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Towards a Net Zero Building Cluster Energy Systems Analysis for a Brigade Combat Team Complex

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Abstract

The Army is required by law (Energy Policy Act of 2005 [EPACT] 2005, U.S. Energy Independence and Security Act of 2007 [EISA] 2007) to eliminate fossil fuel use in new and renovated facilities by 2030 and to reduce overall facility energy usage by 30% by 2015. Army policy is to achieve 25 net zero energy installations by 2025 and to achieve net zero energy (NZE) status for all installations by 2058. Achieving NZE will only be possible if an optimum mix of demand reduction and renewable sources are put in place at a community (installation) or building cluster scale. The Army runs what are essentially small campuses, or clusters of buildings on its installations. The Department of Energy (DOE) is focused on the national grid scale or on individual buildings, while the commercial focus is on retrofits to individual buildings There is a lack of tools and case studies that address dynamics of energy systems at the community scale.

The Army's future building energy requirements are a mixture of ultra-low and high energy intensity facilities. Achieving net zero energy economically in these clusters of buildings will require a seamless blend of energy conservation in individual buildings, combined with building systems automation, utility management and control, and power delivery systems with the capability to integrate onsite power generation (including from renewable energy sources) and energy storage. When buildings are handled individually each building is optimized for energy efficiency to the economic energy efficiency optimum and then renewables are added until the building is net zero. This process works for buildings with a low energy intensity process for its mission, such as barracks and administrative buildings. When the mission of the building requires high energy intensity such as in a dining facility, data center, etc., this optimization process either will not end up with a net zero energy building, or large amounts of renewables will be added resulting in the overall technical solution that is not cost effective. But when buildings are clustered together, after each building is designed to its economic energy efficient option, the building cluster is also energy optimized taking advantages of the diversification between energy intensities, scheduling, and waste energy streams utilization. The optimized cluster will minimize the amount of renewables needed to make the building cluster net zero. This paper describes this process and demonstrates it using as an example a cluster of buildings a Brigade Combat Team Complex at Fort Bliss, TX.

Army Energy Policy Overview

Army energy policy is partly driven by the fact that buildings contribute to a large fraction of energy usage. In the United States alone, buildings consume about 40% of total energy, including 71% of electricity and 54% of natural gas [1]. Army alone spends more than $1 billion for buildings related energy. The Army Energy Security Implementation Strategy [2] sets the general direction for the Army including elimination of energy waste in existing

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facilities, increase in energy efficiency in new construction and renovations, and reduction of dependence on fossil fuels. The 2005 Energy Policy Act [3] requires that Federal facilities be built to achieve at least a 30% energy savings over the 2004 International Energy Code or American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2004 as appropriate, and that energy efficient designs must be life cycle cost effective. According to the Energy Independence and Security Act (EISA 2007) [4], new buildings and buildings undergoing major renovations shall be designed so that consumption of energy generated offsite or on-site using fossil fuels is reduced, as compared with such energy consumption by a similar building in fiscal year 2003 (FY03)—as measured by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey data from the Energy Information Agency—by 55% in 2010, 80% by 2020, and 100% by 2030. The Federal Energy Management Program (FEMP) is drafting a ruling providing interpretation of EISA 2007. Whatever the interpretation will be, newly constructed buildings and buildings after major renovations shall use zero fossil fuels for their energy systems by 2030.

Current U.S. research efforts in this area has focused primarily on renewable energy sources, and (somewhat) on the energy efficiency of single buildings. The building stock at most Army installations is complex, including a mix of buildings with low and high energy use. The diverse energy use in these buildings is due to the nature of the activities they house, and the changing dynamic of buildings on Army installations, which results from installation growth through Base Realignment and Closure (BRAC) and Military Construction (MILCON) Transformation Programs, soldier deployment, and mission change. As yet, researchers have done little work on the integration and minimization of energy use in building communities i.e., Army installations.

In an increasingly energy constrained world, the Army and its logistic support envisions a future where energy needs are designed and fulfilled by a suite of ultra low energy solution options that can be tailored for adaptation at any Army installation depending on climatic zone, mission needs, mix of building types, availability of different sources of renewable energy, etc. Presently there is no overarching power delivery, energy storage, demand architecture and methodology to accomplish this. Commanders require that capability to meet their energy use reduction goals, along with the ability to meet requirements for energy security, affordability, environmental footprint, occupant well-being and productivity, building sustainability as appropriate depending on the threat conditions, mission needs, utility market prices, etc.

Integrated Optimization Process

Introduction

The Army is rapidly changing its views on energy usage to reconsider energy conservation and efficiency. Energy efficiency on Army installations requires serious tracking of all waste energy flows, and energy use and storage within the "installation boundaries," with consideration of realistic thermodynamic constraints for all rejected energy. To accomplish these ends is neither straightforward nor inexpensive. The concept of improved standards and increased energy conservation in buildings can help individual buildings achieve more efficiency. However, it is difficult to have existing buildings achieve Net Zero Energy goals on their own. Therefore, Net Zero Energy cannot be met with efficiency increases alone; there must be efficiency gains on the conversion, supply, and distribution side. Achieving NZE will only be possible if an optimum mix of demand reduction, energy distribution, energy supply, and renewable sources are put in place at a community (installation) or building cluster scale.

The knowledge base needed to build, renovate, and maintain Army installations with the highest levels of energy efficiency do not penetrate far enough into the market. There are many available technologies [6,7], e.g., those related to the building envelope, ventilation, advanced "low exergy" heating and cooling systems, central energy plants with coand tri-generation, hybrid and high efficient lighting systems, integrated solar thermal and electrical systems, etc. Due to economies of scale, a number of technologies, like cogeneration or combined heat and power, waste heat recovery, biomass, geothermal energy, solar heating (and cooling), and others, are (in technical and economic terms) more efficient when used in large systems than in small or individual systems. The use of these technologies will enable an optimized system to reduce the primary energy consumption and costs, including demand and supply, to the best available standards.

