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Energy Master Planning Toward Net Zero Energy Installation—Portsmouth Naval Shipyard

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ABSTRACT

The increasing world-wide emphasis on net zero (NZ) or low-energy communities (LEC) has brought with it requirements for high-quality technical analysis and optimization to support planners. The most ambitious goal is to become net zero relative to fossil fuels or to employ the concept of the energy-neutral community/campus. The achievement of this energy goal in economical and physically realistic ways requires new, unconventional approaches with respect to organization, implementation, funding, and technical decisions. The technical approach involves the emphasis on energy conservation, implementation of energy efficiency measures, use of waste energy streams, reduction of fossil-fuel-based energy, and/or complementation or replacement of fossil fuel-based energy with energy derived from renewable sources. This paper describes the process and results for an energy plan for the Portsmouth Naval Shipyard (PNSY), a historical installation with many energy needs and challenges. The energy planning process incorporates whole-building simulation, community-wide optimization of distribution and supply, geospatial data, and an overall approach to data organization that shows optimal approaches on retrofitting existing structures, standards for new building structures, optimizing the distribution system, and finally looking at supply options to meet the installation's energy efficiency and security goals. The results were computed using two different methods, a hand and spreadsheet calculation by a group of subject matter experts (SMEs) and with the U.S. Army Corps new Net Zero Planner (NZP) tool. The results from both methods are presented and compared and the results from both show several paths to meet the installation's stated goals and provide a project evaluation metric to meet these goals.

INTRODUCTION

The United States Department of Defense (U.S. DoD) has established challenging goals to increase the energy efficiency and reduce the greenhouse gas (GHG) emissions of their installations in all five branches of the armed services (Council on Environmental Quality 2012). The ultimate goal is to achieve net zero energy (NZE) levels, where the energy created on an installation would equal the energy needed in a typical year, with associated deep reductions in GHG emissions. These objectives are similar to those of some U.S. communities and college and university campuses. The Engineer Research and Development Center Construction Engineering Research Laboratory (ERDC-CERL) is researching different approaches to support NZE planning for DoD installations, including the long-range energy planning approaches used by communities around the world.

BACKGROUND

Until very recently, defense installation planners addressed energy systems for new facilities on an individual facility basis without consideration of energy sources, renewable resources, storage, or future needs. Building retrofits under Sustainment, Restoration, and Modernization (SRM) projects typically do not address energy conservation. Energy Savings Performance Contract (ESPC) projects that address only "low-hanging fruit" (improved efficiency of lighting; electrical; heating ventilating, and air-conditioning [HVAC] systems; controls; and building energy management systems) will fail to maintain the current rate of energy reduction, let alone meeting the rate required by the U.S. Energy Independence and Security Act of 2007 (EISA

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2007), and will thereby become less economically attractive (HQUSACE 2011).

There is a lack of tools and case studies that address dynamics of energy systems at the community scale. Development and rapid deployment of such tools with dissemination of lessons learned through pilot energy master plans is essential in achieving the DoD mid- and long-term energy goals.

Most energy-related national and international research and policy efforts in the built environment focus on renewable energy sources and energy efficiency in single buildings. Organizations that have made first efforts to evaluate and analyze international experiences on planning and implementation of low-energy communities include the following: the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) Annex 51, the German-funded project EnEff Stadt (a comprehensive approach to urban areas with local and district heating networks), the World Bank Energy Sector Management Assistance Program (ESMAP) Energy Efficient Cities initiative, and the Clinton Climate Initiative C40 program. The U.S. Army is codifying the best aspects of these many international organizations and approaches and is pioneering a net zero planner software tool (NZP tool), which goes beyond zero energy and includes zero waste and zero water initiatives. The tool helps the user strive toward these goals, but any stated efficiency and sustainability goals can be evaluated.

In community-wide energy planning, it is important to consider the integration of supply and demand, which leads to optimized solutions. The objective is to apply principles of a holistic approach to community energy planning and to provide the necessary methods and instruments to master planners, decision makers, and stakeholders. Such comprehensive decision-making and modeling tools are currently not available.

The U.S. Army Engineer Research and Development Center (ERDC), the U.S. Army Corps of Engineers Research Laboratory, has developed an energy optimization concept and automated tool to support DoD energy policy at its Construction Engineering Research Laboratory (ERDC-CERL). The energy concept minimizes energy use at the building level, improves the efficiency of energy generation and distribution, and, finally, uses energy from renewable sources to balance fossil-generated energy to achieve a net zero fossil energy status. Energy goals will be achieved through synergy between energy use reduction in building-related systems and energy supply and distribution systems. The NZP tool integrates optimization across buildings, distribution, and generation systems. The NZP tool has implemented an optimization at the installation level for supply and generation using mixed-integer linear programming, and is explained in detail in Swanson et al. (2014).

This paper reports on the Portsmouth Naval Shipyard (PNSY) as a case study by which a group of subcontracted subject matter experts (SMEs) use their hand calculations and spreadsheets to do the analysis. These results are compared to the NZP tool results at key points in the energy master planning process.

SITE DESCRIPTION AND PROJECT SCOPE

The scope of the project is the PNSY, which was established in 1800 and is located close to Kittery, ME, on Seavey's Island in the Piscataqua River, close to its outlet to the Atlantic Ocean (Figure 1). The shipyard has buildings and workshops, many of which are listed historical structures. It has three dry docks (DDs) and additional maintenance berths. Figure 2 shows the functional layout of the installation. The site has an existing central energy plant supplying steam to most of the site and generating the bulk of the installation's electricity requirements. There is a single connection to the grid near the access bridge to the installation. The installation's current role is primarily the repair and refit of submarines. The study has 127 industrial and nonindustrial buildings that were included from the shipyard.

PNSY was chosen as a test installation using the NZP tool and SME calculation method, resulting in development of the Installation Energy Master Plan (IEMP) covering 30 years, from 2010 to 2040, using a community planning approach. The IEMP will be sufficiently rigorous to allow support for short-, medium-, and long-term investment and operational energy management decisions. The PNSY project demonstrates the development of holistic net zero energy plans using the NZP tool and hand calculation method at a Navy defense installation.

The NZP tool provides energy planners at installations with the capability to create optimized plans to meet net zero energy goals by reducing overall energy use, using renewable energy sources, reducing GHG emissions, estimating costs, and evaluating risks. In addition to development of the road map to meeting site and source energy goals, the project will address other important DoD objectives, e.g., on-site uninterruptable energy generation to meet or exceed mission critical electrical and thermal needs, installation-wide GHG reduction, and use of solar thermal energy or waste heat from the cogeneration process to cover at least 30% of domestic water heating.

