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Enhanced Refrigerant Management and LEED-NC V4 EA Credit 6

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Enhanced Refrigerant Management and LEED-NC V4 EA Credit 6

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1. Purpose

The purpose of this course is to familiarize you with the background of the Fundamental Refrigerant Management Prerequisite and Enhanced Refrigerant Management Credit (previously called the "Ozone Protection" credit) in the LEED-NC rating system

Energy and Atmosphere category. This topic has evolved over time since LEED-NC's first introduction in 2000 as concerns emerged about the anthropogenic accumulation of ozone depleting and global warming compounds in the atmosphere. As the course title implies, this content scope is limited to LEED-NC (for new construction and major renovations). At the end, a sample calculation will be provided to help further understand the framework of the credit.

2. Introduction

The inception of this LEED credit begins with the Montreal Protocol on Substances that Deplete the Ozone Layer. This Protocol banned the use of ozone depleting chemicals used in refrigeration and air conditioning in a phase-out plan to eliminate the use of chlorofluorocarbons (CFC's) by 2010. First adopted in 1987, it has been amended four times and it was the basis for the formation of the EPA's Title IV of the Clean Air Act [1]. The fourth and most recent amendment to the Protocol in 1990 introduced the phase out of hydrochloroflourocarbons (HCFCs) by 2020 with ultimate elimination of production or import by 2030.

The Clean Air Act includes Specific Regulatory Programs which, among other items, includes regulations on stationary refrigeration and air conditioning known as Section 608 [2]. Among these regulations include provisions to prohibit the release of CFCs (and HCFCs) and reduce their release, maximize their recapture and monitor safe disposal [3]. The Clean Air Act further classifies certain compounds based on their priority of phase out in accordance with the Montreal Protocol. Class I compounds include, in the context of refrigeration applications, CFCs and halons and have been banned for production since 1994 (100% in 1994 for halons, with ban and total phase out of CFCs in 1996) [12]. Class II compounds include hydrochloroflourocarbons (HCFCs) and in the context of refrigerants, HCFC-22 is the primary focus of this class. However there seem to have been a series of challenges and compromises on the nature of the phase-out of this compound [13].

While the Montreal Protocol and the U.S. EPA Clean Air Act addressed ozone depleting substances, there had not yet been a global public focus on greenhouse gases. The United Nations Framework Convention on Climate Change (UNFCCC) took initiative in recognizing that the world's developed countries were contributing the most to the release of greenhouse gases (GHGs). Therefore, the UNFCCC sponsored the Kyoto Protocol in 1997 as an agreement among developed countries to reduce GHG emissions [4]. According to the UNFCCC web site:

> *During the first commitment period, 37 industrialized countries and the European Community committed to reduce GHG emissions to an average of five percent against 1990 levels. During the second commitment period, Parties committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020; however, the*

> *composition of Parties in the second commitment period is different from the first.*[4]

Interestingly enough, while the United States participated in the initial endorsement, it did not bind itself to the measures of the Kyoto Protocol and in 2001 President George W. Bush formally withdrew United States endorsement [5].

The LEED-NC V4 EA Prerequisite 4 and Credit 6[1] both acknowledge the known impact of anthropogenic ozone depleting compounds and greenhouse gas emissions on the atmosphere and their contribution to global warming. The LEED credit in its first inception sought to reinforce the Montreal Protocol for CFC's and reach beyond the phase out requirements of HCFCs as scheduled by the EPA Clean Air Act. Therefore a point was awarded for managing the types, quantities and leakage of refrigerant chemicals both for reduction in global warming potential (GWP) and ozone depletion potential (ODP).

[1] These two items were renumbered in the V4 version. In the 2009 version, they were EA P3 and EA C4 respectively.

3. History

LEED-NC Credit 4 originally appeared in the 2000 pilot (V1) edition of the reference guide and remained mainly unchanged in the V2.0 and V2.1 editions. The original V2.0 credit was entitled "Ozone Protection" and stated [6]:

> *Intent*
>
> *Reduce ozone depletion.*
>
> *Requirements*
>
> *Zero use of CFC-based refrigerants in new building HVAC&R base building systems. When reusing existing base building HVAC equipment, complete a comprehensive CFC phaseout conversion.*

The V2.1 version is similar but deleted the reference to CFCs and added HCFCs and Halons as well as including fire suppression equipment [7]:

> *Intent*
>
> *Reduce ozone depletion and support early compliance with the Montreal Protocol.*
>
> *Requirements*

> *Install base building level HVAC and refrigeration equipment and fire suppression systems that do not contain HCFCs or Halons.*

In September 2004, the LEED Technical & Scientific Advisory Committee (TSAC) published a study related to the impacts of refrigerants on the environment. Specifically the LEED Steering Committee directed the TSAC:

> To review the atmospheric environmental impacts arising from the use of halocarbons in HVAC equipment and recommend a basis for LEED credits that gives appropriate credit to the alternatives [8].

