BASELINE GREEN™ - A Green Building Design Methodology

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SUMMARY OF PROCEDURE

A methodology to design and engineer environmentally and economically sophisticated buildings has been create using national data for the continental U.S.. These data represent about 12 million U.S. businesses.. The approach based on the interconnections between four fundamental tools: 1) Baselining environmental impacts of 489 industri categories within the U.S. economy (including 39 building construction sectors) according to region; 2) Correlatin Construction Specifications Institute and ASTM categorization systems; 3) Depicting impacts graphically of all maj facets of building and support utilities; 4) Showing in GIS format where the generic condition effects loc environment and/or economies. The methodology is demonstrated on large and small-scale buildings.

BACKGROUND

Building accounts for roughly 40 percent of the materials flow in the global economy each year. In the U.S one-sixth to two-thirds of the environmental impact nationwide is due to wood and mineral extraction, wate and energy, and the processing and manufacturing phases of the life cycle within the construction industr associated directly to how all facets of the built environment are constructed, how they operate, and th manner in which maintenance occurs. Which materials -- and how much -- are used in construction and in a facets of industry and commerce have implications for human health, environmental and resource health, an the health of local, regional, and national economies. A new framework which is being built from synthesis of Environmental Life Cycle Assessment (LCA), economic input/output (I/O) modeling an geographic information systems (GIS) enables building designers and planners, product designers, and polic makers to account for all three of these dimensions of sustainable development.

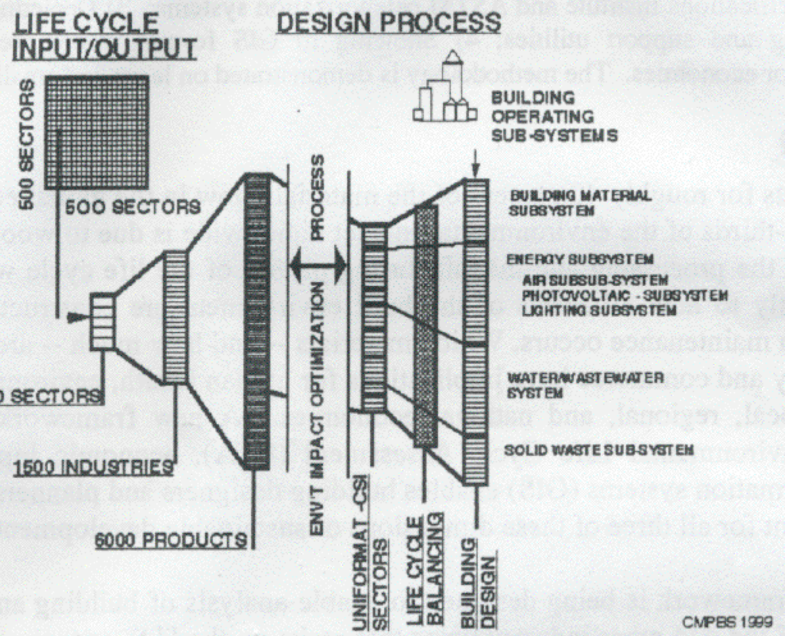
This analytical framework is being designed to enable analysis of building and construction, along with an other (and all) of the 474 other industry types that make up the U.S. economy. It has been built by carefull pooling and integrating numerous federal data resources into a whole-systems analytical framework tha traces the regional, environmental and economic consequences of generic building designs, product design final consumer demand, and policies which might affect one or more of these.

Initially funded by a cooperative agreement with the U.S. Environmental Protection Agency (Contra #CR824509-01-1) and, subsequently, by state and federal clients, CMPBS was able to operationalize national Input/Output-based GIS model to demonstrate the impact across all counties' jurisdictions of generic bill of materials for nine building types for specific air, land and water impacts (including greenhous gases). The system is currently operational and can present results for a given set of pollutants without ye incorporating recently released, detailed federal data on commodity and in-company transportation.

Research funding was recently obtained from the U.S. Department of Energy to fill in these gaps and thereb bring the system to full capability. The DOE model includes the remaining 519 Implan/SIC sectors. Th DOE funding will hopefully enable the use of the model to analyze not only the geographic location c problems but the phase of the life cycle (e.g., source, transport, processing, use or maintenance) withi according to national statistics for total life cycle impact on the environment (39 building types and maintenance and repair categories and the other 466 industrial sectors).

The system presently contains the 6000 level of the SIC/Implan codes and has developed the import linkage between the previous work and the construction specification process. We now possess operational translator between the existing model and common specification standards so that architects engineers can benchmark each facet of any building type according to CSI and Uniformat standards. T relationship between various databases is merged according to figure 1-1 below.

LIFE CYCLE BASELINING & BENCHMARKING OF BUILDINGS AND THEIR ENVIRONS



BASELINING ENVIRONMENTAL IMPACT OF GENERIC BUILDING TYPE Once a building is specified as to square foot building cost, the proportioning of building type to generic categories through input/output and life cycle assessment analyses is carried out to baseline the project. Results are presented in a pie chart as shown below. The chart demonstrates a comprehensive upstream analysis of environmental impacts of singular building types, building Uniformat subsystems by impact type including greenhouse gases, criteria air pollutants and toxic release. This phase shows in general where improvements must be made compared with the generic building. Following this phase is a breakdown according to more specific Uniformat levels so that specific building components can be re-specified according to impact conditions .

Table 2-1: Functional space breakdown for defining the baseline building

Area Description	1000 sq. ft.	cost/ sq. ft.	% total cost	Allocated to:
Convening Area	20	$140	9%	New Academic

Classrooms	60	$140	28%	New Academic
Social Spaces (lobby, academic, mtg.)	30	$140	14%	New Academic
Offices	100	$110	37%	New Office
Labs (computer-based)	30	$110	11%	New Office

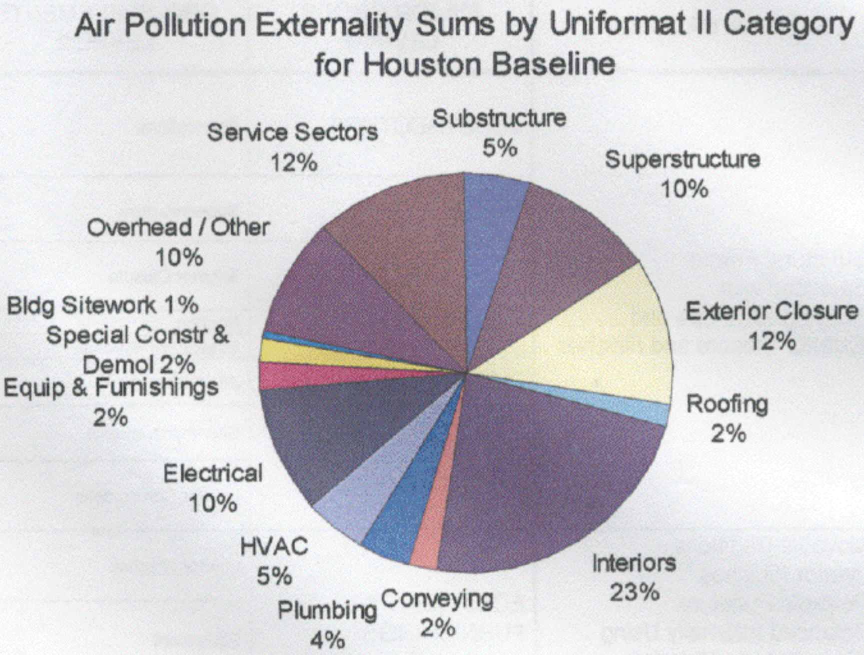


Figure 3-1

LIFE CYCLE BALANCING - CONVERTING UNIFORMAT CATEGORIZATION INTO SUSTAINABLE SYSTEM PERFORMANCE

In order for buildings to perform relative to sustainability principles it is important that system components be organized and become part of a building subsystem that can be modeled for operational performance. Operational performance of subsystems is defined in terms such as energy balance, material balance and water balance. These general topics can be more specifically defined even better in performance terms by working at even a more defined subsystem level such as passive solar under *energy*, CO2 chemical balancing under *materials* and water harvesting under *water*. Each of these subsystems contains both physical and mathematical boundaries and can be placed into systems dynamics performance modeling terms. The most understood of these subsystems amongst architects is passive solar modeling of a building under the energy-balancing category.