Community energy planning and central systems optimization do not require development of a new approach. In the past, energy planning methods were used to design the components of the energy supply systems. For example, a local utility would often plan a district heating network connected to local combined heating and power plant using an “optimization strategy.” Existing energy planning methods can use energy balancing and available planning models (including environmental models). Nevertheless, this approach is still unfamiliar to contemporary energy planners. An important feature necessary in community-wide energy planning is to integrate supply and demand to achieve an optimized solution. The objective in applying the principles of such a holistic approach to community energy is to provide such necessary methods and instruments to master planners, decision makers, and stakeholders (Figure 1).

Figure 1. Community addressing all the energy interactions.

Thermal Energy Systems consist of three major elements: (1) energy generation, (2) energy distribution, and (3) energy demand (Figure 2).

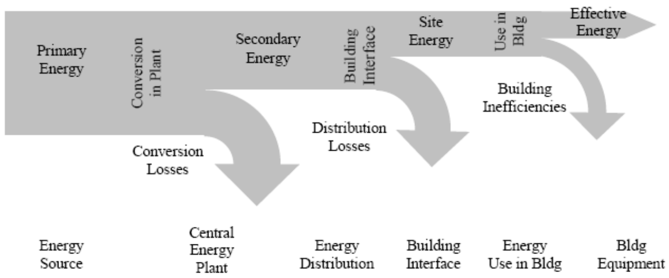

Figure 2. Energy supply chain from primary energy to end use.

The goal of the integrated optimization process is to find the optimum for the entire system. Hence, each element requires consideration. This process can be analyzed in several steps:

- **Site Setup and Analysis**. Determine building locations, geography, utility locations, etc.
  - *Gather Building Energy Data for Benchmarking*. Gather utility bills, available energy demand data, etc., for all new and existing buildings.
  - *Characterize All Buildings in Inventory*. Determine the building type and use characteristics and determine appropriate building model to simulate for demands.
  - *Pre-Planning and Data Gathering*. Gather all building and site data from stakeholders and partners. Gather all of the data with no pre-conceived answers.
- **Building Simulation**. Simulate base and efficient cases for each building type selected in the site inventory.
  - *Determine Baseline Model*. Simulate each building classification type identified in the building characterization step from the inventory.
  - *Energy Efficiency Measures (EEM)*. Determine the appropriate building energy efficiency measures for each simulated building type.
  - *Simulate the Energy Efficiency Cases*. Simulate the energy efficiency scenarios and produce the optimization curve for each building type.
  - *Generate the EEM Project List*. During the optimization process, generate the project

    list to bring the building to net zero ready status.
  - *Produce Building Energy Use Profiles with Peaks*. Develop hourly, monthly, and annual use profiles for all demand energy
- **Distribution and Supply Optimization.** Take data from the building efficient cases to set up the load and network design to determine the optimal distribution and supply network. Integrate all building energy demands. (Use the efficient case for the building cluster to be analyzed.)
  - *Develop Load Duration Curves*. Integrate all energy demands for the building cluster to be optimized and produce curves.
  - *Use Hydraulic Simulation*. Develop the hydraulic parameters for integrated heating and/or cooling systems.
  - *Determine Supply Equipment Inventory*. Determine all of the existing and planned boilers, chillers, solar thermal, generators, renewables, etc.; locations, sizes, age, etc.
  - *Use Electric Distribution Simulation*. Do a grid analysis to determine the optimized distribution of the electrical system and electric renewable energy supplies.
  - *Use Supply & Distribution Optimization Simulation.* Use a model like "POLIS" to determine the optimal distribution and supply systems for both the thermal and electrical and the integrated loads to calculate primary energy demands with the included distribution losses.
  - *Determine Centralized and De-Centralized Options*. Optimization must consider both sets of scenarios.
- **Cost and Emission Analysis.** Integrate energy and fuel use using efficient buildings, optimized distribution systems, and supply scenarios. Calculate fuel costs and associated emissions.
- **Financial Analysis.** Using energy, fuel, distribution and supply costs, calculate the initial costs, investment costs, annual income, yearly cash flows, and cumulative cash flows for the project life for each scenario.
- **Sensitivity and Risk Analysis**. Estimate the sensitivity of important financial indicators in relation to technical and financial input assumptions. Develop final results for each of the scenarios investigated.
- **Overall Scenario Results and Project Recommendations.** Display overall scenario results showing risk and reward for the project and make scenario/project recommendations with the development of the project business plan.

The primary goal here is to calculate the amount of energy delivered, in various forms, by an energy system. The challenges of the model are to assess the system's energy needs in terms of heating, cooling and power generation, and then to estimate how those needs can be met by the various energy systems ultimately chosen. The model calculates the system's load and energy use and evaluates how they can be optimally met.

Building Level Optimization

The Army's present and future building stock is comprised of a variety of building types. Energy requirements in some types (i.e., barracks, office buildings, child development centers) are dominated by climate (heating, cooling and humidity control) with a smaller effect from plug-in loads. Other buildings (e.g., command and control facilities, hospitals, training facilities with simulators, dining facilities, laboratories) have high energy loads dominated by internal processes and high ventilation requirements.

While some energy use reduction methods in most of these facilities are similar and well understood (building envelope improvement, better lighting technologies, etc.), in buildings with high internal loads, energy use reduction can result only with intervention into specific processes and utilization of significant waste streams, which is currently rarely addressed. More work is needed to address energy uses and wastes at such energy intensive facilities like data centers, laboratories, training simulators, hospitals, etc.

The energy demand determines the amount of energy that needs to be provided by the distribution and supply generation side. Building-level energy simulation and optimization can be accomplished using models such as EnergyPlus, ESPr, or TRANSYS or other accurate hourly energy analysis program. When a community or a cluster of buildings is evaluated, there are more opportunities available for energy savings and more challenges for analysis and optimization. Addressing buildings as a community requires a deep evaluation of each building, after which the individual analyses are applied to the community to assess the possibilities for integrated supply services.

