ECOLOGICAL FOOTPRINT ANALYSIS FOR MILITARY HEALTHCARE FACILITY DESIGN AND CONSTRUCTION – CASE STUDY

by

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ABSTRACT

The world’s rapid economic expansion demands the construction of many new buildings annually. Nearly 4.7 million office buildings existed in 1999, and each year since then approximately 170,000 commercial buildings have been constructed and nearly 44,000 demolished. This level of expansion creates an unprecedented demand for land and natural resources. Furthermore, buildings are prominent energy users. According to the United States Green Building Council (USGBC), buildings in the U.S. account for 70% of total energy consumption. For the healthcare industry, one of the fastest growing sectors in the US economy, the situation is even more acute. Hospitals are among the most energy-intensive commercial buildings, rated as the second highest energy users in the nation.

This study explores strategies that help the healthcare industry to embrace sustainable development by understanding the impacts that building design and construction have on the natural environment. This research compares the ecological footprint of a sustainable approach to healthcare construction to that of a baseline level or *code compliance* design. The relative impacts of energy use reduction, waste management and land use serve as a basis for defining the carrying capacity of the case study inherent to this research. One of the focal elements of the study is an assessment of the impact of carbon emissions that is related specifically to energy reduction practices.

An ecological footprint assessment helps to establish a common language for defining sustainability and provides a strategic management tool to help prioritize decisions made in building construction and in the policy-making process. Such analysis can also be used to inform future hospital designs by encouraging restorative site planning that is developed to maximize the ecological capacity of a site and ensure proper selection of construction methods. Consequently, future healthcare-related building design and construction should focus on long-range impact planning and mitigation strategies to further energy efficiency and reduce the impact of carbon emissions.

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I. INTRODUCTION

1. Problem Description

The world's rapid economic expansion demands the construction of new buildings every year. For example, nearly 4.7 million office buildings existed in 1999, and each year since then approximately 170,000 commercial buildings have been constructed and nearly 44,000 demolished.[1] This level of expansion has created an unprecedented demand for land and natural resources. Indeed, the typical North American construction process generates 2.5 pounds of solid waste per square foot of floor space. Buildings are prominent energy users, and their construction and operation contribute significantly to carbon emissions. According to the United States Green Building Council (USGBC), buildings account for 30% of the nation's greenhouse gas emissions and 70% of its total electricity consumed. Forty billion dollars are spent annually in the U.S. simply to air-condition buildings.

With regard to healthcare design and construction, the impact is even more staggering. According to the U.S. Environmental Protection Agency (EPA), the healthcare industry ranks among the top four carbon emissions producers at 16.6 million metric tons of carbon equivalent (MMTCE) per year. The healthcare industry is one of the US economy's fastest growing sectors and hospitals are among the most energy-intensive commercial buildings, rated as the second highest energy users in the country. "Last year, hospitals spent more than $5 billion on energy costs with more than 2.5 times the energy intensity and carbon dioxide emissions of commercial office buildings."[2] This study explores strategies that help the healthcare industry to embrace sustainable development by understanding the impacts that building design and construction have on the capacity of ecosystems to support future activities. The research employed here is based on a case study that compares the ecological footprint of a sustainable approach to healthcare construction to a baseline level design, or minimum code compliance, approach. All human activity can have a detrimental negative impact on the environment unless nature's limits are respected. An understanding and respect of the ecological footprint enables people to take personal and consolidated action in support of a world where humanity lives within its collective means of the planet and the capacity of ecosystems.

Biological Capacity, or Biocapacity

The capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies. [3]

It is unfortunate that, as a species, humans have exceeded the world's available biocapacity. Although the specifics of this assessment depend on the way the calculations are performed, many reputable sources show alarming results. According to the World Wildlife Fund (WWF) and other sources, human consumption now surpasses the world's ability to regenerate by about 30 percent.[4] The statistics are even more alarming for the United States. This country's per capita ecological footprint is now more than 50% larger than its biocapacity,[5] meaning that the U.S. is constantly borrowing biocapacity from other regions in the world. In such a critical state, can society afford to build structures whose ecological footprints are several times larger than the actual footprints they occupy? Human demand on the planet must be balanced; if not, humans face potentially irreversible consequences in the not so distant future.

> *If our demand on the planet continues at the same rate, by the mid-2030s we will need the equivalent of two planets to maintain our lifestyles.*
>
> James P. Leape, Director General, WWF International

Table 1 Ecological Demand and Supply in Selected Countries, 2003

Region/Country	**Total Ecological Footprint** (million gha)	**Per Capita Ecological Footprint** (gha/person)	**Biocapacity** (gha/person)	**Ecological Reserve/deficit** (gha/person)
World	***14,073***	***2.2***	***1.8***	***-0.4***
United States of America	2,819	9.6	4.7	-4.8
China	2,152	1.6	0.8	-0.9
Russian Federation	631	4.4	6.9	2.5
Germany	375	4.5	1.7	-2.8
France	339	5.6	3.0	-2.6
Brazil	383	2.1	9.9	7.8
Canada	240	4.2	14.5	6.9

Table 1 describes ecological demand and supply in selected countries. In the table, the total footprint is described in global hectares (Gha), and the biocapacity and ecological reserves are shown in Gha per person. A global hectare is a measurement that is used to quantify biological productivity on a global scale. It is also used to draw conclusions about local biological demands that are independent of local biological productivity factors (thus normalized to a global scale).[6] For countries with a negative ecological footprint, such as the United States of America, Germany and France, the deficit is shown as a negative Gha/person.

2. Objective

This study develops a comparative analysis and evaluation of sustainable healthcare design and construction practices. The purpose of this research is to compare a sustainable approach to healthcare design and construction with a *status quo* baseline level, or traditional code compliance, design. The outcome introduces the concept of ecological capacity into a large-scale healthcare design. Consideration of the ecological footprint is an emerging field in healthcare planning. Only a handful of studies on specific applications exist, and most of these studies were conducted in the United Kingdom and Canada. Very few studies have been conducted in the United States. The first-ever ecological footprint analysis of a hospital was carried out in the summer of 2001 in North Vancouver, British Columbia. The study was commissioned by the Canadian Association of Physicians for the Environment (CAPE) on behalf of the Canadian Coalition for Green Health Care as a first step in quantifying the environmental effects of a hospital and decreasing healthcare's environmental impact.[7] The ecological footprint method was originated by Dr. William Rees at the University of British Columbia as a way to quantify the sustainability of populations.[8] The method serves as a resource accounting tool and is defined as a measure of the biocapacity that a certain population or activity (including, for example, building construction) requires both to produce all the resources it consumes and to absorb the waste it generates.[9] The ecological footprint helps to define the amount of productive land and water areas in various ecosystems and helps to determine the amount of land and water that is required to support populations at current consumption levels.

Current sustainable metrics consistently lack common language in evaluating design impacts. In addition, they rarely take into consideration the reality of ecological constraints. It makes sense, therefore, to adopt the ecological footprint as a measure to help explore strategies that can potentially move the architectural/engineering industry as well as construction industries to embrace sustainable development. The ecological footprint can help these industries better understand the impacts that building design and construction have on the ability of natural resources and natural systems to produce biological materials and to absorb waste generated by buildings. Moreover, finding a common language between architectural (and engineering and construction) disciplines and ecological disciplines is crucial. When basing the measure of a building's impact on ecological capacity, a conceptual framework is then established that can act as a sustainable planning, management, and policy tool.[10] Although we now understand that sustainable development can contribute to the improved health, well-being, comfort and quality of life of human beings, the question remains whether buildings can maintain these highly desirable outcomes while functioning within the carrying capacity of the supporting ecosystem.

This case study develops a comparative analysis and evaluation of sustainable healthcare design and construction practices. The relative impacts of energy use reduction, waste management and land use serve as a basis for defining the carrying capacity of the hospital. In industrialized countries, such as the U.S., greenhouse gas emissions are attributable mostly to the burning of fossil fuels.[11] Energy-intensive industries, such as healthcare, are major contributors to this problem. Evaluation of energy reduction practices and assessment of the impact of carbon emissions are especially critical, mainly because energy consumption in hospitals is the largest contributor to the hospital’s ecological footprint. Consequently, future healthcare-related building design and construction should focus on long-range impact planning, mitigation strategies, alternative fuels, and other sustainable design, construction and operational practices. It is crucial also to note that the emissions component of the ecological footprint is different from the one commonly used in carbon calculations, because it encompasses not only the physical quantity of carbon that is emitted, but also indicates the amount of nature's minimum regenerative capacity that is required to rid the atmosphere of this carbon.

The study’s goals include defining ecological capacity in the context of the healthcare construction industry and establishing common sustainable metrics between, for example, land and energy impacts. The outcome of the study introduces the concept of ecological capacity into the context of healthcare design and construction practices. The relative impacts of energy use reduction, waste management and land use serve as a basis for defining the carrying capacity of the project. The resulting analysis will inform both the construction and operation of future projects as well as promote restorative design.

The ecological footprint can be used as a single indicator, or it can be broken down into its constituent parts. This study consists of three primary evaluation categories:

- Construction waste management analysis
- Evaluation of land development impacts methodology
- Greenhouse gases and contaminants measurements

Questions addressed in the study include:

- What impact does construction waste management have on the reduction of the ecological footprint?
- At what level can sustainable site design aid in offsetting a project's construction impacts?
- What impact does an energy-efficient design of hospitals have on the overall footprint?

3. Limitations of the study

Ecosystem services must be contextually defined relative to impacts.[12] This paper includes the following components of ecological footprint analysis:

a. Land development due to construction
b. Energy use/CO_2 equivalent (building related energy)
c. Construction waste management
d. CO_2 emissions due to transportation of materials and construction waste

Various limitations also must be assumed, mainly due to time constraints and/or lack of appropriate data. The subject hospital (detailed below) used in this study is now only about 25% into its construction. Therefore, any information related to the building's operations, such as purchasing or waste stream audits, is simply unavailable and would have to be projected. Other limitations stem from the method used to determine the ecological footprint. For example, this method does not account for freshwater withdrawals; therefore, this study excludes all water use and water conservation measures. The energy used to pump and distribute water throughout the site is included as part of the energy model. This study also does not include waste generation caused by the building operations or medical waste because the project is still in the early stages of construction. The calculations further exclude construction materials lifecycle impacts as part of the ecological footprint analysis due to the impact of the final selection of construction products and materials, which is ongoing.

4. Case Study

a) Project Overview

The case study is a new healthcare facility currently under construction at Fort Belvoir in Alexandria, Virginia. The Fort Belvoir Community Hospital (FBCH) will be part of an integrated healthcare network that provides world-class medical services to the nation's wounded soldiers and their families. FBCH is being designed as a primary and secondary level care building. This seven-storey community hospital includes 120 in-patient beds, a 10-bed intensive care unit, a 10-bed behavioral health in-patient unit, a cancer center, an emergency department, a pharmacy, an operative services center with 10 operating rooms, diagnostic centers such as pathology and radiology, and modular clinic space dedicated to out-patient services, with additional space planned for future out-patient expansion. FBCH will house more than 3,000 staff. The building will encompass 1.27 million square feet and is located on more than 60 acres of land Figure 5.

The project's requirements contribute to a design that not only meets the functional requirements of advanced technology, but also create a healing environment and workplace that is environmentally friendly and energy-efficient. The hospital is currently positioned on a natural high point between existing roads, which allows for the continued protection of wetlands, both to the northeast and the southwest. The steep wetland swale east of the hospital includes a mature oak forest that will be preserved and made accessible to users by pedestrian sidewalks and trails. Green roofs visible from the in-patient rooms of the bed tower will capture and treat storm water. Rain gardens and river rock beds will retain water so it can percolate into the ground. Surface parking lots designed with curbless gutter systems will direct water into depressed planting areas for filtration.

The site design is also meant to promote healing and respite, while preserving and restoring the natural environment. For example, six courtyard gardens will serve the hospital's patients and families as well as staff. The importance of these gardens is significant. These areas are considered *bioproductive* as they are planted with native and adaptive vegetation, thus restoring local species to the site and reducing irrigation needs. This native vegetation creates a positive net impact when calculating the ecological footprint for built-up areas (as discussed in Section II.1: Methodology used to Evaluate Impacts of Land Development). Additionally, the plantings and gardens will provide opportunities for quiet reflection and thought within the hectic hospital environment, thus creating a calming and soothing atmosphere (Figure 1).

