reason, it is proposed not to integrate an equivalent piping length proportional to capacity as in the US standard AHRI 1230 for testing performance. However, the piping length should be considered in case a TEWI index is calculated. To that extent, the same values as used in the AHRI 1230 standard and that are presented in Task 1 could be used (an equivalent piping length is defined, which is proportional to the unit capacity).
The study calculations have been performed including the fan consumption and thus the results cannot be used to characterize the outdoor unit alone. In addition, it should be ensured that the indoor fan of split air conditioners and of VRF is operated at full rated speed for thermostat off calculations.

As in the EC regulation 206/2012 regarding smaller capacity air conditioners, multi-split air conditioners and VRF air conditioners capacity ratio[2] of 100 % should be used for rating purpose. For VRF air conditioners, this however leaves open the choice to a wide variety of indoor unit combinations (different types and different capacities) to make a complete unit. Hence, the minimum performance requirements and information requirements could be limited to part of the systems in order to keep the legislation practicable. One solution could be to require that for each capacity range (defined by outdoor unit capacity and type), one combination by type of indoor unit type be declared. It would still be necessary to define a minimum number of indoor units to be connected. As the median

[2] *'capacity ratio' means the ratio of the total declared cooling or heating capacity of all operating indoor units to the declared cooling or heating capacity of the outdoor unit at standard rating conditions;*

capacity of indoor units identified in Task 4 is about 5 kW cooling capacity, the minimum number of indoor units could be defined with the following formula : N >= Cooling output / 5. A technical working group is probably necessary to discuss this issue.

In addition, regarding water/brine source units, the proposed measure builds on the temperature levels already included in the prEN14825 standard to define the SEER measurement.

However, regarding evaporatively-cooled cooling generators, the EN15218 standard is available to rate these products at full load. However, the part load testing conditions and calculation methodology are not included. To this extent, it seems necessary either to add humidity to the inlet air conditions at part load in the prEN14825 standard or alternatively to modify the EN15218 standard to include part load.

Regarding air conditioning condensing units, there is not yet a standard that allow to rate their efficiency. Being in themselves cooling generators, they should be included in the EN14511 standard and in the prEN14825 standard for the assessment of their part load performances. As they are mainly used to pre-cool the air that is provided by an air handling unit to the inside of a building for ventilation purposes, this might lead to define a specific pattern of use for these units to compute an adapted SEER.

Full load energy performance indicator (EER)

In parallel to SEER MEPS, the study team favours the introduction of specific requirements for the EER at standard rating conditions. The rationale behind this is that without this constraint, some manufacturers might develop products with high SEER values but low EER values, which would be detrimental to Southern European countries for which the electrical power demand is already peaking in Summer. Any kW of peak electricity power that is saved and so not required from the electricity grid is as much power plant capacity that can be avoided, which can translate into direct savings on the electricity costs and consequently on the electricity prices for the end-users.

There is no specific need for standard update of this value, which is already defined in the EN14511 standard.

Equivalent CO_2 emission indicator, TEWI, and refrigerant

The TEWI indicator is discussed in Part 7.1.3 as a possible performance indicator for equivalent CO_2 emissions and is defined in the EN378 standard.

It is discussed in this report under a specific format, ie dividing the TEWI by the rated cooling output of the product or divided by the rated cooling energy output, as suggested by stakeholders. This indicator is defined in Task 1 and this definition is reported below.

The TEWI (en: total equivalent warming impact) is a way of assessing global warming by combining the direct contribution of refrigerant emissions into the atmosphere with the indirect contribution of the carbon dioxide and other gas emissions resulting from the energy required to operate the refrigerating system over its operational life. The TEWI factor can be calculated by the following equation where the various areas of impact are correspondingly separated.

$TEWI = GWP \cdot L \cdot n + [GWP \cdot m \cdot (1- \alpha_{recovery})] + n \cdot E_{annual} \cdot \beta$

where

$GWP \cdot L \cdot n$ is the impact of leakage losses;

$GWP \cdot m \cdot (1- \alpha_{recovery})$ is the impact of recovery losses;

$n \cdot E_{annual} \cdot \beta$ is the impact of energy consumption.

where

TEWI is the total equivalent warming impact, in kilogrammes of CO_2;

GWP is the global warming potential, CO_2-related[3]

L is the leakage, in kilogrammes per year;

[3] The GWP default values (time horizon 100 years) can be found in the 4th Assessment report of the IPCC.

n is the system operating time, in years;
m is the refrigerant charge, in kilogrammes;
$\alpha_{recovery}$ is the recovery/recycling factor, 0 to 1;
E_{annual} is the energy consumption, in kilowatt-hour per year;
β is the CO_2-emission, in kilogrammes per kilowatt-hour.

All the input (definition of refrigerant charge, refrigerant GWP) on the refrigerant fluid required for TEWI calculation are defined in the EN378 standard with the exception of the standard piping length to be considered for VRF systems, which vary with capacities. Whether a TEWI calculation appears necessary, this standard equivalent length should be defined for refrigerant pipes (the ARI VRF standard 1230 could be taken as an example).

Sound power level

Sound power should be rated as specified in the EN 12102 standard.

Vapor compression cycles with engine driven compressor

No standard seems to be available for the rating of engine driven vapor compression cycle, either cooling air or chilling water. Such a standard is required. It should include the testing methodology and calculation method for the EER and for the SEER as defined in this study, and should be computed in primary energy. The TEWI calculation above also applies to these products.
No sound measurement standard could be identified neither. It is thus necessary to add a noise standard for these products, if not already existing. However, in the new Blue Angel for heat pumps RAL UZ 118, the EN 12102 is also used for the measurement of sound power emissions of gas-driven heat pumps. Thus, it seems that the simplest solution would be to extend the scope of the EN12102 standard to include those products.

The refrigerant standard also applies to these units.

A standard is also missing to quantify the NOx, CO and HC air emissions for these products.

Absorption/adsorption chiller

Regarding absorption chillers and heat pumps, there is the full load EN 12309 standard which needs to be aligned with the evolutions of the EN14511 standard regarding testing conditions; electricity consumption measurement should also be added. There is not any part load ratings neither; the prEN14825 standard should then serve as a reference. Eventually, the standard should be adapted to include the EER and the SEER testing and calculation methods which should be computed in primary energy.

No sound measurement standard could be identified neither. It is thus necessary to add a sound measurement standard for these products.

The refrigerant standard also applies to these units.

A standard is also missing to quantify the NOx, CO and HC air emissions for these products.

Fan coil units

An efficiency ratio is already defined and used for fan coil units : it is the ratio of the thermal capacity (cooling/heating) to the electric power of the fan. The industry relies on existing specific guidelines and the EN 1397:1998 standard which would need to be updated acoording to current practices. Namely, the EN 1397 standard specifies that the maximum speed should be used for testing which is not what appears in the Eurovent Certification company database, where the speed testing for rating is specified by the manufacturer.

In addition, the industry is moving to use seasonal performance metrics for cooling and for heating, previously described in Task 1. For these metrics, the performance at different fan speeds is weighted to represent an average seasonal performance ratio over the cooling and/or the heating season. The basic information required to do so is the performance at different fan speeds. Hence, the standard should include these supplementary measurements and the associated part load calculation methods which should lead to the seasonal FCEER and FCCOP indexes.

The standby power of these products is unknown and should also be added in the standard.

The industry rates the sound pressure and sound power of fan coil units on the basis of international ISO standards. There is no specific standard for the determination of sound power levels. It is thus necessary to add a sound power measurement standard for these products.

Heat rejection units

Energy performance indicator (EER)

In order to be able to compare different heat rejection units on a common ground, the study team proposes to build, as in the USA, a reference energy efficiency ratio (EER) for all types of heat rejection units. It should be defined as the ratio of the cooling thermal capacity of the unit to the total electric consumption of the unit (including fan motor and controls). In addition, different types of heat rejection units may offer different part load control types and efficiencies, so it should be required that the EER be measured at different air flow, depending on the control of the unit.

This requires adapting the EN 1048 standard for air cooled liquid coolers (dry coolers) to include the partial air flow measurements.

Regarding cooling towers, the EN 14705 standard gives the measurement method to rate the performance of wet cooling towers. The performance metrics used by the industry is an efficiency ratio defined as the ratio of the cooling capacity to the nominal power of the fan motor(s) (the electricity consumption is not measured). In addition, standard rating conditions are not defined.

Hence, this EN 14705 standard should be adapted to include standard rating conditions, the measurement method of the electricity consumption and the ratings at partial air flows.

Eventually, there is no standard to rate the performance of evaporatively-cooled liquid coolers and wet cooling towers; it needs to be developed.

The standby power of these products is unknown and should also be added in the corresponding standards.

Sound power level

There is no specific standard for the determination of sound power levels of heat rejection units. It is thus necessary to add a sound measurement standard for these products.

7.1.3. ENERGY EFFICIENCY AND CO_2 REQUIREMENTS

a) Task 7.1.3 organization and scope of the requirements discussed in part 7.1.3

The specific requirements discussed in this part regard electric air conditioning air cooled chillers and air-to-air air conditioners.

These requirements are based upon the results of the Task 6 analysis and of the previous tasks.

However, looking at the results of the economic optimization made in Task 6, two important questions remain to be addressed.

1. Introduction of a capacity limit threshold for air cooled and water cooled chillers

The evaluation of the improvement potential in Task 6 has been done on the basis of 2 base-case air-cooled chillers and 2 base-case water-cooled chillers, with respective cooling capacities of 100 kW, 400 kW, 100 kW and 1000 kW. As explained in Task 4, the 100 kW base-case air-cooled and water-cooled chillers have been aimed at representing the low to intermediate cooling capacity market segments for both product types, which segments correspond to 1-350 kW cooling capacity ranges in Task 2 data. In the first version of this study, the 400 kW base-case air-cooled chiller and the 1000 kW (900 kW in Task 4) base-case water-cooled chiller have been initially defined as the middle/median of the whole air-cooled and water-cooled chillers markets, but it has been then shown that they could be considered as representative of the > 350 kW market segments.
Looking at Task 6 results, it appears that the LLCC levels evaluated for the 400 kW air-cooled chillers and 1000 kW water-cooled chillers, which represent the intermediate to high cooling capacity market segments, could probably not be reached by lower capacity improved chillers. The main reason is that for high cooling capacity products, the LLCC and higher efficiency options are based upon more efficient compressor technologies which are not available in the lower end capacity ranges, mainly dominated by scroll compressors. The lower capacity end for the introduction of screw and centrifugal compressors is about 200 kW (although it has been shown that screw chillers could be developed at lower cooling capacities in the coming years). However, the economics of their introduction is probably not optimal before 300 or 350 kW because the beginning of product ranges is always more expensive due to higher component and manufacturing costs per kW cooling capacity.

It seems therefore necessary to introduce a cooling capacity threshold that could be used to split the air-cooled and water-cooled chiller markets somewhere in between 300 and 400 kW (350 kW being the threshold in the market data used for Task 2) and more logically between 350 and 400 kW, as this corresponds to the end of low cooling capacity scroll chiller ranges, which dominate greatly the market from 200 kW to these cooling capacity levels. 350-400 kW corresponds also to the beginning of high cooling capacity scroll chiller ranges. Note then that in the Working Document for the implementation of the Directive 2009/125/EC for space heaters and combination heaters, a 400 kW heating capacity threshold allows to split the requirements.

As a conclusion, it is proposed to introduce a capacity segmentation, below and above 400 kW cooling capacity, for both air-cooled and water-cooled electric chillers. In that direction, different MEPS are proposed for the different market segments, and refrigerant policy options are screened separately by segment.

2. Link between energy efficiency and refrigerant policy options

Looking at the results from Task 6, it can be seen that implementing only energy efficiency measures could be counterproductive for several product categories if no additional measure is taken to mitigate the direct emissions related to the refrigerant losses of these products. This can lead to modify the energy efficiency requirements and/or to adopt complementary refrigerant policy measures.

Consequently the following complementary analysis is developed:

- In Part 7.1.3 b), possible policy options to reduce the equivalent CO2 emissions in addition to specific energy requirements are analyzed ; this includes a review of the alternative refrigerant fluids available and the analysis of four possible policy options,

- In Part 7.1.3 c), for each product category, the mid-term refrigerant policy options are screened. This requires screening, for all the base cases, the technical parameters which could have an influence regarding the ambition of energy efficiency requirements and/or refrigerant requirements. This leads to investigate the different product category presented in the table 7-3 below for electric air conditioning chillers and for air-to-air air conditioners. In addition, the short term GWP bonus are discussed.

Table 7 - 3 . List of product categories screened in view of proposing energy efficiency and refrigerant policy scenarios

List of product combinations investigated regarding possible distinct energy efficiency and refrigerant policy options				
Product category	Packaging	Energy source	Sink type	Functions
Air conditioning chillers <= 350 kW	All	Electric	Air-cooled	Cooling only Reversible
			Water-cooled	Cooling only Reversible
Air conditioning chillers > 350 kW	All	Electric	Air-cooled	Cooling only Reversible
			Water-cooled	Cooling only Reversible
Air conditioners	Split, multi-split	Electric	Air-cooled > 12 kW	Cooling only Reversible
Air conditioners	VRF	Electric	Air-cooled > 12 kW	Cooling only Reversible
Air conditioners	Package	Electric	Air-cooled > 12 kW	Cooling only Reversible

Final specific requirements proposed are presented in part 7.1.3 d), followed by benchmark proposed values in part 7.1.3 e), and short discussion regarding labelling (7.1.3. e) and self regulation (7.1.3. f). Eventually, after having studied the different possible policy options regarding energy and equivalent CO_2 emissions for the above categories in part 7.1.3 c), the product categories for specific requirements are reduced as summarized in the table 7-4 below.

Indeed, and as explained later on in this chapter 7.1.3 c), similar energy and refrigerant requirements for all three base case air conditioners (rooftop package, split, VRF) are proposed.

Table 7 - 4 . Summary table for the scope and categories for specific requirements

Scope of specific requirements for ENTR Lot 6 products			
Product category	Energy source	Sink type	Functions
Air conditioning chillers <= 400 kW	Electric	Air-cooled	Cooling only Reversible
		Water-cooled	Cooling only Reversible
Air conditioning chillers > 400 kW	Electric	Air-cooled	Cooling only Reversible
		Water-cooled	Cooling only Reversible
Air conditioners	Electric	Air-cooled > 12 kW	Cooling only Reversible

b) Possible policy options to reduce the equivalent CO_2 emissions in addition to specific energy requirements

Looking at the results from Task 6, it can be seen that implementing only energy efficiency measures could prove counterproductive if no additional measure is taken to mitigate the direct emissions related to the refrigerant losses of the products. Depending on the product category and refrigerant scenario considered in the sensitivity analysis (chapter 6.4) :

- Some improvement options aimed at increasing the SEER of the base-case product lead to a higher TEWI than the TEWI of the base-case. This is notably the case for nearly all standard improvement options of cooling only VRF systems and split systems.

- There are other cases for which once a certain SEER value has been reached by improving the base-case, higher SEER values correspond to options with refrigerant charges so important that their TEWI is greater than the TEWI of this intermediary improvement option. This means that by continuing to improve the energy efficiency over a certain threshold without taking any measure on the refrigerant charge and/or type, there is the risk that the reduced indirect equivalent emissions of CO_2 thanks to high efficiency are offset by higher direct emissions due to refrigerant losses.
  In the example of air-cooled chillers, the LLCC, which is option I5, has a higher SEER but at the same time a greater TEWI than option I4, even with the use of alternative heat exchanger technologies such as a falling film evaporator and a microchannel condenser (option I5c).

The TEWI analyses done in subtasks 6.2 and 6.4 have therefore led the study team to list possible measures aimed at reducing the direct emissions of air-to-air air conditioners and air conditioning chillers. They are listed after a discussion of replacement fluids for HFCs.

Discussion of the alternative refrigerant fluids, with regards to presently used HFCs

As a preliminary remark, discussions with stakeholders and Task 6 calculations have led the study team to take into consideration alternative refrigerant fluids with a GWP greater than 150, contrary to the GWP maximum value threshold that has been defined in the EC regulation 2012/206/EC for the purpose of a bonus on SEER/SCOP. The corresponding fluids are R-32, which has a GWP of 675, and possible mixtures of R-1234yf and R-32.

Currently, the main refrigerant fluids that are being used for air conditioners and air conditioning chillers in the EU are:

- R-134a, R-407C, and R-410A for chillers equipped with screw compressors. However, R-410A is of very limited use for this type of compressor.
- R-410A and R-407C for chillers equipped with scroll compressors
- R-134a for chillers equipped with centrifugal compressors
- R-410A and R-407C for air conditioners

The candidates for replacement are as follows, with regards to the corresponding HFC refrigerant fluid and product type:

- **Replacement fluids for scroll and screw air-conditioning products using R-410A :** R-290 (propane), R-32, R-1234yf and ze, refrigerant blends of HFO and HFC, CO_2. Because of their flammability, the four first categories might face safety issues when put on the market. As explained above, the introduction of an A2L class for “moderately” flammable refrigerants as in the ASHRAE 34 standard could lead to less stringent requirements for R32, HFOs and belnds of HFO and HFC refrigerants. Note also that flammability issues are lower for package products, as in this case, there is no refrigerant piping system inside the building and so in its occupied zones.

  The EN378 standard has put stringent limitations for split type products. The impact is a lower energy efficiency because the charge threshold limits the mass of refrigerant fluid, which degrades the performance. In some other cases, the charge limit is so stringent that it is not possible to develop a product with satisfying energy efficiency. Again, this could evolve for future A2L fluids.

R-32 and refrigerant blends “moderately” flammable could enable to reach similar performance and product costs as R410A with a GWP lower than 675. Pure R-1234yf seems to lead to higher additional costs than these solutions, which explains the interest in refrigerant blends.

Currently, only one manufacturer develops CO_2 charged products. Because of the thermodynamic specificities of this fluid, the additional costs to reach efficiency levels close to the ones of R-410A charged products are particularly important (and possibly the same efficiency levels could not be reached for more efficient R410A products). Note also that CO_2 as a refrigerant fluid for air conditioning applications must be compressed at very high pressure levels, which causes a safety issue different than flammability, as any leak might hurt severely any person close to the product.

- **Replacement fluids for screw chillers using R-134a :** R-290 (propane), R-717 (ammonia), HFOs (R-1234yf and R-1234ze) and refrigerant blends.

  Propane charged chillers are already put on the market, with already relatively good performance levels, as the study team has reported products with efficiency levels higher than those of the base-cases of this study. Safety issues are the same as for air conditioners and air conditioning chillers equipped with scroll compressors.

  From stakeholders’ says, ammonia charged air conditioning chillers are already mature products that can be developed with similar efficiency levels as R-134a charged products. Because of the chemical properties of ammonia, all copper in the refrigerant circuitry must be adapted to aluminum, which impacts the manufacturing costs and so their price. Ammonia being a toxic and flammable substance, it is subject to severe safety requirements in the Member States, which limits its development.

  Currently, the main market for propane and ammonia air conditioning chillers is Denmark, because of its specific legislation. Product sales do not seem to be significant in other countries.

  R-1234ze seems to be the best alternative to propane and ammonia. It causes less safety issues, because of its lower flammability (A2L). As for R-32 by comparison with R-410A, it has relatively similar thermodynamic properties and so should not require a thorough redesign of the product; with slightly higher pressures than the R1234yf (R134a drop-in already adopted for automotive air conditioning), it could lead to a better compromise cost/efficiency than this later. There are already sold chiller charged with it, some stakeholders have therefore highlighted that it could become a reference fluid in the coming years. These two fluids have low GWP of respectively around 10 and 4. In the meanwhile, the chemical industry is also developing blends targeting R134a with higher GWP (between 500 and 1000) and non flammable in order to avoid the cost of the safety adaptation.

- **Replacement fluids for centrifugal chillers using R-134a :** The available alternatives to R-134a for centrifugal chillers are R-1234ze and R-1234yf. As for screw chillers, the first one might have the preference of the industry. Again, refrigerant blends are being developed with different compromises regarding GWP and flammability.

- **Replacement fluids for scroll air conditioning products using R-407C :** The two main replacement fluids that can be quoted are R-290 and R-32, as previously described, although potential molecules planned to replace R22 in other economies could also be adapted.

- **Replacement fluids for screw chillers using R-407C :** The candidates are the same as for screw compressors using R-134a.

As a conclusion, to reach high efficiency levels and low TEWIs at reasonable costs, R-32, HFOs and refrigerant blends including HFC and HFOs, appear to be the soundest options for air conditioners and scroll chillers. For screw chillers, there are already mature technologies that operate with propane and ammonia, but their additional cost is uncertain (thought to be high). HFOs charged units might have lower additional costs. Eventually, HFOs should be the reference alternative fluids for centrifugal chillers.

Possible policy options to reduce the TEWI in addition to reductions in energy consumption

1) Single bonus on SEER MEPS for products using refrigerant fluids with a GWP lower or equal to 675

R-32 is the option envisaged to replace R410A with the highest GWP. As it can be seen that R-32 is an HFC but a relevant alternative to R-410A, the study team proposes to take the GWP value of R-32 as a threshold below which the corresponding refrigerant fluids benefit from a bonus. This value is currently of 675, but whether new reference evaluations of R-32 lead to another GWP estimation for this fluid, the new value should be taken for the bonus threshold.

As for air conditioners with a cooling capacity lower than 12 kW, the idea is to decrease the SEER MEPS by a certain percentage for products that are charged with a refrigerant that has a GWP lower ore equal to the GWP of the R-32. This should not apply to EER MEPS.

The first drawback of this method is that it does not push manufacturers of R-410A/R-134a/R-407C charged products to design units with low refrigerant charges, which should help, on average, to reduce the direct emissions linked to the refrigerant losses.

The second drawback for the legislator is that this measure leverages the TEWI of the products to the level of the present dominant units, charged with R-410A and R-134a. It means that the energy efficiency of products that benefit from the bonus is sacrificed to limit CO_2 emissions. Hence, it should only be a temporary measure used during a transition period towards equivalent or higher efficiency requirements in combination with the use of refrigerants with a low GWP.

In other terms, this type of measure should be set temporarily in view of a future ban of HFCs with a GWP greater than the one of R-32, or of the use of a specific TEWI approach (see policy option 3).

2) Progressive bonus on SEER MEPS adjusted according to the GWP of the alternative refrigerant fluid

As R-32 still has a significantly greater GWP than the other alternative refrigerants, this has made the study team think about a progressive bonus on SEER MEPS that would depend on the GWP of the alternative refrigerant fluid. This means that the bonus would be lower for R-32, greater for R-1234ze/R-1234yf/R-290/CO_2/R-717,, and in between for mixtures or other refrigerant fluids with an intermediary GWP.

In that direction, it could be possible to go for a continuous scale in terms of bonus, which would be proportional to the GWP. For instance, 20 % for a GWP of 0 and 10 % for a fluid that has a GWP in between 0 and the GWP of the current reference fluid (R-410A, R-134a or R-407C) that is replaced (meaning 10% if GWP = $GWP_{reference\ fluid}$ / 2).

The problem is that the reference refrigerant is multiple as 3 main fluids coexist, which would lead to 3 different scales.

At first glance, this approach enables to increase the bonus for low GWP refrigerants by comparison with intermediate GWP refrigerants such as R-32, with an increased competition on the type of new reference refrigerants to be used in the coming years. As for policy option 1, policy option 2 is meaningless if does not used during a transition period at the end of which policy option 3 or 4 is adopted.

3) Specific TEWI approach : TEWI / Cooling capacity (kW) < certain limit (corresponding to SEER minimum requirement)

In the two preceding approaches, the main drawback is that manufacturers of products with HFC refrigerants are not prompted to reduce the refrigerant charge of their products.

To be completely fair to all refrigerant fluids and products (meaning technological choices), it is possible to adopt a specific TEWI scale as suggested by stakeholders. In that case, all the products would be subject to a specific TEWI MEPS that would be calculated from a SEER MEPS and an average reference refrigerant scenario, in terms of refrigerant type, refrigerant charge, and rates of refrigerant leaks and end-of-life losses. The "refrigerant scenario" term has the same meaning as in Task 6 (see chapters 6.2.3/4 and 6.4).

The main points would be therefore to :

- Allow products that have an SEER lower than the SEER MEPS to be put on the market if their specific TEWI is below or equal to the maximum allowed TEWI, meaning the specific TEWI MEPS times their cooling capacity. This would concern products that use alternative refrigerants with a low GWP but also products that use one of the 3 current reference refrigerants but have a lower refrigerant charge than the average of the market thanks to a specific choice and design of component.

- Ban products that have a SEER greater than the SEER MEPS but a refrigerant charge so high that the estimation of the direct emissions due to the corresponding refrigerant losses leads to a higher TEWI than the specific TEWI MEPS times their cooling capacity.

With this method, not only the refrigerant type but also charge limitation options, such as falling film heat exchangers, microchannel heat exchangers or accurate product sizing are favored. With the development of alternative refrigerant fluids, this TEWI maximum value could progressively be reduced to ban higher GWP refrigerants down to the level of R-32 and lower, used in replacement of R-410A.

The main drawback of this method is that it is difficult to adjust, especially because the definition of the refrigerant scenario is uncertain but has a dramatic impact on the results, as it has been show in subtask 6.4. It would be necessary to agree, for each of the 3 current reference refrigerants, on :

- An average relative charge ($kg_{reference\ refrigerant,\ such\ as\ R\text{-}410A}/kW_{cooling\ capacity}$) taken for reference. This point can be particularly subject to bias and controversy, as for instance centrifugal chillers with magnetic bearings have very high levels of SEER but also of refrigerant charge (relative refrigerant charges greater than 0.4 kg/kW). It would be absurd to risk that some of these products become banned because of the assumptions made.