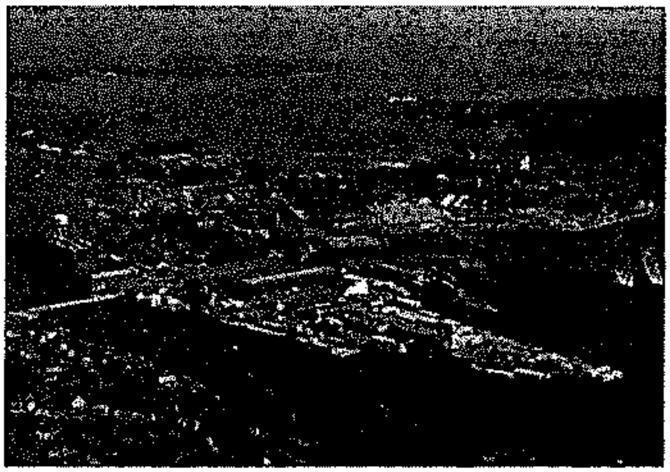
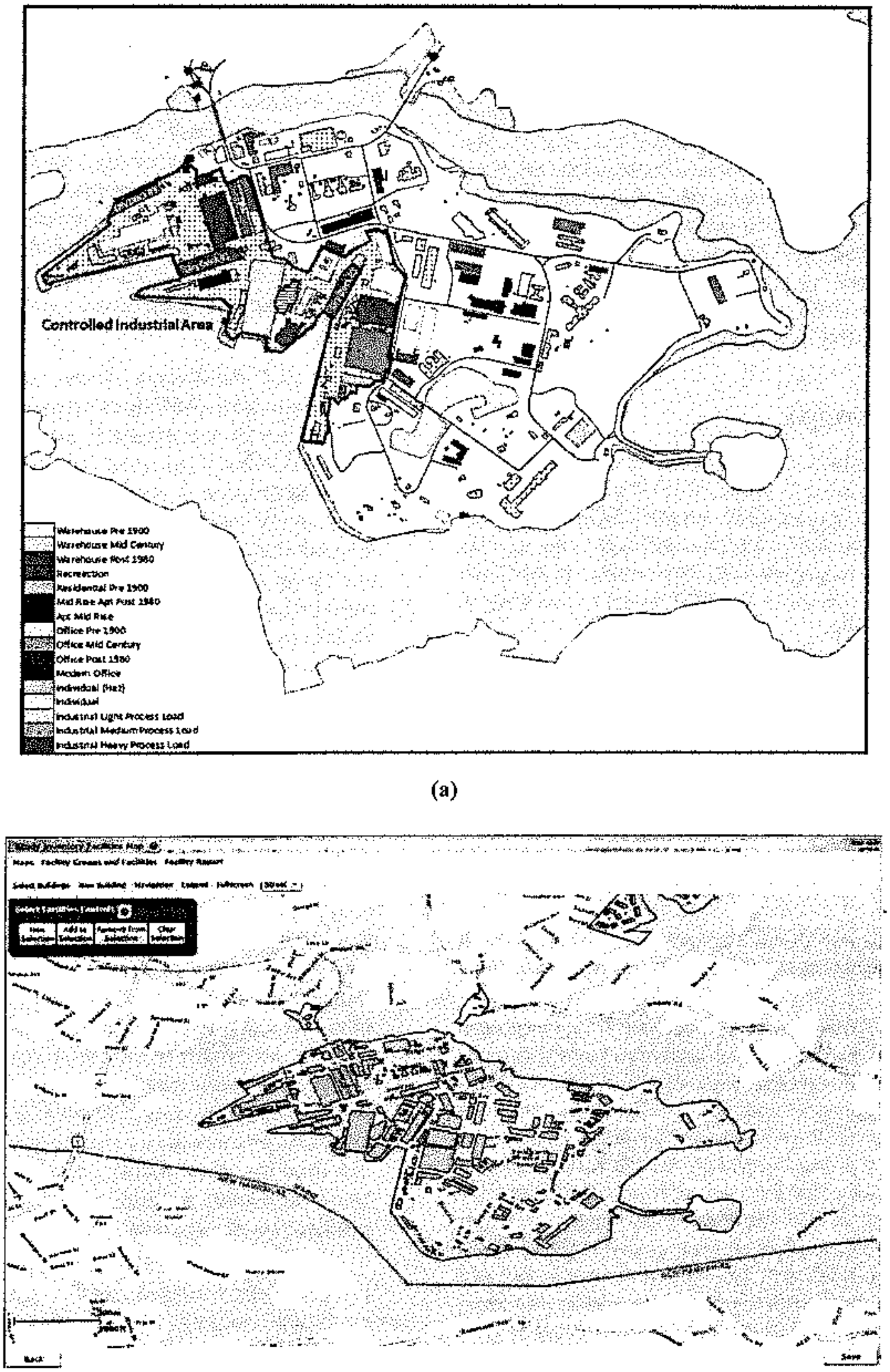


Figure 1 Aerial view of PNSY.



(a)

(b)

Figure 2 *(a) The layout of PNSY by the SME method and (b) the layout of PNSY by the NXP tool.*

ANALYSIS OBJECTIVES

The primary research objective was to test and demonstrate the development of holistic net zero energy plans using the NZP tool at a large, complex, military installation, with the possibility to proliferate the approach to multiple DoD installations. The plans from the NZP tool were compared to the results and plans from the SME group to validate the effectiveness and efficiency of the NZP tool. The NZP tool will provide energy planners at installations a capability to create optimized plans to meet any energy and sustainability goals, including striving toward net zero goals. The purpose of this case study was to provide PNSY with a planning level outline and approximate costs for meeting its energy goals.

PROCESS OVERVIEW

As organizations have adopted policies to meet or exceed high-performance energy community requirements, including a growing movement toward net zero (NZ) fossil-fuel or low-energy communities (LEC), there has been a growing need for comprehensive and integrated energy planning, as described in Zhivov (2012), Zhivov et al. (2014a), and a case study in Zhivov et al. (2014b).

The NZP tool and the SME team used a collaborative and highly integrated planning process based on best practices from around the globe. The process has five major steps: (1) goal setting, (2) baseline and base-case development, (3) facility and industrial process optimization, (4) distribution and supply optimization, and (5) plan and project formulation. A paper describing the framework in more detail is Case et al. (2014), which includes a summary of the process steps and associated tools described below:

1. Goal setting: Establish energy goals and criteria that will be used to compare alternatives against the baseline and base case.
2. Baseline and base-case data collection: A very important and difficult part of doing an analysis is establishing an accurate baseline energy usage. The baseline is defined as the current energy consumption profile of the study. It is essential that the baseline capture the quantity and type of energy used or transformed by the installation, such as grid electricity, natural gas, propane, and renewable resources. It is also important to understand how the energy is used, whether for heating, cooling, plug loads, or industrial processes. The baseline is a snapshot of a point in time and can be derived from a reference year or from consumption data averaged over a number of years to even out climatic variations. The base case includes the baseline and factors in projected changes to the facility inventory or process loads to calculate projected energy consumption over the entire study period. Alternatives considering portfolios of energy efficiency measures (EEMs), distribution, and supply measures may be compared against both the baseline and base case.
3. Facility-level optimization: Improving efficiency and reducing facility loads is almost always less expensive than making changes to distribution or supply systems. Thus, measures such as insulation, lighting, and low-flow fixtures are prioritized before investing in expensive renewable energy devices (e.g., photovoltaic [PV] solar panels) or other supply measures. *Facility-level optimization* refers to selecting the best set of EEMs for facilities on the installation to meet the installation's goals at the lowest cost. Metrics, such as avoided cost of PVs, can be considered in the economic comparison of building-level EEMs.
4. Supply and distribution system optimization: Many installations began with centralized electrical and heating plants, usually using steam, and were then slowly converted to hot- (and sometimes chilled-) water distribution systems or to completely decentralized systems using natural gas as a fuel and commercial power from the grid. Calculations and optimization are performed in this step to determine whether some form of centralized cogeneration or decentralization best meets the framing goals at the lowest cost. Industrial scale supply solutions such as solar PVs, solar thermal, wind energy, biomass (e.g., wood chips), biogas, or synthetic gas need to be considered as part of the mix during distribution and supply optimization.
5. Plan and project formulation: The final, integrated plan is produced by comparing the base case and alternatives using the criteria defined as part of the framing goals. Multicriteria decision analysis (MCDA) methods may be used to support traceable decision processes and to integrate quantitative and qualitative factors for selecting a preferred alternative. Sensitivity analysis should be conducted using the alternatives and risk factors such as price volatility (what happens if natural gas prices double), availability (is there a domestic supply of energy), and maintenance costs (what are the relative risks of decentralized versus centralized equipment). The integrated plan contains a phased implementation strategy over the study period, showing investment costs (public or private), predicted energy, predicted water, and predicted waste reductions, and return on investment.

