

LV-17-005

Deep Energy Retrofit of Presidio Army Barracks

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ABSTRACT

Presidio of Monterey, home to the Defense Language Institute, faces the same challenges as other Army bases in managing its aging building stock. More than 25% of the barracks, for example, were built in the 1960s and lack today's safety, comfort, and energy-efficiency standards. In preparing to address the shortfalls of one such Presidio barracks, Building 630, the Directorate of Public Works staff worked with the U.S. Army Corps of Engineers to chart a path forward. Rather than relying on conventional approaches to infrastructure modernization, stakeholders decided to craft the military's first documented deep energy retrofit (DER) solution.

The Army defines a DER as "major building renovation project in which site energy use intensity (including plug loads) has been reduced by at least 50% from the pre-renovation baseline with a corresponding improvement in indoor environmental quality and comfort" (Zhivov et al. 2016). For Presidio, preliminary energy modeling helped set an ambitious but achievable goal of 86% energy savings using a combination of high performance envelope requirements with super-efficient (but commercially available) HVAC and lighting systems including solar hot-water generation sized for 70% of the domestic load. Ultimately, Presidio will apply the successes and lessons learned of its first DER towards additional retrofit projects to better align with its mandated net zero energy trajectory. The true value, however, lies in leveraging energy savings as a part of renovation projects aimed at raising the quality of facility conditions to a level commensurate with the mission of its occupants.

The goal of this paper is to demonstrate the acquisitions strategies employed and field lessons learned in an attempt to better guide prospective DER project stakeholders. Being a

federal facility, this project employed a regimented process to its various contracting phases with some strategic augmentation to support the DER method that is transferable to similar retrofit efforts. As a pilot effort, there have also been many process-based and technical lessons learned that can be used to bolster future DER work at Presidio, in the Army, and throughout the sustainability industry.

INTRODUCTION

Project Description

Because it lacked any historical renovation efforts and was nearly 60 years old, Building 630 had been flagged by Presidio Public Works staff as failing to meet current Army requirements, including modern criteria for seismic progressive collapse, fire protection, accessibility, anti-terrorism, and space management. Moreover, the building suffered from inadequate ventilation, poor temperature control, and failed components (Figure 1). Project planning commenced in the summer of 2011 to replace the deteriorating and overcrowded gang-latrines style barracks to pursue the military's current configuration for two-person modules, common spaces, and in-room bathrooms (DoD 2010). At nearly 65,000 ft² (6045 m²) and more than 130 kBtu/ft² (410 kWh/m²) in annual site energy usage, Building 630 was one of Presidio's largest and most energy-intensive facilities. Following completion of the first wing in August 2016, soldiers will begin to reoccupy Building 630 with the expectation of less than 20 kBtu/ft² (63 kWh/m²) per year in site energy usage based on contracted performance targets and additional prescriptive system requirements.

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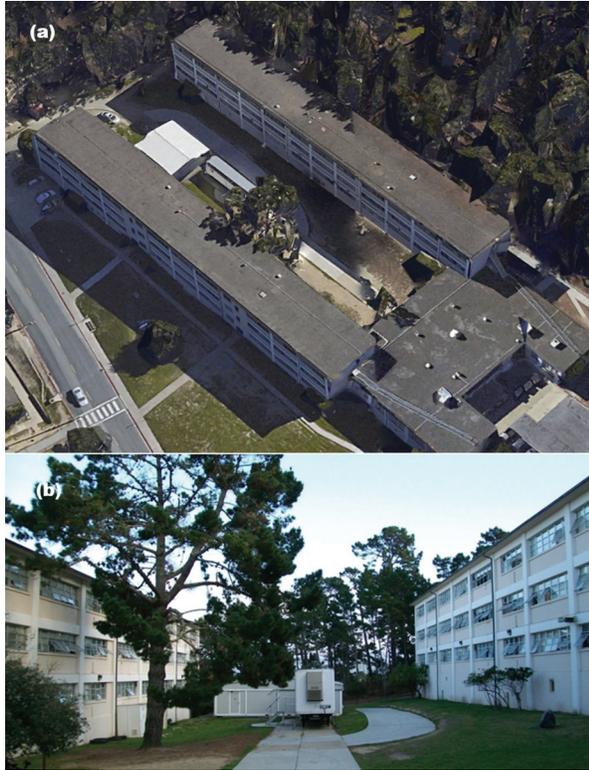


