EP

الأمم المتحدة

Distr.
GENERAL

برنامج
الأمم المتحدة
للبيئة

UNEP/OzL.Pro/ExCom/73/54/Add.1
31 October 2014
ARABIC
ORIGINAL: ENGLISH

اللجنـة التنفيـذيـــة للصنــدوق المـتعـدد الأطــراف
لتنفيــذ بروتوكـول مونتريــال
الاجتمـــــاع الثالث والسبعون
باريس، 9 - 13 نوفمبر / تشرين الثاني 2014

إضافــــــة

تقرير حول استعمال مؤشر الصندوق المتعدد الأطراف المتعلق بالأثر على المناخ

(المقرر 23/69)

تصدر هذه الوثيقة من أجل:

- **إضافة** الفقرة التالية:

17 (مكرراً). وقد أرفقت تقارير الخبراء المؤهلين الثلاثة بهذه الوثيقة. وركزت استعراضاتهم على مدى ملاءمة تكوين أداة مؤشر الصندوق المتعدد الأطراف المتعلق بالأثر على المناخ، وسهولة استخدامها على المستعملين، والجوانب الإيجابية والسلبية لحساباتها، وملاءمة عمليتي استخراج النتائج وعرضها، واتساق هذه الأداة مع أعمال هيئات الأمم المتحدة الأخرى المشتغلة بقضايا تتصل بالمناخ. واعتبرت الاستعراضات تكوين الأداة ملائما كما اعتبرتها مناسبة للمستعملين. وقدم اثنان من الاستعراضات مقترحات محددة لجعل الأداة أكثر دقة في حساباتها. وتعكف الأمانة في الوقت الحالي على المسائل الرئيسية التي أثارتها استعراضات الخبراء. وسيجري تحميل المؤشر المنقح في الموقع الشبكي للأمانة بمجرد الانتهاء من هذا العمل.

- **إضافة** المرفق.

From: Piotr A. Domanski October 23, 2014

Review of the Multilateral Fund Climate Impact Indicator (MCII)

I present my comments on the following aspect of the MCII:

- Concept of MCII and methodology
- Adequacy of the set-up and the user friendliness
- Discussion of calculation results

I. Concept of MCII and Methodology

(based on the document entitled: MCII Model, Refrigeration and AC Systems)

I appreciate the need for the MCII and agree with the goal to provide a simple, easy to use tool that will provide reasonable information on the effect on the climate of conversions from R22-based systems to alternative refrigerants.

The technical concept described in the document is good (integration of energy use over the season using temperature bins), and I agree the thermodynamic cycle simulation assumptions as adequate for this particular purpose. However, I have two general comments about the write-up:

- The presented equations have several errors. I recommend that they a reviewed by the authors and corrected. For example:
    - Equations [cond5] and [evap5] are not consistent with established practice and the definition on page 11 (although accidently the equations used provide the same value for 50 % effectiveness). BTW, the term 'effectiveness' is a more established term than the term 'temperature efficiency' used in the write-up.
    - Several equations for LMTD have incorrect subscripts (e.g., p. 19, or equation [cond 4])
    - Equation [cond7] is applicable to counter flow heat exchangers; not to cross flow heat exchangers as stated in the write-up[1].

  The above observation does not preclude that the simulation code might be done correctly.

- The authors discussed the need for a refrigerant heat transfer correction factor (the same could be said about a correction for pressure drop), and provided a reasonable approach for R407C (zeotropic mixture with a considerable temperature glide). However, no correction (at this point) has been proposed for transport properties and dT_{sat}/dP (relationship between the saturation temperature and pressure) for other fluids. This omission will affect calculated results (discussed later in Section III) since the lack of correction of the heat exchangers' UA values make the MCII analysis consistent with that based on thermodynamic properties alone.

One specific comment: I did not understand the rationale and assumptions used for the equation for $Q_{Base,AC}$ (page 21), and can't comment on it.