Figure 1 Healing Garden, FBCH. *Image made available by HDR Inc.*

b) Policies and Regulations Guiding the Project

As outlined in the military handbook entitled, “Department of Defense Medical Military Facilities Design Criteria” (HDBK 1191), FBCH is being designed as a high performance sustainable facility. This project has three major policy drivers. As a federal facility, the project must comply with the Energy Policy Act of 2005 (EPAct). The other two major drivers are the Evidence-Based Design (EBD) principles under the auspices of the Military Hospital Service (MHS), and the USGBC’s Leadership in Energy and Environmental Design Rating System® for New Construction and Major Renovations Version 2.2 (LEED-NC v2.2). This project will be the first MHS hospital that incorporates both EBD and LEED. Also, as required by the U.S. Army, the hospital has a goal of attaining LEED Silver level certification. The impact of these sustainable policies and regulations on the project is significant. Without these driving forces working simultaneously to enhance sustainability through maximizing energy efficiency and reducing land impacts and storm water run-off, as well as minimizing construction waste, the project’s effect on land use would be much more demanding. The following section describes each of these major policy drivers for the hospital.

i. EPAct

The EPAct sets energy efficiency performance standards for the construction of all new federal buildings. This mandate requires all federal facilities to reduce energy use 30% below the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standard 90.1-2004 (minimum code compliance). Many of the energy-saving measures needed to accommodate this law can be achieved in a variety of building types through energy load shedding, reduction of HVAC, and electrical consumption in off-hours (evenings, nights and weekends) as well as on-site renewable energy sources, as available. Numerous challenges are associated with this law as it applies to healthcare, however. For example, hospitals, as a building type, generally do not receive the benefit of off-hour energy reduction, as they must remain in continuous operation. In order to meet EPAct standards, this particular case study, FBCH, uses strategies such as high efficiency variable speed drive (VSD) chillers, multistack heat recovery chiller systems used for reheating, high efficiency wall and window construction, and lighting design that employs a sophisticated daylight harvesting system or motion sensors.

ii. LEED

The USGBC LEED-NC v2.2 is a tool that measures and certifies the sustainability of a building. The goal for FBCH is to achieve LEED NC v2.2 ® Silver certification while maintaining focus on project objectives, schedule and cost impacts. To accomplish this goal, the hospital must meet all of the LEED prerequisites and achieve at least 33 credit points. The LEED rating system has six categories: Sustainable Sites, Water Efficiency, Energy and Environment, Materials and Resources, Indoor Environmental Quality and Innovation in Design. Although each of these categories has a potential positive impact on the calculation of the ecological footprint, this particular study considers the impact of the LEED rating system using three general categories: site development, construction waste management and energy efficiency measures. Compared to EPAct, LEED cost savings are based on total annual energy costs, whereas EPAct energy savings are based on regulated energy use only (i.e., EPAct does not include energy use associated with computers, elevators, process energy, and other miscellaneous receptacle loads).

iii. EBD

EBD promotes the importance of creating a healing environment, that is, “one that is safe, comfortable, and supports the patient, the patient’s family, and the staff“ (MHS). Using scientific evidence and trial studies, the MHS has developed five EBD principles that have a clearly defined and demonstrable positive impact on patients, staff, the natural environment and resource outcomes. These EBD principles have been integrated into the design of the community hospital at Fort Belvoir. The project design follows the five EBD principles to provide:

- A patient- and family-centered environment
- Enhanced care of the whole person
- Improved quality and safety
- A positive work environment
- A design that provides maximum standardization

As the design has progressed, three overarching themes have emerged: honoring military service and the nation's history, caring for the nation’s veterans, and enhancing access to nature. Although all three themes find expression in the design, the theme of enhancing access to nature offers the opportunity to reduce stress, provide positive expression, facilitate the healing process and provide environmental benefits. Some EBD elements of the project that support the natural environment are: healing gardens, a green roof, low-emitting materials, and individual light and thermal controls that have a direct impact on the ecological footprint through either energy use reduction or land development impact.

II. EVALUATION METHODS AND RESULTS

1. Methodology used to Evaluate Impacts of Land Development

Site Design

The project is sited on 60 acres of land. Its major components include a hospital campus, parking garages, central utility plant and requisite parking lots and access roadways. A rough calculation of the area of the site outside the building footprint is 49 acres (19.8 ha). Hardscape and other impervious surfaces make up approximately 18.6 acres (7.5 ha) of this space, which is four times the amount of impervious areas when compared to the pre-development conditions of 4.5 acres (1.8 ha). Specific types of impervious surfaces included are in Table 2.

Table 2 Site Calculations Habitat Restoration

	Area (acres)	**Area (ha)**	
Total Site Area	60.7	24.60	*Site Area= Approximate based on civil limits of disturbance and LEED boundary
Total Building Footprint	11.8	4.80	Based on civil baseline
Total Site excluding Bldg	***49***	***19.80***	
Roads/ Parking Hardscape	15.5	6.30	Total includes entire parking area (including LID planting strips, hardscape pedestrian areas in front of hospital, and islands in road)- This estimate is conservative
Helipad	0.23	0.01	
Grass Pave Fire Lanes	0.78	0.30	Grass pave w/non-native grass
Courtyard and Trial Hardscape	2.1	0.90	Based on cost estimate10/17/08
Total Hardscape Estimate	***18.61***	***7.51***	
Total Restored with Vegetation	30	12.29	
Total Non-native Vegetation	0.01	0.00	Bamboo
Total Area Restored	***30***	**12.29**	
Percentage of Site Restored to Native Vegetation Excluding Building Footprint	**62%**		

The landscape design incorporates the diversity of flora native to the mid-Atlantic region and, in particular, to the Virginia Piedmont/Coastal Plains areas. The entire site will be planted with native species, including trees, shrubs, perennials, groundcovers, and large swaths of native meadows, all considered to be bioproductive. That is, the planted areas consist of 99% native and adaptive species; and the design outside of the building footprint is comprised almost entirely of native/regional vegetation. Such plantings will restore local species to the site and reduce irrigation needs. Approximately 30 acres, or 62%, will be restored site areas. The exceptions include a couple of small groves of bamboo that cover approximately 675 square feet, which is considered insignificant for this study.

The landscape design will also help to mitigate storm water run-off and absorb impurities generated from the site. One of the project's sustainable goals is to implement a storm water management plan that prevents the post-development discharge rate and quantity of water from exceeding pre-development conditions. Various strategies were implemented to achieve this goal. For example, the green roof system is capable of holding and treating storm water run-off and helps to absorb CO_2 emissions. More than 35,000 square feet of green roof will be visible from the in-patient tower bed. In addition, rain gardens and river rock beds will retain storm water as well as slow it down to allow it to percolate slowly into the ground surface. Parking lots designed with a curbless gutter system will direct water into depressed planting areas for filtration. Permeable paving in parking spaces will further reduce storm water run-off and minimize the heat-island effects of the hardscape.

The method used to calculate the ecological footprint from land development is called the built-up calculation method. This calculation assumes that building construction and infrastructure occupy agricultural fertile regions. In most studies, built-up areas are calculated using the land's potential productivity of prime agricultural land.[13] Only impervious surfaces are counted as part of the built-up area because the footprint includes those areas in terms of their foregone bioproductivity.[14] Other areas of the project, such as the healing gardens, are still considered bioproductive. In this study, the equivalency factor is used to reflect the unique ecosystem of the mid-Atlantic region based on the same equivalency factor that is used for temperate forest landscapes (1.4 Gha/ha). The yield factor is set at 1.0, assuming simply that the productivity of a forest is roughly equivalent to that of the global average. Table 3 outlines the land development footprint calculation method for built-up areas.

Table 3 Land Development Footprint Based on Built-up Land Calculation Method

Calculation Formula:

Footprint: built-up (gha) = area built-up (ha) x equivalency factor (gha/ha) x yield factor

Footprint Built-up	**Calculation**	**Results**
Pre-development	1.8 (ha) x 1.4 (gha/ha) x 1	**2.52 ha (6 acres)**
Current design	7.5 (ha) x 1.4 (gha/ha) x 1	**10.5 ha (26 acres)**
Traditional construction method *(status quo)*	15 (ha) x 1.4 (gha/ha) x 1	**19 ha (47 acres)**

Based on the built-up calculation method, the FBCH project would require 26 acres of bioproductive land in addition to 30 acres of the restored site area to offset its development impact, as currently designed and constructed. If traditional construction methods were used, presumably most of the landscape would be planted simply with turf grass, areas such as courtyards or access roads would be mainly impervious and green roofs and low impact development strategies would not be implemented. Such construction methods would change the dynamics of the site, affecting not only storm water run-off but also the site's bioproductivity. In addition, the project's impervious areas would double from 7.5 ha to 15 ha. A traditional construction method or *status quo* level design would increase an ecological built-up footprint to 47 acres. This built-up footprint from traditional construction methods equates to about a 50% increase over the current design method.

Figure 2 compares three distinct conditions for land development footprint impacts: pre-construction, post-construction based on the current design, and post-construction based on typical construction methods (or, the *status quo*).

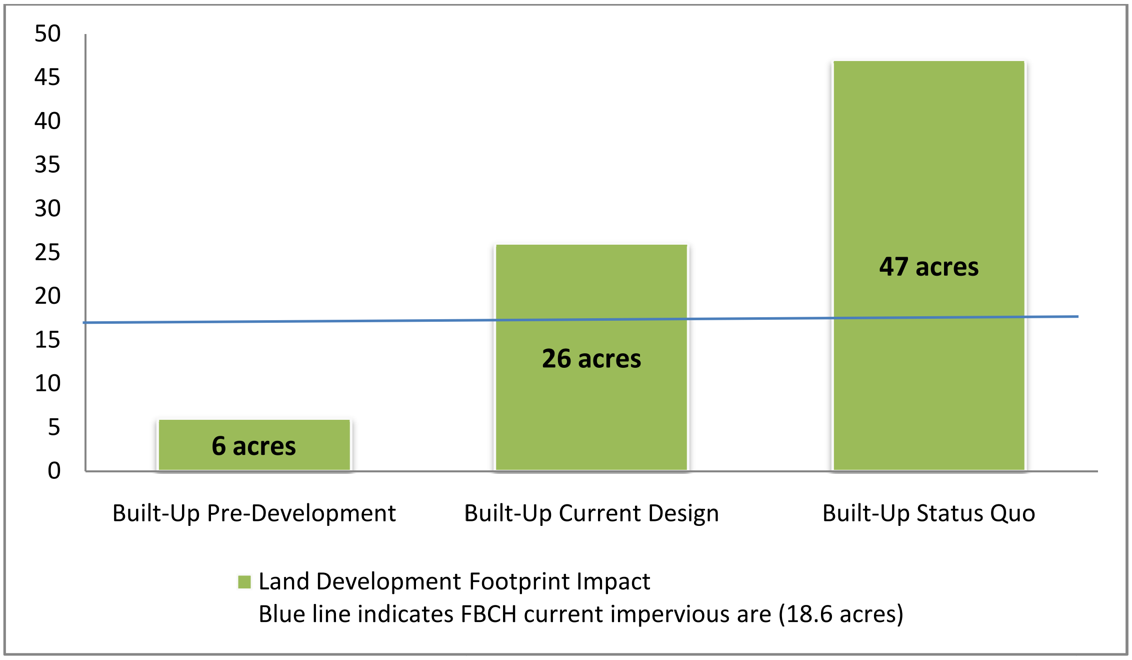


Figure 2 Land development footprint impact from built-up land

Figure 2 also provides a comparison of the land development footprint method to the actual FBCH hardscape area (blue line) estimated in Table 2 Site Calculations Habitat Restoration.

2. **Construction Waste Management Benefit Analysis**

The impact of waste generation on the environment is significant. The U.S. construction industry generates 2.5 pounds of solid waste per square foot of floor space. The ecological footprint of waste generation is the measurement of biologically productive land (fossil energy land, forest, pasture, built-up areas, etc.) needed to assimilate the generated waste.[15] In this study, the overall waste produced due to the case project's construction is measured against construction waste diverted from landfill disposal. Specifically, waste reduction is measured based on non-hazardous solid waste diversion from landfill disposal, which is the result of a comprehensive construction waste recycling program for the project. The construction waste management goal initially set for this project was to recycle and/or salvage 75% of non-hazardous construction and demolition debris (based on LEED Materials & Resources requirements for Credit 2, titled Construction Waste Management). The environmental assessment of waste reduction is comparable to that of more traditional construction methods. FBCH will also provide for an extensive infrastructure to support tenant level recycling; however, waste reduction from the hospital's operations is not included in this study because it is difficult to estimate how much potential waste will be generated in the future. Additional analysis could be conducted once the project's construction is completed and the hospital is in operation.

The project is using an off-site waste separation method for wood, cardboard, paper, aggregate and metals. As outlined in the Construction Waste Management Plan, this process will be expanded to include other materials as construction progresses. To date, the total waste diverted from landfill disposal is 559 tons, or 93%; that is, only about 7% (46 tons) of overall construction waste is not being recovered. The specific percentages of waste recycled according to category are shown in Figure 3.

