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Addendum

REPORT ON THE MULTILATERAL FUND CLIMATE IMPACT INDICATOR (DECISION 59/45)

This document is being issued to:

- **Add** Annex I which contains the related technical descriptions referring to different consumption sectors.

- **Add** Annex II which illustrates a largely automated model for the calculation of the MCII for the refrigeration sector.

- **Add** Annex III which contains results of the calculations for project submissions to the 62nd Meeting for China, Indonesia, Nigeria and Serbia.

Annex I

MULTILATERAL FUND CLIMATE IMPACT INDICATOR TECHNICAL DESCRIPTIONS OF DIFFERENT CONSUMPTION SECTORS

1. Decision XIX/6 of the Meeting of the Parties requested the impact of energy consumption on the climate to be taken into account. The Secretariat focussed its work on achieving progress with the MCII for the refrigeration and air-conditioning manufacturing sectors first, since it is assumed that in these two sectors the effects of energy consumption on the climate are more prevalent than in other sectors.

MCII for refrigeration and air-conditioning manufacture conversion activities

2. The MCII has been developed to allow an indication of the effect on the climate of future conversion projects to be funded by the Multilateral Fund. The MCII is therefore a tool operating on the basis of data available during the preparation and/or review of Multilateral Fund project submissions. Consequently, data related to the characteristics of products using the current technology is often only sketchily documented, information about the conversion and the characteristics of the converted project are not available at all. On this basis, the MCII is meant to help indicating the climate impact of the activities. It is not meant to replace any possibly desired subsequent analysis undertaken on the basis of more detailed data, and maybe detailed performance information of specific models for baseline and alternative, such as a life cycle climate performance (LCCP) or a life cycle analysis (LCA).

3. The MCII for refrigeration and air-conditioning activities takes into account:

(a) the emissions of refrigerant during manufacturing, operation and at the end of life, called the direct emissions; as well as

(b) the energy consumption of products using HCFC and their alternatives as refrigerants, called the indirect emissions.

4. In a first step the model used calculates the emission of one refrigeration or air-conditioning unit over its lifetime as a sum of direct and indirect effects, and multiplies the result with the amount of units produced in one year. This interim result represents the climate impact of the annual production for a given technology. For a qualitative comparison of different alternatives, the ratio between the baseline (HCFC) and the alternative is used (percentage values). For aggregated, sector-or country-wide figures, the difference between the two is being used (absolute values in tonnes of CO_2 equiv.). Negative values for the MCII denote a reduction in the climate impact as compared to the baseline, positive values an increase,

5. The direct emissions of HCFCs and alternatives take into account a large number of factors related to the lifetime of each unit manufactured, and aims to use general assumptions to quantify them. This quantification is carried out for the lifetime of the equipment and relates to:

(a) The HCFC charge, being an input value, and the potentially different charge of the alternatives[1];

(b) A 2 per cent emission at the time of manufacturing for systems assembled and charged in a factory;

[1] Charge differences are generalized assuming same inner volume of the components, and using the ratio of the liquid densities of the different refrigerants in reference to the baseline (e.g. HCFC-22). The liquid density is assumed as the mean of the values for 42°C and, depending on the application, for -32°C, -4°C and 0°C.

(c) Typical annual emissions for an average unit, depending on the type of refrigeration or air-conditioning equipment and on assembly in a factory or on site, as shown in Table 1;

(d) An average lifetime for each unit depending on the various types of refrigeration and air-conditioning equipment as well as on assembly in a factory or on site, as shown in Table 1;

(e) Recovery at the end of life, currently, in line with practices typical for Article 5 countries assumed to be zero, as shown in Table 1; and

(f) The climate impact of the substance, calculated on the basis of the substances Greenhouse Warming Potential (GWP) for a 100-year time horizon.

Table 1: Values used as assumptions for annual emissions and lifetime

Type of application	**AC, factory assembly**	**AC, on site assembly**	**Commercial Cooling, factory assembly**	**Commercial Cooling, on site assembly**	**Commercial Frozen, factory assembly**	**Commercial Frozen, on site assembly**
Baseline refrigerant	R22	R22	R22	R22	R22	R22
Product lifespan	10	10	10	14	10	14
Leakage at manufacturing	2%	0%	2%	0%	2%	0%
Annual leakage	2%	5%	2%	25%	2%	25%
Recharge level	55%	55%	55%	55%	55%	55%
Recovery fraction	0%	0%	0%	0%	0%	0%

6. The carbon dioxide emissions related to energy consumption of refrigeration equipment depends on the size, quality of the components, quality of design, application and the operating conditions (chiefly the ambient temperature), and, finally, the CO_2 emission related to the production of electricity. In order to take the different factors into account, a number of assumptions were made and procedures were developed:

(a) It is assumed that the principle quality of components and quality of the design remain constant; reflecting the content of decision 61/44 of the Executive Committee, asking the Secretariat to "maintain the established practice when evaluating component upgrades in HCFC conversion projects for the refrigeration and air-conditioning sectors, such that after conversion the defining characteristics of the components would remain largely unchanged or, when no similar component was available, would only be improved to the extent necessary to allow the conversion to take place […]"[2];

(b) The parameters entered as input values are also assumed to remain constant; in particular the capacity of the system, the application and whether a unit is factory assembled or assembled in the field, as well as the country and the share of export;

[2] For heat exchangers decision 61/44 was reflected assuming constant product of heat exchange surface and heat transfer coefficient, based on the values calculated for an HCFC baseline system at the design temperature of the system. For compressors, decision 61/44 of the Executive Committee was reflected by using a constant isentropic efficiency while adapting the swept volume to the compressor to provide the specified capacity at the design temperature of the system. The design temperature of the system is either 32°C or 40°C, the selection of which depends on the country of production and, for export, a generalised figure of 32°C.

(c) The load of the system is estimated depending on the design load = capacity of the unit, and an estimated deviation for different temperatures. A more detailed description can be found in Annex II;

(d) The energy efficiency varies, depending on the refrigerant used, for different outdoor temperatures; two refrigerants having the same energy efficiency at one outdoor temperature and otherwise identical operating conditions will show a difference in energy consumption at other conditions. In order to reflect this important effect, the Secretariat has attempted to collect the frequency of occurrence of temperatures for each Article 5 country in steps of 2 deg C. The energy efficiency is accordingly calculated for these outdoor temperatures and multiplied with the occurrence and the number of hours per year. In case of countries with several climate zones, the occurrence has been calculated by weighting the different climate zones according to the population living in them, as a proxy to the number of refrigeration systems used[3];

(e) The emission of carbon dioxide are published for a number of Article 5 countries and have been estimated for the remainder according to information found in literature; however, for most countries with refrigeration manufacturing capacity, i.e. larger Article 5 countries, information has been published[4].