- Reference rates of refrigerant leaks (% of the refrigerant charge of the unit that leaks over a year) and refrigerant end-of-life losses (% of the initial refrigerant charge of the unit that is not recovered when the unit is dismantled). It has been shown in Task 4 that the several reference studies on this topic lead to very different values and that there is a problematic lack of data by product type in the EU at a sufficiently detailed scale.

- A conversion factor to calculate equivalent CO_2 emissions from the knowledge of the final/primary energy consumption of the products. For instance, this factor has decreased from the initial MEEuP methodology to the new MEErP methodology, as it has been considered that more renewable electricity production sources are now integrated in the EU electricity production mix. This trend should continue in the coming years.

- GWPs of all the concerned refrigerant fluids, which is less an issue, but could become one whether new fluids are developed in the coming years and need to be evaluated.

For all of these mentioned points, the study team is able to propose reference values on the basis of the previous Task reports and discuss them with stakeholders to find an agreement. However, the sensitivity of the calculations to these parameters is great and it is uncertain whether the results would reflect well or not the reality, which is a difficult issue to solve.

4) Ban of refrigerants with a GWP greater than a certain value, R-32 (GWP 675) being proposed as the reference for the definition of the threshold

The last option would be to ban some refrigerants according to their GWP. This would of course mainly concern the 3 main current HFC refrigerants (R-410A, R-134a and R-407C). The Task 6 analysis has shown indeed that whatever the refrigerant scenario taken into account (see chapter 6.4), this ensures in all cases a consequent gain in equivalent CO_2 emissions with regards to the average current situation (represented by the base-cases). Very importantly, the gain is already significant even if the product does not have a better SEER than the base-case : in numerous cases, the change in refrigerant fluid suffices to outclass the environmental gain associated with the Best Available Technology in terms of energy efficiency but no change in the refrigerant type.

This implies that if the use of low GWP refrigerants is combined with energy efficiency performance thresholds, the gains in equivalent CO_2 emissions can be particularly consequent, and outclass all the other policy options.

The study team is conscious that such a political decision requires to be sure that alternative refrigerant options do really exist, allow to reach high SEER (and SCOP) levels, are available at reasonable costs and do not cause too important safety issues. It is thus seen as a mid-term measure to be taken after a successful transition period during which the new fluids can be progressively brought to the market. It is necessary to let sufficient time for manufacturers to change the design of their products to adapt to these fluids, but also for the Member States to adapt their legislation on safety measures : everything should be done to ensure that once these new products are put on the EU market at a large scale, there is no risk of accident related to their use.

The threshold should be put at the value of the GWP of R-32, which is currently estimated at 675. This means that R-32 would be authorized, and refrigerant fluids with a greater GWP would be banned.

c) Screening of the energy efficiency and refrigerant requirements per product category

The study team proposes here a screening, by product category (first air-conditioning chillers then air-to-air air conditioners), of the possible energy efficiency requirements and the best suited refrigerant policy options that can be defined. The final policy scenarios are proposed in the policy section in part 7.1.3 d).

Concerning air conditioning chillers, the discussions on the definition of SEER MEPS are based on the $SEER_{gross}$ values that have been calculated in Task 6, which are simply quoted below as SEER values. When necessary, corresponding $SEER_{net}$ values are provided between brackets.

Possible numerical values for GWP bonuses for alternative refrigerants are discussed in a separate subpart at the end of this paragraph 7.1.3 c).

Air conditioning chillers : ambition of SEER requirements and mid-term refrigerant policy options

Air-cooled chillers with a cooling capacity above 400 kW

The evaluation of the improvement potential for this product category has been based in Task 6 on 400 kW air-cooled chillers, the base-case being equipped with screw compressors. The analysis of existing chiller ranges and of the Eurovent database shows indeed that there is no significant variation in seasonal efficiency levels over these ranges when the cooling capacity varies. If the base-case and all the considered improved products considered had had a cooling capacity of for instance 800 kW, similar results would have been found.

Looking at the sensitivity analysis done in chapter 6.4, it has been shown that whatever the costs scenario considered, most of the conventional improvement design options that correspond to R-134a charged chillers lead to a non-negligible gain in Life Cycle Costs with regards to the base-case over a 17 years period. Simple payback periods are lower than 5.5 years for improved products I1 to I5. This shows that in economic terms, there is a range of choices for the fixing of a reference SEER as a MEPS.

This is an important point as the TEWI analysis shows that the LLCC, which is improved product I5 in its versions “a” and “b”, has a greater TEWI than improved product I4, although it has a higher SEER. This is due to the use of a flooded shell and tube evaporator or a falling film evaporator, which greatly increase the refrigerant charge by comparison with a direct expansion shell and tube heat evaporator (used in improved product I4), and so the direct equivalent CO_2 emissions associated with refrigerant losses.

For a good illustration of this point, the following table summarizes the main TEWI results for improved products I4 to I6. The other parameters are the same as in refrigerant scenario 1 of Task 6, which is the average scenario. The last line of the table shows what would be the limit in relative refrigerant charge of a product that has the same SEER as improved products I5 and I6 to get the same TEWI as improved product I4.

Table 7 - 5 . Air-cooled chillers: summary of main energy performance and TEWI results

Air cooled chillers : summary of the main energy and TEWI results for improvement design options I4 to I6 *adapted from Task 6 with a 20 years time period*								
Main results	**Base-case**	**Option I4**	**Option I5a** *= LLCC*	**Option I5b** *= LLCC*	**Option I5c**	**Option I6a** *= energy BAT*	**Option I6b** *= energy BAT*	**Option I6c** *= energy BAT and TEWI BAT*
SEER	3.58	4.58	4.91	4.91	4.91	5.56	5.56	5.56
Gain in electricity consumption	-	22%	27%	27%	27%	36%	36%	36%
Relative	0.25	0.25	0.41	0.37	0.33	0.44	0.40	0.36

refrigerant charge *(kg/kW)*								
Other main parameters	Equivalent hours of use at design capacity : 600 Annual refrigerant leaks : 3% of the refrigerant charge End-of-life refrigerant recovery losses : 20% of the refrigerant charge Conversion factor from kWh (final energy) to kg(CO_2) equ. : 0.384							
Direct emissions *t(CO_2) equ.*	104 000	104 000	170 560	153 920	137 280	183 040	166 400	149 760
Indirect emissions *t(CO_2) equ.*	512 000	402 445	375 397	375 397	375 397	331 511	331 511	331 511
Total emissions *t(CO_2) equ.*	616 000	506 445	545 957	529 317	512 677	514 551	497 911	481 271
Gain in TEWI	-	18%	11%	14%	17%	16%	19%	22%
Maximum relative refrigerant charge to reach a TEWI equal to I4's TEWI *(kg/kW)*	Not considered	0.25	0.32 it is < 0.41	0.32 it is < 0.37	0.32 it is < 0.33	0.42 it is < 0.44	0.42 it is > 0.40	0.42 it is > 0.36

As explained in Task 6, it seems hard to reach SEER levels above a value somewhere in between 4.6 (4.4) and 4.9 (4.7) without increasing significantly the refrigerant charge, which can be observed in this table for improved products I5 and I6. This makes it harder to put a SEER MEPS at the level of the SEER of the LLCC. This table shows clearly that from SEER values of 4.6 (4.4) onwards, a measure should be taken to mitigate the refrigerant charge or the GWP of the refrigerant fluid to limit the direct equivalent CO_2 emissions.

By opting for refrigerant policy option 3, which is the specific TEWI, the soundest solution would be to take the specific TEWI of improved product I4 as the reference. Although the SEER MEPS could be kept at a value of 4.9 (4.7), which is the one of the LLCC, this would lead to ban a lot of products that have a greater SEER, and can be considered as highly efficient technologies in terms of energy efficiency.
Indeed, the specific TEWI approach would require manufacturers to limit the relative refrigerant charge of their product, as is shown in the last line of the previous table : in this example, improved products I5a, I5b, I5c and I6a would be banned, and so similar existing products, though they are today amongst the most energy efficient products put on the EU market. With all the uncertainty on the parameters of the TEWI calculation, this highlights well the difficulty to put this kind of policy option into place.

On the other hand, a SEER MEPS equal to the SEER of the LLCC, rounded to 4.9 (4.7), could be reached, but probably only after several years because of the state of the market. It is seen as a mid-term measure, before which it is more reasonable to put lower SEER MEPS. This lets the time for manufacturers to develop products with alternative refrigerant fluids. A ban of the current high GWP refrigerants can therefore be envisaged more easily than a specific TEWI approach after a transition period.

Air-cooled chillers with a cooling capacity below 400 kW

The evaluation of the improvement potential for this product category has been based in Task 6 on 100 kW air-cooled chillers, the base-case being equipped with scroll compressors. As for higher cooling capacity chillers, similar results would be found at other cooling capacities comprised between 0 and 400 kW, the only difference being that at lower cooling capacities than 100 kW, the BAT/BNAT level evaluated in Task 6 would be reached by products equipped with a single inverter-driven scroll compressor instead of a single inverter-driven screw compressor.

1) SEER MEPS

The improved product I4, which corresponds to a BAT/BNAT level and has also the LLCC, has a SEER of 4.7 (4.5), whereas the improved 400 kW air-cooled chiller with the LLCC has a SEER of 4.9 (4.7). The efficiency improvement potential is therefore limited for low cooling capacity air-cooled chillers by comparison with higher cooling capacity products. Moreover, this BAT/BNAT 100 kW air-cooled chiller is equipped with a screw compressor, while the wide majority of products with a cooling capacity below 400 kW are equipped with scroll compressors, which should continue to greatly dominate this market segment in the coming years. The best improved 100 kW air-cooled chiller equipped with scroll compressors and modeled in Task 6, which is improved product I3, has only a SEER of 4.25 (4.05), which is far below 4.7 (4.5) and 4.9 (4.7).

This clearly shows that a SEER of 4.9 (4.7), which corresponds to the LLCC for larger capacity air-cooled chillers, cannot be used as a MEPS for air-cooled chillers with a cooling capacity lower than 400 kW.

Then, the study team thinks that a mid-term SEER MEPS should not be set above 4.3 (4.1) for this market segment. This corresponds to improved product I3, while the LLCC is improved product I4 : I4 is a BAT/BNAT and cannot be taken as reference to define a MEPS, all the more since screw compressors are currently very uncommon below 200 kW. I3 has also a lower payback period of 7.5 years, instead of 9 years for I4.

2) Refrigerant policy options

Focusing now on the possibility to introduce refrigerant policy option 3 or 4, the analysis is different than for higher cooling capacity chillers:

- The industry does not develop flooded shell and tube evaporators for a cooling capacity lower than 300-400 kW, and these products are nearly always equipped with brazed plate evaporators which allow to limit the refrigerant charge thanks to their compactness. There is therefore no significant refrigerant charge issue for these products when their SEER is improved, as no technological option that allows to reach higher SEER values than an average product leads to a dramatic increase in the refrigerant charge. This is illustrated in Task 6 results and especially the sensitivity analysis done in 6.4, with no significant differences in the relative gains in TEWI by comparison with the base-case between the 2 refrigerant losses scenarios.

- The share of reversible chillers in total chiller sales is significantly higher for products with a cooling capacity lower than 400 kW than products with a cooling capacity greater than 400 kW. On the basis of Task 2 data, it can be estimated that at least a third of the cumulative sales in cooling capacity of < 350 kW air-cooled chillers correspond to reversible products. Adding the heating function to the cooling function multiplies by at least a factor 3 the energy consumption. For more efficient reversible chillers, the additional direct emissions linked to a slight increase in the refrigerant charge due to oversized heat exchangers are of negligible importance by comparison with the gains made in indirect emissions related to a lower electricity consumption.

- To the study team's knowledge, the only main technology that allows to reduce the refrigerant charge of low cooling capacity air-cooled chillers is the microchannel heat exchanger, which is taken into consideration in Task 6, with limited gains in TEWI by comparison with the versions of the improved products equipped with standard fin and coil heat exchangers. The gain in TEWI by comparison with the base-case shifts indeed from 16% to 19% between the versions "a" and "b" of improved product I3. Note then that this heat exchanger technology cannot yet be used for reversible chillers (see Tasks 5 and 6), and it has been reported above that their weight in sales of < 350 kW air-cooled chillers is important.

These three main points show that the specific TEWI approach is of low if not no interest for this product category and more difficult to apply since the issue of a relevant choice of reference parameters is greater because of lower differences between the different refrigerant charge levels.

Water-cooled chillers with a cooling capacity above 400 kW

The evaluation of the improvement potential for this product category has been based in Task 6 on 1000 kW water-cooled chillers, the base-case being equipped with screw compressors. As for the 2 preceding chiller categories, there is no significant variation in seasonal efficiency levels over the chiller ranges from which the base-case and the improved products have been derived, meaning that reasoning on 1000 kW water-cooled chillers does not bias the definition of SEER MEPS for other cooling capacity levels in the > 400 kW market segment.

For water-cooled chillers, the LLCC calculated in Task 6 corresponds to a gain in SEER of 41%, whereas it is only of 27% for the LLCC of air-cooled chillers.

Looking at the sensitivity analysis done in chapter 6.4, it has been shown that whatever the costs scenario considered, the LLCC remains improved product I4, which is an inverter-driven screw chiller equipped with a flooded shell and tube or falling film evaporator. It has a rounded SEER of 7.8 (7.0). The gain in LCC is 10%, with a simple payback period of 5.5 years. This payback period is then multiplied by at least a factor 2 for a centrifugal chiller that has an equivalent (improved product I5) or higher (improved products I6 and I7) SEER, because of very high additional manufacturing costs.

The following table summarizes then main energy and TEWI results for improved products I4 to I7, over a 25 years time period and the average refrigerant scenario defined in Task 6 :

Table 7 - 6 . Water-cooled chillers: summary of main energy performance and TEWI results

Water-cooled chillers : summary of the main energy and TEWI results for improvement design options I3 to I7 *adapted from Task 6 with a 25 years time period*								
Main results	**Base-case**	**Option I4a** *= LLCC*	**Option I4b** *= LLCC*	**Option I5**	**Option I6a**	**Option I6b**	**Option I7a** *= energy BAT*	**Option I7b** *= energy BAT and TEWI BAT*
SEER	4.77	7.77	7.77	7.82	8.77	8.77	9.16	9.16
Gain in electricity consumption	-	29%	29%	30%	37%	37%	40%	40%
Relative refrigerant charge *(kg/kW)*	0.20	0.32	0.28	0.39	0.32	0.28	0.39	0.35
Other main parameters	Equivalent hours of use at design capacity : 600 Annual refrigerant leaks : 3% of the refrigerant charge End-of-life refrigerant recovery losses : 20% of the refrigerant charge Conversion factor from kWh (final energy) to kg(CO_2) equ. : 0.384							
Direct emissions *kg(CO_2) equ.*	222 300	355 680	311 220	433 485	355 680	311 220	433 485	389 025
Indirect emissions *kg(CO_2) equ.*	1 086 792	667 181	667 181	662 916	591 106	591 106	565 939	565 939
Total emissions *kg(CO_2) equ.*	1 309 092	1 022 861	978 401	1 096 401	946 786	902 326	999 424	954 964
Gain in TEWI	-	22%	25%	16%	28%	31%	24%	27%
Maximum relative refrigerant charge to reach a TEWI equal to I4b's TEWI *(kg/kW)*	Not considered	-	-	0.28 it is < 0.37	0.35 it is > 0.32	0.35 it is > 0.28	0.37 it is < 0.39	0.37 it is > 0.35

By comparison with air-cooled chillers, more gains are made in the TEWI at the level of the LLCC because of higher energy savings and a lower refrigerant charge. It appears that direct emissions due to refrigerant losses are less a concern than for air-cooled chillers.

The last line of the table illustrates to what requirements on the refrigerant charge the specific TEWI approach would lead. The reference TEWI should be taken from improved product I4b, which is the LLCC but with a falling film evaporator instead of a standard flooded shell and tube evaporator to reduce the charge. Imposing manufacturers to get a TEWI lower than this reference would ban improved products I5 and I7a, the first one being an inverter-driven centrifugal chiller with standard roll bearings, the second one being an inverter-driven centrifugal chiller equipped with magnetic bearings but also oversized heat exchangers to reach a higher SEER, without a technology to reduce the refrigerant charge.

A conclusion is that the specific TEWI is an interesting approach for > 400 kW water-cooled chillers, as it does not seem to put too much pressure on the market but eliminates the products with too high refrigerant charges.

The ban of high GWP refrigerants would lead to the ban of R-134a, which is nearly the only refrigerant fluid currently used in high capacity water-cooled chillers. It has been stated that this option cannot be envisaged at short-term, and the preceding table, as well as Task 6, illustrates well that contrary to air-cooled chillers, the GWP of the refrigerant does not seem to be a great issue for this product category at short-term.

However, combining high efficiency requirements with GWP requirements would lead to substantial CO_2eq savings : a product that would use ammonia, propane or an HFO (R-1234yf/ze) and have the same SEER as improved product I4b would save 50% of the TEWI by comparison with the base-case, which outclasses by a large margin all the best energy efficiency options used in combination with R-134a.

Water-cooled chillers with a cooling capacity below 400 kW

The evaluation of the improvement potential for this product category has been based in Task 6 on 100 kW water-cooled chillers, the base-case being equipped with scroll compressors. As for higher cooling capacity chillers, similar results would be found at other cooling capacities comprised between 0 and 400 kW, the only difference being that at lower cooling capacities than 100 kW, the BAT/BNAT level evaluated in Task 6 would be reached by products equipped with a single inverter-driven scroll compressor instead of a single inverter-driven screw compressor.

1) SEER MEPS

The improved product I4 that corresponds to a BAT/BNAT level has a SEER of 6.3 (5.5). This is far below the SEER of 7.8 (7.0) of the improved 1000 kW water-cooled chiller which is the LLCC. This suffices to illustrate that it is not possible to require the same MEPS for both market segments.

Then, although improved product 2 is the LLCC, the retained LCC reference in Task 6 is improved product 3, because of a very low difference in LCC between both products, confirmed by the sensitivity analysis done in 6.4. The rounded SEER of I3 is 6.0 (5.2). The payback period is 8 years for this product by comparing its LCC with the LCC of the base-case. This SEER level can therefore be set as a mid-term objective, as the corresponding improved product is equipped with an inverter-driven scroll compressor : this technology is currently not implemented in low cooling capacity water-cooled chillers, more because of their low sales volume than because of technological limitations (manufacturers already sell other chiller types or air conditioners equipped with inverter-driven scroll compressors). Of course, there are other technological means to achieve at least the same performance levels, such as several staged scroll compressors or an inverter-driven screw compressor.

2) Refrigerant policy options

As for low cooling capacity air-cooled chillers, the specific TEWI approach is of very limited interest as :

- There is no heat exchanger technology in this capacity range that significantly increases the refrigerant charge of the system. The commonly used heat exchangers are brazed plate heat exchangers, used as evaporators and condensers, with which the refrigerant charge is limited with regards to the shell and tube heat exchangers that equip larger cooling capacity water-cooled chillers. Specific charges of less 0.15 kg/kW are for instance reported in Task 4 and Task 6 for products equipped with this technology, which dominates nearly exclusively this market segment.

- Oversizing the heat exchangers to reach higher efficiency levels does not lead to great increases in the refrigerant charge, and so direct emissions. Task 6 calculations show that for the improved products, the relative gains (%) in TEWI by comparison with the base-case are the same as the relative gains (%) in electricity consumption. This means that technological changes, including the sizing of heat exchangers, do not cause significantly higher direct emissions, which variation can be neglected.

- To the study team's knowledge, there is no alternative heat exchanger technology that allows to reduce further the refrigerant charge of the products by comparison with the standard heat exchangers used in today's average products.

As a conclusion, the differences in direct emissions between a product and another are tiny, if not negligible : it would be very difficult to rank properly the competitors without inducing a great bias, for a very limited gain in TEWI.

The ban of alternative refrigerants is the only interesting option at mid-term :

- Nearly all intermediate to high efficiency low cooling capacity water-cooled chillers should be charged with R-410A in the coming years, which is the HFC used in ENTR Lot 6 products that has the highest GWP.

- Greater gains in the TEWI associated with the refrigerant change itself can be envisaged by comparison with larger cooling capacity water-cooled chillers : the margin of improvement in energy efficiency is lower, and the current reference fluids have a higher GWP, so there is more to save on the refrigerant side.

Air conditioning chillers: determination of short term GWP bonus policy

Possibilities of a progressive bonus

The idea of a progressive bonus is of no interest for air-cooled and water-cooled chillers with a cooling capacity greater than 400 kW. For these products, which represent respectively around 55% of the market of air-cooled chillers and 80% of the market of water-cooled chillers, alternative refrigerant fluids with a GWP of less than 10 are available : at these levels of GWP, the weight of the direct equivalent emissions in the total equivalent CO_2 emissions can be always considered as nil, and the refrigerant charge of the products has strictly no impact on the TEWI.

Then, as most of the chillers with a cooling capacity lower than 400 kW are equipped with scroll compressors, R-32 becomes a competitor and is an interesting alternative to R-410A and R-407C. As it has a GWP of 675, the idea of a progressive bonus can be studied below 400 kW.

1) Air-cooled chillers < 400 kW

The study team has done TEWI calculations with a SEER at the level of the SEER MEPS of 4.3 (4.1) proposed for low capacity chillers. The reference current fluid is R-410A with a GWP of 2088. The refrigerant scenario 1 of Task 6 is used, with a reference relative charge of 0.20 kg/kW. As a majority of these chillers ensure only a cooling function, 600 equivalent hours at design capacity are considered for energy calculations :

- In the case of a R-32 using product, the gain in TEWI associated with lower direct emissions can lead to a maximum SEER bonus of 20% to reach the same TEWI than the R-410A charged reference product.

- In the case of product charged with a refrigerant that has a GWP lower than 10, the maximum SEER bonus is around 25%.

<u>This small difference does not justify to opt for a progressive bonus</u>.

Note then that doing the calculations again at an intermediate SEER MEPS leads logically to lower SEER bonuses, because the lowest SEER of the products allow less to increase the indirect emissions to the benefit of decreased direct emissions.

2) Water-cooled chillers < 400 kW

The same calculations are done for water-cooled chillers, on the basis of a SEER at the level of the SEER MEPS, which is 6.0 (5.2). R-410A remains the reference high GWP fluid, all the other assumptions of the calculations being the same :

- In the case of a R-32 product, the possible maximum SEER bonus is around 25%.

- In the case of product charged with a refrigerant that has a GWP lower than 10, the maximum SEER bonus is around 30%.

<u>Once again, this difference does not justify to opt for a progressive bonus</u>.

Possibilities of a single bonus

A single bonus is the best option for each chiller category (below and above 400 kW). It remains to be seen whether two different bonuses are defined, and whether they should evolve, or not, with the incremental increases in SEER MEPS proposed by the study team.

1) Air-cooled chillers > 400 kW

As the SEER MEPS of 4.9 (4.7) corresponds to a higher TEWI than the intermediate lower SEER option, the calculations are done on the basis of a R-134a charged chiller that has a SEER equal to an intermediate SEER MEPS of 4.6 (4.4), with a relative charge of 0.25 kg/kW to limit (option ACC I4). The other parameters of the TEWI calculation are the same as in refrigerant scenario 1 (Task 6). As all fluids have a GWP lower than 10, <u>the maximum possible SEER bonus is around 20%</u>.

For an intermediate SEER MEPS of 4.1 (3.9), the maximum possible bonus remains around 20%.

2) Water-cooled chillers > 400 kW

The reference high GWP fluid remains the R-134a. As the SEER MEPS of 7.8 (7.0) corresponds to a higher TEWI than the intermediate lower SEER option, the maximum SEER bonus is calculated from an intermediate SEER MEPS of 6.7 (6.1) and a relative refrigerant charge of 0.30 kg/kW, because of a medium increase in the refrigerant charge at this level of efficiency.

<u>The maximum possible SEER bonus is around 30%, which is a considerable value</u>.

3) Conclusion for cooling only chillers

The highest maximum possible SEER bonus presented above are too high to be chosen :

- The study team proposes to ban high GWP refrigerant fluids at mid-term, after a transition period. From this perspective, manufacturers will have several years to develop progressively higher volumes of chillers charged with alternative refrigerants so that they can be ready for the date at which products charged with high GWP refrigerants are banned from the EU market. As this refrigerant ban is combined with SEER MEPS, a too high bonus for alternative refrigerant using products is counterproductive : it is hard to believe that manufacturers would develop low SEER products using alternative refrigerants during several years, then quickly adapt these products to much higher efficiency levels.

- One of the main Ecodesign goals is to reduce the energy consumption in addition to equivalent CO_2 emissions. In this respect, bonuses greater than 10-15% cannot be proposed.

- It has been shown in Task 6 that there are already available propane or ammonia charged chillers with SEERs that match the intermediate SEER MEPS the study team wants to propose at mid-term. Their manufacturers do not need a bonus as they will be easily able to respect the SEER MEPS of chillers charged with high GWP refrigerants.

As a conclusion, the study team proposes a SEER bonus of 10% at the 1st (2015) and 2nd tier (2017), high GWP refrigerants being banned at the 3rd tier (2019).

4) Conclusion for reversible chillers

The study team thinks that the best option is not to consider any SEER bonus for reversible air conditioning chillers :

- Because the energy consumption is multiplied by at least a factor 3 when shifting from cooling only to reversible chillers, direct emissions weight only around 5% of the total equivalent emissions for these products. The study team has also done bonus calculations for reversible chillers, but as one might expect, the maximum bonuses in SEER range from 5% to 8%, depending on the alternative refrigerant fluid. A separate SEER bonus of 5% for reversible chillers would be ineffective, because it would not be high enough to incite chiller manufacturers to develop quickly products charged with lower GWP refrigerants.

- Reversible chillers are in fact an air-to-water heat pumps or more rarely a ground-to-water heat pumps. While they represent less than 20% of the EU market of air conditioning chillers by cumulative cooling capacity sold, their heating function, which is their primary function as it consumes three times more energy than their secondary cooling function, is already covered in DG ENER Lot 1. In this Lot, no bonuses for alternative refrigerants have been envisaged, so the study team proposes to stick to this point.