Almost any sub-system can in some degree be balanced as to the input and output of resources used. In passive solar the objective is zero energy use; under CO2 chemical balancing there is no net addition of CO_2 from the system; in water balancing, no water use beyond that which is sustainably supplied by precipitation falling on the site. The challenge is to design and engineer these "alternative" systems so that their net upstream impact (e.g., what they are manufactured of and how this effects the environment) is also of less burden. In fact, other research shows that what is termed the "green alternative", depending on how it is specified, is not necessarily better than the conventional once that system is repeated many times over for widespread use. This provides some insight on how important the specification process is. The following diagram shows how we organized our specification process around operational subsystems that in turn are specified to Uniformat .

SUB-SYSTEM	LIFE CYCLE BALANCE	MAJOR GROUP LEVEL 1	GROUP ELEMENTS LEVEL 2	INDIVIDUAL ELEMENTS LEVEL 3
1 BUILDING SHELL SUB-SYSTEM	Structural Frame Balanced with Building Envelope and Exterior Closure and Finishes	SUBSTRUCTURE	Foundations	Standard foundations Special foundations *Slab-on-grade*
		SHELL	Superstructure	Roof construction Floor Construction
		OTHER CONST.	Exterior Closure	Exterior walls Exterior windows Exterior doors
			Roofing	Roof coverings
			Special construction	Integrated construction
		BUILDING SITEWORK	Site Preparation	Site clearing Site earthwork
			Site Improvements	Site development Landscaping
		INTERIORS	Interior Construction	Interior partitions Interior doors Interior specialties
2 INTERIORS SUB-SYSTEM	Movable Partitions Interior Finishes Portable Furniture Balanced Internally Using Biocomposite Materials		Interior Finishes	Wall finishes Floor finishes Ceiling finishes
		EQUIPMENT & FURNISHINGS	Equipment	Commercial equipment Institutional equipment
			Furnishings	*Movable furnishings*
3 FURNISHINGS SUB-SYSTEM	Office Furniture Balanced Internally Using Biocomposite Materials	SERVICES	HVAC	Heat distribution systems Heat transfer Special HVAC systems and equipment
4 ENERGY SUB-SYSTEM	Air Quality Balanced with Interior/Exterior Natural Vegetation Solar Generated Electric Power Balanced with Bldg. Demands	BUILDING SITEWORK	Electrical	Electrical service and distribution *Special electrical systems*
			Site Preparation	Site demolition Site earthwork
		SHELL	Site Improvements	Site development Landscaping
			Roofing	Roof coverings
5 WATER AND WASTEWATER SUB-SYSTEM	*Rainwater Harvesting* Balanced with Occupant Demands Biological Wastewater Treatment On- or Near-Site Balanced with Water Harvesting	SERVICES	Plumbing	Plumbing fixtures Domestic water Sanitary water Rainwater drainage Special plumbing
			Fire Protection	Special fire protection
		BUILDING SITEWORK	Site Preparation	Site demolition Site earthwork
			Site Improvements	Site development Landscaping

			Site Plumbing	Site water supply and distribution Site sanitary sewer Site stormwater/drainage
6 SOLID WASTE SUB-SYSTEM	Organic Waste Collection/Handling On-Site Balanced with Natural Vegetation to Utilize Wastes and Balance GHGs	EQUIP. & FURNISHINGS	Equipment	Other equipment
		BUILDING SITEWORK	Site Preparation	Site earthwork
			Site Improvements	Site development Landscaping
			Site Plumbing	Site sanitary sewer

BUILDING SUB-SYSTEMS ARRANGED BY UNIFORMAT II CLASSIFICATION OF BUILDING ELEMENTS AND SITEWORK

LIFE CYCLE BALANCING EXAMPLE USING CO2 BALANCING WITHIN MATERIAL SPECIFICATION

As in most industrialized countries, by volume, the most significant greenhouse gas emitted in the U.S. is carbon dioxide (CO_2), accounting for 82-84% of the total global warming potential of all U. S. GHG emissions. Greater than 98% of all U.S. emissions of CO_2 originate from the combustion of fossil fuels such as coal, petroleum, and natural gas. Fossil fuel combustion emissions are determined by three factors: a) energy-consuming processes and services, b) their energy intensity (i.e., the amount of energy used for each process or service), and c) the carbon intensity of the fossil fuel energy source (i.e., the amount of carbon dioxide released per unit of fuel used). Less than 2% of U.S. CO_2 emissions are caused by non-combustion industrial processes such as chemical reactions occurring during cement manufacture, soda ash manufacture and consumption, and aluminum production.

Fossil fuel combustion sources of CO_2 emissions can be divided into four energy end-use sectors: transportation, industrial residential, and commercial. Each sector's share of total 1997 U.S. CO_2 emissions is shown in Figure 1. For all the sectors except transportation, a substantial portion of energy-related CO_2 emissions result from the consumption of electricity (including losses).

The industrial sector of the U.S. economy accounts for about one-third of national end-use CO_2 emissions with manufacturing activities accounting for the largest share of the sector. Aside from electric utilities, whose purpose it is to produce electric power for the rest of the economy, the top-ranked manufacturing industry of the industrial sector in terms of the total impact of CO_2 emissions is the building industry, including new, maintenance, repair, and remodeling construction. Consider the building industry's share of total CO_2 emissions for all sectors of the U.S. economy:

- It's the largest sector accounting for roughly 20% of total annual industrial emissions and 7% of the U.S. annual total.
- Upstream CO_2 emissions are roughly 5 times greater than direct emissions (for construction of the building) and 10-20 times greater than the annual operation (use) of the building.
- Within the building industry, the largest single material or product contributing to CO_2 emissions is portland cement-based ready-mix concrete (9%).

For an office/academic type building similar in size and use to the NBSB Project - the baseline comparison building – upstream CO_2 emissions are associated with the various Uniformat Level 1 major building groups or sub-systems as follows (see Figure 2):

- Shell (Superstructure, Exterior Closure, Roofing) 24%
- Service Systems (Electrical, HVAC, Plumbing, Conveying) 22%
- Interiors (Interior Construction and Finishes) 15%
- Service Sector 14%
- Substructure (Foundations) 5%
- Equipment and Furnishings 3%
- Other/Miscellaneous 17%

Aside from the building industry Service Sector group (architects, engineers, etc,), the most significant Level 1 major sub-system building group associated with CO_2 emissions is the building system which consists of the Shell, Interiors and the Substructure, sub-systems accounting for 44% of the entire CO_2 load. The Uniformat classification of the Level 2 group elements and Level 3 individual elements within each Level 1 major group are listed in Figure 3 and graphically illustrated in Figures 4-6. The net CO_2 impact of five Level 2 group elements are examined in this report – Superstructure, Exterior Closure, Interior Construction, Interior Finishes, and Furnishings.