The building optimization process starts with identifying typical buildings and energy systems on Army installations, existing energy wastes, and inefficiencies related to these buildings and systems. One must then develop load profiles for typical base case buildings and do an analysis of suites of technologies for ultra-low energy installation, including waste recovery and energy conserving (ultra-low energy), energy generation and storage technologies that could be applied to buildings, and energy systems that support those buildings—ultimately to minimize traditional electrical and fossil energy use.

There is a debate over whether to conserve energy first or just generate energy with alternatives. Figure 3 shows the theoretical path and process for each individual building optimization. Point 1 is the base case building required to be built to the local code body requirements. From that point, by adding the energy efficiency technologies that add first cost, one eventually reached the lowest life cycle cost (Point 2). One would not add renewables at this point since many more energy efficiency technologies that are more cost effective than adding renewables can be added. Point 3 is reached when the annual life cycle cost equals the base-case building built to code, although at that point, the building is now much more energy efficient and in many cases a much more comfortable to inhabit. By adding energy use improvements to the building, one eventually reaches the crossover point where improvement of energy generation systems is more cost-effective than adding further energy efficiency options. At this point, add the most cost effective energy supply options to the point when including renewables to the building becomes cost effective. By definition, this crossover (Point 4) marks the point where the building is "Net Zero Ready." Once building optimization has reached this point, supply technologies are finally considered.

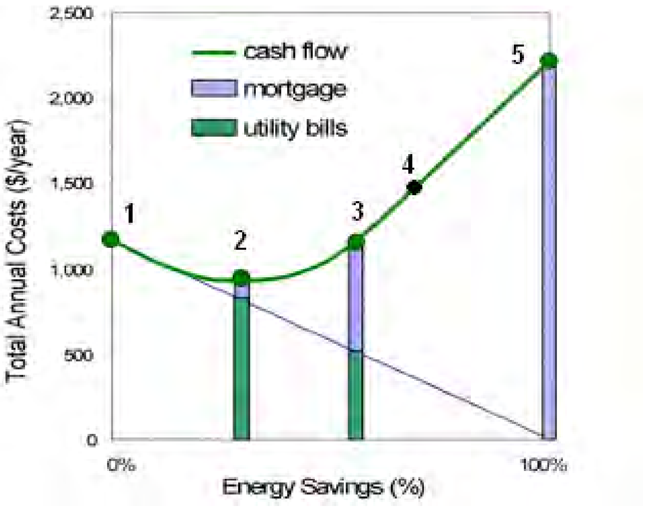

Figure 3. Lowest cost path to a building configuration that uses net-zero energy

When this process has been completed for each building, the results from all of the individual buildings are integrated and put into annual load duration curves. The load duration curve shows the cumulative duration for different loads in the system over a full year. These curves, derived from hourly loads data, show all possible variations to the system generated from the hourly energy simulation program. Due to the diversity of energy use in buildings comprising the cluster (community), the peak of the resulting load curve is much smaller than the sum of peaks of individual buildings; thus the needed generation and back-up capacity is smaller.

To develop the community energy concept, energy models can be used that optimize distribution of energy from central generation/production to the energy usage by the buildings and systems. These models will minimize energy waste and losses and optimize first and operating costs. Based on this concept, a Master Planning process can be developed that will provide an orderly approach to changing the typical Army installation to an ultra-low energy consuming community. The building simulation gives results for demand curves for domestic hot water consumption, electricity consumption, heating, and cooling for those buildings at existing climatic conditions. These are passed to the next step.

Distribution and Supply Optimization

Simulation of Supply systems can be done using an energy system model like POLIS [8]. Between energy generation and energy demand points (at each building level), a distribution system is used to transport the energy via hot or chilled water. These systems can be simulated using a hydraulic flow model. While "energy balancing" means just calculating the correct energy flows (and perhaps also carbon emissions) in a system, to estimate energy costs and to benchmark with other similar systems, simulation and optimization is necessary for system planning. For principal comparisons of available alternatives, a simpler simulation approach is more favorable, one that provides a possibility to make an energy balance for the whole system and to compare the effects of different demand or supply side measures in terms of energy efficiency, capital and energy costs, and Greenhouse Gas (GHG) emissions with the simulated demand curves from the building simulation and optimization step.

For this purpose, one might apply energy system models that have been developed in the past for the optimization of large systems. However, to be used as a regular planning tool, skilled planners are needed that are familiar with them. With POLIS, an energy system is modeled as a closed system including the entire chain from demand, through the distribution system, to the supply systems. Every element like buildings, boilers, generators, grids etc. are described as knots with energy and cost related parameters, and are linked together to an interconnected system where different usages are interlinked. Power supply, heating, and air conditioning is modeled in a common system. This offers the opportunity to compare efficient technologies like co-generation (power + heat) and tri-generation (power + heat + AC). The model this requires at least an hourly time resolution.. The results of such a modeling offer the best suited solution to reduce the energy usage of a building cluster and leads the way to net zero installations with least cost. More than that, the approach of optimizing building clusters will offer new and/or additional options reducing the fossil energy footprint of community systems in a cost efficient manner. The results can be directly taken to be used as a basis for detailed design planning to implement the solution found with the model.

In POLIS an energy system can be modeled by using prototypes of generation equipment, distribution systems, and load profiles (Figure 4). Cost, emissions, and technical parameters are used to describe existing or future elements of the system. Simulation is performed using hourly load profiles for thermal and electrical energy demand throughout a year cycle (8760 hours), which is generated from the summation of the building cluster energy simulations. POLIS allows calculation of the best suited combination of paths to meet the load with the objective to minimize total system costs, or minimize total GHG-emissions.

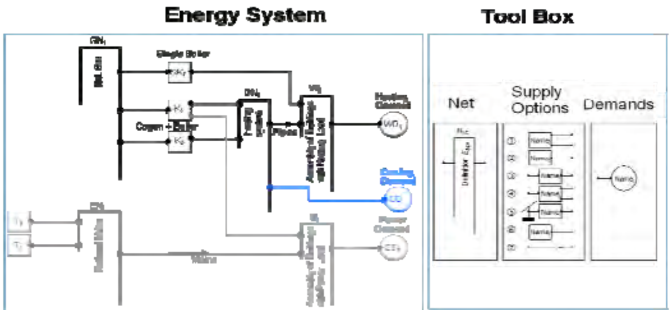

Figure 4. POLIS energy system model.

