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Integration of Master Planning and Energy Planning: From Detailed to Conceptual Analysis

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ABSTRACT

The process of building sustainable communities requires careful coordination between a number of stakeholders, including master planners, energy planners, and building designers. Within the U.S. Department of Defense, these stakeholders work at differing levels of detail and use different planning horizons, which may lead to suboptimimal decisions for the community as a whole. This paper describes a new approach to adapt energy planning processes and tools to scale smoothly between the master planning level, involving thousands of buildings, to the facility design level, involving single buildings. The concept of an energy and sustainability overlay and use of design targets is presented. Examples are provided using the net zero planner tool from studies performed at a U.S. Army installations.

INTRODUCTION

The U.S. Army recently promulgated policy guidance requiring "all installations to implement net zero energy, water, and waste to the maximum extent practical and fiscally prudent" (U.S. Army 2014). For energy, this means that all installations will attempt to implement cost-effective strategies to generate as much renewable energy on site as they use over the course of a year. For water, the Army goal is to generally reduce the amount of water used and to avoid depleting surface and groundwater resources. For waste, the goal can be summarized as zero solid waste to landfills. Energy, water, and waste systems are often coupled. For example, thermal electrical power generation requires water, while some forms of solid waste can be used to produce electrical power in a waste-to-energy system. Zhivov et al. (2014a) discusses an approach to energy master planning that emphasizes reduction of energy loads from buildings first, followed by optimization of distribution and energy conversion (i.e., generation). Case et al. (2014) and Swanson et al. (2014) present a framework and tools for energy planning and optimization that implement the approach. Case studies illustrating the use of the approach and tool at the U.S. Military Academy (USMA) at West Point, NY, and Portsmouth Naval Shipyard, NH, are presented by Zhivov et al. (2015) and Liesen et al. (2015). The energy planning approach and tool are in the process of being extended to include net zero water and net zero solid waste, including modeling of coupling between the domains of energy, water, and waste.

In practice, coordinating the myriad stakeholders involved in planning for net zero installations is daunting. Three levels of stakeholders can readily be identified. At the highest level of abstraction, master planners think in terms of long-term sustainability goals, including community layout, transportation, and street design. In recent guidance to planners, the Department of Defense (DoD 2012) encouraged master planners to use strategies such as compact, infill, and transit-oriented development, as well as landscape elements such as street trees, to decrease energy use and manage storm water. This guidance was a major shift from earlier guidance that largely ignored sustainability goals. Master planners have extended the length of their view from an approximately 5-year capital development plan to 25 or more years oriented to sustainability. Energy managers fall within the middle tier of abstraction and their work is discussed in the USMA and Portsmouth case studies previously referenced. Their focus may vary between longer-term energy infrastructure projects, such as district energy systems, to medium- or near-term projects, such as building retrofits designed to help an installation

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meet its overall goals. Finally, the building (or infrastructure) designer falls into the most detailed level of abstraction. These engineers must create designs for a specific project that can be shown to be effective, buildable, biddable, and cost-effective. Implementation of net zero installations requires that there be effective communication and coordination between these three stakeholders. For instance, the use of compact development in an area development plan (part of a master plan) may lead to more efficient use of district energy systems and result in lower source energy use as required by the Energy Independence and Security Act of 2007 (EISA 2007). Here, the master planner and energy manager should clearly work together to consider energy options in community layout. Similarly, attainment of sustainability goals may require that buildings not exceed particular energy budgets or that they connect to district thermal or electrical systems. The overall goals and their rationale need to be factored into individual building design goals. The authors are aware of projects in which building designers were not aware of the benefits of connecting buildings to a nearby heating and cooling loop that had excess capacity, requiring the purchase of unnecessary additional equipment. Similarly, requirements of ANSI/ASHRAE/USGBC/IES Standard 189.1 (ASHRAE 2014) for condensate collection were met, but the condensate ended up being led to the sanitary sewer system because there was no provision for using the recovered condensate.