Figure 1 (a) Building 630's three-story barracks wings (one-story connecting structure is administrative spaces not part of case study). (b) Uninsulated concrete masonry unit (CMU) walls and single-pane windows—typically left open year-round for ventilation—make for poor building envelope performance.

Existing Systems

Significant energy savings were required to achieve deep energy retrofit (DER) reductions and comply with the 2005 Energy Policy Act (EPA 2005), the Energy Independence and Security Act of 2007 (EISA 2007), UFC 1-200-02 on High Performance and Sustainable Building Requirements (DoD 2013), and current Army directives on energy efficiency. Existing building systems and their conditions at Building 630 were as follows:

- **Building Envelope.** The roof was a built-up gravel system over a 4 in. (102 mm) concrete substrate with no insulation. Walls and floors were uninsulated 8 in. (204 mm) concrete block and 4 in. (102 mm) concrete slabs, respectively. There was no insulation between the first floor slab and crawlspace. Windows were single-pane operable type with metal frames and no seals. Doors were uninsulated with deteriorated or nonexistent weather stripping.
- **HVAC.** Space heating was provided by a failing hydronic system with baseboard radiators in each bedroom, many with control valves stuck open. The radiators were manu-

ally controlled with knob-type capillary tube thermostatic controllers that lacked setbacks or feedback. Because of the absence of forced-air ventilation, occupants were instructed to keep windows open daily year-round to reduce odors. Heating was typically left on all day and all year long. Hot water was supplied at 180°F (82°C) by a series of non-condensing, natural-gas-fired boilers and circulated via constant-speed pumps.

- **Domestic Hot Water.** Domestic hot water was supplied to the gang latrines by additional non-condensing, natural-gas-fired water heaters and a 600 gal (2271 L) storage tank. Flow rates at shower fixtures were measured to be either 1.5 or 1.75 GPM (0.09 or 0.11 L/s). There were six showers per floor per wing. Flow rates at sink fixtures were measured to be either 1.5 or 2.2 GPM (0.09 or 0.14 L/s). The number of washers and dryers was insufficient for current needs and only satisfied 30% of the demand.
- **Lighting.** All built-in lighting used T8 lamps with manual switches. Each bedroom had one overhead fixture with four 4 ft (1.22 m), 32W lamps. Bedrooms also had incandescent task lighting at the desks. Each corridor had 13 fixtures, each with two 4 ft (1.22 m), 32W lamps. Corridor and public area lighting controls were inaccessible to occupants, which resulted in 24/7 operation of these lighting systems.
- **Equipment.** The majority of the equipment load in the building was caused by electrical equipment brought in by occupants. Recent years had seen an increase in personal electronics and appliances such as televisions, computers, gaming consoles, and mini-fridges. The aging electrical system was out of code and suffered from frequent tripped breakers because of the increased loads. Shared laundry equipment (washers and dryers) accounted for the balance of the equipment load.
- **Utility Meters.** Presidio Public Works staff provided metered utility data for electricity, natural gas, and water. Electricity usage was metered from June through October of 2012 and then extrapolated for the rest of the year. Annual natural gas usage (Figure 2) was available for the years 2009 through 2011 (estimated 75% used for space heating and 25% for domestic hot water). Annual water usage was available for 2011 only.

DER Systems

The project scope featured a combination of performance-based and prescriptive requirements for new building systems (see Figure 3) to be installed after a gutting of all nonstructural components.