Since the distribution systems play a significant role in an overall thermal energy system, a hydraulic flow model (Figure 5) should be used to analyze critical capacities and flows in the system.

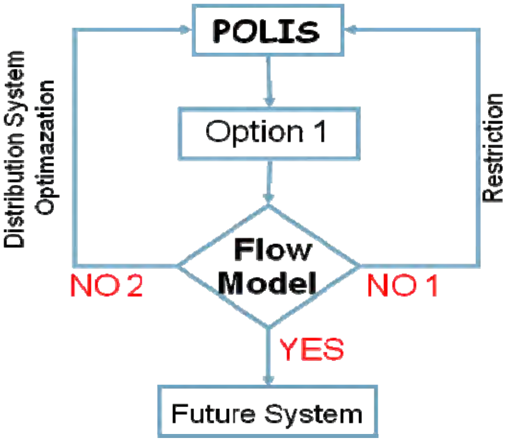

Figure 5. Hydraulic flow model.

Through an iterative process, these two models will determine whether an optimization of the energy system (POLIS results) will lead to a feasible optimized supply and generation system.

Application of the combination of two models has the following gaps. POLIS is based on linear programming (LP) so the system needs to be described with linear equations. Thus, a feedback of supply temperatures on the efficiency of a thermal generation unit cannot be modeled directly. Getting a usable representation requires iterations in the modeling and optimization process. Also, POLIS cannot optimize measures for demand reduction versus measures for increasing the generation efficiency since this process cannot be described with an LP model. Furthermore, the iteration between an hydraulic model and POLIS requires user "know-how" because the user has to integrate the results in each case manually.

Fort Bliss Brigade Combat Team Complex Case Study Results

The integrated energy optimization process described to this point includes analysis of building energy efficiency improvements and optimization of energy generation and distribution. The tools required to optimize individual building were applied to the analysis of eight types of Army buildings with the goal to meet or exceed EPACT 2005 requirements to new construction [9,10,11,12]. One of the major constraints limiting the level of energy use reduction in those studies was the first cost increase not exceeding 2%. Study with aggressive goals to achieve 60 to 80% energy use reduction against CBECS 2003 (Commercial Buildings Energy Consumption Survey) levels with the analysis of first cost implications is on the way [13]. Given the limitations on the length of this paper, this section illustrates only one piece of the puzzle to achieve Net Zero i.e., central energy systems for heating and cooling. The following analysis demonstrates optimization of the central heating and cooling system, given that all the buildings comprising Brigade Combat Team (BCT) at Fort Bliss already meet EPACT 2005 energy requirements approach.

Figure 6 shows the cluster of buildings included in this case study. From the North to the South the BCT consist of Barracks (light blue) with a Dining Facility (purple) in the middle. Then the Headquarter Building (orange) is close to the through street. South of the street and parking spaces the Company Operation Facility (green) and Tactical Equipment Maintenance Facilities (red) are shown. The total building floor space is about 1,402k square feet (sq ft), which is divided into Barracks with 567k sq ft, Dining Facility with 31k sq ft, Tactical Equipment Maintenance with 229k sq ft, Company Operation Facilities with 447k sq ft, and 129k sq ft for the Headquarters. A model was used to develop the synthetic load curves for space heating, domestic hot water (DHW), cooling, and electricity for each building usage. Table 1 lists the average square footage of each building type.

Table 1. Overview on the building footprint of a BCT cluster.

Building	Average floor space [sq ft]
Barracks	51,503
Dining	30,624
Tactical Eq. Maint.	44,204
Company Operation	51,253
Headquarter	129,237
Total	*1,402,021*

EnergyPlus was used to model all of the different building types to simulate the hourly building loads for Domestic Hot Water (DHW), Space Heating (SH), and Cooling. The models were developed from baseline code models with the 30% savings necessary to meet the Energy Policy Act 2005 requirements. Figures 7 and 8 show the overall results for the entire BCT for Fort Bliss weather and climate conditions. The total energy consumption for DHW and SH is about 32.7 billion BTU per year; the annual cooling demand is 48.6 billion BTU per year and the electricity load is 18.2 GWh.

Figure 6. Fort Bliss BCT

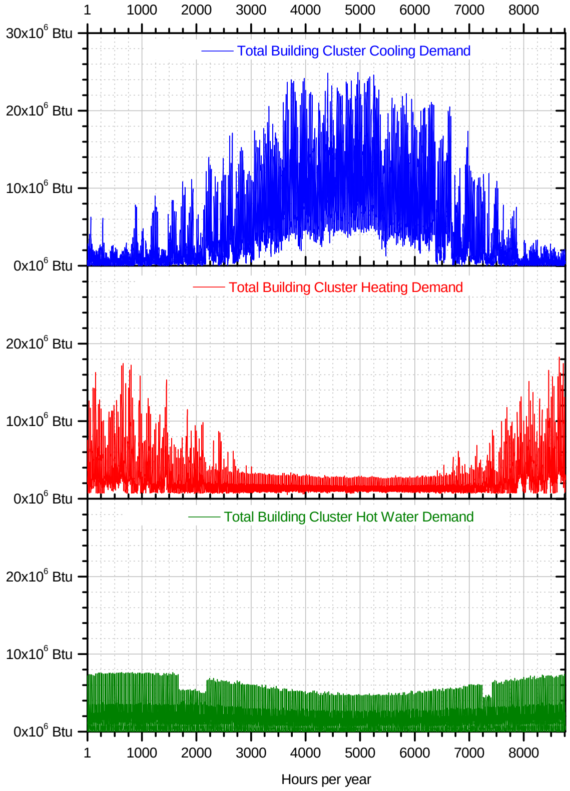

Figure 7. Cooling, DHW and SH load curve hourly scatted for one year for Fort Bliss BCT.