Upstream CO_2 Emissions: A Definition

Annual CO_2 emissions include all life cycle phases of all products, including buildings (see Figure 7, top). The operational or use phase of buildings is included in the residential and commercial sectors. The direct or construction phase, as well as the demolition phase, is included in the industrial sector (the construction industry). The upstream materials acquisition, manufacturing, and distribution phases of building materials and products are also included in the industrial sector (mining and manufacturing industries). The transportation sector includes all phases – downstream, use, direct, and upstream. Passenger transportation may be considered as use phase – people going to and from service jobs, as direct phase – people going to and from construction jobs, as well as upstream phase – people going to and from mining and manufacturing jobs. Freight transport is similar. Freight may be use phase related – products shipped to homes and offices, direct and downstream phase related – building materials shipped to and from a construction site, as well as upstream phase related – raw materials or value-added products shipped to and from manufacturing sites.

Upstream CO_2 emissions related to the building industry are defined here as emissions resulting from the following non-construction activities:

- Manufacturing, mining, and forestry activities within the industrial sector.
- Transport of people and materials to and from mining, manufacturing, and forestry sites within the transportation sector.

Material Flows, Hydrocarbons, and CO_2 Sinks

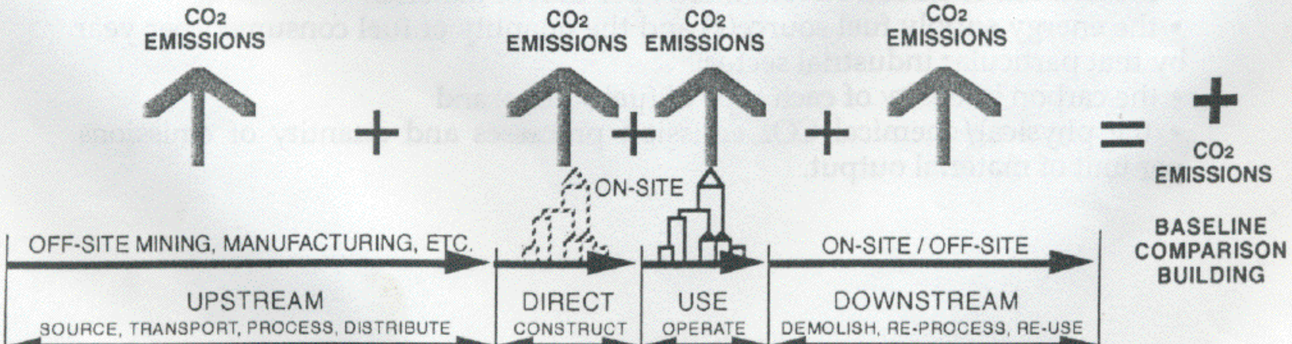
The use of hydrocarbons in life cycle of the production of materials is a major source and sink CO_2. There are two types of hydrocarbons, fossil fuels and biomass (see Figure 8). The conversion of fo fuels to energy, usually by combustion, releases CO_2 into the atmosphere. Renewable biomass, such a managed forest, absorbs CO_2 from the atmosphere and, as a consequence, its combustion results in no CO_2 emissions. The exception is the use of non-renewable biomass, such as tropical hardwoods, which d result in net CO_2 emissions. Fossil fuels and biomass can be used as energy sources and as feedstocks, raw materials of production. When used as energy sources, they are converted directly into CO_2. When u as feedstocks, they are incorporated into materials or products. Depending on their life cycle characterist carbon-containing materials can be divided into short-life and long-life types. Short-life materials, such detergents and fertilizers, are easily dissipated and subsequently quickly converted into CO_2. Long- materials, such as plastics and wood, can potentially last for decades or centuries. As the consumption materials increases, these materials are stored in the increasing product stock, as well as in waste dispo sites.Certain long-life building materials (and wastes), both synthetic and natural, can function storage or sinks of CO_2 (see dark box in Figure 8). For example, biomass materials, such as wo may contain as much as 53% carbon (by weight) in their material content. If significant amounts carbon from atmospheric CO_2 can be stored semi-permanently in certain building materials, th some of these materials can be considered to be net CO_2 sinks. A net CO_2 sink is a material wh contains an amount of carbon in its mass greater than the equivalent amount of CO_2 releas during the upstream stages of the material's life cycle.

CO_2 Balancing

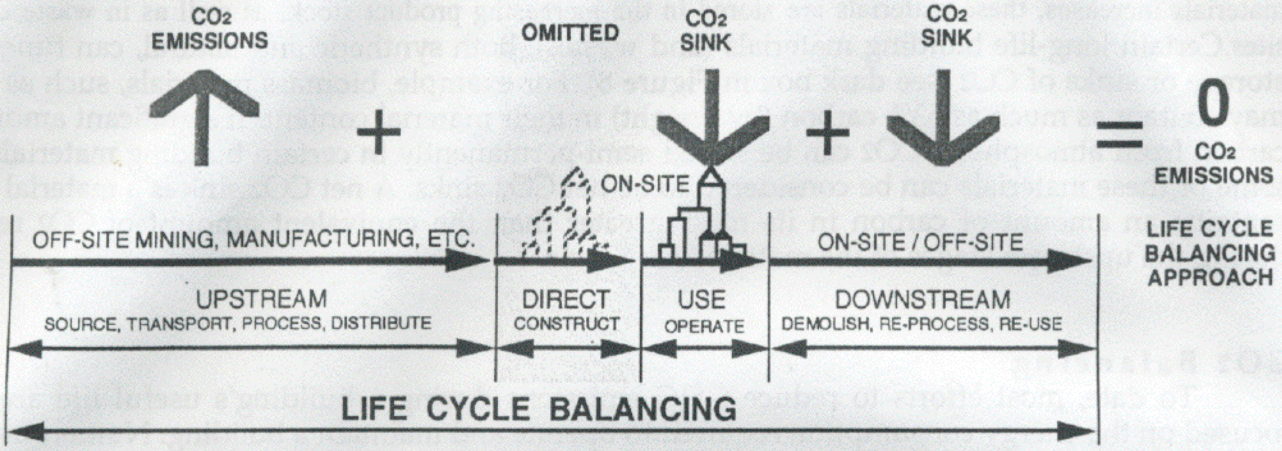
To date, most efforts to reduce GHG emissions during a building's useful life are focused on the energy consumption required to operate and maintain a building. Numerous energy efficiency measures that significantly reduce energy consumption during a building's use, operation, and maintenance (e.g., energy-efficient lighting) have been widely accepted and implemented by design professionals and the building industry. However, the use phase represents only one chapter in the building life-cycle story. The upstream phase of processing and manufacturing building materials and products causes enormous off-site impacts prior to the building's use.

Looking at the above figures, it is evident that the practices of the building design and construction industry play a significant role in releasing GHGs, especially CO_2 emissions. With a potential crisis fast approaching and the likelihood of environmental impact methods being imposed through legislation and regulation, now is the time for the building industry professionals to become leaders rather than followers in developing new approaches to the design of the built environment.

