Version 1.1 July 30, 2002

Synopsis
Spring 2002 Performance Metrics Workshop for High-Performance Buildings
Yarrow Hotel, Park City, Utah
May 20-22, 2002

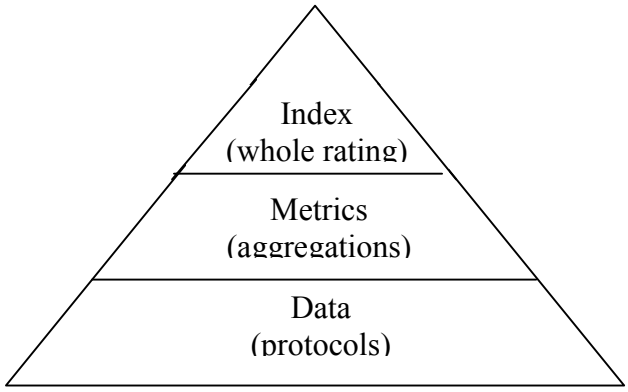
Purpose

The purpose of the Spring 2002 Performance Metrics Workshop was to continue the progress begun during the Fall 2001 Performance Metrics Workshop. Intended outcomes were to: 1) define a vision for the finished product of the Performance Metrics effort; 2) refine, prioritize, and begin to populate the Performance Metrics database; and 3) identify research needs and starting points for gathering/creating the priority data.

Background

The High-Performance Commercial Buildings Technology Roadmap[1] identified a need to establish definitions and metrics for high performance buildings – defining *what* to measure and *how* to measure it. To continue addressing this need, the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) held a two-day Commercial Buildings Performance Metrics Workshop to discuss the issues. Twenty-two experts in building energy performance, environmental issues, worker productivity, psychological aspects of the built environment, and building economics attended the workshop. Those attending the workshop represented both private- and public-sector entities in the United States and Canada.

A similar workshop was held in November 2001[2]. In this Fall 2001 Workshop, the group discussed the purpose of performance metrics and divided the universe of possible metrics into five areas: resource consumption and environmental loadings from energy use, resource consumption and environmental loadings from other building-related activities, human health and other factors, building service quality, and economics. During this workshop, participants began to conceptualize a "container" or "vessel" for collecting the many different kinds of data on those five areas. The structure for the performance metrics "container" was a pyramid.



[1] The Roadmap is posted on http://www.eren.doe.gov/buildings/commercial_roadmap/
[2] The Fall 2001 Workshop synopsis is posted on http://www.nrel.gov/buildings/highperformance/metrics/

Data or protocols populate the bottom layer, combinations of data or metrics occupy the middle layer, and indices or aggregations of metrics are top layer. The group decided the database must be comprehensive, flexible, adaptable, modular, accurate, and useful, and should continue to evolve as future needs unfold.

Synopsis of Discussion

The Spring 2002 Workshop began with a discussion of who the potential users of the database would be and what they might need in terms of content and user interface. This led the group to list major challenges that the project will face: 1) there will be a broad range of prospective users with different interests, 2) the data will have to be accurate and reliable, and such data might not be available, and 3) the database will have to be comprehensive and very broad to meet the wide variety of needs.

Next, the group discussed what the finished product of the Performance Metrics project should be, and how complete the product would have to be before it was potentially useful. After considerable discussion, the group concluded that this project should focus its effort on populating the bottom two layers of pyramid – developing metrics and the data needed to support the metrics; it is beyond the scope of this project to address the top layer of the pyramid. That would require an understanding of the interrelationships among many variables and application of value judgments—combining and weighting the various metrics to make meaningful indices. Most in the group agreed that before we could attempt to go that far, we need to populate the bottom two layers adequately or the value judgments at the top would be meaningless. Further, many agreed that other organizations might be more appropriate for developing the top-level indices.

The group advised the project to work on several levels simultaneously. Work groups have already begun to populate the database with available data and to identify gaps. Using this approach, the project will identify metrics that are difficult to measure and encourage research in these areas. The group agreed that the database needs a framework or structure to organize the data and metrics that the groups are developing. A small group was assigned to preparing a draft of this framework.

