LIFE CYCLE ASSESSMENT, DATABASES AND SUSTAINABLE BUILDING

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1. INTRODUCTION

We are experiencing a fundamental change that affects how products are developed and, more importantly, how they are perceived, especially by large volume purchasers such as governments and members of extended supply chains. The change affects market shares, and it most certainly affects building material choices and design decisions. I'm referring of course to the evolving environmental agenda that has, over the past several decades, come to encompass more and more of the issues and activities that had previously been approached in a more isolated fashion, such issues and activities as biodiversity, water use, transportation and fossil fuel depletion. The 1972 publication of the Club of Rome "Limits to Growth" report is a critical early milestone on a path toward increased environmental awareness and action. Other notable milestones along the way include the 1987 Bruntland Report, "Our Common Future", the Rio Accords of 1992, and the Kyoto Protocol of 1997.

At some point during the late 60's and early 70's, a lesser known activity was starting that today is in the forefront. Two researchers at the Midwest Research Institute, William Franklin and Robert Hunt, began working on a technique for quantifying energy and resource use as well as the environmental emissions from manufacturing and the use of products. Others in Europe were following parallel lines, and the result was what we now know as Life Cycle Assessment (LCA).

As environmental concerns have steadily moved from the periphery in the 1960s to center stage today, transportation, energy and water supply, and other resource issues are no longer focal points to which some environmental considerations are attached. Instead, all of these subjects and many more are routinely considered as topics on the environmental agenda. And that, of course, is a big part of what LCA is all about — casting the net wide to capture the full spectrum of environmental concerns.

Unfortunately, many in the manufacturing sector and in government question the value of doing LCA or, more importantly, of making data available regarding the environmental implications of products and processes. There may be good reasons for this reluctance, but the fact is that the triple bottom line is here to stay and the environment is a part of it. If data and information are not made available one way, they will be acquired in another. Environmental realities such as the following dictate a more open mind when it comes to information flows and the roles of both the public and private sectors.

- Environmental events and decisions are increasingly transnational.
- The environment is geopolitics, not just a subject for activists and scientists.
- There is clutter and confusion, with a proliferation of eco-methods, eco-labels, eco-orgs, and eco-events.
- Misinformation and speculation often push aside science.
- Wrong answers may carry as much weight with the uninformed as correct ones.

LCA practitioners, industry, and government have to work together to make available the best information possible; that means starting with high quality raw data cataloguing flows from and to nature — life cycle inventory (LCI) data. Too often the tendency is to focus on the development of attractive software without at least comparable time and effort being spent on the data side. But the quality of any life cycle assessment can never exceed the quality of the underlying LCI data on which all tools depend.

On the building side, every international agency or organization I know of is jockeying to secure its place in the sustainability movement. Indeed, one of the defining characteristics of the movement today is the extent to which environmental activist organizations are overshadowed by the more traditional and conservative organizations. The acronyms roll like credits at the end of an epic movie: OECD, UNEP, WBCSD, IEA, NATO, SETAC, CIB, RILEM, etc. And no standards organization worth its salt is without a technical committee or publications on sustainable building, life cycle assessment, or some other eco-method. The scene is so cluttered that we now need coordinating organizations like the International Initiative for a Sustainable Built Environment (iiSBE).

ISO, the international standards organization, is probably the most visible and certainly most quoted organization in this field. The ISO 14000 series of environmental management standards alone includes 14 separate publications ranging from auditing and product labeling to the 14040 sub-series on life cycle assessment. A number of other ISO activities and publications are closely related, such as those dealing with durability.

In the rest of this paper, I want to look more closely at the state of the art of LCA, at some specific data development activities, and at how LCA data serves the cause of sustainable building. As background, I will first present a brief overview of the Athena Institute.

2. THE ATHENA INSTITUTE

The ATHENA Sustainable Materials Institute was incorporated as a Canadian not-for-profit organization in 1997 to carry forward the sustainable materials project initiated in 1991 with funding from the Government of Canada (the Athena Project). Its mission has been to use funding from public and private sector contributors to further the cause of sustainability of the built environment through the following three-pronged core program:

1. design and manage research projects to develop consistent, reliable environmental impact data for a full range of building product groups, which means working with major industrial sectors;
2. develop and apply tools to improve environmental assessment capabilities for building products, whole buildings and selected infrastructure; and
3. advance the practice of Life Cycle Assessment (LCA) in relation to the built environment through a variety of international collaborative activities as well as educational and outreach programs.