One goal of the UT Houston Health Science Center project is to respond at a local scale to the Kyoto Protocol by utilizing renewable materials that are potentially net sinks of carbon. Namely, if the carbon from CO_2 "stored" in all of the building materials is equal to or greater than the total carbon released as CO_2 during the upstream life cycle stages of the materials, then the materials (in total) may have "zero impact" on global warming during their useful life (see Figure 7, bottom). The building, or a major portion of it, will then be "CO_2 balanced." The goal of alleviating the global greenhouse effect, however small, may be feasible. The purpose of this report is to explore this possibility. The first diagram below summarizes the typical upstream and down stream CO_2 life cycle of a building, the second the demonstrates one means of balancing CO_2 upsteam with the sequestering power of



material use downstream.



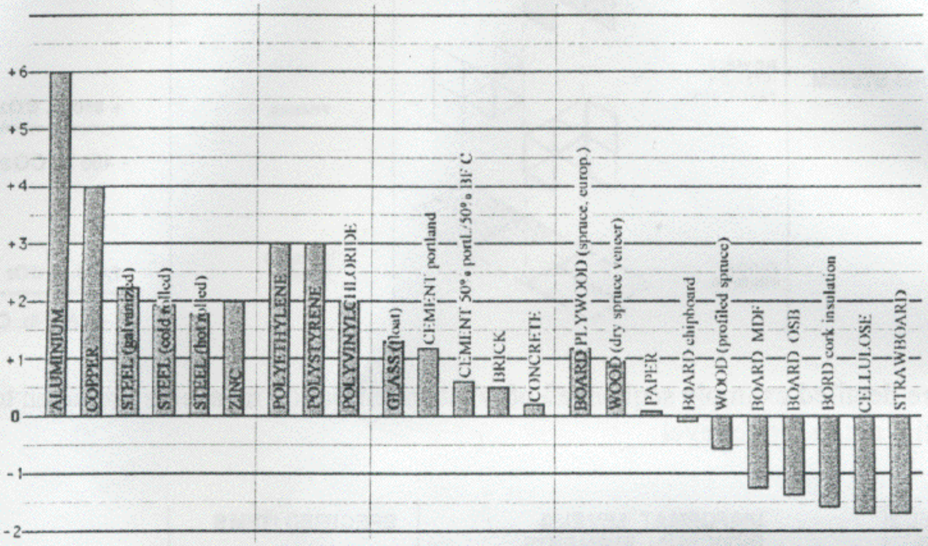
METHODOLOGY

In order to define which materials are CO_2 sources and which are CO_2 sinks, the life cycle of the material must be analyzed. The general methodology relies on an accurate portrayal of two industrial processes occurring during the upstream life cycle stages of each material: the embodied energy used (i.e., fossil fuel consumption) and the physical and/or chemical processes utilized to transform materials. The data can be provided in terms of a) national use and production database per time period (usually annual) for a particular industrial process or b) in terms of energy consumption figures from a specific manufacturer for a specific material for a specific period of time. In the former case, assuming that both the fuel source and production technology are consistent within a particular industrial sector, the following data is required:

- the energy supply fuel source and quantity per unit weight for raw material acquisition and transport to all processing facilities of a particular industrial sector;
- the quantity of material produced by that industrial sector (e.g., steel) per unit weight per year (gross), or the quantity of material actually reaching the national building sector end use stage per unit weight per year (gross – exports = net);
- the amount of carbon stored (if any) per unit of material;
- the energy supply fuel source(s) and the quantity of fuel consumed per year by that particular industrial sector;
- the carbon intensity of each type of fuel source; and
- the physical/chemical CO_2 emission processes and quantity of emissions per unit of material output.

After the upstream CO_2 emissions per unit weight of a material or product are calculated, then carbon sink potential of the material, if any, must be identified. Among major building materials a products, only biomass materials are considered to have any carbon content. Softwood trees, for examp can be as much as 53% carbon by weight. One pound of carbon contained in a biomass material is equival to the sequestering of 3.50-3.75 pounds of CO_2 from the atmosphere. A comparison of CO_2 upstre emissions to the carbon content of a long-life material yields a net CO_2 impact. Comparing the net C impact to the end use weight of a material yields a useful ratio for CO_2 balancing – a carbon dioxide intens factor.Subsequent to assigning a carbon dioxide intensity factor to various materials, the net CO_2 impact building products and components can be estimated. The bar graph below shows the result within each l of the total upstream CO_2 caused by a particular generic material for the U.S

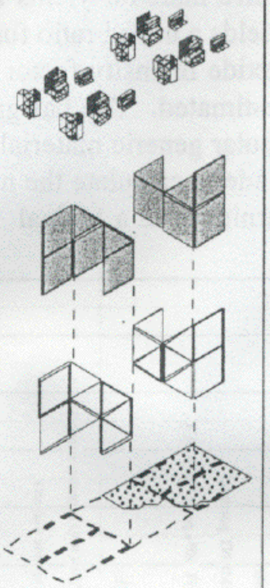
In this report an attempt has been made to calculate the net CO_2 impact of the NBSB project at sca ranging from individual pieces of office furniture, to a typical enclosed office space, to a typical buildi



structural bay. In each case, the goal is to achieve a CO_2 balance at each scale. If, at any scale, a balar cannot be achieved, then an attempt is made to balance the remaining upstream CO_2 emissions at the ne larger scale until the entire building has been included in the balance equation. If, at the end of the proce the entire building is not balanced, that is, is a net CO_2 source rather than sink, then other measures must implemented at the site, city, or regional scale to offset the estimated net CO_2 emissions.

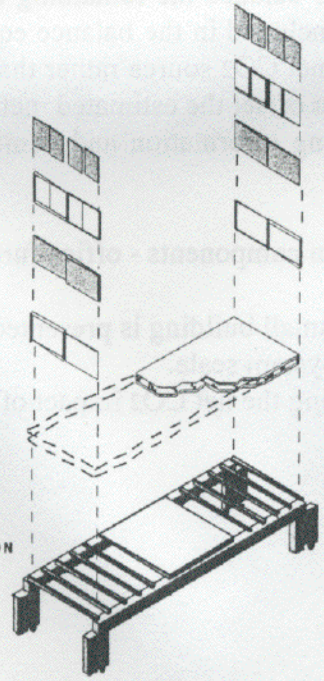
The next table summarizes the following information and demonstrates the sequence of balanc from micro to macro scale:

- The net CO_2 impact of Interiors System components - office furniture and partitions - is estimated.
- The net CO_2 impact of a hypothetical small building is presented as an example of the methodology applied at a Building System scale.
- The methodology is applied to estimating the net CO_2 impact of a typical structural bay of the NBSB project.