There was a discussion about the tension between "purity," the accuracy and adequacy of the data, and "pragmatism," the importance of developing something that will be useful and timely. Since this project is intended to further the *science* of performance measurement, the group agreed to emphasize purity, while still keeping the practical needs of users in mind. The group discussed ways to make the database more useful. For example, it should treat new building design as well as existing buildings and deal with design phases. A long-term goal for the database might be to add a "wizard" option to help users identify targets of opportunity for their buildings. The group seemed to agree that a common language and glossary of terms should be created for this new database to prevent miscommunication.

There was some discussion about the need to create a working model to show users how the finished product could work with a user interface providing access to the database and metrics. One participant commented, "Funders want to see results." Most agreed, however, that this type of model would not be the first priority for the project.

Following this discussion, Paul Torcellini gave a presentation on the database NREL has designed based on discussion at the Fall 2001 Workshop. Paul showed attendees how to use the database to enter metrics. The group discussed the structure of the database and agreed that they would test it to see if they liked the structure or if a new structure should be created. The database currently lacks a user-friendly front end – it does not provide different avenues of entry for different users, and does not contain instructions for users. When it has been tested, the database will serve as a default metrics collection "vessel" and will be posted on the Internet to tap into the Web-based collective mind to see what additional metrics might be available.

Two additional presentations were given to the group: Diane Hartley presented for the General Services Administration (GSA) and Rob Hitchcock represented performance metrics work being done at Lawrence Berkeley National Laboratory.

Hartley presented GSA's "scorecard" approach to measuring building performance. The scorecard is a research tool used for business strategy and GSA is testing this design hypothesis for performance metrics for buildings. In keeping with GSA's mission, the primary focus of this scorecard system is "Design versus Workplace Making." This new system will focus on the interior of a building rather than on construction since most previous work has emphasized construction and work on interior aspects lags behind. GSA is supporting "living laboratories" at federal agencies and facilities to conduct its research. GSA also introduced an interesting concept called "the new office versus the new zoo" to explore spatial and other factors that affect human behavior and production to create a synergy among people, process, and place.

Hitchcock gave a "working lunch" presentation about his work with performance metrics and the database system he created for capturing this information. This project is just getting underway and there is a need for collaboration between the NREL Performance Metrics project and the LBNL project (See powerpoints – Rob has not sent these out yet.)

Group Reports

Much of the workshop was spent in work groups to address major issues: resource consumption and environmental loadings for energy and for other building-related activities, human factors, service quality, and economics. Brief summaries of the group discussions are presented below.

Resource Consumption and Environmental Loadings – Energy Consumption

Rob Hitchcock (group leader), Ron Judkoff, Mark Case, Michael Brambley

This group began by identifying key metrics of concern. They decided that they needed to include site, source, and energy cost for each metric. They also agreed to use British units for convenience to represent general quantities – for example, ft2 and occupant are generic normalizing factors and normalizing factors for time periods are year, month, or hour. Another important consideration is building characteristics so that we can filter and compare multiple buildings. The group developed the following table to summarize identified metrics.

Metric	Site	Source	Cost
Level I Metrics			
Normalized Whole Building Energy Use Units: kBtu/ft2-yr By energy type (including source)	X	X	$/ft2-yr
Normalized Atmospheric Emissions Units: lbs of emissions/ft2-yr By emission type (CO2, SOx, NOx, Mercury, Particulates)	X	X	X
Normalized Water Consumption Units: ft3/ft2-yr By end use (e.g., cooling towers, boiler blow down)	X	X	X
Normalized Water Pollution Units: ft3/ft2-yr By end pollution element/impact	X	X	X
Peak Demand Units: kBtu/hr-ft2 Annual, Daily, and Design Peak By fuel type	X	X	$/ft2-yr
Level II Metrics			
Normalized Heating Energy Use Units: kBtu/ft2-yr By energy type (including source)	X	X	X
Normalized Cooling Energy Use Units: kBtu/ft2-yr By energy type (including source)	X	X	X
Normalized Lighting Energy Use Units: kBtu/ft2-yr By energy type (including source)	X	X	X
Normalized Ventilation Energy Use Units: kBtu/ft2-yr By energy type (including source)	X	X	X
Normalized Process Loads Energy Use Units: kBtu/ft2-yr By energy type (including source)	X	X	X
Normalized Plug Loads Energy Use Units: kBtu/ft2-yr By energy type (including source)	X	X	X