In light of the presented process steps and the goal of using automation to improve and speed up analysis, it is useful to examine automated approaches where they can be found in the literature. Although no integrated software approaches were found that covered all five task areas, there is significant automation support for facility, supply, and distribution optimization. While some support was found for goal setting and decision support, very little was found for organizing collected data and establishing a baseline and base case.

ENERGY GOAL SETTING

The PNSY kick-off meeting identified strategic areas for the framing goals. Specific energy goals were defined for each area and confirmed by the shipyard leadership. The challenges for the project working team are to develop recommendations that meet all of the following goals as closely as possible in a balanced and integrated way:

- Energy efficiency: By 2040, the source energy use of the installation will be 40% less than the 2010/2011 baseline. This was stated as "Forty by Forty." Source energy includes all energy used on the installation plus the energy used to generate and distribute electricity purchased from the grid. The 2040 source energy goal is 221,120 MWh (754,493 MMBtu) from the baseline of 368,530 MWh (1,257,477 MMBtu).
- Supply security: There will be no degradation of the current levels of energy reliability and supply security as a result of the IEMP recommendations. The installation currently meets all necessary reliability and security levels. Energy security cannot be put in jeopardy by energy savings.
- Carbon footprint: By 2040, the installation should strive for zero GHG emissions from both on-site stationary sources (Scope 1) and purchased electricity (Scope 2), from a 65,210 metric ton (mt).
- Energy economics: The net investments aimed at achieving the goals will be cost-effective by using standard government life-cycle cost analysis.

These framing goals were agreed to by the team and the facilities leadership at the shipyard. The 2040 efficiency target is relative to the source energy and encompasses efficiencies in fuel conversion, energy distribution, and end use.

ESTABLISHING BASELINE AND BASE CASE

PNSY provided detailed usage and rate breakdowns for fiscal year 2010 (FY10) and fiscal year 2011 (FY11). Table 1 lists both the energy consumed on the installation itself (site energy) along with the total energy used to generate and transport electricity and gas to the site (source energy). The site-to-source factors are U.S. averages of 3.34 for electricity, 1.047 for natural gas, and 1.01 for heating oil/propane. Table 1 also provides a complete energy use picture that includes the cost and energy consumed on the installation itself (site energy), along with the total energy used to generate and transport electricity and gas to the site (source energy).

Two-thirds of all energy purchases are ultimately used for heating in buildings, industrial processes, and berths and DDs; by far the largest part of that portion is used for the heating of buildings. Over three-quarters of the installation's energy costs are for natural gas, primarily to run the gas turbines (GT). Notice that the purchased electricity is ~9% of total energy purchases but is ~22% of the energy costs.

BASELINE SITE ENERGY USES

Of the total 1,010,140 MMBtu (296,043 MWh) purchased by PNSY, 113,450 MMBtu (33,249 MWh), or 11%, is lost in boiler and turbine inefficiencies, leaving the balance of 896,700 MMBtu (262,797 MWh) for distribution around the shipyard. The inefficiencies assumptions are based on the manufacturers' specifications and input from the PNSY operating staff. Of this total on-site energy supply, 896,700 MMBtu (262,797 MWh), 64% is distributed as steam, 25% is electricity generated on-site by the two GTs, with the balance, or 10%, being electricity purchased from Central Maine Power. There is also a small amount or 0.4% propane and ~1% heating oil of additional fuels.

After determining the on-site distribution losses and the off-site conversion and distribution losses, the next task was to estimate how this energy was broken down by all end uses in the shipyard. The detailed distribution of site energy is as follows:

- steam losses—29%
- deaerator—9%
- building and industrial energy—6%
- building and industrial heating—27%
- electricity for compressed air, water, sewer, others—3%
- berth and DD electricity—12%
- berth and DD steam—3%
- electrical losses—1%

From the detailed energy breakdown, the high level of steam losses,—38% (29% steam and 9% deaerator losses)—is very significant. The PNSY staff was aware that the steam system had high losses. To confirm the level of these losses, a "no load" or "dark factory" test of the steam network was carried out in September 2012. *Dark factory test* is a phrase attributed to Toyota as an element of their systematic energy efficiency treasure hunts." These include at least one day where no production is running to assess how well the site manages nonproductive energy use. This entailed systematically removing all steam use from the system to get data on the network losses. Steam generated at this no-load moment is an accurate estimate of the losses in the steam distribution network. In the no-load condition, the dark factory steam test confirmed very high network losses of about 40%. This was underlined by the high level of steam maintenance costs of nearly $2 million in 2012.

BASELINE SOURCE ENERGY USES

The total source energy consumed by the shipyard is 1,257,000 MMBtu (368,500 MWh) per year. The estimated breakdown of the total source energy is summarized as follows: building and industrial processes at 29%, berths and DDs at 12%, on-site distribution at 21%, on-site conversion at 18%, and off-site conversion and distribution at 20%.

Source energy is roughly equivalent to the total fuel needed to supply the shipyard, including that used by elec-

Table 1. Baseline—Total Energy Footprint for 2010/2011 and Energy Purchases

Utility	Cost	Usage	Site Energy	Source Energy	Site Energy	Source Energy
			MWh/yr		MMBtu/yr	
Gas	$8,540,400	9,908,000 ccf	269,550	282,200	919,800	963,000
Oil-propane	$46,000		920	930	3140	3170
Electricity	$2,446,500	25,560,000 kWh	25,560	85,400	87,200	291,200
Totals	$11,032,900		296,030	368,530	1,010,140	1,257,370

