

BASELINEGREEN™ AND GREENBALANCE™ : A Step Beyond Sustainability in Building Performance

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ABSTRACT

CMPBS has been developing several procedures using an inter-operational frame-work based of the life cycle structure. These procedures span between land use planning incorporating the land area footprints necessary to balance the sourcing and re-sourcing of human needs at or near site to tools for baselining and balancing the economic and environmental burdens associated with 14 major building types so that a city or region can start establishing the criteria upon which to develop a green building agenda. The present incorporation of these tools has been tremendous while others such as the potential for using these methods for establishing a regionalized industrial ecology plan are still on the horizon. At this time we are fortunate to be incorporating our approach nationwide; from land use planning work on projects totaling 10,000 acres, to developing guidelines and green specifications for the interior of the U.S. Pentagon, and helping set up the City of Seattle Green Building Program where for the first time regional planning of procurement is being considered according to life cycle requirements. This paper will address two particular tools and procedures that CMPBS has developed; BaseLineGreen™ and GreenBalance™.

BaselineGreen™ is based on the input / output model of the U.S. economy “overlaid” with the environmental impacts per dollar for all the SIC codes so that a per dollar value for that product or service can be represented in environmental impact as well as economic terms. This relationship is then linked through approximately 8000 descriptors to the CSI/Uniformat specification procedures. In this manner, buildings are linked directly to the economic and environmental impact models of the U.S.

BaseLineGreen™ first examines the upstream external environmental cost and regional employment impacts of

the inputs to construction of a generic baseline building or buildings modeled after a proposed building (s) design. The upstream external environmental costs are summarized in an “external environmental cost ratio” (EECR). The upstream employment impacts are summarized in an “employment impact ratio” (EIR). Both an EECR and an EIR are assigned to all high priority inputs to construction within major architectural Uniformat Building Group Element categories of the baseline building.

Second, BaselineGreen™ establishes a new “greener” baseline with reduced upstream environmental costs. This green baseline becomes the new benchmark for measuring the proposed building design.

Following the BaselineGreen™ analysis, the GreenBalance™ assessment provides a framework to go beyond the present approach of simply minimizing environmental burdens. GreenBalance™ attempts to neutralize or “balance” these conditions with the objective of mitigating and, in some cases, actually counteracting external environmental costs.

1. BASELINEGREEN™

1.1 Environmental Prioritization of Uniformat Building Group Elements

Step one of BaselineGreen™ identifies the high priority building group elements associated with upstream environmental burdens. (In this report, negative environmental impacts are called environmental burdens since they impose health risks and economic costs to society.) The method of analysis is environmental life cycle assessment (LCA) using Bureau of Economic Analysis (BEA) national data. The upstream (or

“embodied”) environmental consequences of the hundreds of inputs required to provide the bill of materials and products for the baseline building design are assessed using an economic input-output model of the entire construction sector of the U.S. economy. The input-output model is fully comprehensive and includes inputs of raw materials, energy, equipment, fabricated products, intermediate products, and services that can be correlated to various geographic locations and scales.

Three summary environmental burden indicators associated with each upstream input to construction of the baseline building - total air pollution, global warming (greenhouse gases), and toxic releases –are identified and quantified. After all upstream inputs to construction are categorized according to Unifomat Level 2 Building Group Elements, the Building Group Elements are subsequently ranked according to each of the three environmental burdens and then an overall “final ranking”

is given that combined rankings for all three burdens. The rankings for one example municipal building project in Seattle, Washington are presented in Table 1 below.

The “final ranking” column indicates that the Interior Finishes Unifomat Level 2 Building Group Element is the most significant in terms of all three types of environmental burdens combined. Superstructure is the second most significant, Exterior Closure is third, and so on. (Note that this simplified ranking method does not prioritize the three summary environmental burden indicators. Some toxic releases for example, although regulated, may be a greater environmental burden per unit than the other two indicators.)

TABLE 1: RANKING OF UNIFORMAT LEVEL 2 BUILDING GROUP ELEMENTS BY UPSTREAM ENVIRONMENTAL BURDENS

UNIFORMAT LEVEL 2 BUILDING GROUP ELEMENTS	ENVIRONMENTAL BURDEN RANKING			COMBINED RANKING	FINAL RANKING
	AIR POLLUTION	GLOBAL WARMING	TOXIC RELEASES		
C30 INTERIOR FINISHES	2	2	1	5	1
B10 SUPERSTRUCTURE	1	1	4	6	2
B20 EXTERIOR CLOSURE	4*	3*	3	10	3
D50 ELECTRICAL	4*	5	2	11	4
A10 FOUNDATIONS	3	3*	8	14	5
D30 HVAC	7	6	5	18	6
C10 INTERIOR CONSTRUCTION	6	7	6	19	7
D20 PLUMBING	8	8	7	23	8

NOTES: 1.) * Denotes equal contribution to environmental burden indicator.
2.) The Miscellaneous and Service Sector categories have been omitted.