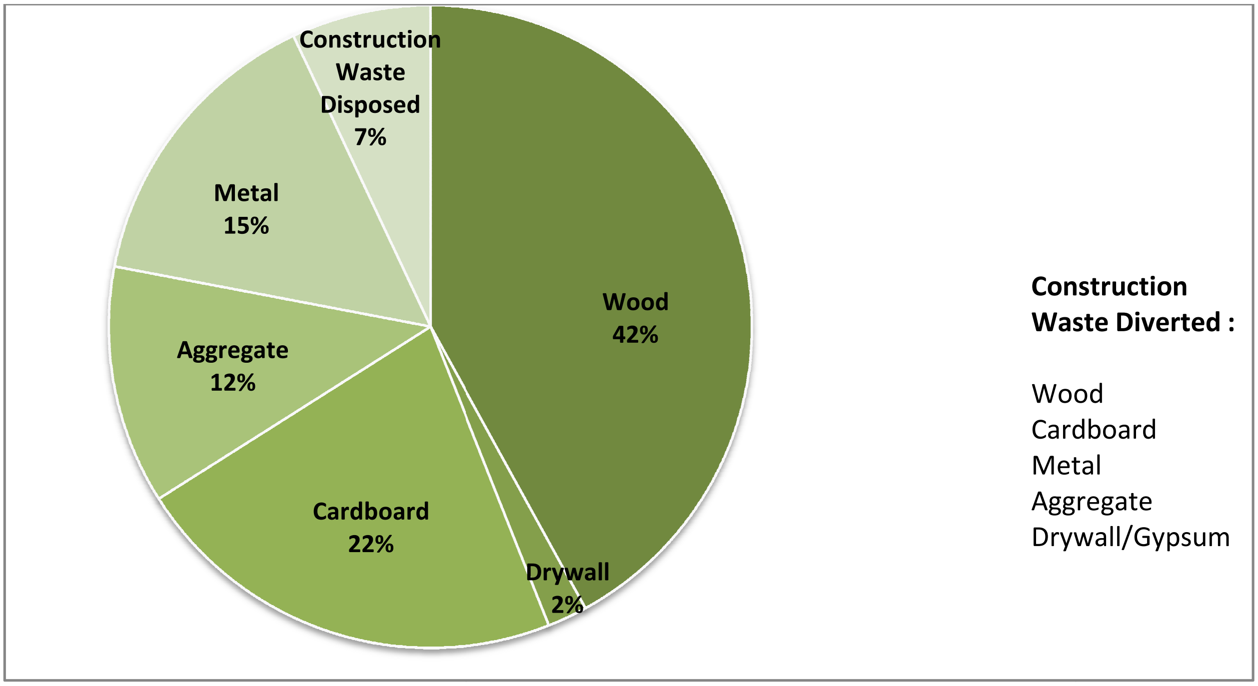


Figure 3 Construction Waste by Percentage

The majority of the waste recycled to date comes from wood-related products and cardboard (total of 64%). A breakdown if waste recycled according to weight is shown in Table 4 below.

Table 4 Construction Waste Management Report Summary

		Construction Waste Management Data Summary 2009 & Prior Total		
	Material	**Total Waste in Tons**	**Total Diverted in Tons**	**Diverted % of Total Waste**
1	Aggregate	**71.84**	**71.84**	**12%**
2	Drywall / Gypsum	**14.6**	**14.6**	**2%**
3	Cardboard / Paper	**129.99**	**129.99**	**22%**
4	Wood	**251.28**	**251.28**	**42%**
5	Ferrous Metals	**91.08**	**91.08**	**15%**
6	Trash	**46.68**	**46.68**	**0%**
Total		**605.05**	**558.82**	**93%**

The ecological footprint for waste generation means the measurement of biologically productive land (fossil energy land, forest land, pasture land, built up area etc) to assimilate the generated waste.[16] The methodology utilized to calculate the resource consumption and waste generation was developed by Mathis Warckernagel, Ritik Dholakia, Diana Deumling and Dick Richardson, Redefining Progress v 2.0, March 2000. Although this paper excludes ecological footprint for waste generation calculations due to a lack of sufficient data, general procedure for approaching this topic is outlined below. The information listed below is referenced from "Ecological footprint of Waste Generation: A Sustainable Tool for Solid Waste Management of Khulna City Corporation of Bangladesh" study by Dr. Salequzzaman.

Generalized procedure for ecological footprint waste generation method:

- The sum of the land requirements for the six individual land categories represents the community's ecological footprint.

- The methodology presents all results in per capita figures. Multiplying the per capita data by the selected area's population gives the total footprint of that area.
- The EF is expressed in land "area units" (in hectares) where each area unit corresponds to one hectare of biologically productive space with world-average productivity.
- To calculate the ecological footprint of waste generation, the generated waste is categorized as paper, plastic, glass, metal, aluminum and organic waste.

3. Greenhouse Gases and Contaminants Measurements

In order to define the reduction of greenhouse gas emissions for the project, three major calculation methods were performed: a whole building energy model analysis,[17] the sustainable return on investment method,[18] and the carbon ecological footprint calculation method. The energy percentage of cost savings is based on total annual energy costs when compared to the baseline building performance rating per ASHRAE/IESNA Standard 90.1-2004. In order to demonstrate a percentage improvement in the building performance rating, a whole building project was stimulated.

(a) Building Energy Consumption Study – Whole Building Energy Model

The whole building energy model is used to determine the energy baseline and operating impacts for the hospital. This method includes a comprehensive energy analysis and assessment of the building's systems and configuration. Many of the inputs used to define greenhouse gas emissions were derived directly from this model. The process of identifying energy efficiency and conservation measures relies on the following three-step strategy, which is applied to optimize and fully capitalize on the associated savings and emphasis on waste reduction.

- Minimize building loads. Improve the building envelope, reduce lighting power density and usage, incorporate suitable daylighting techniques, reduce equipment power density and usage, and reduce water consumption flow rates.
- Improve system effectiveness. Improve HVAC system design, increase motor efficiency, utilize solar heating technologies, incorporate energy recovery technologies, and utilize applicable control strategies.
- Optimize resource delivery. Provide renewable energy generation, incorporate energy storage techniques, increase the efficiency of the plant, review utility rate options, and investigate district heating and cooling options.[19]

This method of evaluation closely follows the guidelines stipulated by the USGBC's LEED® design approach and ASHRAE/IESNA 90.1-2004 Performance Rating Model (PRM). A building model is established based on the code compliance minimum requirements of the ASHRAE standard 90.1-2004. The energy modeling effort also includes the development of a design level model of the building, which is used to determine the energy baseline and operating impacts for the hospital. For the purpose of this study, two alternatives were compared to an ASHRAE baseline PRM:

1) An "as designed" model of the building with updates, herein known as the Design Energy Cost (DEC) model and,
2) A model that reflects energy measures needed to meet the 30% energy use reduction required by EPAct 2005, herein known as Current Design 30%.

The delta between these two assessments determines the difference between the project's reduction in energy use for the building and that of the industry standards (base model). The energy percentage of cost savings is based on total annual energy costs when compared to the ASHRAE standards. The following alternative was compared to the PRM: an “as designed” model of the building with updates, herein known as the Current Design with Updates. In total, six energy efficiency components were assessed:

- Windows
- Rain screen (curtain wall) system
- Roof systems: R-20 roof, Zone 4A and green roof, Zone 4B
- Lighting controls with photocells and occupancy sensors
- High efficiency variable speed chillers
- Multistack heat recovery chiller system used for reheating

For the energy end-use breakdown information between the DEC and PMR models, refer to Figure 6 and Figure 7 in the Appendix. The current design offers 14.6% more energy cost savings than the ASHRAE PRM or 25% more energy cost savings based on the regulated energy savings calculation, as directed by the EPAct Standard. If calculations are based on regulated energy use, then due to the project’s energy efficient design, savings are about 23,337 MBtu per year, which is equal to an annual energy cost reduction of $349,494 (Table 5). The aggregate virtual utility rates for this facility, as calculated by DOE-2.2, are $0.0811/kWh and $1.4958/therm.[20]

Table 5 Whole Building Energy Model Summary of Results

Case	**Annual Energy Cost**	**% Cost Savings (LEED)**	**% Regulated Energy Savings (EPAct)**	**Annual Energy Cost savings**
ASHRAE Baseline (PMR Model)	$2,393,575	0%	0%	0
Current Design (DEC Model)	$2,044,081	14.6%	25.0%	$349,494
Current Design with Improvements Required to save 30% Regulated Energy ("Current Design 30%").	$1,858,549	22.4%	30.6%	$535,026

The comparison of the two building models against the PRM also provides the percentage of saving, as determined by LEED and EPAct (reflected as the percentage of regulated energy savings). The annual energy reduction calculation further serves as a basis for determining the reduction in greenhouse gas emissions associated with energy use. A comparison of emissions impacts for the project is based specifically on energy percentage savings and is investigated in the following section.

(b) Sustainable Return on Investment (SROI)

HDR's Sustainable Return on Investment (SROI) process was used to provide a Life Cycle Cost Analysis (LCCA) for the case project. The energy percentage of cost savings was used to calculate the tons of CO_2 emissions avoided. The SROI process incorporates risk analysis and goes even further to provide a triple bottom-line view of a project's economic results. This financial/economic analysis also monetizes all social and environmental impacts related to a given project. The value of hidden costs and benefits, such as changes in greenhouse gases and air contaminant emissions, health and safety effects or productivity, etc., can be captured in this process and then used in decision making. The added monetary value of sustainable strategies, such as saving water and reducing greenhouse gases and other pollutants, is otherwise impossible to appreciate simply by looking at utility bills. Capturing the impact of externalities (benefits to society), especially when calculating the emissions component of the ecological footprint, is needed later in the process when the carbon ecological footprint is calculated.

An integral part of the SROI process is a Risk Analysis Process (RAP) session, similar to a one-day charrette. The RAP session for this case project was conducted February 24, 2009. All key stakeholders were brought together to develop and reach consensus on the inputs and calculations used in the model. Once these inputs were agreed upon risk analysis and Monte Carlo simulation techniques were used to account for uncertainty in both the input values and model parameters. These techniques are based on a 25-year economic simulation model. The model indentifies all the costs and benefits associated with the hospital's conservation measures. The results indicate that the energy conservation measures proposed in the Current Design with Updates alternative have the lowest life-cycle costs when compared to standard construction (the PRM). That is, the energy savings ascribed to this alternative are sufficient to warrant their initial capital costs and their ongoing operational, maintenance and replacement costs, and represent $1.8M in net savings. However, to achieve the required 30% energy reduction (the goal established by EPAct) will require additional capital investments of almost $20M, which cannot be offset by the energy savings produced. Table 6 provides a thorough summary of the study's key risk-adjusted outputs.

Table 6 Financial Metrics

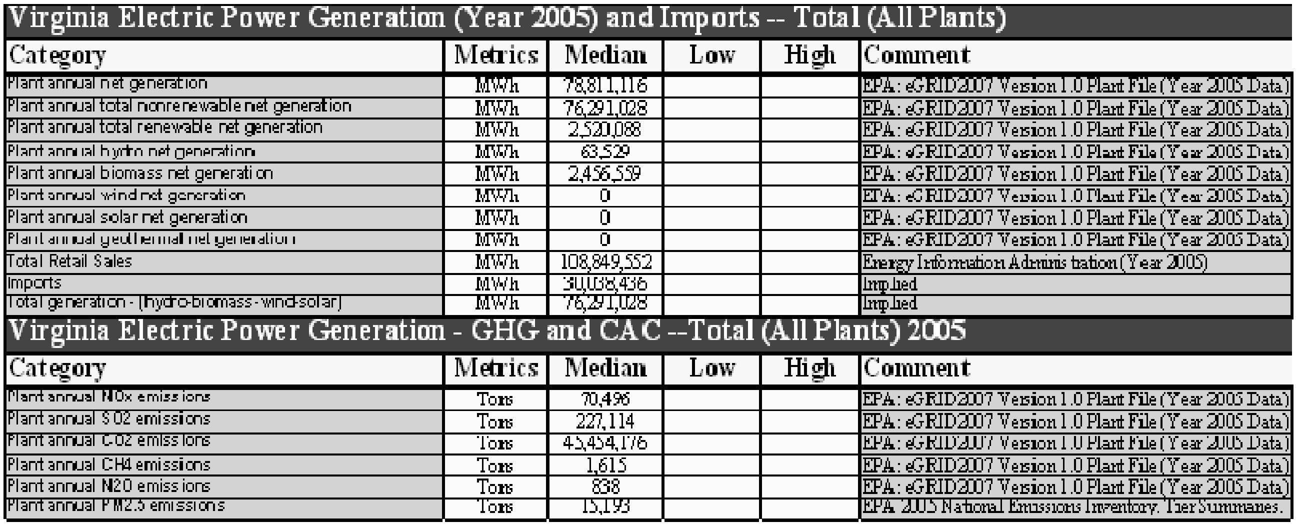
SROI	Current Design with Updates	Current Design 30%	Notes
Annual Value of Benefits	$930,485	$1,232,955	The total value of the benefits in one year
Energy Reduction	*369,591*	*565,600*	Incremental relative to PRM model
Water Reduction	*80,039*	*80,039*	Incremental relative to PRM model
Greenhouse Gases Savings	*97,924*	*119,991*	Incremental relative to PRM model
Air Pollutants Savings	*374,844*	*459,315*	Incremental relative to PRM model
Savings From Reduced Water Use - Economic Value	*8,088*	*8,088*	Incremental relative to PRM model
Net Present Value	$10,193,620	-$7,360,988	PV Benefits - PV All Costs
Return on Investment	27%	1%	Arithmetic average rate of return on capital investment
Discounted Payback Period	6	N/A	Time in years until positive discounted cash flow
Internal Rate of Return (%)	23%	2%	Discount rate that would make NPV = 0
Benefit-to-Cost Ratio	3.3	0.7	PV Benefits / PV Costs

Note:
All dollar figures are in thousands of U.S. dollars.
SROI = Sustainable Return on Investment calculations (includes health plus externalities)
FROI = Financial Return on Investment calculations (traditional cash return)
PV = Photovoltaic

Table 6 also provides the mean expected SROI results, i.e., those that correspond to the triple bottom line. The benefits that are included in the calculation of these metrics include real cash benefits, non-cash benefits and externalities. The results clearly show that, after accounting for externalities, FBCH's energy and water conservation measures are effective when the Current Design with Updates alternative is compared to the PRM. However, the net value of the benefits (including externalities) is not sufficient to cover the high cost of measures that would be required to reach the 30% energy use reduction threshold. Although this paper does not focus on financial metrics, it is worth noting that reductions in carbon emissions and energy conservation measures help to account for the annual value of benefits and overall return on investments for the building. The findings also suggest that the Current Design with Updates alternative is beneficial based on a traditional LCCA and even better from a triple bottom-line perspective, whereas the Current Design 30% alternative fails to recover the major additional capital requirements.