Energy Breakdown	Baseline 2010/2011	FY11	FY10
Energy Cost by Conversion ($)			
Natural gas for electricity—GTs	2,386,050	2,355,400	2,416,700
Natural gas for heating—GTs	5,720,000	5,652,700	5,787,300
Natural gas for heating—steam boilers	355,050	687,800	22,300
Natural gas for heating—individual boilers	79,400	96,000	62,800
Heating oil/propane	46,000	46,000	46,000
Electricity—grid purchases	2,446,500	2,681,000	2,212,000
Total end energy	11,032,900	11,518,800	10,547,000
Energy Use by Conversion (SI units)	**MWh**	**MWh**	**MWh**
Natural gas for electricity—GTs	75,500	75,000	76,000
Natural gas for heating—GTs	181,000	180,000	182,000
Natural gas for heating—steam boilers	11,300	21,900	700
Natural gas for heating—individual boilers	1750	2100	1400
Heating oil/propane	920	920	920
Electricity—grid purchases	25,560	27,160	23,960
Total end energy	296,030	307,080	284,980
Energy Use by Conversion (I-P units)	**MMBtu**	**MMBtu**	**MMBtu**
Natural gas for electricity—GTs	257,600	255,900	259,300
Natural gas for heating—GTs	617,600	614,200	621,000
Natural gas for heating—steam boilers	38,600	74,700	2,400
Natural gas for heating—individual boilers	6000	7200	4800
Heating oil/propane	3140	3140	3140
Electricity—grid purchases	87,200	92,700	81,800
Total end energy	1,010,140	1,047,840	972,440

tricity generation and transmission supplied by the external grid. An estimated 59% of all this fuel used by PNSY is attributable to the generation and distribution of heat and electricity, both on and off the shipyard, of which 20% is grid-purchased electricity.

BASELINE ENERGY USE—BUILDINGS

The shipyard has 127 industrial and nonindustrial buildings, many of which, with minor exceptions, do not have metering. To estimate their energy needs, a modeling approach was used to estimate both the magnitude and type of energy use. The first step of the building modeling process is to select all buildings to be considered as a part of the installation's energy master planning and distribute them among different building types/categories. The era of construction of the buildings at the PNSY range from the early 1800s up to the present. From a review of the site plans and site visit, there were four main usage types on site: office, residential, warehouse, and industrial. To further refine the categories, a walkthrough of all major buildings was carried out to assess age, construction, and systems. At the same time, any anomalies that did not fit comfortably into the broad categories were noted. Construction on the site had clearly happened in waves, allowing the initial categorization of the nonindustrial buildings.

Industrial buildings on the site were categorized in a slightly different way. First, they were grouped by age, and then, generalized models for warehouse and offices of an appropriate age were assigned to each industrial building. In addition to the energy end use from the normal building functions, the industrial buildings had an industrial process load added to them by the SME team.

The black box buildings that the shipyard had no control over were included in the installation total energy use based on their total metered or allocated utility data. While there are a large number of buildings, relatively few account for the bulk of the energy use. The detailed categorization of each building is summarized in Table 2 by building function and age within the shipyard. This categorization of the buildings was used by the SME team and the NZP tool for building energy use estimation.

All energy use estimates used the weather profile for Pease Air Force Base, Portsmouth, NH (ASHRAE Station Code: 726055_TMY3) from the 2005 *ASHRAE Handbook—Fundamentals*. The modeling approach derives the energy use and annual total by major building function for each building and then totaled for the site estimates.

Table 2. Baseline—Summary of Categorization of Shipyard Buildings by Age and Function

Building Category	Area, ft^2	Area, m^2	% Total
Barracks/residential—modern	76,336	7092	2%
Barracks/residential—post-1980s	28,909	2686	1%
Barracks/residential—pre-1900	30,340	2819	1%
Black box—assigned energy intensity	81,593	7580	3%
Individual buildings	118,698	11,027	4%
Industrial—mid-century	127,104	11,808	4%
Industrial—post-1980s	22,862	2124	1%
Industrial—pre-1900	94,955	8822	3%
Industrial—with a heavy process load	15,743	1463	0.5%
Industrial—with little or no process load	310,644	28,860	10%
Industrial—with medium process load	398,213	36,995	12%
Industrial—with some local process load	418,592	38,888	13%
Office—mid-century	37,921	3523	1%
Office—modern	29,807	2769	1%
Office—post-1980s	182,749	16,978	6%
Office—pre-1980s	129,023	11,987	4%
Recreation	32,261	2997	1%
To be demolished	53,653	4984	2%
Warehouse—mid-century	112,982	10,796	4%
Warehouse—post-1980s	124,793	11,594	4%
Warehouse—pre-1900	770,830	71,612	24%
Unconditioned—excluded from modeling	7033	653	0.2%
Total floor area	3,205,052	297,757	100%

Of the total 1,010,140 MMBtu (296,043 MWh) purchased by PNSY, only about 368,000 MMBtu (108,000 MWh), or 37%, is used for buildings and industrial process. Of that, more than half, 53%, is for space heating. Industrial processes are 8% of end use, about 3% of purchased energy, and were much less than expected by the intended function of this installation. The building and process energy end use estimates were as follows:

- space heating—53.3%
- service hot water—3.3%
- space cooling—3.7%
- fans—7.1%
- pumps—0.2%
- equipment—11.5%
- lighting—12.9%

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- equipment—11.5%
- lighting—12.9%

- process electric load—3%
- process ventilation heating—5%

PNSY repairs and modernizes nuclear submarines. The basic industrial processes carried out in the industrial buildings surrounding the DDs are typical for any naval repair and refit facility. These include the following:

- Metal: cutting, bending, punching, heat treating, forming, machining, welding, pipe-forming, assembly and welding, cleaning, and painting
- Wood: sawing, shaping, sanding, assembly and painting
- Rubber: design, cutting, forming
- Ropes and cables: repair, testing
- Electronic systems: testing, repair, calibration
- Motors: rebuilding, testing
- Plastic fabrics: fabrication, manufacture
- Batteries: charging, maintenance, repair
- Ovens: heating, bonding, curing
- Systems: assembly and installation of structural, mechanical, and electrical systems.

In addition, there are industrial processes specific to the nuclear plant and systems on the submarines. For security reasons, these were beyond scope. The 35 buildings categorized as industrial support the shipboard activities by providing places for repairing, staging, modifying, manufacturing, and finishing components and assemblies for the specific tasks. By the nature of these tasks, the use of the various machines is intermittent with varying work intensity. Most of the equipment appeared to be at a modern level of industrial practice, flexibly organized to accommodate sporadic workloads. The site nominally works three shifts with by far the greatest concentration during the day and afternoon shifts.

BASELINE ENERGY USE—BERTHS AND DRY DOCKS

The steam and electricity system of the shipyard supplies the three DDs along with their associated berths. As with all other major end uses on the shipyard, there is no metering or similar monitoring data available. The following estimating approaches were used:

- Steam: The total delivery of steam to the DDs and berths was assumed to be the balance remaining after the network losses and the modeled requirements for heating buildings and industrial processes. This amounted to 36,400 MMBtu (10,668 MWh) annually. This was then broken down into estimates of the main applications for the steam: Dehumidifying one DD is 14,420 MMBtu (4226 MWh); heating two DDs—9800 MMBtu (2872 MWh); barge heating systems and usage—2530 MMBtu (741 MWh); temporary structures, portable heaters, freeze protection, etc.—9650 MMBtu (2828 MWh) for a total of 36,400 MMBtu (10,668 MWh).
- Electricity: A similar approach was adopted to estimate the total electricity use in the absence of any metered data. The total electricity use was derived from the balance of the remaining demand after subtracting distribution losses, building usage, and industrial process usage from the total purchases and on-site generation. Based on this approach, the baseline electricity usage is 115,100 MMBtu/yr (33,720 MWh/yr). The applications contributing to this are as follows:

  a. air handlers for dehumidifying one DD
  b. cooling and air handling for conditioning DDs
  c. electricity needs of barges, including some heating services
  d. miscellaneous electrical loads including tools and lighting

In summary, the berths and DDs consume about 17% of all the energy distributed on the installation.