The TSAC paper is provided along with this course content for review. This TSAC paper, to be discussed in more detail further on, being made available to the engineering community, prompted a Credit Interpretation directed to LEED on January 11, 2005. LEED Interpretation ID 5874 inquired if the methodologies described in the TSAC report could be used for projects registered under V2.0 or V2.1 as alternative compliance. The initial response was in the positive and spelled out the methodology to be used, but this decision was later rescinded by the USGBC Board of Directors for V2.1 projects registering after September 30, 2005 and indicated the TSAC report was being considered for inclusion in V2.2.

In the V2.2 edition of the reference guide, the credit was modified more significantly through the TSAC recommendations by taking the V2.0 and V2.1 versions and creating the EA P3 (now EA P4) prerequisite that is summarized as follows [10]:

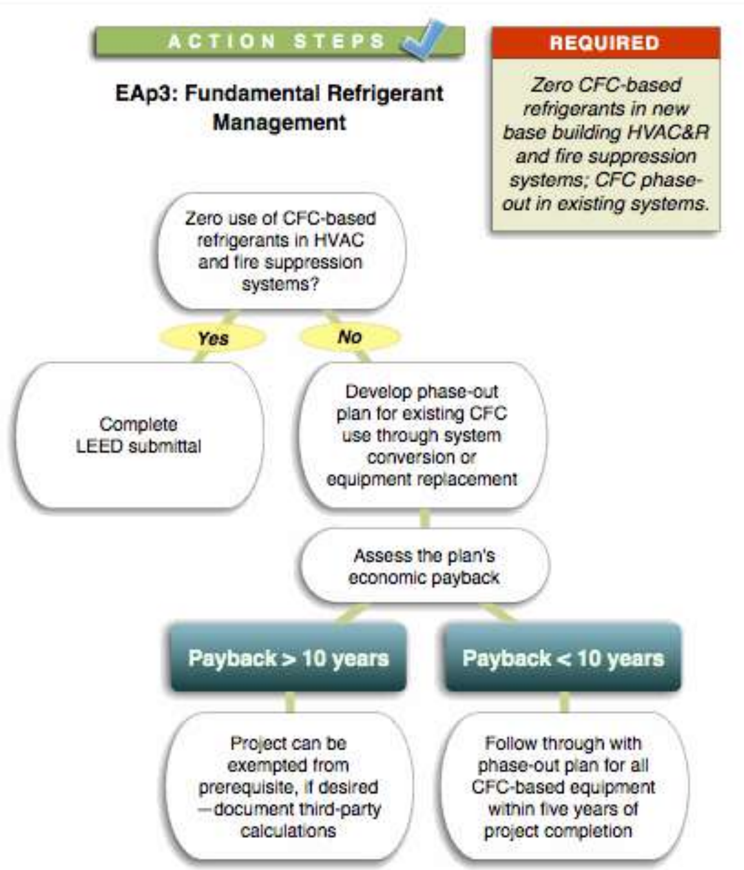

Figure 1: EA P3: Fundamental Refrigerant Management

This Prerequisite returns to addressing CFCs by requiring no CFCs in HVAC or fire suppression systems or developing a phase-out program. While CFCs are now banned by the Montreal Protocol, this Prerequisite seems to address continued use for existing equipment both in the United States and overseas. According to the 2009 LEED Reference Guide, about 50% of existing chillers still use CFC-11 [14, p. 307] therefore this prerequisite is still included in the rating system.