Quantifying input assumptions and assigning risk ranges also help define non-financial metrics, such as greenhouse gases and air pollutants. The process by which greenhouse gas emissions are calculated starts with the energy model described in Section II.3.a. Energy efficiency savings (23,337 MBtu) serve as a basis to establish the tons of carbon reduced. This information is based on the EPA listing for Virginia Electric Power Generation per year for MWh hour electricity produced in Virginia, as shown in
Table **7**. The breakdown includes information such as where this energy is actually produced (box 1); it also shows emissions from that generation. Based on this information, the amount of incremental NO_2 and CO_2 that is being produced per incremental MWh in Virginia can be determined. The CO_2 annual emissions avoided are based on the U.S. EPA eGRID, a data support tool that produces labeling/environmental disclosures. Table 7 shows an example of Virginia’s electric power generation information. These are being used to determine CO_2 emission for the project based on MBtu’s used by the facility.

Table 7 eGRID Virginia Electric Power Generation Information[21]



Virginia Electric Power Generation (Year 2005) and Imports -- Total (All Plants)

Category	Metrics	Median	Low	High	Comment
Plant annual net generation	MWh	78,811,116			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual total nonrenewable net generation	MWh	76,291,028			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual total renewable net generation	MWh	2,520,088			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual hydro net generation	MWh	63,529			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual biomass net generation	MWh	2,456,559			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual wind net generation	MWh	0			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual solar net generation	MWh	0			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual geothermal net generation	MWh	0			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Total Retail Sales	MWh	108,849,552			Energy Information Administration (Year 2005)
Imports	MWh	30,038,436			Implied
Total generation - (hydro-biomass - wind-solar)	MWh	76,291,028			Implied

Virginia Electric Power Generation - GHG and CAC --Total (All Plants) 2005

Category	Metrics	Median	Low	High	Comment
Plant annual NOx emissions	Tons	70,496			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual SO2 emissions	Tons	227,114			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual CO2 emissions	Tons	45,454,176			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual CH4 emissions	Tons	1,615			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual N2O emissions	Tons	838			EPA : eGRID2007 Version 1.0 Plant File (Year 2005 Data)
Plant annual PM2.5 emissions	Tons	15,193			EPA 2005 National Emissions Inventory. Tier Summaries.

Finally, the total annual emissions avoided, presented in Table 8 can be used later to determine the demand on bioproductive areas to offset CO_2 emissions. The footprint therefore includes the biocapacity of, in our case, unharvested forests, which are needed to absorb that fraction of CO_2 and other greenhouse gases that are not absorbed by the ocean.

Table 8 Annual Emissions Avoided FBCH

Annual Emissions Avoided	Current Design	Notes
Tons of CO_2	3944	The number of tons of carbon dioxide avoided based on the energy savings due to the project's sustainable strategies. (23,337 MBtu/year)
Tons of CH_4	0.14	The number of tons of methane avoided based on the energy savings due to the project's sustainable strategies.
Tons of NO_2	0.07	The number of tons of nitrous oxide avoided based on the energy savings due to the project's sustainable strategies.
Notes: Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2) are considered greenhouse gases		

4. Ecological Footprint Analysis Methodology and Results

How does the ecological footprint account for the use of fossil fuels?

"The carbon footprint is calculated by estimating how much natural sequestration is necessary in the absence of sequestration by human means. In 2005, for example, 1 global hectare could absorb the CO_2 released by burning approximately 1,450 liters of gasoline."[22]

The emissions component of the ecological footprint defines the amount of nature's minimum regenerative capacity that is required to take carbon back out of the atmosphere. The Waste Assimilation Method was used to calculate the area of land needed to absorb the difference in CO_2 emissions between the current design and the status quo, or minimum code compliance design.

The sequestration rate used in this method defines the amount of carbon stored due to non-anthropogenic means. For the purpose of this exercise, the sequestration rate used is equivalent to that of a temperate forest landscape. This type of landscape is common in Northern Virginia where FBCH is located. The amount of carbon stored per hectare of a temperate forest landscape is equal to about 100 metric tons. The sequestration rate here is presumed to be the annual rate for these forests equal to 1.0 ton/ha/year. Further, the calculation method also takes into consideration the fraction of CO_2 absorbed by the ocean. Because of its solubility and chemical reactivity, CO_2 is absorbed by the ocean much more effectively than other anthropogenic gases, e.g., chlorofluorocarbons (CFCs) and CH_4.[23] The sequestration area is calculated by deducting about one-third of the anthropogenic emissions absorbed by the ocean from the total anthropogenic emissions. For this project, the amount of carbon avoided due to energy efficiency measures and other factors is 3,944 tons/year (Table 8). That is, if the project were developed using traditional design and construction methods, it would emit an additional 3,944 tons of CO_2 per year. Table 9 Waste Assimilation Method illustrates the waste assimilation method that calculates the reduction in area of land needed to absorb the difference in CO_2 emissions between the current design and the energy conservation measures proposed in the Current Design with Updates alternative.

Table 9 Waste Assimilation Method

Calculation Formula:

Area (ha) = CO_2 Emission (tons) x (1-fraction absorb by ocean) / Sequestration Rate (tons/ha)

CO_2 Emission Footprint	**Calculation**	**Results** (land impact reduced)
Based on **25%** Energy Use Reduction (DEC model)	3,944 tons/year x (1-0.33)/1	2,603 ha (**6,432 acres)**
Based on **30%** Energy Use Reduction (current design w/updates)	4,832 tons/year x (1-0.33)/1	3,192 ha (**7,902 acres)**

Waste Assimilation Method can be used to extrapolate the impact of greenhouse gas emissions from the area of land needed to absorb the CO_2 emissions based on the status quo PRM. If a similar calculation method were used, the baseline building performance rating per ASHRAE/IESNA Standard 90.1-2004 would require a total of 26,000 acres of bioproductive land to offset the CO_2 emissions from the hospital and to take carbon back out of the atmosphere through the process of natural sequestration (Figure 4).

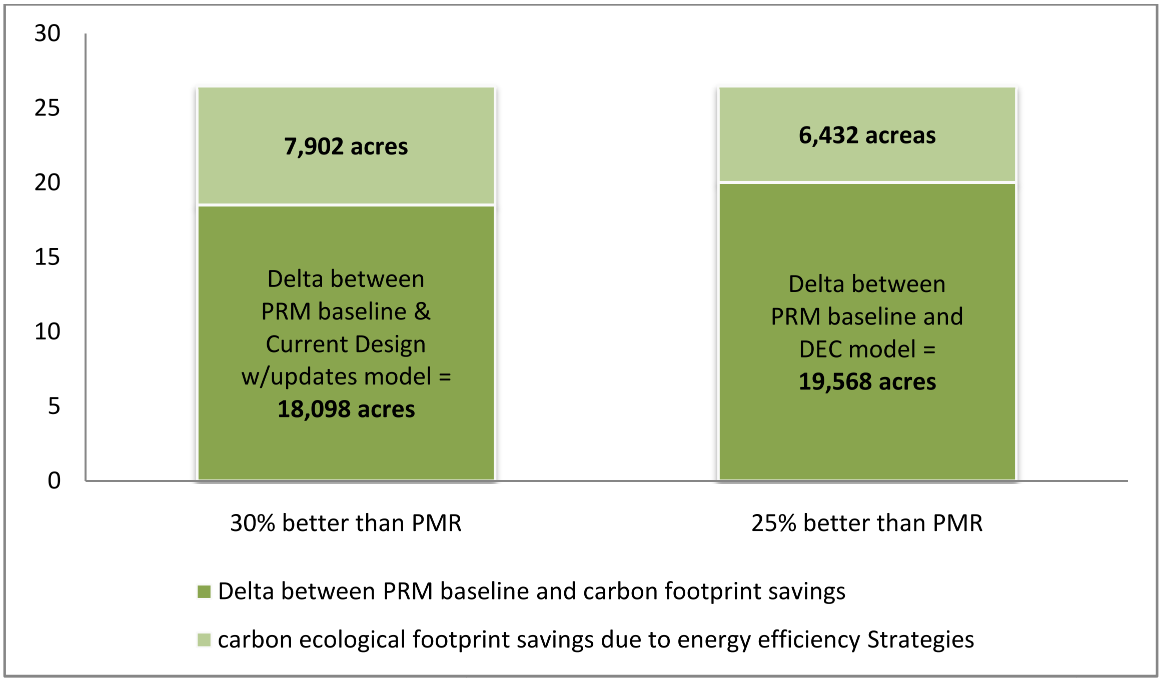


Figure 4 The Ecological Carbon Footprint: Land Needed to Absorb the Difference in CO_2 Emissions.

The current design model (DEC) requires that 19,568 acres (7,919 ha) of bioproductive land must be absorbed from CO_2 emissions. This number is reduced even further, by about 1,470 acres (595 ha), if the energy efficiency for the project is increased to 30% better than the PRM baseline. The waste assimilation method suggests that the ecological footprint due to CO_2 emissions from the hospital is more than 320 times larger than the project's actual site footprint; this area corresponds to a bioproductive land area that is equal in size to one-half of the land area of Washington, DC, as defined by the District of Columbia city limits. Such a calculation is based solely on energy-efficient strategies implemented at FBCH.

III. CONCLUSIONS

An ecological footprint assessment helps to establish a common language for defining sustainability and, unlike other methods, can be a powerful tool for engaging the general public in sustainability awareness. If carefully used, footprint analysis can also prove to be an aid to policy-making. The federal government is in an especially unique position to impact national policy changes and is now poised to affect new national policy changes.

An ecological footprint analysis can also be used to inform future design by encouraging restorative site planning developed to maximize the ecological capacity of a site and ensure proper selection of construction methods to increase its ecological efficiency.

Future focus also needs to be on potential adverse effects from greenhouse gas emissions and other pollutants from energy generation activities. Although improved energy efficiency is gaining much needed attention, more work must be done, especially in energy-intensive industries such as healthcare. The US EPA website states, “If hospitals improved their energy efficiency by an average of 30 percent, the annual electricity bill savings would be nearly $1 billion and 11 million fewer tons of carbon dioxide would be emitted.”[24] This study concurs with the EPA’s statistics; the main impact on land biological capacity comes from energy generation activities and related CO_2 emissions. Other demands on the biocapacity that are required to offset built-up areas or waste are insignificant in comparison to the ecological carbon footprint.

In addition to quantifiable impacts on the environment, qualitative impacts, such as social justice and equitable energy use, are likewise critical considerations. Accommodating North America’s enormous ecological footprint is no longer acceptable and is not sustainable.

It is mainly western countries that experience an ecological deficit, thus shifting ecological demands for natural resources to undeveloped regions and depleting natural capital, mainly in the southern hemisphere. The potential effects on social as well as environmental structures suggest that investing in technology and infrastructure to allow the design, construction and operation of complex buildings, such as hospitals, in a resource-constrained world must happen now.