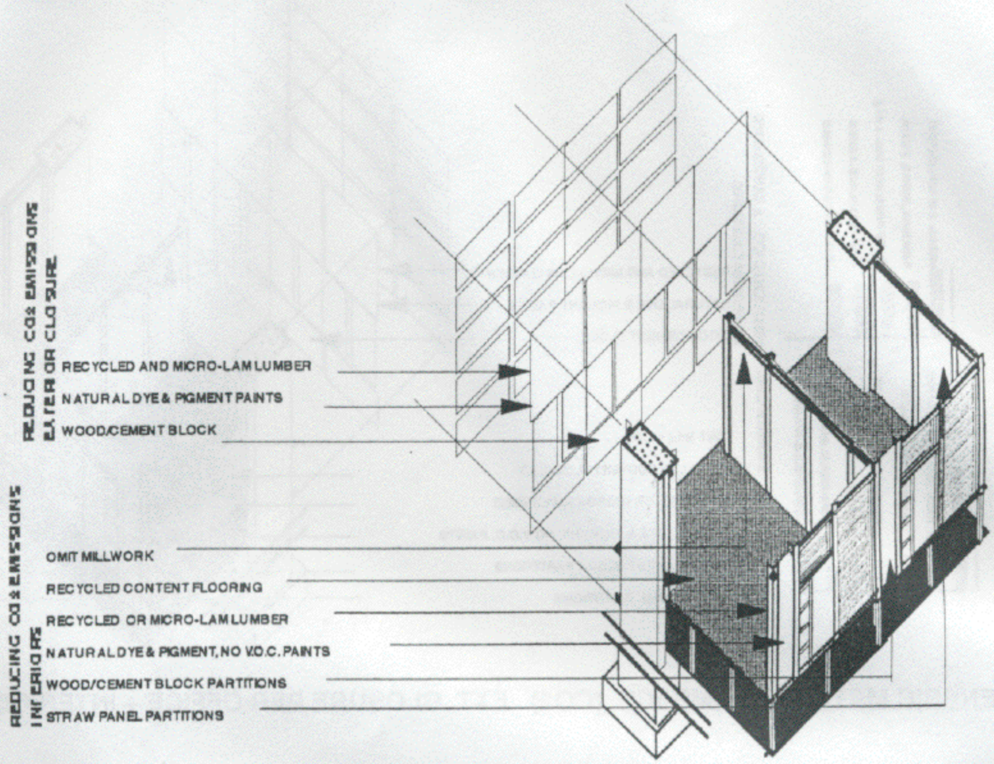
UNIFORMAT LEVEL 2 GROUP ELEMENTS	UNIFORMAT LEVEL 3 INDIVIDUAL ELEMENTS	SPECIFIED ITEMS	CO_2 EMITTED/ SEQUESTERED PER 20' x 60' BAY
FURNISHINGS	MOVABLE FURNISHINGS	CABINET UNITS	0 lb. CO_2
		DESK UNITS	0 lb. CO_2
		SHELF UNITS	0 lb. CO_2
			0 lb. CO_2
INTERIORS SYSTEM	MOVABLE INTERIOR PARTITIONS	PARTITIONS	-1,250 lb. CO_2
		FRAMES	+ 850 lb. CO_2
			- 400 lb. CO_2
	FLOOR FINISHES	FINISHED FLOOR	- 1,800 lb. CO_2
			- 1,800 lb. CO_2

Below is a more detailed example sequenceß of what specification measures are taken to improve balance potential at the office level



UNIFORMAT LEVEL 2 GROUP ELEMENTS	UNIFORMAT LEVEL 3 INDIVIDUAL ELEMENTS	SPECIFIED ITEMS	
EXTERIOR CLOSURE	EXTERIOR WALLS	GLASS PANES	+ 871 lb. CO_2
		WINDOW FRAMES	+ 38 lb. CO_2
		EXT. INFILL WALLS	- 804 lb. CO_2
		EXT. INFILL WALL FRAMES	+ 16 lb. CO_2
			+ 121 lb. CO_2
SUPERSTRUCTURE	FLOOR CONSTRUCTION	FLOOR	- 4,710 lb. CO_2
		SLAB	+ 3,520 lb. CO_2
		BEAMS	- 800 lb. CO_2
		GIRDERS	+ 5,580 lb. CO_2
		COLUMNS	+ 4,100 lb. CO_2
			+ 7,690 lb. CO_2

LIFE CYCLE BALANCING
BUILDING, INTERIORS, AND FURNISHINGS SYSTEMS



ALTERNATIVE MATERIALS - SHELL, INTERIORS, AND FURNISHINGS
FOR
BALANCING STRUCTURE AND SHELL

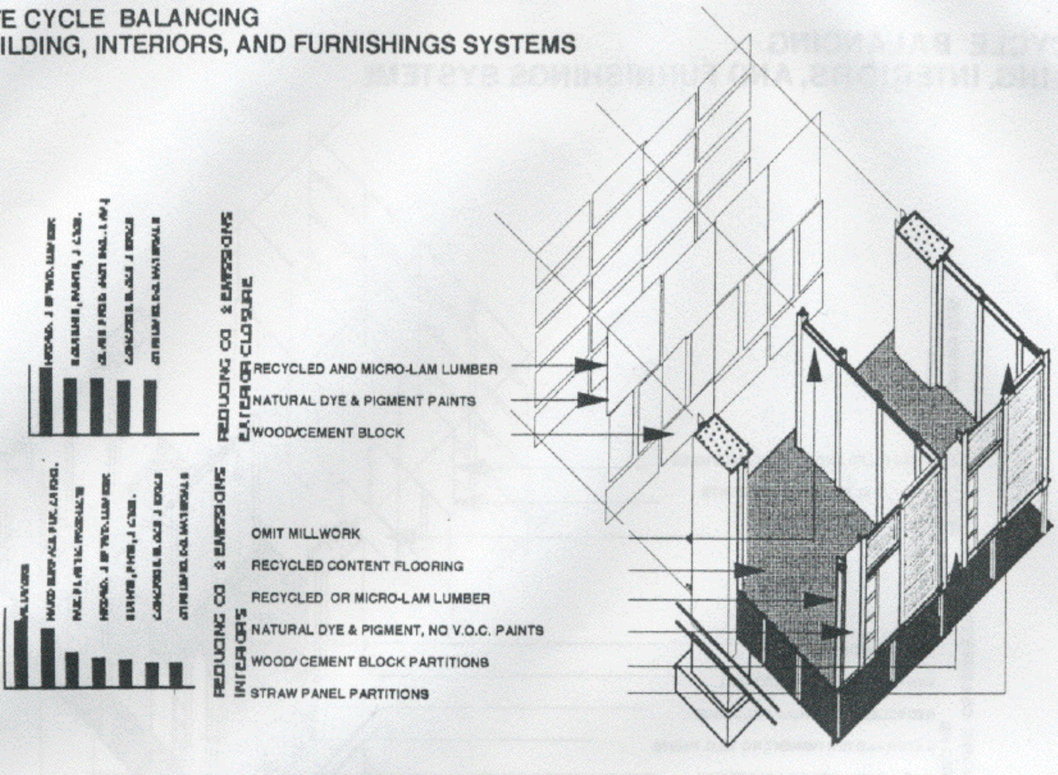
ADVANTAGES I/0 BASED LCA

The advantages of a nationally derived baselining method using Input-Output modeling procedures are:

1) The degree of scientific peer reviewed support;
2) The number of total upstream business entries behind each level or tier phase of the life cycle;
3) The fact that the system is rapid in its ability to develop answers to queries;
4) The results are transparent from the standpoint of backup data investigation;
5) The model is economic-based which means we can flip between economic or environmental impacts;
6 The results of the model occur at the 6-7,000 product level where correlation exists between generic product types and CSI/Uniformat categories.