The Institute's database work is reflected in more than 1,800 pages of research reports and ranks as one of the most comprehensive and transparent undertakings of its kind in the world. A central feature of those reports is the life cycle inventory analysis of major building product groups, including maintenance and replacement cycles in the context of building systems. The data is used in the ATHENA*Environmental Impact Estimator,* software designed to make the LCA task as easy as possible for architects and engineers who need answers about the environmental implications of their decisions. The data has also been used to assess the relative merits of infrastructure options — concrete versus asphalt roads, for example.

The Institute's collaborative activities focus on the application of LCA techniques to buildings, and on a range of building assessment and rating or certification issues, including the further development of appropriate tools. Over the years, the Athena project has involved a broad alliance of university, government, manufacturing and consultant interests, and most of the Institute's work is done through contracts with a diverse group of research organizations and individuals. As a result, the Institute's reports reflect the combined talents of architects, economists, scientists, engineers and environmentalists in universities, government, manufacturing industries and private practice.

The Institute is currently leading the US LCI Database Project under contract to the US National Renewable Energy Laboratory. As discussed in Section 4, this is a major initiative with a combination of public and private sector funding to develop publicly available life cycle environmental data for commonly used products and processes.

3. THE STATE OF THE LCA ART

Dr. Greg Norris, a close associate of the Athena Institute, recently presented a paper on the future of LCA. [Norris, 2002] Dr. Norris is one of the world's leading authorities on LCA and is intimately involved in international LCA developments. With his permission, I have borrowed heavily from his paper in order to provide a thorough up-date on the state of the art.

Dr. Norris cites the following four main areas of activity that deserve highlighting:

1) a burgeoning of efforts at the national level to develop transparent and publicly available LCI databases;
2) the UNEP/SETAC Life Cycle Initiative;
3) greater academic capability and involvement; and
4) increasing momentum behind major applications and users of LCA.

3.1 Public Database Development

In a growing number of countries, there are national projects planned, underway, or already completed, whose purpose is to develop publicly available LCI data for common materials, energy carriers, energy use and electricity generation. Such projects exist in Japan, China, Chinese Taipei, Korea, India, Australia, Switzerland, Germany, Italy, Canada, and the USA. Each of these projects is described, with citations to documents and websites, in a paper presented by Dr. Norris in Tokyo in December 2001, which is available for download at www.sylvatica.com/unepsumm.htm .

This development is important for LCA for a number of reasons. First of all, without high quality, transparent LCI data there can be no high quality, transparent LCAs. A major driver of the cost of LCAs is data collection, and public databases addressing basic, commonly-occurring processes in life cycles therefore go a long way to reducing the cost of all LCAs. Their use also increases the consistency among LCAs and LCA-based comparisons. Their availability reduces the barrier to entry into LCA, broadening the base of academics and practitioners who have first-hand LCA experience and capability. As demonstrated by experience in Europe during the past two decades, the existence of publicly available data on core processes tends to increase the overall level of interest and activity in LCA, improving the market for consulting, tools, and specialized databases.

3.2 The UNEP/SETAC Life Cycle Initiative

This global initiative seeks to promote advances in consistency, practicality, credibility and availability of LCA-related information and resources. The initiative has three programs based on preliminary definition studies that emphasized information gathering about LCA stakeholders' needs and concerns, and resulted in detailed work plans for the programs.

- The **life cycle inventory** program is undertaking activities to promote access to, consistency among, and availability of LCI data. This includes facilitating database development in countries and regions now lacking LCI data, and promoting greater consensus on methodological issues on which ISO may be silent or insufficiently prescriptive. The Athena Institute is serving as Secretariat to this program and Dr. Norris is the Project Manager.
- The **life cycle impact assessment** (LCIA) program is working toward consensus and scientific validation of recommended practice on LCIA methodology, including the development and dissemination of related models and data to support the recommended practice methods.
- The **life cycle management** program aims to characterize and disseminate information concerning the practical application of life cycle methods in industry, and the integration of LCA into management, accounting, and decision making systems. Rather than attempt to define "recommended practice" in the LCM arena, this program will aim to communicate practices that are working and lessons learned in Life Cycle Management.

Up-to-date information on the Life Cycle Initiative may be found at the UNEP website: www.uneptie.org/pc/sustain/lca/lca.htm.