---

[1] E.g., F.C. McQuiston, J.D. Parker, 1994. Heating, Ventilating, and Air Conditioning, Analysis and Design, J. Wiley & Sons. Page 571

II. Adequacy of the set-up and the user friendliness

I found the tool to be easy to use. The tool presents simulation results in a very friendly manner.

III. Discussion of calculation results

To review results generated by MCII, I performed an analysis for an air-conditioning unit in Seychelles (attached). My observation is that the obtained results on indirect impact for different fluids are not correct to a degree that will provide incorrect relative rankings of alternative fluids.

The MCII analysis shows that the transition from R22 to isobutane and R-1234yf will results in a reduced indirect effect, i.e., improved equipment efficiency. On the other hand, transition from R22 to R410A and R32 will result in an efficiency decrease, while a change from R22 to propane will be efficiency neutral. These results correlate with critical temperatures of the analyzed fluids (fluids with a lower T_{crit} (R410A and R32) have a lower efficiency than fluids with a high T_{crit} (R134a, isobutene and R1234yf); because of the modeling methodology they may correctly represent relative performance of these fluids in chiller systems employing shell-and-tube heat exchangers (pool-boiling and space-condensation refrigerant heat transfer).

However, the obtained results are in disagreement with the current recognition of relative merits of refrigerants applied in systems using optimized serpentine heat exchangers (forced convection evaporation and condensation heat transfer), such as residential and small commercial units. To start with propane, the literature is full of claims of propane having a 5 % - 10 % better efficiency than R22[2]. Regarding R410A, the industry learned to optimize R410A heat exchangers and to match COP_{R22} with R410A systems. Our 2006 study[3] confirmed the COP equivalency between R22 and R410A. It also indicated that R134a and isobutene will underperform R22, propane and R410A in an optimized system (when transport properties and system effects are accounted for), while the MCII model predicts isobutene and R134a to be the most efficient fluids.

A general observation is that high-pressure fluids (such as R32 and R410A) have a lower dT_{sat}/dP (lower drop of saturation temperature for a given pressure drop). It means that these refrigerants can be used with a higher mass flux in heat exchangers for a given drop in saturation temperature; a higher mass flux improves the refrigerant heat transfer coefficient[4]. Obviously, transport properties (chiefly liquid thermal conductivity and viscosity) also affect performance of heat exchangers as demonstrated by propane, which T_{crit} (and normal boiling point) is not much different than that for R22.

In conclusions, I believe that the MCII overrates low-pressure fluids (such as R134a, isobutane, and R1234yf) and underrates high-pressure fluids (R410A, R404A, and R32) by not considering the dT_{sat}/dP relationship.
Besides the dT_{sat}/dP consideration, isobutane, propane, and R32 would gain some benefit if the MCII included transport properties in the analysis.

---

[2] Some claims go as high as 20 % but these system most likely have different heat fluxes in the evaporator and condenser

[3] Domanski, P.A., Yashar, D., 2006. Comparable Performance Evaluation of HC and HFC Refrigerants in an Optimized System, 7th IIR G/ Lorentzen Conference on Natural Working Fluids, Trondheim, Norway. (Figure 6)

[4] This physical 'behavior' is exploited in CO_2 heat exchangers, which circuitries are designed to effect high mass fluxes.

Multilateral Fund Climate Impact Indicator (MCII)