SIMULATING BASELINE ENERGY USE

The above assumptions for buildings, utilities, and process load calculations were the starting point for the SME approach and NZP tool. Table 3 lists the analysis results for the two procedures for comparison. In the NZP tool there is the job server that runs a program called "Params," a parametric software tool that overlays the EnergyPlus building energy simulation software. The same energy simulation program was ultimately used for both methods, but the process to specify each of the models is quite different. The results listed in Table 3 indicate that the answers are different, but relatively close. For the larger building groups, industrial, warehouse, and office, the differences between the methods are smaller and this cumulative effect shows up with the total energy differences for the installation being small. Some of the smaller groups have more variance but balance each other out in the total. Even with the simplified parametric program input in the NZP tool with different persons entering the installation data, the output data for each of the building categories shows good overall comparison.

BASE CASE

The base case covers the energy used on the installation from present to the end of the study period in 2040 and assumes that the buildings and site would undergo business as usual. This generally assumes that the activity level would be unchanged and function of existing buildings would not change. The major changes from the baseline to the base case for buildings are those involved in the consolidation of the structural shops, consisting of demolition of building numbers 155 and 46 and integration into building 76. An additional impact is from the consolidation of demolished building 176 into building 45.

Table 3. Baseline—Comparison of SME Calculations to NZP Tool Calculations

	SME Calculation Baseline						NZP Tool Calculation Baseline					
Building Category	Electric	Steam	Total	Electric	Steam	Total	Electric	Steam	Total	Electric	Steam	Total
	MWh/y	MWh/y	MWh/y	MMBtu/y	MMBtu/y	MMBtu/y	MWh/y	MWh/y	MWh/y	MMBtu/y	MMBtu/y	MMBtu/y
Industrial	22,739	29,285	52,024	77,585	99,920	177,505	24,333	28,384	52,717	83,027	96,850	179,877
Warehouse	10,970	20,103	31,072	37,428	68,590	106,018	10,996	17,885	28,881	37,519	61,027	98,547
Office	6844	4330	11,174	23,352	14,773	38,125	5813	3555	9368	19,834	12,132	31,966
Barracks/ Residential	2234	2043	4277	7623	6970	14,593	1785	3122	4907	6089	10,654	16,743
Recreation	555	2050	2605	1893	6994	8887	2075	5147	7222	7081	17,562	24,643
Other	3488	3319	6807	12,449	14,461	23,602	1389	3139	4527	4739	10,709	15,448
Berths and Dry Docks	33,732	10,668	44,400	115,100	36,400	151,500	33,819	10,656	44,475	115,395	36,359	151,754
Total	80,562	71,798	152,359	275,430	248,108	520,230	80,209	71,888	152,097	273,685	245,292	518,977

An additional DD will be dehumidified and climate controlled from 2013, increasing both steam and electricity needs. As a result, annual DD steam use will increase by 14,420 MMBtu (4226 MWh) and electricity by 6031 MMBtu (1830 MWh), extrapolated from existing DD usage. The result is that steam use increases annually to 59,490 MMBtu (17,435 MWh) from 36,400 MMBtu (10,668 MWh) and electricity to 121,131 MMBtu (35,550 MWh) from 115,100 MMBtu (33,720 MWh). Both then remain constant through 2040.

FACILITY LEVEL OPTIMIZATION

The facility level optimization is the next step in the process after determining the baseline and the base case to compare against. At the facility level, all of the building EEM options are applied to each facility group. The NZP tool saves substantial time when conducting studies through its ability to automatically apply packages of EEMs to facility types. Packages are put together by subject matter experts with experience in facility optimization and are organized by facility type and era of construction (e.g., built to ASHRAE 90.1-2007). The NZP tool obtains the EEM package from the "Params" server in an XML format and dynamically modifies the user interface to display them to the user. The NZP tool displays packages of EEMs, such as lighting, high-efficiency equipment, and airtightness (infiltration). Up to 12 different sets of packages might be applied, although there is no limit, and packages can depend on each other. The user can review the EEM parameters or accept the defaults for a first pass, coming back later to refine the EEMs and possibly select newer technology. At the end of the facility optimization step, the NZP tool contains a data set for each alternative with a full set of building load profiles. The user selects the EEM package based on the cost effectiveness, site criteria, DoD policy, and meeting the stated energy goals.

The electric and heating results from the facility optimization (Table 4) show significant reductions in energy consumption, especially in heating energy. If decentralized options are being investigated, the EEM case would have a significant impact on the sizing of HVAC equipment and, ultimately, the cost. Table 4 lists both the building and DDs and berth energy together for comparison. The NZP tool calculated building energy savings from baseline as 42% (baseline 367,252 MMBtu [107,631 MWh] to EEM's 213,453 MMBtu [62,557 MWh] and the SME energy savings as 45% (baseline 368,375 MMBtu [107,960 MWh] to EEM's 203,739 MMBtu [59.710 MWh]. The process on how EEMs are applied is different by applying standard packages, but the overall results are still similar. The efficient buildings are then analyzed with the supply and distribution alternatives.

The assumptions for the EEMs are that the easier and less costly improvements may be done earlier on their own energy savings merit. The more extensive energy-efficiency measure retrofits will be accomplished during a deep energy retrofit. Deep energy retrofits are done on the building for reasons other than for energy efficiency and then the incremental cost for energy improvements are only considered as justification for the building EEM. For PNSY, most of the buildings are old and many are designated as historical and will be in need of a deep retrofit in the near future.

Since the building savings are not enough to meet the framing goals, additional optimization of the supply and distribution infrastructure was performed. The NZP tool recommendations were compared with the SME recommendations.

Table 4. Building Results, EEMs Calculated From the SME Method and the NZP Tool

			SME Calculations			NZP Tool Calculations		
Study Plan	Building Facilities	Building Total Area, m^2	Building and DD Electricity, MWh	Building and DD Gas, MWh	Building and DD Total Energy, MWh	Building and DD Electricity, MWh	Building and DD Gas, MWh	Building and DD Total Energy, MWh
Baseline	122	297,610	80,562	71,798	152,360	80,209	71,888	152,097
Base case	118	281,700	78,680	70,350	149,030	88,445	71,795	160,240
EEM case for buildings	118	281,700	70,440	42,250	112,690	75,323	45,357	120,680
District steam	118	281,700	70,440	42,250	112,690	75,323	45,357	120,680
District hot water	118	281,700	70,440	42,250	112,690	75,323	45,357	120,680
Decentralized	118	281,700	70,440	42,250	112,690	75,323	45,357	120,680
Net zero fossil fuel	118	281,700	70,440	42,250	112,690	75,323	45,357	120,680
	Building Facilities	**Building Area, ft^2**	**Building and DD Electricity, MMBtu**	**Building and DD Gas, MMBtu**	**Building and DD Total Energy, MMBtu**	**Building and DD Electricity, MMBtu**	**Building and DD Gas, MMBtu**	**Building and DD Total Energy, MMBtu**
Baseline	122	3,203,449	274,889	244,985	519,874	273,684	245,292	518,977
Base case	118	3,032,196	268,467	240,044	508,512	301,787	244,975	546,762
EEM case for buildings	118	3,032,196	240,351	144,163	384,514	257,013	154,765	411,777
District steam	118	3,032,196	240,351	144,163	384,514	257,013	154,765	411,777
District hot water	118	3,032,196	240,351	144,163	384,514	257,013	154,765	411,777
Decentralized	118	3,032,196	240,351	144,163	384,514	257,013	154,765	411,777
Net zero fossil fuel	118	3,032,196	240,351	144,163	384,514	257,013	154,765	411,777