1.2 Environmental Prioritization of Inputs to Construction

In the second part of the upstream environmental burdens analysis, the high priority individual inputs to construction within each Unifomat Level 2 Building Group Element were identified that contributed most to the upstream environmental burdens within each Unifomat category. The purpose of this more detailed analysis is to provide environmental burden indicator data for a more specific building material and/or product type.

For example, according to Table 1 above, Superstructure was ranked the number one Building Group Element in terms of total upstream air pollution. Within this Unifomat Building Group Element, the inputs to construction are ranked from largest to smallest contribution for the air pollution environmental burden indicator as indicated in Table 2 below. (Note that the first four inputs to construction account for more than 80% of cumulative contribution and the top seven account for more than 90% of cumulative contribution.)

TABLE 2: RANKING OF INPUTS TO CONSTRUCTION BY UPSTREAM AIR POLLUTANTS WITHIN SUPERSTRUCTURE UNIFORMAT LEVEL 2 BUILDING GROUP ELEMENT

B10 SUPERSTRUCTURE Inputs to Construction	% CONTRIBUTION	CUMULATIVE %
1. Ready mixed concrete	39.8%	39.8%
2. Fabricated structural iron, steel, and aluminum for buildings	19.0%	58.8%
3. Cement, hydraulic	17.4%	76.2%
4. Fabricated structural metal, not elsewhere classified	4.4%	80.6%
5. Hardwood & softwood lumber, rough & dressed, except siding	4.3%	84.9%
6. Fabricated bar joists and conc. reinforcing bars	3.7%	88.6%
7. Structural wood products	2.8%	91.4%
8. Structural shapes, sheet piling, & conc. reinforcing bars	2.4%	93.8%
9. Other fabricated structural metal, not elsewhere classified	2.3%	96.1%
10. Rough & dressed lumber – treated, not edged	1.6%	97.7%

1.3 External Environmental Cost Ratio

Based on a literature review of societal costs of air pollution, monetary values were calculated for upstream environmental burdens associated with each input to construction in the Uniformat Building Group Element categories. This monetary value can be expressed as a ratio. The units of the ratio are external cost of upstream environmental burden in dollars per dollar (or thousand, hundred, etc. dollars) of the market cost of the input to construction. We have called this ratio the “external environmental cost ratio” (EECR) for each input to construction within the Uniformat categories.

In Table 3 below, the EECR for the state of Washington for each of the high priority (80-90% cumulative contribution) inputs to construction within each of five major architectural Uniformat categories is indicated. Table 3 can be used to determine which inputs to construction within Uniformat categories have the highest per dollar upstream external environmental cost. For example, in the Uniformat category Interior Finishes, “tufted carpets” has an EECR of 0.24 meaning that for every \$1.00 of market cost, \$0.24 is generated in upstream external environmental cost. Compare that with “ceramic wall and floor tile” which has an EECR of 0.17 meaning that \$0.17 of upstream external environmental cost is generated for each \$1.00 of market cost. Dollar for dollar, tufted carpets have 40% greater upstream external environmental cost than ceramic tile.

Of course, the total upstream external environmental costs for any input to construction must be adjusted according to the unit cost of that input to construction. In the example above, if the unit cost of ceramic tile is higher than that of tufted carpet, then the cost difference must be accounted for in determining the upstream external environmental cost in providing a floor finish for a particular area.

1.4 Employment Impact Ratio

Finally, the BaselineGreen™ analysis can estimate the employment impact for major Uniformat categories as well as each input to construction for local, regional, or national geographic regions. Summaries by county and by state of employment associated with each input to construction within the Uniformat categories can be provided. The total number of jobs associated with the input to construction for the baseline building alongside the market cost of that input to construction in the baseline building can be indicated. The “employment impact ratio” (EIR) is the ratio between these two numbers. For the same project in Seattle for example, in the Uniformat category Superstructure, the job total associated with “ready mix concrete” input to construction is 11.52 and the regional market cost is \$744,800. The ratio between these two numbers is 15.47 meaning that this is the number of jobs per \$1 million dollars of market cost. This is the employment impact ratio (EIR) for ready mix concrete within the Uniformat category Superstructure. These figures represent employment in King County and Washington only and not the rest of the U.S.