Heating Peak Demand Units: kBtu/hr-ft2 By energy type (including source)	X	X	X
Cooling Peak Demand Units: kBtu/hr-ft2 By energy type (including source)	X	X	X
Level III			
System and sub-system effectiveness indicators (*End Use* Lights (FC) W/ft2 FC/W on work plane W/ft2/unoccupied hour *HVAC* KW/ton W/CFM Equipment efficiency Tons/ft2 CFM/ft2 BTU/ft2 Etc. *Plug/other* Desegregated large load types Process loads/productivity)	X	X	X

The group also discussed data required to support these metrics.

Level I

This section identifies the data requirements for calculating Level I metrics, and for filtering subsets of comparable buildings in a database.

Filtering Variables

Filtering variables are those that can be used to filter subsets of comparable buildings in a database.

Building Description

- Building Type and Use
- Building Size by Use
  - Gross Floor Area
  - Conditioned Floor Area
  - Stories
- Location
  - Weather
  - Utility Service Area
  - Air Shed
  - Water Shed
- HVAC System Type

- Special Design Features
  - Daylit
  - Naturally ventilated
  - etc.
- Rented vs. Owner Occupied

Metric Calculation Variables

Metric calculation variables are those that are required to calculate identified metrics.

Building Description

- Building Size
  - Gross Floor Area
  - Conditioned Floor Area
- Location
  - Weather
- Energy Rate Structure by Fuel Type
- Unit of Productivity
- Occupancy
  - Occupants
  - Occupied Hours/Time

Energy

- Energy Use by Fuel Type at Site and Source
- Peak Demand by Fuel Type at Site and Source

Atmospheric Emissions

- Pounds of Emissions by Pollutant Type at Site and Source

Water

- Consumption at Site and Source
- Pollutant quantities at Site and Source (need help)

Level II

This section identifies the data requirements for calculating Level II metrics, and for filtering subsets of comparable buildings in a database. Only those variables in addition to the ones identified in Level I are included here.

Filtering Variables

Filtering variables are those that can be used to filter subsets of comparable buildings in a database.

Metric Calculation Variables

Metric calculation variables are those that are required to calculate identified metrics.

Energy

- Sub-metered Energy Use by End Use by Fuel Type at Site and Source
- Sub-metered Peak Demand by End Use Fuel Type at Site and Source

Level III

This section identifies the data requirements for analysis, design, operations, and diagnostics. Only those variables in addition to the ones identified in Levels I and II are included here.

Metric Calculation Variables
Metric calculation variables are those that are required to calculate identified metrics.
Building Description

- Adequate description to support energy simulation.

Resource Consumption and Environmental Loading – Other Building-Related Factors

Sandy Mendler (leader), Joel Ann Todd, Wayne Trusty, Michael Deru

The group began its discussion by trying to define "high performance" in this category. One definition is a building that "gives back more than it takes." More specifically, a high-performance building 1) reduces or eliminates consumption of scarce resources over full life cycle of a building; 2) reduces environmental loadings to air, water, and land over the full life cycle; and 3) protects and restores the health of whole ecosystems.

Next, the group listed topic areas in which metrics are needed:
1) Metrics for reducing/eliminating consumption of scarce resources:

- land (forests, ag. land, wetlands)
- water (ground, surface)
- material resources/raw materials
- fossil fuels (will also be addressed by the energy group)
- biomass fuels (will this also be addressed by the energy group?)

2) Metrics for reducing environmental loadings

- global warming (primarily from materials transport since energy is separate)
- nutrification/ eutrophication
- ozone depletion
- acidification
- human health/toxic releases (to air, water, land)

3) Metrics for restoring/protecting ecosystems

This area is least well-developed. The AIA Committee on the Environment proposed a metric that is a good starting point. It reads:

> What percentage of the total site area acts as an on-site ecosystem? This may include landscaped open spaces, urban plazas, bioswales, vegetated rooftops, etc. that are predominantly self-maintaining, and accomplish the following at a minimum: stormwater filtration, groundwater recharge, and habitat for native plants and animals.

