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Summary

The building sector is being called upon to help fight climate change by achieving ambitious reduction targets for greenhouse gas emissions while at the same time incorporating other "green" considerations. To resolve this dilemma, the Green Building Initiative (GBI) has embarked on converting Green Globes™ into an official national green building rating standard. At the heart of this proposed standard are an operational energy section that uses CO_2 as the basis for its calculations and a materials section that has global warming potential as a key Life Cycle Assessment (LCA) measure. This paper will review how both operational energy and materials CO_2 calculation protocol operates in this proposed standard. The authors of this paper are on the standards committee and were particularly active in developing the energy and materials sections. It will be argued that such a CO_2 calculation protocol will become an important new tool for promoting sustainable technologies and one that needs to be understood by the sustainable building community.

1. Introduction

With the launch of several recent carbon reduction initiatives, the U.S. is finally beginning to tackle the reduction of carbon emissions. These initiatives range from Kyoto Now, a movement to get corporations to address their carbon emissions similar to the Architecture 2030 initiative, which is asking the building community to design carbon-neutral buildings by 2030. Cities are also anxious to demonstrate their commitment to carbon reduction, as evidenced by the recent adoption of a resolution very similar to the Architecture 2030 goals by the U.S. Council of Mayors. In addition, the U.S. Congress has begun to discuss how best to introduce carbon emission reduction into national environmental policy. For example, carbon reduction strategies such as a carbon tax or a cap and trade type of system are being actively discussed in Washington, D.C.

Unfortunately, what these business people, designers, city administrators and politicians are quickly realizing is that there is a lack of proven tools to help them determine if they are on track to achieving such goals. To help resolve this dilemma, the Green Building Initiative (GBI) has embarked on developing a national green building rating standard. At the heart of this proposed standard are an operational energy section that uses CO_2 as the basis for its calculations and a materials section that has global warming potential as a key Life Cycle Assessment (LCA) measure. This standard has undergone one public review and is targeted for completion later this year. Significant changes could result from the public review process, thus this paper represents the thinking of the standard committee as of Spring 2008.

2. Green Globes™

Green Globes is a web-based environmental rating system which has been operating in Canada for a number of years. There it has been widely used by several federal agencies and is the basis for the Building Owners and Managers Association of Canada's "Go Green Plus" program for assessment of existing buildings. In 2004, the Green Building Initiative (GBI) acquired the rights to distribute Green Globes in the U.S. (www.thegbi.org). Since then it has been operating in the U.S. and a wide range of buildings have been certified. In the process of bringing this system to the U.S., GBI made a commitment to continually improve the system to ensure that it reflects changing opinions and ongoing advances in the field. In 2005, GBI applied for and became the first green building organization to be accredited as a standard developer by the American National Standards Institute (ANSI), and began the process of establishing Green Globes as an official ANSI standard. The GBI ANSI technical committee and sub-committees feature a range of nearly 100 building science experts including representatives from federal agencies, states, municipalities, universities, leading AEC firms and building owners. Unlike other U.S. attempts at developing a green building standard, such as the ASHRAE 189 Standard, the proposed Green Globes Standard will be an environmental rating system which will allow a building to achieve several levels of environmental performance.

3. The Green Globes Operational Approach

The energy or operational approach proposed by the GBI/ANSI committee is based on what has transpired in Europe in regards to CO_2 calculations procedures for buildings. Documents produced by the European Union provides a framework for all 27 EU countries to put into place CO_2 based calculation procedures for buildings by 2007 (EU 2003). The best application of this framework document is the United Kingdom's L2A Standard which became a requirement for all new U.K. buildings. The L2A Standard requires a new building design team to model the building's energy performance based on a set of prescriptive criteria, and then multiply the fuel mix of the building by the CO_2 emissions factor in order to determine a building's CO_2 target. This process is repeated for the proposed building and if the proposed building's CO_2 level is below the target, the building passes.