1.5 BaselineGreen™ Benchmark

BaselineGreen™ indicates which material and product types of the baseline building have the lowest EECR and should therefore replace types with higher EECR values. For example, under Interior Finishes, ceramic floor tile has a lower EECR than hardwood flooring, hard surface floor coverings, and tufted carpets. Thus, depending on unit cost, it should be considered as an environmentally preferred product type.

Once the EECR and EIR values have been determined for the baseline building, ways to improve the environmental performance (i.e., reduce the external environmental costs)

of the inputs to construction are considered. This “greener” baseline building is the BaselineGreen™ Benchmark. The upstream environmental burdens of material and product types are evaluated and low-embodied energy, recycled content/by-product, and locally/regionally available materials are substituted for high-embodied energy, high environmental impact raw materials. Three examples are:

- 1) fly ash may be substituted for cement (e.g., 50%) in hydraulic cement and ready mix concrete,
- 2) high-recycled content structural steel (90%) may be substituted for average recycled content steel (65%), and
- 3) synthetic (flue gas desulphurization) gypsum may be substituted for mined gypsum (up to 100%).

In each of these examples, the upstream (or “embodied”) environmental consequences of the materials and products comprising a particular input to construction has been significantly reduced by the selection of appropriate environmentally preferred substitutes.

Figure 1 illustrates in graphic form the difference between the baseline building and the BaselineGreen™ Benchmark. For each input to construction within the major Unifomat Level 2 Building Group Elements, material substitutes like the ones mentioned above have decreased the external environmental cost ratio (EECR). In some cases this reduction can be more than 50%. The BaselineGreen™ Benchmark is then used as a reference for evaluating the environmental performance of the proposed building design.

TABLE 3: EECR AND EIR DATA FOR HIGH PRIORITY INPUTS TO CONSTRUCTION

UNIFORMAT LEVEL AND CATEGORY		EECR COST/\$	EIR JOBS/\$M
LEVEL 1	A SUBSTRUCTURE		
LEVEL 2	A10 FOUNDATIONS & A20 BASEMENT CONSTRUCTION		
INPUTS TO CONST.	Cement, hydraulic	2.22	51.01
	Structural shapes, sheet piling, and concrete reinforcing bars	0.61	18.01
	Ready mix concrete	0.49	15.49
	Fabricated bar joists and concrete reinforcing bars	0.34	11.70
	Wood poles, piles, & posts	0.16	22.89
LEVEL 1	B SHELL		
LEVEL 2	B10 SUPERSTRUCTURE		
INPUTS TO CONST.	Cement, hydraulic	2.22	51.01
	Structural shapes, sheet pilings, & concrete reinforcing bars	0.61	17.81
	Ready mix concrete	0.49	15.47
	Fabricated bar joists and concrete reinforcing bars	0.34	11.78
	Fabricated structural iron, steel, aluminum for buildings	0.23	13.84
	Fabricated structural metal, nec	0.23	13.85
	Other fabricated structural metal	0.23	13.85
	Hardwood & softwood lumber, rough & dressed, exc. siding	0.20	16.34
	Rough & dressed lumber, treated	0.16	23.04
Structural wood products	0.12	17.68	
LEVEL 2	B20 EXTERIOR CLOSURE		
INPUTS TO CONST.	Gypsum building materials	0.63	12.70
	Brick and structural clay tile	0.41	18.27
	Concrete block and brick	0.38	15.32
	Other glass products including tempered, multiple glazed, & stained	0.26	27.83
	Interior and exterior architectural solvents and paints	0.25	N/A
	Commercial and industrial metal doors and frames	0.24	14.59
	Residential metal doors and frames	0.24	14.60
	Building and construction plastic foam products	0.24	109.86