Air-to-air air conditioners: ambition of SEER requirements and mid-term refrigerant policy options

Split systems

A summary table proposes to look main energy and TEWI results from relevant design options. The term of “more realistic reference option” (MRRO) is introduced.

The study team takes into account in the analysis the Commission Regulation N° 206/2012 of 6 March 2012. For split systems with a cooling capacity comprised between 6 kW and 12 kW, the SEER MEPS defined for the 1st January of 2014 is estimated to amount to 4.5 in Lot 6 metrics.

According to Task 6, the LLCC option for reversible products has a SEER of 6.11, which is considerably higher than 4.5. It is of 5.24 for cooling only products. Although it is technologically feasible to reach such values, it is not sound to have a difference in SEER MEPS of this order of magnitude between less than 12 kW and more than 12 kW split systems, even if they come into force at a few years interval. This is why the study team defines option I3 as the good reference for a possible mid-term SEER MEPS, meaning that it could be of this order of magnitude a few years after 2014, but not in 2014.

Table 7 - 7 . Split systems: summary of main energy performance and TEWI results

Split systems : **energy and TEWI results for relevant design options** *15 years time period = product life – reversible and cooling only products* *MRRO stands for “more realistic reference option”*									
Main results	**Reversible products**				**Cooling only products**				
	Base-case	**Option I7** *= LLCC*	**MRRO** *= I3*	**BAT in energy** *= I11*	**Base-case**	**Option I4a** *= LLCC*	**Option I4b** *= LLCC*	**MRRO** *= I3*	**BAT in energy** *= I11*
SEER	3.97	6.11	4.97	6.87	3.97	5.24	5.24	4.97	6.87
SCOP	3.31	4.57	4.01	5.12	-				
Gain in electricity consumption	-	29%	15%	37%	-	24%	24%	20%	42%
Relative refrigerant charge *(kg/kW)*	0.40	0.63	0.50	0.78	0.40	0.53	**0.42**	0.50	0.78
Other main parameters	Equivalent hours of use at design capacity – cooling function : 600 Equivalent hours of use at design capacity –heating function : 1400 Annual refrigerant leaks : 6% of the refrigerant charge End-of-life refrigerant recovery losses : 15% of the refrigerant charge Conversion factor from kWh (final energy) to kg(CO_2) equ. : 0.384								
Direct emissions *$t(CO_2)$ equ.*	12.3	19.2	15.2	23.9	12.3	16.2	12.9	15.2	23.9
Indirect emissions *$t(CO_2)$ equ.*	51.2	36.1	43.3	32.2	12.2	9.2	9.2	9.7	7.0
Total emissions *$t(CO_2)$ equ.*	63.5	55.3	58.5	56.2	24.5	25.4	22.2	25.0	31.0
Gain in TEWI	-	13%	8%	12%	-	-4%	9%	-2%	-26%

For reversible products, the SEER of the MRRO leads to 15% energy savings and 8% TEWI savings by comparison with the base-case. By comparison, the BAT in energy leads to 37% energy savings but only 12% TEWI savings.

This highlights well the point that it is useless to ask high SEER MEPS without taking a measure to mitigate the direct equivalent emissions. A specific TEWI option would probably not be effective as the main option identified to decrease the direct emission is to use micro-channel heat exchangers and that this technology is not available for reversible products. Hence, the only solution is to ban high GWP refrigerant fluids at mid-term to benefit at the same time from important savings in indirect and direct equivalent emissions. From Task 6, the alternative refrigerant option with the highest GWP, which is the R-32 product, already allows to make 16% savings in the TEWI with a SEER close to the one of the base-case, while the BAT in energy only leads to 12% savings in the TEWI with a SEER 67% greater than the SEER of the R-32 charged product.

For cooling only products, the MRRO leads to a 2% increase in the TEWI and the BAT in energy to a 26% increase, with all the uncertainty behind the inputs of the calculations. The interest in the specific TEWI approach is illustrated by the gain in TEWI of option I4b by comparison with option I4a (the study team has not modeled a version “b” of option I3 with a microchannel condenser). It would require manufactures to limit the relative refrigerant charge of their products, probably by at least 15% to 20%, as illustrated in this table.

Then, according to Task 6, the R-32 cooling only split system already ensures a 38% gain in TEWI. Noting that it is the least performing in TEWI of the 4 modeled options, there is a considerable margin of improvement in the TEWI of Lot 6 split systems by banning high GWP refrigerant fluids from the EU market after a transition period.

VRF systems

A summary table proposes to look main energy and TEWI results from relevant design options. The term of “more realistic reference option” (MRRO) is used as for split air conditioners.

As mentioned in part 7.1.2, the SEER metric the study team proposes for VRF systems is based on part-load control method 2[4] (all indoor units operate in parallel at part load), with a piping length of 7.5 m and so no cooling capacity correction factor is included. This is also the case for SCOP values.

In Task 6, the improvement design option that has been highlighted, both for cooling only and reversible products, is the best improvement design option that seems realistic to develop. Better options are technically feasible, but would lead to oversize so greatly the products that this would cause issues of footprint (high dimensions of the outdoor unit), integration of cassette type indoor units to suspending ceilings, poor dehumidification performances and bother building occupants because of the large size of the indoor units.

However, even this option cannot be taken as a reference to define a SEER MEPS. The reason behind is that most efficient VRF products cannot reach SEER levels above options I8 to I10 (which is thought to be the very best product available). Thus, a mid-term objective is more realistically the option I7[5].

Table 7 - 8 . VRF systems: summary of main energy performance and TEWI results

VRF systems : **energy and TEWI results for relevant design options** *15 years time period = product life – reversible and cooling only products* *MRRO stands for “more realistic reference option”* *part-load control method 2 / equivalent piping length = 7.5m*									
Main results	**Reversible products**				**Cooling only products**				
	Base-case	**Option I13** *= Task 6 reference option*	**MRRO** *= I7*	**BAT in energy** *= I16*	**Base-case**	**Option I13a** *= Task 6 reference option*	**Option I13b** *= Task 6 reference option*	**MRRO** *= I7*	**BAT in energy** *= I16*
SEER	4.20	5.41	4.82	6.41	4.20	5.41	5.41	4.82	6.41
SCOP	3.32	3.91	3.61	4.47	-				
Gain in electricity consumption	-	17%	11%	28%	-	22%	22%	13%	34%
Relative refrigerant charge *(kg/kW)*	0.50	0.69	0.59	0.89	0.50	0.69	**0.58**	0.59	0.89
Other main parameters	Equivalent hours of use at design capacity – cooling function : 600 Equivalent hours of use at design capacity – cooling function : 1400 Annual refrigerant leaks : 6% of the refrigerant charge End-of-life refrigerant recovery losses : 15% of the refrigerant charge Conversion factor from kWh (final energy) to kg(CO_2) equ. : 0.384								
Direct emissions *t(CO_2) equ.*	54.8	75.6	64.7	97.6	54.8	75.6	63.6	64.7	97.6
Indirect emissions *t(CO_2) equ.*	174.7	145.2	158.6	126.1	41.1	31.9	31.9	35.9	27.0
Total emissions *t(CO_2) equ.*	229.5	220.9	223.2	223.7	96.0	107.6	95.5	100.5	124.5
Gain in TEWI	-	4%	3%	3%	-	-12%	-0.5%	-5%	-16%

[4] The values in the table below thus differ from Task 6 results as the control method 1 (progressive deconnection of indoor units) was used and a correction for piping length was applied.

[5] This analysis bases upon the comparison of the LCC analysis led in Task 6 and of the published data on the US market which are available on the AHRI website of certified products. This comparison is developped in Task 6.2.

For reversible products, the SEER of the MRRO leads to 11% energy savings and 3% TEWI savings by comparison with the base-case. Gains are lower than for split systems because the base-case has a higher SEER. By comparison, the BAT in energy leads to 28% energy savings but only 3% TEWI savings : the gain in TEWI is the same as with a technology that has a 25% lower SEER.

This highlights well the point that it is useless to ask high SEER MEPS without taking a measure to mitigate the direct equivalent emissions. For the same reason as for split systems, the specific TEWI approach cannot apply to reversible products here, the only solution is to ban high GWP refrigerant fluids at mid-term to benefit at the same time from important savings in indirect and direct equivalent emissions.

The alternative refrigerant option with the highest GWP, which is the R-32 product, already allows to make 17% savings in the TEWI with a SEER close to the one of the base-case, while the BAT in energy only leads to 5% savings in the TEWI with a SEER 44% greater than the SEER of the R-32 charged product.

For cooling only products, the MRRO (I7) quoted above leads to a 13% gain in electricity consumption but a -0.5% decrease in the TEWI. The TEWI is dramatically worse for the BAT in energy, with a 16% decrease, though with all the uncertainty behind the inputs of the calculations. The interest in the specific TEWI approach is illustrated by the gain in TEWI of option I13b by comparison with option I13a (the study team has not modeled a version “b” of option I7 with a microchannel condenser). It would require manufactures to limit the relative refrigerant charge of their products, probably by at least 15% to 20%, as illustrated in this table with the lower relative charge of option I13b.

Then, according to Task 6, the R-32 cooling only VRF system already ensures a 39% gain in TEWI. Noting that as it is the least performing in TEWI of the 4 modeled options, there is a considerable margin of improvement in the TEWI of Lot 6 cooling only VRF systems by banning high GWP refrigerant fluids from the EU market after a transition period.

Package air conditioners

1) Proposed SEER MEPS

The main conclusion that can be derived from Task 6 on package air conditioners is that there are important margins of improvement of their energy efficiency at relatively low costs. Average products that correspond to the base-case are not very efficient and have not significantly been improved over the past decade.

It has been shown that the improvement design option with the LLCC is also the BAT in terms of SEER, because of low additional costs estimated at 7% of the investment costs of the base-case. The simple payback period is then less than 3.5 years for cooling only products and only of 1 year for reversible products. This means that in economic terms, there is a wide range inside which a SEER MEPS can be defined.

However, the study team thinks it is not relevant to take a SEER close to the SEER of the LLCC = BAT as the MEPS :

- Package air conditioners represent small market shares in the EU, contrary to the US market. There are therefore relatively uncommon products, which should imply higher additional manufacturing costs for the products sold in the EU, if they are manufactured locally but also if they are imported because of the associated costs.

- An SEER of 5.25 would be a very high MEPS value, as it would ban all the current existing products. There is the risk that by asking too much to package air conditioner manufacturers, this niche market disappears.

The proposed option is to opt for a mid-term SEER MEPS of 4.80, which corresponds to the standard improvement option 4 (out of the 6 standard improvement options). The corresponding MEPS is then similar as the realistic mid-term MEPS previously estimated for split and VRF systems.

The option 4 leads in Task 6 to a gain in energy consumption of 19% if the product ensures only a cooling function and 11% if the product is reversible. The corresponding gains in TEWI are respectively of 6% and 9%.

2) Refrigerant policy options

It has been shown that it is not possible to ask for a specific TEWI approach for reversible products.

Concerning cooling only products, the use of a microchannel heat exchanger, as reported in Task 6, allows to save an additional 9% in the TEWI from the 6% gains in TEWI obtained with the LLCC = BAT. The gain in TEWI is more than doubled, which is an interesting point.

As for cooling only split systems and VRF systems, the specific TEWI approach can thus be envisaged for cooling only package air conditioners.

Once again, significantly higher gains in the TEWI can be obtained by banning high GWP refrigerant fluids. For the reversible case, the R-32 product modeled in Task 6 allows a gain in TEWI of 9%, whereas the option that has the closest SEER, which is option one (SEER of 4.13 instead of 4 for the R-32 product), only leads to a 4% gain in the TEWI. For the cooling only case, the R-32 product leads to a 32% gain in the TEWI, which is better than the BAT in energy combined with a microchannel condenser (only 15% gain in the TEWI for this product).

Air-to-air air conditioners: determination of short term GWP bonus policy

Possibilities of a progressive bonus

The study team does not retain the idea of a progressive bonus for air-to-air air conditioners because the TEWI sensitivity analysis done in Task 6 has proven that TEWI calculations are especially sensitive to the refrigerant charge of the products, which implies it is very difficult to fix a reference for this progressive bonus.

Single bonus

1) Reversible air-to-air air conditioners

With all the uncertainty related to the refrigerant charge and the rates of refrigerant losses, the study team has again done estimations of maximum SEER bonuses on the basis of TEWI calculations.

R-410A is the refrigerant fluid for standard improvement design options. The intermediate SEER MEPS the study team proposes in its policy scenarios are taken for reference, with the corresponding refrigerant charges.
If average rates of refrigerant losses are considered (refrigerant scenario 1 in subtask 6.4), bonuses in SEER range from 25% to 30% for split systems and VRF systems, and from 15% to 20% for package air conditioners, depending on the alternative refrigerant fluid that is considered.

It is also interesting to consider lower rates of refrigerant losses, which is the refrigerant scenario 2 in subtask 6.4. Indeed, they could correspond to the consequences in the coming years of a more stringent F-gas regulation on refrigerant handling (charge checking, refill and end-of-life recovery) and piping design. Under this scenario, bonuses in SEER range from 15% to 20% for split systems and VRF systems, and from 8% to 12% for package air conditioners, once again depending on the alternative refrigerant fluid that is considered.

As the idea is to use the same bonus for all alternative refrigerant fluids, it is necessary to take the lowest maximum SEER bonus calculated for reference. For split systems and VRF systems, it is then 25% with refrigerant scenario 1 and 15% with refrigerant scenario 2. For package air conditioners, it is 15% for refrigerant scenario 1 and 8% for refrigerant scenario 2.

The study team proposes to base upon the low scenario, which leads to similar hypothesis and results as in the regulation 2012/206/EC for less than 12 kW air-to-air air conditioners. The proposal is thus to adopt a 10 % bonus for all reversible air-to-air conditioners.

2) Cooling only air-to-air air conditioners

Most air-to-air air conditioners being reversible, it is proposed to adopt the same bonus for cooling only products as for reversible as they would probably keep the same design as reversible ones in the coming years.

As a consequence, the study team proposes a 10% bonus on SEER MEPS for reversible air-to-air air conditioners and for cooling only air-to-air air conditioners, for which the bonus potential is greater.

c) Energy efficiency and TEWI limitation policy options

Preliminary remark on gas engine air conditioning chillers and air-to-air air conditioners

Although the study team has not defined base-case gas engine products because of currently very low market shares, it is necessary to estimate whether these products could cope or not with the proposed SEER MEPS.

The study team has technical data on several product ranges, part of which has been supplied by manufacturers. Although some energy performance tables are reported, a great uncertainty remains on the displayed values. But to the study team's knowledge, this is the only existing information source on the performance of these products. These products are initially manufactured so that they can be used as the outdoor units of VRF systems, the indoor units being exactly the same as for electric VRF systems. The study team is not aware of gas engine split systems or package/rooftop air conditioners.

By fitting a water cooling module to these outdoor units (water-to-refrigerant heat exchanger and its associated piping), instead of a refrigerant distribution piping system and indoor units, the obtained product becomes an air-cooled air conditioning chiller. In this case, the energy performance is slightly lower, as the water temperature at the inlet evaporator leads to a less efficient thermodynamic cycle by comparison with the temperature of the ambient indoor air in the case of an air conditioner mode.

In both cases, the cooling capacity ranges generally from 50 kW to 100 kW, with some products that have a lower cooling capacity, down to 22 kW (beginning of most VRF outdoor unit ranges).

Current products have then EER values, expressed in primary energy, that range from 1.3 to 1.4 for gas engine air conditioners, and 1.2 to 1.3 for gas engine chillers. With a 2.5 conversion factor from final energy to primary energy, this corresponds respectively 3.25 to 3.5 and 3 to 3.25 in final energy, which is very close to the EER of base-case air-cooled chillers and VRF system outdoor units.

Using now the same SEER calculation model defined for Task 6 than for electric products, it is estimated that for gas engine air-cooled VRF systems, the SEER expressed in primary energy of current products can be up to 1.7 for the best products. By comparison, the base-case electric air-cooled VRF systems has a SEER of around 1.4 in primary energy, and the 2019 SEER MEPS of policy scenario 2 (see after) is of 1.8 for air-to-air air conditioners.

Concerning now gas engine air-cooled chillers, the same calculation tool leads also to SEER values up to 1.7 in primary energy for current product : although the chilled water temperature is less favorable to a good thermodynamic cycle, there is no more additional electricity consumption related to any indoor unit, and the consumptions in standby and thermostat off mode are lower. By comparison with electric chillers, an average low cooling capacity air-cooled chiller of 100 kW has today a SEER value of 1.3-1.4 in primary energy, and the 2019 SEER MEPS of policy scenario 2 (see after) corresponds to a SEER of 1.7 in primary energy.

However, manufacturer claim that these values correspond to gas motor efficiency lying between 35 % and 38 %, or an average value about 37 %.

As a conclusion, in order to ensure a level playing field, it is proposed to require SEER MEPS in primary energy computed with a gas motor efficiency of 37 % instead of the 40 % deduced from the standard primary energy factor, and to round the results to the nearest tenth.

Because of very low market shares, the study team does not define three policy scenarios for gas engine products and does not evaluate them in chapter 7.2 1990-2025 calculations. The policy scenario 2 is taken for reference and adapted to primary energy, so that possible SEER MEPS are proposed. The method to define SEER MEPS for gas engine products is therefore explained and illustrated, and should be used for final measures.

Eventually, note that gas engine products do not put pressure on the electricity grid when the electricity demand is peaking during the warm reason. There is no need to ask for EER MEPS calculated in primary energy.

Policy scenarios

The following tables summarize the different policy options proposed by the study team concerning energy efficiency enhancement and limitations in TEWI.

The product categories for which different energy efficiency MEPS are defined are :

- Electric air-cooled air conditioning chillers with a cooling capacity lower than 400 kW
- Electric air-cooled air conditioning chillers with a cooling capacity greater than 400 kW
- Electric water-cooled air conditioning chillers with a cooling capacity lower than 400 kW
- Electric water-cooled air conditioning chillers with a cooling capacity greater than 400 kW
- Electric air-to-air air conditioners with no distinction between split systems, VRF systems and package air conditioners

An additional table is proposed for gas engine products, with one set of measures for each of the two product categories :

- Gas engine air-cooled air conditioning chillers with a cooling capacity lower than 400 kW
- Gas engine air-to-air air conditioners with no distinction between split systems, VRF systems and package air conditioners

Inside each of these product categories, the distinction is drawn between cooling only and reversible products in terms of SEER bonuses when a refrigerant with a GWP lower or equal to 675 is used. As previously explained, this value is taken equal to the GWP value of R-32, as reported in the 4th assessment report of IPCC.

Concerning chillers, $SEER_{gross}$ MEPS have been first defined, on the basis of Task 6 results. $SEER_{net}$ values have been calculated for all base-case chillers and improved products modeled in this Task and reported in its Annex 2. By fitting the correspondence between $SEER_{net}$ and $SEER_{gross}$ values of these products, the obtained interpolation functions allow to calculate $SEER_{net}$ values from the proposed $SEER_{gross}$ MEPS. These values are then rounded to defined the $SEER_{net}$ MEPS. $SEER_{gross}$ and $SEER_{net}$ values are provided in the policy scenario tables.

The study team opts for three tiers in 2015, 2017, 2019, the goal being to increase the gradualness of the requirements. The gap in SEER MEPS between the second and third tiers is lower than between the first and the second tier, to put more pressure on energy efficiency enhancement at short-term, and less at mid-term to allow manufacturers to prepare more smoothly the possible ban of high GWP refrigerants. It should be noted that this is in line with the results of the TEWI, energy efficiency requirements should be parallel to the decrease of GWP in order to avoid to rise the CO2eq emissions.

As explained before, it does not appear necessary to make distinct requirements for the different types of air-to-air air conditioners.

In all policy scenarios, SEER bonuses for products charged with low GWP refrigerants are proposed at the 1st and 2nd tiers. A ban of high GWP refrigerants is always proposed at the 3rd tier, as it has been shown above that it is the most efficient refrigerant policy option once high levels of SEER have been reached.

For cooling only air conditioning chillers, the specific TEWI option is also taken into consideration. This measure could prove interesting at the level of the 1st and 2nd tiers as an alternative to SEER bonuses for low GWP refrigerant fluids.

Conversely, the ban is the only way to improve further the TEWI of air-to-air air conditioners over a certain SEER threshold. The specific TEWI could only be of interest at the 1st and 2nd tier for cooling only air conditioners, but the study team thinks that there is too much uncertainty on the values of relative refrigerant charges and other TEWI calculation parameters to propose this option. Of course, the discussion should remain open on this point.

<u>Note</u> : Rounded SCOP values that correspond to the proposed SEER MEPS are provided. The correlation between SEER and SCOP that is used for doing so is described in Task 6.

Eventually, EER_{gross} MEPS are defined on the basis of the analysis of the 2010 Eurovent database, in which EER_{gross} values of all the certified air conditioning chillers and air-to-air air conditioners are reported. They are also adjusted by taking into consideration EER MEPS imposed in other countries such as USA (which correspond to “gross” values). Please refer to Task 1, where these already existing EER MEPS have been reported. The calculation tools used in Task 6 allow to calculate EER_{net} values from EER_{gross} values, which are then rounded. In the end, differences are negligible for air-cooled chillers, and small for water-cooled chillers.

Table 7 - 9 . Policy scenarios for air-cooled air conditioning chillers < 400 kW

Policy scenarios for air-cooled air conditioning chillers < 400 kW *in 3 Tiers* *SEER metrics based on the newly defined set of reference hours* *2 sets of SEER and EER MEPS : gross and net values – net values indicated by (*)*			
Scenarios	**1st Tier : 1st January 2015**	**2nd Tier : 1st January 2017**	**3rd Tier : 1st January 2019**
Scenario 1	* SEER MEPS : 3.6/3.5(*) * EER MEPS : 2.6/2.6(*) * SEER bonus for GWP <= 675: 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.0/3.8(*) * EER MEPS : 2.8/2.8(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.3/4.1(*) * EER MEPS : 2.8/2.8(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products
Scenario 2	* SEER MEPS : 4.0/3.8(*) * EER MEPS : 2.6/2.6(*) * SEER bonus for GWP <= 675: 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.2/4.0(*) * EER MEPS : 2.8/2.8(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.3/4.1(*) * EER MEPS : 2.8/2.8(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products
Scenario 3	* SEER MEPS : 4.2/4.0(*) * EER MEPS : 2.6/2.6(*) * SEER bonus for GWP <= 675: 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.3/4.1(*) * EER MEPS : 2.8/2.8(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.3/4.1(*) * EER MEPS : 2.8/2.8(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products

Table 7 - 10 . Policy scenarios for air-cooled air conditioning chillers >= 400 kW

Policy scenarios for air-cooled air conditioning chillers >= 400 kW *in 3 Tiers* *SEER metrics based on the newly defined set of reference hours* *2 sets of SEER and EER MEPS : gross and net values – net values indicated by (*)*			
Scenarios	**1st Tier : 1st January 2015**	**2nd Tier : 1st January 2017**	**3rd Tier : 1st January 2019**
Scenario 1	* SEER MEPS : 3.6/3.5(*) * EER MEPS : 2.6/2.6(*) * SEER bonus for GWP <= 675: 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.1/4.0(*) * EER MEPS : 2.8/2.8(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.6/4.4(*) * EER MEPS : 2.8/2.8(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products
Scenario 2	* SEER MEPS : 4.1/4.0(*) * EER MEPS : 2.6/2.6(*) * SEER bonus for GWP <= 675: 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.6/4.4(*) * EER MEPS : 2.8/2.8(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.9/4.7(*) * EER MEPS : 2.8/2.8(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products
Scenario 3	* SEER MEPS : 4.6/4.4(*) * EER MEPS : 2.6/2.6(*) * SEER bonus for GWP <= 675: 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.9/4.7(*) * EER MEPS : 2.8/2.8(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 4.9/4.7(*) * EER MEPS : 2.8/2.8(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products

Table 7 - 11 . Policy scenarios for water-cooled air conditioning chillers < 400 kW

<table>
<tr><th colspan="4">Policy scenarios for water-cooled air conditioning chillers < 400 kW
in 3 Tiers
SEER metrics based on the newly defined set of reference hours
2 sets of SEER and EER MEPS : gross and net values – net values indicated by (*)</th></tr>
<tr><th>Scenarios</th><th>1st Tier : 1st January 2015</th><th>2nd Tier : 1st January 2017</th><th>3rd Tier : 1st January 2019</th></tr>
<tr><td>Scenario 1</td><td>* SEER MEPS : 5.0/4.5(*)
* EER MEPS : 4.0/3.9(*)

* SEER bonus
for GWP <= 675:

10% for cooling only products
0% for reversible products

or

* maximum specific TEWI
value for cooling only products</td><td>* SEER MEPS : 5.6/4.9(*)
* EER MEPS : 4.5/4.4(*)

* SEER bonus
for GWP <= 675 :

10% for cooling only products
0% for reversible products

or

* maximum specific TEWI
value for cooling only products</td><td>* SEER MEPS : 6.0/5.2(*)
* EER MEPS : 4.5/4.4(*)

* Ban of refrigerant fluids
with GWP > 675

or

* maximum specific TEWI
value for cooling only products</td></tr>
<tr><td>Scenario 2</td><td>* SEER MEPS : 5.6/4.9(*)
* EER MEPS : 4.0/3.9(*)

* SEER bonus
for GWP <= 675:

10% for cooling only products
0% for reversible products

or

* maximum specific TEWI
value for cooling only products</td><td>* SEER MEPS : 5.8/5.1(*)
* EER MEPS : 4.5/4.4(*)

* SEER bonus
for GWP <= 675 :

