Developing a Business Case Using Whole Building Performance Measurement

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ABSTRACT

Since 1998, the U.S. Navy's Naval Facilities Engineering Command (NAVFAC) has had a policy for incorporating sustainable design principles into new building construction. The policy states it is the intent of NAVFAC to accomplish this within the given budget constraints and while meeting customer requirements. Programming a building using a first cost approach instead of a life cycle cost approach is one of the biggest challenges for integrating sustainable design into Navy projects. Due to this hurdle, an attempt to develop a Navy-specific business case was undertaken. Through this process, it was discovered that consistent data were not being collected for all applicable Navy buildings. Therefore, the current business case information being used by the Navy is the conglomeration of existing business case analysis in the literature. Although this business case information is useful, there is still a need for collecting and analyzing the Navy business case. To develop the Navy-specific business case, NAVFAC is developing program metrics to capture the status of buildings in the design and construction phase, and started to collect whole building cost and performance data for 14 buildings (7 sustainably designed and 7 traditionally designed buildings) to capture data on the existing inventory of sustainably designed buildings. Performance measurement data are being collected on water, energy, operations and maintenance, waste generation, purchasing, occupant satisfaction, and transportation. The building cost and performance data will be collected for a minimum of 12 months. Both of these data collection and analysis efforts have offered lessons learned that will be shared alongside the current Navy business case information.

INTRODUCTION

Is sustainable design worth the investment? This has been asked many times and answered in many ways. Business case analysis for sustainably designed buildings is used to demonstrate how investing in whole building, integrated design strategies results in lower total operating costs. To date, the common method has been to compare the modeled or estimated performance from the design specifications and drawings to a pre-established standard. Projected operational savings are useful design tools and offer business case information for many audiences.

The current set of business case analysis studies offers various mechanisms for collecting data, analyzing the building information, and presenting results. The information in these reports is noteworthy and offers useful narratives for sustainable design experts. In addition to the current set of business case analysis studies that use design projections to make the case, there is a need for analyzing measured building performance data from currently operating, sustainably designed buildings. [1,2,3]

Since 1998, the U.S. Navy's Naval Facilities Engineering Command (NAVFAC) has had a policy for incorporating sustainable design principles into new building construction. The policy states it is the intent of NAVFAC to accomplish this within the given budget constraints and while meeting customer requirements. Programming a building using a first cost approach instead of a life cycle cost approach is one of the biggest challenges for integrating sustainable design into Navy projects. Navy-specific information to address these challenges is preferred.

To address the need for Navy-specific information, existing business case studies are being used as models for the type of metrics and data collection needed on an annual basis. To address the need for whole building performance measurement data, 14 buildings are included in a project that involves collecting water, energy, operations and maintenance, waste generation, purchasing, occupant satisfaction, and transportation data to compare the performance of sustainably designed to traditionally designed buildings.

This article will summarize some existing business case analysis studies, provide an overview of the lessons learned during the initial attempt to collect Navy-specific business case data, and describe the

project underway to collect whole building performance measurement data for 14 Navy buildings.

EXISTING BUSINESS CASE ANALYSIS

Sustainable design strategies are becoming more commonplace in the commercial building industry. The market penetration of the U.S. Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) rating system is evidence of the increased acceptance of sustainable design strategies. In early 2006, USGBC could claim 23,000 LEED Accredited Professionals, greater than 3400 buildings registered, and greater than 400 buildings certified. [4] Additionally, federal agencies are committing to building high performing, sustainably designed facilities, most recently through the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding and the Energy Policy Act. [5,6]

To offer evidence to the Navy that sustainable design strategies are an effective technique for achieving the lowest "total ownership cost," results from the following existing sustainable design business case analysis studies were provided:

- *The Business Case for Sustainable Design in Federal Facilities* [7]
- *Examining the Cost of Green* [8]
- GSA *LEED™ Cost Study* [9]
- *The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force* [10]
- *City of Seattle 2002 LEED™ Evaluation Report* [11]

There are many ways to display all of the critical performance metrics. First cost, life cycle cost, and energy and water use were the metrics summarized because they offered the most transferable results for the Navy. First cost and life cycle cost comparisons were available in more unique formats than the other metrics.