	Other granite products including building stone	0.23	61.45
	Marble building stone, monument tone, & other marble products	0.23	113.88
LEVEL1	C INTERIORS		
LEVEL 2	C10 INTERIOR CONSTRUCTION		
INPUTS TO CONST.	Concrete block and brick	0.38	15.21
	Softwood plywood products, rough, sanded, and specialties	0.23	16.65
	Commercial and industrial metal doors and frames	0.24	14.63
	Hardwood and softwood lumber, rough and dressed exc. siding	0.20	10.20
	Partitions and fixtures, except wood	0.18	17.09
	Movable partitions except freestanding	0.18	17.03
LEVEL 2	C30 INTERIOR FINISHES		
INPUTS TO CONST.	Gypsum building materials	0.63	12.70
	Wallcoverings	0.28	14.05
	Interior and exterior architectural solvents, paints, and coatings	0.25	N/A
	Tufted carpets, rugs, and artificial grass	0.24	14.79
	Metal flooring and siding	0.24	10.70
	Hard surface floor coverings	0.23	N/A
	Hardwood flooring + Hardwood dimension lumber and flooring	0.20	21.30
	Ceramic wall and floor tile	0.17	20.37
	Millwork	0.15	19.00

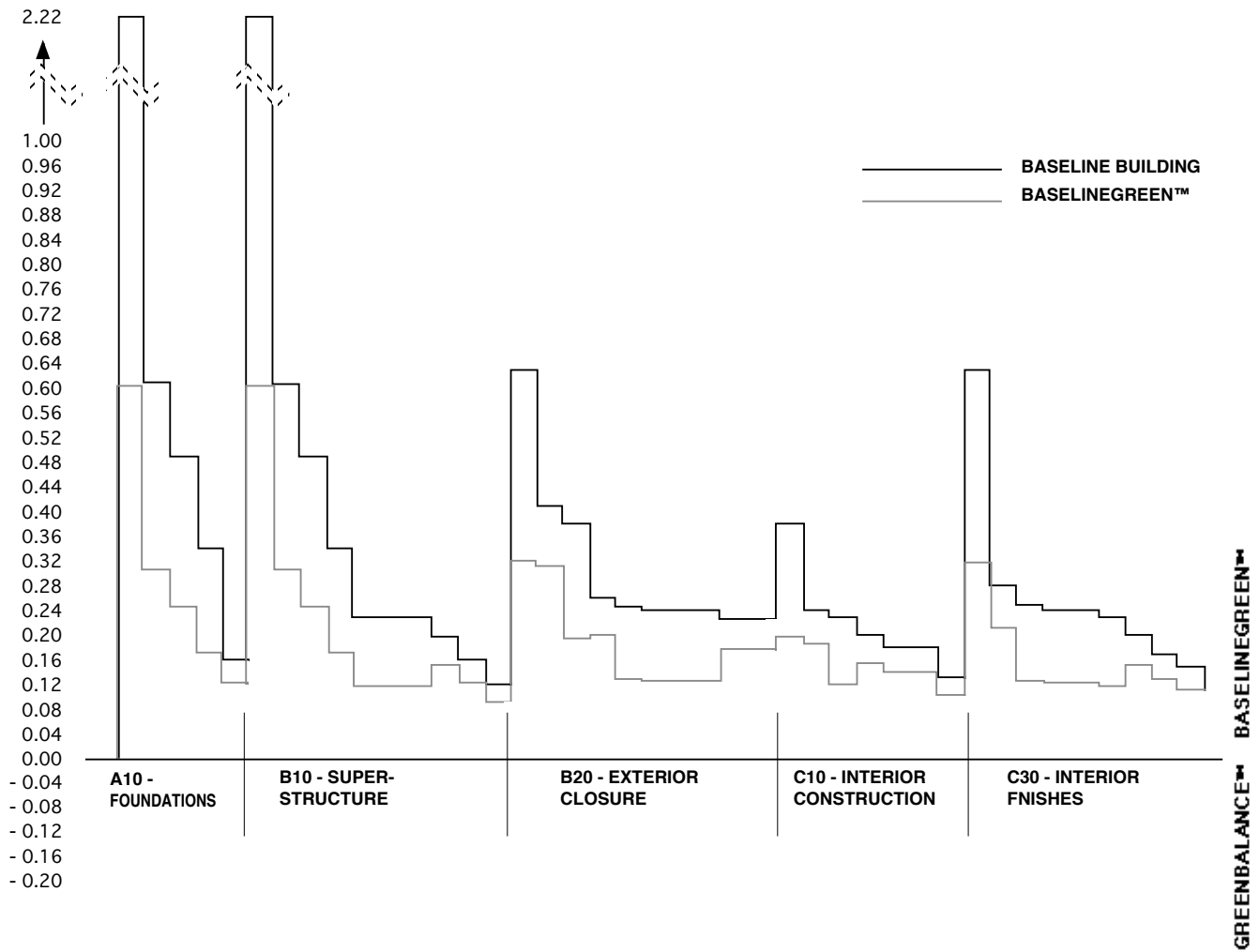


Fig. 1: External Environmental Cost Ratio (EECR) values from Table 3 for inputs to construction of a baseline building are indicated by the black line. EECR values for a hypothetical BaselineGreen™ benchmark building are indicated by the gray line. The assumed BaselineGreen™ inputs to construction have reduced upstream (or “embodied”) external environmental costs of the materials and products comprising a particular input to construction by 25-50% through the selection of appropriate environmentally preferred substitutes. BaselineGreen™ establishes a “greener” benchmark than the baseline building for evaluating the environmental performance of a proposed building design. GreenBalance™ offsets or balances upstream environmental burdens in attempting to attain a “zero-impact” or even “negative impact” building design

2.0 GREENBALANCE™

The analysis thus far has described the inputs to a generic baseline building in terms of a) upstream environmental burdens equated to external environmental cost for each input to construction and b) regionalized economic impact in terms of employment per \$M of input to construction. In addition, a new benchmark, BaselineGreen™, has been established as the “green” reference for the proposed building design (see Figure 1).

GreenBalance™ attempts to neutralize or “balance” upstream environmental burdens with the objective of mitigating and, in some cases, actually counteracting upstream external environmental costs.

To date, GreenBalance™ has been applied in the design phases of several proposed building and infrastructure projects in response to the following high-priority environmental issues:

- 1) Greenhouse gases (GHG): balance atmospheric carbon dioxide and methane emissions with carbon accumulation in long-life biomass building materials and forest mantle wastewater treatment systems.
- 2) Atmospheric pollution: balance sulfur dioxide emissions with the use of sulfur in long-life, sulfur-based building materials.
- 3) Indoor air quality: balance volatile organic compound (VOC) emissions by indoor vegetation.
- 4) Water supply and quality: balance annual on-site surface water supplies and on-site wastewater treatment with building and site needs.