7. Major challenges encountered by the Secretariat were related to the lack of precedent as to how countries and implementing and bilateral agencies would address the issue of data collection for refrigeration and air-conditioning equipment, due to a significant amount of submissions for projects covering more than one enterprise coming forward only to the 61st and 62nd Meetings of the Executive Committee. The formats used by the agencies to collect data lead to the need for significant changes in data management as compared to the original concept. It is assumed that these challenges faced by the Secretariat can be largely reduced in the next round of submissions by providing sufficiently detailed yet still practical data formats for submission.

MCII for foam manufacture conversion activities

8. For products manufactured in the foam sector, the direct effect caused by the foam blowing agent used over the lifetime of the product is relatively easily determined for the current use of HCFCs, since the entire foam blowing agent is emitted[5]. For post conversion emission, the case is more complex, since the amount of foam blowing agent used to produce a pre-defined quantity of foam will change; in addition, in some cases this quantity is defined based on mass of foam, in others on the volume of the foam. Additional variations are possible by using more than one blowing agent, e.g. in case of the common practice of adding water to HFC-245fa. Finally, in the case of insulation foams, the thickness of the insulation foam might be changed to accommodate changes in the insulation properties of the foam; a different foam thickness would be equivalent to a higher volume of foam, leading to a respective increase in foam blowing agent used.

[3] For example, Algeria shows both Mediterranean climate as well as hot and arid climate. However, the population is predominantly concentrated at the more temperate coast; consequently the coastal conditions have a higher relative weight than the conditions in the centre of the country.
[4] The Secretariat is still in the process of assessing the quality of the related data and improving it, where necessary.
[5] While the indicator is being set-up in a way which allows accounting for collection and destruction of the substance at the end of life of the product, at this time there is little indication to assume that in Article 5 or non-Article 5 countries a significant portion of foam blowing agent will be collected from products containing such foam.

9. Based on these considerations, a concept was developed on how to incorporate energy efficiency in the calculation of the MCII. After consultation with experts, the current concept is to distinguish between several different scenarios:

(a) Use of polyurethane foam for applications which require constant insulation effect. The related calculation model is meant to use some basic information and standardized properties of polyurethane foam to determine the change in wall thickness necessary to provide the same insulation effect when changing the foam blowing agent from an HCFC to an alternative technology from a pre-defined list. The change in wall thickness, in combination with the different amount of blowing agent per volume of foam needed and the change in density, will allow a calculation of the amount of alternative foam blowing agent needed. Typical applications would be all types of insulation with a defined insulation effect: e.g. based on regulatory requirements;

(b) Applications requiring the same volume of polyurethane foam, calculating the different amounts of blowing agent for the various technologies needed to produce a given volume of foam. This would be for example applicable to integral skin foam products for automotive use;

(c) Insulation foam used in confined refrigerated spaces, where the wall thickness cannot be changed to accommodate different insulation properties and where the insulated space is refrigerated. This option can be used for the insulation of refrigerators, commercial refrigeration equipment etc. where an increase in insulation thickness is often not possible due to space constraints[6];

(d) Use of extruded polystyrene foam for applications which require constant insulation effect. The calculations are performed similar those in the case indicated in sub-paragraph (a) above for the manufacture of polyurethane foam. This is a likely occurrence in the building industry;

(e) Use of extruded polystyrene foam in confined spaces, for applications where the wall thickness cannot be changed. The calculations are carried out similar to those in sub-paragraph (c) above manufacture of polyurethane foam.

MCII for conversion activities in other manufacturing sectors

10. In preparation for the 62nd Meeting, the Secretariat has also received projects and activities in the solvent and fire fighting sectors. The concept of the MCII can be extended to those sectors by assuming a certain release pattern. For solvent as well as for process agent uses, an assumption of a complete release in a short period of time after consumption is certainly meaningful. For the fire fighting sector, a more differentiated approach is necessary, since large quantities of fire fighting agents are simply stored and typically not released or released only after many decades of storage in fire fighting systems. The Secretariat has not yet developed a methodology for the MCII for the fire fighting sector.

[6] The cycle calculation model and country-specific data from the refrigeration model is meant to be used to calculate a change in energy consumption and related emissions of CO_2 related to electricity generation, which is added to the climate impact of the blowing agents. The reason for the calculation of energy related emissions only in cases where the energy use is refrigeration, and not for heating is that the difference is in energy used for heating, from sun powered over electricity, gas, oil, and coal as well as heat pumps is so diverse that no meaningful assumptions can be made for the emissions of carbon dioxide related to the additional heating needs of e.g. a building caused by a change in the insulation properties used.

MCII for the servicing sector

11. The Secretariat has attempted to extend the concept of the MCII to the servicing sector by addressing specific activities that are undertaken as part of the funded service sector activities in HPMPs. The basis for a methodology considered for submissions is that only those emission reductions are taken into account which are directly and quantifiably linked to activities funded by the Multilateral Fund, and that double counting with manufacturing sector activities is avoided. Consequently, changes in the climate impact caused by political agreements, for example the phase-out of HCFCs, are not covered since they are not linked to funded activities but to a commitment of the country to phase-out HCFCs. Accordingly, activities such as awareness and customs training will not contribute positively to the climate impact, since they are supporting compliance with a political agreement and are not directly causing reductions in climate relevant emissions. The remaining activities have in common that they are meant to reduce the consumption of HCFCs through reducing inefficient use of refrigerant. However, should the demand for HCFCs in the country be larger than the supply, any HCFC saved by reducing inefficient use of refrigerant would be used to satisfy the demand. The likely reasons why the supply would be smaller than the demand are import restrictions caused by the need to comply with the reduction schedule of the Montreal Protocol. If the activity leads to a better distribution of refrigerant away from inefficient use towards servicing more existing refrigeration systems, this would help the country to remain in compliance with the provisions of the Montreal Protocol. It would, however, not reduce the absolute amount of HCFC refrigerant used. Consequently, it would be difficult to assign under these circumstances a reduction in climate-relevant emissions directly related to the activity. However, the effect of this provision is likely to be very small, since according to reported data most countries consume less than their compliance target.