In 2013, the authors were asked to contribute to a course taught by the U.S. Army Corps of Engineers on energy and sustainability planning as it relates to master planning. Case studies were presented in this course on the detailed energy planning work being performed at USMA and Portsmouth Naval Shipyard, while elsewhere in the course, very general rule-of-thumb calculations for building energy intensity, water usage, and waste generation calculations were given. This led to a discussion among the instructors regarding whether the modeling tools and processes used for energy planning could be used at the high level of abstraction needed for master planning but still provide better calculations than the rule-of-thumb ones being used, i.e., whether the tools could take building types, energy technologies, and local weather into account. A further concern was whether increased consideration of energy, water, and waste issues would enable better energy planning and provide improved guidance for building designers. This conversation led to a series of practicums (guided planning exercises) at Fort Hunter Liggett (FHL), CA, in 2013 and Schofield Barracks, HI, in 2014, in which the net zero planning was used on a set of area development plans to estimate required building energy intensities and supply strategies to meet energy goals. This paper describes the results of the FHL practicum, how the tools provided added value to planning, and the use of an energy and sustainability overlay to communicate requirements to energy planners and building designers. At the time of submission of this paper, the FHL practicums were complete, so examples are drawn from that report.

ESTMATING THE ENERGY AND SUSTAINABILITY IMPACT OF AREA DEVELOPMENT PLANS

The process of real property master planning within the U.S. Army is multitiered. Generally, it starts with an overarching 25-year sustainability plan that lays out overarching goals for the installation community. These goals typically include a vision, support for the installation's mission, energy, water, waste, natural resources, and other topics. The master planner produces a real property master plan (RPMP) that may contain the following subsections or subplans (DoD 2012):

- Master plan
  - Vision plan
    - Framework plan (which subdivides the installation into planning districts and identifies key planning concepts to guide the district planning effort)
    - Constraints and opportunities map
  - Installation development plan
    - Area development plans
      - Regulative plan
      - Illustrative plan
      - Implementation plan
    - Network plans
      - Overall regulation plan
      - Illustrative plan
      - Transportation plan
      - Pedestrian plan
      - Open space plan
  - Installation planning standards
  - Installation design guide

The vision plan contains notes about assumptions for environmental conditions over at least 50 years and conceivably over 100 years. The overall regulation plan may require a section on water use limitations. The installation planning standards and installation design guide contain explicit instructions about design conditions.

The area development plan (ADP) breaks the overall installation into areas, each of which is planned separately. FHL was subdivided into three ADPs: Hacienda Heights, Blackhawk Hills, and Mission Valley. Figure 1 shows an overall illustrative plan for FHL. Figure 2 shows the illustrative plan for the Blackhawk Hills ADP. The ADP documents the envisioned future state for the listed area of the installation, including a description of existing buildings that will be retained (and possibly renovated), buildings that will be demolished, and buildings to be built. Adopting the terminology of Zhivov et al. (2014b), the baseline represents current energy use for the ADP, the base case represents the future state (existing buildings – demolished buildings + planned buildings), and other alternatives represent the base case with modifications. In this case, the base case with additional energy conservation measures is called *after reduction*. When this exercise is performed without energy planning tools, an average energy use intensity (EUI) is calculated