3.3 Increased Academic Capability and Involvement

The past five years have seen considerable growth of academic involvement in LCA. While Europe has enjoyed a significant level of academic expertise and involvement in LCA since the 1970's, this has not been the case everywhere. In North America, for example, LCA has until recently been strictly the purview of consulting firms. Increasing academic involvement in LCA should bring a number of benefits to LCA practice, including methodological advances and a steady growth in LCA capacity in the form of knowledgeable data users and trained practitioners.

Three peer-reviewed journals regularly publish a high level of LCA content, including methods advancement and discussion as well as results of case studies:

- International Journal of LCA: http://www.ecomed.de/journals/lca/welcome.htm
- Journal of Industrial Ecology: http://mitpress.mit.edu/journal-home.tcl?issn=10881980
- Journal of Cleaner Production: http://www.elsevier.nl/locate/jclepro

3.4 Momentum Increase Among Major Applications and Users

There are a number of major application areas for LCA information, the growth of which will increase the demand for this information and will further increase the visibility of LCA. These areas include Environmental Product Declarations (EPDs) at the national and international level, Product Policy initiatives, especially in the European Union, and the development of decision support tools that use LCI data or draw upon LCA information.

EPDs, also known as ISO Type III Environmental Declarations, are intended to provide easily accessible, quality-assured and comparable information regarding the environmental performance of products and services. They are used in a growing number of countries, and the European Commission is considering the development of a Europe-wide Type III EPD framework. Already, some countries require that an EPD accompany imported products, and I think we can expect to eventually see a more widespread adoption of that policy. As a result, countries that fail to develop national databases, and to thereby support the individual data development efforts of their export industries, may find themselves at a serious competitive disadvantage.

The ISO 14025 Technical Report provides guidance, principles and protocols on EPDs. Information about the rapidly evolving field of EPDs can also be found at the website of GEDNet, an international non-profit association of Type III EPD organizations and practitioners. The purpose of GEDNet is to encourage information exchange between parties developing or undertaking Type III EPD programs, and to discuss key issues in developing such programs.
See: http://www.environdec.com/gednet/info.html.

On the policy front, the European Commission adopted a "Green Paper" on Integrated Product Policy (IPP) in February 2001, with the objective of launching a debate on the role of IPP and possible measures that could be taken on a European Union level. IPP is seen as a facilitative, rather than regulatory, policy approach that seeks to reduce the life cycle environmental impacts of products by focusing on three key decision points: environmental design of products; informed consumer choice; and the "polluter pays principal", or "getting the prices right." The first two elements, eco-design and informed consumer choice, clearly draw directly upon LCA.
See: http://europa.eu.int/comm/environment/ipp.

Finally, the development of design or decision-support tools is a third major application area for LCA information. One important example area is the environmental design of buildings, discussed in more detail in Section 5. Another important application of LCA is in the field of solid waste management. In these and other fields, the challenge is to develop field-specific design tools that make LCA data readily usable by non-LCA specialists facing specific decision problems.

4. THE US LCI DATABASE PROJECT

The US LCI Database Project is a public/private research partnership to develop and make available LCI data for commonly used products and processes. The underlying intents are to support cost-effective LCA work by others; to facilitate the development of environmentally-oriented decision support systems and tools; to provide regional benchmark data for assessing company, plant or new technology data; and to provide a firm foundation for subsequent LCA tasks such as life cycle impact assessment.

The project was conceived as a three-phase effort: *Phase I* was an intensive initiation and planning phase; *Phase II* involves basic data collection, analysis and review; and the third phase will involve ongoing data dissemination, database expansion, and maintenance.

Phase I was undertaken by the Athena Institute in association with Franklin Associates Limited and Sylvatica, with funding through the National Renewable Energy Laboratory (NREL) from the US Department of Energy, the General Services Administration, and the US Naval Facilities Engineering Command. The Athena Institute and its associates are now in the second year of Phase II of the project, with funding provided by a combination of these and other public sources, as well as private sources such as the Vehicle Recycling Partnership and the American Plastics Council.

The objective of Phase I was to develop a research protocol and establish research parameters including products, processes, data categories and data quality. In LCA parlance, Phase I was the goal and scope definition step. An advisory group was formed with 45 representatives of manufacturing, data user, government and non-government interests, as well as LCA experts. A workshop was held to discuss issues and develop a Phase I work plan. The workshop participants agreed that the goal of the project was not to carry out full product LCIs, but rather to make the creation of such LCIs easier while reducing the level of data inconsistency and incompatibility that currently plagues the LCA field in general.