12. The attempt to calculate the value for the MCII for the servicing sector focuses on three types of activities in the servicing sector:

(a) Activities related to recovery can reduce the amount of refrigerant used by recovering, possibly recycling and reclaiming refrigerant during service and end-of-life of the equipment. For recovery, recovery and recycling and reclamation equipment, the existing experience of the Multilateral Fund allows for some broad assumptions regarding the amount of substance recovered, recycled, or reclaimed per year. The amount of refrigerant recovered, recycled or reclaimed will reduce the amount of new HCFCs to be used, and will consequently have a climate impact for those cases where otherwise new HCFC could have been used. The available data will allow this climate impact to be quantified depending on the number of machines to be used. A problem yet unresolved is how to determine a maximum meaningful number of machines for a given country in order to take into account the law of diminishing returns for increasing effort to recover refrigerant from existing systems.

(b) Servicing practices can be improved to some extent through training and provision of better tools for servicing. It is possible to assume that training of a refrigeration technician (as compared to no training) has some impact in terms of a reduction in refrigerant consumption. However small the effect might be for each technician, the relatively large training programmes supported by the Multilateral Fund are likely to show a noticeable positive effect in reduction of use of refrigerant during the service of refrigeration and air-conditioning equipment. Since every kilogramme of reduced consumption is reducing the impact on the climate accordingly, a figure for the climate impact of these measures can be calculated for those cases where otherwise new HCFCs could have been used.

(c) Activities related to replace HCFC-22 in existing refrigeration systems:

(i) The precondition of a positive impact on the climate for any replacement of HCFC-22 in existing systems is the recovery of the remaining refrigerant and its destruction or, for those countries with HCFC consumption below the compliance requirements, possibly its recycling. In all other cases, the impact of a replacement on the climate is most probably negative;

(ii) The replacement of existing HCFC-22 systems in refrigeration or air-conditioning with new systems using an alternative technology might lead to an impact on the climate. In order to avoid double-counting, such replacements would only be accounted for under the MCII for systems which would not be covered by a manufacturing sector phase-out project under the Multilateral Fund, i.e. the impact would only be calculated for custom-made systems, typically assembled, installed and charged at the owners location; an example would be a supermarket system. The implementing agency would have to provide the number of systems to be replaced, their approximate refrigeration capacity[7], whether the system is assembled and charged locally, and the alternative technology. The impact indicator would use this data to estimate the charge of HCFC-22 per refrigeration system, and extend this information to all systems covered by this specific activity. Based on an average remaining charge of HCFC-22 in the system at the time of replacement, and the design charge for the replacement, the difference in climate impact between the two can be determined. In those cases, the energy efficiency is not taken into account since the specific conditions of systems assembled on site do not allow the meaningful use of the relatively small differentiation in energy consumption between the system before conversion and afterwards.

(iii) After some consideration, the Secretariat has decided not to propose retrofit of existing systems in the activities which lead to a climate impact. The reason is that for existing systems, the typical retrofit technology would be the refrigerant with the closest match in thermodynamic and thermophysical properties, i.e. HFC-407C. Other than certain efforts related to exchanging the refrigeration oil and possibly replacing some controls, chiefly the expansion valve, the retrofit would be very simple to undertake. The difference in GWP between HCFC-22 and HFC-407C is fairly small (2.0 per cent) with HFC-407C having the lower GWP, further amplified by the density difference leading to a difference in climate impact based on the amount of fluid within the system of 5.43 per cent. However, the energy consumption in an existing system is more likely to increase than decrease with a conversion to HFC-407C. In combination, the climate impact is likely to be marginal, and should be assumed zero. While in terms of refrigeration characteristics HC-290 (propane) could be used in a similar way as HFC-407C, the flammability of HC-290 should in the vast majority of cases prevent HC-290 from being used for retrofits. Should a large retrofit programme be submitted to address this particular issue in an attempt to overcome the barrier for using HC-290 safely in systems designed for non-flammable refrigerants, the related calculations could be established based on principles explained above.

[7] The refrigeration capacity would be used to calculate the likely charge of these systems, since at the time of project submission such an approach might be the most accurate one.

13. The Secretariat is presently in the conceptual phase and wanted to present the above considerations regarding the service sector to the Executive Committee and the bilateral and implementing agencies; the Secretariat welcomes any feedback on these considerations. Some modelling calculations done by the Secretariat have shown that even using conservative assumptions and despite the limitations spelled out above, the effect that the activities in the servicing sector have on the climate might in some cases be significant.

Annex II

BACKGROUND INFORMATION REGARDING THE CALCULATION OF THE MCII (REFRIGERATION PART)

Introduction

1. The refrigeration model described in this document is part of the Multilateral Fund Climate Indicator (MCII) developed by the Multilateral Fund Secretariat; this model has been developed by Re/gent, a Research & Development centre in The Netherlands specialised in refrigeration, air conditioning and heat pumps. It has been integrated into a Microsoft Excel shell for data entry and, in particular, data management by Mr. Anton Driesse from Canada. The model can at this time be used to assess the environmental impact of HCFC-22 and its alternatives under different climatic conditions. It is still in a state of development, and therefore details described in this annex might be subsequently changed and documented accordingly. This annex concentrates mainly on the description of the model used for the calculation of the refrigeration cycle.

2. This version of the model is entirely developed as a spreadsheet tool, which is able to calculate refrigeration and AC system performances under a variety of ambient conditions and compare the results with an HCFC¬22 base case. This comparison does include both energy consumption as well as the related CO_2 emissions for which regional data is included in the model.

3. The spreadsheet model is structured as follows:

(a) A main sheet which contains the user input data (such as refrigeration system to be studied, country of application, etc.). Also the main output data is shown here, such as annual energy consumption and CO_2 emission for all the HCFC-22 alternatives included. The results are shown in tabular format;

(b) A transfer sheet into the actual refrigeration model, which is contained in a separate Excel file. This second Excel file contains also the other refrigeration-relevant information, such as

(i) A detail sheet which contains some of the main results calculated. It shows the system performance at the design point as well as a diagram of system efficiencies and compressor run time over the various ambient temperatures;

(ii) A set of cycle x sheets containing the refrigeration cycle calculations[8], based on ideal loop calculations extended with isentropic efficiencies of the compression process. The cycle calculations are automatically be performed for all relevant ambient temperatures (using a bin approach with temperature intervals);

(iii) A settings sheet which contains predefined data for the refrigeration/AC systems which can be assessed; and

(iv) A work area sheet where some background calculations, intermediate results etc. are placed.

[8] With “x” representing the name of the refrigerant.

