2009 BFRL Project Description

Project Title: Metrics and Tools for Sustainable Building

9/4/08

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BFRL Program: Healthy and Sustainable Buildings

Objective: To develop, integrate, and apply measurement science assessing the sustainability performance of energy technologies and systems in an integrated building design and operation context.

Problem:

What is the problem? The OSTP/NSTC buildings technology R&D subcommittee has concluded that, to enable a transformation to performance-based design and operation of the Nation's buildings, next-generation metrics, methods, and tools must be developed that permit a building's sustainability to be measured across the dimensions of performance, scale, and time. In its November 2007 report, *A National Green Building Research Agenda*, the U.S. Green Building Council identifies as a key barrier to widespread adoption of green building technologies, "the question of how much benefit is obtained and at what cost," citing the need for basic research to "develop protocols for measurement and an integrated database of measured performance at various project scales." In its 2008 *Energy Efficiency in Buildings* report, the World Business Council for Sustainable Development calls for carbon measurement and verification to make sure policies and regulations (including building codes) are effective and support market measures such as trading. Finally, noting the critical importance of environmental challenges in addition to energy and climate change, the North American Commission for Environmental Cooperation recommends in its green building roadmap that performance metrics across a full range of environmental impacts be developed and integrated.

Why is it hard to solve? Buildings are complex systems of interacting subsystems with energy performance that varies with technology, level of design integration, geographical region, and time. Assessing building sustainability performance adds more complexity due to the wide range of potential environmental, health, and economic impacts. Furthermore, an integrated portfolio of sustainability performance measurements that captures system complexities and interactions seen in a real building requires a multidisciplinary collaboration among mechanical engineers, building designers and owners, environmental scientists, and economists.

How is it solved today, and by whom? The U.S. Green Building Council has a major "LCA[1] into LEED[2]" effort that takes a "bottom-up" approach to life-cycle assessment, but it neither addresses building energy technologies nor the integrated design context. "Top-down" LCA approaches are promising, but current, detailed data are inaccessible and the approach has not been applied to the building industry for any country. Even if other countries were interested in applying top-down approaches, their inferior national databases preclude application at the building scale. Business cases for sustainability investments are anecdotal at best. None of these efforts address the underlying need for integrated measurement science permitting traceable sustainability assessment of building energy technologies as installed in a building.

Why NIST? This project supports the BFRL core competence in measurement science for building energy technologies and is aligned with the BFRL strategic priority, Measurement Science for Net Zero Energy, High-Performance Buildings. This research fully supports the measurement science needs that will be articulated in a forthcoming NSTC report. Finally, BFRL is a world leader in sustainability performance measurement.

Approach:

What is the new technical idea? The new idea is to address building sustainability measurement in a holistic, integrated manner that considers complex interactions among building energy technologies and systems across dimensions of performance, scale, and time. Energy performance measurements being developed under other projects within this program will be translated into life-cycle environmental and economic performance measurements. At the technology scale, reliable energy efficiency measurements being developed for emerging building energy technologies will be translated into environmental efficiency, or "eco-efficiency," metrics highlighting the strengths and weaknesses in new technology sustainability performance. At the building scale, building energy use reductions enabled by in situ energy monitoring systems and embedded intelligence will be translated into sustainability measurements at the system and whole building scales to enable investment decisions. In consultation with U.S. Department of Energy (DOE) building energy simulation experts, simulation tools will be applied to such technology- and building-scale measurements in an integrated design context. In this way, the new measurement systems being developed under this BFRL program will be integrated to provide reliable data for sustainability performance measurements of building energy technologies as installed. These sustainability performance measurements will be embodied in a decision framework including eco-efficiency metrics, carbon trading metrics, and reporting tools designed to deliver the most effective support to building industry decision makers.

Why can we succeed now? There is widespread public interest in sustainability and recognition that energy efficiency is a highly desirable National goal. Yet the building industry is confused as to the very definition of sustainability and is demanding performance-based, traceable measurements to help define and measure what makes a building sustainable. Success is likely at this time as the result of recent extensions in traceable measurement science within BFRL—for both energy and environmental performance measurement—providing the heretofore

[1] LCA: Life Cycle Assessment
[2] LEED: Leadership in Energy and Environmental Design

missing links enabling integration and translation of technology measurements into building sustainability performance measurements. Furthermore, new BFRL staff with expertise in developing decision frameworks for cost-effective emissions trading will permit this emerging dimension of economic sustainability, with its potentially important energy market consequences, to be included in the measurement framework for the buildings sector.