In 2003, the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy's (EERE) Federal Energy Management Program (FEMP) in collaboration with the Interagency Sustainability Working Group prepared *The Business Case for Sustainable Design in Federal Facilities*. This report uses two 20,000 square foot simulated office

buildings to compare the life cycle energy, water, and materials costs, environmental impact, and societal impacts. From a cost analysis perspective, this report offers estimated first and life cycle costs by design strategy. Knowing the specific impact of each design element is useful when the goal is to identify which sustainable design investments are offering the "biggest bang for the buck." However, this information isn't always available or easy to pull out of design documentation.

The FEMP business case report offers a comparison of the baseline to the sustainable building energy operating cost by end use as well as a percent reduction, which could be used to compare element first costs and return on investment. The energy information was generated as part of the DOE2 analysis. The energy end use analysis is not required for LEED documentation, but it would offer the Navy more information about which aspects of the energy design are offering the greatest operational savings. This report also offers design feature specific estimated waste use savings. A summary of percentage of water savings based on end use is also included in the report. This report showed that the estimated first cost for the sustainably designed building was expected to be less than the traditional building estimate. It also showed lower life cycle costs for energy and water use.

The Davis Langdon 2004 Greenbuild presentation, *Examining the Cost of Green*, shared the results of a study comparing the construction costs of sustainably designed buildings with buildings that have similar functions but did not establish sustainable design goals. The data for this study came from collected construction costs and design parameters for approximately 600 projects. The analysis concluded that the first cost of the sustainably designed buildings varied tremendously based on the clarity of the design objectives and many other causes that were not always correlated to sustainable design.

In 2004, the U.S. *General Services Administration (GSA) LEED™ Cost Study* was prepared by Steven Winter Associates as a cost study on two building types to determine the first cost impacts of differing levels of the LEED rating system. This report compared cost estimates documentation for a new courthouse and the renovation of an office building. Two estimates were made for LEED certified, silver, and gold levels. Similar to the Davis Langdon Study, this study showed that there is no significant correlation between the "green-ness" and the first cost. Although some of the first cost estimates for the sustainably designed buildings were higher, this analysis showed that for these specific build-

ing scenarios, an LEED silver building could be accomplished without adding significant first cost. Other lessons from this report include:

- The cost of some LEED credits will vary by building type;
- The cost of some LEED credits will vary by region/location; and
- Different strategies can be used to attain the same LEED credit.

The *GSA LEED Cost Study* also communicated the anticipated energy use based on the designed energy efficiency measures. The information was presented as a percent improvement over a national standard, which offers a way to compare the efficiency of buildings across regions. A general list of features included in the designs was part of the report. For Navy use, the energy information provided in this report would be helpful to offer a summary of estimated energy savings for all new buildings and a general summary list of design strategies that have been used. This general list does not offer estimated cost savings or enough detail on the design features to determine whether or not they should be included in future design projects.

California's Sustainable Building Task Force commissioned a study in 2003 to evaluate the business case for sustainable design, which concluded that life cycle benefits of sustainable design outweigh the initial first cost investment. This study used data from actual buildings and personal communications. There were a variety of baseline techniques used and costs were attributed to environmental and productivity impacts. The collected information was summarized into an estimated 20 year net present value of the "green" building features. These data show that the energy savings alone exceeded the average increased first cost. These data also show that the productivity impact of the buildings offered the most significant positive impact. In addition to the life cycle cost analysis, this report summarized the first cost of 33 different LEED certified buildings. The summary charts regarding the additional first cost of sustainably designed buildings imply that there is a premium for LEED certified buildings, but that it is a relatively small additional project cost.

The *City of Seattle 2002 LEED Evaluation Report* includes design process overview, suggested tools for collecting data, and estimates for building performance measurement. The Seattle cost data are estimates for the annual savings associated with key operational costs for 16 of their Green Buildings. The Navy could use this as a model of what

information to collect, as much of this information is collected as part of the LEED certification documentation.