(v) The spreadsheet model further contains some code modules (using VBA programming language), which is used for the necessary user interfacing.

(c) The spreadsheet model does require refrigerant property data. The data included in the model has been derived from the refrigeration property software (Refprop 6) from the National Institute for Standards and Technology in Boulder, United States of America. The Refprop data is included in the model by using tabular data and using interpolation methods to find intermediate data points. This avoids that a real property model needs to be installed along with the spreadsheet model, in order to be able to distribute the spreadsheet model without issues related to intellectual property.

Model description

4. Within the cycle model the refrigeration system is calculated using various refrigerants and for various ambient conditions. The ambient conditions are taken from the country specific occurrence of temperatures, which is for the purpose of the calculation converted to 20 different ambient temperatures where for each temperature the number of hours is known.

5. In a first step, a calculation of the base system is performed using HCFC-22 in the design condition. This generates some system data which is then used to calculate the cycle in the various ambient conditions in the off-design point calculations. For each of the operating temperatures this results in a system cooling capacity and the energy consumption. By multiplying the consumption with the number of hours in each temperature interval, it is possible to establish the total annual energy consumption of the system.

6. There are some special cases in the cycle calculations:

(a) If the compressor run time exceeds 100 per cent in general the system will not maintain the product temperature any more (e.g. the cooling unit will start to increase in temperature). In the model this is not compensated for, i.e. it is assumed that the compressor runs 100 per cent of the time, and the product or room is actually increasing in temperature. However, this is only the case at temperatures very significantly higher than the design temperature, and has not been reached in the simulations carried out;

(b) At very low ambient temperatures the condensation temperature may drop below the evaporation temperature (e.g. for the cooling application). This is prevented in the programme by setting a minimum temperature differential between condenser and evaporator and assuming for all temperatures below 10^{o}C constant conditions similar to 10^{o}C outdoor temperature. This is the simulation equivalent of the reality of a condenser fan control or a condensation pressure regulator; and

(c) The model has been extensively tested and rewritten to improve both running times and convergence of the result.

Design calculation

7. After the selection of the type of refrigeration or air-conditioning system, and the country with its climate data in the background, it is necessary to specify the required thermal load for which the system was designed (the amount of heat the cooling system must extract at design condition). This is equal to the capacity to be provided by the user. By the selection of the refrigeration and air-conditioning system and the country, a large number of parameters are preset; those are partially referred to already in Annex I

of this document. With these parameters being set the following calculation structure is applied for the base refrigerant HCFC-22:

(a) First the main refrigerant loop parameters are calculated, condensation and evaporation temperatures and outlet conditions of the evaporator as well as the condenser;

(b) From the system cooling capacity, an evaporator analysis is carried out leading to the evaporator conductance used for further calculations at off-design conditions;

(c) The refrigerant mass flow is determined;

(d) From the compression process the exit conditions at the compressor, which are equal to the inlet conditions of the condenser are derived; and

(e) Finally a condenser analysis can be made leading to the condenser conductance and the condenser air flow rate.

8. After the analysis of the HCFC-22 system at design condition, the evaporator and condenser sizes (conductance or UA values) are known as well as the air flows through evaporator and condenser. In addition also the compressor size needed for HCFC-22 to match the thermal load supplied is calculated. The evaporator and condenser information (UA and flow rate) is then applied to calculate the operation of the selected system with all alternative refrigerants. For each of these refrigerants a compressor size is selected which matches the thermal load at the design condition. After these preliminary calculations the off-design point calculations can start.

<u>Main circuit parameters</u>

9. It is possible to derive the evaporation temperature from the air inlet temperature to the evaporator and the temperature differential given by the user. From the refrigerant properties the evaporation pressure can be calculated. As the evaporator superheat is defined by the system selection, it is possible to calculate the evaporator exit enthalpy using the appropriate refrigerant relations.

10. For the condenser side, the condensation temperature can be derived from the air temperature entering the condenser and the temperature differential given by the user. Also here the condensation pressure is derived from refrigerant properties. The condenser exit temperature can be found by subtracting the sub-cooling supplied by the system selection from the condensation temperature. Using the appropriate refrigerant relations it is possible to calculate the condenser exit enthalpy.

11. Assuming isenthalpic expansion in the throttling device in the circuit, the evaporator inlet enthalpy can be set equal to the condenser exit enthalpy.

<u>Evaporator calculation at design</u>

12. The cooling capacity of the system can be calculated from the thermal load given and the compressor run time:

$$Q_r = \frac{Q_L}{R_p}$$

13. For the evaporator air side, the temperature differential is specified during system selection. As the cooling capacity is known, it is possible to calculate the air mass flow (and hence also the air volumetric flow):

$$\dot{m}_{e,air} = \frac{Q_r}{c_{\ p,air}\left(T_{\ e,air,in} T_{e,air,out}\right)}$$

14. As all temperatures are defined it is further possible to calculate the logarithmic mean temperature difference for the evaporator. It is then simply possible to calculate the evaporator conductance by:

$$(UA)_e = \frac{Q_r}{LMTD_e}$$

This implies that the evaporator heat transfer characteristics at design conditions are fixed and can be used later for other temperature conditions.

Refrigerant mass flow at design

15. The refrigerant mass flow can be calculated from:

$$m_r = \frac{Q_r}{h_{e.out} - h_{e.in}}$$

Compression process at design

16. The compressor exit conditions can be calculated using the isentropic efficiency and the inlet conditions. These are typically taken equal to the exit conditions of the evaporator. This allows calculating in the next step the compressor exit enthalpy as follows:

$$h_{comp,out} = \frac{h_{isentropic} + h_{comp,in}(\eta_i - 1)}{\eta_i}$$

17. From the compressor volumetric relations it is possible to derive the compressor displacement volume.

Condenser calculation at design

18. For the warm side (the condenser) it is now possible to perform the heat transfer calculations. First it is assumed that the air entering the condenser coil is at ambient temperature (so the design ambient temperature). As the condensation temperature is known and the temperature efficiency is supplied by the user, it is possible to calculate the air exit temperature:

$$T_{c,air,out} = \eta_c\left(T_c - T_{c,air,in}\right)$$

Knowing all temperatures also the logarithmic temperature difference can be calculated.