- 5) Renewable energy: balance annual consumption with site-available (e.g., daylighting) and site-generated (e.g., photovoltaics) energy supplies.
- 6) Toxic releases: obtain the goal of zero upstream toxic releases and/or incorporate interior and exterior landscapes that bio-remediate toxic chemicals and render them harmless.

Projects now being undertaken which include these principles include specifications for the paving of the U.S./Mexican border with the North American Development Bank (NADBank), the U T Health Science Center Nursing and Biomedical Sciences Building (NBSB) in Houston, Texas, and the Advanced Green Building Demonstration Project (AGBDP) in Austin, Texas.

The NADBank project investigates the potential for all present SO₂ pollution emanating from petroleum refining industries in both countries to be balanced through the use of proven sulfur paving technology. A paving strategies research project reported that low-cost, durable, sulfur-modified paving materials can be made along the border and that the annual demand for alternative paving materials greatly exceeds annual sulfur emissions.

The NBSB project demonstrates how upstream carbon dioxide (CO₂) emissions can be balanced with the carbon content of long-life biomass building materials. For example, Interior Construction and Interior Finish product types such as medium density fiberboard, cellulose board, and strawboard, if manufactured from renewable or by-product sources, can store more carbon dioxide (in the form of carbon) in biomass than emitted upstream during their manufacture. These “CO₂ sink” product types can offset (or balance) the CO₂ emissions of other product types used in the interior of the proposed NBSB project. The design objective is that the Superstructure, Exterior Closure, Interior Construction, and Interior Finishes Uniformat categories be CO₂ balanced, i.e., have zero net CO₂ emissions for the life of the building.

The AGBDP exemplifies the CO₂ balancing concept in the selection of Superstructure and Interior Construction material and product types. Upstream CO₂ emissions are significantly reduced by using high recycled content (95% or more) structural steel and fly ash substitutes for portland cement. Long life CO₂ accumulation in the carbon content of biomass materials is accomplished through the use of fiberboard and strawboard panel products in movable partitions. Balancing of water and wastewater is also demonstrated at the AGBDP.

These cases of applying the GreenBalance™ methodology suggest that a deeper re-evaluation of many sustainable architecture performance assumptions, including design objectives, material and product specifications, and

operational performance, is needed, both within the boundaries of the building as well as the supporting landscape and infrastructure. GreenBalance™ attempts to balance the upstream environmental burdens with use/downstream building environmental mitigation to promote and develop a new set of standards that could bring building environmental performance to a new and more relevant level. GreenBalance™ attempts to shift the focus of building design from general (and often vague) sustainability guidelines to quantitative and more definitive materials balance assessment tools.