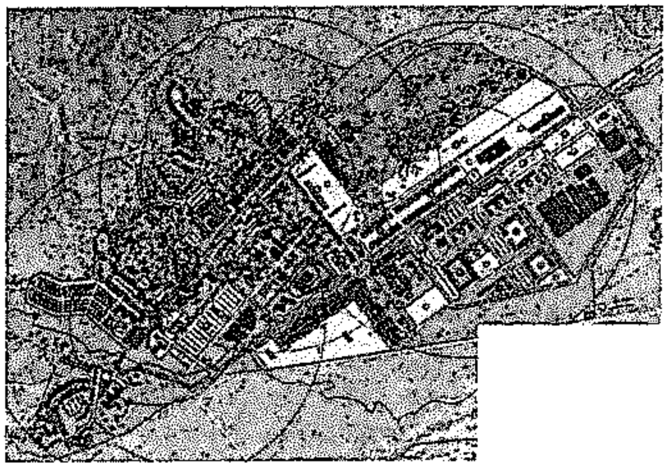

Figure 1 *Illustrative plan for Fort Hunter Liggett.*

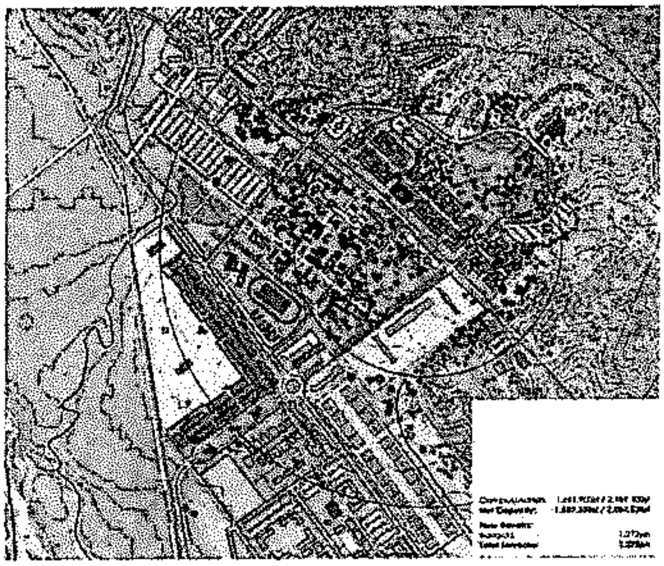

Figure 2 *Illustrated plan for the Blackhawk Hills ADP.*

based on annual bills for electrical power and fuels (in this case propane) used for heating and other purposes. The base case future energy consumption is calculated by multiplying the future conditioned area by the current average EUI (Table 1). To estimate the future energy consumption if additional energy efficiency measures (EEMs) are implemented, the planners assume that some of the buildings will be brought up to some benchmarked level, such as ANSI/ASHRAE/IESNA Standard 100-2006, *Energy Efficiency in Existing Buildings* (ASHRAE 2006) (i.e., the 75th percentile for each surveyed use in FHL's Climate Zone 3C) or by comparison to some other recognized standard, such as the European Union's *Energy Performance of Buildings* (EU 2012). To meet FHL's future net zero energy goals, the area of photovoltaic (PV) panels for electricity and solar thermal panels for domestic hot-water was calculated to fill the remaining gap.

Table 1. Rule-of-Thumb Calculation of Base Case and Alternative Scenarios

Alternative	Number of Buildings	Conditioned Area, ft^2 (m^2)	Total Energy, kBtu/yr (kWh/yr)	EUI, $kBtu/ft^2/yr$ ($kWh/m^2/yr$)
Baseline	184	1,225,298 (113,953)	81,987,140 (24,028,053)	66.91 (211)
Base case	377	4,565,135 (4,565,135)	305,462,313 (89,522,146)	66.91 (211)
Passive projection	377	4,565,135 (4,565,135)	140,660,940 (41,223,643)	30.81 (97)

There are advantages and disadvantages to this rule-of-thumb approach to estimating the sustainability of ADPs. One positive aspect is that it is commendable for the planners to pay attention to the energy and sustainability implications of these ADPs. FHL is one of the Army's pilot net zero energy installations. Given that this master plan contemplates more than tripling the amount of conditioned built area, failure to plan for energy would act counter to the installation goals. Second, the rule-of-thumb approach does not require a significant amount of additional data collection compared to normal master planning activities. On the other hand, the rule-of-thumb approach misses a lot of detail about the types of buildings being constructed or demolished, load profiles of buildings compared to renewable options, and coincident versus noncoincident loads. There is no real opportunity to assess the feasibility of improving the building stock to benchmark levels adequate to address their goals. Moreover, it is difficult to determine the scale of net metering that might need to be negotiated with the local electrical utility. Many installations, including FHL, have limits imposed by their utilities on the amount of excess renewable power that they will accept from the installation.

APPLYING ENERGY PLANNING PROCESSES AND TOOLS TO IMPROVE MASTER PLANNING

In the initial experiment at FHL, the practicum team asked several questions:

- Could energy planning processes and tools provide information at an appropriate level of abstraction for master planners to use without overwhelming them with details?
- How much extra work (cost) would it take to generate this information using the tools compared to the normal process used to generate an installation sustainability component plan?
- What are the benefits of using the information provided by the energy planning process compared to the normal process?