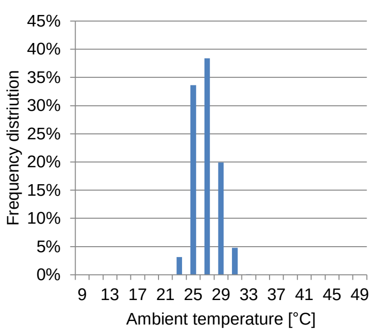
Version 3.1

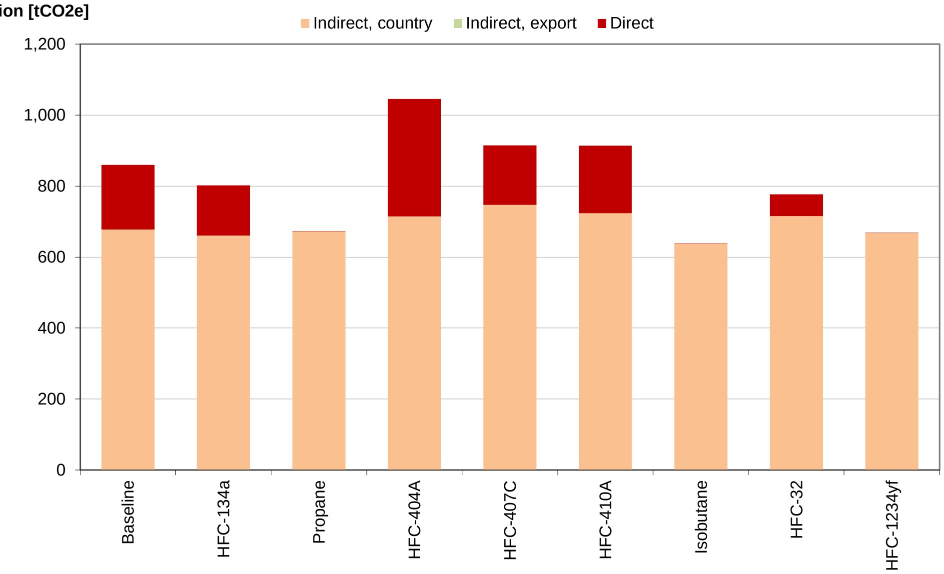
	Calculating	Done
General information	*Elapsed Time [s]*	101
Enterprise		AB Refrigeration
City		Capital City
Country		Seychelles
Agency		UNEP
Product information		
Application		AC, factory assembly
Model name or number		A1000
Number of units produced per year	[#/y]	100
Percentage exported	[%]	0%
Refrigerant charge per unit	[kg]	1
Product lifespan	[y]	10
Cooling capacity per unit		
Minimum for this application type	[W]	1,000
Maximum for this application type	[W]	20,000
Cooling capacity per unit	[W]	1,000
Alternatives to evaluate		
HFC-134a		x
Propane		x
HFC-404A		x
HFC-407C		x
HFC-410A		x
Isobutane		x
HFC-32		x
HFC-1234yf		x

		Baseline	HFC-134a	Propane	HFC-404A	HFC-407C	HFC-410A	Isobutane	HFC-32	HFC-1234yf
Direct impact (over lifetime)										
ODS consumption (including service)	[t ODP]	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Climate impact of emissions	[t CO2e]	183	142	1	331	168	191	1	61	0
Indirect Impact, related to electricity production										
Country										
Design ambient temperature	[°C]	32								
Electricity consumption, annual	[GWh/y]	0	0	0	0	0	0	0	0	0
Climate impact of lifetime emissions	[t CO2e]	677	660	673	714	747	723	638	716	668
Export										
Global design temperature	[°C]	32								
Electricity consumption, annual	[GWh/y]	0	0	0	0	0	0	0	0	0
Climate impact of lifetime emissions	[t CO2e]	0	0	0	0	0	0	0	0	0
Total impact breakdown										
Change in direct impact	[t CO2e]		-41	-182	148	-15	8	-182	-121	-182
Change in indirect impact, country	[t CO2e]		-17	-5	37	70	46	-39	39	-9
Change in indirect impact, global	[t CO2e]		0	0	0	0	0	0	0	0
Total impact summary										
Total	[t CO2e]	860	802	673	1,045	915	914	639	777	668
Change	[t CO2e]		-58	-186	186	55	54	-221	-83	-192
Percent change	[%]		**-7%**	**-22%**	**22%**	**6%**	**6%**	**-26%**	**-10%**	**-22%**

Total lifetime climate impact of one year of production [tCO2e]

Enterprise
AB Refrigeration
City
Capital City
Country
Seychelles
Model name or number
A1000





-----Original Message-----
From: "胡建信(Jianxin Hu)" [mailto:jianxin@pku.edu.cn]
Sent: Saturday, October 25, 2014 3:52 PM
To: Eduardo Ganem

Subject: Re: MCII tool (Excel) and manual

Dear Eduardo,

Please find my review comments attached with this email.