10% for cooling only products
0% for reversible products

or

* maximum specific TEWI
value for cooling only products</td><td>* SEER MEPS : 6.0/5.2(*)
* EER MEPS : 4.5/4.4(*)

* Ban of refrigerant fluids
with GWP > 675

or

* maximum specific TEWI
value for cooling only products</td></tr>
<tr><td>Scenario 3</td><td>* SEER MEPS : 5.8/5.1(*)
* EER MEPS : 4.0/3.9(*)

* SEER bonus
for GWP <= 675:

10% for cooling only products
0% for reversible products

or

* maximum specific TEWI
value for cooling only products</td><td>* SEER MEPS : 6.0/5.2(*)
* EER MEPS : 4.5/4.4(*)

* SEER bonus
for GWP <= 675 :

10% for cooling only products
0% for reversible products

or

* maximum specific TEWI
value for cooling only products</td><td>* SEER MEPS : 6.0/5.2(*)
* EER MEPS : 4.5/4.4(*)

* Ban of refrigerant fluids
with GWP > 675

or

* maximum specific TEWI
value for cooling only products</td></tr>
</table>

Table 7 - 12 . Policy scenarios for water-cooled air conditioning chillers >= 400 kW

Policy scenarios for water-cooled air conditioning chillers >= 400 kW *in 3 Tiers* *SEER metrics based on the newly defined set of reference hours* *2 sets of SEER and EER MEPS : gross and net values – net values indicated by (*)*			
Scenarios	**1st Tier : 1st January 2015**	**2nd Tier : 1st January 2017**	**3rd Tier : 1st January 2019**
Scenario 1	* SEER MEPS : 5.5/5.1(*) * EER MEPS : 4.5/4.4(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 6.7/6.1(*) * EER MEPS : 5.0/4.9(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 7.4/6.6(*) * EER MEPS : 5.0/4.9(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products
Scenario 2	* SEER MEPS : 6.7/6.1(*) * EER MEPS : 4.5/4.4(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 7.4/6.6(*) * EER MEPS : 5.0/4.9(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 7.8/7.0(*) * EER MEPS : 5.0/4.9(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products
Scenario 3	* SEER MEPS : 7.4/6.6(*) * EER MEPS : 4.5/4.4(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 7.8/7.0(*) * EER MEPS : 5.0/4.9(*) * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products or * maximum specific TEWI value for cooling only products	* SEER MEPS : 7.8/7.0(*) * EER MEPS : 5.0/4.9(*) * Ban of refrigerant fluids with GWP > 675 or * maximum specific TEWI value for cooling only products

Table 7 - 13 . Policy scenarios for air-to-air air-conditioners

Policy scenarios for air-to-air air-conditioners *in 3 Tiers* *SEER metrics based on the newly defined set of reference hours*			
Scenarios	**1st Tier : 1st January 2015**	**2nd Tier : 1st January 2017**	**3rd Tier : 1st January 2019**
Scenario 1	* SEER MEPS : 4.0 corresponding rounded SCOP : 3.2 * EER MEPS : 2.5 * SEER bonus for GWP <= 675 : 10% for cooling only products 10% for reversible products	* SEER MEPS : 4.3 corresponding rounded SCOP : 3.4 * EER MEPS : 2.8 * SEER bonus for GWP <= 675 : 10% for cooling only products 10% for reversible products	* SEER MEPS : 4.5 corresponding rounded SCOP : 3.5 * EER MEPS : 2.8 * Ban of refrigerant fluids with GWP > 675
Scenario 2	* SEER MEPS : 4.3 corresponding rounded SCOP : 3.4 * EER MEPS : 2.5 * SEER bonus for GWP <= 675: 10% for cooling only products 10% for reversible products	* SEER MEPS : 4.6 corresponding rounded SCOP : 3.5 * EER MEPS : 2.8 * SEER bonus for GWP <= 675 : 10% for cooling only products 10% for reversible products	* SEER MEPS : 4.8 corresponding rounded SCOP : 3.6 * EER MEPS : 2.8 * Ban of refrigerant fluids with GWP > 675
Scenario 3	* SEER MEPS : 4.6 corresponding rounded SCOP : 3.5 * EER MEPS : 2.5 * SEER bonus for GWP <= 675: 10% for cooling only products 10% for reversible products	* SEER MEPS : 4.8 corresponding rounded SCOP : 3.6 * EER MEPS : 2.8 * SEER bonus for GWP <= 675 : 10% for cooling only products 10% for reversible products	* SEER MEPS : 4.8 corresponding rounded SCOP : 3.6 * EER MEPS : 2.8 * Ban of refrigerant fluids with GWP > 675

The values proposed for SEER ratings include a tolerance of 8 %, i.e. the SEER values should be superior or equal than 92 % of the required thresholds. This value is limited to 5 % for the EER and cooling output in standard rating conditions.

Table 7 - 14 . Proposed set of measures for gas engine products

Policy sets of measures for gas engine products *in 3 Tiers* *SEER metrics based on the newly defined set of reference hours and expressed in primary energy* *adapted from policy scenarios 2 of corresponding electric products*			
Product category	**1st Tier : 1st January 2015**	**2nd Tier : 1st January 2017**	**3rd Tier : 1st January 2019**
Gas engine air-cooled air conditioning chillers	* SEER MEPS : 1.4 * SEER bonus for GWP <= 675: 10% for cooling only products 0% for reversible products	* SEER MEPS : 1.45 * SEER bonus for GWP <= 675 : 10% for cooling only products 0% for reversible products	* SEER MEPS : 1.5 * Ban of refrigerant fluids with GWP > 675
Gas engine air-to-air air conditioners	* SEER MEPS : 1.6 corresponding rounded SCOP : 1.35 * SEER bonus for GWP <= 675: 10% for cooling only products 10% for reversible products	* SEER MEPS : 1.7 corresponding rounded SCOP : 1.4 * SEER bonus for GWP <= 675 : 10% for cooling only products 10% for reversible products	* SEER MEPS : 1.8 corresponding rounded SCOP : 1.45 * Ban of refrigerant fluids with GWP > 675

d) Proposed benchmark regarding energy efficiency and refrigerant fluids

Although the final text of the revision of the 2006/32 Energy Service Directive has not been voted yet and is still being discussed, it seems that the benchmarks reported in the Eco-design Regulations should become more stringent references for green public procurement than in the past in the coming years. In this view, the study team thinks that the proposed benchmarks in this preparatory study should be set carefully and realistically, so that they correspond to available products. Note also that as shown in Task 2, the so-called "public buildings", which correspond here mostly to office buildings used by administrations/public authorities, represent around 10% of the current product sales. But the market share of the whole public sector increases up to around 20% when including the educational and the health sectors, since they are in majority public buildings.

In this view, the study team proposes to define a low and a high benchmark[6] for each product category. The low benchmark should serve as reference for green public procurement policies, unless it can be proven after concerted discussions that the high benchmark can be achieved by several manufacturers. The low benchmark is therefore set a little below the Best Available Technology (BAT) estimated in Task 6, whereas the high benchmark corresponds to a BAT or BNAT level (Best Non yet Available Technology, which has proven to be hard to estimate).

Before 2019, the proposed benchmark values should only consider the energy consumption and so SEER. The study team does not think it is realistic to ask manufacturers to develop very efficient products close to the BAT that are the same time charged with low GWP refrigerant fluids, on the very short term, because of the current state of the market.

Energy consumption

Concerning air conditioning chillers, it has been shown in chapter 6.3 that above 200 kW cooling capacity, the best available technologies in terms of energy efficiency are centrifugal chillers equipped with magnetic bearings. These chillers are not developed below 200 kW. Although concerning SEER MEPS, it is more rational to split the market on the basis of a 400 kW cooling capacity threshold, the cooling capacity threshold for benchmarks definition should be of 200 kW, because of this technological reason. For air-cooled and water-cooled chillers, benchmarks are thus differentiated on the basis of a 200 kW threshold, rather than the 400 kW threshold that is used to define different SEER MEPS. High benchmark SEER values are then derived from Task 6. The study team proposes to take in all cases the low benchmark close to the BAT, with a SEER around 10% lower than the SEER of the Task 6 benchmark. This is then adapted to chillers < 200 kW so that it is ensured real products can reach these levels of efficiency. All SEER benchmark values are taken as constant over the time :

- The difference between the future estimated average products and the products at the level of the low SEER benchmarks remains significant even in 2019.
- It does not seem that new technological options should allow to shift to greatly higher levels of efficiency, even in 2019.

Concerning air-to-air air conditioners, the future possible market is seen as narrower in terms of energy efficiency and so SEER range. Very high SEER values cannot be defined for the low benchmark. On the basis of Task 6 calculations, the study team defines a low SEER benchmark that evolves with the SEER MEPS, whereas the high SEER benchmark remains constant at a high value.

Refrigerant fluid global warming potential

As previously explained, no GWP benchmark is defined for the 2015-2018 period, as it does not seem that a great range of products charged with low GWP refrigerant fluids and developed by several manufacturers could be massively produced at this time.

[6] It has been proposed instead to call the low benchmark GPP criteria and the high benchmark simply benchmark, which translates correctly the idea proposed.

In the view of a possible ban of refrigerant fluids with a GWP greater than the GWP of R-32 (currently 675), and as mixtures of HFC with low GWP HFO refrigerant fluids should be progressively developed, for all product categories, the benchmark value to be used from 2019 should be a global warming potential (GWP) below 150.

Summary table

For the sake of clarity, the following table summarizes all the benchmark values defined for the different relevant product categories :

Table 7 - 15 . SEER and GWP benchmarks for air conditioning chillers and air-to-air air conditioners

<table>
<tr><th colspan="4">SEER and GWP benchmarks
2 sets of low and high SEER benchmarks : gross and net values – net values indicated by (*)</th></tr>
<tr><th>Product categories</th><th>2015</th><th>2017</th><th>2019</th></tr>
<tr><td>Air-cooled chillers
< 200 kW</td><td colspan="2">High benchmark :
SEER >= 5.5/5.3(*)

Low benchmark :
SEER >= 5/4.8(*)</td><td>High benchmark :
SEER >= 5.5/5.3(*)
GWP <= 150

Low benchmark :
SEER >= 5/4.8(*)
GWP <= 150</td></tr>
<tr><td>Air-cooled chillers
> 200 kW</td><td colspan="2">High benchmark :
SEER >= 6/5.7(*)

Low benchmark :
SEER >= 5.5/5.3(*)</td><td>High benchmark :
SEER >= 6/5.7(*)
GWP <= 150

Low benchmark :
SEER >= 5.5/5.3(*)
GWP <= 150</td></tr>
<tr><td>Water-cooled chillers
< 200 kW</td><td colspan="2">High benchmark :
SEER >= 8/7(*)

Low benchmark :
SEER >= 7/6(*)</td><td>High benchmark :
SEER >= 8/7(*)
GWP <= 150

Low benchmark :
SEER >= 7/6(*)
GWP <= 150</td></tr>
<tr><td>Water-cooled chillers
> 200 kW</td><td colspan="2">High benchmark :
SEER >= 10/9(*)

Low benchmark :
SEER >= 9/8(*)</td><td>High benchmark :
SEER >= 10/9(*)
GWP <= 150

Low benchmark :
SEER >= 9/8(*)
GWP <= 150</td></tr>
<tr><td>Air-to-air air conditioners</td><td>High benchmark :
SEER >= 6.5
SCOP >= 4.5

Low benchmark :
SEER >= 5
SCOP >= 3.7</td><td>High benchmark :
SEER >= 6.5
SCOP >= 4.5

Low benchmark :
SEER >= 5.3
SCOP >= 3.9</td><td>High benchmark :
SEER >= 6.5
SCOP >= 4.5
GWP <= 150

Low benchmark :
SEER >= 5.5
SCOP >= 4.0
GWP <= 150</td></tr>
</table>

e) Labelling

No labeling requirement is proposed. There are different reasons why:
- as opposed to boilers, product category for which several different types coexist with very different primary heating efficiency (from 0,4 for electric heating until more than 1,6 for heat pumps, it gives 400 % variation of the minimum primary energy efficiency), each air conditioning product type is planned to be classified on a specific scale of limited amplitude (maximum 125 % of the MEPS SEER for air cooled chillers) ;

- SEER MEPS should again narrow the market in terms of energy efficiency, especially concerning air-to-air air conditioners, for which minimum requirements are close to the best products available today. It means that it is anticipated that the amplitude of SEER will pass from average to low. This means that the market will become more competitive and that it will be also harder to define properly energy efficiency classes, with no real effect on the EU market. Regarding chillers, the requirements are very close to the BAT levels. With 8 % tolerance, it would not be possible to define more than 2 classes byproduct category.
- It should also be reminded that the performances of these products greatly vary with the operating conditions. That is the reason why performance tables are defined in the information request. If this is reasonable to require minimum performance requirements based upon a single SEER indicator corresponding to a specific load curve, as it is profitable in most situations (as shown in Task 6), it does not mean units should be chosen on the sole basis of this indicator. Instead, specific calculations should be led on the basis of the product off design and part load data and of the real operating conditions for a given site.

f) Self regulation

No voluntary agreement has been indicated by the industry nor is presently active to the study team knowledge.

7.1.4. OTHER ECODESIGN REQUIREMENTS

Products concerned by other Ecodesign proposed requirements

Table 7 - 16 . Summary of main other proposed requirements

Description of products in the scope of ENTR Lot 6 study			Sound		Resource efficiency		Energy
Product category	Cooling principle	Sink type	Max level	Inf. request	Ext RoHS WEEE	Components Labelling	Inf. request
Air conditioning chillers	Electric	Air-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Evaporatively-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Water-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Condenserless	below 70 kW	Yes	below X kW	Yes	Yes
	Gas engine vapor compression	Air-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Water-cooled	below 70 kW	Yes	below X kW	Yes	Yes
	Absorption / adsorption	Air-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Water-cooled	below 70 kW	Yes	below X kW	Yes	Yes
Air conditioners	Electric	Air-cooled > 12 kW	below 70 kW	Yes	below X kW	Yes	Yes
		Water-cooled	below 70 kW	Yes	below X kW	Yes	Yes
	Gas engine vapor compression	Air-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Water-cooled	below 70 kW	Yes	below X kW	Yes	Yes
Air conditioning condensing unit	Electric	Air-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Water-cooled	below 70 kW	Yes	below X kW	Yes	Yes
	Gas engine vapor compression	Air-cooled	below 70 kW	Yes	below X kW	Yes	Yes
		Water-cooled	below 70 kW	Yes	below X kW	Yes	Yes
Heat rejection units	Electric	N/A	No	Yes	below X kW	Yes	Yes
	Electric	N/A	No	Yes	below X kW	Yes	Yes
	Electric	N/A	No	Yes	below X kW	Yes	Yes
Fan coil units	Electric	N/A	Yes	Yes	below X kW	Yes	Yes

N/A: not applicable | below X kW : X to be defined

Maximum sound power levels

The sound level of the products is one of the more important criteria for the design engineers to select a unit.

The A-weighted sound power level (LwA) should be used to compare different products:
LwA = 10 log (P / Pref)
where
P = absolute sound power of the product (W)
Pref = absolute reference sound power (W), equal to 1 pW (10^-12 W) (sometimes noted as dB re 10-12W)

Complete information is already supplied in the technical documentation of air conditioners and chillers and standard ratings are readily available in product information in catalogues.

However, increasing the competition on energy efficiency without fixing sound emission constraints could lead to increased sound power levels. For large size projects, it is likely that the design engineer would systematically include the assessment of both the sound power of the installation and of its performance in order to make the best choice. However, for smaller capacities, it can be assessed that the time allocated to the design of the unit may not be sufficient to take all the parameters into consideration. Hence, it appears necessary to limit the sound power levels of at least the smaller capacity range of air conditioning products.

The study team proposes to build on the ENER lot 1 proposed measures for boilers, in which maximum power requirements are fixed below 70 kW. These requirements are reported in the table below, where the rated heat output refers to standard rating conditions.

Chillers

These requirements already apply to reversible chillers up to 70 kW and should correspondingly also apply to cooling only chillers up to 70 kW. <u>It is proposed to keep the same limits for cooling only chillers, based on the rated cooling capacity (synonym of ouput) in standard rating conditions (instead of the rated heating capacity).</u> These values are reported in the table below.

Table 7 - 17 . Maximum sound power values in the boiler draft Ecodesign measures

Rated heat output ≤ 6 kW		Rated heat output > 6 kW and ≤ 12 kW		Rated heat output > 12 kW and ≤ 30 kW		Rated heat output > 30 kW and ≤ 70 kW	
Sound power level (L_{WA}), indoor measured	Sound power level (L_{WA}), outdoor measured	Sound power level (L_{WA}), indoor measured	Sound power level (L_{WA}), outdoor measured	Sound power level (L_{WA}), indoor measured	Sound power level (L_{WA}), outdoor measured	Sound power level (L_{WA}), indoor measured	Sound power level (L_{WA}), outdoor measured
60 dB	65 dB	65 dB	70 dB	70 dB	75 dB	80 dB	85 dB

Note that there is no need to ask for different sound power levels for gas engine chillers. These products are in fact directly adapted from gas engine air-to-air air conditioners (outdoor units of VRF systems with gas engine driven compressors) by fitting a water cooling module to the compressors + condenser module. For the latter, and as explained after in the air conditioners section, the noise level is lower than for equivalent electrically driven products. Eventually, in the Working Document for the implementation of the Directive 2009/125/EC, no differentiation is made on this point between electric and gas engine driven heat pumps, which are reversible chillers.

Air conditioners

Regarding the adaptation of these products to air conditioners, it should be noted that for smaller than 12 kW units, the values in the table above are in line with air conditioner requirements in the

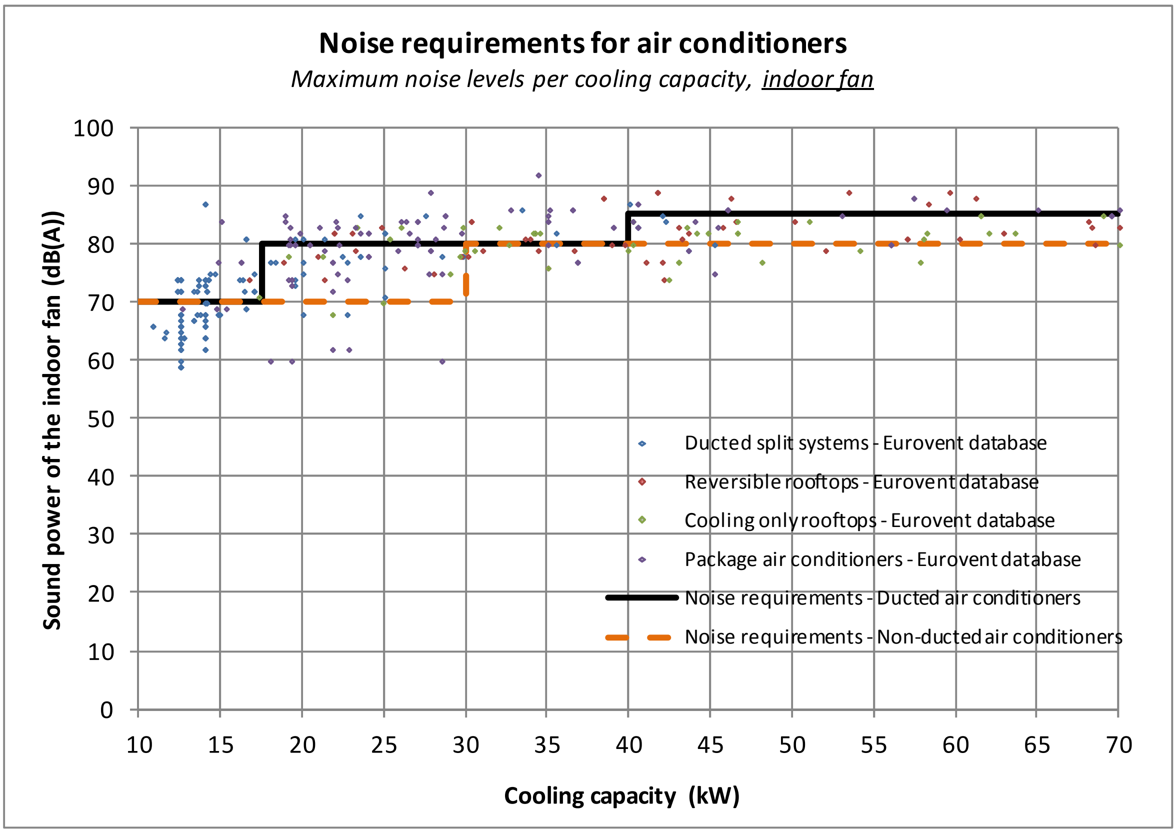
Regulation 2012/206/EC. Above that, apart from package air conditioners, there is no reason to change the outdoor sound power level requirements as outdoor units for heating in DG ENER Lot 1 and cooling products in ENTR Lot 6 are of the same design. It is proposed to keep the same limits for the outdoor sound power of air conditioners above 12 kW, based on the rated cooling capacity (capacity is a synonym of output) in standard rating conditions (instead of the rated heating output).

Concerning 12-30 kW package air conditioners, the analysis of the Eurovent database shows that nearly no product has a measured sound power level, on the outdoor side, that is lower than 75 dB, and only a few products have measured sound power levels lower than 80 dB. The 75 dB threshold is therefore too low and would discriminate this product category. It is thus proposed to ask for a 80 dB sound power threshold for the outdoor side of 12-30 kW cooling capacity package air conditioners, instead of 75 dB.

Regarding the indoor side, for air conditioners with non ducted indoor units, most indoor units are the same as for split below 12 kW. The values above 12 kW correspond to about the median sound power identified in Task 4. Hence, the requirements proposed in DG ENER Lot 1 also apply to non ducted air conditioners, changing the rated heat output by the rated cooling output in these proposed requirements for air conditioners.

Nevertheless, these latter sound power requirements appear too high regarding air conditioner which are ducted on the indoor side ; these products may be ducted package air conditioners, ducted split or rooftop. For these products, the graph below shows the sound power in-duct of products in the ECC[7] catalogue in 2010 and the proposed maximum sound power proposed by the study team. These values have been designed to be compatible with the minimum requirements in terms of energy efficiency.

Figure 7 - 1 . Comparison of noise requirements for indoor ducted air conditioners and product performances (source Eurovent Certification Company online catalogue, 2010)



[7] Eurovent Certification Company

The final proposed maximum requirements regarding sound power for air conditioners are included in the table below.

As for air conditioning chillers, there is no reason to ask for different sound power requirements for gas engine air conditioners than for electrical air conditioners, at the level of their compressors + outdoor fan(s). Current gas engine products for which the study team has found technical documentation display lower sound levels than the corresponding electrical products. The difference in sound pressure levels is for instance around 5 dB(A), which translates also in lower sound power levels. Eventually, both product categories use the same types of indoor units : there are strictly no differences at the level of their indoor fans.

Proposed sound power requirements

The remarks made in Task 4 concerning old products and currently sold products show that for air-cooled chillers, products with cooling capacities below 70 kW have become, on average, at least 3 dB(A) quieter in 8 years, with gains greater than 5 dB(A) around some cooling capacity levels. This has happened without any regulatory incentive to enhance the sound characteristics of these products. Concerning air conditioners, sound characteristics have not evolved over a decade, but between ranges of similar products sold by different manufacturers, a few dB(A) differences can be noticed.

Sufficient data to conduct a statistical analysis has not been found for water-cooled chillers. However, the proposed sound power requirements apply only to products with a cooling capacity lower than 70 kW, which correspond to less than 5% of the total water-cooled chiller market, according to Task 2 data.

In Task 5 and Task 6, it has been shown that there is no technological or economical barrier from manufacturers' side to ensure a slight decrease in the sound power levels of the products, still meaning a few dB(A). In Task 6, LCC results for 100 kW air-cooled chillers have not been significantly affected when applied to low noise and extra low noise versions of these products. With the similarities in the design of scroll compressors and condenser fans that equip air-to-air air conditioners and air-cooled chillers, the observations made in Task 6 for air-cooled chillers can also be transposed to air conditioners.

Therefore, it is realistic to have a limited evolution of maximum sound power thresholds for ENTR Lot 6 products. A 2 dB(A) decrease in maximum sound power thresholds is proposed over a 4 years period and so between 2015 and 2019. An intermediate 1 dB(A) decrease can be possibly asked for 2017.

Table 7 - 18 . Proposed maximum sound power requirements for ENTR Lot 6 products except the indoor side of indoor ducted air conditioners

Sound power level requirements : maximum sound power levels (L_{WA}) Cooling only chillers & air conditioners (outdoor side and non ducted indoor side) & fan coil units (non ducted indoor)						
Rated cooling output	**1st Tier : 1st January 2015**		**2nd Tier : 1st January 2017**		**3rd Tier : 1st January 2019**	
	Indoor measured	Outdoor measured	Indoor measured	Outdoor measured	Indoor measured	Outdoor measured
≤ 6 kW	60 dB	65 dB	59 dB	64 dB	58 dB	63 dB
> 6 kW and ≤ 12 kW	65 dB	70 dB	64 dB	69 dB	63 dB	68 dB
> 12 kW and ≤ 30 kW	70 dB	75 dB / 80 dB(*)	69 dB	74 dB / 79 dB(*)	68 dB	73 dB / 78 dB(*)
> 30 kW and ≤ 70 kW	80 dB	85 dB	79 dB	84 dB	78 dB	83 dB

(*) Maximum sound power levels for the outdoor side of package air conditioners. As the initial requirement is 5 dB greater than for the other products, this 5 dB is kept for the 2nd Tier and the 3rd Tier.

Regarding ducted air conditioners, the outdoor requirements are the same as in the table above. Regarding the indoor sound power, the proposed values are summarized in the table below.