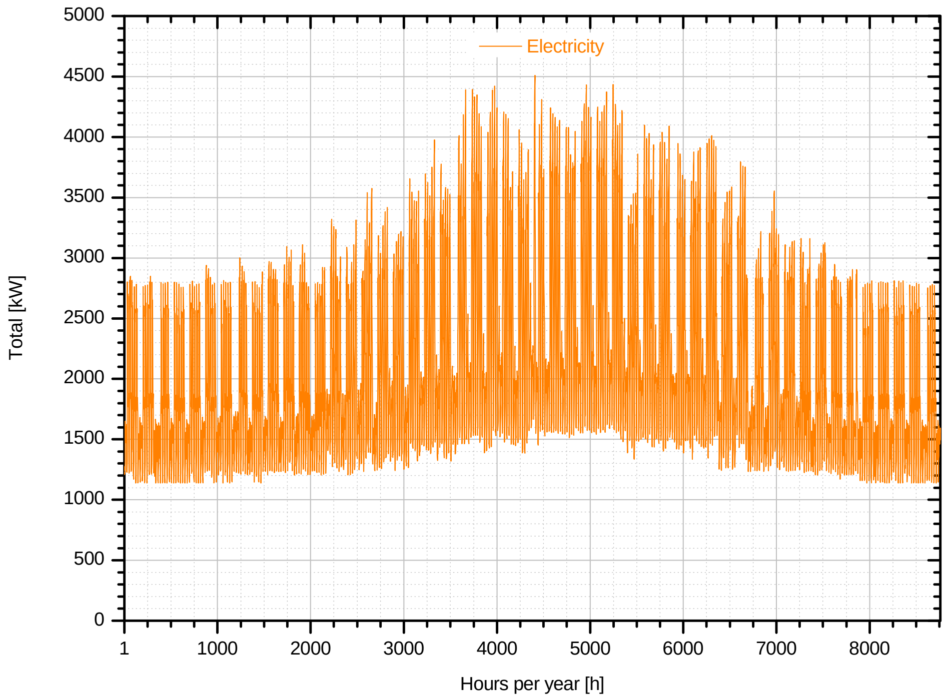

Figure 8. Cooling, DHW and SH load curve hourly scatted for one year for Fort Bliss BCT.

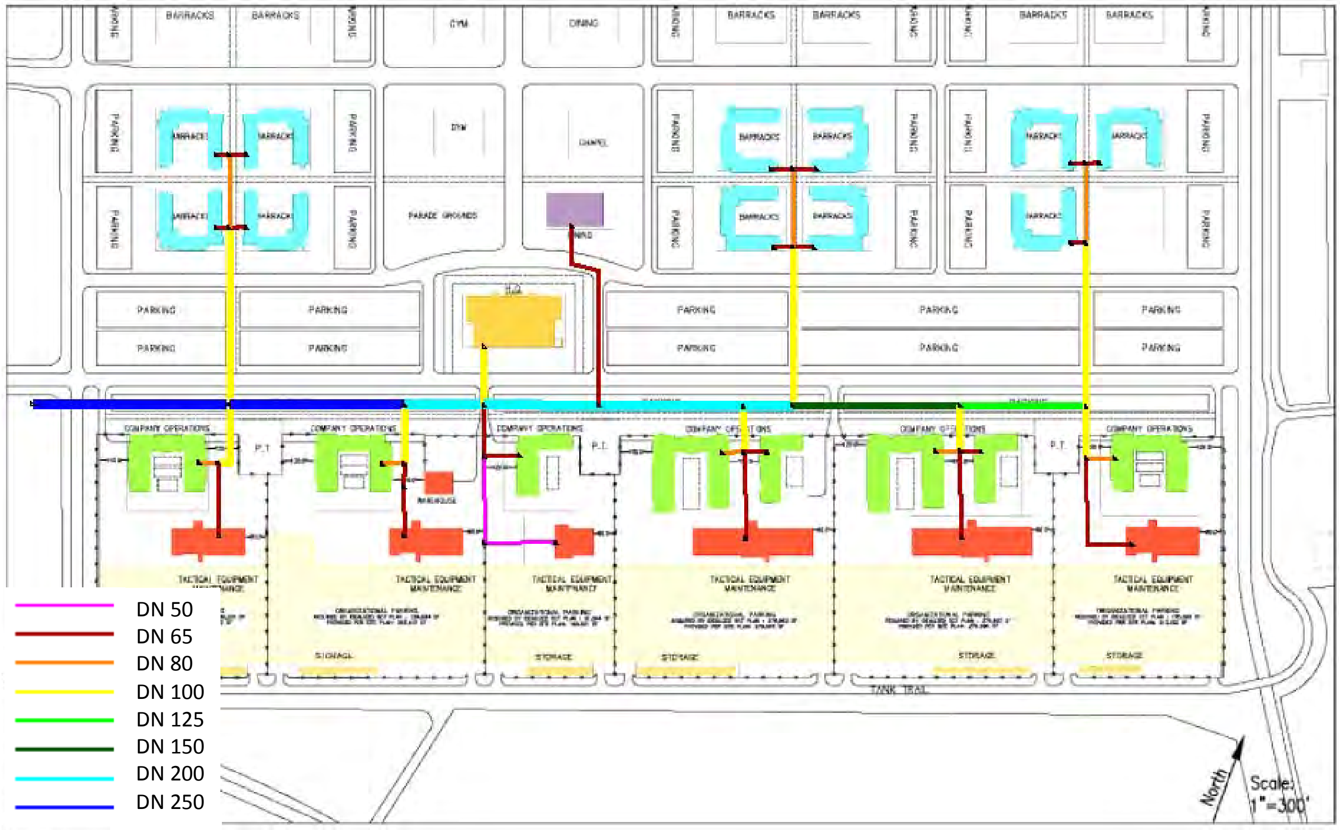

Figure 9. Sizes of the pipes for the central heating system.

Figure 10. Sizes of the pipes for the central cooling system.