The proposed GBI/ANSI energy approach has some similarities to the ASHRAE Standard 90.1 (ASHRAE 2007), though it differs in several fundamental ways. For example, the Green Globes standard does not have any mandatory provisions except that minimum points have to be met in this category and that all buildings must meet local energy code, which would be most likely either ASHRAE Standard 90.1 or the International Energy Conservation Code. Points within the proposed standard are achieved only by going beyond code, which can be accomplished by either using the prescriptive or performance approach. The prescriptive approach gives points for meeting incrementally higher levels of component efficiencies, while the performance approach gives points as a function of how much better the proposed building performs vs. an industry agreed upon benchmark, which for the energy section is determined by the U.S. Department of Energy's Commercial Building Energy Consumption Survey (CBECS) database (DOE 2006). This is the most comprehensive source for building energy benchmarking currently available in the U.S. The CBECS database is also used by the U.S. Environmental Protection Agency's Energy Star Target Finder tool, which has been incorporated into Green Globes.

Unlike approaches such as ASHRAE Standard 90.1, which require designers to model a benchmark building as well as the building being proposed, the Green Globes standard is a much easier modeling exercise. Since CBECS is being used to determine the benchmark, only the building simulation for the proposed building needs to be completed. In order to determine a building's benchmark the EPA Energy Star Target Finder is used (www.energystar.gov/target_finder), which is a web based calculator that uses the CBECS database. This tool has the ability to normalize CBECS data to location, space type, occupancy density, internal load and hours of use (see Figure 1). In the example shown in Figure 1, Target Finder has been used to generate an Energy Use Intensity (EUI) value and typical fuel mixes for a proposed 60,000 square foot Academic Administration building (see Figure 2), which is then multiplied by the CO_2 equivalent (CO_2e) emission factor in order to determine the CO_2 target. Table 1 presents the CO_2e emission factors that are being proposed; a majority of these factors were generated by the National Renewable Energy Laboratory (NREL 2007). CO_2e has been used rather than CO_2, because CO_2e takes several other greenhouse trapping gases into consideration, particularly methane (CH_4) and nitrous oxide (N_2O). CO_2e also has a time horizon due to the atmospheric reactivity or stability of these contributing gases over time. The International Panel on Climate Change (IPCC 2001) 100-year time horizon figures have been used as the basis for establishing the CO_2e for both the operational energy and material calculations. That equivalence per unit mass is as follows:

$$CO_2 \text{ equivalent} = CO_2 + (CH_4 \times 23) + (N_2O \times 296) \qquad (1)$$

When the proposed building is simulated; the resulting EUI and fuel mix is multiplied by the CO_2e emission factors in order to determine the proposed building's CO_2e level. This value is then divided into the CO_2e benchmark that was generated by Energy Star Target Finder to get percentage savings. The proposed Green Globes Standard currently awards 150 points to buildings that achieve a 50% CO_2e emission reduction from the average CBECS's building for that location. In addition, for every 1% CO_2e emission reduction beyond 50%, 2 points will be assigned to a maximum of 100 points (the Green Globes system has a total of 1000 points). Thus a CO_2e neutral building would score the maximum points allowable, 250 points which is one-