The EA Credit 4 was then substantially revised in V2.2 as summarized in the following decision chart [11]:

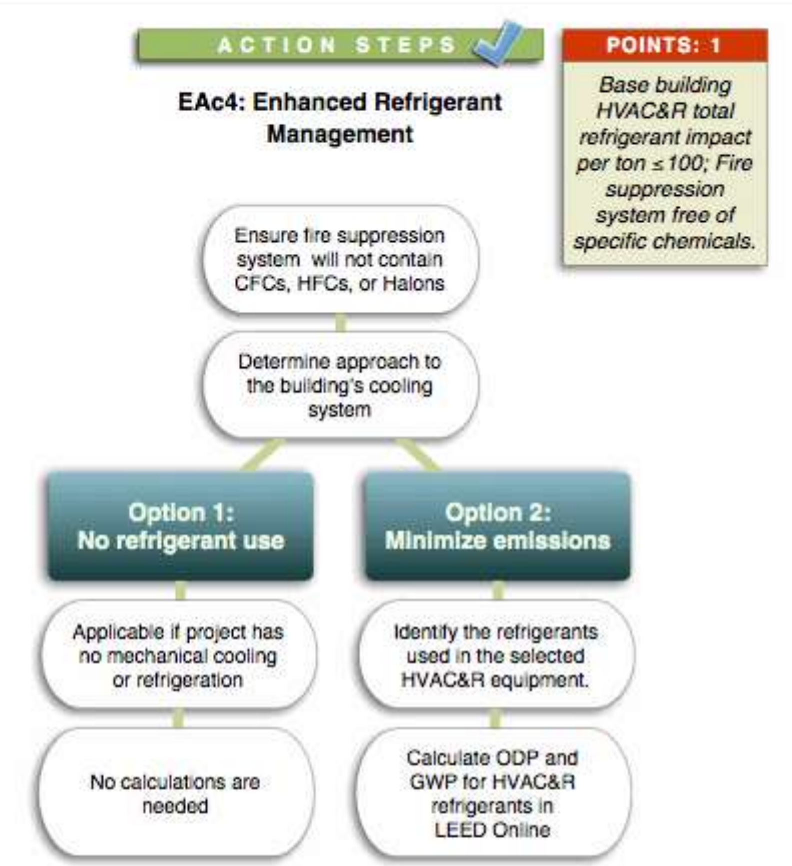

Figure 2: EA C4 Enhanced Refrigerant Management

In this version of the Credit, now renamed Enhanced Refrigerant Management, the project team is given two choices. The first is full compliance by having no refrigerant use. The second is to identify the refrigerant(s) used in base building HVAC central and unitary equipment and calculate the life cycle global warming potential (LCGWP) and the life cycle ozone depletion potential (LCODP) and compare both to ensure their combined effect falls below a stated threshold.

The LEED-NC 2009 version remained substantially the same as the V2.2 version [14]. All versions awarded one (1) credit toward LEED Certification.

4. LEED TASC Report

The major change to the approach to the EA C4 credit was driven by the LEED Technical & Scientific Advisory Committee's report on the environmental impact of HVAC refrigerant compounds release on November 8, 2004. Therefore, a summary of this report is appropriate to outline the reasons for the changes to EA C4 for the V2.2 version and beyond. This summary is entirely based on the text of the report cited as Reference [8].

First, this report acknowledges that the V2.1 and prior versions of this credit addressed only ozone depletion potential of CFCs, HCFCs and Halon compounds. Due to the ban and phase-out of CFCs, replacements with low ODP needed to be produced in response. This lead to the introduction of HCFCs, which have low (although measurable) ODP but still have a moderate GWP. When the Montreal Protocol was ratified for the fourth time in 1990, the phase-out of HCFCs (in essence any compound with a non-zero ozone depletion potential (ODP)) began and the U.S. EPA Clean Air Act responded accordingly. Up to this point only ODP was of concern. To respond to the change in policy, the air conditioning and refrigeration industry had to respond and hydrofluorcarbons (HFCs) were introduced into the market. These compounds have immeasurable ODP, but have GWP values similar to the CFC and HCFC compounds they were designed to replace.

At this point, LEED decided it needed to investigate the combined impact on direct global warming effects of refrigerants and not just ODP. While LEED EA Credit 1 addresses the indirect effects of global warming by incentivizing heating and cooling equipment efficiency, the versions prior to V2.2 were not concerned with the direct effects by the use of refrigerants.

To attempt to quantify the relative effects of each type of refrigerant typically used in the market, the TSAC team devised a metric for the direct effects to global warming by defining the life-cycle ozone depletion index (LCODI) and the life-cycle global warming index (LCGWI) and normalizing the values by dividing these factors by the cooling Tons typical for the refrigerant equipment over a year using a random sampling of various types of HVAC equipment and their relative market share.