19. The condenser reject heat can be calculated as the refrigerant mass flow has already been established and the refrigerant state points at inlet and exit of the condenser are already known from the previous analysis:

$$Q_c = \dot{m}_r \left(h_{c,in} - h_{c,out}\right)$$

Knowing the condenser heat flow, it is possible to calculate the condenser conductance:

$$(UA_c) = \frac{Q_c}{LMTD_c}$$

It is further possible to resolve the condenser air mass flow from:

$$\dot{m}_{c,air} = \frac{Q_c}{c_{\ p,air}\left(T_{c,air,out} - T_{c,air,in}\right)}$$

Compressor

20. The compressor mass flow can be calculated as follows:

$$\dot{m} = \rho_{comp,in}\eta_v\phi_v$$

With the compressor volumetric efficiency defined as follows (using the clearance volume ratio CL):

$$\eta_v = 1 - CL\ \left\|\left[\left(\frac{p_c}{p_e}\right)^{1/k} - 1\right]\right\|$$

and the compressor displacement is typically found as the product of the compressor swept volume and the operating frequency. In the model the compressor displacement is used rather than swept volume in order to make systems independent on operating frequency as this is generally linked to the main supply frequency.

The compressor outlet conditions can typically be found using the isentropic efficiency given by the selection of the system:

$$\eta_i = \frac{h_{isentropic} - h_{comp,in}}{h_{comp,out} - h_{comp,in}}$$

if the inlet enthalpy to the compressor is known. The isentropic enthalpy is typically found using the appropriate refrigerant property relations.

Condenser

21. Basically three heat transfer relations are relevant for the condenser, for the air side, refrigerant side and the heat transfer between air and refrigerant, respectively:

$$Q = \dot{m}_{c,air} c_{p,air} \left(T_{c,air,out} - T_{c,air,in} \right)$$
$$Q = \dot{m}_{r} \left(h_{c,in} - h_{c,out} \right)$$
$$Q = (UA)_c \; LMTD_c$$

which must result in the same heat transfer in a stationary situation.

In this relation the logarithmic mean temperature difference is defined as:

$$LMTD_c = \frac{T_{c,air,in} - T_{c,air,out}}{\text{In} \left(\frac{T_c - T_{c,air,in}}{T_c - T_{c,air,out}} \right)}$$

To evaluate the heat transfer for a coil type of heat exchanger, it is possible to use the classical number of transfer units approach. This requires first the definition of the heat exchanger temperature efficiency:

$$\eta_c = \frac{T_c - T_{c,air,out}}{T_c - T_{c.air.in}}$$

It is possible to express the number of transfer units as the ratio of the conductance and the flow capacity:

$$NTU_c = \frac{(UA)_c}{\dot{m}_{c,air} \; c_{\rho,air}}$$

Assuming a cross flow heat exchanger, it is now possible to relate the number of transfer units and the heat exchanger efficiency with

$$\eta_c = 1 - e^{-NTU}$$

In total this is a set of seven equations, with the following 11 variables:

$Q, \dot{m}_{c,air}, T_{c,air,in}, T_{c,air,out}, \dot{m}_r, h_{c,in}, h_{c,out}, (UA)_c, T_c, NTU_c, \eta_c$

In general it requires therefore that four variables needs to be specified in order to solve the remaining parameters. Typically the mass flow of air is a given parameter as well as the air inlet temperature. If also the UA-value of the condenser coil is supplied and the refrigerant inlet enthalpy is supplied the remaining parameters can be calculated.

Note that the above only holds for the single fluid refrigerants. For the mixed refrigerants using a temperature glide, an extended model for the heat transfer effectiveness is integrated.

Evaporator

22. Basically three heat transfer relations are relevant for the evaporator, for the air side, refrigerant side and the heat transfer between air and refrigerant, respectively:

$$Q = \dot{m}_{e,air} c_{p,air} \left(T_{e,air,in} - T_{e,air,out} \right)$$
$$Q = \dot{m}_r \left(h_{e,out} - h_{e,in} \right)$$
$$Q = (UA)_e \, LMTD_e$$

which must result in the same heat transfer in a stationary situation.

In this relation the logarithmic mean temperature difference is defined as:

$$LMTD_e = \frac{T_{e,air,out} - T_{e,air,in}}{\text{In}\left(\frac{T_{e,air,in} - T_e}{T_{e,air,out} - T_e} \right)}$$

To evaluate the heat transfer for a coil type of heat exchanger, it is possible to use the classical number of transfer units approach. This requires first the definition of the heat exchanger temperature efficiency:

$$\eta_e = \frac{T_{e,air,out} - T_e}{T_{e,air,out} - T_e}$$

It is possible to express the number of transfer units as the ratio of the conductance and the flow capacity:

$$NTU_e = \frac{(UA)_e}{\dot{m}_{e,air} \; c_{\rho,air}}$$

Assuming a cross flow heat exchanger, it is now possible to relate the number of transfer units and the heat exchanger efficiency with

$$\eta_e = 1 - e^{-NTUe}$$

In total this is a set of seven equations, with the following 11 variables:

$$Q_r, \dot{m}_{e,air}, T_{e,air,in}, T_{e,air,out}, \dot{m}_r, h_{e,in}, h_{e,out}, (UA)_e, T_e, NTU_e, \eta_e$$

In general it requires therefore that four variables needs to be specified in order to solve the remaining parameters. Typically the mass flow of air is a given parameter as well as the air inlet temperature. If also the UA-value of the evaporator coil is supplied and the refrigerant inlet enthalpy is supplied the remaining parameters can be calculated.

Note that the above only holds for the single fluid refrigerants. For the mixed refrigerants using a glide, an extended model for the heat transfer effectiveness is integrated.

Off-design point calculation

23. Once the system has been selected and the calculation of the refrigeration system in the design point has been completed, it is possible to calculate the refrigeration cycle at other conditions. From the design point the air flow and thermal conductance (UA) of both the evaporator and condenser have been derived and are assumed to be the same in other operating conditions. Other parameters, such as superheat, sub-cooling and isentropic compressor efficiency are all supposed to remain constant when the operating conditions of the system changes.

24. With this given set of data an iterative calculation of the system is needed. This is due to the fact that only the air entrance temperatures are given for both the condenser and evaporator, but the condensation temperature and evaporation temperature are unknown. In fact the set of relations described under the compressor, condenser and evaporator topics are all applied and calculated. This requires first some assumptions for certain parameters, here the evaporation and condensation temperature are applied. Once assumed, it is possible to derive an error in the set of equation, which is used for revising the assumed evaporator and condenser temperature, this until convergence is achieved. In the cycle sheets, the off-design calculations are performed for different external ambient conditions, which generally impact the condenser performance.