IV. FIGURES

Figure 5 FBCH site plan. *Image made available by HDR Inc.*

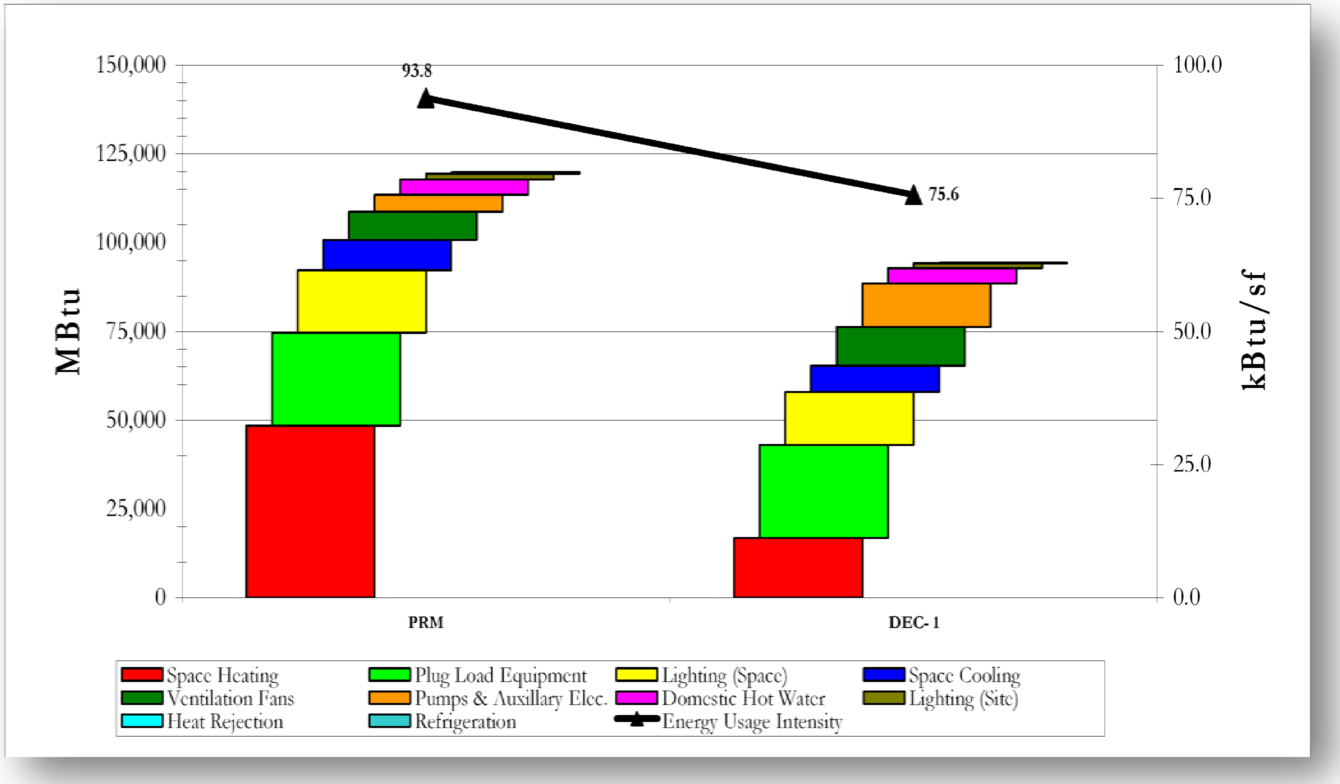
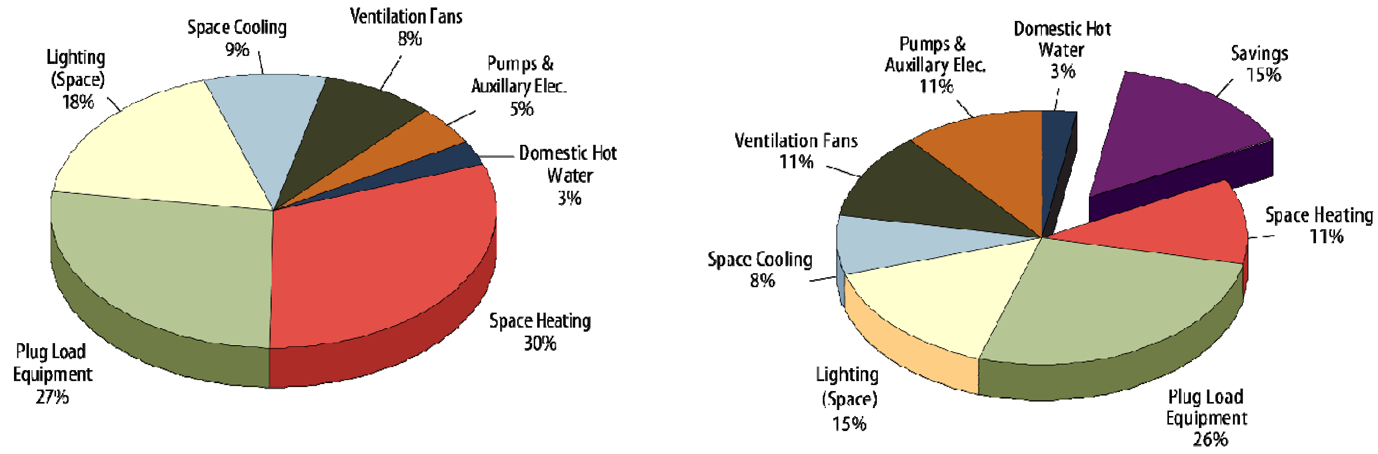


Figure 6 Energy End-Use Breakdown between the DEC and PRM Modeled Facility. *Image made available by EMO Solutions.*

The energy cost breakdown is shown by end use.
Based on the *FBCH Energy Report* by EMO Solutions LLC, August 7, 2008



Cost Breakdown by End Use	**Cost Breakdown by End Use**
PMR – ASHRAE Baseline Total cost: $2,393,575/year Normalized Cost: $1.8808/sf/year	DEC – Building As-Designed Total cost: $2,045,098/year Normalized Cost: $1.6070/sf/year

Figure 7 Total Annual Energy Cost by End-User and Total Savings. *Image based on graph developed by EMO Solutions LLC.*

The total energy cost is represented by resource. Based on the *FBCH Energy Report* by EMO Solutions, August 7, 2008

V. APPENDICES

Appendix A: FBCH Energy Model Summary EMO Energy Solutions, LLC (June 5, 2008)

Based on: “Analysis of Performance Rating Method DD Whole Building Energy Model Analysis & LEED®-NC VER 2.2 Energy & Atmosphere Credit 1 Calculations, Fort Belvoir Community Hospital.”

EMO Energy Solutions, LLC (EMO) has performed a whole building energy model, comprehensive energy analysis, and assessment of building systems and configuration for the proposed Fort Belvoir Community Hospital in Fort Belvoir, Virginia. This report covers the results of the energy modeling effort and is based on drawings dated February 1, 2008

The energy modeling effort includes development of an “as designed” model of the building, which in LEED® terminology, is the called the Design Energy Cost (DEC) model. EMO also developed a building model based on the minimum requirements of the ASHRAE standard 90.1-2004. This model is called the Performance Rating Method (PRM) model. The comparison of the results of these two building models provides the percentage savings that will determine the number of LEED® for New Construction version 2.2 Energy & Atmosphere (EA) Credit 1 point that can be achieved by the project. In addition, this building was analyzed to determine savings associated with the 30% regulated energy use reduction required by EPACT 2005.

The current design saves approximately $153,971/yr (6.4%) when compared to the ASHRAE PRM Baseline. This meets EA Prerequisite 2 for New Construction projects registered before June 26, 2007 and earns 0 EA Credit 1 points. The design saves approximately 12,659.2 MBtu (13.5%) and falls well below the EPACT 30% requirement.

EMO and HDR identified three potential energy efficiency opportunities for this building: VSD Chillers, Heat Recovery, and Lighting Power Reductions to average 1.0 W/sf. The current design with these energy improvements saves approximately $439,748 / yr (18.4%) when compared to the ASHRAE PRM Baseline, meeting EA Prequisite 2 for New Construction, earning 3 EA Credit 1 points and creating a regulated energy use savings of 24,483.4 MBtu (26.2%), falling short of the 30% requirement.

EMO identified measures in addition to those previously described that would be required to reach the 30% regulated energy use reduction threshold, although we believe these measures would be very difficult to achieve. The measures include: Reducing Fan Powers to ASRHAE maximum levels, Lighting Power Reductions to average 0.9 W/sf. These improvements in addition to those previously listed save approximately $535,026/yr (22.4%) when compared to the ASHRAE PRM Baseline, meeting EA Prerequisite 2 for New Construction, earning 4 EA Credit 1 points and creating a regulated energy use savings of 28,596 MBtu (30.6%), meeting the 30% requirement.

Summary of Results

Case	Annual Energy Cost	% Cost Savings	% Regulated Energy Savings	LEED-NC EAc1 Points
ASHRAE Baseline	$2,393,575	--		--
Current Design	$2,293,604	6.4%	13.5%	0
Current Design with Recommended Improvements	$2,048,014	18.4%	26.2%	3
Current Design with Improvements Required to save 30% Regulated Energy Use	$1,858,549	22.4%	30.6%	4

FBCH ENERGY MODEL MEMORANDUM

Date: July 27, 2008
Re: Fort Belvoir CH Energy Model Update

Building Performance Summary

EMO Energy Solutions, LLC (EMO) has performed a whole building energy model, comprehensive energy analysis, and assessment of building systems and configuration for the proposed Fort Belvoir Community Hospital in Fort Belvoir, VA. EMO issued a report dated June 5, 2008 and has provided updates to the model as requested by HDR and described in this memo. These updates include: changes to the section C reheat system and inclusion of Multi-stack heat recovery chillers, VFD chillers, lighting improvements based on current design.

The energy modeling effort includes development of an “as designed” model of the building, which in LEED® terminology is the called the Design Energy Cost (DEC) model. EMO also developed a building model based on the minimum requirements of the ASHRAE standard 90.1-2004. This model is called the Performance Rating Method (PRM) model. The comparison of the results of these two building models provides the percentage savings that will determine the number of LEED® Energy & Atmosphere credit 1 points that can be achieved by the project. In addition, this building was analyzed to determine savings associated with the 30% regulated energy use reduction required by EPACT 2005.

The current design saves approximately $349,494/yr (14.6%) when compared to the ASHRAE PRM Baseline. This meets EA Preq. 2 for New Construction projects registered before June 26, 2007 and earns 2 EA Credit 1 points. The design saves approximately 23,337 MBtu (25.5%) and falls below the 30% requirement. Based on this analysis, EMO believes the project should track between 1 and 2 points under
EAc1 of LEED-NC v2.2.

Summary of Results

Case	Annual Energy Cost	% Cost Savings	% Regulated Energy Savings	LEED-NC EAc1 Points
ASHRAE Baseline	$2,393,575	--		--
Current Design with Updates	$2,044,081	14.6%	25.5%	2

<u>Description of Model Updates</u>

EMO has updated its initial energy model for Fort Belvoir Community Hospital (6/5/2008) based on comments during a review meeting conducted 6/16/2008 and additional information provided by HDR. Updates to the energy model included the following.

1. Section C of the building is supplied with a separate reheat loop with a 130ºF EWT. This loop is supplemented by a Multi-stack chiller heat recovery system with a total estimated capacity of 700 tons.
    a. Multi-stack Heat Recovery Chiller with 130ºF LCWT
        i. 1.2 kW/ton (Design VFD chillers are 0.613 kW/ton)
    b. 70-ton unit used as basis of design. Analysis assumes units are controlled so that only enough heat recovery chillers run to meet the current reheat load. Otherwise, more efficient VFD centrifugal chillers run.
2. Update chillers and pumps per directions included in 6/27/2008 email from Bill Hoffman and Mark Heinrich.
    a. Per chiller cutsheet units are 0.613 kW/ton @ design conditions
    b. Chiller pumps are 4+1 standby @ 224’ head / 200 hp each
3. Update model lighting per current design power and descriptions provided emails correspondence with HDR. Descriptions of current system are described below. Throughout the building improvements are modeled as a 15% LPD improvement in all spaces.
    a. Section A & B
        i. 0.991 W/sf installed, 1.17 W/sf allowed (15.3% better than code)
    b. Section D & E
        i. 0. 954 W/sf installed, 1.15 W/sf allowed (17.0% better than code)
    c. Section C – no update provided for Section C

Appendix B: (Sustainable Return on Investment SROI)

Based on: SROI and Life-Cycle Cost Analysis of: The Energy and Water Conservation Measures for the Proposed Fort Belvoir Community Hospital” Executive Summary Draft Report (March, 2009)

Sustainable Return on Investment and Life-Cycle Cost Analysis of: The Energy and Water Conservation Measures for the Proposed Fort Belvoir Community Hospital

U.S. Army Corps of Engineers – Norfolk District

Executive Summary Draft Report

Prepared by:

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April 24, 2009

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EXECUTIVE SUMMARY

HDR|Decision Economics (HDR) was engaged by the HDR|Dewberry Joint Venture and the Norfolk District of the U.S. Army Corps of Engineers to provide a Life-Cycle Cost Analysis (LCCA) and a Sustainable Return on Investment (SROI) Analysis of energy and water conservation measures for the proposed Fort Belvoir Community Hospital in Fort Belvoir, Virginia.

The Federal Energy Management Program (FEMP) of the U.S Department of Energy has published life-cycle costing rules and procedures in its Code of Federal Regulations, 10 CFR 436, Subpart A. These FEMP rules include a requirement for LCCA analysis to be used to evaluate the cost effectiveness of potential energy or water conservation projects and renewable energy projects in federally owned and leased buildings.