This group stressed the importance of an overall framework for the project and for the database. It suggested a framework that could include all of the groups' work, defining high performance buildings as those that:

1. Reduce and/or eliminate use of scarce materials
2. Reduce environmental loading over the full lifecycle
3. Protect and restore the health of whole ecosystems

4. Promote individual occupant health and well-being
5. Promote organizational occupant effectiveness
6. Support livable "high performance" communities
7. (The group did not include a factor on economics.)

Human Factors

Merle McBride (leader), Paul Torcellini, Judi Heerwagen

This group began by discussing the relationship of human factors metrics to service quality metrics and identified potential areas of overlap. The group identified three areas for development of metrics: occupant benefits, organizational effectiveness, and community connectivity. Metrics for individual and organizational factors are often similar. (Note: An asterisk [*] means that methods and procedures are available to collect data. Two asterisks [**] means data already available for these areas.)

1) Occupant benefits
   - Health – includes psychological health and well being, physical health, stress*, building-related illnesses (IAQ)*, ergonomics**, insurance claims*
   - Comfort – psychology of space such as color, view, privacy, daylight, form, texture, special perception, accessibility/way finding, spatial measures-proportion, connection to nature, ergonomic assessment, natural ventilation, light (glare)**, thermal comfort (% satisfied)**, olfactory, acoustics (surveys/measurements)**, vibrations
   - Productivity – personal control of area (windows and daylight), occupant amenities, daycare, cafeteria, workout rooms, coffee nooks, office plans (open vs. closed, workstations size and dimensions, overall density).

2) Organizational effectiveness
   - Organizational factors* -- managers/job assignment
   - BSC (balanced scorecard)
   - Human, business process, attrition, turnover, reputation/image
   - Community connectivity (services/health amenities)
   - Productivity/performance
   - Access to resources (human, technology) (amenities)
   - Motivation
   - Attention
   - Amenities
   - Social benefits (sense of community/social networks)

3) Community connectivity
   - Facility use/satisfaction with services
   - Dual function (reduces need to duplicate building)
   - Social benefits (sense of community/social networks)

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Service Quality

Bruce Hunn (group leader), Jim Hood, Ellen Franconi, Sheila Hayter, Dru Crawley

The Service Quality breakout group members defined *service quality* as how well a building serves its occupants to achieve the mission of the organization owning and/or occupying the building. Service quality is a measure of how well the building promotes organizational/occupant effectiveness (robustness). It is equally important to satisfy both the owner and the occupant. Service quality is related to building design, operation and maintenance, commissioning, and on-going use of the building.

Group members agreed that the focus of their discussion would be on building service quality at the organizational level. Group members felt that issues concerning the building's relationship to human health and productivity (building interior environment) was within the domain of the Human Factors breakout group. They also agreed that it is important to coordinate Service Quality group discussion with the Human Factors group to show how indoor environmental quality (IEQ) issues overlap Service Quality and Human Factors areas of concern.

The Service Quality stakeholders were identified as the:

- owner,
- organization occupying the building (tenant), and
- facility manager.

Each of these groups is concerned with different service quality issues. It is important that all of these concerns be identified and addressed.

Signs of service quality success are:

- The building supports worker productivity.
- The building can be reconfigured flexibly at low cost
- Reduced churn (the building is adaptable to minimize churn).
- A happy customer.
- A healthy customer (area of interest to the Human Factors group).
- A productive customer (area of interest to the Human Factors group).
- A repeat customer.
- A non-complaining customer (no power outages, maintain comfortable conditions, etc.)
- Minimized disruptions to customer operations (utility and services reliability)

Group members categorized Service Quality issues into three principle areas and several subcategories:

1) flexibility/adaptability
    a. turn over
    b. building/workspace architecture
    c. service/utility configuration
2) durability/reliability
3) safety/security

The table in Appendix D summarizes performance objectives, metrics, and data for each of these categories.