In addition to the detailed business case analysis reports, there are many studies that discuss building occupant productivity. Generally, these studies show that when considering the life cycle cost of a building, the salaries of the building occupants are the most significant cost. In other words, if a building could be designed in a life cycle manner that improved occupant productivity, it would quickly be a cost effective element. [12,13]

These sustainable design business case analysis studies have been a valuable addition to the general understanding of the costs and benefits of sustainable design. Some of the studies focused on specialty buildings such as courthouses, libraries, and laboratories; however, the majority of the studies have focused on administrative/office buildings. There is still a need for Navy-specific information to provide persuasive data for key Navy financial stakeholders. The Navy-specific information needs to address the occupancy differences (active military versus typical office worker), building type differences (barracks, hangars, etc.), and cost effectiveness in a manner that will be accepted by the Navy comptrollers.

NAVY-SPECIFIC BUSINESS CASE ANALYSIS

Until recently, the Navy has been expending its sustainable design efforts on getting sustainable design into as many projects as possible, rather than on measuring progress. NAVFAC is currently emphasizing:

1. Continuing to incorporate sustainable design principles into all phases of a project for all applicable project types.

2. Identifying and resolving the systems/processes that are prohibiting, challenging, or slowing the use of sustainable design principles, such as
   a) Instructions in the programming documents regarding sustainable design,
   b) Changes to the project planning/design documentation (1391 form) rating factors to include sustainable design, and

c) Claimant education regarding requirements for new buildings.

3. Measuring building performance in order to better understand the "total ownership cost" to the Navy for its sustainably designed buildings.

4 Communicating successes to improve design strategies across the Navy.

The Navy has been making significant progress in the field of sustainable design, but due to the lack of consistently available data, that progress can only be shared through case studies and anecdotal stories. The Navy recognizes the need to gather this information in a more consistent manner, which has led to two activities to assist in the recurring collection of data:

- Sustainable program metrics data collection, and
- Building performance measurement project.

The sustainable program metrics data would be the type of information used to develop a Navy-specific business case. The information that needs to be collected to offer a defendable and easy-to-explain Navy-specific business case includes:

- List of all planned/programmed buildings
  - Project identification number
  - Project status (i.e., planned, design, construction, etc.)
  - Size in square footage
  - Estimated number of occupants
  - Estimated occupancy hours
  - Building type/function
  - Expected completion/occupation date
  - Location

- LEED Certification
  - Number of buildings with potential to incorporate sustainable design
  - Number of buildings LEED Certified/Silver/Gold/Platinum
  - Number of buildings LEED Certifiable

- Costs for each building
  - Design cost
  - Construction cost
  - Estimated operation cost

- Energy
  - Designed energy use
  - Estimated energy cost
  - Estimated percent energy savings to baseline
  - Energy efficient design features

- Water
  - Designed water use
  - Estimated water cost
  - Estimated percent water savings to baseline
  - Water efficient design features

- Sustainable design features summary

Several attempts were made to collect business case information for all relevant 2004 through 2006 Navy building projects. Information was gathered from the Federal High Performance Buildings Database, currently available sustainable program metrics data, and additional specific requests for updated Navy data. To date, although some useful information was collected, the comprehensive set of data needed to prepare a business case was not consistently available. The data collection efforts uncovered many challenges and identified the need to formalize the collection of data through the sustainable program metrics data collection efforts. Some of the challenges that were identified during this data collection and analysis effort include:

- Master list of applicable buildings was not readily available.

- Building size data were not available in a consistent manner for all of the buildings of interest.

- Building cost data were not available in a consistent manner for all of the buildings of interest and would need to be adjusted to present-day dollars using Navy method for calculating net present value.

- Building energy data were not available in a consistent manner for all of the buildings of interest (e.g., simulated, measured, averaged, etc.).

- Energy data units were not available consistently as estimated energy consumption, energy use cost estimates, and percent energy savings.