LCCA is a financial method of project evaluation in which all costs arising from a project (owning, operating, maintaining, and ultimately disposing of it) are considered. The primary reason for an LCCA is to demonstrate that the operational savings of a project are sufficient to justify its additional investment cost. SROI is an enhanced form of LCCA which incorporates risk analysis and goes even further, providing a triple-bottom line view of a project's economic results. In essence SROI's key feature is that it monetizes (converts to monetary terms) all social and environmental impacts related to a given project. Note that the SROI analysis also provides the equivalent of traditional LCCA metrics which are called Financial Return on Investment (FROI) metrics in the analysis.

For the purpose of this study two alternatives were compared to an AHSRAE baseline (PRM Model):

1) An "as designed" model of the building with Updates (herein known as "Current Design with Updates") and,
2) A model reflecting energy measures needed to meet the 30% energy use reduction required by EPACT 2005 (herein known as "Current Design 30%").

Table 1 below provides a thorough summary of the study's key risk-adjusted outputs. The first grouping provides the mean expected SROI results - i.e. those that correspond to the triple bottom line. The benefits that are included in the calculation of these metrics include real cash benefits, non-cash benefits and externalities (benefits to society). The second box provides the mean expected FROI results, which only accounts for the traditional cash benefits and is equivalent to a traditional LCCA. The findings are clear; the "Current Design with Updates" is a beneficial project on a traditional LCCA basis and even better from a triple-bottom line perspective while the "Current Design 30%" fails to recover the major additional capital requirements no matter how it is analyzed.

Table 1: Summary of the Study’s Key Risk-Adjusted Outputs

SROI	“Current Design with Updates”	“Current Design 30%”	Notes
Annual Value of Benefits	$930,485	$1,232,955	The total value of the benefits in one year
Energy Reduction	*369,591*	*565,600*	Incremental relative to (PRM) model
Water Reduction	*80,039*	*80,039*	Incremental relative to (PRM) model
Greenhouse Gases Savings	*97,924*	*119,991*	Incremental relative to (PRM) model
Air Pollutants Savings	*374,844*	*459,315*	Incremental relative to (PRM) model
Savings From Reduced Water Use - Economic Value	*8,088*	*8,088*	Incremental relative to (PRM) model
Net Present Value	$10,193,620	-$7,360,988	PV Benefits - PV All Costs
Return on Investment	27%	1%	Arithmetic Average Rate of Return on Capital Investment
Discounted Payback Period	6	N/A	Time in years till positive discounted cash flow
Internal Rate of Return (%)	23%	2%	Discount rate which would make NPV = 0
Benefit to Cost Ratio	3.3	0.7	PV Benefits / PV Costs
FROI	**"Current Design With Updates”**	**“Current Design 30%”**	**Notes**
Annual Value of Benefits	$449,537	$645,646	The total value of the benefits in the first year
Net Present Value	$2,660,205	-$16,559,260	PV Benefits - PV All Costs
Return on Investment	12%	N/A	Arithmetic Average Rate of Return on Capital Investment
Discounted Payback Period	12	N/A	Time in years till positive discounted cash flow
Internal Rate of Return (%)	11%	N/A	Discount rate which would make NPV = 0
Benefit to Cost Ratio	1.6	0.4	PV Benefits / PV Costs

Notes
All dollar figures are in thousands of US dollars
SROI = Sustainable Return on Investment calculations (includes Health plus Externalities)
FROI = Financial Return on Investment calculations (traditional cash return)

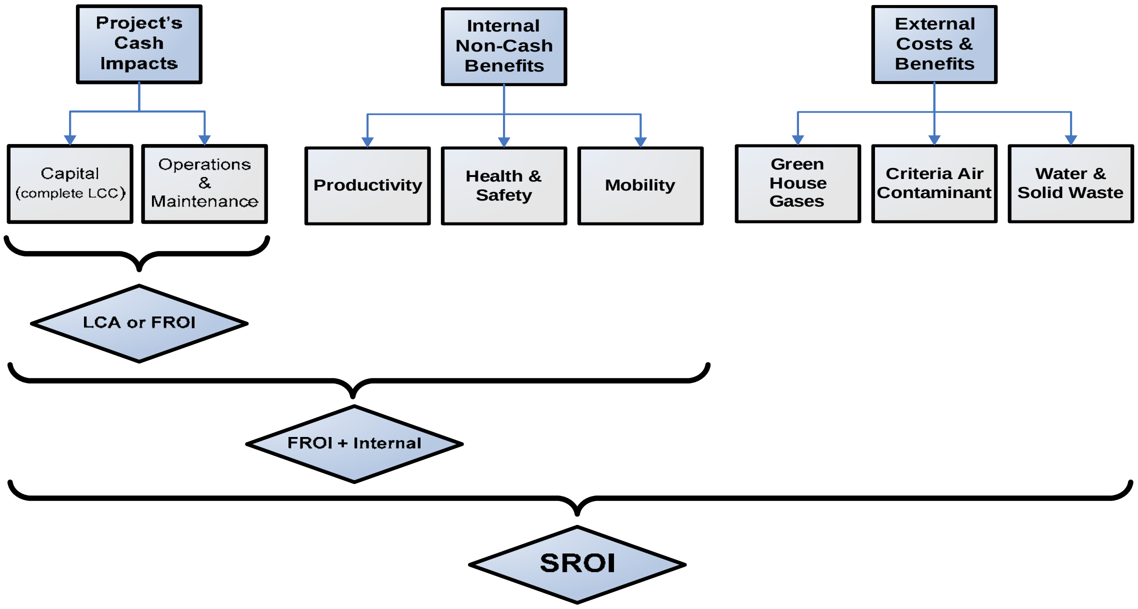
1. PROJECT OVERVIEW

HDR|Decision Economics (HDR) was engaged by the HDR|Dewberry Joint Venture and the Norfolk District of the U.S. Army Corps of Engineers to provide a Life-Cycle Cost Analysis (LCCA) and a Sustainable Return on investment (SROI) Analysis of energy and water conservation measures for the proposed Fort Belvoir Community Hospital in Fort Belvoir, Virginia.

The Federal Energy Management Program (FEMP) of the U.S Department of Energy has published life-cycle costing rules and procedures in its Code of Federal Regulations, 10 CFR 436, Subpart A. These FEMP rules include a requirement for LCCA analysis to be used to evaluate the cost effectiveness of potential energy or water conservation projects and renewable energy projects in federally owned and leased buildings.

LCCA is a financial method of project evaluation in which all costs arising from a project (owning, operating, maintaining, and ultimately disposing of it) are considered. The primary reason for an LCCA is to demonstrate that the operational savings of a project are sufficient to justify its additional investment cost. <u>SROI is an enhanced form of LCCA</u> which incorporates risk analysis and goes even further, providing a triple-bottom line view of a project's economic results (see figure 1). In essence SROI's key feature is that it monetizes (converts to monetary terms) all social and environmental impacts related to a given project. Note that the SROI analysis also provides the equivalent of traditional LCCA metrics which are called Financial Return on Investment (FROI) metrics in the analysis.

Figure 1: Comparison of Traditional LCCA to SROI



The Fort Belvoir Community Hospital (FBCH) will be part of an integrated health care network providing world-class medical services to the nation's wounded soldiers and families. The seven-level community hospital includes 120 in-patient beds, a 10-bed intensive care unit, a 10-bed behavioral health in-patient unit, a cancer center, an emergency department, a pharmacy, an operative services center with 10 operating rooms, diagnostic centers such as pathology and radiology, and modular clinic space dedicated to out-patient services, with additional space planned for future out-patient expansion.

The FBCH project is being designed by a joint venture team consisting of the HDR office in Alexandria, VA and the Dewberry office in Fairfax, VA and is being constructed through Integrated/Design/Bid/Build (IDBB) procurement. This innovative process uses a construction contractor to increase constructability reviews, provide accurate cost/schedule impacts of design decisions, and help improve design coordination resulting in fewer design omissions and errors.

The ground-breaking for the new Fort Belvoir Community Hospital project was held on November 8th, 2007. This marked the beginning of on-the-ground work to construct the new 1.2 million square foot, state-of-the-art hospital facility. The completion of the first component of the construction phase is expected in February 2011. The overall $747 million project, initiated as part of the 2005 Base Realignment and Closure (BRAC) program, is being managed by the Norfolk District of the U.S. Army Corps of Engineers.

This report documents the comprehensive economic analysis of the eight energy conservation measures and one water conservation measure provided by the design team.

This report is organized into the following sections:

- Executive Summary: This section summarizes the results
- Section 1 – Project Overview: This section introduces the reader to the project purpose and scope
- Section 2 - Life-Cycle Cost Analysis: This section provides a description of the baseline scenario and the alternatives analyzed, including the results of the LCCA analysis
- Section 3 - Sustainable Return on investment Analysis: This section discusses the limitation of LCCA and provides a description of the main economic performance metrics
- Appendix A: FBCH Energy Model Summary
- Appendix B: Example of Monetizing a Non-Cash Benefit
- Appendix C: Overview of the Risk Analysis Process

2. LIFE-CYCLE COST ANALYSIS (LCCA)

This section documents the basic Life-Cycle Cost Analysis that was performed based on the energy model[1] for the proposed hospital. The software used to complete the basic LCCA was the Building Life-Cycle Cost (BLCC 5.3-08) program developed by the National Institute of Standards and Technology (NIST).[2] Outputs include measures of financial performance such as Net Savings, Savings-to-Investment Ratio and Discounted Payback as requested in 10 CFR 436, Subpart A.

Many of the study's inputs were derived from the FBCH Whole Building Energy Model which is a comprehensive energy analysis that compares an "as designed" model of the building versus a building model based on the minimum requirements of the ASHRAE standard 90.1-2004. This baseline model is called the Performance Rating Method (PRM) model. The comparison of the results of these two building models forms the basis for the LCCA results.

Two alternatives were compared to PRM model (Baseline):

1) An "as designed" model of the building with Updates[3] (herein known as "Current Design with Updates") and,
2) A model reflecting energy measures[4] needed to meet the 30% energy use reduction required by EPACT 2005 (herein known as "Current Design 30%").

In total, six energy efficiency opportunities were assessed:

- Ribbon Windows;
- Curtainwall System;
- R-20 roof, Zone 4A;
- Green Roof, Zone 4B;
- Lighting Controls and,
- Chilled Water Generation and Distribution (Heat Recovery Chillers).

Tables 2 and 3 below summarize all of the LCCA inputs used in the BLCC model. Future cost estimates are presented in 2008 constant dollars[5].

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[1] See appendix B. EMO Energy Solutions, LLC (EMO). June 5th, 2008. *Analysis of Performance Rating Method DD Whole Building Energy Model Analysis & LEED®-NC VER 2.2 Energy & Atmosphere Credit 1 Calculations, Fort Belvoir Community Hospital*"

[2] Six types of analysis can be run with this software. For this project, the MILCON (military construction) module was selected. MILCON module supports LCC studies for the Army, Navy, and Air Force when the primary purpose of the study is to assess the costs and benefits of investments in energy and/or water conservation. The module is consistent with DoD's Memorandum of Agreement on Criteria/Standards for Economic Analysis/Life-Cycle Costing for MILCON Design, (March 1994). It also follows the rules of the DOE/FEMP Life-Cycle Cost Methodology and Procedures in 10 CFR 436A and fulfills the requirements of Executive Order 13123, Greening the Government Through Efficient Energy Management.

[3] These updates include: changes to the section C reheat system and inclusion of Multi-stack heat recovery chillers, VFD chillers, lighting improvements based on current design.

[4] These measures are: reducing Fan Powers to ASRHAE maximum levels, and Lighting Power reductions to average 0.9 W/sf.

[5] The term Constant dollars refers to dollar amounts that have been adjusted to eliminate the effects of price inflation and allow direct comparison of values across years.