Discussion that followed the Service Quality Group's presentation to the Workshop attendees included the following:

- There should be an indicator within the durability/reliability category to represent the equipment that is known not to be functioning as it should be. What O&M measures should be completed but are not because of external factors such as limited staff or funds? One suggested method to measure these savings is the projected cost total of the deferred maintenance items.
- A high-performance building will minimize the number of service calls.
- Commissioning metrics may be established on Managers' budgets and/or expenses for "training", "test and balance services", "commissioning services", etc.
- Need to include metastudies in the work plan to survey companies in a region to find out why organizations moved from one facility to another. Possible reasons may be because the organization outgrew the space or the organization felt the worker comfort and health were adversely affected as a result of poor service quality.

It was recommended to investigate the work of other organizations. For example, GSA spends a considerable effort studying the reasons for churn and DOD is especially interested in the safety and security of their facilities.

Economics

Mike MacDonald (leader), Diane Hartley, David Hansen, Doug Brookman

Overall, the economics groups raised several issues that affect most, if not all, parts of any performance measuring system to be developed. These issues, with some highlights specific to economics, include:

- The tension / conflict between the higher level desire for flexibility and adaptability of any performance measurement system and the middle level development process that sometimes focuses on one part of the commercial market and also tends to ask for more detail rather than less — For the economics group, the concern relative to flexibility and adaptability is that performance measurement is potentially needed and could be developed for four basic (and possibly more) market cases:
    - New building design
    - Building purchase
    - Lease of a building or space
    - Existing buildings already in use

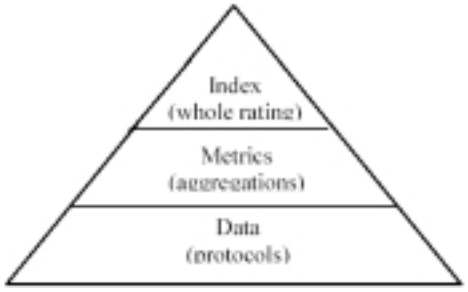
- Normalization of data is possibly the crux of all efforts to develop any building performance metrics tool or system, and the overall results so far have not

indicated a good understanding of data needs and methods for normalization, so normalization data and methods are a potential area of concern

- Although the metrics work overall has been divided into "spheres," there is overlap that must be dealt with at some time. Relative to any potential overlap, economics is quite pragmatic and economists would typically suggest that results from all the "spheres" should be monetized to allow quick, reliable, and most informative integration. Overlaps would typically have to be coordinated and any double counting eliminated in an overall economic representation of performance. For reference the spheres are:
    - Resource Consumption and Environmental Loadings — Energy Consumption
    - Resource Consumption and Environmental Loading — Other Building-Related Factors
    - Human Factors
    - Service Quality
    - Economics

- Building owners' economic interest can be viewed from both the level of individual buildings and also as a portfolio of buildings, and this dual level represents potentially one more division that may be of interest to potential users of performance metrics

The results from the economics group are arranged according to the pyramid structure that was conceptually described as part of the November 2001 performance metrics workshop as a "container" for the different pieces that feed into the metrics to be considered in defining or partially defining high performance buildings.



Input to the pyramid from the bottom comes from expert and reference sources, which includes both data needed to measure performance and data needed to normalize performance. Diane Hartley indicated that there is major work both in the past and ongoing in the areas of valuation and economic performance of real estate, and these sources should be reviewed and possibly tapped. Possible data and tool sources include: experts working with GSA, higher education experts, accounting firm experts, real estate industry experts, and fiduciary experts. Diane volunteered to try to summarize some of the main resources and possibly some results for the overall work and provide that summary to be posted on the metrics website. Given that this work is not done yet, there could be important modifications to what is presented below.

Building owners have two main perspectives on buildings: as an Investment or as a Resource. Owners with these two main perspectives approach building economics in fundamentally different ways, with overall performance probably being of more interest

initially to those who consider buildings as a resource. This distinction influences the data requirements.