- **Envelope.** The envelope has been upgraded to exceed the minimum requirements of ANSI/ASHRAE/IES/USGBC Standard 189.1 (ASHRAE 2011). The roof was retrofitted with R-25 continuous insulation and solar hot-water panel mounts. Exterior walls have been retrofitted with external R-12 continuous insulation and cladding. Windows were

replaced with double-pane operable upgrades and installed with thermally-broken insulated frames. Exterior doors were replaced with weather-stripped, insulated doors. The entire envelope was sealed to minimize air infiltration with a contractually required leakage rate below 0.15 cfm/ft² (0.76 L/s-m²) of envelope at 75 Pa (0.011 psi). This was 40% more stringent than the standard U.S. Army Corps of Engineers (USACE) testing requirement of 0.25 cfm/ft² (1.06 L/s-m²) of envelope at 75 Pa (0.011 psi) (Lamb 2016).

- **HVAC.** Space heating in each bedroom is provided by low-temperature hydronic radiant heating in the ceiling space

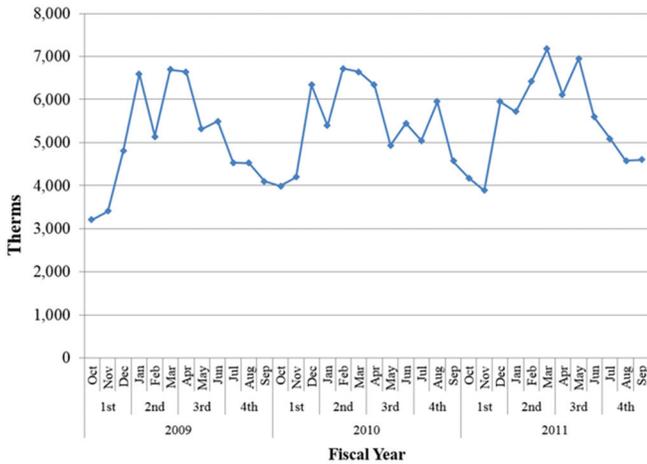


Figure 2 Building 630 Natural-gas usage.

and controlled with digital thermostats. Variable-flow hot water is supplied from stratified storage tanks connected to solar water heating panels and booster heat from high-efficiency condensing natural-gas-fired boilers. Mechanical ventilation is delivered to each bedroom at all times at low volume from a central dedicated outdoor air system (DOAS) that includes heat recovery from exhaust air streams. As is the case for all Presidio barracks, there is no space cooling except for one conference room and communications equipment closets because of Monterey's mild coastal climate. All systems are operated with digital HVAC controls and use graphical interfaces for configuration, programming, and trending of connected systems.

- **Domestic Hot Water.** Domestic hot water is supplied to bedroom suites for showers and sinks from a large storage tank that is preheated by greywater heat recovery from showers and solar hot water designed to provide 70% of domestic hot water needs and space heating. Gang latrines have been converted into laundry rooms and furnished with water-saving washers; however, only one washer per laundry room is equipped for hot-water usage and has been labeled "for extreme sanitation purposes only." Greywater systems provide water for toilet flushing and irrigation. Low-flow fixtures were installed for showers and sinks. The flow diagram shown in Figure 4 indicates the interconnectedness of many HVAC and domestic hot-water systems.
- **Lighting.** All built-in lighting was replaced with T5 and T8 lamps and high-efficiency electronic ballasts. All