First LCODP and $LCGWP_d$ are determined by the following two equations:

$$LCODP = \frac{ODP_r \ x \ R_c x(L_r x \ Life + \ M_r)}{Life}$$

Equation 1: Life Cycle Ozone Depletion Potential

$$LCGWP_d = \frac{GWP_r \ x \ R_c x(L_r x \ Life + \ M_r)}{Life}$$

Equation 2: Life Cycle Global Warming Potential, Direct

Where:

LCODP= Life-Cycle Ozone Depletion Potential (in lb CFC-11 equivalent/ (ton-year))[2]

[2] One may notice that the LEED TSAC Report refers to this as a Life Cycle Index (i.e. LCODI), however, the LEED-NC rating system has adopted the term Potential as in LCODP, which is used here to be consistent with the published rating system terminology.

$LCGWP_d$= Life-Cycle Global Warming Potential, Direct (in lb CO_2 equivalent/ (ton-year))[3]

ODP_r = Ozone Depletion Potential or Refrigerant (in lb CFC-11 eq/lb)

GWP_r = Global Warming Potential of Refrigerant (in lb CO_2 eq/lb)

L_r = Refrigerant Leakage Rate (in % of charge per year)

M_r = Refrigerant End-of-Life Loss (in % of charge)

Rc = Refrigerant Charge (in lb of refrigerant per Ton of cooling capacity)

Life = Equipment Life (in years)

Using collected data in Appendix C of the TSAC report, these two primary factors were further normalized to take into account market share, typical equipment life, estimated leakage rates and other indicators to develop the proposed credit concept to account for both direct global warming potential and ozone depletion potential of refrigerants. The combined effect is established by a green line through this normalized chart. In essence anything to the right is "bad" and anything to the left is "less bad" and is the zone that qualifies for the EA C6 credit. This recommendation is illustrated in the report's Figure 5 on page 11:

[3] Direct contribution is regarded as the direct release of refrigerant compound to the atmosphere. Indirect contribution, by contrast, is through electric power consumption in the refrigerant cycle resulting in CO_2 emissions from power plant(s).