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Annex III - Results of the calculations for project submissions to the 62nd Meeting for China, Indonesia, Nigeria and Serbia

Input	Documents UNEP/OzL.Pro/ExCom/62/26 and Add.1						Total
	Generic						
	Country	[-]	**China**				
	Company data (name, location)	[-]	**ICR Sector Plan**				
	Select system type	[list]	AC factory assembly	Commercial frozen onsite assembly	AC factory assembly		
	General refrigeration information						
	HCFC to be replaced	[-]	HCFC-22	HCFC-22	HCFC-22	HCFC-22	
	Amount of refrigerant per unit	[kg]	33.77	23.00	-	-	
	No. of units	[-]	114,019	6,522	117,723	7,692	245,956
	Refrigeration capacity	[kW]	96.0	96.0	96.0	96.0	
	Selection of alternative with minimum environmental impact						
	Share of exports (all countries)	[%]	-	-	-	-	
	Calculation of the climate impact						
	Alternative refrigerant (more than one possible)	[list]	HFC-32	HFC-32	HFC-410A	R-134a	

NOTE
All data displayed is specific to the case investigated and is not generic information about the performance of one alternative; performance can differ significantly depending on the case.

Output	*Note: The output is calculated as the climate impact of the refrigerant systems in their life time as compared to HCFC-22, on the basis of the amount produced within one year. Additional/different outputs are possible*						
	Country		**China**				
	Identification of the alternative technology with minimum climate impact						
	List of alternatives for identification of the one with minimum climate impact	[Sorted list, best = top (% deviation from HCFC)]	HC-600a (-21%)	HC-600a (-10%)	HC-600a (-21%)	HC-600a (-16%)	
			HC-290 (-18%)	HC-290 (-6%)	HC-290 (-18%)	HC-290 (-12%)	
			HFC-32 (-10%)	HFC-134a (-3%)	HFC-134a (-5%)	HFC-134a (-5%)	
			HFC-134a (-5%)	HFC-32 (-3%)	HFC-407C (-1%)	HFC-407C (0%)	
			HFC-407C (-1%)	**HCFC-22**	**HCFC-22**	**HCFC-22**	
			HCFC-22	HFC-407C (3%)	HFC-410A (5%)	HFC-410A (5%)	
			HFC-410A (5%)	HFC-410A (5%)			
	Calculation of the climate impact						
	Per unit, over lifetime (for information only):						Total
			HCFC-22	HCFC-22	HCFC-22	HCFC-22	
	Energy consumption	[kWh]	31,041,593,467	20,951,578,333	32,050,004,892	2,114,526,046	86,157,702,738
	Direct climate impact (substance)	[kg CO2 equiv]	7,108,648	1,132,200	7,261,336	266,059	15,768,243
	Indirect climate impact (energy): In country	[kg CO2 equiv]	32,076,313	21,649,964	33,118,338	2,185,010	89,029,625
	Indirect climate impact (energy): Global average	[kg CO2 equiv]	-	-	-	-	-
	Calculation of the climate impact of the conversion						
	Selected refrigerant		**HFC-32**	**HFC-32**	**HFC-410A**	**R-134a**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*(4,774,055.0)*	*(760,368.0)*	*196,363.0*	*(53,125.0)*	(5,391,185)
	*Indirect impact (country)***	*[t CO2 equiv]*	*679,466.0*	*170,934.0*	*1,887,588.0*	*(60,484.0)*	2,677,504
	*Indirect impact (outside country)***	*[t CO2 equiv]*	-	-	-	-	-
	Total indirect impact	*[t CO2 equiv]*	*679,466.0*	*170,934.0*	*1,887,588.0*	*(60,484.0)*	2,677,504
	Total impact of the selected refrigerant	**[t CO2 equiv]**	**(4,094,589)**	**(589,434)**	**2,083,951**	**(113,609)**	**(2,713,681)**
	Alternative refrigerant		**HC-290**	**HC-290**	**HC-290**	**HC-290**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*(7,076,192)*	*(1,127,031)*	*(7,228,183)*	*(264,844)*	
	*Total indirect impact (country)***	*[t CO2 equiv]*	*146,968*	*(225,534)*	*151,742*	*(23,959)*	
	*Total indirect impact (outside country)***	*[t CO2 equiv]*	-	-	-	-	
	*Total indirect impact***	*[t CO2 equiv]*	*146,968*	*(225,534)*	*151,742*	*(23,959)*	
	Total impact of alternative refrigerant	**[t CO2 equiv]**	**(6,929,224)**	**(1,352,565)**	**(7,076,441)**	**(288,803)**	

*Direct impact: Different impact between alternative technology and HCFC technology for the substance-related emissions.

**Indirect impact: Difference in impact between alternative technology and HCFC technology for the energy-consumption-related emissions of CO2 when generating electricity.

Input	Documents UNEP/OzL.Pro/ExCom/62/26 and Add.1				Total
	Generic				
	Country	[-]	**China**		
	Company data (name, location)	[-]	**RAC Sector phase I**		
	Select system type	[list]	AC on site assembly		
	General refrigeration information				
	HCFC to be replaced	[-]	HCFC-22		
	Amount of refrigerant per unit	[kg]	1.20	1.20	
	No. of units	[-]	5,000,000	2,500,000	7,500,000
	Refrigeration capacity	[kW]	3.5	3.5	
	Selection of alternative with minimum environmental impact				
	Share of exports (all countries)	[%]	-	-	
	Calculation of the climate impact				
	Alternative refrigerant (more than one possible)	[list]	HC-290	HFC-410A	

NOTE
All data displayed is specific to the case investigated and is not generic information about the performance of one alternative; performance can differ significantly depending on the case.