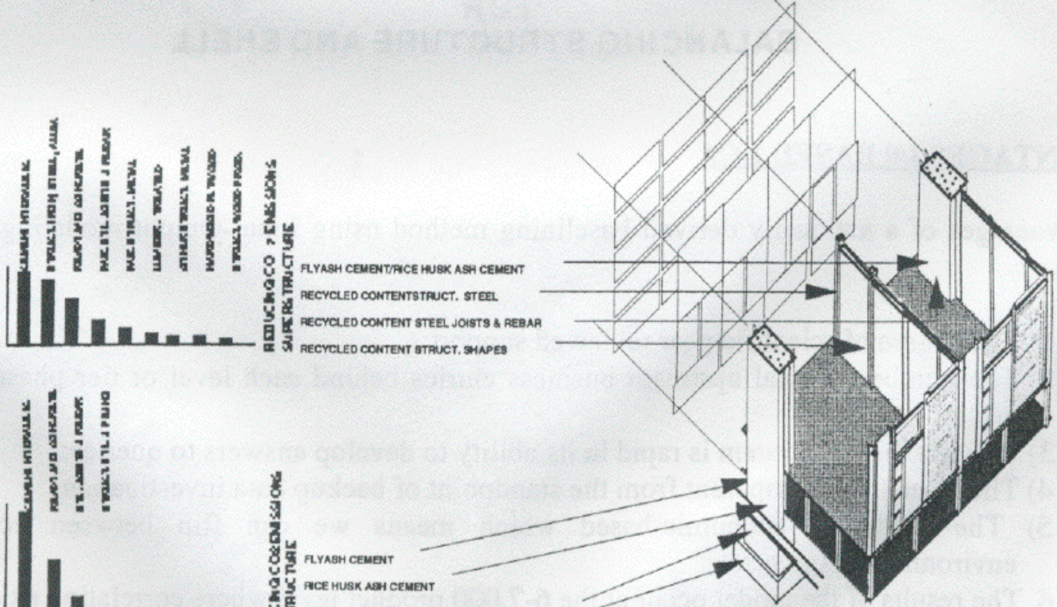
The total number of establishments represented by a single building component or product type can reach into the 100's per layer. The result of methods that don't account for the "small stuff" can result in inaccuracy of up to 40%. Other "bottom up" analysis driven life cycle methods are

LIFE CYCLE BALANCING
BUILDING, INTERIORS, AND FURNISHINGS SYSTEMS



<u>GENERIC MATERIALS IMPACT</u> (CO2) EXT. CLOSURE PER OFFICE + INTERIORS

LIFE CYCLE BALANCING
BUILDING, INTERIORS, AND FURNISHINGS SYSTEMS



<u>GENERIC MATERIALS IMPACT</u> (CO2) STRUCTURE AND SUBSTRUCTURE

dependent on procedures whose accuracy is dependent on time and funding limitations. In addition to comprehensiveness and peer review the I/O method can really represent whole buildings and support facilities whereas other techniques only fulfill the parts of the building in which life cycle analysis has occurred. The latter is particularly important in the sustainable design field because such items as wastewater systems can be baselined as well as the power generating source, or the water or the solid waste system. Alternatives to these traditional techniques must live up to and better the impact conditions of this baseline before we should be able to call them "greener". The biggest advantage is that the model is economic based which means we can flip between economic or environmental impacts: each is extremely important relative to decisions encountered by federal, state, and municipal governments. Finally, since the results of the model occur at the 6-7,000 product level, there is good correlation between generic product types and CSI/Uniformat categories so that details of a building project at whatever scale can be pinpointed as to relative impact.

DISADVANTAGES

The disadvantages of the baselining approach include:

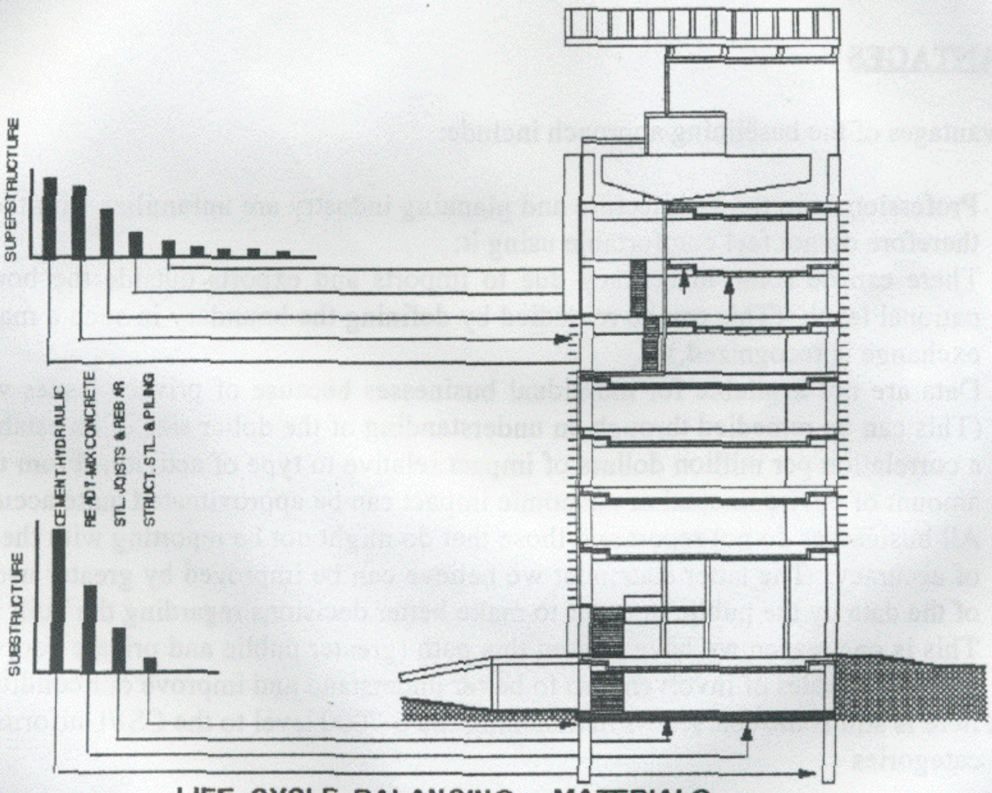
1) Professionals in the architecture and planning industry are unfamiliar with the method and therefore do not feel comfortable using it;
2) There can be some inaccuracy due to imports and exports outside the boundary at the national level. (This can be remedied by defining the boundary in such a manner that this exchange is recognized.)
3) Data are not available for individual businesses because of privacy issues with industry. (This can be remedied through an understanding of the dollar size of an establishment and a correlation per million dollars of impact relative to type of activity. From this the likely amount of environmental or economic impact can be approximated quite accurately.)
4) All businesses do not report and those that do might not be reporting with the same degree of accuracy. The latter statement we believe can be improved by greater use of and need of the data by the public in order to make better decisions regarding the built environment. This is one reason we have chosen this path (greater public and private cooperation at the necessary scales of involvement) to better understand and improve our condition.
5) There is still some coarseness in matching the 6-7000 level to the CSI/Uniformat categories

APPLICATIONS

Several significant building types have used or are using this model to date (e.g., the EpiCenter in Montana, The University of Texas/Houston Health Sciences Center Nursing & Biomedical Sciences Building, the Build America Program for industrialized housing (funded by U.S. DOE), and the Pentagon Renovation Project. Additionally, the approach has been used for projects funded by the Texas State Energy Conservation Office, and for commercial and residential building types proposed by large developers or commercial chains.