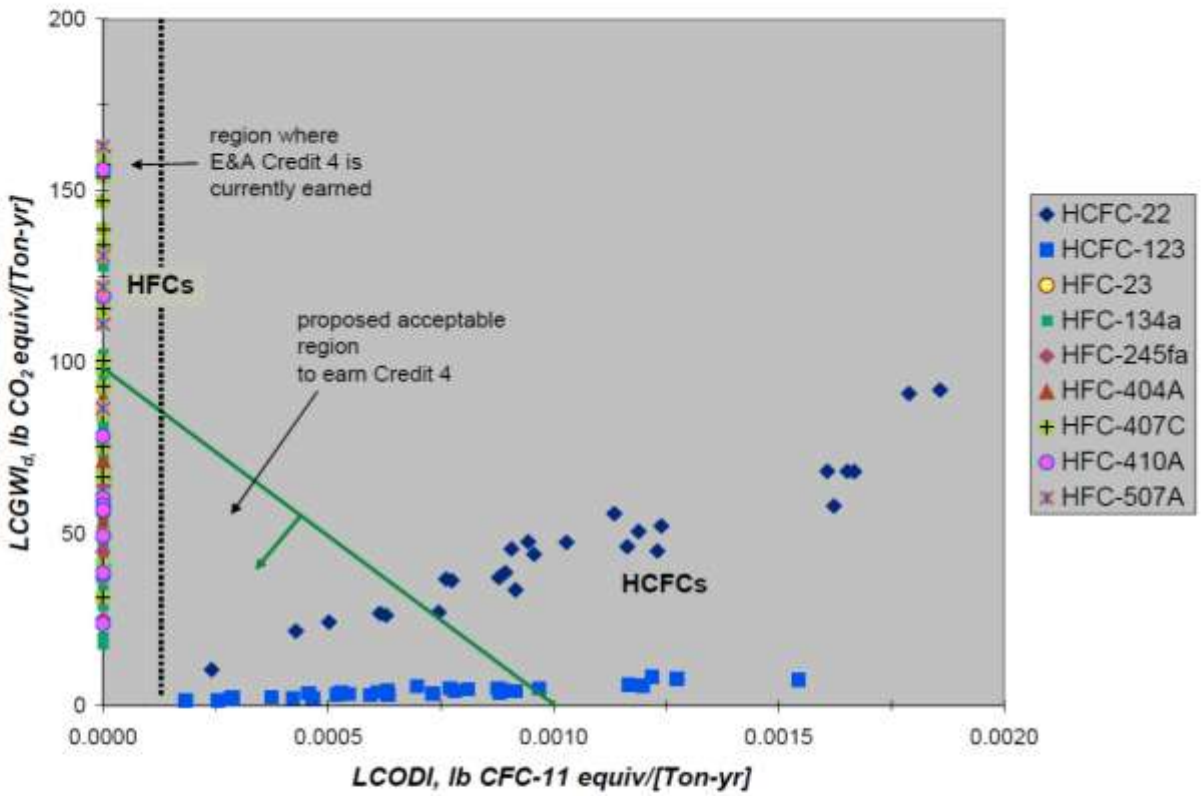

Figure 3: Representation of Figure 5 of the TSAC Report

The placement of the green line sets a boundary to be eligible for the EA C4 (now EA C6) credit. The line is defined by the equation:

$$LCGWP_d + 100{,}000 \text{ x } LCODP \leq 100$$

Equation 3: GWP and ODP Combined Threshold

The TSAC report acknowledges that setting this threshold is somewhat subjective and is lacking in any scientific basis, but the TSAC members felt that this line represented a capability of the top 25% of the market to reach, which is a basic

LEED policy. This methodology was included without significant revision into V2.2 and carried through to LEED-NC 2009 and V4. As stated at the beginning of this section, the information presented is an overall summary of the LEED TSAC report cited as reference [8].

5. Baseline Data

LEED provides default values and properties necessary to evaluate the EA C6 credit. First, the ODP and GWP for various refrigerant compounds are provided in Table 1 of the 2009 LEED Reference Guide [14, p. 309]:

Refrigerant	ODP	GWP	Common Building Applications
Chlorofluorocarbons			
CFC-11	1.0	4,680	Centrifugal chillers
CFC-12	1.0	10,720	Refrigerators, chillers
CFC-114	0.94	9,800	Centrifugal chillers
CFC-500	0.605	7,900	Centrifugal chillers, humidifiers
CFC-502	0.221	4,600	Low-temperature refrigeration
Hydrochlorofluorocarbons			
HCFC-22	0.04	1,780	Air-conditioning, chillers
HCFC-123	0.02	76	CFC-11 replacement
Hydrofluorocarbons			
HFC-23	~0	12,240	Ultra-low-temperature refrigeration
HFC-134a	~0	1,320	CFC-12 or HCFC-22 replacement
HFC-245fa	~0	1,020	Insulation agent, centrifugal chillers
HFC-404A	~0	3,900	Low-temperature refrigeration
HFC-407C	~0	1,700	HCFC-22 replacement
HFC-410A	~0	1,890	Air-conditioning
HFC-507A	~0	3,900	Low-temperature refrigeration
Natural refrigerants			
Carbon dioxide (CO_2)	0	1.0	
Ammonia (NH_3)	0	0	
Propane	0	3	

Table 1: Properties of Typical Refrigerant Compounds

Next, the maximum default refrigerant charge ratio (in pounds of refrigerant per cooling Ton capacity) that is part of the LCODP and LCGWP calculations (R_c) is provided in Table 2 as a function of the equipment type and default lifecycle [14, p. 310]:

Refrigerant	10-Year Life (Room or Window AC, Heat Pumps)	15-Year Life (Unitary, Split, Packaged AC, Heat Pumps)	20-Year Life (Reciprocating or Scroll Compressors, Chillers)	23-Year Life (Screw, Absorption Chillers)
R-22	0.57	0.64	0.69	0.71
R-123	1.60	1.80	1.92	1.97
R-134a	2.52	2.80	3.03	3.10
R-245fa	3.26	3.60	3.92	4.02
R-407c	1.95	2.20	2.35	2.41
R-410a	1.76	1.98	2.11	2.17

Table 2: Maximum Refrigerant Charge by Equipment Type and Refrigerant Type

Manufacturer refrigerant charges must be at or below these values to be eligible for pursuing the credit. This table further assumes a 2% annual leakage rate and a 10% end-of-life loss. These assume rates are currently a point of controversy connected to this EA credit and are discussed further. However, the LEED calculation methodology is based on these assumptions.