It was also generally agreed that the data would be developed and made available as a set of modules that quantify the environmental burdens of common unit processes encountered during product manufacture, use, and disposal. The intent was to make it possible for relatively knowledgeable users to readily access, combine and augment the modules to develop more complex LCIs or full LCAs.

Since we do not know in advance precisely how or why individual database modules will be used, we had to develop the research protocol on the assumption that potential uses of the data would dictate the most stringent requirements in terms of data categories, transparency, review and other factors that are normally determined by the starting goal and scope statement of a study. In general, that meant assuming the data will be used in full LCAs for the purpose of making public comparative assertions.

It was decided that individual data modules should be developed in Phase II for the following:

- common energy combustion and pre-combustion processes, including transportation and electricity generation;
- basic cradle-to-gate manufacturing processes for a wide range of commonly used materials and intermediate products;
- transformations (stamping, molding, etc.) and finishing operations (painting, welding, etc.); and
- end-of-life processes such as composting, baling, incineration, etc.

The project is focusing on data modules that can be combined and used in more complete LCAs. For example, data modules for electricity generation cover the mix of energy forms used, efficiency factors, line losses and generating plant effects in defined grids, with the pre-combustion effects associated with the energy forms provided in separate modules. Similarly, the LCI for a specific product need only specify the amount of transportation required by mode. Common modules then provide the basic transportation energy use factors and direct combustion emissions, with other modules providing the pre-combustion effects, as in the electricity generation case. Still other modules will provide data on generic production effects for a range of commonly used input materials and processes. For example, there will be modules dealing with basic steel and aluminum production, lumber and board products, a range of petrochemical feedstocks, and so on, all reflecting average or typical production practices.

The use of common data modules allows those doing LCAs of specific products to focus on the elements that are unique to the specific plant or process. Figure 1, below, illustrates the situation for two flooring manufacturers who would add their own in-plant and use-phase data to the common elements like transportation or basic petrochemical production. The result is a much fairer comparison at greatly reduced costs for each manufacturer. The costs will be especially affected by the fact that suppliers will no longer have to trace all of the important process inputs back through the entire supply chain.