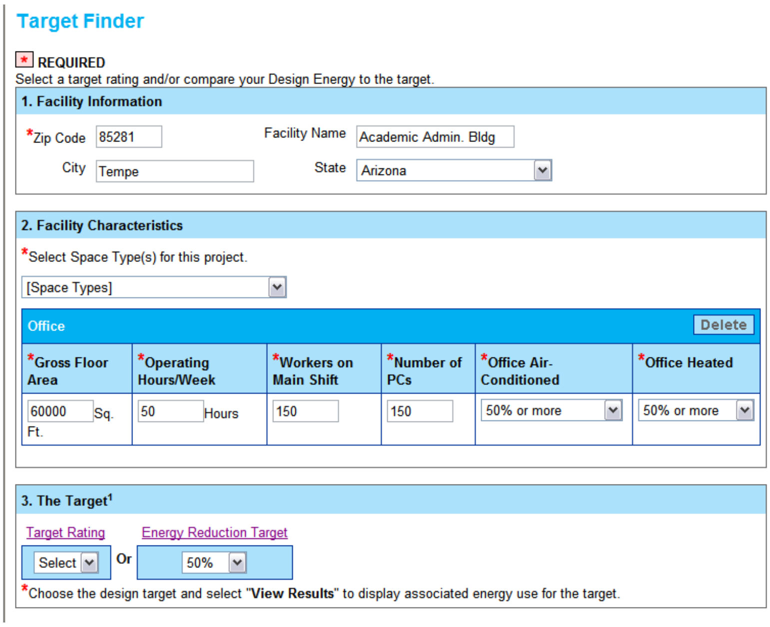
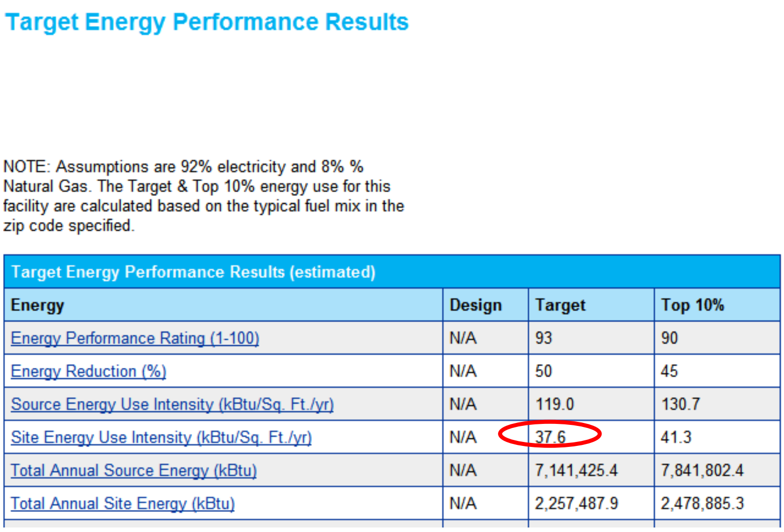


Figure 1. Target Finder's Input Screen for Example Building



Target Energy Performance Results

NOTE: Assumptions are 92% electricity and 8% % Natural Gas. The Target & Top 10% energy use for this facility are calculated based on the typical fuel mix in the zip code specified.

Target Energy Performance Results (estimated)			
Energy	**Design**	**Target**	**Top 10%**
Energy Performance Rating (1-100)	N/A	93	90
Energy Reduction (%)	N/A	50	45
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	119.0	130.7
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	N/A	37.6	41.3
Total Annual Source Energy (kBtu)	N/A	7,141,425.4	7,841,802.4
Total Annual Site Energy (kBtu)	N/A	2,257,487.9	2,478,885.3

Figure 2. Target Finder's Output Screen for Example Building

Table 1. CO_2e Emission Factors

Fuel	kg-CO_2e/kWh(lb-CO_2e/kWh)
Natural gas	0.232 (0.510)
LPG	0.274 (0.602)
Fuel oil (residual)	0.311 (0.686)
Fuel oil (distillate)	0.299 (0.660)
Coal (bituminous)	0.373 (0.822)
Coal (lignite)	0.585 (1.289)
Gasoline	0.326 (0.719)
Biomass	0.026 (0.057)
Grid delivered electric	0.758 (1.670)
Grid displaced electric	-0.833 (-1.835)
Off-site renewable electric	-0.758 (-1.670)
Waste heat	0.019 (0.042)

quarter of all available points. As presently structured the GBI/ANSI energy approach dovetails very nicely with the Architecture 2030, only the time dimension (target for specific year) would have to be included.

3.1 The Operational CO_2e Benchmarking Calculation

From the Target Finder exercise we determined the building's baseline EUI to be 37.6 kBtu/sf/yr. Target Finder also assumes the fuel mix to be 92% for electricity and 8% for natural gas. Thus, the operational CO_2e benchmark that the proposed building will need to improve on is 17.39 lb/sf/yr.