Setup

The normal installation sustainability component plan process was augmented using the energy planning process (EPP) described by Zhivov et al. (2014b) and the net zero planner tool (Case et al. 2014). The baseline (current building inventory) was imported from existing geospatial information system (GIS) files, as shown in Figure 3. The baseline contains 184 buildings with a total conditioned area of approximately 1,220,298 ft^2 (113,833 m^2). Buildings are depicted as light-colored rectangles. The base case, depicting the buildings to be included in the future state, contains 377 buildings with a total floor area of 4,565,135 ft^2 (424,113 m^2) and is shown in Figure 4. All alternatives except the baseline use this set of buildings. Note that the base case contains approximately 370% more conditioned area than the baseline. Buildings were grouped and modeled by type using EnergyPlus (DoE 2013) and calibrated against FHL's energy bills. EnergyPlus models were based on a standard set developed for the U.S. Army (HQUSACE 2011) and subsequently expanded into a library of 12 of the most common Army buildings.

Base Case and EEMs

In addition to the baseline, three alternative scenarios were considered using the EPP approach (Table 2). The base case assumed that all new buildings would be built to the then-current 2007 edition of ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (ASHRAE 2007) and that existing buildings would not have energy improvements. The advanced EEM alternative assumes that buildings are built to a level approximately

Figure 3 *Baseline buildings. Existing buildings on Fort Hunter Liggett.*

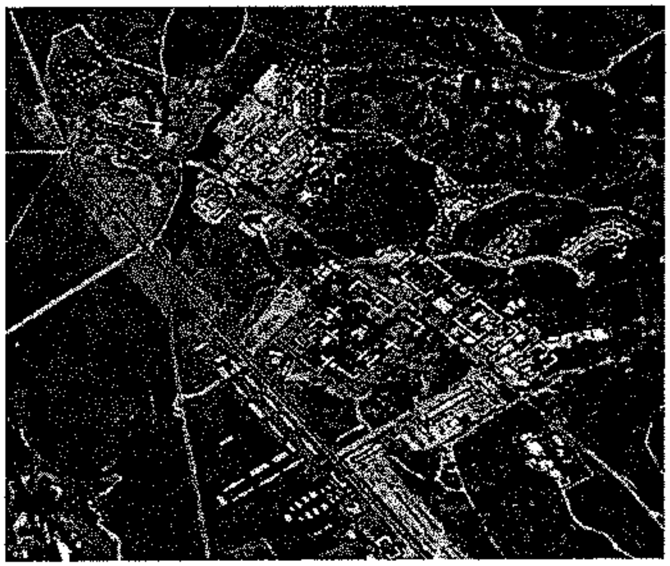

Figure 4 *Base case buildings. Planned build-out for Fort Hunter Liggett over about 25 years.*

Table 2. Alternative Scenarios and Results Using the Energy Planning Process and Tools

Alternative	Facilities	Area, ft^2 (m^2)	Electricity, kBtu (kWh)	Electric EUI, kBtu/ft^2 (kWh/m^2)	Gas, kBtu (kWh)	Gas EUI, kBtu/ft^2 (kWh/m^2)	Energy cost, $	Total Energy, kBtu (kWh)	Total EUI, kBtu/ft^2 (kWh/m^2)
Baseline	184	1,225,298 (113,953)	49,233,365 (14,428,872)	40.18 (127)	27,996,042 (8,204,828)	22.85\ (72)	1,840,581	77,229,400 (22,633,698)	63.03 (199)
Base Case	377	4,565,135 (424,558)	215,623,568 (63,193,015)	47.23 (149)	78,381,606 (22,971,376)	17.17 (54)	6,976,969	294,005,248 (86,164,413)	64.40 (203)
Advanced EEM (New and Retrofit)	377	4,565,135 (424,558)	161,350,256 (47,287,081)	35.34 (111)	37,988,984 (11,133,472)	8.32 (26)	4,714,374	199,339,232 (58,420,548)	43.66 (138)
High Performance	377	4,565,135 (424,558)	143,664,798 (42,103,986)	31.47 (99)	36,201,521 (10,609,616)	7.93 (25)	4,341,058	179,866,319 (52,713,602)	39.40 (124)

30% better than ANSI/ASHRAE/IESNA 90.1-2007, while the high-performance alternative improves over the advanced EEM alternative by about 7%.