- Factors affecting energy use are not consistently available, such as the hours the building is occupied, unique use areas, etc.

- Actual heating and cooling energy is unknown for weather-adjusted comparisons.

- Building water data were not clearly identified as indoor only or indoor and outdoor water use.

- Water data comparability needs building occupancy data.

- Measured water data were not available consistently, nor were the data provided clearly identified as design simulated, measured, or estimated based on known algorithm.

An example of the data quality and consistency issues that were encountered can be demonstrated through the LEED certification data. From the 2004-2006 funded 1391 project data, it showed that 32 administrative and/or barracks projects have been planned. It was initially thought that this number could be used as the minimum number of applicable projects for LEED certification. However, it was discovered that a variety of unique projects, such as hangars, are pursuing LEED certification and that the only way to collect information on which projects pursued certification was through the Regional Sustainable Program contacts. The information collected from those contacts included projects from 2001. There were 8 LEED certified projects (planned and completed) and 33 projects identified as certifiable. It is impressive that the Navy has so many green buildings, but with the current data there is no way of knowing if all applicable buildings have incorporated sustainable design principles.

In general, to complete a Navy-specific business case analysis,

more data are needed to extrapolate the data into a business case analysis. As important as more data is the need for consistent data collected for both the sustainably designed and traditionally designed buildings. And finally, the data need to be representative for all Navy sites and for both traditionally and sustainably designed buildings, which means data need to come from all Navy sites and applicable climate zones.

NAVY PROJECT TO MEASURE WHOLE BUILDING PERFORMANCE

To address the data gap of consistently collected and measured performance data, a building performance measurement project is underway with the Navy. The approach being applied to Navy buildings is the comparison of whole building, measured performance between "sustainably-designed" and "traditionally-designed" buildings. Using measured performance data to further develop the business case is expected to offer the financial decision makers data on how sustainable design strategies have impacted actual building performance and life cycle cost. To accomplish the goal of providing actual data on sustainably designed Navy facilities, a project was initiated to measure the performance of 14 Navy buildings. The intent of the project is to use measured building performance rather than manufacturer estimates and modeling to determine return on investment. The information collected will be used to identify opportunities for individual building performance improvement and to measure the design's effectiveness to assist in future Navy sustainable design efforts.

The beginning stage of the project involved selecting the performance metrics and identifying the building sets. The project execution stage involves getting appropriate measurement devices and systems in place to measure cost and performance and then collecting the building data for a minimum of 12 months. Once the data have been collected, the final stage involves analyzing the data and preparing useful documentation that clearly communicates the findings. (See Figure 1 for visual representation of the project approach.)

To date, the Navy project has selected metrics, identified the target buildings, identified the current metering capability, and collected site and building characteristics data for the seven building sets.

Sustainable building cost and performance metrics developed for

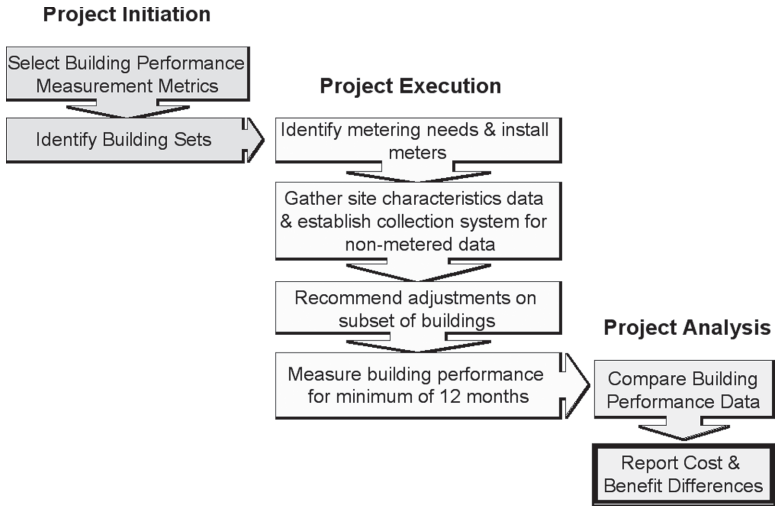

Figure 1. Project approach.

a DOE FEMP project were selected and tailored for this project. [14] These building cost and performance metrics were developed to offer an "easy" means of data collection for key areas of sustainability. The information that needs to be collected for each building is broken into two groups:

1) Building and Site Characteristics
2) Building Performance Metrics

The building and site characteristics are used to provide a valid comparison between buildings. The building performance metrics are used to measure the actual performance of the building over time.