Examples of data needed at the bottom of the pyramid include:

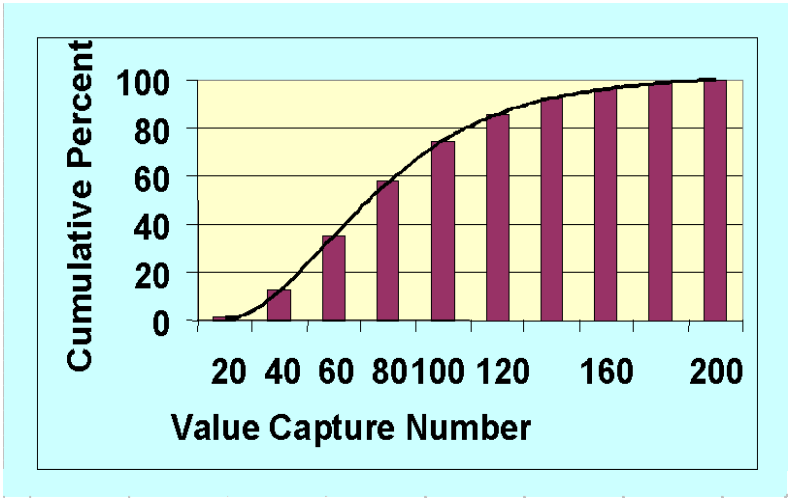
- Characteristics data are important relative to any normalization that may be needed. Unfortunately, without modeling and analysis to determine relative importance for normalization, informed judgment must be used to specify likely candidates for data needed for normalization. Examples of characteristics data expected to be important for normalization are:
    - Building type
    - Owner / occupant typologies, which could include recognition of the investment vs resource distinction mentioned above, and which also might include some of the factors mentioned below, such as investment model and corporate resource model
    - Asset value, mission / vision, and occupant objectives
    - Desired image factors
    - Floor area
    - Sources of funds and uses of funds
    - Investment model
    - Corporate resource model
    - Organizational objective model
    - Other models?
    - Historic structure issues?
    - Derived occupancy and use indicators, such as people per 1000 sq.ft., PCs per 1000 sq ft, and many others
- $$ data
    - Cost quantities for valuation (differ depending on market case)
    - Investment quantities
    - Value generated quantities
    - Other
- Other performance indicator data ? (others may be needed)

At the middle metrics level of the pyramid, both simple and model-based metrics may be needed.

- Simple Models
    - Already familiar, empirical indicators of performance such as % rented / % used / % rentable / % usable could form the basis of a simple metric determination
    - Cost options
        - Workplace cost per person
        - Ratio of workplace cost per person to total enterprise cost per person
    - Other simple metrics remain TBD
- More Complex Metrics Models

    - Possibly require Investment vs Resource segmentation
    - Economic Return / Investment Metrics
        - ROI, LCC, cash flow
        - Difficult to value metrics/factors from other spheres, e.g., space quality, well-being, may require adjustments to more standard ROI, LCC, or cash flow calculations
    - Investment model easier to quantify, so inversely,
    - Resource model is more difficult to quantify as many factors are considered (e.g., see second bullet following)
    - Balanced Scorecard
        - Simplify all data to some type of index of "Value Generated" in building to "Total Cost of Facility" (Value Capture)
        - Total cost, as example, might include major categories of: Real Estate, Human Resources, Information Technology
        - Cost factors must be balanced against: human capital, customer satisfaction, business/mission objectives
        - Time of data capture is major issue, and some segmentation may be required
- Portfolio ratings and/or metrics may be needed
- Valuation or adjustments of tough to monetize, but critical to consider, quantities from other spheres, e.g., space quality, may be necessary and critical to economic metrics, depending on relationships and integration of such factors in any final index or indexes at the top of the pyramid (high level rating of a facility)

At the top of the pyramid is where output index ratings are derived. When deriving a final index, the notion that a cumulative distribution can be used was presented.



In the economic sphere, if the metrics development can lead to one overall output from some type of balanced scorecard approach, the cumulative distribution of this output for a representative population of buildings could serve as the economic index or rating basis, with the specific percentile position of a specific building providing the ranking for a specific building.