Output	*Note: The output is calculated as the climate impact of the refrigerant systems in their life time as compared to HCFC-22, on the basis of the amount produced within one year. Additional/different outputs are possible*				
	Country		**China**		
	Identification of the alternative technology with minimum climate impact				
	List of alternatives for identification of the one with minimum climate impact	[Sorted list, best = top (% deviation from HCFC)]	HC-600a (-28%)	HC-600a (-28%)	
			HC-290 (-24%)	HC-290 (-24%)	
			HFC-134a (-7%)	HFC-134a (-7%)	
			HFC-407C (-1%)	HFC-407C (-1%)	
			HCFC-22	**HCFC-22**	
			HFC-410A (5%)	HFC-410A (5%)	
	Calculation of the climate impact				
	Per unit, over lifetime (for information only):				Total
			HCFC-22	HCFC-22	
	Energy consumption	[kWh]	50,111,866,510	25,055,933,255	75,167,799,765
	Direct climate impact (substance)	[kg CO2 equiv]	15,964,200	7,982,100	23,946,300
	Indirect climate impact (energy): In country	[kg CO2 equiv]	51,782,262	25,891,131	77,673,393
	Indirect climate impact (energy): Global average	[kg CO2 equiv]	-	-	-
	Calculation of the climate impact of the conversion				
	Selected refrigerant		**HC-290**	**HFC-410A**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*(15,891,312.0)*	*215,854.0*	(15,675,458)
	*Indirect impact (country)***	*[t CO2 equiv]*	*(567,818.0)*	*1,463,492.0*	895,674
	*Indirect impact (outside country)***	*[t CO2 equiv]*	-	-	-
	Total indirect impact	*[t CO2 equiv]*	*(567,818.0)*	*1,463,492.0*	895,674
	Total impact of the selected refrigerant***	**[t CO2 equiv]**	**(16,459,130)**	**1,679,346**	**(14,779,784)**
	Alternative refrigerant		**HFC-410A**	**HC-290**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*431,707*	*(7,945,656)*	
	*Total indirect impact (country)***	*[t CO2 equiv]*	*2,926,985*	*(283,909)*	
	*Total indirect impact (outside country)***	*[t CO2 equiv]*	-	-	
	*Total indirect impact***	*[t CO2 equiv]*	*2,926,985*	*(283,909)*	
	Total impact of alternative refrigerant	**[t CO2 equiv]**	**3,358,692**	**(8,229,565)**	

*Direct impact: Different impact between alternative technology and HCFC technology for the substance-related emissions.

**Indirect impact: Difference in impact between alternative technology and HCFC technology for the energy-consumption-related emissions of CO2 when generating electricity.

***China also chose to convert some of the units into R-161. The impact of conversion to R-161 cannot be provided.

Input	Documents UNEP/OzL.Pro/ExCom/62/35 and Add.1							Total
	Generic							
	Country	[-]	**Indonesia**					
	Company data (name, location)	[-]	**RAC Sector Plan**					
	Select system type	[list]	Commercial frozen onsite assembly					
	General refrigeration information							
	HCFC to be replaced	[-]	HCFC-22			HCFC-22		
	Amount of refrigerant per unit	[kg]	0.69	14.60	291.3	14.6	291.3	
	No. of units	[-]	266,641	16,000	3	282,641	226	565,511
	Refrigeration capacity	[kW]	1,875	7,115	33,541	7115	33541	
	Selection of alternative with minimum environmental impact							
	Share of exports (all countries)	[%]	-	-				
	Calculation of the climate impact							
	Alternative refrigerant (more than one possible)	[list]	HFC-410A	HFC-410A	HFC-410A	HFC-32	HFC-32	

NOTE
All data displayed is specific to the case investigated and is not generic information about the performance of one alternative; performance can differ significantly depending on the case.

Output	*Note: The output is calculated as the climate impact of the refrigerant systems in their life time as compared to HCFC-22, on the basis of the amount produced within one year. Additional/different outputs are possible*							
	Country		**Indonesia**					
	Identification of the alternative technology with minimum climate impact							
	List of alternatives for identification of the one with minimum climate impact	[Sorted list, best = top (% deviation from HCFC)]	HC-600a (-21%)	HC-600a (-65%)	HC-600a (-88%)	HC-600a (-65%)	HC-600a (-31%)	
			HC-290 (-17%)	HC-290 (-63%)	HC-290 (-87%)	HC-290 (-63%)	HC-290 (-27%)	
			HFC-134a (-5%)	HFC-134a (-14%)	HFC-134a (-18%)	HFC-32 (-41.5%)	HFC-134a (-7%)	
			HFC-407C (-1%)	HFC-407C (-3%)	HFC-407C (-4%)	HFC-134a (-14%)	HFC-32 (-1.4%)	
			HCFC-22	**HCFC-22**	**HCFC-22**	HFC-407C (-3%)	HFC-407C (-1%)	
			HFC-410A (6%)	HFC-410A (4%)	HFC-410A (3%)	**HCFC-22**	**HCFC-22**	
						HFC-410A (4%)	HFC-410A (6%)	
	Calculation of the climate impact							
	Per unit, over lifetime (for information only):							Total
			HCFC-22	HCFC-22	HCFC-22			
	Energy consumption	[kWh]	2,327,145,837	534,707,446	472,627	216,422,839	751,602,912	3,830,351,661
	Direct climate impact (substance)	[kg CO2 equiv]	339,668	621,540	2,323	251,568	623,863	1,838,962
	Indirect climate impact (energy): In country	[kg CO2 equiv]	1,614,993	371,076	328	150,193	371,404	2,507,994
	Indirect climate impact (energy): Global average	[kg CO2 equiv]	-	-	-	-	-	-
	Calculation of the climate impact of the conversion							
	Selected refrigerant		**HFC-410A**	**HFC-410A**	**HFC-410A**	**HFC-32**	**HFC-32**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*9,185.0*	*16,807.0*	*63.0*	(168,949)	(541,244)	(684,138)
	*Indirect impact (country)***	*[t CO2 equiv]*	*111,873.0*	*25,139.0*	*22.0*	2,201	(219,010)	(79,775)
	*Indirect impact (outside country)***	*[t CO2 equiv]*	-	-	-	-	-	-
	Total indirect impact	*[t CO2 equiv]*	*111,873.0*	*25,139.0*	*22.0*	*2,201.0*	*(219,010.0)*	(79,775)
	Total impact of the selected refrigerant	**[t CO2 equiv]**	**121,058**	**41,946**	**85**	**(166,748)**	**(760,254)**	**(763,913)**
	Alternative refrigerant		**HC-290**	**HC-290**	**HC-290**	**HFC-410A**	**HFC-410A**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*(338,117)*	*(618,702)*	*(2,312)*	*6,803*	*(620,417)*	
	*Total indirect impact (country)***	*[t CO2 equiv]*	*10,298*	*(3,695)*	*(3)*	*10,175*	*24,896,415*	
	*Total indirect impact (outside country)***	*[t CO2 equiv]*	-	-	-	-	-	
	*Total indirect impact***	*[t CO2 equiv]*	*10,298*	*(3,695)*	*(3)*	*10,175*	*24,896,415*	
	Total impact of alternative refrigerant	**[t CO2 equiv]**	**(327,819)**	**(622,397)**	**(2,315)**	**16,978**	**24,275,998**	

*Direct impact: Different impact between alternative technology and HCFC technology for the substance-related emissions.