What is the research plan? In the context of providing a measurement science portfolio enabling Net Zero Energy, high-performance buildings, three major research activities will be conducted in parallel. They consist of developing databases, measurement protocols, and decision support tools.

Databases. Baseline databases enabling sustainability performance assessment for a range of energy technologies and systems will be compiled. These will include energy, environmental, and economic performance measurements. Practical "bottom-up" data protocols will be developed in cooperation with the BFRL Building Environment Division for reporting energy performance for emerging building technologies, in situ energy monitoring systems, and embedded intelligence. Decision makers at the Commerce Bureau of Economic Analysis, which maintains the world-class U.S. economic I/O database, will systematically be engaged to seek NIST access to more detailed "top-down" I/O data for the building industry, permitting development of building-specific environmental I/O data. Finally, data protocols will be developed enabling sustainability assessment of the implications of various carbon trading scenarios on major building investment decisions.

Measurement Protocols. To enable consistent, meaningful comparisons of sustainability performance in an integrated design context, standard measurement protocols will be developed. These will model how to translate technology-based energy performance data into building-specific measurements through use of building simulation tools. A "hybrid" environmental performance measurement protocol based on these energy measurements will synthesize bottom-up and top-down data, permitting development of building-scale environmental assessments, including energy efficiency and carbon footprint metrics. Life-cycle costing frameworks will be expanded to consider the business implications of energy efficiency as well as carbon and other emissions trading scenarios. The focus will be on developing an overarching measurement framework that integrates these sustainability performance dimensions at the building scale to produce sustainability metrics (e.g., energy efficiency, carbon efficiency, and eco-efficiency ratios) keyed to alternative energy technologies and system designs.

Decision Support Tools. In cooperation with the Council for Tall Buildings and Urban Habitat (CTBUH) and other industry leaders (especially architects and engineers who design buildings), BFRL will convene a workshop of key building industry stakeholders to better understand their needs for sustainability performance measurement and to learn how best to deliver BFRL measurements to meet these needs. The results of the workshop will be reflected in the overarching measurement framework and be used to direct reporting formats (e.g., scorecards, eco-efficiency ratios) for web-based tool development.

USDA Office of Energy Policy and New Uses, "Using BEES to Evaluate the Life-Cycle Environmental and Economic Performance of Biobased Products in Support of BioPreferred:" $550K/yr .

Recent Results:

Activities:

- Developed prototype of web-based sustainability performance measurement tool.

Outputs:

- Lippiatt, B., and Helgeson, J., "NIST BusiBEES Metrics and Tools for Green Buildings," *SB08: World Sustainable Building Conference*, Melbourne, Australia, September 2008.
- Suh, S., *Mapping Input-Output with BEES Life Cycle Flows*, University of Minnesota Final Report, NIST Contract NB860010-7-05927, August 2008.
- Sunder, S., Lippiatt, B., and Helgeson, J., "NIST Metrics and Tools for Tall and Green Buildings," *Tall and Green: Typology for a Sustainable Urban Future, CTBUH 8th World Congress*, Dubai, UAE, March 2008.
- Lippiatt, B., "Evaluating Sustainability Using Standard Approaches: The BEES Tool," *Journal of ASTM International (JAI)*, Vol. 5, No. 1, 2008.
- Gloria, T., Lippiatt, B., Cooper, J., "Life Cycle Impact Assessment Weights to Support Environmentally Preferable Purchasing in the United States," *Environmental Science and Technology*, Vol. 41, No. 21, 2007.
- Lippiatt, B., *BEES 4.0: Building for Environmental and Economic Sustainability*, NISTIR 7423, August 2007 (includes software).

Outcome:

- Since October 2007, BEES material ranks first in at least three Top 10 lists of "most requested" BFRL web activity: web pages, downloads, and search terms, representing 35%, 48%, and 31% of BFRL Top 10 activity, respectively.

Standards and Codes:

Participation in ASTM E06.71, Sustainability Subcommittee