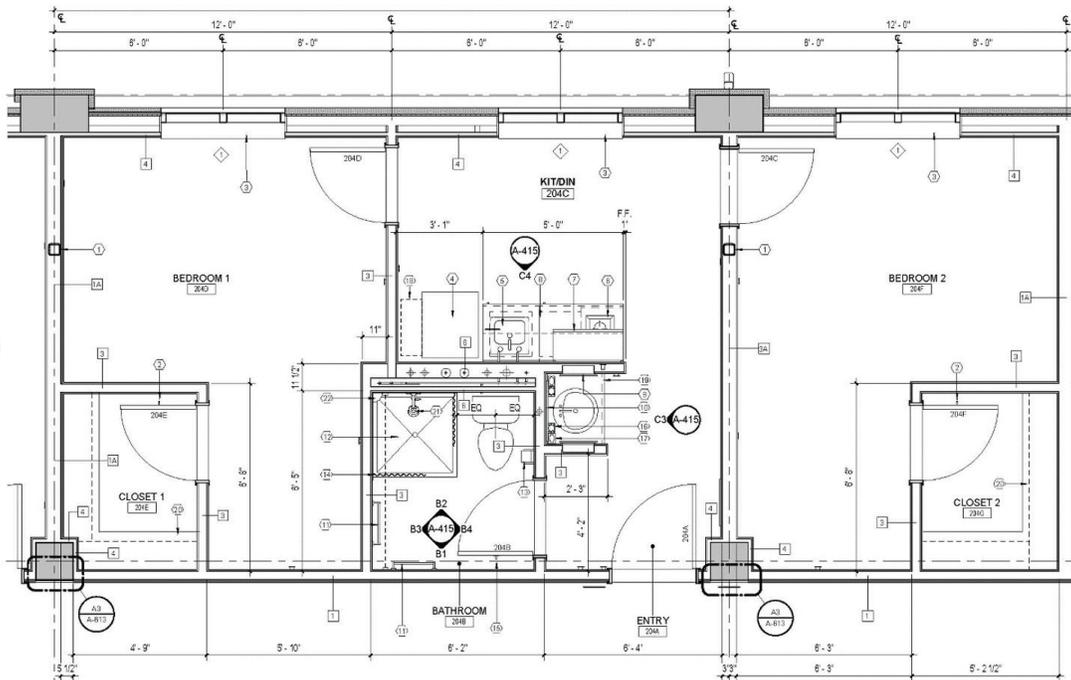


Figure 3 The Army's updated barracks room layouts provides more space and improved indoor environmental quality through forced air ventilation and better controllability of HVAC systems.