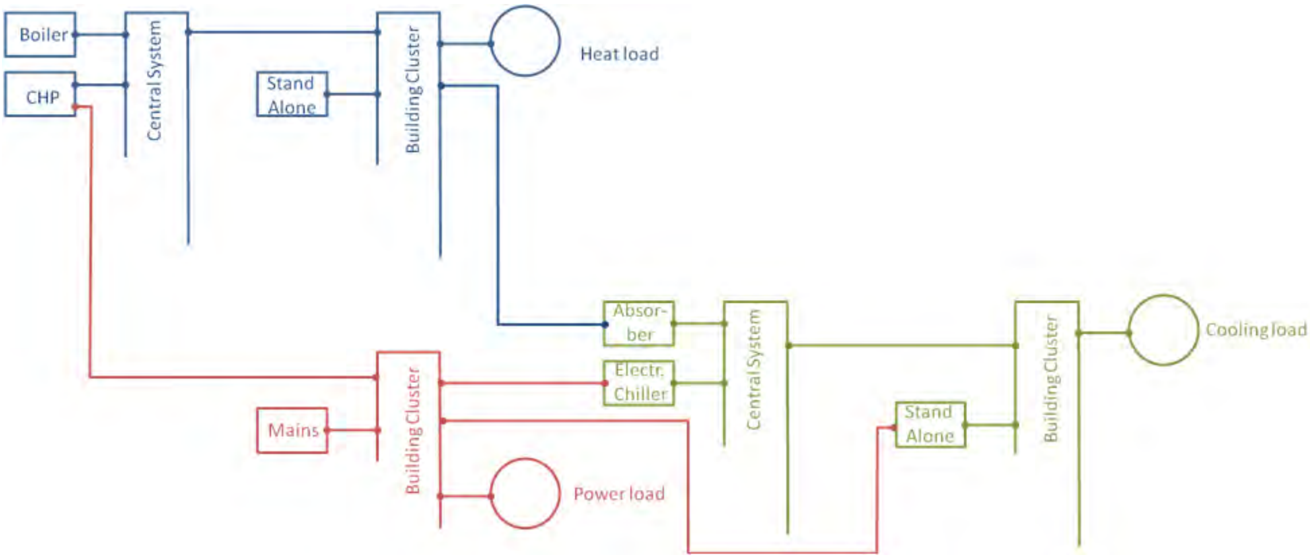

Figure 11. POLIS model of the BCT cluster.

Since the goal of this study was to show an approach towards NZE with central energy systems for heating and cooling, the integrated modeling approach described in the “Distribution and Supply Optimization” section is applied. The first thing is to derive the distribution system for both heating and cooling. This was done using the hydraulic flow model sisHYD to model each building and its connected load. A location for the Central Energy Plant (CEP) outside the building cluster was selected to serve the BCT.

The flow model is applied to derive the sizes, and from that, the first costs for the piping system. The peak loads for both heating and cooling is critical to size the piping system. Doing that requires the presetting of the piping runs, which is done manually. Then the peak load case is executed while the parameters *supply water temperature*, *building return temperature* and diversity *factor* (e.g., 67.5%) are set. Figure 10 shows the results for the flow model for heating and Figure 11, for cooling. The sizes of the pipes were chosen by the modeling software and for the pressure drop between the CEP and the buildings. In metric units, the peak pressure for mains is about 120 Pa/m, and for laterals, about 150 Pa/m. The pipes will have some reserve capacity for adding additional buildings and/or higher loads in future. The colors in the figures indicate the nominal diameter of the pipes in standard DN. The number indicates the median pipe diameter in mm.

The first cost estimation for the piping system is based on European Standard Pre-Insulated Bonded pipes. This is a direct-buried piping system that has been used for central heating and cooling system in Europe for more than 35 years and reduces first costs compared to a concrete trench piping system by about 25 to 35%. The first costs can be reduced further by using a common trench for both heating and cooling systems.

After the hydraulic modeling, the results were used to model the integrated energy system in POLIS. POLIS is used to derive the supply generation concept and optimize the energy supply represented in Figures 7 and 8. The objective function is minimizes total annual costs or minimized carbon dioxide emissions. The POLIS model for the BCT is shown in Figure 11. As shown in Figure 11, heating and cooling thermal demands for two different options are given: centralized and decentralized. Additionally the electric system is considered.

The annual load curves, defined as the demand that needs to be served, are shown in Figure 7 and 8. The annual heating load curve is the sum of SH and DHW. Then in both heating and cooling systems a connection to a central system as well as the decentralized option is optimized. In the central heating systems, a Coupled Heat and Power Plant (CHP Plant) and peak load boilers are available. In the central cooling system, central electrical chillers and absorption chillers as tri-generation option are available. All of the central equipment supply generation feeds its energy production in the distribution system. The properties of the central distribution system were derived via the flow analysis with sisHYD.

The electric power system is also modeled. The CHP plant feeds into the power system and both electric chiller options are supplied by the power system. If those chillers are used to provide cooling, more electricity is required by the demand curve. Besides, the CHP plant electricity can be supplied from the utility, or (see Figure 11) the Mains.

The properties of each piece of equipment are defined. The important properties are the equipment efficiency, first costs, operation costs, fuel costs, and transport efficiencies. In addition some other constraints like minimum load for the chillers, boilers, etc. are also defined. Also important is the fact that a security of supply is considered. The most common strategy is a level of redundancy of (N+1). That means that the peak load should be served even if the biggest piece of generation equipment has had a failure. Moving towards NZE for the BCT cluster first the building loads have been reduced. Then the generation needs base as much on renewable fuel sources as possible. Using this approach means that for both centralized and decentralized options, renewable fuels are the main input.