Table 7 - 19 . Proposed maximum sound power requirements for the indoor side of ENTR Lot 6 indoor ducted air conditioners

Sound power level requirements : in duct maximum sound power levels (L_{WA}) Indoor side of indoor ducted air conditioners & ducted fan coil units → indoor side			
Rated cooling output	**1st Tier : 1st January 2015**	**2nd Tier : 1st January 2017**	**3rd Tier : 1st January 2019**
≤ 6 kW	60 dB	59 dB	58 dB
> 6 kW and ≤ 12 kW	65 dB	64 dB	63 dB
> 12 kW and ≤ 17.5 kW	70 dB	69 dB	68 dB
> 17.5 kW and ≤ 40 kW	80 dB	79 dB	78 dB
> 40 kW and ≤ 70 kW	85 dB	84 dB	83 dB

Air conditioning condensing units

There is no reason not to extend the proposed outdoor maximum sound power levels to all types of heat rejection units.

Consequently, the outdoor maximum sound power levels should also apply to air conditioning condensing units (electric and gas engine)

Heat rejection units

There is no reason not to extend the proposed outdoor maximum sound power levels to all types of heat rejection units.

Consequently, the outdoor maximum sound power levels should also apply to heat rejection units.

Fan coils

There is no reason not to extend the proposed requirements for air conditioners indoor to fan coils.

Consequently, the same distinction between ducted and non ducted fan coils as between ducted and non ducted air conditioners should be respected, as the indoor unit of these products is quite similar to the one of split air conditioners.

Benchmarks

To define realistic benchmarks, the study team has calculated for Eurovent certified products the difference between median outdoor/indoor measured sound power levels and tenth percentile sound power levels (tenth percentile means that 90% of the products have higher sound power levels, and 10% of the products have lower sound power levels). Minimum sound power levels have not been considered, as some values can be mistakenly reported, which biases the statistical analysis (for instance, sound pressure values may be reported instead of sound power values). This has been done per product category (air-cooled chillers, single split systems, rooftop air conditioners ...) on the basis of the 2012 Eurovent database, and per cooling capacity category (<= 6 kW and 6-12 kW for air-cooled chillers and fan coil units, 12-30 kW and 30-70 kW for all product categories including the different types of air conditioners).

The minimum difference between the median and the tenth percentile that has been observed is 2 dB, and the maximum difference is 5 dB. On average, it can be considered that the difference is around 3 dB. Therefore, the study team proposes for all categories benchmark sound power levels that are 3 dB lower than the maximum sound power levels required, which leads to the following tables :

Table 7 - 20 . Proposed sound power benchmarks for ENTR Lot 6 products except the indoor side of indoor ducted air conditioners

Sound power benchmarks (L_{WA}) Cooling only chillers & air conditioners (outdoor side and non ducted indoor side) & fan coil units (non ducted indoor)						
Rated cooling output	**1st Tier : 1st January 2015**		**2nd Tier : 1st January 2017**		**3rd Tier : 1st January 2019**	
	Indoor measured	Outdoor measured	Indoor measured	Outdoor measured	Indoor measured	Outdoor measured
≤ 6 kW	57 dB	62 dB	56 dB	61 dB	55 dB	60 dB
> 6 kW and ≤ 12 kW	62 dB	67 dB	61 dB	66 dB	60 dB	65 dB
> 12 kW and ≤ 30 kW	67 dB	72 dB / 77 dB(*)	66 dB	71 dB / 76 dB(*)	65 dB	70 dB / 75 dB(*)
> 30 kW and ≤ 70 kW	77 dB	82 dB	76 dB	81 dB	75 dB	80 dB

(*) Sound power benchmarks for the outdoor side of package air conditioners. The reasoning is the same as for maximum sound power levels.

Table 7 - 21 . Proposed sound power benchmarks for the indoor side of ENTR Lot 6 indoor ducted air conditioners

Sound power benchmarks (L_{WA}) Indoor side of indoor ducted air conditioners & ducted fan coil units → indoor side			
Rated cooling output	**1st Tier : 1st January 2015**	**2nd Tier : 1st January 2017**	**3rd Tier : 1st January 2019**
≤ 6 kW	57 dB	56 dB	55 dB
> 6 kW and ≤ 12 kW	62 dB	61 dB	60 dB
> 12 kW and ≤ 17.5 kW	67 dB	66 dB	65 dB
> 17.5 kW and ≤ 40 kW	77 dB	76 dB	75 dB
> 40 kW and ≤ 70 kW	82 dB	81 dB	80 dB

Air quality requirements

The air quality degradation environmental impact does not apply to electrically driven products. However, it is of concern for gas engine driven products and absorption chillers.

The air emissions of interest are the NOx emissions, the CO emissions and the HC emissions. Particulate matter is not an issue for these units burning gas. Little or no information could be found on the emissions of products concerned in this lot. One of the problems mentioned previously is the absence of test standards to do so, although the procedures applied for other products could be easily transposed.

On this topic, the only reference at the study team's disposal is the Working Document for the implementation of the Directive 2009/125/EC for space heaters and combination heaters. In this document, the emissions of nitrogen oxides, expressed in nitrogen dioxide, should not exceed 240 mg/kWh fuel input for heat pump space heaters equipped with internal combustion engine using gaseous fuels, meaning gas engine driven heat pumps.

As previously explained, gas engine Lot 6 products are identical in terms of gas engine + compressors + condenser combination. Manufacturers keep exactly the same components : they fit to this "outdoor unit module" a refrigerant piping system or a water cooling module to get a VRF air-to-air air conditioner or an air-cooled air conditioning chiller, and the latter is identical to an air-to-water heat pump space heater if it is reversible. It is also very similar if it is a cooling product.

As a conclusion, the study team proposes to keep the 240 mg/kWh maximum nitrogen oxide emissions requirement for Lot 6 gas engine air-to-air air conditioners and air-conditioning chillers, which is planned for 2017 onwards. So it is proposed to start with these requirements only in 2017 (no requirement above information requirement in 2015) and to keep the same value in 2019.

Resource efficiency

Although the impact of the production and recycling phases (except refrigerant fluids) is thought to be low, two proposals have been made during the study to improve the recycling of products in scope. This regards the extension of the WEEE and ROHS directive to air conditioning products and the labeling of product parts with precise composition information in order to ease the recycling process.

Extension of the WEEE and ROHS directive to air conditioning products

There are very different viewpoints on whether to include or not other air-conditioning products than portable units within the WEEE and RoHS scopes.

During the review of the WEEE directive, EPEE has clearly stated its viewpoint (August 2006). The term 'fixed installations' is too broad and being used to claim exemptions. The introduction of a distinction between 'appliances' and 'systems' is seen as necessary. Moreover, it is thought that the spirit of the WEEE directive concerns primarily household appliances that can be purchased in retail stores and installed and uninstalled by consumers, which is not the case of systems. The major concern is that the present situation creates great uncertainty for Member States and industry. As a consequence, the EPEE does not believe that large-scale chillers and HVAC systems (including rooftops and large non-portable split systems) to be bound by the WEEE directive.

The main arguments in favour of the exemption of fixed air-conditioning products are that :

- The initial goal of the WEEE directive was to prevent households and private individuals (private customers, contrary to professionals) from sending indirectly waste appliances to landfills through garbage collectors. On the contrary, as fixed installations must be dismantled by professionals, it is thought that the latter send them to scrap yards and steel mills to make profit. They should be therefore properly recycled, processed or shredded.
- Chillers and air-conditioning systems are made with substantial amounts of steel, aluminium and copper, as stated by the EPEE and reported in task 3 of this report. These materials are valuable and so should be easily recycled and bought for scrap when the air-conditioning system/product is dismantled.
- The current F-gas regulation is commonly seen as very stringent, or at least stringent enough on the collection of refrigerants, which are reused or destroyed. It is indeed compulsory that refrigerant-handling is made by certified professionals.

Yet, there is a gap between what are thought to be common practices and real ones. In this respect and by matter of example, though chapter 3.3 of Task 3 of this study focuses on refrigerant/ODS end-of-life, some of the reported issues similarly concern the end-of-life of the corresponding products once discharged. There is no nationally organized collection program for waste air-conditioning commercial equipment in part of the EU, which clearly raises the issue of uncontrolled and unmanaged waste streams of ENTR Lot 6 products at their end-of-life.

Some Member States have already enlarged the initial scope and included air conditioners, making hard to believe that they will go back in time through the transposition of the recast WEEE and RoHS directives. Some major air-conditioning equipment manufacturers are, as well, already complying with these directives, although there are exempted to do so in part of the EU.

Another issue here is that some products/elements such as scroll compressors are used within small-capacity chillers, which are exempted from the directives, and the cooling generation units of DXair conditioners, which fall under the directives in some countries. From the angle of its Bill-of-Materials, a scroll compressor used in chillers is very similar to a scroll compressor used in a DX-system. Similarly, fan-coil units are not very different from the indoor units of split-systems and VRFs, but as they are products that are part of a fixed installations, they are not covered by the directives.

The study team shows in the Task 2 report that around one third of ENTR Lot 6 products sold in the EU are sold for refurbishment purposes. It is also reported that nearly half of the chiller units sold in the EU have a capacity lower than 17.5 kW. This implies that the corresponding air-conditioning systems are only equipped with a few terminal units, mostly fan-coils, whose casing is often primarily made of plastics rather than metals. Such a system might not allow to make a consequent profit through its sending to scrap yards, especially in the case of terminal units replacement.

Moreover, most air-conditioning products covered by ENTR Lot 6 now use programmable controllers, sensors & transducers (pressure, flow and temperature), electric motors, control panels and interfaces (as quoted before) which are very close to similar products that fall under the scope of the WEEE and RoHS directive, when they can be used on their own as 'finished products' (see the Orgalime guide with the distinction between components of industrial installations and finished products).

Eventually, only approximately a third of the waste electrical and electronic equipment in the EU is reported to be treated according to the legislation. The rest goes to landfills (13%) and out of the remaining 54%, a large amount is potentially subject to sub-standard treatment inside or outside the EU. Illegal trade to non-EU countries is still widespread.

Therefore, the possible inclusion of part or all of ENTR Lot 6 products within the scope of WEEE and RoHS directives seems feasible. Because it can be cost-effective to recycle high cooling capacity units, as reported in Task 3 chapter 3.2, a cooling capacity threshold, below which ENTR Lot 6 products would fall under the scope of the directives, might be worth being discussed. Some current RoHS exemptions, which look necessary and justified, would not have to be modified.

Labelling of the component parts of products

The study team proposes also to open the discussion on the implementation of additional requirements in view of improvements in the recycling of ENTR Lot 6 products, as stressed out by the ASHRAE:
- Manufacturers could be made responsible for labelling the component parts of their machines.
- The labelling should be very specific, differentiating for instance among types of plastics, metals, constituencies of composite materials.
- Materials should be classified regarding their ability to be recycled and by their compatibility with other materials (certain thermoplastics may be recycled together, while others should be separated).

Obviously, it is thus probable that more attention is paid to a proper recycling of products from an AC system with a high cooling capacity and similarly to cold production units with high cooling capacities, rather than terminal units or refrigerant-based systems with limited capacities. As for the previous point, a cooling capacity ceiling might be worth being discussed.

Information requirements

The minimum information requirements are defined hereafter by product category.

Air conditioners and chillers

The information requirement for air conditioners should comprise the same information as required in the regulation 2012/206/EC but for the 3 climates. For reversible heating product, the heating information should also be required (and is defined in Lot 1 for reversible chillers and in Lot 21 for air conditioners).

Information requirement is shown below for air conditioners. Although it is intended to cover electric and gas engine air conditioners, further adaptation may be required for the latter.
Note that for gas engine air conditioners NOx and CO emission information requirement is added.

Figure 7 - 2 . Information request for air conditioners (cooling mode)

Information requirements for air conditioners ***
(the number of decimals in the box indicates the precision of reporting)

SEER and EER are in primary energy for gas engine air conditioners, with PER = 2.5.

Information to identify the model(s) to which the information relates to:	

Item	symbol	value	unit
Design load			
cooling / Average / Warm	Pdesignc	x,x	kW
cooling / Colder	Pdesignc	x,x	kW
Declared capacity* for cooling, at indoor temperature 27(19)ºC and outdoor temperature Tj (Average / Warm)			
Tj=35ºC	Pdc	x,x	kW
Tj=30ºC	Pdc	x,x	kW
Tj=25ºC	Pdc	x,x	kW
Tj=20ºC	Pdc	x,x	kW
Declared capacity* for cooling, at indoor temperature 27(19)ºC and outdoor temperature Tj (Cold)			
Tj=28ºC	Pdc	x,x	kW
Tj=25ºC	Pdc	x,x	kW
Tj=22ºC	Pdc	x,x	kW
Tj=19ºC	Pdc	x,x	kW
Cycling interval capacity			
cooling (Average / Warm)	Pcyc	x,x	kW
cooling (Cold)	Pcyc_c	x,x	kW
Degradation co-efficient cooling**	Cdc	x,x	-
Electric power input in power modes other than 'active mode'			
off mode	P_{OFF}	x,x	kW
standby mode	P_{SB}	x,x	kW
thermostat-off mode	P_{TO}	x,x	kW
crankcase heater mode	P_{CK}	x,x	kW
Capacity control (indicate one of three options)			
fixed	Y/N		
staged	Y/N		
variable	Y/N		

Item	symbol	value	unit
Seasonal efficiency			
cooling / Average	SEER	x,x	-
cooling / Warmer	SEER	x,x	-
cooling / Colder	SEER	x,x	-
Declared energy efficiency ratio*, at indoor temperature 27(19)ºC and outdoor temperature Tj			
Tj=35ºC	EERd	x,x	-
Tj=30ºC	EERd	x,x	-
Tj=25ºC	EERd	x,x	-
Tj=20ºC	EERd	x,x	-
Declared energy efficiency ratio*, at indoor temperature 27(19)ºC and outdoor temperature Tj			
Tj=28ºC	EERd	x,x	-
Tj=25ºC	EERd	x,x	-
Tj=22ºC	EERd	x,x	-
Tj=19ºC	EERd	x,x	-
Cycling interval efficiency			
cooling (Average / Warm)	EERcyc	x,x	-
cooling (Cold)	EERcyc_c	x,x	-
Annual electricity consumption			
cooling (Average / Warm)	Q_{CE}	x	kWh/a
cooling (Cold)	Q_{CE_C}	x	kWh/a
Other items			
Sound power level (indoor/outdoor)	L_{WA}	x,x / x,x	dB(A)
Global warming potential	GWP	x	kgCO2 eq.
Rated air flow (indoor/outdoor)	-	x / x	m3/h
Nox emissions (mg / kWh input GCV)	-	x / x	mg/kWh
CO emissions (mg / kWh input GCV)	-	x / x	mg/kWh

Contact details for obtaining more information	Name and address of the manufacturer or of its authorised representative.
*= For staged capacity units, two values divided by a slash (‘/’) will be declared in each box in the section “Declared capacity of the unit” and "declared EER" of the unit.	
**= If default Cd=0,25 is chosen then (results from) cycling tests are not required. Otherwise either the heating or cooling cycling test value is required.	
*** For multisplit appliances, data shall be provided at capacity ratio of 1.	

Information requirement is shown below for chillers. Note that for combustion chillers chillers, the NOx and CO emission information is added. Although it is intended to cover electric, gas absorption / adsorption, heat driven absorption / adsorption and gas engine chillers, further adaptation may be required for other than electric chillers.

Figure 7 - 3 . Information request for chillers (cooling mode)

Information requirements for chillers (the number of decimals in the box indicates the precision of reporting)							
SEER and EER are in primary energy for gas engine chillers, with PER = 2.5.							
Information to identify the model(s) to which the information relates to:							
"air cooled" or "water cooled"							
Item	**symbol**	**value**	**unit**	**Item**	**symbol**	**value**	**unit**
Design load				**Seasonal efficiency**			
cooling / Average / Warm	Pdesignc	x,x	kW	cooling / Average	SEER	x,x	-
cooling / Colder	Pdesignc	x,x	kW	cooling / Warmer	SEER	x,x	-
				cooling / Colder	SEER	x,x	-
Declared capacity* for cooling, at evaporator leaving temperature 7ºC and outdoor temperature Tj (Average / Warm)				Declared energy efficiency ratio*, at evaporator leaving temperature 7ºC and outdoor temperature Tj			
Tj=35ºC / Twj = 30 °C	Pdc	x,x	kW	Tj=35ºC / Twj = 30 °C	EERd	x,x	-
Tj=30ºC / Twj = 26 °C	Pdc	x,x	kW	Tj=30ºC / Twj = 26 °C	EERd	x,x	-
Tj=25ºC / Twj = 22 °C	Pdc	x,x	kW	Tj=25ºC / Twj = 22 °C	EERd	x,x	-
Tj=20ºC / Twj = 18 °C	Pdc	x,x	kW	Tj=20ºC / Twj = 18 °C	EERd	x,x	-
Declared capacity* for cooling, at evaporator leaving temperature 7ºC and outdoor temperature Tj (Cold)				Declared energy efficiency ratio*, at evaporator leaving temperature 7ºC and outdoor temperature Tj			
Tj=28ºC / Twj = 23 °C	Pdc	x,x	kW	Tj=28ºC / Twj = 23 °C	EERd	x,x	-
Tj=25ºC / Twj = 21 °C	Pdc	x,x	kW	Tj=25ºC / Twj = 21 °C	EERd	x,x	-
Tj=22ºC / Twj = 19 °C	Pdc	x,x	kW	Tj=22ºC / Twj = 19 °C	EERd	x,x	-
Tj=19ºC / Twj = 17 °C	Pdc	x,x	kW	Tj=19ºC / Twj = 17 °C	EERd	x,x	-
Cycling interval capacity				Cycling interval efficiency			
cooling (Average / Warm)	Pcyc	x,x	kW	cooling (Average / Warm)	EERcyc	x,x	-
cooling (Cold)	Pcyc_c	x,x	kW	cooling (Cold)	EERcyc_c	x,x	-

Degradation coefficient cooling (measured)	Cc	x,x	-

Electric power input in power modes other than 'active mode'			
off mode	P_{OFF}	x,x	kW
standby mode	P_{SB}	x,x	kW
thermostat-off mode	P_{TO}	x,x	kW
crankcase heater mode	P_{CK}	x,x	kW

Annual electricity consumption			
cooling (Average / Warm)	Q_{CE}	x	kWh/a
cooling (Cold)	Q_{CE_C}	x	kWh/a

Capacity control (indicate one of three options)	
fixed	Y/N
staged	Y/N
variable	Y/N

Other items			
Sound power level (indoor/outdoor)	L_{WA}	x,x / x,x	dB(A)
Global warming potential	GWP	x	kgCO2 eq.
Rated air flow (indoor/outdoor)	-	x / x	m3/h
Nox emissions (mg / kWh input GCV)	-	x / x	mg/kWh
CO emissions (mg / kWh input GCV)	-	x / x	mg/kWh

Contact details for obtaining more information	Name and address of the manufacturer or of its authorised representative.
*= For staged capacity units, two values divided by a slash (‘/’) will be declared in each box in the section “Declared capacity of the unit” and "declared EER" of the unit.	

In addition, it is very important to ensure that enough information is available to the design engineer in order he may make the best system design (within the EPBD national legislations).

Most engineering manuals contain the necessary information to size the products according to the (sensible and latent) cooling and/or heating capacity. However, to make an optimal design in view of reducing the energy consumption, not only the design information should be supplied but also the energy consumption detailed information for a specific design. This means that once the system cooling load is established for a given climate/system/building, it is then necessary to evaluate the performance of the unit for this specific building load. This building load is not the average load curve of prEN14825 standard ; cooling may be required at much lower outdoor temperature and some chillers may operate at very low load at high outdoor temperature (several chillers working in parallel).

Every project is thus specific and requires different part load / source temperature / sink temperature variations, as a minimum (in some cases, air or water flow rate variations, the addition of antifreeze solutions may also impact the performance).

This set of information is clearly the minimum input required to compute the energy consumption of products in the frame of the EPBD. And it would be an important step forward to generate a standard format for this minimum set of information that is to be generated and published by manufacturers and then could be used as an harmonized input data to all national building regulations.

Hence it is proposed to standardize the minimum following information to be published for cooling generators under the frame of the proposed measures, so as to enable energy optimal design and to make the best choice between competing machines in the frame of the Energy Performance of Building Directive. Minimum information required is described hereunder for chillers and air conditioners. Note that the same information should be adapted also to other products not yet considered here (absorption chillers, water cooler air conditioners, gas engine air conditioners).

As a standardized input for the EPBD, it could be included in the standard EN 15243:2007 - Ventilation for buildings - Calculation of room temperatures and of load and energy for buildings with room conditioning systems. This could then be a standardized input for informatics linkage with building/systems regulatory tools at national levels.

A technical working group including manufacturer associations might be necessary to associate reasonable tolerances for these set of data and to manage the information chain from declaration till use.

Chillers – performance map information requirements

This proposal is inspired from (planned) optional requirements in the ISO working document PWD 928 for chillers (ISO, 2006).

Published ratings shall include application ratings (at other than standard rating conditions) within the operating limits of the equipment for a variation of:
- Chilled water temperature (indoor side), in increments of 2 °C or less,
- Condenser inlet temperature (whether air-cooled, water-cooled or evaporatively-cooled, in increments of 5 °C or less,
- Part load information (100 % load refers to the full rated capacity): for discrete step unloading machines part load rating data shall be provided at each stage of capacity ; for continuously variable unloading machines part load data shall be provided at a minimum of 75%, 50%, 25% or to the minimum load point ;

These ratings include cooling capacity, power input and COP at each point.

Air conditioners – performance map information requirements

The same requirement is adapted for air conditioners below.

Published ratings shall include application ratings (at other than standard rating conditions) within the operating limits of the equipment for a variation of:
- Indoor air temperature (wet bulb), in increments of 2 °C or less,
- Condenser inlet temperature (whether air-cooled – dry bulb air temperature, water-cooled – water temperature or evaporatively-cooled – wet bulb temperature), in increments of 5 °C or less.
- Part load information (100 % load refers to the full rated capacity): for discrete step unloading machines part load rating data shall be provided at each stage of capacity ; for continuously variable unloading machines part load data shall be provided at a minimum of 75%, 50%, 25% or to the minimum load point.

These ratings include cooling capacity, power input and COP at each point.

Fan coils

Energy performance

At standard rating conditions and for each fan speed (and at least 3 speeds for inverter controlled units, minimum, maximum, and intermediate), the following information should be supplied:
- EER (Energy efficiency ratio)
- Cooling output (sensible and latent) in W
- Electricity consumption in W

In addition, the standby consumption should also be indicated in W.

Sound power

At standard rating conditions and for each fan speed, the sound power level in dB(A).

Heat rejection units

Energy performance

At standard rating conditions and for each step of capacity control (and at least 3 speeds for inverter controlled units, minimum, maximum, and intermediate), the following information should be supplied:
- EER (Energy efficiency ratio)

- Cooling output in W
- Electricity consumption in W

In addition, the standby consumption should also be indicated in W.

Sound power

At standard rating conditions and for each fan speed, the sound power level in dB(A).

7.1.5. ALTERNATIVE POLICIES

In the previous sections, various policy options to reduce the environmental impacts of central air conditioning products have been discussed regarding energy efficiency, air emissions, refrigerants, material consumption and waste production. The alternatives to the policy options discussed are "self regulation" or "no EU action".
- "Self regulation" is an available option foreseen by the Ecodesign Directive as an alternative to mandatory implementing measures. Industry in this case would be responsible for proposing eligible measures for the products in the market responding to the Ecodesign Directive criteria.
- "No EU action" is an option if the market, energy consumption or saving potential of the products examined are not significant enough to justify an implementing measure.

The total consumption of these products is about 110 TWh yearly, including the cooling and heating modes. The cooling part represents about half the total energy consumption. The market analysis shows a constant increase of sales and stock of these products, and consequently an increase of total energy consumption in the EU. This is reinforced by the progression of reversible products, knowing that average consumption in heating mode is about twice the energy consumption in cooling mode.

It should be added that the improvement potential in cooling mode per product at minimum LCC is close to 20 % and can reach 30 % for some products and that BAT level are 30 to 40 % more efficient than present average products.

The total savings potential of the cooling mode per se are important enough to justify the establishment of implementing measures, either by self regulation or by mandatory regulation issued by the Commission.

So far, the manufacturers have not started any voluntary agreement procedures, even though the European companies are actively involved in the Ecodesign regulatory process and in R&D.

Hence it does not seem that "self regulation" or "no EU action" may be an option.

7.2. IMPACT ANALYSIS

7.2.1. DESCRIPTION OF THE SCENARIOS

Main scenarios hypotheses

General hypotheses

As reported in Task 4, the reference year at which the base-cases are considered as being representative of the EU market is 2010.

The study team chooses the parameters so that he impacts of the scenarios are in line with the hypotheses made to compute LCC values in Task 6 and with the discussions in chapter 7.1.

Product lives

On the basis of Task 4, it is considered that :

- The product life of air-cooled chillers with a cooling capacity lower than 400 kW is 15 years.
- The product life of air-cooled chillers with a cooling capacity greater than 400 kW is 20 years.
- The product life of water-cooled chillers with a cooling capacity lower than 400 kW is 20 years.
- The product life of water-cooled chillers with a cooling capacity greater than 400 kW is 25 years.
- The product life of all air conditioners considered is 15 years.

Inputs for the economic analysis

On the basis of the hypotheses made in Task 6 for LCC calculations, the electricity tariff is therefore :
- 0.12 c€/kWh for air-cooled chillers and water-cooled chillers with a cooling capacity lower than 350 kW
- 0.10 c€/kWh for water-cooled chillers with a cooling capacity greater than 350 kW
- 0.14 c€/kWh for air conditioners

The increase rate of the electricity price, independently of the inflation rate, is supposed to be of 6 % from 2005 onwards, and of 4% before.