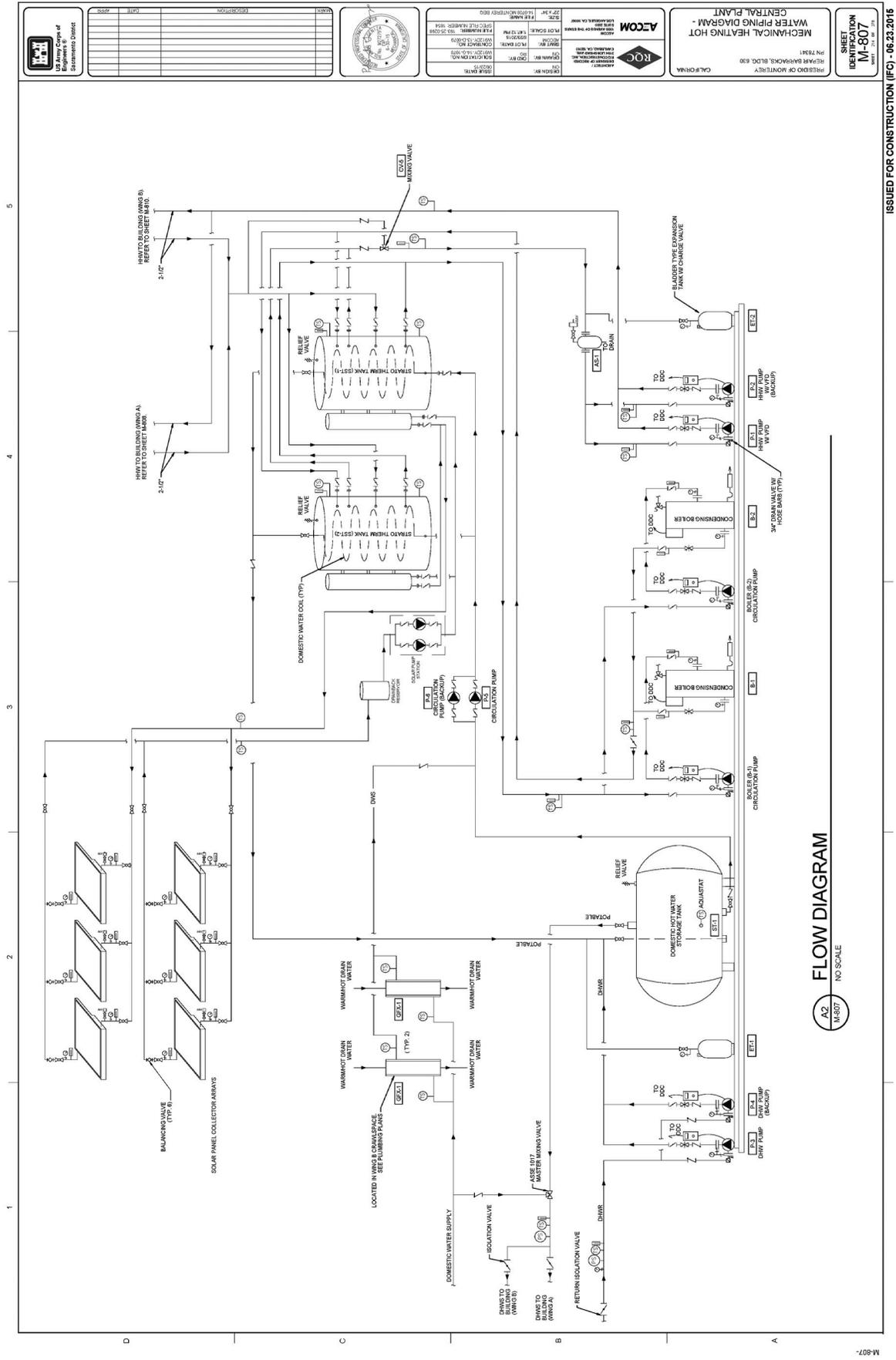


Figure 4 Flow diagram indicating the interconnectedness of many HVAC and domestic hot-water systems.

task lighting has been updated to compact fluorescent lamps. Corridor and public area lighting controls have been replaced with occupancy sensors. Exterior lighting uses multi-level dimming LED fixtures with occupancy sensors to boost from a 10% power standby mode to full power temporarily.

- **Equipment.** ENERGY STAR[®]-rated appliances have been provided for shared washers and room refrigerators. No other specific measures were implemented for reducing equipment loads.
- **Utility Meters.** Electric and water submetering has been required on each floor. Electric meters use current transformers on each branch feeder allowing measurement to spaces that can be regulated by building occupants while separately measuring equipment such as communications equipment and mechanical equipment. Three water meters per floor allow for domestic cold, hot, and return monitoring (hot-water return line metering is required to determine actual usage). Interval and cumulative data are available to facility management as well as to building occupants through a building automation system monitoring kiosk in the lobby to foster energy and water usage awareness and competition.

APPROACH

Energy Modeling

Consideration for DER tactics at Building 630 began in 2012 with predesign efforts that included energy modeling. EnergyPlus (2012) modeling of Building 630 (Figure 5) helped establish the performance targets and systems to achieve DER results. Presidio investigated several retrofit packages to determine the feasibility for substantial energy reduction in pursuit of recent federal mandates. The most stringent of these mandates, EISA 2007, calls for a 65% reduction in the source energy intensity of a baseline building from the 2003 Commercial Buildings Energy Consumption Survey (CBECS) by 2015 (EISA 2007). Using “Lodging—Dormitory, Fraternity, or Sorority” as the closest matching CBECS building type, post-retrofit performance is limited to a source

energy usage index (EUI) of 52.5 kBtu/ft² (165 kWh/m²)—roughly a quarter of the existing source EUI (210.4 kBtu/ft² [663.14 kWh/m²]). Determining that a DER approach would be necessary to achieve such substantial energy reductions, Presidio funded the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) to support DER modeling.