Example of the benchmarking calculation:

For Electricity

$$\frac{0.92 \times 37.6\ \text{kBtu/sf/yr}}{3.412\ \text{kBtu/kWh}} = 10.14\ \text{kWh/sf/yr} \times 1.670\ \text{lb/kWh} = 16.94\ \text{lbs/sf/yr}$$

For Gas

$$\frac{0.08 \times 37.6\ \text{kBtu/sf/yr}}{3.412\ \text{kBtu/kWh}} = 0.88\ \text{kWh/sf/yr} \times 0.510\ \text{lb/kWh} = 0.45\ \text{lbs/sf/yr}$$

17.39 lbs/sf/yr

4. The Green Globes Material Approach

It is no longer enough to assume that individual material attributes, such as recycled content, the use of rapidly renewable materials, or local purchasing, automatically deliver the desired environmental benefits. Instead, those who design or build green buildings are increasingly being asked to look at a range of real environmental performance indicators or measures. This is done through a process called life cycle assessment (LCA), which takes into account the cradle to grave effects of manufacturing, transporting, using and ultimately disposing of products using a range of environmental impact indicators. Global warming potential (GWP in LCA parlance is the same as CO_2e) is one of the most important of those indicators. In the past, LCA's practical use was limited by the fact that it was perceived as too complex or time consuming for widespread use. That is no longer the case.

The Athena Institute recently introduced an online tool — the ATHENA® *EcoCalculator for Assemblies* —that provides instant LCA results for hundreds of common building assemblies. Developed by the Athena Institute in association with the University of Minnesota and Morrison Hershfield Consulting Engineers, the *EcoCalculator* provides LCA results generated using its parent software, the ATHENA® *Impact Estimator for Buildings*. The results take into account resource extraction and processing, product manufacturing, on-site construction of assemblies, all related transportation, maintenance and replacement cycles over an assumed building service life of 60 years, structural system demolition and transportation to landfill of those materials that are currently land filled as opposed to being recycled or reused. In addition, all energy use at every stage is factored up to account for the energy and other environmental effects of manufacturing and transporting different energy forms, termed pre-combustion effects in LCA.

The *EcoCalculator* was originally developed for use with the Green Globes and will be incorporated into the GBI/ANBSI version of the rating system. Because of its value as an indicator of climate change potential and other effects, the GBI also supported the team's creation of a generic version for use by the entire sustainable design community. This version is available free of charge from the Athena web site (www.athenasmi.ca), and is therefore available to other green building rating systems and programs that want to encourage greater use of LCA in material selection.

The *EcoCalculator* can be used for new construction projects, retrofits and major renovations on industrial, institutional, office or residential designs, either to compare specific assemblies or to assess all building assemblies. Building assemblies are evaluated in the following six categories, with the number of assemblies in each category varying widely depending on the possible combinations of layers and materials:

- Exterior Walls
- Interior Walls
- Roofs
- Windows
- Intermediate Floors
- Columns and Beams

Design results are available in spreadsheet form and show real time changes as the inputs are adjusted (see Figure 3). This allows different assembly options to be considered in light of their environmental impacts and provides the information necessary to make informed, scientifically-based choices. Individual assembly impacts are then summed to determine whole building impacts for each of the categories currently included in the tool: primary energy, GWP (CO_2e), weighted resources, air and water pollution (see Figure 4). The next version of the EcoCalculator, scheduled for release mid-2008, will include a more extensive list of mid-point impact indicators but with global warming remaining as a key measure.

In the development of specific assembly LCA results using the parent Impact Estimator software, one must provide basic dimensional and other information, such as the length of an exterior wall or the live load on a beam. The results are presented in the EcoCalculator on a per unit area basis (e.g., per square foot), but the base Estimator runs used large quantities, such as 1000 linear feet of wall. In other words, the assembly effects are estimated in a whole building context to take account of end conditions, such as the additional stud at the end of a wall or the perimeter columns in a beam and column assembly, window-to-wall ratios, and other realistic aspects of building design.