The elasticity in product investment costs is based upon the Task 6 results : for products with efficiency levels above the base-case, a correlation is drawn to estimate the increase in total investment costs of future products. For products sold before 2010, it is supposed that a 1% difference in SEER leads proportionally to a 1% difference in investment costs.

An inflation rate of 2 % is retained over the whole 1990-2025 period of the scenarios and applied to investment costs, maintenance costs and electricity prices.

Sales and stock values

Based on the Task 2 results, the following data is used for the baseline sales and stock figures over the 1990-2025 period. It should be noticed that the impact of the economic crisis is included in the sales scenarios although it is supposed that sales return to normal after 2010, which might be a bit optimistic retrospectively.

Table 7 - 22 . 1990-2025 product sales for electric air conditioning chillers and air conditioners

Year	1990	1995	2000	2005	2010	2015	2020	2025
SALES (GW)								
Electric air conditioners	2.3	4.9	7.8	8.8	10.6	11.6	12.3	12.6
Electric chillers	3.12	4.84	7.20	9.67	9.29	11.6	13.3	15.2

SALES (Numbers - Millions)								
Electric air conditioners	0.098	0.21	0.35	0.39	0.46	0.50	0.53	0.55
Electric chillers	0.023	0.038	0.061	0.083	0.082	0.098	0.12	0.14

Table 7 - 23 . 1990-2025 product stock for electric air conditioning chillers and air conditioners

Year	1990	1995	2000	2005	2010	2015	2020	2025
STOCK (GW)								
Electric air conditioners	10.5	25.6	51.5	79.4	104.7	123.0	139.9	159.3
Electric chillers	68.6	84.6	109.0	143.5	181.9	216.4	249.5	279.2
STOCK (Numbers - Millions)								
Electric air conditioners	0.42	1.0	2.1	3.3	4.3	5.0	5.6	6.2
Electric chillers	0.51	0.62	0.81	1.2	1.5	1.8	2.2	2.4

Energy consumption

In the scenarios, the energy consumption of the products in stock in cooling or heating mode is simply computed as the product of the average SEER/SCOP of the stock times the equivalent active hours in cooling/heating. The equivalent active hours are of <u>600 hours in cooling mode and of 1400 hours in heating mode for reversible products</u>.

The study team does not plan here a significant evolution of the equivalent average cooling/heating requirements (loads) for the products. The main reason behind this is that most products are installed in existing buildings for the first time or as replacement. On the contrary, new products in new buildings represent a minor and decreasing proportion of the sales. Hence, the evolution of the cooling/heating requirements relies mainly on the evolution of the cooling/heating requirements in the building stock, which evolution is very low. At longer term, because of global warming, local heat island effects and also of more insulated buildings, the sum of cooling + heating requirements will evolve towards higher cooling requirements and lower heating requirements. These effects are not taken into account in the scenarios, which stop only in 2025. Indeed, this is a mid-term time horizon.

Regarding efficiency, the following hypothesis are made for each scenario :

- At Tiers 1, 2 and 3, it is considered that the product that should be representative of the market (future equivalent base-case) has a SEER that is greater than the SEER MEPS by 0.1, 0.2, 0.2, 0.3, 0.1, respectively for air-cooled chillers < 400 kW, air-cooled chillers > 400 kW, water-cooled chillers < 400 kW, water-cooled chillers > 400 kW, air conditioners.

- The SEER of the average sales product increases linearly between 2010 and Tier 1 (2015), Tier 1 and Tier 2 (2017), Tier 2 and Tier 3 (2019). It continues to increase similarly in 2020, then reaches a constant level between 2021 and 2025. The rationale behind this is that the market should be then narrower in terms of SEER range than the current market, because of the SEER MEPS requirements and an increased competition.

- For the business-as-usual scenario, it is considered that the average product sold in the EU should have a SEER equal to the Tier 1 SEER MEPS of scenario 1 in 2020, and of the Tier 2 SEER MEPS of scenario 1 in 2025 (scenario 1 being the less constraining/ambitious scenario of the three proposed scenarios). Therefore, the average sales product keeps on improving, but at a low pace.

- A “freeze” scenario is also computed as an alternative to the business-as-usual scenario, the latter accounting for continued technical advances as observed in the past 10 years. In this case, it is considered that the average efficiency of the sold products does not evolve from 2012 onwards. This means that the average SEER of sold products is the same in 2025 as in 2012. Gains in electricity consumption and CO_2 emissions are then greater when the policy scenarios are compared with the freeze scenario rather than the business-as-usual scenario.

Hypothesis related to the direct equivalent CO2 emissions

Regarding direct equivalent emissions, the rates of refrigerant leakage and end-of-life losses are those defined for the average refrigerant scenario in Task 6, which corresponds to the average between the two refrigerant scenarios defined in Task 2 (low losses, high losses). This leads to an underestimate of direct equivalent emissions for the 1990-2005 period, but a plausible estimate over the 2005-2025 period.

For sales and stock products, the market shares of the following refrigerant fluids are estimated on the basis of refrigerant fluids inventories done by Armines for the French market over the past 15 years :

- Shares of R-12, only in the stock of products (it is considered that sales have stopped at the beginning of the 1990-2000 period). They become nil around 2010.
- Shares of R-22. Sales stop between 2001 and 2004, depending on the product categories. The shares in the stock become nil between 2020 and 2025.
- Shares of R-407C, for which sales start around 1998.
- Shares of R-410A, for which sales start around 2001.
- Shares of low GWP refrigerant fluids (GWP lower than 10). They are considered as constant over the 1990-2012 period and related to products charged with ammonia or propane. They increase from 2013 onwards for the three policy scenarios, because of the ban of high GWP refrigerant fluids in 2019.
- Shares of R-32, for which sales are nil before 2014. It is then considered that because of the 2019 ban, their sales increase relatively quickly from 2014 to 2019.

The shares of R-32 and low GWP refrigerant fluids in 2018 sales is generally around 30% of the market, whereas it becomes of 100% in 2019 because of the ban. The transition is therefore sharp between 2018 and 2019, which corresponds to what the study team has observed for the period of the HCFCs ban and so R-22 ban, as well as for the CFCs ban a few years before.

Calculations are done with $GWP_{100\ years}$ and $GWP_{20\ years}$ values to characterize the possible impact of refrigerant fluid losses over different time scales, which leads to different TEWI results :

- In the first case, the figures reported for one year show the possible equivalent global warming impact of the electricity consumption of the products in the stock and of their refrigerant losses over the following 100 years : for instance, TEWI values reported for 2015 correspond to the equivalent impact on global warming of the products that are operating in 2015 over the 2015-2115 time period. This is therefore characterized by X equivalent megatons of CO_2 emissions emitted in 2015 with an impact over the 2015-2115 time period.

- Similarly, in the second case, TEWI values reported for instance for 2015 correspond still to the impact on global warming of the products in use in 2015, but over the 2015-2035 time period. This is therefore characterized by X equivalent megatons of CO_2 emissions emitted in 2015 with an impact over the 2015-2035 time period.

This shows that direct equivalent emissions due to HFC refrigerant fluid losses impact more the global warming on the short term than on the long term. This is due to their short average atmospheric lifetime, which is lower than 20 years (after which, part of the HFC emitted remains in the atmosphere, but at a small concentration rate). This leads thus to higher GWP values over 20 years than over 100 years, the GWP of CO2 being 1 in both cases (GWP values characterize the equivalent impact on global warming, over a certain time period, of other gases by comparison with CO_2).

It is important to note that the common use is to do TEWI calculations with $GWP_{100\ years}$, as proposed by the IPCC. For the time being, 100 years is the recommended and recognized time horizon. TEWI calculations with $GWP_{20\ years}$ are provided for a matter of discussion on the balance between indirect and direct emissions in the short term and in a longer term.

7.2.2. SAVINGS AND IMPACTS IN THE DIFFERENT SCENARIOS

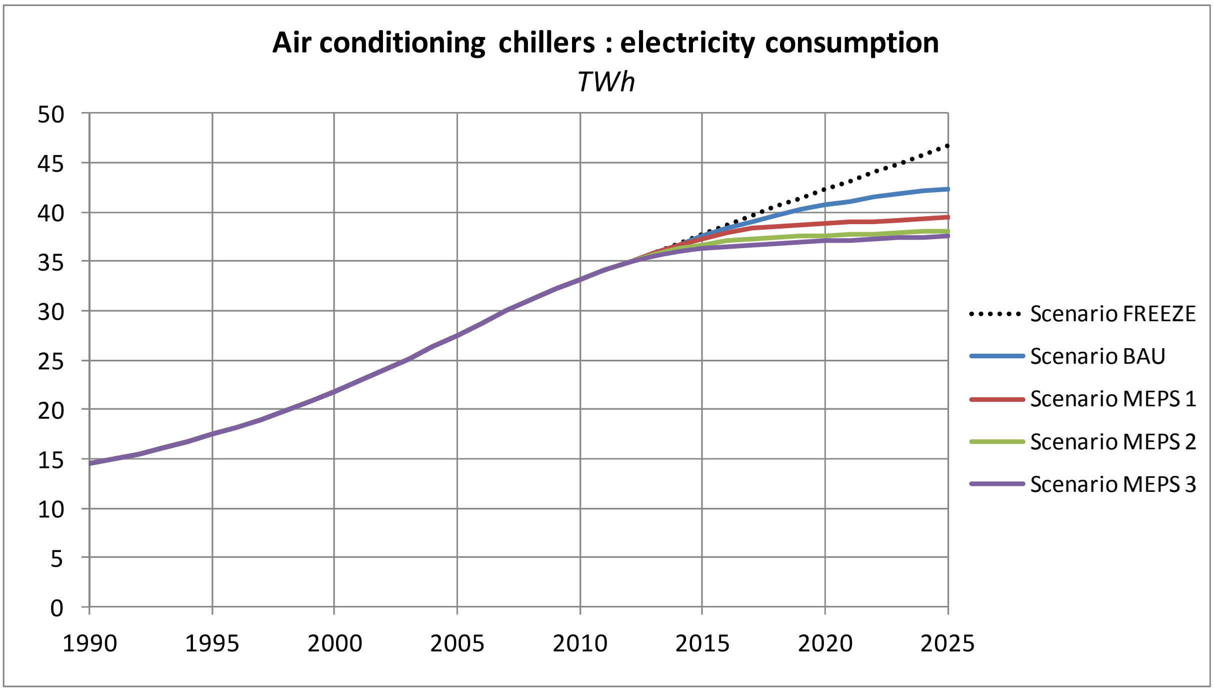
Two summary tables, one for air-conditioning chillers, the other for air-to-air air conditioners, are provided at the end of this chapter. They include key values of total electricity consumption and total equivalent CO_2 emissions for the freeze, the business-as-usual and the policy measures scenarios. Savings in electricity consumption and in equivalent CO_2 emissions are also provided by comparing the policy measures scenarios with the freeze and the business-as-usual scenarios. As the following discussion on the scenarios does not include all these results for a better readability, please refer to these tables for more details. In this discussion, policy measures scenarios are compared with the business-as-usual scenario, which is thought to be more plausible than the freeze scenario.

Air-conditioning chillers

Note : Since there is a 350 kW cooling capacity threshold in Task 2 data concerning chiller sales, the SEER MEPS defined in the different policy measures scenarios for > 400 kW chillers have also been applied to sales of chillers with a cooling capacity comprised between 350 and 400 kW (which sales in themselves are unknown as they are part of sales of the 350-500 kW cooling capacity range). This assumption has a negligible impact on the results.

Substantial gains can be observed for the 2014-2020/2025 period, which come more from gains made for intermediate to large cooling capacity chillers (> 350 kW). Over the 2014-2020 period, the cumulative gains in electricity consumption are respectively of 5.7 TWh, 12.1 TWh and 15.6 TWh for scenarios 1, 2 and 3. Over the 2014-2025 period, the gains become significantly greater, because of the time that is needed so that new high efficiency products impact to an important extent the electricity consumption of the whole stock, which effect becomes more significant from 2020 to 2025. They are respectively of 18.7, 31.5 and 37.6 TWh.

Figure 7 - 4 . Scenario analysis of electricity consumption in TWh/a electric (Electric chillers)

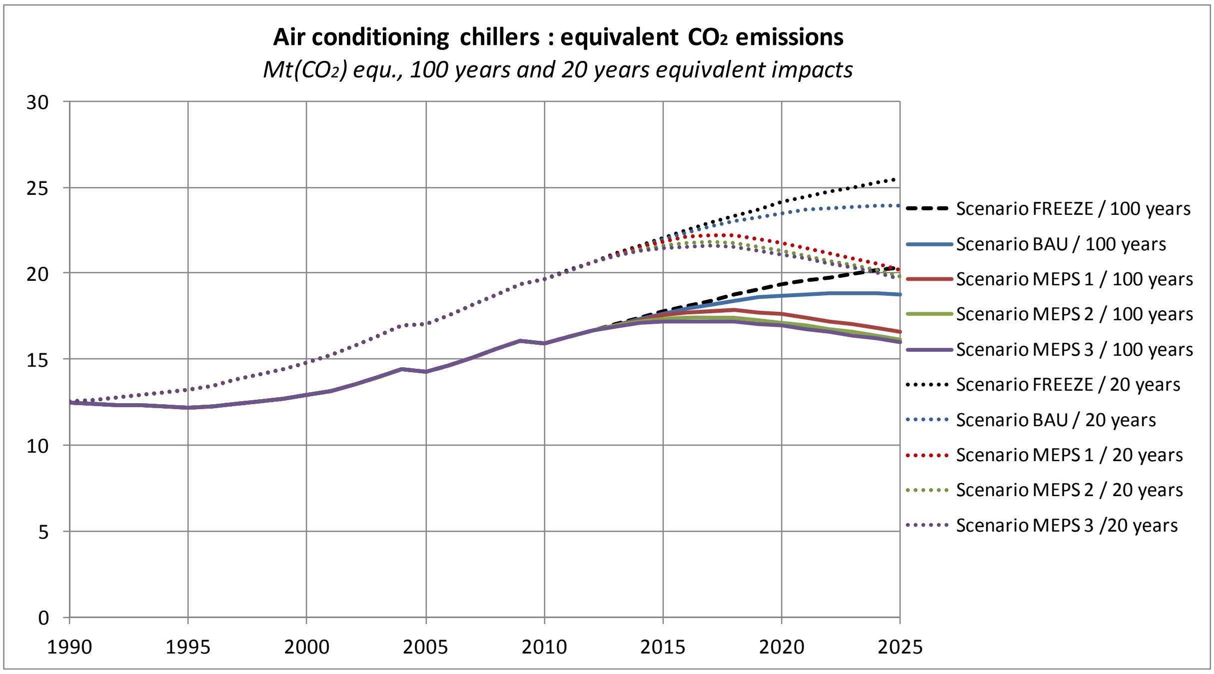


It is now interesting to see that thanks to energy efficiency MEPS, to the high GWP refrigerant fluids ban and to a less carbonated electricity production in the future years, the gap between the business-as-usual scenario and the policy scenarios widens when coming to total equivalent CO_2 emissions. For products in use during the 2014-2020 period, the cumulative gains in total equivalent CO_2 emissions that impact global warming over the next 100 years (2014-2120) are respectively of 3.2 Mt(CO_2) equ., 5.7 Mt(CO_2) equ., and 7.1 Mt(CO_2) equ. for scenarios 1, 2 and 3. Over the 2014-2025 period, the gains in total equivalent CO_2 emissions are then respectively of 12.2 Mt(CO_2) equ., 16.9 Mt(CO_2) equ., and 19.2 Mt(CO_2) equ. for scenarios 1, 2 and 3, which means that the gains made over the 2020-2025 period are twice the gains over the 2014-2020 period.

For the calculations done with GWP $_{20\ years}$ values and over the 2014-2020 period, the gains in total equivalent CO_2 emissions that impact global warming over the next 20 years (2014-2040) are then respectively of 4.8 Mt(CO_2) equ., 7.3 Mt(CO_2) equ. and 8.6 Mt(CO_2) equ. The gains amount then respectively to 19.8 Mt(CO_2) equ., 24.3 Mt(CO_2) equ. and 26.4 Mt(CO_2) equ. for the products in use over 2014-2025 period, their equivalent impact on global warming corresponding here to the 2014-2045 time period.

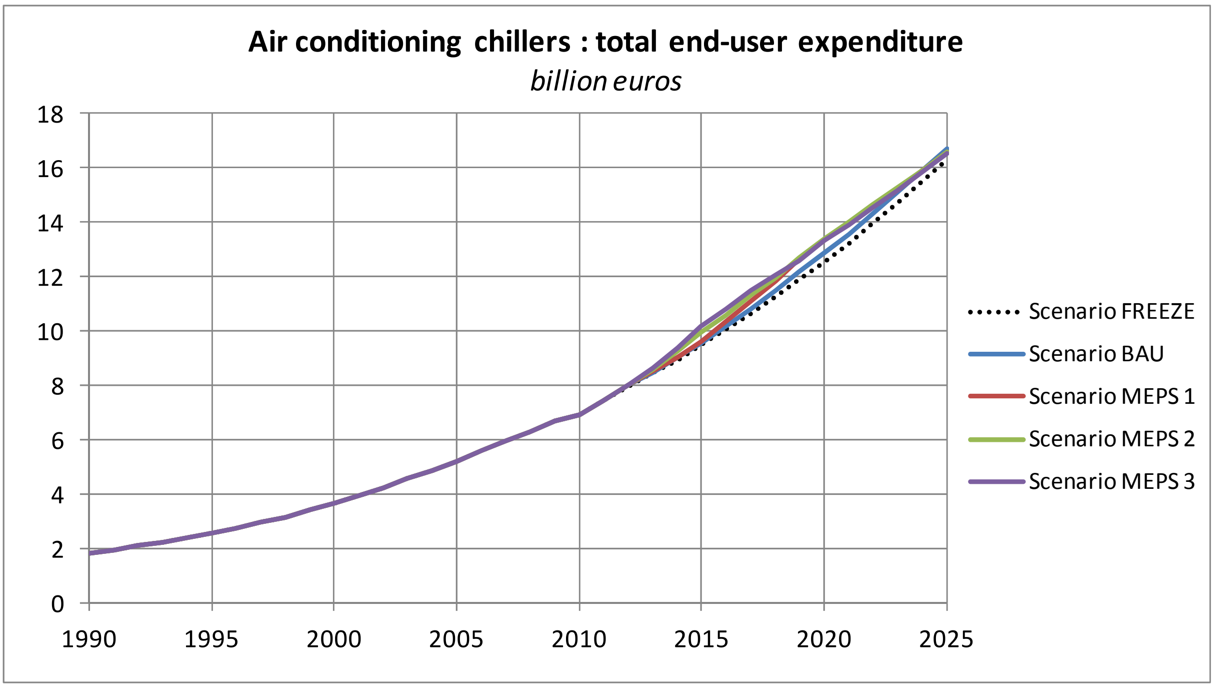
Note that the bumps in the curve that can be seen around 2004/2005 and 2008/2009 correspond to the vanishing of CFCs and mostly R-12 from the stock of refrigerant fluids (in the first case, for low cooling capacity products that have a shorter product life, and in the second, for larger cooling capacity products). Indeed, the GWP of R-12 is greater than 10000 (and very similar if calculated over 20 years and 100 years), which impacts significantly direct equivalent emissions.

Figure 7 - 5 . Scenario analysis of total warming impact (TEWI) in Mt CO2 eq./year (Electric chillers)



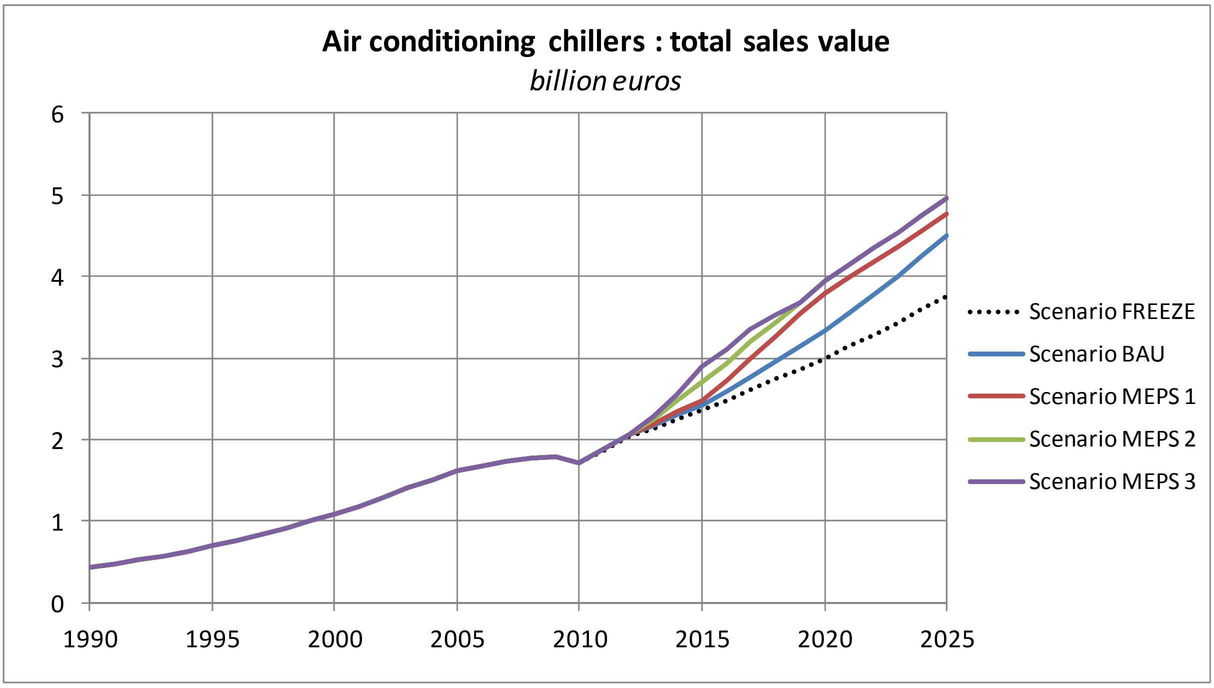
From an economic view point, the slight increase in total end-user expenditure over the 2014-2022 period relates to the sales of more expensive products because of their higher efficiency. This difference disappears progressively after 2020 because of the largest shares of high efficiency products in the stock : they begin then to reduce significantly the electricity consumption of the stock, and so the related end-user expenses. Note that in 2020, the increase in total end-user expenditure is less than 4%.

Figure 7 - 6 . Scenario analysis of end-user expenditure in bln. Euro 2010 per year (Electric chillers)



Eventually, it can be seen that total sales values increase significantly by comparison with the business-as-usual scenario, which is due to the higher products costs of more efficient products. It is considered indeed that the number of sales should not be affected due to sales of slightly more expensive products. Note that the bump around 2005 comes from a small interpolation mistake that will be corrected in the final version of this report.

Figure 7 - 7 . Scenario analysis of sales value units in end-user prices, in bln. Euro 2010 per year (Electric chillers)



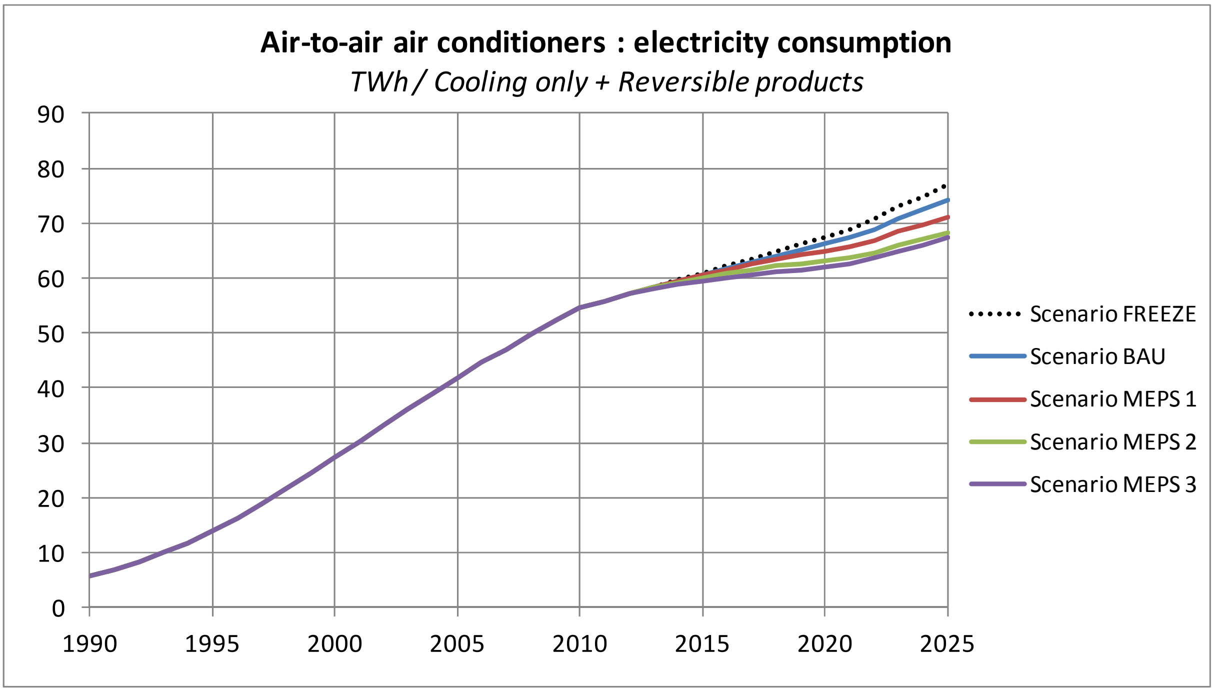
Air-to-air air conditioners

Unsurprisingly, the results for air-to-air air conditioners are quite similar with the results for air conditioning chillers, because of equivalent policy options. The main difference is that the gains in electricity consumption are lower for the less stringent policy scenario, which is scenario MEPS 1 : indeed, current air conditioners are already relatively efficient, and the margin of improvement by comparison with chillers is lower. Therefore, this 1st scenario, which is not very stringent by comparison with the estimated current market, leads to only limited SEER improvement by comparison with the business-as-usual scenario. Note that whatever the policy scenario, it leads also to a narrower market in terms of energy efficiency range.