As mentioned previously, these metrics are being used to document and compare the measurement of the performance and cost of a sustainably designed building to a similar traditionally designed building (together comprising a building set). Identifying building sets is critical to the success of the measurement. The buildings in the set needed to be located near each other to minimize the effect of climate on the performance data; they needed to be the same building type (e.g., office, barracks, etc.) and have a similar occupant population (e.g., active military, government employees, contractors, etc.); and both buildings needed to have been in operation for six months or longer. Fourteen

buildings, or 7 building sets, were selected for this analysis. Each building set includes one sustainably designed building and a similar building on the same Navy site designed in a more "conventional" fashion. In addition to using the conventionally designed building for comparison, industry benchmarks and existing Navy data will be used when available. The building types included in the project are office buildings and barracks. (See Table 1 for list of building sets and locations).

Table 1. Building set list.

	Building Type	*Location*
1	Barracks	Great Lakes, IL
2	Barracks	Camp Pendleton, CA
3	Administration/Office	Port Hueneme, CA
4	Barracks	Yorktown & Virginia Beach, VA
5	Administration/Office	Little Creek & Norfolk, VA
6	Barracks	Camp Lejeune, NC
7	Administration/Office	Washington D.C.

Once the building sets were identified, the building and site characteristics were collected. The building and site characteristics will be used to make the building performance metric data comparable and to ensure the costs and benefits are representing the building design and operation rather than other non-building related factors. Building and site characteristics include:

- Building location
- Building size
- Building design features
- Occupancy statistics
- Typical building operation statistics
- First cost details

Building performance metrics are collected regularly over the length of the project. They were selected to represent the whole building performance typically impacted by sustainable design strategies. Some of the metrics are considered required, such as energy and water use, while others are optional, such as environmentally preferable purchas-

ing. Metrics were identified as optional when it was suspected that the data would be difficult to collect at each of the sites. (See Table 2 for a summary of the building performance metrics.)

Metric	Required	Optional
Water	Total Building Water Use	Indoor Potable Water Outdoor Water Use
Energy	Total Building Energy Use	Source Energy Peak Electricity Demand
Maintenance & Operations	Building Maintenance Requests	Grounds Maintenance Churn Cost
Waste Generation	Solid Sanitary Waste	Recycled Materials
Purchasing		Environmentally Preferable Purchasing
Occupant Health & Productivity	Occupant Turnover Rate Absenteeism Building Occupant Satisfaction Self-Rated Productivity	
Transportation	Regular Commute	

Table 2. Building performance metrics.

For the Navy project, a portion of the required meters and data collection systems needed to be installed at all of the buildings. The data from these buildings will be used to calculate a return on investment for the sustainably designed facilities, to identify opportunities for individual building performance improvement, and to develop design guidance on the sustainable design techniques that appeared to be contributing the greatest to the buildings' performance. Once the data have been collected and analyzed, there will be many ways it can be represented. Sample reporting charts include energy (Figure 2), cost (Figure 3), and occupant productivity (Figure 4).