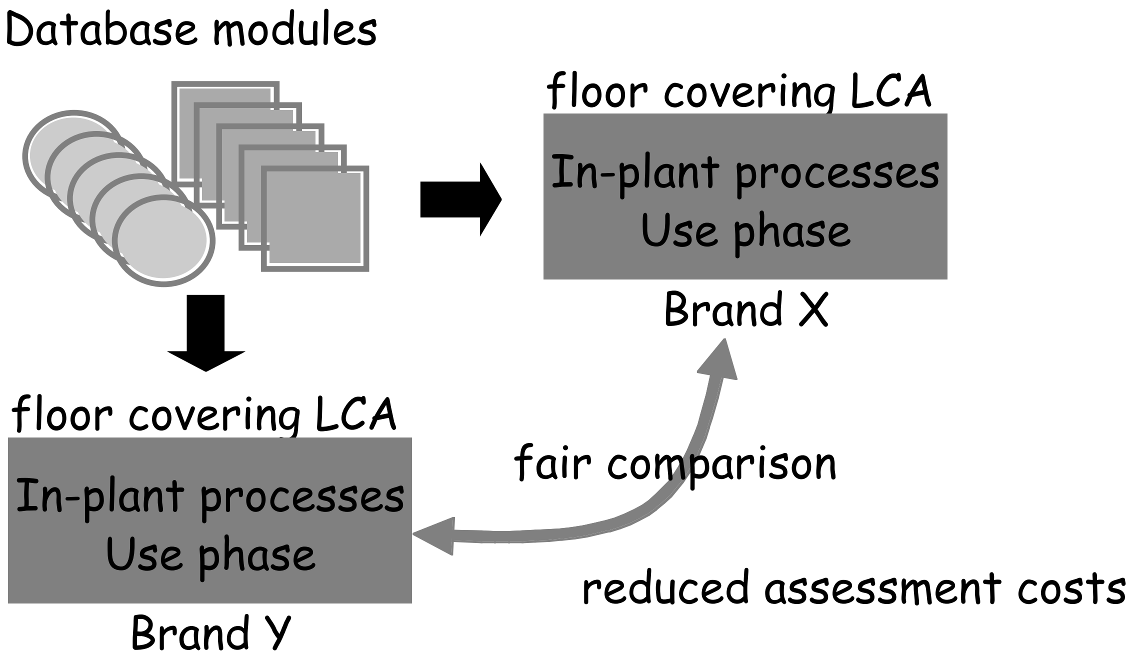

Figure 1 Illustration of the use of LCI data modules for supplier-specific LCAs

During Phase I, NREL committed to serve as the data repository and access agency, and to take responsibility for long term database maintenance, updating, and expansion. NREL also established a project web site <http://www.nrel.gov/lci/> to ensure transparency from the outset and encourage participation from any interested parties. All key working documents, the research protocol and the final Phase I report have been posted to that site, which also has provision for receiving comments on specific documents or the process in general.

Currently the web site contains about 50 data modules covering the following products and processes:

- primary fuel production;
- primary fuel combustion;
- electricity generation;
- transportation;
- transformation processes (e.g., aluminum casting);
- wood products; and
- agricultural products.

Additional modules currently under study or planned for the near future include more wood products, steel, aluminum, plastic polymers and various mining or quarrying activities (e.g., limestone, salt, aggregates).

5. THE ATHENA *ENVIRONMENTAL IMPACT ESTIMATOR*

From the Athena Institute's perspective, this kind of national database is essential if we are to continue to expand the geographic and material scope of our own software tool, the *Environmental Impact Estimator*.

We developed the *Estimator* to make it possible for architects, engineers and researchers to assess the environmental implications of building designs and material choices at an early stage in the project delivery process. A sizeable portion of the initial environmental footprint of a building is locked in at the very early conceptual stage of design, when basic structural decisions are often made — decisions that may never be revisited. Indeed, key decisions of this type may even be made in the design competition or during that first lunch when the architect and developer talk concept and make preliminary 'back-of-the-napkin' sketches. We believe it essential that objective, quantified information — LCA information — be brought to bear on decisions as early as possible, and that means providing reliable tools that allow a design team to focus on the design issues without having to find and interpret basic environmental data.

The *Impact Estimator* was therefore conceived as an LCA-based decision support tool focused at the level of whole buildings, or complete building assemblies (walls, floors and roofs, for example). It applies to industrial, institutional, office, and residential buildings and captures the systems implications of product selections related to a building's structure and envelope, taking into account the environmental effects of the following:

- material manufacturing, including resource extraction and recycled content;
- related transportation;
- on-site construction;
- regional variation in energy use, transportation and other factors;
- building type and assumed lifespan, which can be varied to allow users to assess relative durability effects;
- maintenance, repair and replacement effects, distinguishing between owner-occupied and rental facilities where relevant; and
- demolition and disposal.

If an energy simulation has been completed for a design, the estimated annual operating energy use by type can be entered through a simple dialogue box; the *Estimator* will then take account of operating energy emissions and pre-combustion effects (i.e., the energy and emissions associated with making and moving energy). It will also let the user compare life cycle embodied energy use to operating energy use.

A conceptual building design is entered in the tool using preset building assembly dialogues. The user can then instantly see the cradle-to-grave, region-specific implications of a design in terms of a detailed list of flows from and to nature (inventory results) as well as the following summary measures:

- embodied primary energy use;
- global warming potential;
- solid waste emissions;
- pollutants to air;
- pollutants to water; and
- natural resource use.