6. Public Feedback Leading to the Status of EA C6 for LEED-NC V4

In late 2013 (as of this course material creation) the latest version of LEED-NC is expected to be released, designated V4. As part of the process of revising a consensus document, proposed revisions and existing language are put out for public review and comment. To understand the current thinking and assessment of EAP4 and EAC6 it is instructive to review a sampling of the various comments forwarded to the V4 revision committee:

Public Comment Round 2:

No. 884 "This prerequisite should be dropped form LEED 2012. CFC refrigerants have been banned by international treaty since 1996 and existing CFC based systems are heavily regulated by the EPA and the clean air act. It is unnecessary to continue to have LEED project teams attest that they are not installing or maintaining CFC refrigerants. LEED does not require declaratiosn (sic) related to lead paint, asbestos, or any other banned compounds that are no longer used in the building industry in the US --- why are CFC refrigerants any different? The MPR to 'comply with all environmental laws' should suffice for all of these issues."

The committee response is, "Many existing buildings still have CRC (sic) refrigerants, as well as international projects. The prerequisite will be easy to meet for most projects, but will prevent a loophole for those remaining."

Provider Comment: Therefore, it is important to the designer to keep mindful that existing systems being reused in building renovation, systems installed overseas, equipment being relocated and older equipment installed in district cooling systems may still in fact use CFC compounds. It is the intent of EAP3 not necessarily to tell the designer what they should already know (i.e. follow the EPA Clean Air Act for new installations), but rather to impose a phase-out plan for these compounds when they are encountered.

Public Comment round 3:

No. 576 Remarks on the cumulative quantities of exempt refrigerated devices (with less than 0.5 lbs charge). But LEED is maintaining the exemption for V4.

Provider Comment: This comment has merit. The exemption for refrigerant charges less than 0.5 pounds seems to reflect the "boundary" set by LEED to permanently installed cooling systems such as building infrastructure. Whereas, equipment with less than 0.5 pounds of refrigerant would typically be portable systems (i.e. window air conditioner units) or small systems not permanent to the building like small domestic refrigerators. However, the cumulative effect of several such unitary equipment can have a measurable impact on ODP and GWP and should be considered at least as a subset in determining compliance for a building as it is ultimately configured.

No. 580 Remarks on the use of sulfur hexafluoride (SF6) in electrical switchgear to be included in the scope of the Prerequisite due to the GWP of 22,200 CO2e. LEED declined to include into the scope of V4.

Provider Comment: This comment also appears to have merit and should be considered in future versions of LEED-NC.

No. 844 "For certain types of equipment, default leakage rates are very high." Response is "There is no current universally accepted method for testing leakage rates. When one is established, non-default leakage rates will be allowed."

Provider Comment: Currently the EAC4 default leakage rate over the lifespan of refrigeration equipment is 2%. The end of life loss default value is 10%. These two values have not been sufficiently explained by the committee. It is understood by many that the leakage rates for specified manufacturers and models are typically rates determined under controlled conditions by testing equipment in "factory condition" which do not reflect the actual conditions in the field and the practices of maintenance technicians or their vigilance in tracking leaks. However, more data should be gathered. As an example, data can be collected for selected facilities to determine the quantity of refrigerant consumed per installed ton to determine average leakage rates.

No. 845 "Provide additional consideration for the energy related performance of specific refrigerants in vapor compression cycles. Some refrigerants allow for greater energy efficiency, which could significantly offset any global warming potential from leakage." Response is, "VRV will be addressed in the reference guide."

Provider Comment: This was an insightful comment. This issue was addressed in the TSAC report. Certain refrigerant compounds, that show lower ODP and GWP values may in fact result in less efficient energy efficiency, thereby contributing to indirect GWP through the higher consumption of electric power and the higher emissions resulting at power plants.

No. 846 "This credit remains problematic. I have reviewed the research from all 4 of the top manufacturers of HVAC equipment and the TSAC report which is outdated. This issue needs to be resolved and it is greatly disappointing that LEED 2012 has not done anything to advance our understanding of the science on this issue or establish best practice for engineers facing decisions based on refrigerants." Recommendation is, "I would like to suggest we make this a priority for the EA committee. The credit should be removed from the rating *system until there is some innovative thinking around how to deal with the credit. I suggest bringing in unbiased experts from the academic field to help the USGBC address the refrigerant issue."*

Provider Comment: This comment probably reflects the attitude of many engineers. In terms of the LEED rating system, the EAC4 credit has very little impact on the overall ability of a building to achieve any level of certification. On the other hand, the issue of global warming due to anthropogenic release of ODP and GWP compounds into the atmosphere is a serious one that requires more rigorous analysis with respect to refrigerant selection, priorities for the selective removal of higher GWP compounds in favor of natural refrigerants, and a clearer connection between overall refrigerant cycle efficiency versus the indirect contribution of carbon due to power consumption.