The first costs for each option (shown in Figure 11) were assumed via specific costs in $ per MBH and $ per cooling ton. The assumed costs were derived from comparable reference projects and consist of all required equipment for the installation like pumps, pressure maintenance, de-aerator, internal piping in CEPs, cooling towers for chillers, etc. The costs then were broken down to annual amounts using the annuity method (6% interest rate over 20 years, annuity factor of 8.72% per yr.). The fixed annual costs were estimated via an annual percentage of the total first costs, like 2.5% for wood chip boilers and 0.5% for piping systems. This includes Operation and Maintenance (O&M) as well as other annual services. The variable annual costs are results of the optimization from POLIS, where the fuel costs are a modeling parameter.

With these inputs, the POLIS run was executed. In the first run, only the central equipment was enabled. Figure 12 shows that the demand is met for the heating system. The following figures do not show the demand line for better data visibility of the results. Figures 13, 14, and 15 show the results for heating, cooling, and electricity, respectively.

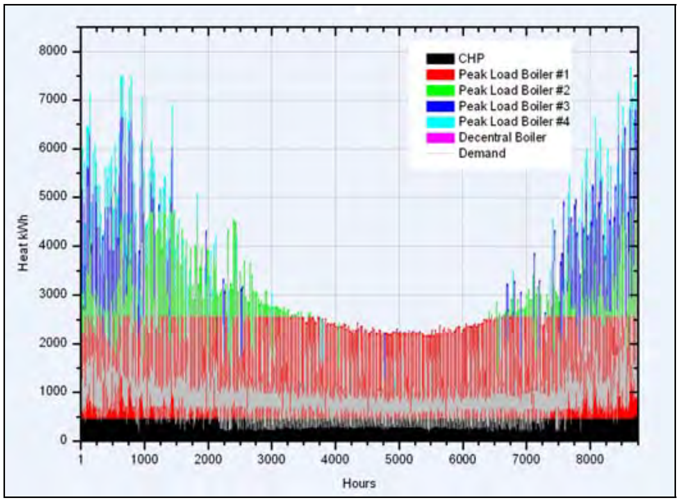

Figure 12. POLIS output of the heating system. The demand curve of the cluster is met.

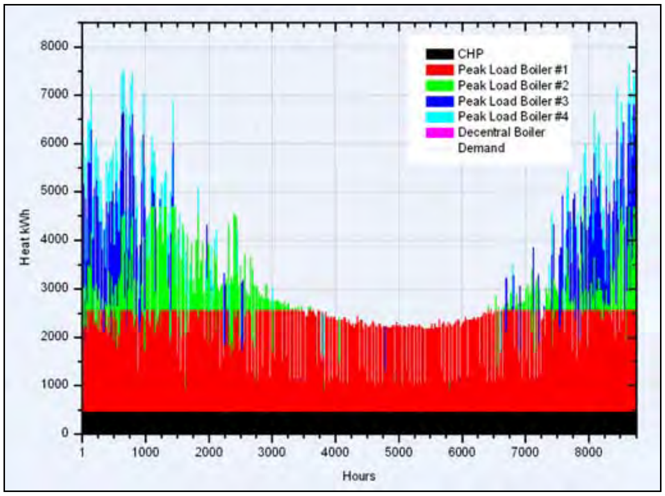

Figure 13. POLIS output of the heating system.

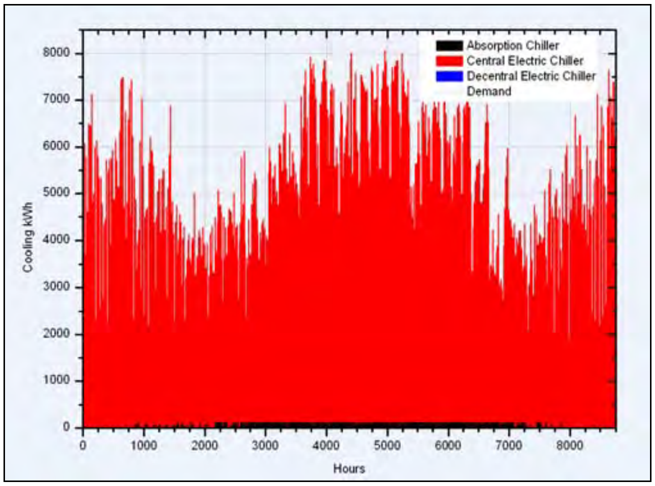

Figure 14. POLIS output of the cooling system.

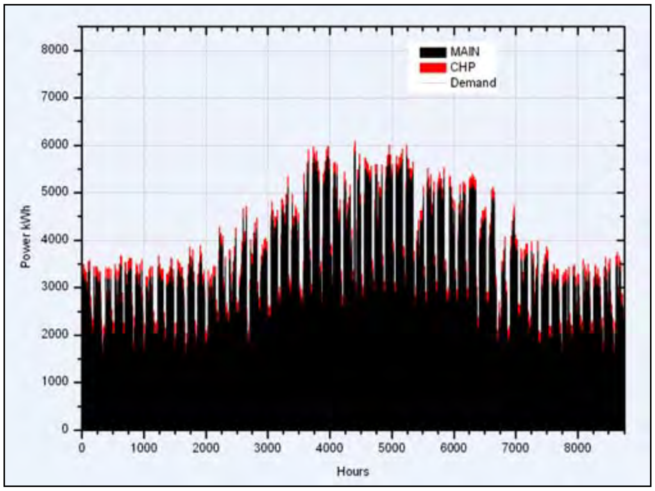

Figure 15. POLIS output of the power system.

The model output shows total primary energy consumption for heating in the boilers and CHP plant of 49.74 billion Btu/yr and an electricity consumption from the mains of 20.4 GWh/yr.

In the second model run, only the decentralized options were enabled. Figures 16, 17, and 18 show the results for heating, cooling, and power, respectively.