A second difference is that although the stock of electric chillers remains significantly greater than the stock of electric air conditioners in terms of GW installed, the electricity consumption of the second category is greater because of the heating function of reversible products, which requires around three times the electricity consumption of their cooling function.

For products in use over the 2014-2020 period, the gains in electricity consumption are then respectively of 3.2 TWh, 10.5 TWh, and 16.3 TWh for the 3 policy scenarios. They become of 14.8 TWh, 34.7 TWh and 45.2 TWh over the 2014-2025 period.

Figure 7 - 8 . Scenario analysis of electricity consumption in TWh/a electric (Electric air conditioners)



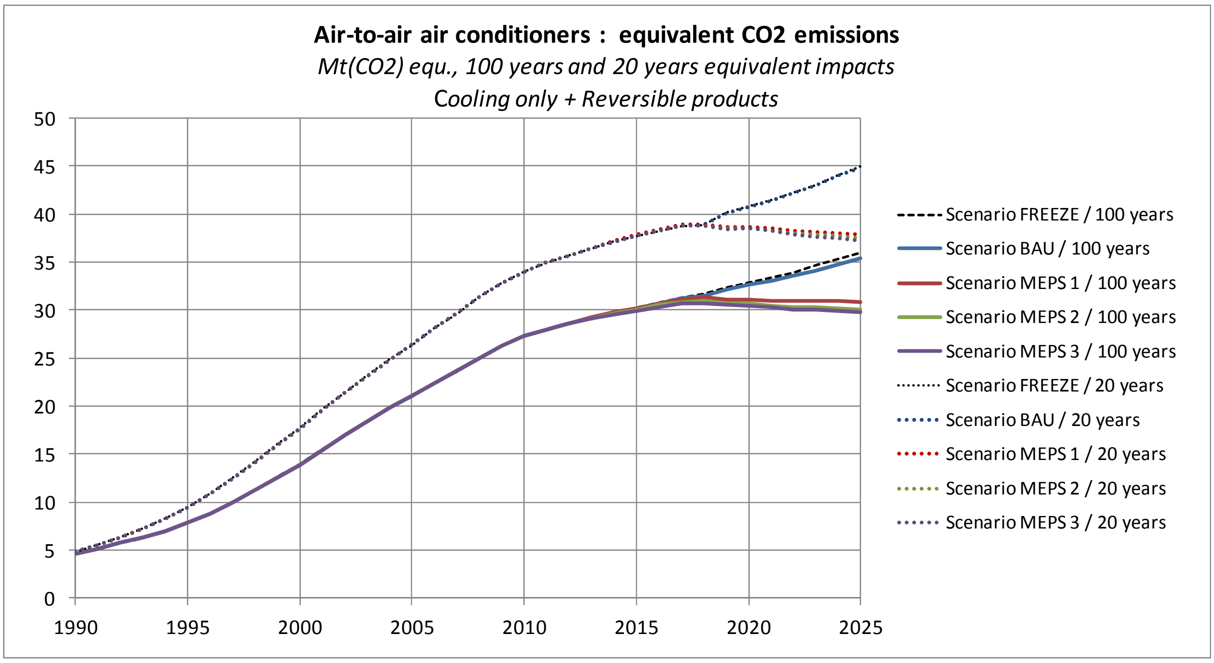
On the contrary, gains in equivalent CO_2 emissions are significantly greater for electric air conditioners, because of their greater sensitivity to refrigerant charge and so losses (the main technological improvement being to increase the size of the heat exchangers and so the refrigerant charge of these products).

Concerning TEWI calculations with $GWP_{100\ years}$, the gains in equivalent CO_2 emissions for the products in use during the 2014-2020 period (which means again the possible equivalent gain on global warming over the 2014-2120 period) are respectively of 2.6 Mt(CO_2) equ., 4.4 Mt(CO_2) equ. and 5.7 Mt(CO_2) equ. for the 3 policy scenarios. Over the 2014-2025 period, they become respectively of 18.8 Mt(CO_2) equ., 23.8 Mt(CO_2) equ. and 26.5 Mt(CO_2) equ. (possible equivalent gain on global warming over the 2014-2125 period). The gain during the 2020-2025 time period is therefore more than 4-5 times greater than during the 2014-2020 time period and amplified by the ban of high GWP refrigerant fluids (essentially R-410A in this case). This is due to the short product life of these products, which leads to very high shares of replacement sales by comparison with 1st time sales in total sales, as estimated for the coming years. In other terms, the stock of electric air conditioners is renewed faster than the stock of electric chillers, and so is impacted more quickly by policy measures, which materializes during the 2020-2025 time period.

Another important remark is that until low GWP refrigerant fluids begin to weight on the EU market (around 2018 onwards, with increases in sales in view of the 2019 ban), the equivalent CO_2 emissions do not seem to be reduced, because more energy efficient products do not weight yet a lot in the stock of products but have a higher R-410A charge.

Concerning TEWI calculations with $GWP_{20\ years}$, the gains in equivalent CO_2 emissions for the products in use during during the 2014-2020 period (possible equivalent gain on global warming over the 2014-2040 period) are respectively of 3.1 Mt(CO_2) equ., 3.7 Mt(CO_2) equ. and 4.1 Mt(CO_2) equ. for the 3 policy scenarios. Over the 2014-2025 period, they become respectively of 27.6 Mt(CO_2) equ., 29.6 Mt(CO_2) equ. and 30.8 Mt(CO_2) equ. (possible equivalent gain on global warming over the 2014-2045 period). Once again, the policy scenarios mainly impact the 2020-2025 stock of products, rather than the stock during the preceding years.

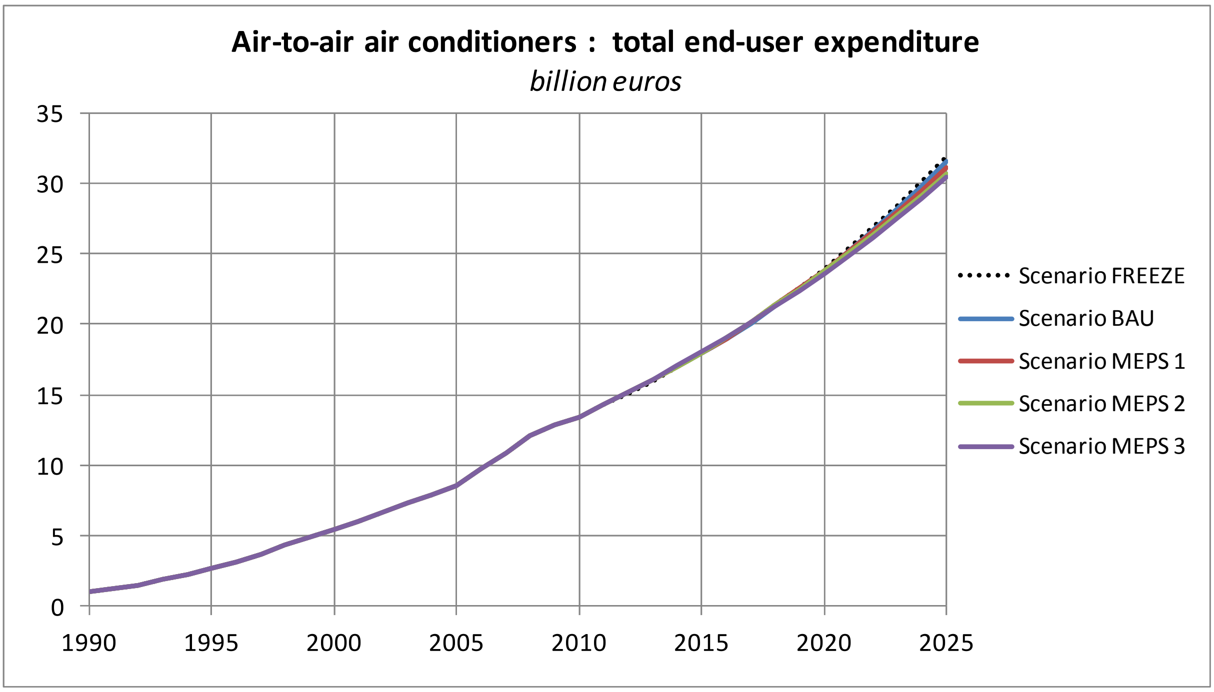
Figure 7 - 9 . Scenario analysis of total warming impact (TEWI) in Mt CO2 eq./year (Electric air conditioners)



End-user expenditures vary very little with the different scenarios, and less than for electric chillers. This is due to the highest share of replacement sales in total sales for air conditioners : the stock being renewed faster, the gains in electricity consumption benefit faster the end-user. Note also that because technological changes are less significant than for chillers, investment costs increase here to a lower extent.

All in all, slight economic gains in total end-user expenditure seem to be possible from 2020 onwards.

Figure 7 - 10 . Scenario analysis of end-user expenditure in bln. Euro 2010 per year (Electric air conditioners)

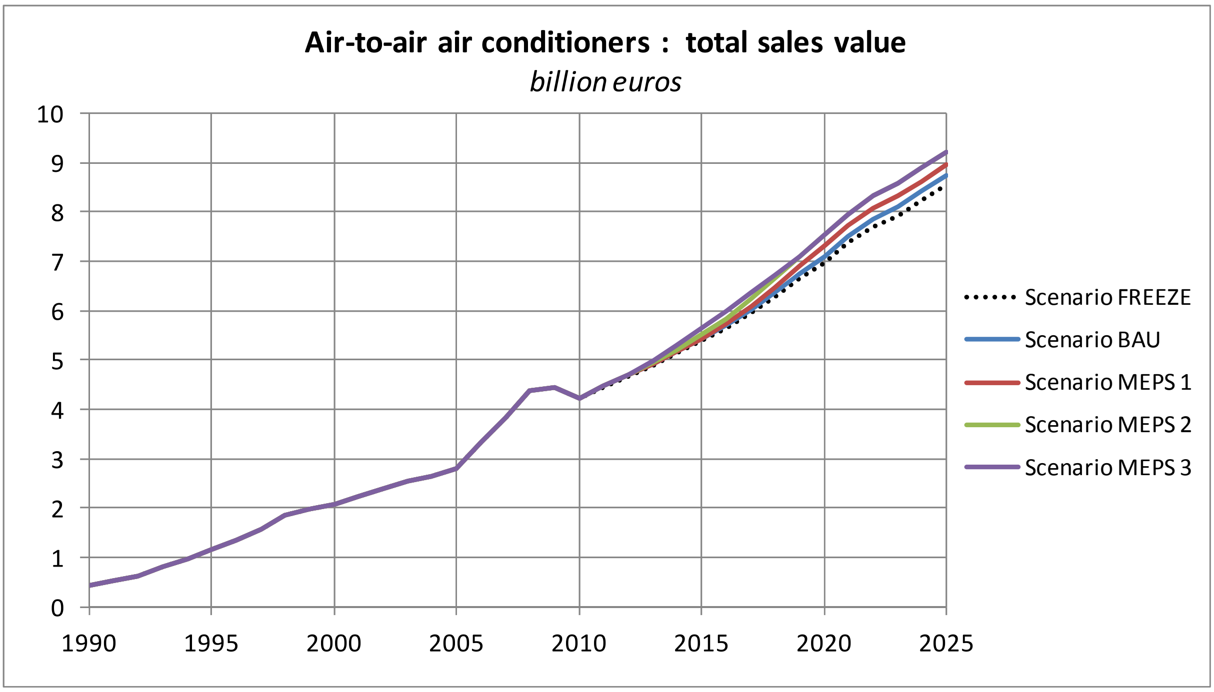


Eventually and as for chillers, total sales values increase significantly by comparison with the business-as-usual scenario, which is due to the higher products costs of more efficient products. It is considered indeed that the number of sales should not be affected due to sales of slightly more expensive products.

Note that although results look strange for the 2005-2010 period, this is due to two things :

- From 2005 onwards, it has been estimated (Task 2 data) that the VRF market begins to expand at a significantly faster rate than before, which can be seen from 2005 to 2008.
- Sales decrease then from 2008 to 2010 because of the economic crisis, and come back to their 2005 level in 2010. The market restarts to expand in the next years, but a lower rate than for the 2005-2008 period.

Figure 7 - 11 . Scenario analysis of sales value units in end-user prices, in bln. Euro 2010 per year (Electric air conditioners)



Air-to-air air conditioners : total sales value
billion euros
10
9
8
7
6
5
4
3
2
1
0
1990
1995
2000
2005
2010
2015
2020
2025
Scenario FREEZE
Scenario BAU
Scenario MEPS 1
Scenario MEPS 2
Scenario MEPS 3

Electricity consumption and equivalent CO_2 emissions : summary of the results

It can be seen that replacing the business-as-usual scenario by the freeze scenario leads to around 30% to 100% additional savings from the policy measures scenarios, depending on the considered indicators. For instance, for the intermediate policy measures (scenario MEPS 2), savings in 2025 in electricity consumption shift from 4.3 to 8.6 TWh (+100%) concerning air-conditioning chillers, and from 5.9 to 8.7 TWh (+47%) concerning air-to-air air conditioners. Still, the study team suggests not to consider the freeze scenario as a business-as-usual scenario. It is very unlikely that without any policy measure, no improvement in the average efficiency of cooling generators would occur. This would contradict for instance the evolution of average EER/ESEER levels in the Eurovent database over the 1995-2010 period.

Table 7 - 24 . Air-conditioning chillers : summary of the main results concerning electricity consumption and equivalent CO_2 emissions, per scenario

Stock of air-conditioning chillers - Summary of the main results concerning electricity consumption and equivalent CO_2 emissions, per scenario

for calculations done with GWP_{100} values : equivalent impact on global warming of stock products that operate during a given year/period over the next 100 years after the year/period considered

for calculations done with GWP_{20} values : equivalent impact on global warming of stock products that operate during a given year/period over the next 20 years after the year/period considered

Scenarios	2020	2025	2014-2020	2014-2025	2020 → 2120	2025 → 2125	2014-2020 → 2114-2120	2014-2025 → 2114-2125	2020 → 2040	2025 → 2045	2014-2020 → 2034-2040	2014-2025 → 2034-2045
	Electricity consumption (TWh)				Equivalent CO_2 emissions (Mt) - GWP_{100}				Equivalent CO_2 emissions (Mt) - GWP_{20}			
FREEZE	42.3	46.7	277	501	19.3	20.3	129	228	24.1	25.5	160	285
BAU	40.7	42.4	272	481	18.7	18.8	127	221	23.5	23.9	158	277
MEPS 1	38.8	39.4	266	462	17.6	16.6	124	209	21.7	20.2	154	258
MEPS 2	37.6	38.1	260	449	17.1	16.1	121	204	21.3	19.8	151	253
MEPS 3	37.0	37.6	256	443	16.9	16.0	120	202	21.1	19.7	150	251
Scenarios	Savings in electricity consumption / Scenario BAU (TWh)				Savings in equivalent CO_2 emissions / Scenario BAU (Mt) - GWP_{100}				Savings in equivalent CO_2 emissions / Scenario BAU (Mt) - GWP_{20}			
MEPS 1	1.8	2.9	5.7	18.7	1.1	2.2	3.2	12.2	1.7	3.7	4.8	19.8
MEPS 2	3.0	4.3	12.1	31.5	1.6	2.6	5.7	16.9	2.2	4.1	7.3	24.3
MEPS 3	3.6	4.8	15.6	37.6	1.8	2.8	7.1	19.2	2.4	4.3	8.6	26.4
Scenarios	Savings in electricity consumption / Scenario FREEZE (TWh)				Savings in equivalent CO_2 emissions / Scenario FREEZE (Mt) - GWP_{100}				Savings in equivalent CO_2 emissions / Scenario FREEZE (Mt) - GWP_{20}			
BAU	1.6	4.3	5.0	20.7	0.6	1.5	1.9	7.7	0.6	1.5	1.9	7.7
MEPS 1	3.4	7.2	10.8	39.3	1.7	3.7	5.2	19.9	2.4	5.3	6.7	27.5
MEPS 2	4.6	8.6	17.1	52.2	2.2	4.2	7.6	24.6	2.8	5.7	9.2	32.0
MEPS 3	5.2	9.1	20.7	58.3	2.4	4.3	9.0	26.9	3.0	5.8	10.6	34.1

Table 7 - 25 . Air-to-air air conditioners : summary of the main results concerning electricity consumption and equivalent CO_2 emissions, per scenario

Stock of air-to-air air conditioners, including the heating function of reversible products - Summary of the main results concerning electricity consumption and equivalent CO_2 emissions, per scenario

for calculations done with GWP_{100} values : equivalent impact on global warming of stock products that operate during a given year/period over the next 100 years after the year/period considered

for calculations done with GWP_{20} values : equivalent impact on global warming of stock products that operate during a given year/period over the next 20 years after the year/period considered

Scenarios	2020	2025	2014-2020	2014-2025	2020 → 2120	2025 → 2125	2014-2020 → 2114-2120	2014-2025 → 2114-2125	2020 → 2040	2025 → 2045	2014-2020 → 2034-2040	2014-2025 → 2034-2045
	Electricity consumption (TWh)				Equivalent CO_2 emissions (Mt) - GWP_{100}				Equivalent CO_2 emissions (Mt) - GWP_{20}			
FREEZE	67.5	76.9	445	809	32.9	36.0	219	392	40.8	44.9	271	487
BAU	66.1	74.1	440	793	32.6	35.4	218	389	40.7	44.8	272	487
MEPS 1	64.8	71.2	436	778	31.1	30.9	215	370	38.7	37.8	268	459
MEPS 2	63.0	68.2	429	758	30.7	30.1	214	365	38.5	37.5	268	457
MEPS 3	62.0	67.3	423	748	30.5	29.8	212	362	38.5	37.2	267	456
Scenarios	Savings in electricity consumption / Scenario BAU (TWh)				Savings in equivalent CO2 emissions / Scenario BAU (Mt) - GWP100				Savings in equivalent CO2 emissions / Scenario BAU (Mt) - GWP20			
MEPS 1	1.3	2.9	3.2	14.8	1.5	4.5	2.6	18.8	2.0	7.0	3.1	27.6
MEPS 2	3.1	5.9	10.5	34.7	1.9	5.3	4.4	23.8	2.2	7.3	3.7	29.6
MEPS 3	4.1	6.8	16.3	45.2	2.1	5.6	5.7	26.5	2.3	7.6	4.1	30.8
Scenarios	Savings in electricity consumption / Scenario FREEZE (TWh)				Savings in equivalent CO2 emissions / Scenario FREEZE (Mt) - GWP100				Savings in equivalent CO2 emissions / Scenario FREEZE (Mt) - GWP20			
BAU	1.3	2.8	5.0	16.1	0.3	0.6	1.0	3.4	0.0	0.1	0.0	0.5
MEPS 1	2.6	5.7	8.3	30.9	1.7	5.1	3.6	22.2	2.1	7.1	3.0	28.1
MEPS 2	4.4	8.7	15.5	50.8	2.2	5.9	5.4	27.1	2.2	7.5	3.7	30.1
MEPS 3	5.4	9.6	21.4	61.3	2.4	6.2	6.7	29.8	2.3	7.7	4.1	31.3

7.2.3. IMPACTS ON THE MAIN ACTORS

Users

The product functionality of the different products has been respected and should not be affected by the proposed measures.

The main risk was the size limitation, which mainly regards split and VRF air conditioners indoors. It was already included when drawing the LCC analysis and the scenarios. Options to decrase the energy consumption of the products are available in the different scenarios with reasonable heat exchange surface increase and consequent limited size increase. It also means that this is completely possible to reach the present efficiency requirements, without complicated options to increase the dehumidification capability of the products.

The main monetary impact for the buyer is because of higher prices. In practice, this is an important market barrier for the penetration of higher efficient products in the commercial area. At the time of design, first cost is still the main parameter looked at. The adversion to risk is also relatively high as the designer bears the consequence of not satisfying systems and not the benefit of low energy bills. These split incentives can only be reduced by regulatory measures.

Manufacturers

Manufacturers are mainly international companies with some important European players but no or little SME could be identified in the design and sales of series products. A few SMEs have been identified regarding designing on demand, which consequently should not be affected by the measures.
Most air conditioning products on that segment are assembled in Europe, and most components (except smaller ones as small compressors and expansion valves) are also produced/assembled in Europe. With higher energy efficiency requirements, the assembly costs will increase, favoring the creation of jobs in Europe. The effects on research and development will most likely be more limited as most companies are international multinational corporations.

The proposed measures are accessible with technologies that are available to all players. In addition, when setting the energy efficiency requirements, the product range effects have been considered in order to include the manufacturing cost reduction techniques in the final requirements.

There is no proprietary technological development necessary in order to reach the specific energy requirements proposed. Although it was thought to be the case for centrifugal chillers with magnetic bearings, several players now develop their own solutions, with one OEM proposing compressors to be integrated by chiller manufacturers.

Regarding refrigerants, the policy measure proposed at mid-term is the ban of HFC refrigerants with GWP above 675. However, this radical change to replace R410A by R32 is not fully done yet, and there may be further barriers to come in this direction. The same applies for using HFOs in chillers. In case this is more complicated than planned, the TEWI specific approach can help to make sure that the energy efficiency and the refrigerant emissions can be controlled at the same time in order to avoid counterproductive effects due to unilateral energy efficiency measures.

Regarding the different product range, the impact assessment analysis could look at the impact of the different product ranges created for the chillers in the different Ecodesign studies and proposed measures. Indeed, it was still possible up to know to design the same chiller and to use it for medium temperature refrigeration, air conditioning and for process application with positive temperatures. The entering into force of three different measures for the same initial product is likely to lead to significantly increased manufacturer costs.

It is true that requiring more information on the products is likely to lead to increased administrative burden and higher costs. Nevertheless, the required additional information is small as compared to the information the manufacturers already have to supply for existing regulations (Europe and by Member State). In addition, this should help to standardize the final requirements for information request for the

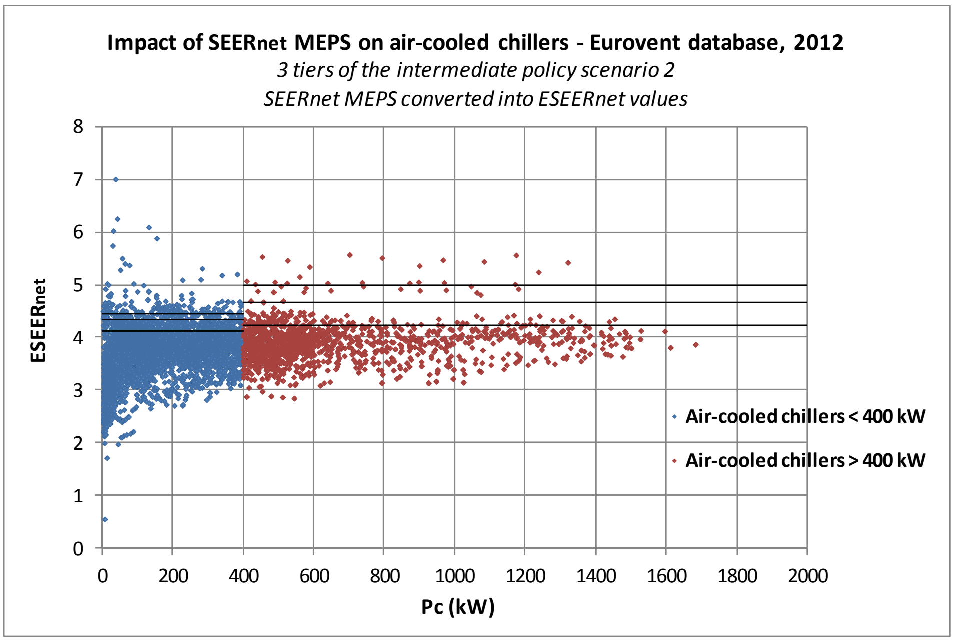
EPBD and so at the end, this should help to drastically decrease the costs of producing data for each one of the national building thermal regulations.

Illustration of the impact of EER/SEER MEPS on Eurovent certified products

In addition to the previous discussion, it is possible to partly illustrate the equivalent impact of future MEPS on current products, on the basis of the Eurovent database. EER and ESEER values are indeed reported for certified air-conditioning chillers, and EER are reported for certified air-to-air split systems and package/rooftop air conditioners. Concerning chillers, the most recent data set at the study team's disposal is the 2012 Eurovent database, in which EER_{net} and $ESEER_{net}$ values can be found. The calculation tools used in Task 6 allow to calculate $ESSER_{net}$ values for the base-cases and the improved products, which can be then correlated with $SEER_{net}$ values computed for the same products. The $SEER_{net}$ MEPS previously proposed can thus be converted into $ESEER_{net}$ values, which allows to calculate what percentage of the 2012 certified products could still be sold in the EU after the implementation of the MEPS.

The results of the analysis show that SEER MEPS are stringent for currently sold chillers: whatever the category, less than 5% of the 2012 certified products would be in line with the 2019 MEPS of the intermediate policy measures scenario 2, which is generally close to the efficiency level of the LLCC improved chillers in Task 6. The 2017 MEPS of policy measures scenario 1 already eliminates around 80% of the 2012 certified products. This important market change is however already on-going (but slow because of first cost limitation) with most technologies necessary to reach these SEER levels readily available on the shelf.