We assumed that all assemblies would be installed in either low- or high-rise buildings, using components and loadings typical for central areas of the United States (i.e., no unique seismic loadings were considered), but with a differentiation between northern and southern climates in order to properly define assemblies in terms of thermal performance.

Other specific assumptions and definitions are provided on the Athena Institute web site at www.athenasmi.ca.

4.1 The Material CO_2e Calculation

Figure 3 presents the LCA results for the same 60,000 square foot Academic Administration building that was benchmarked in Section 3.1. Figure 4 sums the whole building impacts for each of the six building component categories; here we see that the GWP (CO_2e) is 3306 tons or 110.2 lbs/sf. If we divide this value by the assumed 60 year service life for this building we get 1.84 lbs/sf/yr which is approximately 10% of the annual operational CO_2e for this same building. Correcting for the fact that this building is benchmarked to be 50% better then CBECS, a 1 to 10 ratio is very consistent with studies that found a similar ratio between embodied and operational energy (Cole and Kernan 1996).

5. Conclusion

This paper illustrates that both operational and materials CO_2e can be easily calculated, providing an opportunity for whole building CO_2e analysis. For our 60,000 square foot Academic Administration building example, the whole building CO_2e analysis amounted to 19.23 lbs/sf/yr. After the GBI/ANSI version becomes automated, as is the current version of Green Globes, this protocol will operate in a seamless manner. In addition, we envision that this protocol could be easily introduced into a Building Information Modeling (BIM) environment. Thus, as thermal properties and material assemblies are entered into a BIM program, the results of the whole building CO_2e calculation would automatically appear in a performance window.

We are sure that the protocol outlined here will move towards increased comprehensiveness; however, the trick will be to be comprehensive without becoming too complex or time consuming. As our knowledge increases, CO_2(e) calculation methods will undoubtedly improve. It is clear that the building industry is transitioning away from energy to CO_2(e) as a metric. This is an important transition in that it eliminates several issues that were problematic with energy as a metric. For example, the site vs. source energy issue that was current in the energy circles for so many years diminishes because site energy gets converted into source CO_2(e), thus, allowing the environmental impact of buildings to be accounted for more rigorously. However, new issues are beginning to emerge that may take some time to resolve, such as allowing fuel switching to take place between the benchmarked and proposed building or how on-site vs. off-site renewables are properly accounted for. While these are policy questions, they will have to be answered before we can develop a more definitive CO_2 calculation protocol, and they will undoubtedly get resolved. We believe the protocol outlined here will help us frame that discussion and become an important new tool for promoting sustainable buildings that move us toward carbon neutrality.