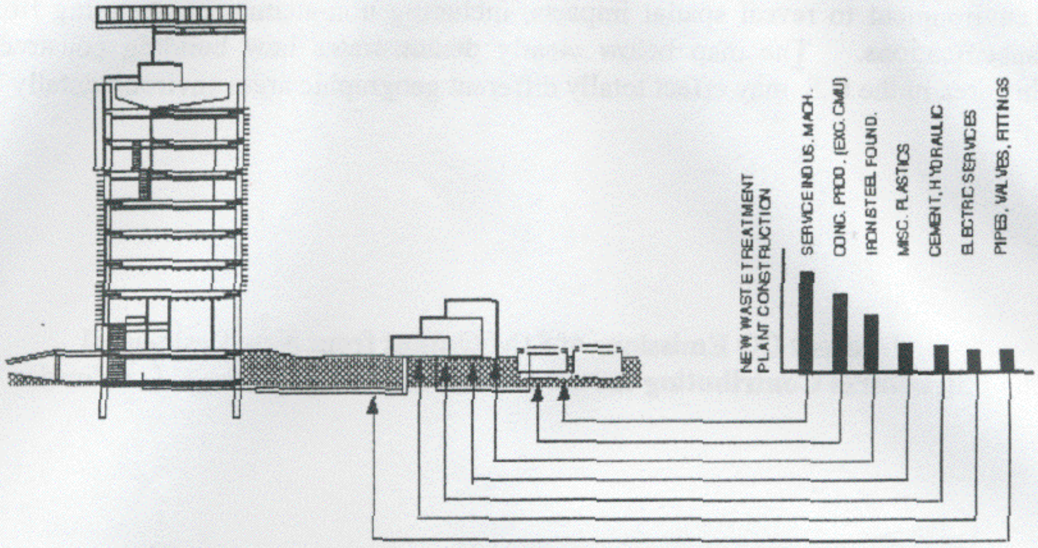
BUILDING SECTIONS DETAILING ENVIRONMENTAL IMPACT

The following sections show the results of identifying national impact data to building details. From this baseline information the designer/engineer develops a new benchmark using the life cycle balancing procedures in the next section.

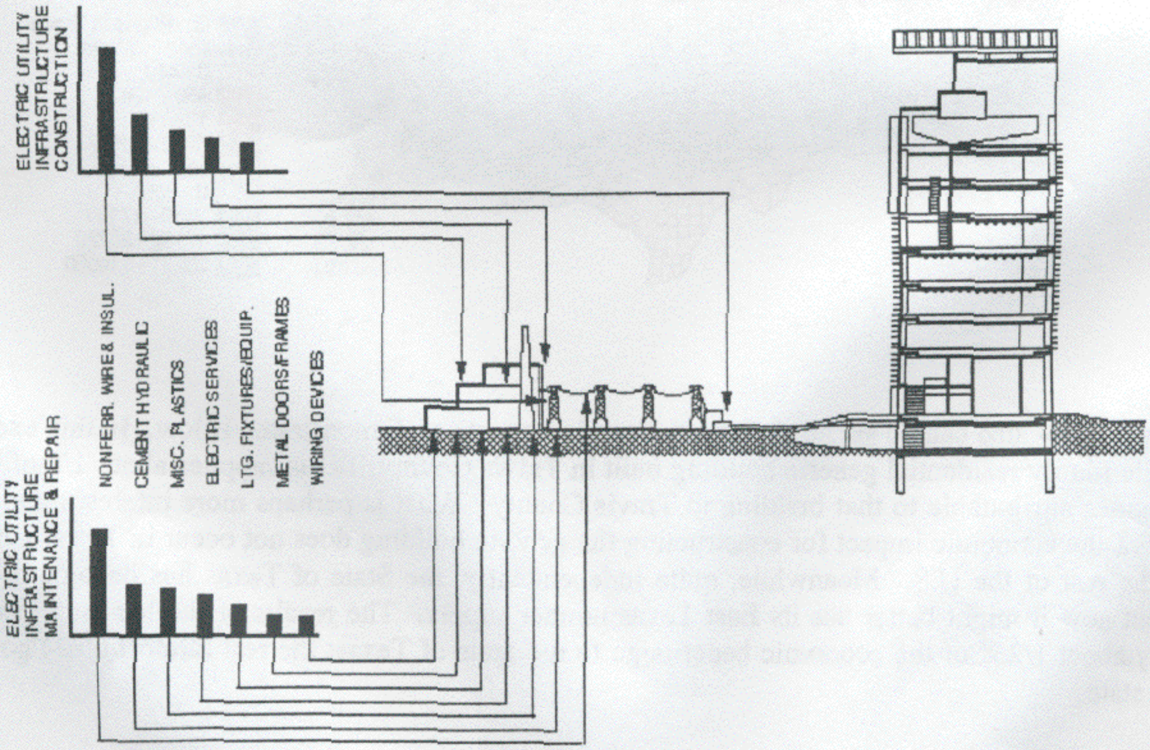


LIFE CYCLE BALANCING - MATERIALS

LIFE CYCLE BALANCING - WASTEWATER



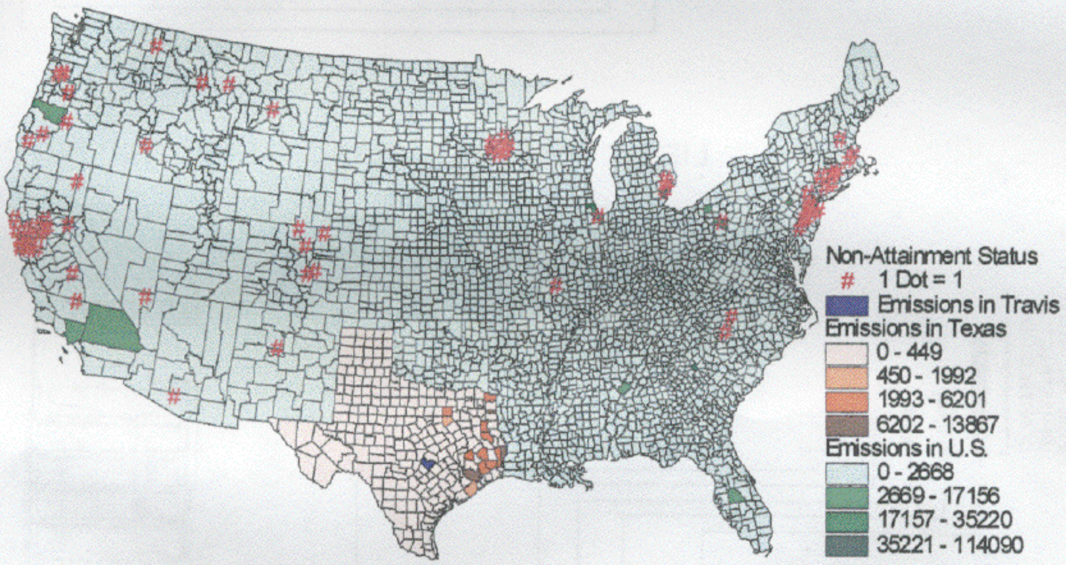
LIFE CYCLE BALANCING - ELECTRIC SUPPLY



ENVIRONMENTAL / ECONOMIC FOOTPRINTING

System capabilities can overlay on a county-by-county display using a geographic information systems environment to reveal spatial impacts, including non-attainment, resulting from building-related specifications. The map below clearly demonstrates how building construction in one geographic area in the U.S. may effect totally different geographic areas environmentally