No. 848 "No comments, however, I believe that the District Energy System (DES) Guidance document should be modified as follows: Projects served by District Energy Systems and that are pursuing the Enhanced Refrigerant Management credit shall be required that all new equipment upstream of the project that serves the project will comply with the enhance refrigeration management requirements. Existing central plant equipment that serves the new LEED project shall be exempt from mandatory compliance with the refrigeration management requirements."

Response is, "DES guidance is being included in the reference guide."

No. 850 "As written, Annual refrigerant leakage must be 2% in 2012 (in 2009 calculation allowed values between 0.5% and 5%), however actual annual leakage rates can be much less in practice. At the same time, project teams are incentivized to maintain appropriate refrigerant charge to maintain equipment efficiency. Also, the end of life refrigerant loss factor sufficiently accounts for significant losses once the equipment is no longer under the control of the project team."

Response is, "There is no current universally accepted method for testing leakage rates. When one is established, non-default leakage rates will be allowed."

No public comments were offered in either EA P3 or EA C4 in the Fifth or Sixth Public Comment rounds.

7. LEED-NC V4

The EA P3 prerequisite has been renumbered as EA P4 but has no material changes from LEED 2009. [17]

The EA C4 has been renumbered as EA C6 but has no material changes from LEED 2009. [17]

8. Exemplary Performance

This credit is not eligible for exemplary performance credits under the Innovation in Design (ID) categories.

9. Regional Variations

Unlike other LEED categories like Water Efficiency, Sustainable Sites and Materials & Resources, this credit is not given any added or diminished weight due to regional priorities.

10. Example Calculation

In order to perform the required calculation, the designer has to determine the base building equipment types which are used to determine life expectancy, the refrigerant type used for each equipment type from Table 1 to determine ODP and GWP values and the maximum allowed refrigerant charge (Rc). In addition, the equipment life expectancy, refrigerant charge, and rated cooling capacity in Tons must be known. These parameters are reduced to a formula to determine the Average Refrigerant Atmospheric Impact [14, p. 311]:

$$\frac{\sum_{i=1}^{n}(LCGWP_i + 100{,}000\ x\ LCODP_i)\ x\ Q_i}{Q_{total}} \leq 100$$

Equation 4: Multiple Equipment Weighted Average for EA C6

Where:

n is the quantity of units included in the EA C4 (now EA C6) calculation;

$LCGWP_i$ and $LCODP_i$ are the life cycle global warming potential and life cycle ozone depletion potentials for the i^{th} piece of equipment as calculated from Equations 1 and 2;

Q_i is the gross ARI cooling capacity for the respective i^{th} equipment in cooling Tons, and;

Q_{total} is the gross ARI cooling capacity combined for all equipment included in the calculation in cooling Tons.

For the purposes of the scope of this calculation and the EA C4 credit, small units with less than 0.5 pounds of refrigerant charge such as refrigerators, small water coolers and small unitary cooling equipment are not considered part of the base building system and are not included in calculating this credit.

As an example, consider an office building with the following base building cooling equipment:

(A) Two 500 Ton absorption chillers with HFC-134a refrigerant,

(B) One 50 Ton reciprocating chiller with HCFC-22,

(C) Five 10 Ton computer room air conditioning units with HCFC-22.

According to the credit defaults, the annual leakage rate for each unit is 2% and the end-of-life loss is 10%, so those values must be used for the calculations.

For each unit, the listed manufacturer refrigerant charges (pounds per Ton) are:

(A) 3.0

(B) 0.69

(C) 0.64

One parameter to establish is the total combined cooling capacity in Tons. This is calculated by multiplying the quantity (N) of each unit by the Capacity per unit (Qunit) and adding them together In this case, Qtotal = (2)(500) + (1)(50) + (5)(10) = 1100 Tons. Using these values the calculation can be summarized as follows:

Unit	A	B	C
Equipment Type	Absorption Chiller	Reciprocating Chiller	Unitary AC Unit
Quantity (N)	2	1	5
Capacity/Unit (Tons) (Qunit)	500	50	10
Qtotal	1100		
Refrigerant Type	R-134a	R-22	R-22
ODP (Table 1)	0	0.04	0.04
GWP (Table 1)	1320	1780	1780
Life (Table 2)	23	20	15
Refrigerant Charge/Ton (Rc)*	3	0.69	0.64
Leakage Rate (Lr) per Year	2.0%	2.0%	2.0%
End-of-Life Loss (Mr)	10.0%	10.0%	10.0%
Total Leakage Rate (Lr x Life + Mr)	56.00%	50.00%	40.00%
LCODP (Equation 1)	0	0.00069	0.000682667
LCGWP (Equation 2)	96.4	30.7	30.4
TSAC Factor (LCGWP + 100,000 x LCODP)	96.4	99.7	98.6
TSAC Factor x N x Qunit	96417.4	4985.3	4932.3
Average Refrigerant Atm Impact (Equation 4)	96.7		
*Typically provided by the equipment manufacturer. Compare to Table 2 to ensure the maximum permitted charge is not exceeded, otherwise the equipment does not qualify for the credit.			

Because the ARAI of 96.7 is < 100, this set of chiller/ac equipment would be eligible for the EA C6 credit (1 point).

11. Efficacy and Critique

Note that although Units A, B and C of the example above each have refrigerant atmospheric impacts less than 100, there is no requirement stated in this credit that if any one piece of equipment exceeds 100 the project does not qualify. Only the overall average result is the qualifying factor. This seems counterintuitive to the ideals of what this particular credit is trying to achieve. This is of particular curiosity since any one piece of equipment not meeting the maximum refrigerant charge per Ton listed in Table 2 <u>disqualifies</u> the project for the Credit, while the weighted average of ARAI is only considered for qualification of the Credit and not the individual sets of equipment.

In addition, as was mentioned previously, the TSAC report, by its own acknowledgement sets the boundary between “bad” and “less bad” seemingly arbitrarily with no scientific rigor or data to establish what, if any, impact this limit will have on overall anthropogenic effects of ODP and GWP compounds.

Also, the life expectancy default values used in this credit are probably good for informing facilities managers when their equipment transforms from an asset to an increasing liability in terms of maintenance. However, it is quite common for facilities to continue to maintain or overhaul their equipment well past their statistical life expectancies. And with increased age comes the likelihood of increased leakage rate and losses due to periodic maintenance requiring the evacuation of the refrigerant. With a typical facility lifespan of 50 to 100 years, using the lifespan default values alone does not seem realistic as it assumes that if a piece of equipment has a lifespan of 15 years, it will be replaced with a new unit in exactly 15 years.

The default leakage rate of 2% per year and the default end-of-life loss of 10% have been arbitrarily established. There has been much disagreement about these values, particularly by equipment manufacturers. Certainly LEED wishes to establish a level playing field in their qualifying methodology, but further scientific analysis of leakage rates and loss is warranted to determine rates that reflect actual operating conditions.

Finally, this credit does not adequately address ODP and GWP compounds used in fire suppression systems, other than to require that CFC's and HCFC's or halons not be used. No metric is provided with regard to classes of compounds that may be used and how their quantities, leakage rates, end-of-life losses and other factors contribute to atmospheric effects. While it is implicit that the nature of a fire suppression may result in the total release of the stored agent to suppress a fire, the likelihood is relatively low and should be accounted for on a statistical basis to try to quantify the effect of these systems not only from standby leakage rates, repair and replacement, but also in the incidence of discharge.

Finally, as suggested in LEED V4 Public Comment Round 3 No. 580 [16], the use of other ODP and GWP compounds such as sulfur hexafluoride (SF6) use in electrical gear should be included.

It would seem appropriate to rename this credit as "Enhanced Global Warming Potential Management" to reflect a larger scope of compounds used in buildings that contribute to anthropogenic accumulation of ODP and GWP compounds into the atmosphere.

12. Conclusion

Due to the efforts and intent embodied in the Montreal and Kyoto Protocols as well as the regulatory responses of the EPA, the nature of refrigerant (and other purpose) compounds that contribute to GWP and ODP is in flux. There has been no manufactured compound or set of compounds that offer a silver bullet alternative to HFCs. The only compounds available are natural refrigerants (see Table 1) such as ammonia or propane. However, these two compounds present significant safety concerns due to toxicity and flammability.

Although this LEED EA Credit attempts to find a balance or compromise between the ODP and GWP effects of available refrigerants, it is still lacking in scientific grounds to quantify its efficacy. For a metric-based rating system such as the LEED rating system, it would seem necessary to assess these effects further to modify the Credit methodology accordingly and to offer other incentives to designers to reduce or eliminate power-cycled refrigeration altogether when possible.

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