	A	B	C	D	E	F	G	H	I	J	K
1	Academic Administration Building -- As Built			Assembly R-Value	Square footage	Percentage of total	Primary Energy per SF (MMBtu)	GWP per SF (lbs) (tons in Bold)	Weighted Resource Use per SF	Air Pollution Index	H2O Pollution Index
2											
3	A. COLUMNS AND BEAMS										
4		ASSEMBLY TYPE Column	ASSEMBLY TYPE Beam			AVERAGE:	0.05	5.30	28.29	0.40	0.01
5	14	Wide-flange Steel	Wide-flange Steel		70,084.00	100%	0.09	8.19	21.55	0.57	0.0107
6				TOTAL	70,084.00		6,006	287	755	39,625	753
7											
8	B. INTERMEDIATE FLOORS										
9		Floor Structure	Interior Ceiling Finish			AVERAGE:	[illegible]	11.51	72.19	1.19	0.0056
10	1	Concrete Flat Plate and Slab Column System 25% flyash	gypsum board; latex paint		22,523.00	36%	[illegible]	31.98	210.37	2.50	0.0025
11	5	Concrete Hollow Core Slab	none		36,075.00	57%	[illegible]	14.14	90.33	1.31	0.0025
12	11	Open Web Stell Joist w/ Steel decking System and Concrete Topping	gypsum board; latex paint		3,005.00	5%	[illegible]	12.67	68.66	1.03	0.0139
13	13	Steel Stud Joist and OSB Flooring System	none		1,462.00	2%	[illegible]	9.42	27.00	0.77	0.0217
14				TOTAL	63,065.00		[illegible]	641	4,121	107,678	220
15											
16	C. EXTERIOR WALLS										
17		Assembly Type				AVERAGE:	[illegible]	21.51	70.01	2.07	0.69
18	4	Concrete block, EIFS, vapor barrier		16.51	22,118.00	43%	[illegible]	18.52	32.69	1.68	0.0014
19	30	Concrete Tilt-up, EIFS cladding, vapor barrier		16.15	5,421.00	11%	[illegible]	19.34	111.17	1.60	0.0010
20	48	2x4 steel stud 16"oc, steel cladding (26 ga) gypsum board sheathing, batt insulation, vapor barrier, gypsum board, latex paint		7.23	8,378.00	16%	[illegible]	35.98	29.36	3.00	4.4034
21	89	Curtainwall: Opaque Glazing (with insulated backpan)		0.00	4,548.00	9%	[illegible]	32.16	50.19	3.86	0.0046
22		Steel Siding			10,964.00	21%	[illegible]	28.21	5.95	2.27	4.3900
23				TOTAL	51,429.00		[illegible]	636	933	113,402	85,081
24											
25	D. WINDOWS										
26		Assembly Type				AVERAGE:	[illegible]	65.83	97.28	8.03	0.0031
27	5	Curtainwall viewable glazing		1.67	14,766.00	100%	[illegible]	61.60	91.70	7.30	0.0010
28				TOTAL	14,766.00		3,990	455	677	107,781	15
29											
30	E. INTERIOR WALLS										
31		Assembly Type				AVERAGE:	[illegible]	7.11	17.64	0.87	0.0012
32	4	Steel stud (16"oc) gypsum board + latex paint each side			24,684.00	98.04%	[illegible]	3.51	10.57	0.47	0.0034
33	8	6" concrete block; latex paint each side			492.36	1.96%	[illegible]	14.22	24.74	1.25	0.0000
34				TOTAL	25,176.36		888	47	137	12,164	85
35											
36	F. ROOF										
37		Assembly Type				AVERAGE:	0.25	23.15	70.05	3.07	0.0053
38	4	Cocrete flat plate slab and column 4-ply built-up roofing, vapor		22.27	23,257.00	79%	0.88	89.77	294.29	9.73	0.0044
39	14	Open-web Steel joist w/ steel decking 4-ply built-up roofing, vapor barrier, rigid insulation, gypsum board, latex paint		21.88	6,284.00	21%	0.77	62.51	81.91	7.74	0.0146
40				TOTAL	29,541.00		25,300	1,240	3,680	274,858	194
41											

Figure 3. EcoCalculator's Assembly Spreadsheet for Example Building

Academic Administration Building -- As Built

TOTAL IMPACTS BY BUILDING COMPONENT	Primary Energy (MMBtu) TOTAL	GWP per (tons) TOTAL	Weighted Resource (tons) TOTAL	Air Pollution Index TOTAL	H2O Pollution Index TOTAL
COLUMNS AND BEAMS	6,006	287	755	39,625	753
INTERMEDIATE FLOORS	6,005	641	4,121	107,678	220
EXTERIOR WALLS	6,587	636	933	113,402	85,081
WINDOWS	3,990	455	677	107,781	15
INTERIOR WALLS	888	47	137	12,164	85
ROOF	25,300	1,240	3,680	274,858	194
WHOLE BUILDING	**48,776**	**3,306**	**10,302**	**655,509**	**86,349**
PER SQUARE FOOT	**0.8129**	**0.0551**	**0.1717**	**10.9252**	**1.4392**

Figure 4. EcoCalculator's Impact Summary Spreadsheet for Example Building

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