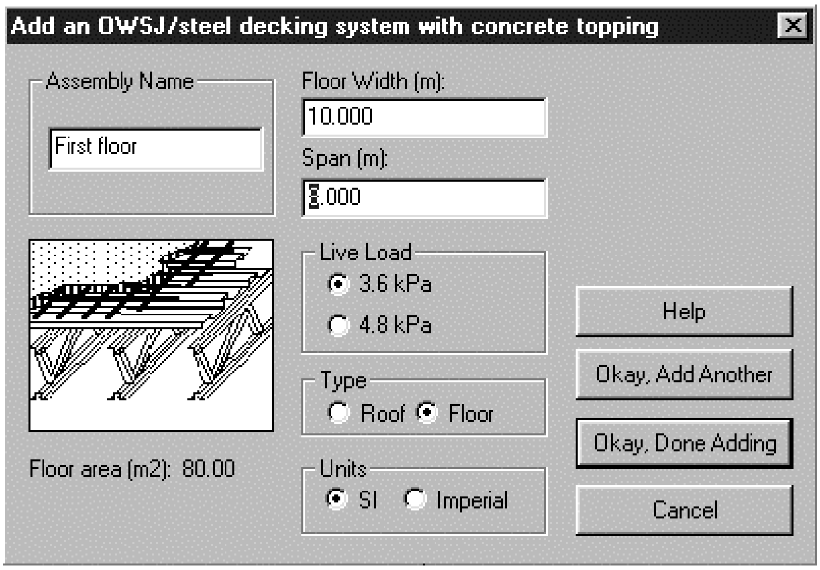

Figure 2 Typical dialogue box for entering designs

As design data is entered using the assembly dialogues, the software builds a tree to help track entries (Figure 3). The tree can also display, in value or percentage terms, any one of the above summary measures. This enables the user to track the effects of each assembly addition as it is made, or to quickly pinpoint which one is causing a particular environmental effect.

Results from an individual design can be seen in summary tables and graphs by assembly group and by life cycle stage (Figure 4). Detailed tables and graphs show individual energy use by type or form of energy, and emissions by individual substance for both the assembly group and life cycle stage breakouts. A comparison dialogue can be used to make side-by-side comparisons of as many as five alternative designs, for any one or all of the summary measures. The comparisons can be among up to five variations on a base case, or can include completely separate projects on a per unit of floor space basis. Similar projects with different floor areas can be compared on a unit floor area basis. In addition, all of the summary measures can be viewed on one graph by selecting a baseline case and normalizing to that baseline.