ENERGY SUPPLY AND DISTRIBUTION ANALYSIS OPTIMIZATION

The next major step in the process is to define the appropriate supply and distribution alternatives for this installation, determined by SME experience, site visits, and discussions with site energy personnel. The supply and distribution analysis of PNSY was broken down into four different groups of buildings based on their current heating sources. The heating load for these groups are met by steam from the central plant, natural gas from a distributed network, propane with building-specific storage tanks, and fuel oil with building-specific storage tanks. This breakdown was chosen to best account for the existing network infrastructure, which transports the majority of the energy used on PNSY. This study will focus on the energy sources for the first cluster, as these buildings consist of approximately 93% of PNSY's total energy usage.

The buildings in this cluster use steam to meet their space heating, domestic hot water, and industrial process loads. The cooling loads are primarily met with distributed air-cooled chillers and the electricity loads are met using a combination of generation at the central plant and power from the electrical grid. This study focuses on the heating and electricity loads, since the cooling loads for this installation are very small in comparison. Hourly heating, cooling, and electric loads for these buildings were provided using methods described in the previous section. The resulting load data for the combined ~3,205,000 ft^2 of buildings in the baseline are presented as load duration curves in Figure 3.

With the integrated building demand, supply and distribution scenarios were considered for the buildings connected to the existing steam network for comparative analysis and comparison to baseline and base case. These scenarios are:

1. Baseline: This scenario models the building cluster as it exists today. All of the existing central plant equipment (Table 5) is included in this study and its operation is simulated. The energy and cost values from this scenario should match closely with PNSY's current situation.
2. Base case: This scenario models the building cluster as it would be with all planned building construction, renovation, and demolition. It includes the existing central plant equipment and provides a status quo scenario that can be used as a comparison for the remaining scenarios.
3. District steam: This scenario models the building cluster with a modern steam system. One of the existing natural gas turbines is replaced with two natural gas reciprocating engines with approximately half the electrical output capacity each. These were added to increase the electricity to heat ratio of the generation equipment and better match PNSY's needs.
4. District hot water and spot steam (district hot water): The scenario models the building cluster with a modern hot-water system and spot steam generation to meet process load requirements. As with the district steam scenario, one of the existing natural gas turbines is replaced with two natural gas reciprocating engines with approximately half the electrical output capacity each.
5. Decentralized: This scenario models the building cluster with decentralized boilers/furnaces and spot steam generation to meet process load requirements. The central plant equipment is not maintained in the scenario, but the same level of electrical backup is still required (15.4 MW [52.5 MMBtu/hr for the installation, as is present in the existing central plant).

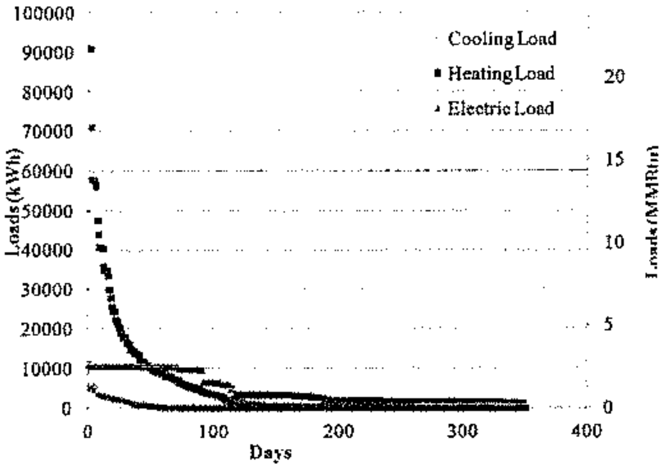

Figure 3 *Heating, cooling, and electric load duration curves for the baseline.*

6. Net zero fossil fuel: This scenario models the building cluster with a modern hot-water system and finds the lowest equivalent annual cost equipment suite to meet net zero fossil fuel goals. This scenario allows many different energy conversion technologies to be evaluated to find the lowest-cost solution. This scenario was only analyzed using the NZP tool.

This study was performed with an interest rate of 5% and the following energy rates—electricity: $0.095/kWh ($27.84/MMbtu), natural gas (at the central plant): $0.032/kWh ($9.38/MMbtu), retail natural gas (distributed to individual buildings): $0.05/kWh ($14.65/MMbtu), diesel: $0.10/kWh ($29.30/MMbtu), propane: $0.06/kWh ($17.58/MMbtu), and biomass: $0.036/kWh ($10.55/MMbtu).

SUPPLY AND DISTRIBUTION ANALYSIS RESULTS

Tables 5 and 6 summarize the results of the alternatives with the base case. The analysis shows the potential for long-term cost savings by investing in the infrastructure now.

Results from the baseline and base-case scenarios show the cost and usage that would be expected when the existing equipment is used with an optimal dispatch schedule. Though no investment costs are associated with these scenarios, they are among the most costly solutions on an annualized basis. These high annual costs are primarily the result of an aging and very inefficient steam network. The dark factory test determined the standby energy loss to be ~29,000 lb/h (~10,000 kW). This is about 25% more heat than is produced by full-load operation of one of the natural gas turbines. Additionally, maintenance and operations costs for the network topped $4.5 million for FY 2012. This has resulted in a very expensive and energy-intensive supply and distribution system. However, the electricity produced by the natural gas turbines at the central plant has helped to significantly reduce PNSY's source energy usage, when compared to using grid electricity and provided a secondary source of electricity for the installation.