Best regards,

Jianxin

Review on the Multilateral Fund Climate Impact Indicator (MCII)

General comments: I like this work very much. We are facing the questions about energy efficiencies and GWP of refrigerants in many discussions for alternative technologies related to HCFCs and HFCs phaseout. The instruction is not too long and not complicated. The methodology for set-up the calculation is acceptable based on my knowledge; and the MCII is easy to use.

1. terms of the adequacy of the set-up

The fixed data in table “Refrigeration/AC system settings” are similar to what we are using for calculation in China. The recommend default data are also reasonable. However, “*Annual leakage” 25%* for commercial Cooling and Frozen, on site assembly may be a little higher, but I don’t have recommendation data based on reference.

The calculations descripted in “Cycle model description” are acceptable based on my knowledge.

The description for “Emission model” is clear. I have only one concern related to the “Direct emissions ”. Based on my understanding, the calculation for direct emissions is based on production. That means the “Direct emissions” including recharge amount for the export products in the import countries. I will recommend to separate “Direct emissions” as the term for “indirect emission”, especially when considering on commercial Cooling and Frozen, on site assembly. The MCII assume the recycle amount is zero currently in developing countries. It will be better to present a figure considering there are and will be many recycling projects in developing countries.

2. the user friendliness

My testing software: windows 8.1, Microsoft office 2013 enterprise version.

It is very simple to run the calculation just simply to input a few data. It takes about 1 minute to finish the calculation. The results are clear and same as the description in the instruction report.

I will say MCII is very friendly model for use.

3. recommendations

- The MCII could present what key data used for the calculation, such as: carbon density. When selected country, carbon density could present with the city, country.
- To separate “Direct emissions” as the term for “indirect emission”.
- Default Recycling amount in developing countries could be zero, but I suggest the default data is changeable.
- Can you make MCII workable for MAC OS user?

I also test MCII using MAC OS X Yosemite, Microsoft office for MAC 2011. I cannot make the MCII works, because it mentions that it doesn’t support “activeX” in the model.

Review MCII Tool

for

Secretariat of the Multilateral Fund for the Implementation of the Montreal Protocol

United Nations Environment Programme

1000 De La Gauchetière Street West, Suite 4100

Montreal, Quebec H3B 4W5

Canada

Prepared by

ref-tech engineering

Dipl.-Ing. Holger König

October 31, 2014

1 Task

Review of the Multilateral Fund Climate Impact Indicator (MCII), a tool developed by the Secretariat to provide an indication of climate impact of future conversion projects in the refrigeration and air conditioning manufacturing sectors as compared to the HCFC-22 baseline.

2 Adequacy of the set-up

The MCII is meant as an indicating tool which is able to take the direct emissions and the indirect emissions due to energy consumption of some specified refrigeration applications with R22 and alternative refrigerant replacements into account. Since it is only regarded as an indicating tool with a limited set of inputs of the user, the set-up/method of the tool can be generally accepted as adequate. It seems reasonable to extend the cycle calculations for the estimation of energy consumption from only one calculation for a design point to the calculation for different operation points depending on the climate of the location of the system.