Table 1 summarizes DER simulation results using EnergyPlus and parametric template tool developed by Big Ladder Software to automatically generate and manage model input files (Zhivov et al. 2012). Building 630's location and orientation were established at 36.6 N latitude, 121.9 W longitude, and 47.5 degrees clockwise from North. To account for site topography, wings A and B were modeled at 385 and 395 ft (117 and 120 m), respectively. Nearby trees were modeled as shaded surfaces on the building and the adjoining Wing C that was not part of the study was modeled as an adiabatic surface. Increased infiltration to 1.5 cfm/ft² (7.62 L/s/m²) is considered as capturing the open operable windows condition. The Monterey typical meteorological year (TMY) weather file was input from the EnergyPlus website.

Once the existing building model had been calibrated against utility data to within a 0.4% discrepancy, the reduced occupancy from 225 to 150 soldiers resulting from the Army's more spacious barracks configuration was simulated. The EISA baseline from the 2003 CBECS (National Energy Information Center 2003) is listed below this revised occupancy simulation in Table 1 and is used as the common reference to calculate the relative energy savings for each retrofit package. The standard retrofit, defined as an upgrade to meet ANSI/ASHRAE/IES Standard 90.1 performance requirements for envelope, lighting, and HVAC systems (ASHRAE 2010), contributes roughly half of the energy savings needed to achieve the EISA 2007 target. Additional retrofit packages were subsequently applied as DER measures until the 65% mandate was met.

By combining iterative effects of each of the DER measures listed and using national site-to-source conversion factors of 3.34 for electricity and 1.047 for natural gas (DOE 2011), the EISA 2007 mandate (equating to an 86% reduction

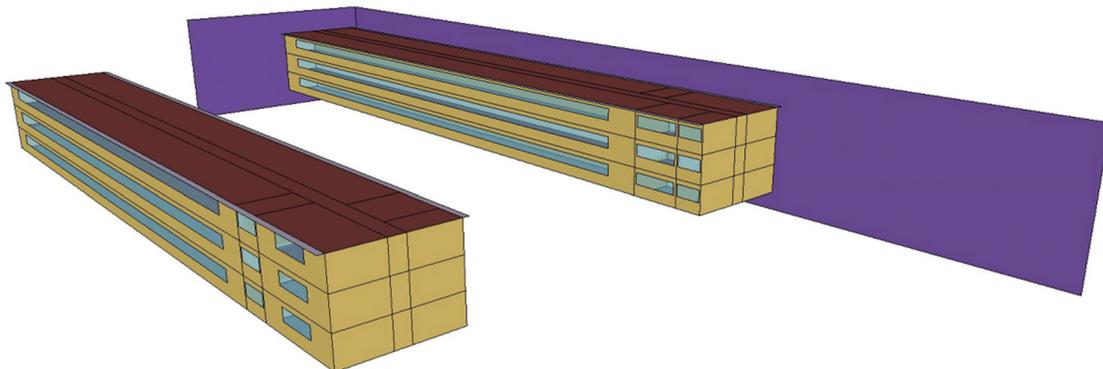


Figure 5 Representation of EnergyPlus modeling of Building 630.