The district steam scenario would require an approximately $54.6 million investment (NZP tool estimate) in a modern steam system and two reciprocating engines but would be significantly less expensive than the base case on an annual basis. The heat from the exhaust of the two engines would be used to produce steam for the network, but the heat that could be recovered from the engine itself will be at too low a temperature to be useful for providing heat to the network. This means that some of the heat is wasted from the reciprocating engines. However, there are two advantages to

Table 5. Summary of the Energy Supply Equipment Used for Each Alternative

	Baseline	Base Case	District Steam	District Hot Water	Decentralized	Net Zero Fossil Fuel
Existing Nebraska boilers, 25500 kW (87 MMBtu/h) thermal	3	3	3	3		2
Existing natural gas turbines, 5700 kW (19.4 MMBtu/h) electric 8040 kW (27.4 MMBtu/h) thermal	2	2	1	1		1
Existing duct boilers, 18,200 kW (62.1 MMBtu/h) thermal	2	2	1	1		1
Existing diesel generators, 2000 kW (6.7 MMBtu/h) electric	2	2	2	2	2	2
Natural gas reciprocating engine with steam generation, 3000 kW (10.2 MMBtu/h) electric 2000 kW (6.7 MMBtu/h) thermal)			2			
Natural gas reciprocating engine with hot-water generation, 3000 kW (10.2 MMBtu/h) electric 3100 kW (10.55 MMBtu/h) thermal				2		
Diesel generators, 2000 kW (6.7 MMBtu/h) electric					4	
Biomass with hot-water generation, 5100 kW (17.3 MMBtu/h) electric 7650 kW (26 MMBtu/h) thermal						1
Biomass boiler, 16,000 kW (54.6 MMBtu/h) thermal						1
Decentralized boilers, (sized for building loads in base case)					1	

Table 6. Summary of Cost and Energy Usage for the Six Scenarios

NZP Results	Baseline	Base Case	District Steam	District Hot Water	Decentralized	Net Zero Fossil Fuel
Supply and distribution investment cost ($)	0	0	54.6 million	43.9 million	40.6 million	153.3 million
On-demand capacity:						
Heating, kW (MMBtu/h)	129,000 (440)	129,000 (440)	107,000 (364)	109,000 (371)	NA	118,000 (402)
Electricity (kW)	15,400	15,400	15,700	15,700	16,000	15,400
Net electricity purchase (kWh)	23.2 million	31.0 million	14.5 million	16.2 million	78.2 million	0
Electricity generation (kWh)	59.2 million	59.8 million	63.9 million	62.3 million	0	61 million
Natural gas use, kWh (MMBtu)	259 million (885,000)	259 million (887,000)	196 million (670,000)	188 million (643,000)	46 million (157,000)	0
Biomass use, kWh (MMBtu)	0	0	0	0	0	245 million (838,000)
Green house gas, mt (t)	60,300 (66,470)	65,000 (71,650)	43,500 (47,950)	43,300 (47,730)	61,700 (68,010)	0
Source fossil-fuel-based energy use, kWh (MMBtu)	348 million/ 1,190,000	375 million/ 1,283,000	254 million/ 868,000	251 million/ 858,000	308 million/ 1,057,000	0
Renewable percentage	0	0	0	0	0	100
Equivalent annual cost ($)	21.2 million	22 million	16.4 million	15.7 million	17.0 million	29.30 million

maintaining steam distribution. First, steam is still used for a few of the process loads throughout the installation, and alternative steam sources will be needed if the steam network is replaced with hot water. Second, many of the buildings have low-pressure steam distribution, which would need to be largely replaced if the building is to be heated with hot water. The source energy and annual equivalent cost for this scenario drops approximately one-third when compared to the base case.

The district hot-water scenario is very similar to the district steam scenario but with a few key differences. This scenario would require an approximately $44 million investment (NZP tool estimate) for a modern hot-water distribution network and the same two reciprocating engines used in the modern steam alternative. Switching to a hot-water network will require changing out some of the heat exchangers for buildings that currently distribute low-pressure steam. Spot steam generation will be required for the few remaining process-related loads. Both of these changes increase the investment cost of the scenario, but it still remains significantly less costly than the modern district steam scenario. The lower operating temperatures of the system lead to lower conduction losses in the network and, ultimately, lower costs of operation. Further, this hot-water system can take advantage of all of the waste heat generated by the natural gas reciprocating engines. This fact leads to the district hot-water scenario having lower source energy consumption and operating costs than the district steam scenario.

The decentralized scenario would meet the building heating loads for the buildings connected to the current steam system using individualized building boilers and would require an investment of approximately $41 million (NZP tool estimate). The costing for this scenario was done using RS Means Per Square Foot costing estimates and the total was multiplied by the PNSY mark-up rate. Additionally, four new diesel generators were included to meet the 15.4 MW (52.5 MMBtu/hr) critical electricity requirements (same as the other scenarios). This scenario assumes that the extension of the natural gas lines to the remaining buildings (either by PSNY or a third party) would result in a natural gas rate that is the same as what is currently paid for the existing decentralized buildings. This "retail" natural gas rate is about 50% higher than the rate paid for natural gas at the central plant. The additional cost reflects the increased cost of distributing natural gas to many buildings with lower usage. This brings up an interesting point: a pipeline network of some sort (whether a fuel or thermal fluid) is currently required for buildings in a climate that requires significant heating. Some have argued against centralized heating systems due to the costs related to thermal distribution networks; however, pipeline network costs are present even in decentralized solutions. These costs are often masked, as they are rolled into the energy price of the natural gas. The modeling results show that the decentralized scenario uses less source energy than the base case and costs significantly less on an annual basis but uses more source energy and costs more on an annual basis than the two modern thermal distribution systems. This scenario has the additional benefit of being relatively simple and modular to implement. This scenario does not provide the same site energy security as the central systems.

The net zero fossil fuel scenario finds the lowest equivalent annual cost solution to providing the heating, cooling, and electrical needs of the building cluster without netting any fossil fuel over the course of the year. In theory, this means the installation can use fossil fuel, but must export power (generally renewably generated) off the installation to offset someone else's fossil fuel consumption. Table 5 lists the energy supply equipment used in this scenario, including the addition of biomass cogeneration and biomass boilers. A few points stand out from the results. First, most of the existing equipment was maintained in this solution. This equipment was maintained to fulfill the thermal and electrical capacity/redundancy requirement. Essentially, this fossil-fuel-based equipment would be used for peaking (using biogas) and to meet loads during emergencies. The majority of the time, the loads would be met using heat and electricity derived from biomass. Second, this scenario is about twice as expensive on an annual basis as the modernized hot-water system alone and almost 50% more expensive annually than the base case, but achieves the net zero fossil fuel energy goal. This analysis provides a rough estimate of the cost of attaining the net zero goals for PNSY. Finally, the solution lends itself well toward having a resilient and highly redundant installation. The installation would be able to provide electricity from four different sources (grid, natural gas turbines, diesel generators, and biomass-based steam turbines) and heating from four sources (natural gas, biogas, diesel/fuel oil, and biomass). This should allow the installation to maintain critical functions even under severe fuel supply restrictions.

COMPARISON OF SME AND NZP TOOL RESULTS

The SME group analyzed the same set of alternatives as for the NZP tool, except the net zero fossil fuel scenario. Table 7 lists a comparison of the SME and NZP tool results. The table shows that the energy and investment costs results of the two groups have some differences, but the cost and energy ranking of the scenarios by both groups are nearly the same. The major differences in the life-cycle costs (LCC) between the SME group and the NZP tool are determined by what is included in the base-case finances.