In the case of FHL, assuming that the base case overall mean EUI would remain relatively constant was not a bad rule-of-thumb assumption compared with building new buildings to ANSI/ASHRAE/IESNA Standard 90.1-2007. The rule-of-thumb assumption that FHL could achieve a Passivhaus-like standard of 30 kBtu/ft^2/yr (94.6 kWh/m^2/yr) was probably overly optimistic for planning purposes. Even over 25 years, it is unlikely that all of the existing buildings would undergo the deep retrofits required to become high-performance buildings and, at least within the U.S. federal government, even new buildings must pass a life-cycle cost (LCC) efficiency test to be built to higher than the minimum stands. (The current Army standard is to build new buildings to meet ANSI/ASHRAE/IES 90.1-2010 [ASHRAE 2010] and to attempt to achieve 12% better than that if LCC effective).

There is another advantage to the EPP approach. Table 3 lists a breakdown of the EUIs required to achieve the advanced EEM alternative by building type. The full report from the energy planning tool shows exactly which EEMs were considered in the analysis and gives a kind of energy budget for each type of building that is built in the future for the installation to achieve its net zero goals.

Distribution and Supply

Given the baseline and three alternatives defined above, the advanced EEM alternative was selected for further study with respect to achieving net zero energy at FHL. The energy planning tool uses a mixed integer linear programming (MILP) approach to identify the best option for meeting the building energy demands (after reduction using EEMs). A number of different strategies were considered to reduce the energy demand on an installation-wide basis. The first alternative was to maintain the current energy supply strategy (mixed grid electric, propane, and JP8 fuel oil). The second was to shift heating loads from petroleum fuel to all electric using heat pumps. The final alternative was to investigate a cogeneration strategy using either combined-cycle gas turbines or reciprocating engines. FHL does not have a natural gas supply and it turns out that a heat pump strategy significantly reduces the overall site energy (Table 4). Note also the source energy that is required for each alternative. This assumes that all electricity is sourced from the grid and that it uses a site-to-source conversion of 3.43.

The use of the energy planning process tool simplified exploration of distribution and supply options. Because the building loads data was calculated and summarized by the tool, changes to building options could quickly be made and rerun using different supply alternatives. New alternative

Table 3. EUI Breakdown by Building Type for Advanced EEM Alternative (Partial Table)

Facility Group	Facilities	Total Area, ft^2 (m^2)	Electricity EUI, kBtu/ft^2 (kWh/m^2)	Gas EUI, kBtu/ft^2 (kWh/m^2)	Total EUI, kBtu/ft^2 (kWh/m^2)	EEM Package
Barracks UEPH—Existing—Pre-1980	4	130,277 (12,116)	30.05 (94.71)	25.32 (79.80)	55.37 (174.52)	Cool roof package
Barracks UEPH—Planned 90.1-2010	28	902,133 (83,898)	27.27 (85.95)	14.91 (46.99)	42.18 (132.94)	Equipment package
Barracks UEPH—Planned Pre-1980	4	141,880 (13,195)	27.27 (85.95)	14.91 (46.99)	42.18 (132.94)	Equipment package
Bde HQ Existing—Pre-1980	3	20,171 (1,876)	33.75 (106.37)	1.24 (3.91)	34.99 (110.28)	Cool roof package
Bde HQ—Planned—90.1-2010	7	268,217 (24,944)	43.05 (135.68)	0.2 (0.63)	43.25 (136.32)	Energy recovery package
BHQ —Existing—Pre-1980	6	32,314 (3,005)	23.87 (75.23)	1.62 (5.11)	25.49 (80.34)	Cool roof package
BHQ—Existing—Pre-1980—Metal Building	1	844 (78)	23.87 (75.23)	1.57 (4.95)	25.44 (80.18)	Cool roof package
BHQ—Planned—90.1-2007—Mass	59	1,334,502 (124,109)	23.28 (73.37)	0.21 (0.66)	23.49 (74.04)	Energy recovery package
BHQ—Existing—Post-1980—Metal Bldg.	6	32,198 (2,994)	23.49 (74.04)	1.07 (3.37)	24.56 (77.41)	Cool roof package