Table 1. DER EnergyPlus kBtu/ft² (kWh/m²) Modeling Results for Building 630

	Site EUI	Source EUI	Versus Site Existing	Versus Source Existing	Versus EISA
Existing (metered)	131.4 (414.1)	210.4 (663.1)	—	—	—
Existing (calibrated)	131.9 (415.7)	210.8 (664.4)	—	—	—
Reduced occupancy (250 to 150)	124.3 (391.8)	192.2 (605.8)	6%	9%	—
EISA baseline (National Energy Information Center 2003)	58.0 (182.8)	150.0 (472.8)	56%	29%	—
Standard retrofit (ASHRAE 2010)	40.1 (126.4)	96.4 (303.8)	70%	54%	36%
Enhanced envelope package	40.7 (128.3)	98.7 (311.1)	69%	53%	34%
Low lighting power density lighting package	34.2 (107.8)	76.2 (240.2)	74%	64%	49%
DOAS/radiant HVAC package	34.0 (107.2)	75.7 (238.6)	74%	64%	50%
High-efficiency domestic hot-water package	31.5 (99.3)	73.1 (230.4)	76%	65%	51%
Drain water heat recovery package	28.4 (89.5)	69.9 (220.3)	78%	67%	53%
Equipment package (plug loads)	25.6 (80.7)	60.4 (190.4)	81%	71%	60%
Solar hot water 30% package	22.3 (70.3)	56.9 (179.3)	83%	73%	62%
Solar hot water 70% package	17.9 (56.4)	52.4 (165.1)	86%	75%	65%
EISA target	—	52.5 (165.5)	—	75%	65%

Table 2. Example Cost Breakdowns for DER Measures with Small Cost Increases or First-Cost Savings

	Quantity	Unit	Material	Labor	Equipment	Indirect Factor	Total Costs
Wall Insulation							
Existing (none)	0 (0)	ft ² (m ²)	—	—	—	—	—
Standard retrofit, R-7.6	45,000 (4185)	ft ² (m ²)	\$2.05	\$2.29	\$2.01	19.8%	\$342,800
DER, R-12 (installed)	45,000 (4185)	ft ² (m ²)	\$2.49	\$2.29	\$2.01	19.8%	\$366,300 (7% increase)
Hot-Water Boilers							
Existing, 1000 kBtu/h (293.1 kW)	5	each	—	—	—	—	—
Standard retrofit, 750 kBtu/h (219.8 kW)	4	each	\$41,900	\$21,000	—	19.8%	\$301,300
DER, 500 kBtu/h (146.5 kW) (installed)	2	each	\$34,600	\$19,700	—	19.8%	\$129,900 (57% savings)

in site EUI) was revealed as viable. This process of energy modeling during the pre-design project phase provided Presidio with two key deliverables: realistic DER performance targets for Building 630 and a list of facility system parameters to attain them.

Cost Estimating

As part of the project funding request to the Army, Presidio was required to demonstrate the cost effectiveness of the

DER approach as compared to a default new construction method in accordance with Army Regulation 420-1, Chapter 2 (HQDA 2012). The USACE Sacramento District took the lead on cost comparisons using the Parametric Cost Engineering System (PACES). According to these government cost estimates, the DER-to-replacement value for Building 630 using facility systems identified in the energy model was calculated at 54% (AECOM 2005). This means that the cost of the DER effort was almost half the cost to demolish Building

630 and build a new barracks to meet ANSI/ASHRAE/IES Standard 90.1 performance requirements.

Much of the cost savings is tied to the tremendous amount of demolition, site work, and structural work avoided by renovating instead of tearing down and building new (Figure 6). The same level of hazardous material abatement would have

been required in either case to remove the asbestos found in interior wall boards. Avoiding various site demolition and building foundation/shell construction for the three-story, 65,000 ft² (6045 m²) facility, however, was estimated as saving on the order of \$10M in related project funds. This does not account for the conserved natural capital associated with

Table 3. Summary of Key Energy System Performance Requirements Identified in the Request for Proposal (RFP)