Figure 7 - 12 . Illustration of the impact of the $SEER_{net}$ MEPS of policy scenario 2 on air-conditioning chillers certified by Eurovent in 2012



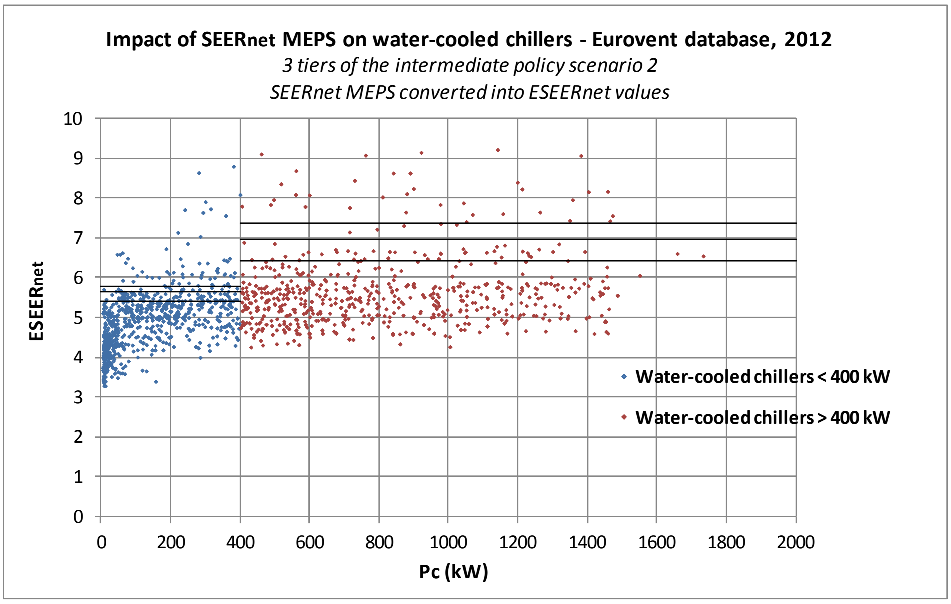


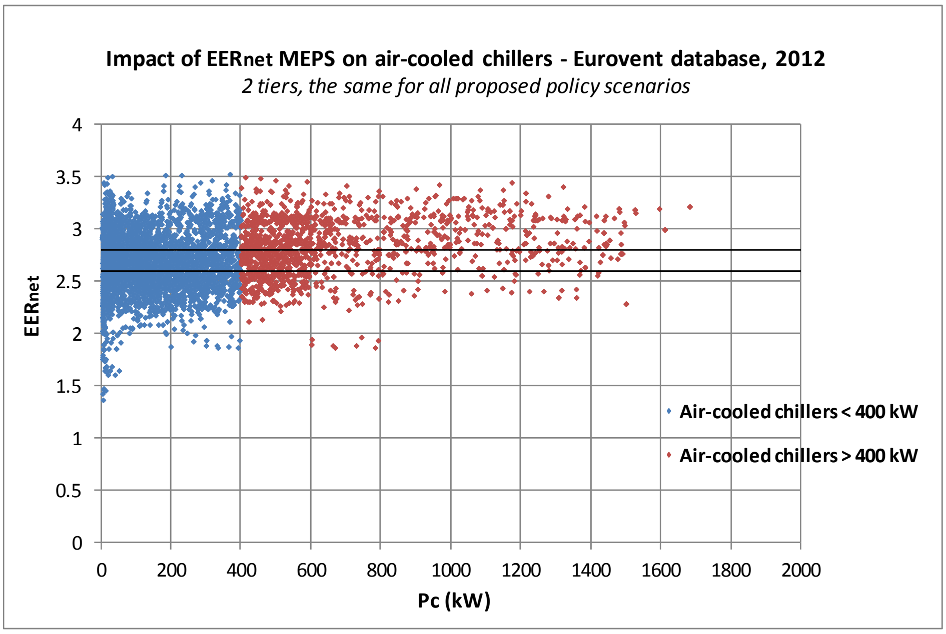
Table 7 - 26 . Illustration of the impact of $SEER_{net}$ MEPS on air-conditioning chillers certified by Eurovent in 2012

Illustration of the possible impact of $SEER_{net}$ MEPS on air-conditioning chillers *remaining products in the 2012 Eurovent database*									
Indicators	**Scenario 1**			**Scenario 2**			**Scenario 3**		
	2015	**2017**	**2019**	**2015**	**2017**	**2019**	**2015**	**2017**	**2019**
Air-cooled chillers < 400 kW									
$SEER_{net}$	3.5	3.8	4.1	3.8	4.0	4.1	4.0	4.1	4.1
$ESEER_{net}$	3.8	4.1	4.45	4.1	4.35	4.45	4.35	4.45	4.45
% RP(*)	46%	17%	4.5%	17%	6.5%	4.5%	6.5%	4.5%	4.5%
Air-cooled chillers >= 400 kW									
$SEER_{net}$	3.5	4.0	4.4	4.0	4.4	4.7	4.4	4.7	4.7
$ESEER_{net}$	3.7	4.25	4.65	4.25	4.65	5.0	4.65	5.0	5.0
% RP(*)	70%	12%	1%	12%	3.5%	1%	3.5%	1%	1%
Water-cooled chillers < 400 kW									
$SEER_{net}$	4.5	4.9	5.2	4.9	5.1	5.2	5.1	5.2	5.2
$ESEER_{net}$	4.95	5.4	5.75	5.4	5.65	5.75	5.65	5.75	5.75
% RP(*)	54%	20%	7.5%	20%	9%	7.5%	9%	7.5%	7.5%
Water-cooled chillers >= 400 kW									
$SEER_{net}$	5.1	6.1	6.6	6.1	6.6	7.0	6.6	7.0	7.0
$ESEER_{net}$	5.35	6.4	6.95	6.4	6.95	7.35	6.95	7.35	7.35
% RP(*)	55%	13%	5.5%	13%	6%	5.5%	6%	5.5%	5.5%

(*) : % RP stands for "percentage of Remaining Products above $SEER_{net}$ MEPS in the 2012 Eurovent database"

EER_{net} MEPS are less stringent and have only been designed to prevent some manufacturers from developing products in line with the SEER MEPS but to the detriment of the full-load efficiency, with a negative impact on the electricity grid of summer-peaking EU countries. The share of the 2012 certified products that do not meet these MEPS are provided in the following table.

Figure 7 - 13 . Illustration of the impact of the EER_{net} MEPS on air-conditioning chillers certified by Eurovent in 2012



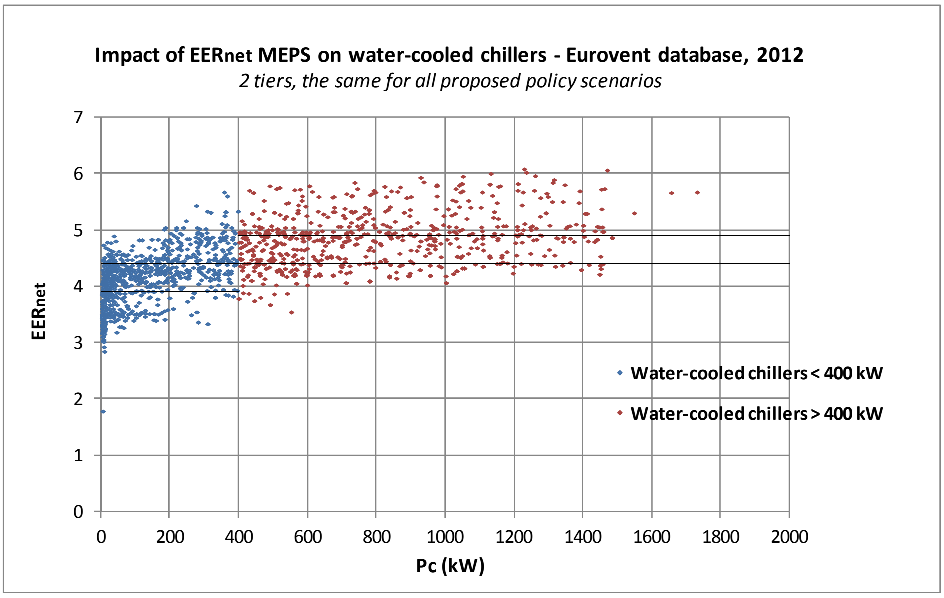


Table 7 - 27 . Illustration of the impact of EER_{net} MEPS on air-conditioning chillers certified by Eurovent in 2012

Illustration of the possible impact of EER_{net} MEPS on air-conditioning chillers *remaining products in the 2012 Eurovent database*		
Indicators	**2015**	**2017**
Air-cooled chillers < 400 kW		
EER_{net} MEPS	2.6	2.8
% Remaining Products	65%	35%
Air-cooled chillers > 400 kW		
EER_{net} MEPS	2.6	2.8
% Remaining Products	82%	59%
Water-cooled chillers < 400 kW		
EER_{net} MEPS	3.9	4.4
% Remaining Products	77%	27%
Water-cooled chillers > 400 kW		
EER_{net} MEPS	4.4	4.9
% Remaining Products	76%	39%

Concerning air conditioners, it is not possible to illustrate the impact of SEER MEPS on currently sold products. Indeed, the existing products have not been rated yet on the basis of a seasonal performance index, the first one of this kind in the EU being the future SEER index.

Conversely, it is still possible to illustrate the impact of EER MEPS on certified products. It appears that these MEPS are a little more stringent for rooftop and especially package air conditioners than single split and multisplit systems. This is probably due to the fact that the latter represent a larger market, on which there is a greater focus from manufacturers. On the overall, only a limited amount of the certified air conditioners is affected by the EER MEPS.

This analysis cannot be done for VRF systems. The only European database at the study team's disposal is the ETPL database of the UK ECA scheme, for which data is provided separately for outdoor units and indoor units : no full system including the outdoor unit and the indoor units is rated.

Figure 7 - 14 . Illustration of the impact of the EER MEPS on single split systems certified by Eurovent in 2012

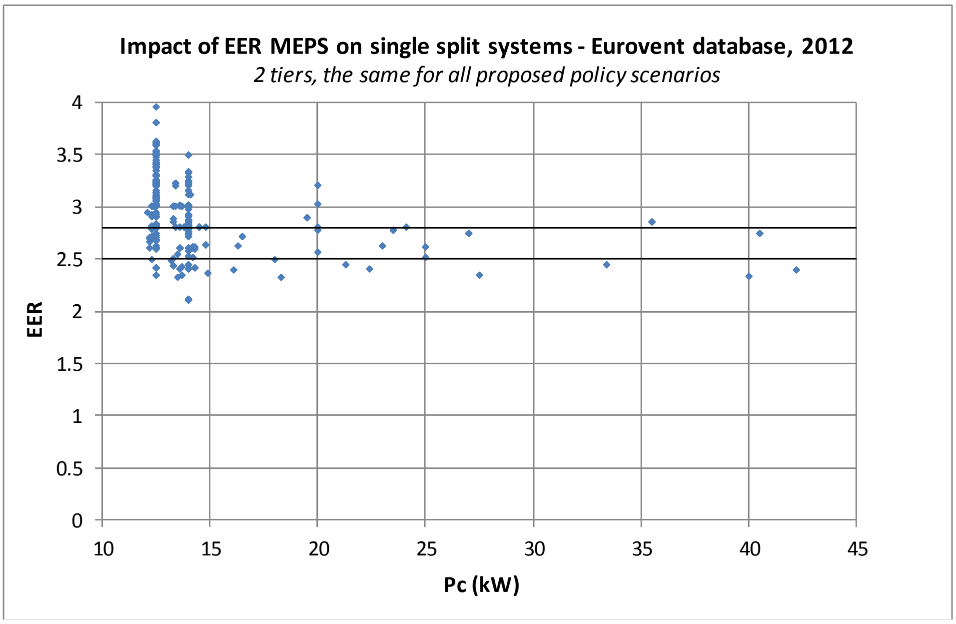


Figure 7 - 15 . Illustration of the impact of the EER MEPS on multisplit systems certified by Eurovent in 2012

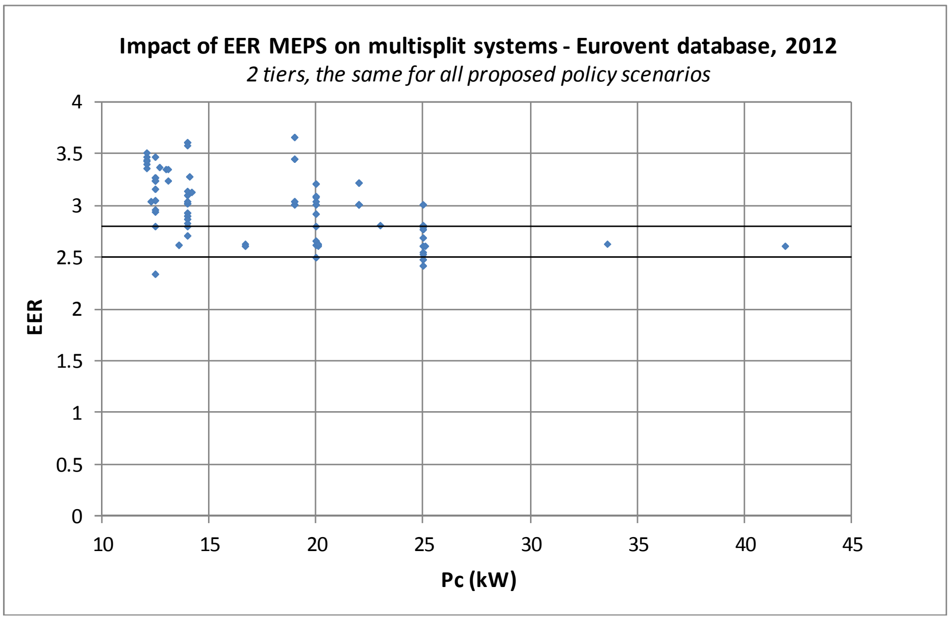


Figure 7 - 16 . Illustration of the impact of the EER MEPS on rooftop and package air conditioners certified by Eurovent in 2012

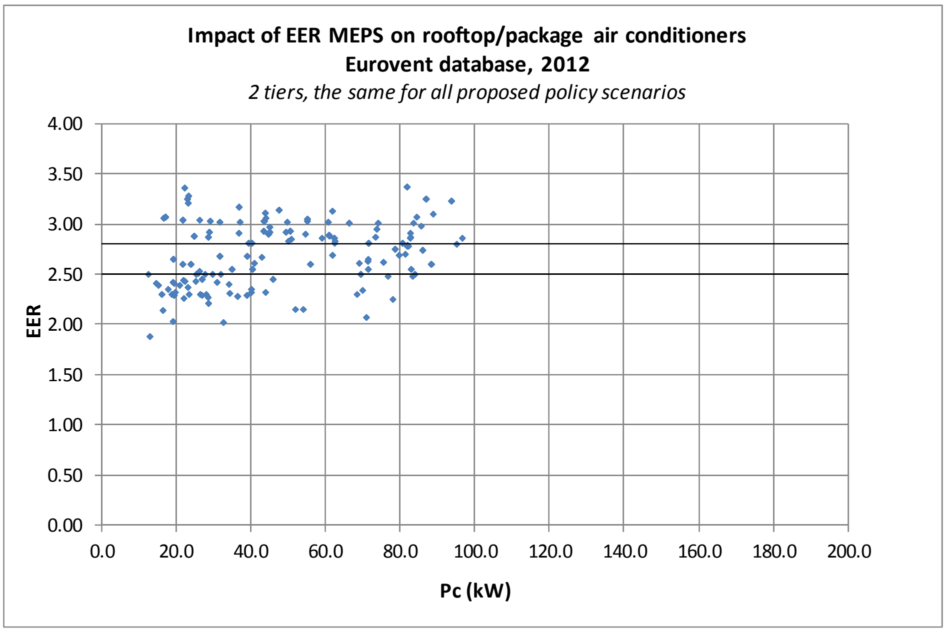


Table 7 - 28 . Illustration of the impact of EER_{net} MEPS on single split systems, multisplit systems and rooftop/package air conditioners certified by Eurovent in 2010

Illustration of the possible impact of EER MEPS on air-conditioning chillers *remaining products in the 2012 Eurovent database*		
Indicators	**2015**	**2017**
Single split systems		
EER MEPS	2.5	2.8
% Remaining Products	92%	74%
Multisplit systems		
EER MEPS	2.5	2.8
% Remaining Products	96%	76%
Rooftop and package air conditioners		
EER MEPS	2.5	2.8
% Remaining Products	79%	53%

Utilities

As for smaller air conditioners, the gain for the utilities, and thus indirectly for the users' electricity bill at mid-term, is much more sensitive to the EER and COP of the products than to the SEER of the products.

CONCLUSION

The final scope of Lot 6 products that should fall under EU policy requirements has been adapted from Task 1 and the whole preparatory study, distinctions being made between the types of requirements proposed for the different product categories. The five main generic product categories are air conditioning chillers, air conditioners, air conditioning condensing units, heat rejection units and fan coil units. For the 3 first categories, distinctions in cooling principle and sink type have been made.

Standardization needs have been detailed. For part of the different product categories, as classified by cooling principle and sink type, and concerning seasonal energy performance, it is only necessary to adapt and update the current prEN 14825 standard to take into account the new sets of reference hours evaluated in Task 6 for an average EU climate. Gas engine air conditioning chillers, air conditioners as well as all air conditioning condensing units, whatever their cooling principle, require a new energy performance standard. For the remaining product categories, the existing energy performance standards shall be updated as described in this report.

The main subcategories for which one or more base-cases have been defined in Task 4, for which an improvement potential has been estimated in Task 6 and for which different sets of energy efficiency and refrigerant fluids political measures have been proposed are electric air-cooled air conditioning chillers < 400 kW, electric air-cooled air conditioning chillers > 400 kW, electric water-cooled air conditioning chillers < 400 kW, electric water-cooled air conditioning chillers > 400 kW and electric air-to-air air conditioners. In terms of energy efficiency MEPS and refrigerant fluid policy options, split systems, VRF systems and package air-to-air air conditioners have been therefore grouped together into this air conditioners single category, because of low differences in energy performance levels for current products as well as future improved products, due to very similar improvement potentials.

Although the Eu(r)P methodology designates the Task 6 LLCC improved products as the reference to be taken for energy performance MEPS, discussions have been proposed to define more soundly, when necessary, realistic SEER MEPS. This applies especially for air-to-air air conditioners.

Three policy scenarios of energy performance MEPS have been proposed in terms of SEER (final energy = electricity) and EER (final energy = electricity) for the five main categories of electric products, on a three Tiers basis, which comes down to 2015, 2017 and 2019. EER MEPS have been introduced to forbid products with a sufficiently high seasonal performance but a low full-load performance that could have an impact on the electricity grid at the time of summer electricity peaking demand in warm countries. Although a seasonal energy performance index in cooling mode lacks for gas engine products, equivalent SEER MEPS expressed in primary energy have been discussed for gas engine air-cooled air conditioning chillers and gas engine air-to-air air conditioners.

The new possible stringent role of SEER and GWP benchmarks for green public procurement (GPP), which might represent 10% to 20% of the air conditioning EU market, has been discussed, with the definition of a high and a low SEER benchmark for each of the 5 main electric product categories quoted before. The low benchmark should serve as the basis for GPP policies, unless it is proven that the indicative high value can be achieved by several manufacturers. A 150 $GWP_{100\ years}$ benchmark has only be proposed for 2019 and is not realistic to ask before. These measures should lead to the definition of top efficiency classes that would replace energy efficiency labels, which appear to be obsolete for Lot 6 products.

It has been shown as too soon and biased to introduce energy performance MEPS for fan coil units and heat rejection units, while more gains can be expected from higher temperature cold emitters (instead of fan coil units) and more efficient heat rejection product types than dry coolers, which currently dominate the EU market. As this comes down to the optimization of systems and not products only, information requirements have been consequently asked to characterize and report more precisely the performance of fan coil units, heat rejection units but also air conditioning chillers.

Equivalent CO_2 emissions related to refrigerant fluid losses being a significant environmental impact of many Lot 6 product categories, 4 main types of policy options have been described and explained on a theoretical basis, then discussed for each of the 5 main product categories previously quoted. This has led to propose a stringent mid-term measure on high GWP refrigerant fluids, by discussing the possibility of the ban of refrigerant fluids with a $GWP_{100\ years}$ greater than the one of R-32 (675) in 2019 or instead of a maximum specific TEWI measure. Bonuses on SEER MEPS have been proposed for cooling only air conditioning chillers as well as cooling only and reversible air conditioners and air conditioning condensing units, whatever their cooling principle and sink type. These bonuses are seen as only interesting in view of the more stringent political measures refrigerant fluids discussed for 2019.

The main barrier to the ban of high GWP refrigerant fluids is that the alternative intermediate GWP (R-32) and low GWP (HFOs, natural refrigerants) refrigerant fluids are flammable, to a more or less great extent. Because of their relatively low flammability, HFOs, R-32 and mixtures of R-32 or other HFCs with HFOs should not fall anymore under strong restrictions from the EN 378 standard, which might evolve in this sense. Still, the remaining barriers are national regulations in some countries, that might forbid the use of flammable refrigerant fluids in some building types, as in France, or limit the charge of the products.

The impact of energy efficiency MEPS and the ban of high GWP refrigerant fluids in 2019 has been evaluated over the 2014-2025 period for each of the 5 electric product categories and each of the 3 policy scenarios defined by category, by comparison with a business-as-usual base scenario calculated over the 1990-2025 period. Results have been grouped together for air conditioning chillers on one side, and air-to-air air conditioners on the other one. Gains in electricity consumption and total equivalent CO_2 emissions appear to be at least 3 times more significant over the 2020-2025 period than the 2014-2020 period, because of the time needed for new products to impact the stock to a great extent. Stringent measures on refrigerant fluids in 2019 seem to be the right way to avoid increased direct equivalent emissions due to increased refrigerant fluid losses but also to reach higher gains in equivalent CO_2 emissions than with energy efficiency measures only. Before this date, the low share of new products in the stock does not justify to ask for stringent political decisions on refrigerant fluids. Economic gains look slightly positive for end-users, gains in electricity expenses offsetting the higher product prices. Economic gains are also positive but to a greater extent for manufacturers/installers/distributors, because of the highest price of more efficient products.

All in all, looking at policy scenarios 2, the expected savings in electricity and equivalent CO_2 emissions are :

- 3.0 TWh and 1.6 Mt(CO_2) equ. for air conditioning chillers, in 2020
- 4.3 TWh and 2.2 Mt(CO_2) equ. for air conditioning chillers, in 2025
- 3.1 TWh and 1.9 Mt(CO_2) equ. for air-to-air air conditioners (including the heating function of reversible products), in 2020
- 5.9 TWh and 5.3 Mt(CO_2) equ. for air-to-air air conditioners (including the heating function of reversible products), in 2025

For products with a cooling capacity lower than 70 kW, the same noise levels as in the Working Document for the implementation of the Directive 2009/125/EC for space heaters have proven to be adapted to non indoor ducted Lot 6 products. Different noise levels have only been defined for indoor ducted air conditioners and ducted fan coil units.

Concerning resource efficiency, two proposals have been made, which come down to extension of the WEEE and ROHS directive to air conditioning products and the labeling of the component parts of products as already done in the EU car industry. Both measures could apply below a certain cooling capacity threshold to be discussed further.

To help design engineers improve the selection and sizing of Lot 6 products when designing an air conditioning system to be fitted with a specific building, information requirements on their energy performance according to different temperature and load conditions have been discussed per product category, and the corresponding standardizing needs have been reported.

TASK 7 REFERENCES

ASHRAE, 2004 & 2008, 2004 and 2008 ASHRAE Handbooks, HVAC systems and equipments (SI edition).

EC, DIRECTIVE 2010/31/EC of the European Parliament and of the Council on the energy performance of buildings, 19.5.2010 (EPBD, recast of 2002/91/EC)

EC, Regulation 2009/1005/EC of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer.

EC, REGULATION 2012/206/EC, 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, Official Journal of the European Union, L 72/7, 10.3.2012.

EN 12309-1:1999 - Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances with a net heat input not exceeding 70 kW - Part 1: Safety

EN 12309-2:2000 - Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances with a net heat input not exceeding 70 kW - Part 2: Rational use of energy

EN 14511-1:2007 - Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling - Part 1: Terms and definitions

EN 14511-2:2007 - Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling - Part 2: Test conditions

EN 14511-3:2007/AC:2008 - Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling - Part 3: Test methods

EN 14511-4:2007 - Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling - Part 4: Requirements

EN 14705 : 2005 - Heat exchangers - Method of measurement and evaluation of thermal performances of wet cooling towers

EN 14825 (prEN):2011 - Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling – Testing and Rating at part load conditions and calculations of seasonal performances

EN 15218:2006 - Air conditioners and liquid chilling packages with evaporatively cooled condenser and with electrically driven compressors for space cooling - Terms, definitions, test conditions, test methods and requirements

EN 378-1:2011 - Refrigerating systems and heat pumps - Safety and environmental requirements - Part 1 : basic requirements, definitions, classification and selection criteria

EN 378-2:2011 - Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2 : design, construction, testing, marking and documentation

EN 378-3:2008 - Refrigerating systems and heat pumps - Safety and environmental requirements - Part 3: Installation site and personal protection

EN 378-4:2008 - Refrigerating systems and heat pumps - Safety and environmental requirements - Part 4: Operation, maintenance, repair and recovery

ISO, 2006, ISO/TC 86/SCG/WG9, Date: 2006-03-01, N250C, DRAFT # 17 with all comments, Authors: M. Mondot, Newson, R. Lord, PROPOSED WORKING DRAFT (PWD 19298-1) LIQUID-

CHILLING PACKAGES USING THE VAPOUR COMPRESSION CYCLE. PART 1: METHOD OF RATING FOR PERFORMANCE

Rivière et al., 2008, Technical analysis of best available technologies, Task 6 report, July 2008, Service Contract to DGTREN, Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation), Contract TREN/D1/40-2005/LOT10/S07.56606.

Rivière et al., 2009, Technical analysis of best available technologies, Task 7 report, March 2009, Service Contract to DGTREN, Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation), Contract TREN/D1/40-2005/LOT10/S07.56606.

RSMeans, 2011, RS Means Mechanical Cost Data

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