Table 2: General BLCC LCCA Inputs

Input Data Common to All BLCC Models	
Analysis Type:	MILCON Analysis, Energy Project
Base Date:	1-Apr-09
Beneficial Occupancy Date*:	1-Mar-11
Study Period:	27 years
Discount Rate:	3%
Discounting Convention:	Mid-Year
Inflation Rate:	All Cash Flows in Constant Dollars
Residual Value:**	Based on Remaining Service Life
Replacement Costs:	100%
Real Energy Escalation Rates:	
1-Apr-2008	3.32%
1-Apr-2009	0.11%
1-Apr-2010	-2.45%
1-Apr-2011	-1.53%
1-Apr-2012	-1.71%
1-Apr-2013	-1.78%
1-Apr-2014	-0.87%
1-Apr-2015	0.04%
1-Apr-2016	0.21%
1-Apr-2017	-0.29%
1-Apr-2018	0.46%
1-Apr-2019	-0.17%
1-Apr-2020	-0.42%
1-Apr-2021	0.21%
1-Apr-2022	0.08%
1-Apr-2023	0.04%
1-Apr-2024	0.17%
1-Apr-2025	0.25%
1-Apr-2026	0.08%
1-Apr-2027	0.66%
1-Apr-2028	0.16%
1-Apr-2029	0.25%
1-Apr-2030	0.20%
1-Apr-2031	0.16%
1-Apr-2032	0.16%
1-Apr-2033	0.16%
1-Apr-2034	0.16%
1-Apr-2035	0.16%
1-Apr-2036	0.20%
1-Apr-2037	0.16%
1-Apr-2038	0.17%

* The Beneficial Occupancy Date is the point in time during the Study Period when a building or building system is put into use, and operating, maintenance, and repair costs (including energy and water costs) begin to be incurred

** The estimated remaining percent of the value, net of any Disposal Costs, of any building or building system removed or replaced during the Study Period, or remaining at the end of the Study Period, or recovered through resale or reuse at the end of the Study Period

Table 3: Scenario Specific BLCC LCCA Inputs

Input	(PRM) Model	" Current Design With Updates"	"Current Design 30%"
Energy: Electricity			
Annual Consumption:	119,374 MBtu	96,037 MBtu	90,778 MBtu
Normalized Price per MBtu:	N/A	$14.98	$18.7
Utility Rebate:	$0	$0	$0
Location:	Virginia	Virginia	Virginia
Rate Schedule:	Commercial	Commercial	Commercial
Electricity Usage Indices			
Usage Index:	100%	100%	100%
From Date:	1-Mar-11	1-Mar-11	1-Mar-11
Duration:	Remaining	Remaining	Remaining
Initial Investment			
Initial Cost (base-year $):	$58,126,398	$60,326,088	$77,826,088
Investment Cost-Phasing			
Cost Adjustment Factor:	0%	0%	0%
Years/Months (from Date)	0 years 0 months	0 years 0 months	0 years 0 months
Date	1-Apr-09	1-Apr-09	1-Apr-09
Portion	100%	100%	100%
Major Repair and Replacement Costs*			
Years/Months:	0 years 0 months	20 years 0 months	20 years 0 months
Amount:	$0	$2,020,690	$11,497,729
Annual Rate Of Increase:	0%	0%	0%
Expected Asset Life:	0 years 0 months	25 years 0 months	25 years 0 months
Residual Value Factor:	0%	75%	75%
Routine Recurring OM&R Costs*			
Annual Amount:	$0	$61,726	$351,216
Annual Rate of Increase:	0%	0%	0%
Usage Indices From Date	1-Mar-11	1-Mar-11	1-Mar-11
Duration	Remaining	Remaining	Remaining
Factor	100%	100%	100%
* These costs are incremental relative to (PRM) model			

2.1 LCCA Results From the BLCC Model

The results indicate that the energy conservation measures proposed in the "Current Design with Updates" alternative have the lowest life-cycle costs when compared to a standard construction (PRM model). That is, the energy savings ascribed are sufficient to warrant their initial capital cost and their ongoing operating, maintenance and replacement costs to the tune of $1.8M in net savings. However, in order to achieve the 30% energy reduction (goal established by the EPACT) requires additional capital investments of almost $20M which cannot be offset by the energy savings produced. Table 4 below summarizes the LCCA results and provides the measures of economic performance estimated for the two set of calculations.

Table 4: FBCH LCCA Results From the BLCC Model

Present Value (PV) Life-Cycle Cost*	"Current Design With Updates”	“Current Design 30%”	Notes
Initial Investment Cost:			
Capital	$2,199,690	$19,699,690	Incremental investment relative to (PRM) model
Future Cost:			
Energy Consumption Cost	-$5,439,199	-$9,467,600	Relative to (PRM) model
Energy Utility Rebates	$0	$0	
Water Cost	$0	$0	
Routine Recurring and Non-Recurring OM&R Costs	$1,030,814	$5,865,303	Incremental costs relative to (PRM) model
Major Repair and Replacements	$1,057,275	$6,015,895	Incremental costs relative to (PRM) model
Residual Value at End of Study Period	-$684,025	-$3,892,101	Offset to capital
Subtotal (for Future Cost Items)	-$4,035,135	-$1,478,504	
Total PV Life-Cycle Cost	-$1,835,444	$18,221,187	Higher costs makes for a less profitable project
Measures of Economic Performance	**"Current Design With Updates”**	**“Current Design 30%”**	**Notes**
Net Savings	$1,835,444	-$18,221,187	PV Savings (or Benefits) less PV All Costs
Savings-to-Investment Ratio (SIR)	1.71	0.17	PV Savings / PV All Costs
Adjusted Internal Rate of Return	5.08%	N/A**	Discount rate which would make NPV = 0
Payback Period:			
Simple Payback occurs in year	9	N/A**	A measure of the length of time required for the cumulative savings from a project to recover the Investment Cost and other accrued costs, without taking into account the Time Value of Money.
Discounted Payback occurs in year	11	N/A**	The time required for the cumulative savings from an investment to pay back the Investment Costs and other accrued costs, taking into account the Time Value of Money
Life-cycle Energy Savings	583,409 MBtu	714,880 MBtu	

* All dollar figures are in 2008 constant dollars

** Investment costs are not recovered during the study period

3. SUSTAINABLE RETURN ON INVESTMENT (SROI) ANALYSIS

FEMP rules for evaluating the cost effectiveness of potential energy or water conservation projects and renewable energy projects in federally owned and leased buildings allow for the use of more advanced modelling techniques. Since traditional life-cycle costing methods fall short in the accurate quantification of all positive and negative externalities[6] HDR has developed the SROI process.

Today, corporate social responsibility is the idea that organizations should consider the interests of society by accounting for the impact of their actions on customers, employees, shareholders, their communities and other stakeholders – including the environment. While there has been talk about responsible corporate citizenship, and there have indeed been tangible examples of its implementation, for the most part the discussion has not translated into a systematic action plan. If positive and negative externalities were quantified, managers and investors could design, manage and fund organizations that maximized the combined financial, environmental and social returns.

The HDR Sustainable Return on Investment (SROI) process takes into account the entire scope of potential costs and benefits related to energy and water conservation measures, while simultaneously incorporating a risk analysis component over the project's life-cycle. These include traditional inputs such as savings on utility bills, but also inputs such as quantifying the environmental savings from reduced carbon emissions, or the value of enhanced productivity from employees working in a green building (e.g. fewer sick days or performing a task more efficiently).

HDR SROI process involves four distinct steps:

1. Develop the structure and logic of the business case: This involves economic analysts researching all information available regarding the relevant sustainable strategies and graphically illustrating the calculations required.
2. Quantify input assumptions and assign risk ranges: This step involves building the "first cut" of the SROI model, populating the model with the best preliminary information available and developing the initial calculations regarding the sustainable strategies to be analyzed.
3. Facilitate a Risk Analysis Process (RAP) session: This is a meeting, similar to a one-day charrette, whereby all key stakeholders are brought together to develop and reach consensus on all of the inputs and calculations used in the model.
4. Simulate outcomes and quantify probabilistically: The final step in the process involves generating the SROI metrics such as Net Present Value, Discounted Payback Period, Internal Rate of Return, etc.

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[6] In economics, an externality is a non-internalized cost or benefit resulting from one economic agent's actions that affect the well-being of others. For instance, pollution and other forms of environmental degradation are the result of some production process and are not reflected in the price of the goods or services being produced.

3.1 Background Information

Following a RAP session held in January 2009, HDR produced a comprehensive set of sustainable output metrics for FBCH. The findings were generated by a 25-year spreadsheet-based economic simulation model which identified all of the costs and benefits associated with the conservation measures at the hospital. In addition to the energy conservation measures described in the LCCA, two energy conservation measures and one water conservation measure (reuse water system) were quantified.

Risk analysis and Monte Carlo simulation techniques were used to account for uncertainty in both the input values and model parameters. All projections were expressed as probability distributions (a range of possible outcomes and the probability of each outcome). Finally, each element was developed or converted into monetary values for the purpose of estimating the overall impacts in comparable financial terms.

Our analysis produced results on both a financial and a sustainable basis using many of the most popular financial metrics. For example:

- Net Present Value (NPV): The net value that an investment or project adds to the value of the firm, calculated as the sum of the present value of future cash flows less the present value of the project's costs

- Return On Investment (ROI): The ratio of the net value of an investment relative to the cost of the investment

- Discounted Payback Period (DPP): The period of time required for the return on an investment to recover the sum of the original investment on a discounted cash flow basis

- Internal rate of return (IRR): The discount rate at which the net present value of a project would be zero; represents the annualized effective compounded return rate which can be earned on the invested capital, and is compared relative to the cost of capital

- Benefit/Cost Ratio (B/C ratio): The overall "value for money" of a project, expressed as the ratio of the benefits of a project relative to its costs, with both expressed in present-value monetary terms

In addition to some of the inputs and assumptions already explained in the first section of this document, HDR' SROI analysis includes:

- Inflation was added to the model averaging 2.2% over the study period[7];
- The social costs of greenhouse gases and air pollutants are based on the best available scientific studies[8]. They include, among others: human health impacts,

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[7] Congressional Budget Office's forecasts

[8] Muller, et al. 2007: *Measuring the Damages of Air Pollution in the United States*
http://www.rff.org/Publications/WPC/Pages/12_17_07_Air_Pollut

reduced agricultural yields, accelerated depreciation of man-made materials, and lost recreation usage due to impaired forest health and other impacts.

- The social cost of water which depends on its supply and demand. In a competitive market (i.e., tap water or mineral water), willingness to pay for the use of water may exist for changes in quantity, quality, or timing. However, the social value of water "*per se*" goes beyond its market price. Because water is not only consumed but as well used (fishing, recreational activities, etc.), its economic value depends of the value people place on its existence ("existence" value) and what it will be for others to use ("bequest" value). This report uses two different economic values for water representing low and high values of the social cost of water[9]. The low value corresponds to the economic value of streamflow from national forests estimated by Brown (2004)[10]. The high value represents the economic cost of water delivery and sewage treatment (Renzetti 2003)[11].

Table 5 provides a list of input parameters utilized to populate the SROI model. The inherent uncertainty around inputs is reflected in the probability (risk) range displayed as an 80% confidence interval. Values are incremental over the (PRM) model.

Holland and Watkiss. 2002: *Estimates of the marginal external costs of air pollution in Europe*. Published Studies. http://ec.europa.eu/environment/enveco/air/index.htm#marginal
Friedrich, Rabl and Spadaro. 2001: *Quantifying the Costs of Air Pollution: the ExternE Parameter of the EC*. http://www.arirabl.com/publications/PUBLICATIONS.html
H. Scott Matthews and Lester B. Lave. 2000: *Applications of Environmental Valuation for Determining Externality Costs*. http://pubs.acs.org/doi/full/10.1021/es9907313
U.S DOT. 2002. *Highway. Economic Requirements System State-Version, Technical Report*. http://www.fhwa.dot.gov/infrastructure/asstmgmt/hersdoc.cfm

[9] We are not including the "existence" value or the "bequest" value of water because their magnitudes are difficult to accurately measure and there are not sufficient estimates from the literature.

[10] Brown C. Thomas. 2004. *The Marginal Economic Value of Streamflow From National Forests*. http://www.fs.fed.us/rm/value/research_watermarkets.html

[11] Renzetti Steven. 2003. Full Cost Accounting for Water Supply and Sewage Treatment: A Case Study of the Niagara Region. http://siteresources.worldbank.org/INTWRD/Resources/ARDenoteWRMEIRenzetti.pdf

Table 5: SROI Inputs Summary

Inputs	Metrics	Median	Low	High	Comment
General Information					
Base Date					2009
Beneficial Occupancy Date					March 2011
Residual Value					Assumed straight line depreciation
Energy Savings “Current Design with Updates” model	MBtu/year	23,337	19,836	26,838	FBCH Whole Building Energy Model
Energy Savings “Current Design 30%” model	MBtu/year	28,596	24,307	32,885	FBCH Whole Building Energy Model
Normalized Cost of Energy “Current Design with Updates” model	$/MBtu	14.98	10.48	19.47	Calculated from Energy Model
Normalized Cost of Energy “Current Design 30%” model	$/MBtu	18.70	13.09	24.31	Calculated from Energy Model
Irrigation Water Savings per Year in Gallons	Gallons/year	1,640,602	1,148,421	2,132,783	RAP Session
Irrigation Demand (first 2 years green roof)	Gallons/year	170,000	119,000	221,000	RAP Session
Irrigation Water Savings (first 2 years)	Gallons/year	1,470,602	1,029,421	1,911,783	RAP Session
Investment Capital “Current Design 30%” model	$	17,500,000	15,000,000	20,000,000	RAP Session
Operating, Maintenance and Replacement Costs “Current Design 30%” model	Factor	5.9	4	8	HDR
Cost of Water	$/gallon	0.04615	0.02490	0.067400	Schedule No. 6—Retail Service Metered Rates; Meter Size (inches); Commercial, Industrial. Source: FAIRFAX COUNTY WATER AUTHORITY
Social Cost of Water					
Water	$/gallon	0.003697	0.00003	0.0148	HDR

Table 5: SROI Inputs Summary (Cont'd)