Table 4. Heat Pumps Decrease Reliance on Propane and JP8 Fuel Oil

Number	Alternative	Total Equivalent Annual Cost, $/yr	Total Source Energy, MMBtu/yr (MWh/yr)	Total Site Energy, MMBtu/yr (MWh/yr)	Electricity, MMBtu/yr (MWh/yr)	Propane and JP8, MMBtu/yr (MWhr/yr)
	Base Case	17,748,322	659,082 (193,158)	284,109 (83,264)	212,344 (62,232)	71,764 (21,032)
1	Status Quo Energy Supply	15,998,017	516,237 (151,294)	212,068 (62,151)	172,757 (50,630)	39,311 (11,521)
2	Air-Source Heat Pump	8,196,610	502,588 (147,294)	183,454 (53,765)	183,454 (53,765)	0 (0)
3	Cogeneration	11,774,46	505,847 (148,249)	232,606 (68,170)	162,005 (47,479)	78,472 (22,998)

supply options can be added at any time by making an entry in the devices table of the tool to include purchase prices, installation costs, annual maintenance costs, and conversion efficiency (e.g., COP).

Solar and Waste Gasification Strategy

FHL adopted a strategy of solar PV panels for electrical power and solar thermal panels to satisfy domestic hot-water requirements. The question posed in the study was to identify how much of each type of panel would be required to meet electrical and thermal loads. FHL has an experimental waste gasification system from which they expect to obtain about 1,467,662 MBtu/yr (430,021 kWh/yr) of electricity. The energy planning tool estimated a solar hot thermal potential for domestic hot-water heating of 59.23 kWh/ft^2/yr (202.10 kBtu/ft^2/yr), the area referring to the collector panel area. Using the National Renewable Energy Laboratory (NREL) PVWatts Viewer (DoE 2014a), the estimated solar potential for Jolon, CA, (near FHL) is 0.55 kWh/ft^2/day (1,871.4 Btu/ft^2/day; 5.88 kWh/m^2/day), adjusted for panel efficiency and siting to yield 12.96 kWh/ft^2/yr (44,248.0 Btu/ft^2/yr; 139.5 kWh/m^2/yr). If Alternative 2 is selected, approximately 3.9 million ft^2 (362,700 m^2) of solar thermal for domestic hot water (DHW) and 3.9 ft^2 (0.4 m^2) of PV electric would be required to generate as much electricity on site as is consumed. If Alternative 3 were to be selected, which includes heat pumps for DHW, approximately 4.2 million ft^2 (390,600 m^2) would be required. The average utility scale cost for solar PV in 2013 was 11.2 cents/kWh (DoE 2014b), or roughly $6 million for Alternative 3, with costs trending downwards. A planning-level analysis of current and future available space on rooftops and open land determined that sufficient space is available for solar PV and thermal panels.

Further power analysis is certainly warranted here, even at a planning level. Like many installations, FHL faces restrictions from their utility on net metering and selling power back to the grid. The all-electric strategy considered will require significant storage, primarily electric, but potentially thermal as well. An analysis using NREL's REopt (NREL 2013) and new thermal models being developed for the net zero planner would help to assess additional power conditioning and storage costs. This type of analysis would require hourly load profiles that would be available from either tool but not from a rule-of-thumb approach.