There have been several challenges during the early stages of the project. The first challenge for the project was identifying which sustainably designed buildings in the Navy portfolio would be the best candidates. Having buildings that were occupied for more than 6 months and identifying a "matching" conventionally designed building at the same site with the same function proved to be significant limiting factors. Once the buildings were selected, the challenge was to clearly identify the metering needs, which have been greater than expected,

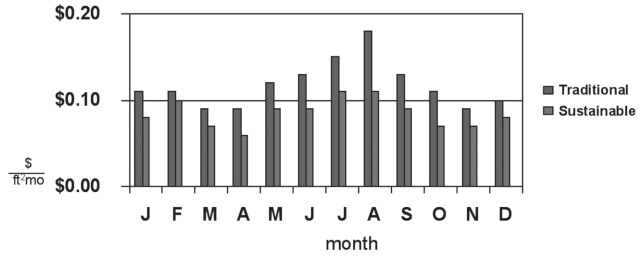

Figure 2. Sample energy analysis results.

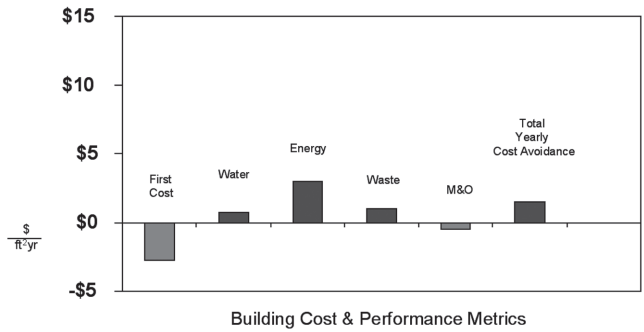

Figure 3. Sample cost analysis results.

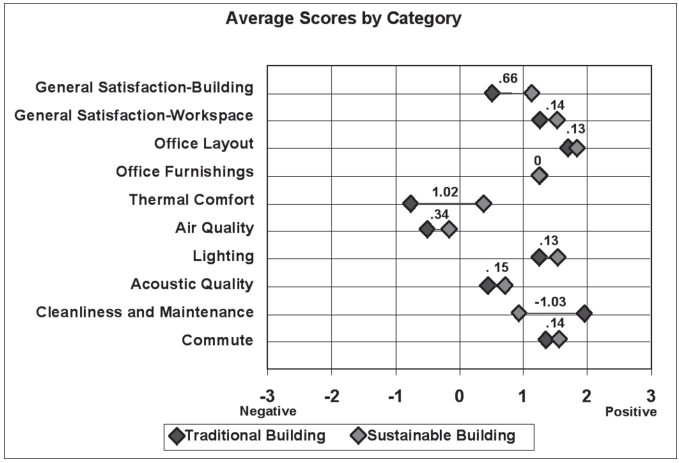

Figure 4. Sample occupant productivity results.

and to gather the site and building characteristics for each building. Once the building meters are in place, the collection of monthly performance data begins.

The metering data that already exist are being reviewed to determine if the buildings are operating as expected. If necessary, recommendations for building adjustments will be made. Unfortunately, none of the building sets had a full set of meters in place that could be used to jump start the building performance measurement project.

The process that is being used to collect the data is broken into multiple steps:

- The "metering assessment" for energy and water metrics involved a site visit, metering plan, meter installation, installation of communication devices, and the testing of the metering and communication equipment.

- The "building characteristics data" collection involved the review of existing building documentation, a telephone interview and email exchange with key personnel, and a site visit.

- The ongoing collection of sustainable design related data for this project involves identifying the key personnel and systems in place that can be used to consistently collect the data and to formalize a process for regularly collecting the data.

There are always challenges with collecting and analyzing large quantities of data. To date, the challenges have been diverse, but are primarily focused on establishing a system for collecting the data:

- Ensuring electrical safety requirements are included in the metering contracts.

- Identifying current metering status.
  - Availability of meters
  - Age of existing meters
  - Communication ability from existing meters
  - Location of meters
  - Telephone line hook up for new and existing meters
  - Timeliness of new meter installation

- Collecting non-metered data:
  - Data not available
  - Data collected differently at each building and/or for each building set
  - Potential comparability issues between buildings or across building sets

- Coordinating data collection requires multiple site contacts which are all busy with other priorities.