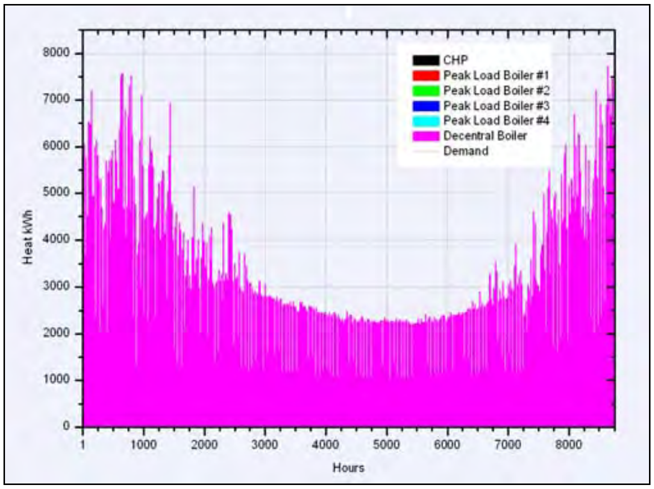

Figure 16. POLIS output of the heating system.

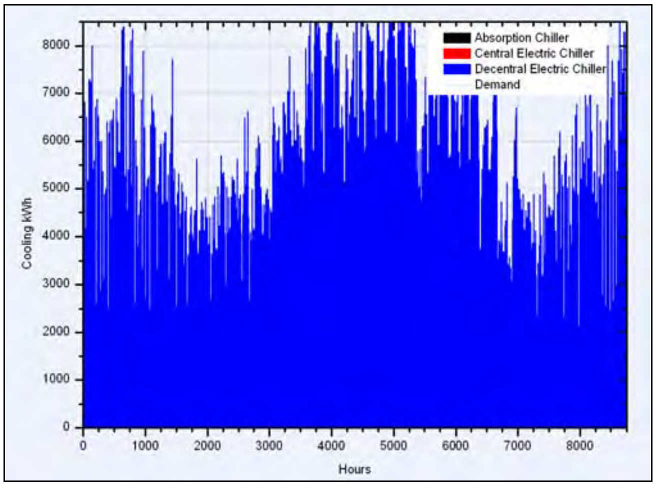

Figure 17. POLIS output of the cooling system.

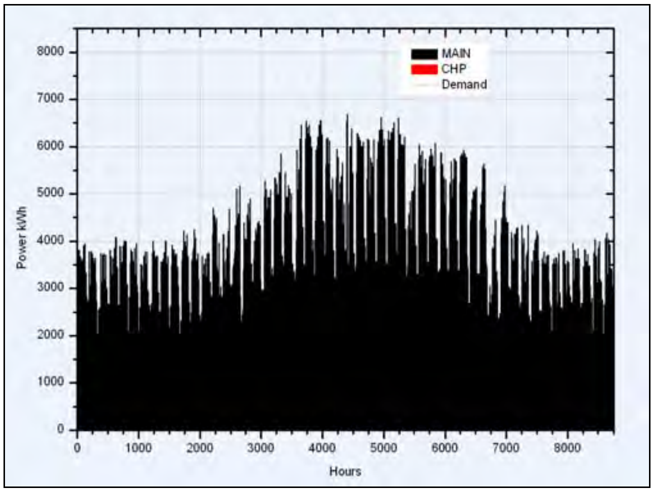

Figure 18. POLIS output of the power system.

The model output shows total primary energy consumption for heating in the boilers and CHP plant of 45.14 billion Btu/yr and electricity consumption from the utility of 24.7 GWh/yr.

The fuel for the CHP is the reason why the fuel consumption for heating decreases from centralized to decentralized even though the CHP provides heating and electricity at the same time. Thus, the power consumption from the mains increases from centralized to decentralized by 21% or 4.3 GWh/yr.

The fact that heat is a local commodity with a lower exergy factor and electricity is a non-local commodity with an exergy factor of 1 that cannot be stored easily like heat, indicates that this is a good path to achieving NZE.

Conclusions

This paper has shown the Net Zero Energy optimization process and an example with the illustration of one of its parts using the study for a BCT cluster of buildings in Fort Bliss. The integrated optimization process is being developed under the Army research and development project “Modeling Net Zero Energy (NZE) Installations” [13] and is a part of the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) Annex 51 [14]. The process includes optimization of each building clustered together to meet its economic energy efficient option. The building cluster is then also energy optimized taking advantage of the diversification between energy intensities, scheduling, and waste energy streams utilization. The optimized cluster will minimize the amount of renewables needed to make the building cluster net zero.

The analysis of the central cooling and heating system of a cluster of buildings of a Brigade Combat Team Complex at Fort Bliss gave an example of how, for given loads and building density, a centralized system is more lifecycle cost effective and reduces the green house gas (GHG) footprint significantly. The implementation of a centralized system can yield many other additional benefits as well. It is technically very easy to add alternative heat sources to district heating systems depending on their operating costs and technical maturity. At present, the two most likely that could be added are direct-burn biomass (woodchips or similar) and solar thermal collectors. These decisions can be made based on prevailing future market conditions with minimal disturbance to the basic infrastructure as well as energy security.

The combined solution of efficient construction, district heating, centralized heat supply sources, optimized cooling, and efficient use of electricity has a major impact on the greenhouse gas impact on the building cluster. This already dramatically low level can potentially be further reduced with the addition of biomass heating, solar photovoltaic, and solar thermal renewable sources as they become more cost effective.

Under a future U.S. climate regulatory regime, the credits associated with greenhouse gas emissions may have significant value and should be included in the financial evaluation of all projects. The costs of natural gas, alternative energy technology, alternative fuels and the impact of greenhouse gas regulation are significant uncertainties looking forward. For this reason, implementing centralized systems as an approach minimizes the potential future risks. The integrated energy solution recommended demonstrates that vastly improved energy efficiency and greenhouse gas reduction is feasible in the context of a normal scale development using proven approaches from the United States and elsewhere.

"Business as usual" leads to individual boilers and chillers for each building. This leads to significant total overcapacity, and over time, to a wide range of boiler inefficiencies and chiller COP's with limited overall system control to meet the diverse demands of an installation. Alternatively, district heating and cooling systems link buildings in common networks. This eliminates inefficient overcapacity of boilers and chillers and allows the integrated system to meet the integrated peak loads instead of all the individual peak loads. Therefore efficient machines can be added now, allowing for easily adding new technologies in the future at one location instead of each building.

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