There were additional costs to augmenting the planning process with the energy planning analysis discussed in this paper. The authors logged labor hours and recorded 60 person-hours for setup, 80 person-hours to participate in the practicum, and another 120 person-hours for post-practicum analysis and reporting. Labor costs vary, but at a fully burdened rate of $75/h, this imposes an additional cost of approximately $20,000, plus travel expenses. These costs may vary considerably depending on the size of the installation. This does not include costs associated with producing the final report, which was produced as part of the normal planning process. Additional benefits accrued from the augmented process include a reusable planning level energy model of the installation, a model-based decomposition of energy end-uses, an 8760 h/yr load profile estimate for each building, physics-based models of the potential for energy-efficiency gains, and EUI targets by building type for future construction to meet installation energy goals.

THE INSTALLATION SUSTAINABILITY COMPONENT PLAN AS GUIDANCE FOR BUILDING DESIGNERS

So far, this paper has described the master planning level approach to estimating current electrical and thermal loads, decomposing the loads by building type, and estimating their potential for energy-efficiency improvements. Selecting the alternative with the lowest load, the area of solar PV or PV and thermal panels was determined to meet FHL's net zero energy goal. From a planning level, the installation leadership has decided to pursue an all-electric option similar to Alternative 3. The goals are expressed in an installation sustainability component plan, a new section in the master plan. Figure 5 shows the base case (same EUI as currently measured) for the Blackhawk Hills ADP, with the buildings shaded by EUI. This plan communicates with future building designers by showing that, if buildings are built to the current level of energy efficiency, the net zero goals will not be achieved without the purchase of significantly more PV generating capability (light gray buildings). Figure 6 shows the high-performance alternative for buildings, with the buildings achieving lower than 34.12 kBtu/ft^2/yr (107.5 kWh/m^2/yr) depicted in black. Finally, Figure 7 shows the plan for placement of solar PV and thermal panels for the Blackhawk Hills ADP.