There have been many lessons learned since the beginning of this project. The building contacts that were provided were primarily building energy managers. Generally speaking, they are a very busy group of professionals. When communicating with them, it was easier to get their attention when only the metering portion of the project was discussed; that is, some of the broader sustainability issues offered too many details at the beginning of the project. The Energy Policy Act metering requirement created an opportunity to communicate with the building energy managers, because additional metering capability was being offered as part of the project. When considering costs, it is typically less expensive to use the site installation personnel for the meters and phone lines, when feasible; however, that will decrease the ability to control the timeliness of the installation. And, finally, increased flexibility on how data are collected must be part of the process, but the differences must be well documented in order to address comparability issues during the analysis stage.

CONCLUSION

Since 1998, the U.S. Navy's Naval Facilities Engineering Command (NAVFAC) has had a policy for incorporating sustainable design principles into new building construction. The Navy has been making significant progress in the field of sustainable design, but due to the lack of consistently available data, that progress can only be shared through case studies and anecdotal stories. Until recently, the Navy has been expending its sustainable design efforts on incorporating sustainable design into as many projects as possible, rather than on measuring progress. Currently, NAVFAC is emphasizing:

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2. Identifying and resolving the systems/processes that are prohibiting, challenging, or slowing the use of sustainable design principles, such as:
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4. Communicating successes to improve design strategies across the Navy.

To develop the Navy-specific business case, NAVFAC is developing sustainable program metrics to capture the status of buildings in the design and construction phase. To address the data gap of consistently collected measured performance data, a building performance measurement project is underway where whole building cost and performance data for 14 buildings (7 sustainably designed and 7 traditionally designed buildings) are being collected to contribute to the business case, which will offer the financial decision-makers data on how sustainable design strategies have impacted actual building performance and life cycle cost.

References

1. Building Design and Construction (BD&C), editors. 2003. White Paper on Sustainability: A Report on the Green Building Movement. Building Design and Construction (Supplement).
2. Carmona Andreu, Isabel and Tadj Oreszczyn. 2004. Architects Need Feedback on Environmental Performance. Jul-Aug 2004, Vol. 32 (4). Building Research and Information.
3. ENSAR Group. 2003. Sustainable Federal Facilities Task 2.1 Business Case. November 2002 workshop notes. Boulder, CO.
4. USGBC. 2006. U.S. Green Building Council. http://www.usgbc.org/.
5. Memorandum of Understanding. January 2006. Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding. http://

www.wbdg.org/pdfs/sustainable_mou.pdf.
6. Energy Policy Act of 2005 (EPAct). July 2005. Public Law 109-58.
7. U.S. Department of Energy (U.S. DOE). 2003. The Business Case for Sustainable Design in Federal Facilities. Interagency Sustainability Working Group, Federal Energy Management Program, Washington, D.C.
8. Matthiessen, LF. 2004. Examining the Cost of Green. Greenbuild 2004 International Conference and Expo Proceedings, Portland, Oregon. http://www.dladamson.com/Attachment%20Files/Research/The%20full%20report.pdf.
9. General Services Administration. 2004. GSA LEEDTM Cost Study. http://www.wbdg.org/.
10. Kats, G, L Alevantis, A Berman, E Mills, and J Perlman. 2003. The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force. Prepared by Capital E, Department of Health Services, and Lawrence Berkeley National Laboratory for California's Sustainable Building Task Force, Sacramento, California. http://www.cap-e.com/ewebeditpro/items/O59F3259.pdf.
11. Paladino & Company, Inc. 2003. City of Seattle 2002 LEED Evaluation Report. Prepared for The City of Seattle, Seattle, Washington.
12. Morton, Steven. 2002. "Business Case for Green Design." Building Operating Management, November 2002 Issue. http://www.facilitiesnet.com/bom/article.asp?id=1481.
13. Romm, Joseph and William D. Browning. 1994, 1998. Greening the Building and the Bottom Line. Rocky Mountain Institute.
14. Fowler, K.M., A.E. Solana, and K. Spees. 2005. Building Cost and Performance Metrics: Data Collection Protocol, Revision 1.0. PNNL-SA-15217. Pacific Northwest National Laboratory, Richland, Washington.

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