**Indirect impact: Difference in impact between alternative technology and HCFC technology for the energy-consumption-related emissions of CO2 when generating electricity.

Input	Document UNEP/OzL.Pro/ExCom/62/43		
	Generic		
	Country	[-]	**Nigeria**
	Company data (name, location)	[-]	**RAC**
	Select system type	[list]	AC factory assembly
	General refrigeration information		
	HCFC to be replaced	[-]	HCFC-22
	Amount of refrigerant per unit	[kg]	1.3
	No. of units	[-]	462,240
	Refrigeration capacity	[kW]	1.5
	Selection of alternative with minimum environmental impact		
	Share of exports (all countries)	[%]	-
	Calculation of the climate impact		
	Alternative refrigerant (more than one possible)	[list]	HFC-410A

NOTE
All data displayed is <u>specific</u> to the case investigated and is <u>not</u> <u>generic</u> information about the performance of one alternative; performance can differ significantly depending on the case.

Output	*Note: The output is calculated as the climate impact of the refrigerant systems in their life time as compared to HCFC-22, on the basis of the amount produced within one year. Additional/different outputs are possible*		
	Country		**Nigeria**
	Identification of the alternative technology with minimum climate impact		
	List of alternatives for identification of the one with minimum climate impact	[Sorted list, best = top (% deviation from HCFC)]	HC-600a (-53%)
			HC-290 (-50%)
			HFC-134a (-11%)
			HFC-407C (-3%)
			HCFC-22
			HFC-410A (5%)
	Calculation of the climate impact		
	Per unit, over lifetime (for information only):		
			HCFC-22
	Energy consumption	[kWh]	3,350,637,086
	Direct climate impact (substance)	[kg CO2 equiv]	1,066,734
	Indirect climate impact (energy): In country	[kg CO2 equiv]	1,027,529
	Indirect climate impact (energy): Global average	[kg CO2 equiv]	-
	Calculation of the climate impact of the conversion		
	Selected refrigerant		**HFC-410A**
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*28,847.0*
	*Indirect impact (country)***	*[t CO2 equiv]*	*73,581.0*
	*Indirect impact (outside country)***	*[t CO2 equiv]*	-
	Total indirect impact	*[t CO2 equiv]*	*73,581.0*
	Total impact of the selected refrigerant	**[t CO2 equiv]**	**102,428**
	Alternative refrigerant		**HC-407C**
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*(54,987)*
	*Total indirect impact (country)***	*[t CO2 equiv]*	*2,106*
	*Total indirect impact (outside country)***	*[t CO2 equiv]*	-
	*Total indirect impact***	*[t CO2 equiv]*	*2,106*
	Total impact of the alternative refrigerant	**[t CO2 equiv]**	**(52,881)**

*Direct impact: Different impact between alternative technology and HCFC technology for the substance-related emissions.
**Indirect impact: Difference in impact between alternative technology and HCFC technology for the energy-consumption-related emissions of CO_2 when generating electricity.

Input	Document UNEP/OzL.Pro/ExCom/62/47				Total
	Generic				
	Country	[-]	**Serbia**		
	Company data (name, location)	[-]	**Four companies**		
	Select system type	[list]	Commercial cooling, factory assembly		
	General refrigeration information				
	HCFC to be replaced	[-]	HCFC-22	HCFC-22	
	Amount of refrigerant per unit	[kg]	Average 11.26	Average 11.26	
	No. of units	[-]	2,753	918	3,671
	Refrigeration capacity	[kW]	between 0.66 and 750	between 0.66 and 750	
	Selection of alternative with minimum environmental impact				
	Share of exports (all countries)	[%]	0	0	
	Calculation of the climate impact				
	Alternative refrigerant (more than one possible)	[list]	R-410A	R-717	

NOTE
All data displayed is specific to the case investigated and is not generic information about the performance of one alternative; performance can differ significantly depending on the case.

Output	*Note: The output is calculated as the climate impact of the refrigerant systems in their life time as compared to HCFC-22, on the basis of the amount produced within one year. Additional/different outputs are possible*				
	Country		**Serbia**		
	Identification of the alternative technology with minimum climate impact				
	List of alternatives for identification of the one with minimum climate impact	[Sorted list, best = top (% deviation from HCFC)]	HC-600a (-14%)	R-717 (-14%)	
			HC-290 (-11%)	HC-600a (-14%)	
			HFC-134a (-3%)	HC-290 (-11%)	
			HCFC-22	HFC-134a (-3%)	
			HFC-407C (2%)	**HCFC-22**	
			HFC-410A (5%)	HFC-407C (2%)	
				HFC-410A (5%)	
	Calculation of the climate impact				
	Per unit, over lifetime (for information only):				
			HCFC-22	HCFC-22	Total
	Energy consumption	[kWh]	703,263,494	703,263,494	1,406,526,988
	Direct climate impact (substance)	[kg CO2 equiv]	57,230	19,084	76,314
	Indirect climate impact (energy): In country	[kg CO2 equiv]	464,419	154,863	619,282
	Indirect climate impact (energy): Global average	[kg CO2 equiv]	-	-	-
	Calculation of the climate impact of the conversion				
	Selected refrigerant		**HFC-410A**	**R-717**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*1,548*	*-19,084*	(17,536)
	*Indirect impact (country)***	*[t CO2 equiv]*	*22,308*	*-5,161*	17,147
	*Indirect impact (outside country)***	*[t CO2 equiv]*	*0*	*0*	-
	Total indirect impact	*[t CO2 equiv]*	*22,308*	*-5,161*	17,147
	Total impact	**[t CO2 equiv]**	**23,856**	**-24,245**	(389)
	Alternative refrigerant		**R-290**	**HFC-404A**	
	*Total direct impact (post conversion – baseline)**	*[t CO2 equiv]*	*-56,969*	*17,189*	
	*Total indirect impact (country)***	*[t CO2 equiv]*	*604*	*8,809*	
	*Total indirect impact (outside country)***	*[t CO2 equiv]*	*0*	*0*	
	*Total indirect impact***	*[t CO2 equiv]*	*604*	*8,809*	
	Total impact	**[t CO2 equiv]**	**-56,365**	**25,998**	

*Direct impact: Different impact between alternative technology and HCFC technology for the substance-related emissions.
**Indirect impact: Difference in impact between alternative technology and HCFC technology for the energy-consumption-related emissions of CO_2 when generating electricity.