The building loads and fuel usage for the scenarios are different and discussed in the facility-level optimization section with all the energy results compared in more detail and listed in Table 4. The baselines are close, but the SME process for applying EEMs is customized, while the NZP tool applies standardized packages by facility group with customization of the input parameters for the installation. This leads to different and more conservative results than the SME process. Table 7 shows the deviation between fuel usages starting to vary more

Table 7. Energy Comparison Between SME Analysis and the NZP Tool Results by Scenario

SI Units SME Energy, MWh/yr

Scenarios	Total Fossil Fuel	Total Electricity	Total Site Energy	Total Source Energy	% Source Energy Reduction from Baseline	Investment $	Life Cycle Cost (Discount Rate = 3%)	Internal Rate of Return
Baseline	269,550	25,560	295,110	368,520	0%			
Base case	280,230	20,170	300,400	360,740	2%		$262,290,000	
District steam	120,600	24,310	144,910	207,450	44%	$119,160,000	$267,020,000	1.8%
District hot water	68,130	46,320	114,450	226,030	39%	$106,940,000	$250,070,000	3.6%
Decentralized	34,740	67,870	102,610	263,050	29%	$116,690,000	$268,930,000	1.8%

SI Units NZP Energy, MWh/yr

Scenarios	Total Fossil Fuel and Biomass Fuel	Total Electricity	Total Site Energy	Total Source Energy	% Source Energy Reduction from Baseline	Investment $	Life Cycle Cost (Discount Rate = 3%)	Simple Payback Years
Baseline	258,810	23,228	282,038	348,550	0%			
Base case	259,424	31,020	290,444	375,219	–8%		$477,361,000	
District steam	196,254	14,488	210,742	253,866	27%	$155,220,000	$460,051,000	25
District hot water	188,011	16,189	204,200	250,916	28%	$144,570,000	$435,313,000	21
Decentralized	45,564	78,232	123,796	308,998	11%	$141,240,000	$467,827,000	27
Net zero fossil fuel	2828/303,132	2297	307,957	40,628	88%	$193,155,480	$562,650,000	* see note

I-P Units SME Energy, MMBtu/yr

Scenarios	Total Fossil Fuel and Biomass Fuel	Total Electricity	Total Site Energy	Total Source Energy	% Source Energy Reduction from Baseline	Investment $	Life Cycle Cost (Discount Rate = 3%)	Internal Rate of Return
Baseline	919,743	87,214	1,006,957	1,257,443	0%			
Base case	956,185	68,823	1,025,007	1,230,896	2%		$262,290,000	
District steam	411,504	82,949	494,453	707,849	44%	$119,160,000	$267,020,000	1.8%
District hot water	232,469	158,050	390,520	771,246	39%	$106,940,000	$250,070,000	3.6%
Decentralized	118,538	231,582	350,120	897,564	29%	$116,690,000	$268,930,000	1.8%

I-P Units NZP Energy, MMBtu/yr

Scenarios	Total Fossil Fuel	Total Electricity	Total Site Energy	Total Source Energy	% Source Energy Reduction from Baseline	Investment $	Life Cycle Cost (Discount Rate = 3%)	Simple Payback Years
Baseline	883,096	79,257	962,354	1,189,302	0%			
Base case	885,192	105,845	991,036	1,280,301	–8%		$477,361,000	
District steam	669,647	49,435	719,082	866,227	27%	$155,220,000	$460,051,000	25
District hot water	641,520	55,239	696,759	856,161	28%	$144,570,000	$435,313,000	21
Decentralized	155,471	266,939	422,410	1,054,345	11%	$141,240,000	$467,827,000	27
Net zero fossil fuel	8626/1,034,329	7838	1,050,793	138,629	88%	$193,155,480	$562,650,000	* See Note

* Note: Savings-to-investment ratio is lower than 1.0 and annualized internal rate of return is lower than discount rate; project is not cost effective.

after the building EEMs are applied beyond the base-case scenario. However, most important is that the strategic decisions and rankings are maintained between the two processes.

The assumptions for the building EEM investments are made using a generalized investment strategy, much like the generalized energy modeling. The SMEs used on average overall ~\$10/ft^2 (\$107.64/m^2) for the 3,205,000 ft^2 (297,754 m^2) of buildings at PNSY for a cost of \$32,000,000. With the PNSY DoD markup, the investment becomes \$59,200,000. The NZP analysis used an approximate investment cost of \$17/ft^2, (182.99/m^2) or \$54,000,000, and, with the PNSY DoD markup, the EEM incremental investment is \$100,640,000. This incremental EEM investment is the additional cost to upgrade the energy efficiency of the buildings added on to the base cost when the buildings are retrofitted or repaired. This investment is assumed to take place over the first 10 years in the NZP analysis.

The supply and distribution investment costs determined by the SME group for the three scenarios agreed with the NZP estimates to within ±17% for all components except the thermal distribution networks. The NZP estimates for the thermal network costs were significantly higher than those of the SME group (~40% larger). This difference underscores the difficulty in costing large networks in built-up urban areas. However, the investment cost ranking was still consistent between the two groups (decentralized has the lowest first cost and district steam has the highest). Some of the differences may also be a result of the different costing data sources. NZP cost estimate data for the networks and central plant equipment were determined from recent work with other military installations, discussions with a company that does costing work for the Army Corps of Engineers, and National Renewable Energy Laboratory publications (NREL) on current price ranges for renewable energy technologies. The SME team cost estimates were determined from European and Canadian costing guides and sources.

The same trend in LCC appears in both methods, where doing nothing is costly and investing in a district heating system is cost effective. In both sets of results, decentralization is not as cost effective as the district heating system and district steam system. In the SME results, decentralization is not shown to be as cost effective as business as usual or the base case, but these results are very close and may be within error bars for assumptions used. Remember that the modern steam system is not the old steam systems that we typically see in legacy systems. These modern systems are direct buried with very few steam traps and no rigid supports. They are installed with the same standards as the medium temperature district heating system and currently there are systems of this type in use in Europe.

Since the approaches by the SME group and NZP tool are different in the way that building EEMs are applied and observation and measurements are determined, the base-case LCC numbers cannot be directly compared. Comparison of LCC numbers should not be done because there are different base-case values included in each individual analysis. The important aspect is that with similar investments, both methodologies recommend the same strategic direction. The economic analysis by the SMEs was done by a proprietary spreadsheet method, while the NZP results were input into *Building Life Cycle Cost* (BLCC-NIST 2013) 5.3 software program from National Institute of Standards and Technology.

It should be noted that currently the LCC analysis for the net zero fossil fuel case is not cost effective. Either the price of fuel will escalate faster than the NIST predictions, or there will be a valuation of GHG or carbon tax to make these types of scenarios cost effective using government LCC procedures.

CONCLUSION

In summary, the two methods showed very similar modeling results at the building loads step in the process. The reduction of the loads with the EEMs was not enough to meet the framing goals for the installation, which include energy security and carbon footprint reduction with source energy and GHG. Navy installations can purchase RECs (renewable energy credits), but PNSY leadership does not want to exercise that option to attain the targets.

The baseline analysis of the installation is always very insightful and allowed the analysis teams to quantify the magnitude of the steam distribution losses. It was fortunate that PNSY took this seriously and performed the dark factory test, and provided the data from the procedure.

The investment cost and energy usage results for both groups agreed within 10%–20% for all of the scenarios, despite the differences in the process used by each group. Further, the energy usage and investment cost rankings were the same for both groups and, ultimately, resulted in the same recommendations to the installation.

The NZP tool increases the speed and efficiency of the IEMP process significantly by providing repeatability and reduction of human error in the tedious tasks in the process. In addition, this provides repeatability by less-skilled persons and allows access to many additional users typically under the guidance of SMEs. The NZP tool still allows for the artistic interpretation by the user to add the customization needed to meet the intricacies of an individual installation.

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