During the study of the manual the following findings rise to doubts concerning the consistency of the calculation, although the method can be accepted in general:

- The table in section 2.2 provides for all "on site assembly"-systems evaporator exit temperatures $T_{e,out}$ (corresponding to the calculation given in section 3.2.1) which are higher than the air inlet temperatures $T_{e,air,in}$ which is physically not possible. The energy balances for the evaporator might be incorrect within the calculation process which could influence the correctness of the whole calculation.
- Wrong equation for calculation of $T_{c,air,out}$ at the beginning of section 3.2.5 using the “temperature efficiency” and also the equation [cond5] for the efficiency in section 3.3.2.
- The same equation concerning the evaporator in section 3.3.3 [evap5] is also wrong.
- The symbol Q_R is used for refrigeration capacity as well as for thermal load.
- It is not explained how the charges of the alternative refrigerants are calculated within the tool although this value is important for the determination of the direct emissions.
- According to the first equation in section 4.5 the compressor run time R_p is a required factor for the calculation of the annual energy consumption $E_{T,country}$ as well as $E_{T,export}$ but the determination of this factor is not described within the manual.

The code of the simulation tool was not checked within this review. It was hidden within the excel workbook and such a check was not part of the aim of the review.

The results of the energy consumption calculation are much and the results of the direct emissions calculation are totally determined by the pre-set parameters. The assumptions for these values are provided and explained in section 2.2 but there is no reference to any investigation concerning the selection of these values. With respect to the importance of these assumptions to the results of the tool it is advised to perform a critical review of these values.

The concept to use fixed conductance’s (UA-values) for evaporator and condenser calculated from the baseline R22 system reduces the calculated energy consumption for all refrigerants in comparison to a concept where the temperature differentials at these heat exchangers were fixed since it results in smaller temperature differentials for operation with lower thermal loads. But it does not reflect any different heat exchanging behaviour of the investigated refrigerants and consequently there is no real effect for the comparison of the energetic behaviour of the refrigerants. Since this concept needs time-consuming iterations the advantage is questionable.

3 User friendliness

In general the user friendliness of the manual and the tool is good. User friendliness of the manual:

\+ The manual provides a good structure.

- **+** The use of Hyperlinks is very helpful to get through the text (only the link “cycle model” at the beginning of section 2.1 leads wrong).
- **-** A short concrete description of the input section of the tool is missing in section 2.1. All inputs should be listed and explained. It should be specified that the typical charge is the charge of the baseline R22 system (has to be specified in the tool, too).
- **-** It would be helpful for understanding, if the symbols of all quantities would be used already in section 2.2 especially within the table.
- **-** Section 2.6 only includes a screen-shot of one calculation and no explanation.
- **-** Section 3.3.5 introduces and explains a factor *r*, but it is unclear which value of *r* is used within the tool.

User friendliness of the <u>tool</u>:

- **+** Only very few inputs are necessary for calculation. The user does not need much time for understanding and editing of inputs.
- **+** The table of results is meaningful and provides all required results clearly represented.
- **+** The figure is clear and allows to recognize the influences of the different climate impacts and to compare the contributions of the alternative refrigerants.
- **-** Input and output sections of the table could be divided by frames or background colours to get a faster overview.
- **-** Inputs for documentation and inputs for the calculation could be distinguished for better orientation and an explanation comment could be helpful for all inputs.
- **-** Confusing: Some inputs start an immediate calculation others need the use of the calculation bottom.
- **-** Change of “Agency” starts a calculation, but the influence on the results is unclear.
- **-** Calculation time is higher than expected.
- **-** Since the pre-set parameters of the application are fixed, the user has no possibilities to adopt them to the given application if required.

4 Positive and negative aspects of calculations and the adequacy of generating and presenting the results

There are no comments on positive or negative aspects of calculations. The generating and presentation of results is adequate.

5 Feedback on elements lacking and possible future efforts

In general there is a lack of references to literature or other sources of information concerning the following input data:

- Pre-set parameters, cycle conditions as well as leakage data,
- Climate data,
- Data for carbon intensity of generation of electricity.

An annex should be added which provides a presentation of the climate data of the integrated countries and of the global temperature distribution which is used within the tool.

6 Consistency of the tool with the work of other United Nations bodies working on climate-related issues

Consistency is expected to be given because the tool is developed according a mandate of the Secretariat of the Multilateral Fund for the Montreal Protocol.