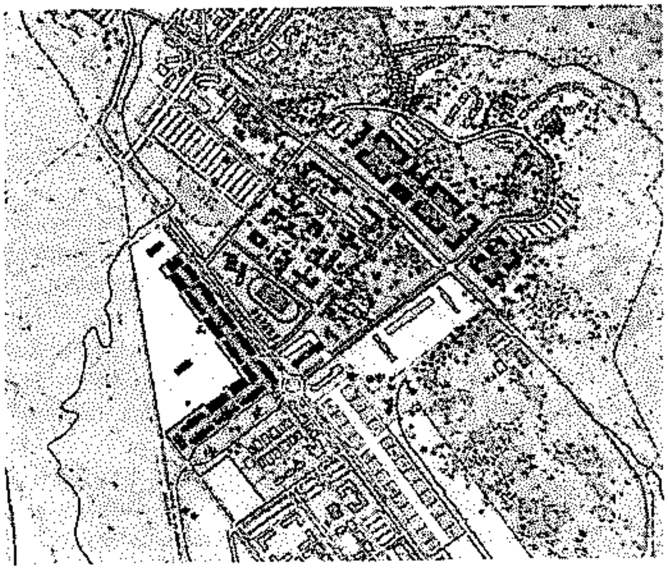

Figure 5 *Blackhawk Hills ADP base case energy use intensity plan.*

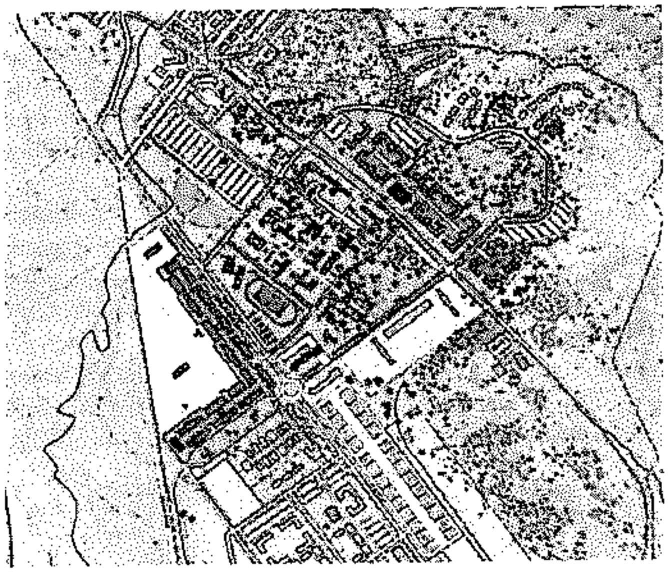

Figure 6 *Blackhawk Hills ADP passive (high-performance) EUI plan.*

SUMMARY AND DISCUSSION

This paper focused on the results from the first of a series of experiments in applying energy planning processes and tools to the master planning process for U.S. Army installations. The results, which were considered highly useful by the installation and master planner involved, provided additional rationale for decisions beyond currently used rule-of-thumb assumptions. The rule-of-thumb assumption that future buildings in the base case would match the baseline of approximately 65 kBtu/ft^2/yr (204.9 kWh/m^2/yr) EUI was borne out (somewhat surprisingly to the authors) by assuming that future buildings would be built to ANSI/ASHRAE/IESNA Standard 90.1-2007 and that existing buildings would be renovated to a reasonable level. This result is likely to change significantly for buildings built to ANSI/ASHRAE/IES Standard 90.1-2013 or later.

Modeling results also suggested that the initial rule-of-thumb assumption that FHL buildings could achieve a passive mean EIU of 30.8 kBtu/ft^2/yr (97.1 kWh/m^2) might be difficult to achieve for the particular mix of buildings planned. The feasibility of a particular target varies tremendously by climate and building type, considering that internal mission loads often drive EUI. More importantly, perhaps, modeling provided a breakdown of target EUIs by building type that would be necessary to meet the installation goals. At the distribution and supply level, the energy analysis showed that a combined heat and power strategy was probably not a good fit for FHL, given their lack of low-cost natural gas or biomass.

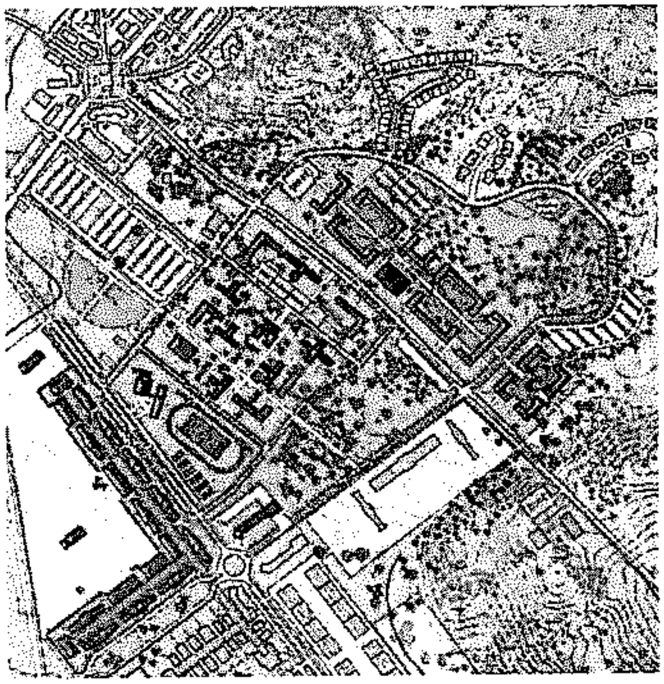

Figure 7 *PV and solar thermal panel layout for Blackhawk Hills ADP.*

In an area with abundant solar energy, as is the case with FHL, a solar electric PV and thermal strategy makes a lot of sense. Additional analysis of storage and net-metering options is still needed.

In the end, energy planning processes and tools can bring clear benefits to the master planning process, even without diving deep into the intricacies of detailed engineering analysis. The analysis augments the installation sustainability component plan (ISCP) with more specific targets for building design that will be required for successful implementation of the plan and provides supporting rationale for its recommendations. In addition, the energy planning model makes the ISCP a "living" plan, capable of being modified and rerun as conditions change. This makes the plan more flexible and likely to be implemented. Additional master planning practicums incorporating the energy planning process and tools have been conducted at Schofield Barracks, HI, and are scheduled for Fort Hood, TX, in 2014–2015. During this period, additional analysis capabilities will be added to the tools to consider net zero water and solid waste reduction strategies, including their interactions with energy.

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