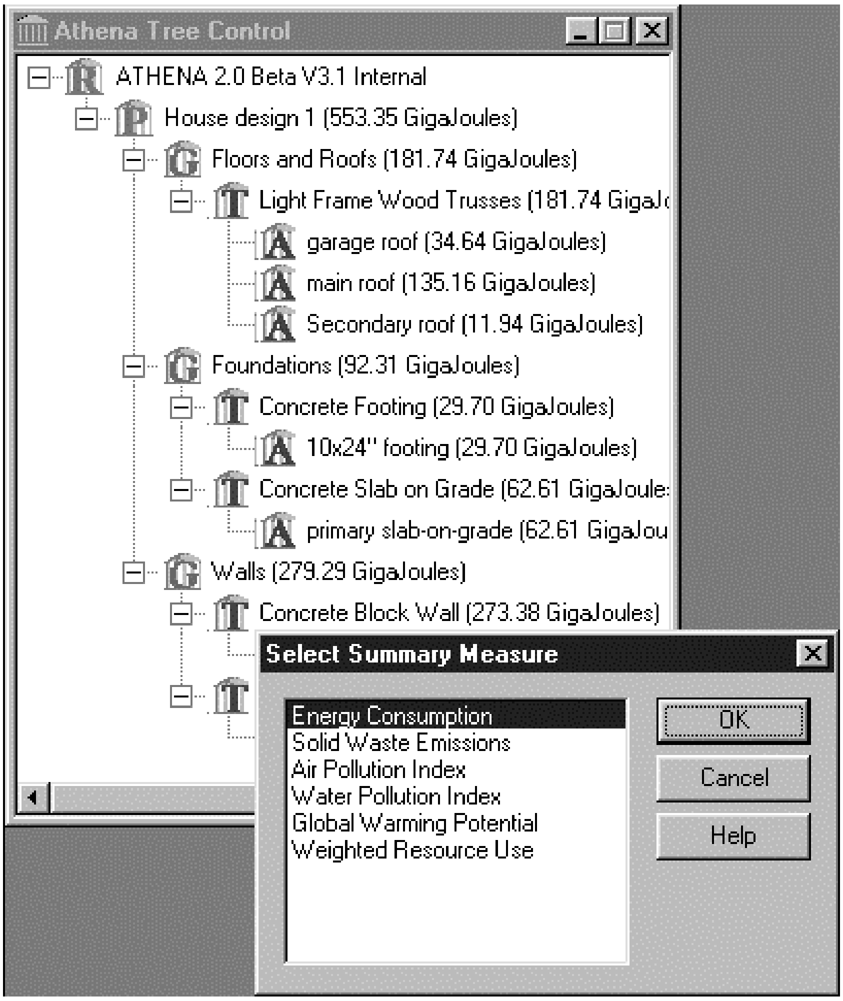

Figure 3 Athena tree control with summary measure choice

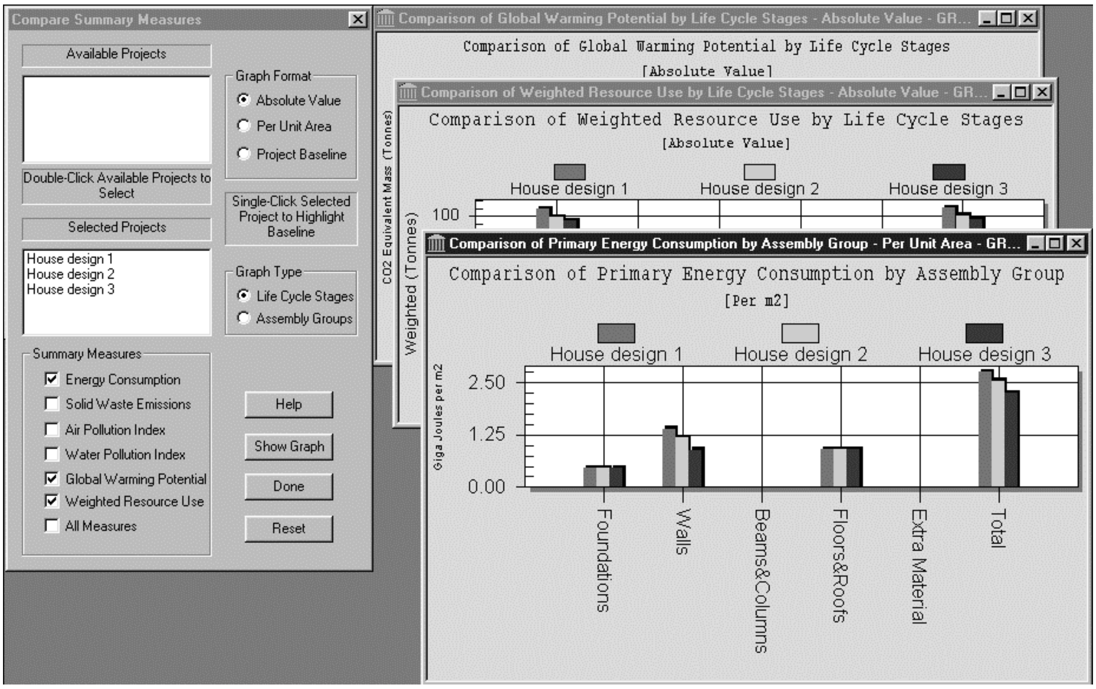

Figure 4 Results comparison

For more information, and to download a demonstration version of the *Environmental Impact Estimator*, please visit the Institute's web site, www.athenaSMI.ca.

6. CONCLUDING COMMENTS

The central theme in all of this is information: the development of the best possible data and its dissemination to those who make or influence decisions about design, purchasing or environmental policies. Good data also allows industry to exercise a greater degree of control, or at least to argue a case to best effect, and it allows governments to assess and understand environmental issues and to then develop appropriate policy responses. In the future, data in the form of environmental declarations or labels may be an essential part of an export package, and those who fail to lay the groundwork early will be at a serious competitive disadvantage.

Putting good data to use requires reliable tools. The Athena Institute is not alone as a developer of LCA-based decision support tools aimed at the building design community; there are comparable tools in use or under development in the Netherlands, the United Kingdom and Australia. These whole-building oriented tools are complementary to product-oriented tools such as BEES, developed by the U.S. National Institute of Standards and Technology. A tool such as the Athena *Environmental Impact Estimator* is used in the early stages of design, while BEES is more relevant in the specification and procurement stages. These tools, in turn, are or should be used to support whole building assessment systems such as BREEAM, LEED, Green Globes and, of course, the Green Building Challenge Tool.

Overarching all of this is the fact that the concept of sustainability — however you chose to define that word — is becoming embedded as a fundamental way of thinking and perceiving our world and actions. Nowhere is that more true than in the case of the built environment. Political shifts may alter the priorities, and may even temporarily suppress the sustainability movement in some countries. Humankind, however, is not going to back away from a fundamental concern for the environment, or fail to do whatever is necessary to solve, or at least redress, critical environmental problems like climate change. Our future, and the future of our children, must rest on a firm and stable tripod of economic, social and environmental consciousness.

REFERENCES

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