Next Steps

The meeting concluded with a discussion of next steps. The group suggested the following:

1) A short description of the project is needed to provide a uniform message when we talk to people as potential partners.
2) Joel, Sandy, and Wayne will finish the "framework" developed by their group and circulate it.
3) A steering committee and strategic plan are needed.
4) Everyone should try to enter data into the database so we can discuss structure and potential improvements.
5) The project needs additional partners to bring expertise and resources; once we have appropriate written materials and a strategy, we will begin to contact other organizations to get them involved. The following were recommended:
    - GSA (Diane or Kevin will contact)
    - EPA (TRACI [Jane Bare], Environmentally Preferable Purchasing in the Office of Pollution Prevention [Julie Shannon], BASE PROGRAM, Community Based Environmental Protection Metrics project [Jerry Filbin]
    - AIA – Center For Livable Communities
    - EGRID – Source pollutants at power plant level
    - Navy – Mike Chapman
    - Postal Service
    - NIH
    - BOMA and ASHRAE
    - Center for the Built Environment at Berkeley
    - Pacific Northwest Laboratory
    - Human Resource Managers Association
    - American Lung Association

Comments on Report

This report summarizes the activities and principal results of the Spring 2002 Workshop. The agenda for the meeting is including in Appendix A and the list of participants is included in Appendix B. Paul Torcellini and Sheila Hayter (of the National Renewable

Energy Laboratory, NREL), Doug Bookman (facilitator for the Workshops), and Joel Ann Todd (workshop participant and consultant) assembled this report. Comments are welcome and should be addressed to sheila_hayter@nrel.gov. Comments can be sent to the entire participant list by addressing metrics@mail.nrel.gov. This report and related materials can be found at www.nrel.gov/buildings/highperformance/metrics.

Appendix A – Agenda

Agenda
Spring 2002 Performance Metrics Workshop
May 20 – 21, 2002
Park City, Utah

The goal of the Spring 2002 Performance Metrics Workshop is to continue the progress begun with the Fall 2001 Performance Metrics Workshop.

Outcomes:

- Define a vision for the finished product of the Performance Metrics effort.
- Refine, prioritize, and begin to populate the 5 categories in the Performance Metrics database.
- Identify research needs and starting point for gathering/creating the priority data.

Day 1	**May 20, 2002**
12:30 – 1:00	Overview of the Fall 2001 Workshop outcomes Confirm needs identified at Fall 2001 Workshop: • Performance metrics database • Research • Reference information
1:00 – 1:30	Who are the perspective users and what do they want?
1:30 – 2:15	What does the Performance Metrics finished product look like? • How complete does the product need to be for a version 1.0 release?
2:15 – 2:30	Break
2:30 – 3:00	Review database
3:00 – 3:30	GSA Performance Metrics Overview
3:30 – 5:00	Breakout groups • Each group will begin populating the database with information specific to the focus the individual breakout group
5:00 – 5:30	Brief report back on progress

Day 2	**May 21, 2002**
7:30 – 8:00	Continental breakfast
8:00 – 8:30	Refocus large group
8:30 – 10:30	Breakout groups reconvene
10:30 – 10:45	Break
10:45 – 12:30	Breakout group reporting
12:30 – 1:30	Working lunch (presentation on LBNL activities)
1:30 – 2:30	Conclude breakout group reporting
2:30 – 2:45	Break
2:45 – 4:30	Clearly define what needs to be done first. • List and prioritize protocols to be develop
4:30	Workshop wrap up

Appendix B – Attendees

Mike Brambley	Pacific Northwest National Laboratory
Doug Brookman, Facilitator	Public Solutions
Mark Case	ETC Group
Dru Crawley	U.S. Department of Energy
Mike Deru	National Renewable Energy Laboratory
Ellen Franconi	Nexant
David Hansen	U.S. Department of Energy
Diane Hartley	U.S. General Services Administration
Sheila Hayter	National Renewable Energy Laboratory
Judi Heerwagen	JH Heerwagen and Associates, Inc.
Rob Hitchcock	Lawrence Berkeley National Laboratory
Jim Hood	Utah Energy Office
Bruce Hunn	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
Ron Judkoff	National Renewable Energy Laboratory
Bob Kobet	Carnegie Mellon University
Mike MacDonald	Oak Ridge National Laboratoyr
Merle McBride	Owens Corning
Sandy Mendler	HOK
Lauren Poole	National Renewable Energy Laboratory
Joel Ann Todd	Environmental Consultant
Paul Torcellini	National Renewable Energy Laboratory
Wayne Trusty	Athena Sustainable Materials Institute