Inputs	Metrics	Median	Low	High	Comment
Social Cost of Greenhouse Gases					
Price of Carbon dioxide CO2	$/ton	15	8	74	See Appendix B
Price of Methane CH4	$/ton	305	170	1,550	C02 value * 21
Price of Nitrous Oxide N2O	$/ton	4,507	2,505	22,875	C02 value * 310
Social Cost of Air Pollutants (Rural)					
NOx	$/ton	4,280	354	25,000	Sources: Muller, Nicholas Z. and Robert Mendelsohn. 2007; Holland and Watkiss, 2002; Friedrich, Rabl and Spadaro, 2001; H. Scott Matthews and Lester B. Lave, 2000; HERS-ST v2.0, 2002
VOC	$/ton	3,247	354	6,662	
PM2.5	$/ton	2,849	1,196	20,452	
SO2	$/ton	9,919	979	65,737	
Social Cost of Air Pollutants (Urban)					
NOx	$/ton	6,421	354	25,000	Sources: Muller, Nicholas Z. and Robert Mendelsohn. 2007; Holland and Watkiss, 2002; Friedrich, Rabl and Spadaro, 2001; H. Scott Matthews and Lester B. Lave, 2000; HERS-ST v2.0, 2002
VOC	$/ton	4,871	590	6,662	
PM2.5	$/ton	5,697	3,897	65,690	
SO2	$/ton	14,878	1,771	65,737	
Construction Category	**Metrics**	**Median**	**Low**	**High**	**Comment**
Windows (Zone 4A)					
Capital Cost:					
Ribbon Windows	$	18,000	13,500	22,500	RAP Session. Cost above baseline is approx. $0.40/sf. Quantity (SF) = 45000
Curtainwall System	$	36,000	27,000	45,000	
Life estimate					
Ribbon Windows	Years	25			RAP Session
Curtainwall System	Years	25			RAP Session
Replacement cost:					
Ribbon Windows	%	100%			RAP Session. Percent of the capital cost
Curtainwall System	%	100%			RAP Session. Percent of the capital cost
Operating and Maintenance Cost:					
Ribbon Windows	%	1.0%	0.5%	1.5%	RAP Session. Percent of the capital cost
Curtainwall System	%	1.0%	0.5%	1.5%	RAP Session. Percent of the capital cost

Table 5: SROI Inputs Summary (Cont'd)

Construction Category	Metrics	Median	Low	High	Comment
Roof Construction					
Capital Cost:					
R-20 roof (ZONE 4A)	$	111,190	55,595	166,786	RAP Session
Green Roof (ZONE 4B)	$	409,500	204,750	614,250	RAP Session
Life estimate					
R-20 roof (ZONE 4A)	Years	20			RAP Session. Based on the warranty
Green Roof (ZONE 4B)	Years	20			RAP Session. Based on the warranty
Replacement cost:					
R-20 roof (ZONE 4A)	%	100%			RAP Session. Percent of the capital cost
Green Roof (ZONE 4B)	%	100%			RAP Session. Percent of the capital cost
Operating and Maintenance Cost:					
R-20 roof (ZONE 4A)	%	5%	2.5%	7.5%	RAP Session. Percent of the capital cost
Green Roof (ZONE 4B)	%	5%	2.5%	7.5%	RAP Session. Percent of the capital cost
Water Reuse System					
Capital Cost:					
L.I.D. (4 Total)	$	0	0	0	RAP Session
L.I.D. Areas in front irrigation	$	6,000	5,100	6,900	RAP Session
Pump Station, piping (excluding irrigation piping)	$	80,000	68,000	92,000	RAP Session
Incremental capital cost of the system (the cost of the rain leaders and the swoop roof)	$	0	0	0	RAP Session
Incremental capital cost of the system (cistern, etc.)	$	380,000	323,000	437,000	RAP Session
Life estimate	Years	25			RAP Session
Replacement cost:	%	100%			RAP Session. Percent of the capital cost
Operating and Maintenance Cost:	%	5%	2.5%	7.5%	RAP Session. Percent of the capital cost

Table 5: SROI Inputs Summary (Cont'd)

Construction Category	Metrics	Median	Low	High	Comment
Lighting					
Capital Cost:					
Light controls	$	534,500	454,325	614,675	RAP Session. Light controls cost $507,000 plus design cost: 160 hour @ $170/hour = $27,200
Life estimate					
Light controls	Years	15			RAP Session
Replacement cost:					
Light controls	%	100%			RAP Session. Percent of the capital cost
Operating and Maintenance Cost:					
Light controls	%	0.0%	0.0%	0.0%	RAP Session
Chilled Water Generation & Distribution:					
Capital Cost:					
Heat Recovery Chillers	$	1,500,000	750,000	2,250,000	RAP Session
Life estimate					
	Years	20			RAP Session
Replacement cost:					
Heat Recovery Chillers	%	100%			RAP Session. Percent of the capital cost
Operating and Maintenance Cost:					
Heat Recovery Chillers	$/year	11,851	5,925	17,776	RAP Session

3.2 SROI Analysis Results

The results highlight the importance of accounting for external costs resulting from actions that affect the well-being of others. In a given year, the monetized value of greenhouse gases and pollutants account for half of benefits coming from conservation measures considered in the analysis. Figure 2 provides a breakdown of the annual benefits of conservation measures of the “Current Design with Updates” alternative.

Figure 2: FBCH Annual Value of Benefits “Current Design with Updates” Vs. PRM Model (Baseline)

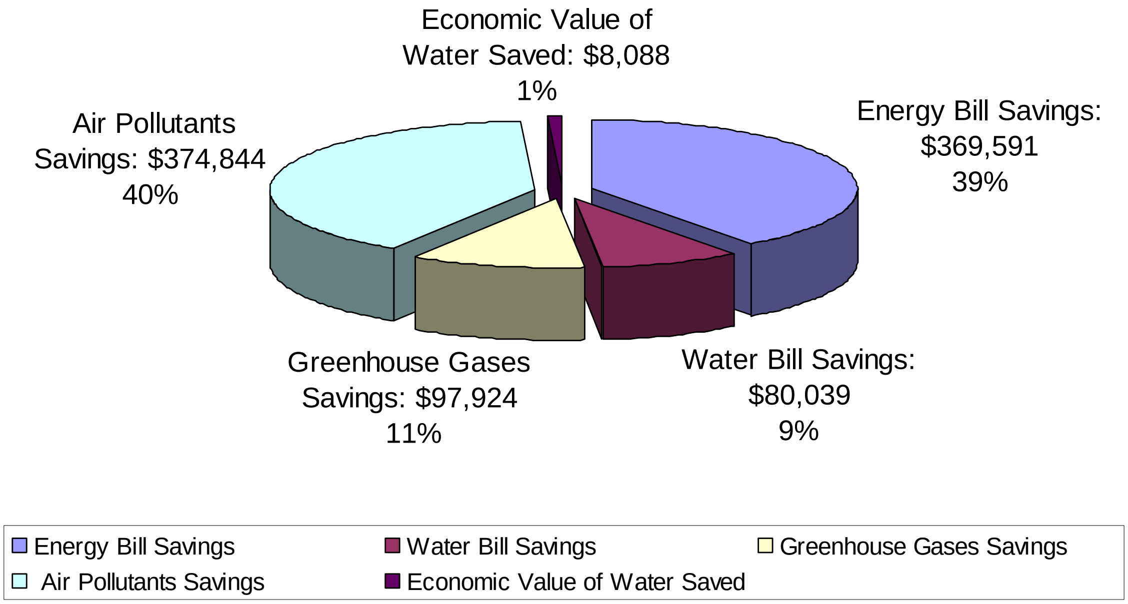

Table 6 and 7 identify the annual amount of greenhouse gases and pollutants that are expected to be avoided as a result of the conservation measures.

Table 6: Non-Financial Metrics: Greenhouse Gases (GHGs) Avoided per Year

Resource Related	"Current Design With Updates"	"Current Design 30%"	Notes
Tons of CO2 Emissions Avoided	3944	4832	The number of tons of carbon dioxide avoided based on the energy savings due to the project
Tons of CH4 Emissions Avoided	0.14	0.17	The number of tons of methane avoided based on the energy savings due to the project
Tons of N2O Emissions Avoided	0.07	0.09	The number of tons of nitrous oxide avoided based on the energy savings due to the project

Notes

Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) are considered Greenhouse Gases (GHGs)

Table 7: Non-Financial Metrics: Other Air Pollutants* Avoided per Year

Resource Related	"Current Design With Updates"	"Current Design 30%"	Notes
Tons of SO2 Emissions Avoided	14.3	17.5	The number of tons of sulphur dioxide avoided based on the energy savings due to the project
Tons of NOx Emissions Avoided	4.43	5.43	The number of tons of nitrogen oxides avoided based on the energy savings due to the project
Tons of PM2.5 Emissions Avoided**	0.95	1.17	The number of tons of particulate matter avoided based on the energy savings due to the project
Tons of VOC* Emissions Avoided**	0.04	0.05	The number of tons of volatile organic compounds avoided based on the energy savings due to the project

Notes

* Air pollutants cause smog, acid rain and other health hazards. EPA regulated six common air pollutants: particulate matter (PM), ground-level ozone, carbon monoxide (CO), Sulfur dioxide **(**SO_2) (which belongs to the family of sulfur oxide gases, SOx), nitrogen oxides (NOx), and lead

** Particulate matter (PM) or fine particles, are tiny particles of solid or liquid suspended in a gas

*** Volatile Organic Compounds are hydrocarbon-based emissions released through evaporation or combustion. Many VOCs are harmful and are classified as hazardous air pollutants by US EPA

Table 8 (below) provides a thorough summary of the study's key risk-adjusted outputs. The first grouping provides the mean expected SROI results - i.e. those that correspond to the triple bottom line. The benefits that are included in the calculation of these metrics include real cash benefits, non-cash benefits and externalities (benefits to society). The second box provides the mean expected FROI results, which only accounts for the traditional cash benefits and is equivalent to a traditional LCCA. In fact, the only differences between the BLCC model's \$1.8M NPV and the FROI NPV of \$2.6M are the variance in future energy costs assumed in the BLCC, the fact that SROI includes inflation while the BLCC does not and the risk analysis techniques used in the SROI process.

It is clear from Table 8 that after accounting for externalities, FBCH's energy and water conservation measures are very much winners when the "Current Design With Updates" alternative is compared to the (PRM) model. However, the net value of benefits (including externalities) are not sufficient to cover the high cost of measures that would be required to reach the 30% energy use reduction threshold.

Figures 3 and 4 provide risk-adjusted information for both FROI and SROI with regard to the Net Present Value results. The NPV calculation is derived by discounting the project's cash flows over a 25-year period. In Figure 2, there is 100 percent probability that the present value of all the positive cash flows (benefits) exceeds the present value of all the negative cash flows (capital, operating, maintenance and replacement costs). This means that society will be better off, over the course of the next 25 years as a result of the energy and water conservation measures taken into count in the "Current Design with Updates" alternative. In contrast, Figure 3 indicates that when the energy measures required to meet the 30% energy use reduction are added there is at least a 90 percent chance of having a negative NPV.

Table 8: Financial Metrics in ($000 USD)

SROI	**“Current Design with Updates”**	**“Current Design 30%”**	**Notes**
Annual Value of Benefits	$930,485	$1,232,955	The total value of the benefits in one year
Energy Reduction	*369,591*	*565,600*	Incremental relative to (PRM) model
Water Reduction	*80,039*	*80,039*	Incremental relative to (PRM) model
Greenhouse Gases Savings	*97,924*	*119,991*	Incremental relative to (PRM) model
Air Pollutants Savings	*374,844*	*459,315*	Incremental relative to (PRM) model
Savings From Reduced Water Use - Economic Value	*8,088*	*8,088*	Incremental relative to (PRM) model
Net Present Value	$10,193,620	-$7,360,988	PV Benefits - PV All Costs
Return on Investment	27%	1%	Arithmetic Average Rate of Return on Capital Investment
Discounted Payback Period	6	N/A	Time in years till positive discounted cash flow
Internal Rate of Return (%)	23%	2%	Discount rate which would make NPV = 0
Benefit to Cost Ratio	3.3	0.7	PV Benefits / PV Costs
FROI	**"Current Design With Updates”**	**“Current Design 30%”**	**Notes**
Annual Value of Benefits	$449,537	$645,646	The total value of the benefits in the first year
Net Present Value	$2,660,205	-$16,559,260	PV Benefits - PV All Costs
Return on Investment	12%	N/A	Arithmetic Average Rate of Return on Capital Investment
Discounted Payback Period	12	N/A	Time in years till positive discounted cash flow
Internal Rate of Return (%)	11%	N/A	Discount rate which would make NPV = 0
Benefit to Cost Ratio	1.6	0.4	PV Benefits / PV Costs

Notes
All dollar figures are in thousands of US dollars
SROI = Sustainable Return on Investment calculations (includes Health plus Externalities)
FROI = Financial Return on Investment calculations (traditional cash return)

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