Indirect CO Emissions of $1M Output from New Residential Structures Contributing to Non-Attainment Status in the U.S. Counties



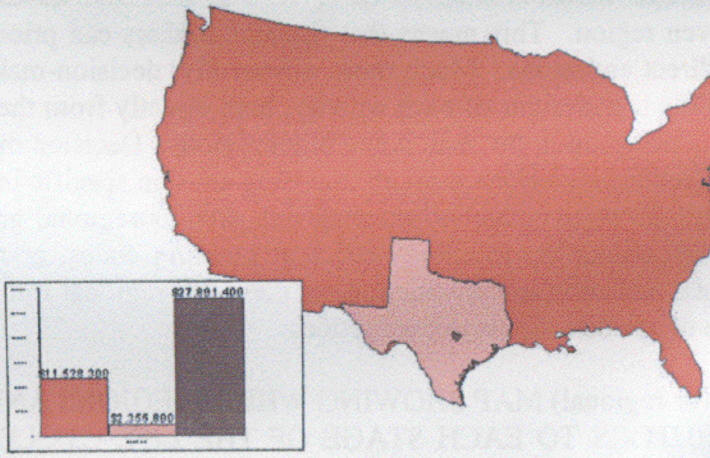
This display also can be set up to show economic impacts as demonstrated below. In this example, a single family residential generic building built in Travis County, Texas supplies about 1/5 of the total revenues attributable to that building to Travis County. What is perhaps more interesting is that the rest of the economic impact for constructing the generic building does not occur in Texas but mostly in the rest of the U.S. Meanwhile, quite independently, the State of Texas has become concerned about how it might better use its East Texas lumber supply. The results of the bar graph show that only about 1/25th of the economic benefits go to the State of Texas; the rest (almost 60%) go outside the state.

Our baseline economic analysis applied to Montana State University's EpiCenter, funded by the National Institute of Standards & Technology, can provide the following types of results for each of three study regions, or for any number of other boundaries desired:

1) Output sales in dollars
2) Personal income
3) Total value added
4) Wages
5) Employment (full time equivalents)
6) Indirect business taxes

The second phase that would parallel the alternative Life Cycle Balanced System in economic terms characterizes the regional economic benefits of locally sourcing some of the inputs to the project.

Economic Impact According to Boundary
County, State Country
Industrial output Induced by Producing $1M of New Residential Construction



SUMMARY CONCLUSION
In summary, the methodology can be used for the following analyses:

A) REGIONALIZED LIFE CYCLE ENVIRONMENTAL AND ECONOMIC ASSESSMENTS alternative buildings or product designs, in tabular, graph, and map form. This capability means decision makers can identify and compare the county-by-county environmental consequences of alterna building or product designs, and relate the emissions resulting from a given life cycle to ambient conditi where they occur. The GIS environment for the LCA also means that LCA results can be directly linkec origin/transport/exposure/risk modeling, for more rigorous impact and damage assessment than is curre possible in life cycle impact assessment (which currently lacks a spatial dimension).

Buildings and building designs can be described either by:

1) Using a national average total bill of materials (and services) referenced to the roughly commodities in the national input/output accounts for the appropriate building type, selected fro set of over 20 such building types. (This is useful to define the benchmark against which to comp specific building types and components);

2) Defining a building's total bill of materials by modifying the default set of commodities. defining an entirely new set of commodities;

3) Defining the building requirements in terms of the CSI Masterformat categories or the Uniformat II categories;

4) Defining the requirements in terms of the Department of Commerce's taxonomy of roughly 6000 products and services.

B) Regionalized, sector-by-sector COMPARISONS OF THE SOURCES AND CAUSES OF EMISSIC of a given pollutant in a given region. This means that decision-makers can prioritize industrial sector activities in terms of their direct emissions. Much more powerfully, decision-makers can begin to thin and act -- in terms of the TOTAL emissions of each activity, both directly from the activity and those w the activity's use of inputs induces within the region and other regions. Decision makers also can investi and compare the potential to reduce emissions through imposing caps on specific industries' direct emiss vs. on more demand- and design-based reduction mechanisms such as regional greenhouse gas and rel economic consequences to implement more energy-efficient building codes, or the regional toxic rel impacts of alternative material selection in construction, or the multi-regional impacts of specific indus achieving more efficient use of specific inputs to production.

C) Displays of the national (or regional) MAP SHOWING WHICH REGIONS AND COUNTIES ARE T DOMINANT CONTRIBUTORS TO EACH STAGE OF THE LIFE CYCLES OF BUILDINGS (other products if desired). This can help decision makers identify which regions of the country are n active in supporting the production processes associated with each of the major life cycle stages, f raw materials acquisition, through manufacturing and distribution, to final disposal or recycling.

CREDITS AND BIBLIOGRAPHY

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References:

Fisk, P., Norris, G., Bavinger, B., 1995, Center for Maximum Potential Building Systems, "*Establishing National Measurable Goals for Total Quality Building*", Cooperative Agreement CR824509-01-0, U.S. Environmental Protection Agency.

Fisk, P., Norris, G. 1996."*Life Cycle Assessment for the Architecture and Planning Professions*", AWMA National Conference, Knoxville, Tenn.

Fisk P., MacMath, R. "CO2 Balancing of Human Metabolic Needs with Vegetation" Report, University of Texas Health Science Center, January, 1999.

Fisk P. MacMath R. "CO2 Balance Potential of Building Materials and Products within the Boundary of the Building, Report, University of Texas Health Science Center, January, 1999.

Fisk, P. Walker, J., "Life Cycle Balancing of CO2 and Alternative Wastewater Systems Report, University of Texas Health Science Center, in progress, 1999.

Fisk, P."The Infinit Life Cycle Grid: The Architecture of Environmental Information in Design", AIA Committee on the Environment, November, Miami, FL. 1997

Fisk, P., MacMath R., Vittori G."Life Cycle Design Principles for the Architecture and Planning Professic ASES Annual Meeting, Asheville, NC. 1996

Fisk, P., "Environmental / Economic National Baselining to Create a New Generation of Sophisticated Buildings and Developments", 3rd International Conference on Technology Policy and Innovation, Aug,/Sept 1999 in press

Norris, G.A. 1998. *Systematic/Holistic Application of Environmental Life Cycle Assessment to Building Material Selection.* Report to Center for Maximum Potential Building Systems & BNIM Architects, Kansas City, MO. 1999

Norris, G.A., and H.E. Marshall. 1995. *Multiattribute Decision Analysis Method for Evaluating Buildings and Building Systems.* NISTIR 5663, US Dept. of Commerce - National Institute of Standards & Technology. Sept.

Norris, G.A. 1998. "Multiplicity of Sites in the Upstream Environmental Impacts of Products and Sectors. Presented at *Gordon Research Conference on Industrial Ecology,* New London, NH. June.

Norris, G.A. 1997. "An Integrated Economic/Environmental Accounting Analysis System for the USA." *Regional and National Material Flow Accounting: From Paradigm to Practice of Sustainability.* Wuppertal Institute for Climate, Environment, and Energy, Germany.