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Appendix C – Version Control

This report was assembled by, Paul Torcellini and Sheila Hayter (NREL), Doug Brookman (Public Solutions), and Joel Ann Todd (environmental consultant).
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Appendix D – Details on Service Quality Group Discussion

	Performance Objective	Metric	Data	Notes
Flexibility/adaptability				
Turnover	Stakeholder (owner, manager, tenant) satisfaction	Churn rate (frequency)	Years/churn	Maximum acceptable churn cost – this may represent how someone uses the metric; we are not so concerned with how people use the metric as we are with identifying the metrics
		Churn Cost	Cost/event Cost/occupant Cost/area % building area affected BOMA data	
		Churn Cause (Proportion of one cause vs. others)	Survey BOMA data	
Building/Workspace Architecture	Appearance/image (how well does it represent the organization's image/ ethic/culture?)	Aesthetic Index (scaled result such as 8 on a 1-to-10 scale)	Survey	Can you reuse the space without having to reconfigure it? Research needed to learn how to measure cost avoidance if space does not need to be reconfigured. What was the savings because the space did not need to be reconfigured?
	Reconfigurability (flexibility/adaptability)	Reconfigurability Index or total annual cost spent on reconfiguration	Cost for new equipment Cost for labor to reconfigure Cost for the disruption to business during reconfiguration Cost/occupant move (per individual)	
	Organizational functionality/effectiveness (connectivity/collaboration, circulation, privacy/space ergonomics, common spaces, meeting rooms, access after hours, etc)	Standard performance metrics from Organization and its peers	Test scores Profit	
		Usability and support for work outside normal hours	Worker effectiveness	
		Satisfaction of owner/ manager/occupant	Survey Employee turnover rate	

Service/Utility Configuration	Controllability of systems and services (Individual environmental control and data access.)	System controllability (organization level)	Benefit from system controllability O&M cost (centralized versus distributed systems)	Research needed to learn how to measure the benefit from system controllability. Can the Human Factors help?
		Service controllability	Number of people per control point (lighting, HVAC, data access (networking, internet), quality of data access (e.g., high-speed internet)	For example, number of people per thermostat or light switch. Does the building offer individual occupant controls? Is this a benefit or a cost? Can Human Factors help?
	Flexibility to deal with changing needs	Ease of reconfiguration	Cost and time required to reconfigure Lost opportunities Available power (power capacity less historical peak) Data and telecomm surplus capacity	
Durability/Reliability				
Durability	Building's ability withstand evolving or changing uses	Building life cycle	Replacement rate and cost for furnishings (including carpet) and equipment Replacement rate and cost for building components (e.g., windows, roof, façade) Maintenance costs Expected building life	Can the building adequately withstand day-to-day operations? An environmental loading question (Group 1) is whether to lease or purchase (e.g., carpet). A high-performance building will minimize service calls.

Reliability		Reliability of utility services	Number of service calls Cost per service call Mean time between failures O&M costs Capability to operate in an electricity disruption	Utility services include electric, data, network, HVAC, lighting, and other similar services.
		Continuous commissioning		
		Design for reliability		
Safety/Security				
Safety	Level of risk acceptable to the owner/manager/ occupant	Acceptable safety risk to owner	Code building constructed to meet	Does the building exceed code? Older codes may result in buildings that are not safe according to current standards. Safety codes include fire, earthquake, wind (hurricane, tornados) and others.
		Acceptable safety risk to manager	Insurance cost and/or coverage	
		Acceptable safety risk to occupant	Access control	Are employees protected during and after hours?
Security (extraordinary incidences)	Adequate but not excessive Security	Access control and surveillance	Fraction of access points that are controlled (keyed, security personnel, etc.)	Prevention against terrorism. How much is adequate?
		Bio-terrorism protection	Sensors/alarms cost and reliability	How much is adequate?

		HVAC system security	Response time to incidents Control of outside air access Sensors/alarms cost and reliability	How much is adequate?
		Insurance	Cost Coverage/Liability	Does Federal Facilities Council have data?