Performance Parameter	Existing Building	Reduced Occupancy	Standard Retrofit	DER Requirements
Occupants	228	150	150	150
Roof insulation	R-0	R-0	R-20	R-25
Wall insulation	R-0	R-0	R-7.6	R-12
Window U-value	U-1.27	U-1.27	U-0.65	U-0.40
Window solar heat gain coefficient (SHGC)	0.85	0.85	0.25	0.25
Infiltration at 75 Pa, cfm/ft ² (L/s/m ²)	1.5 (7.62)	1.5 (7.62)	0.6 (3.05)	0.15 (0.76)
Lighting power density, W/ft ² (W/m ²)				
Bedroom	1.15 (0.35)	1.15 (0.35)	1.1 (0.34)	0.6 (0.18)
Corridor	0.82 (0.25)	0.82 (0.25)	0.5 (0.15)	0.35 (0.11)
Stair	1.0 (0.3)	1.0 (0.3)	0.6 (0.18)	0.29 (0.09)
Equipment power density, W/ft ² (W/m ²)	1.75 (0.53)	1.15 (0.35)	1.15 (0.35)	0.86 (0.26)
HVAC system type	Hot-water radiator	Hot-water radiator	DOAS/radiant	DOAS/radiant
Zone thermostat control	No	No	Yes	Yes
Variable-speed pumps	No	No	Yes	Yes
Hot-water temperature reset	No	No	Yes	Yes
Condensing boiler/water heater	No	No	No	Yes
Drain water heat recovery	No	No	No	Yes
Mechanical ventilation	No	No	Yes	Yes
Operable windows	Yes	Yes	Yes	Yes



Figure 6 Gutted (a) exterior and (b) interior of Building 630.

new concrete material, additional construction equipment emissions, and increased stormwater and site degradation issues.

Schedule and First-Cost Savings

Because of the constrained land area of the Presidio of Monterey, there are no “green field” sites. This means that for projects at the Presidio, any work involving earth-moving activities have typically caused unforeseen costs and delays. This is because of three primary reasons, unforeseen cultural/historical artifacts uncovered on the site, unforeseen underground utilities, and stringent stormwater regulations. The dining facility project is 60% complete at the time of this writing, yet Building 630 is in the final stages of commissioning. The advantage of renovations is that the concrete structure is already in place. Additionally, most of the underground utility lines are in place.

There are extra costs associated with a DER renovation relative to one that meets ANSI/ASHRAE/IES Standard 90.1 performance requirements (ASHRAE 2010); however, these costs are minimized for two reasons. First, many DER measures add some fractional purchase cost at no additional labor. For example, one would normally consider the labor and scaffolding equipment associated with mounting any building insulation to be included in standard retrofit project costs, and the added material price for the R-12 insulation selected (rather than a more conventional R-7.6) would be estimated to add only 7% of this total installed insulation cost. Second, several DER measures were found to have initial savings rather than costs due to electric or HVAC load reduction leading to smaller equipment component sizing. One example of this type of first-cost saving was with the new hot water boilers. The enhanced envelope design contributed to load reductions that allowed two high-efficiency 500 kBtu/h (136 kW) boilers to replace the five existing conventional 1000 kBtu/h (293 kW) boilers at an estimated 57% of the standard retrofit cost. Table 2 summarizes the cost breakdowns using RS Means (RSMeans 2013) associated with these two examples.

Funding

One aspect of renovation is that it allows the use of Sustainment, Restoration, and Modernization (SRM) funding to be used instead of Military Construction (MILCON) funding. This can allow for a more responsive funding of a project. Presidio received funding just two years after putting the project in the funding pipeline. This contrasts with MILCON funding, which typically takes a minimum of five and often as long as 10 years. The approval level for SRM funding is done at a lower level, the Major Command (MAJCOM) level, instead of requiring congressional approval. In the case of Building 630, the MAJCOM had funding for upgrades of training barracks and expedited the funding.

An alternative funding strategy was considered that would have supplemented SRM funds for a standard retrofit with financing from an Energy Savings Performance Contract

(ESPC). The benefits of this approach include limiting Army funding requests to conventional amounts, delegating advanced energy saving tasks to a specialized contractor, and using utility bills to pay back the incremental DER costs. Though Building 630 was fully funded for the project and did not require third-party financing supplementation, this approach remains a potential strategy for achieving DER in future projects.

RFP Requirements

In 2011, Presidio funded USACE Sacramento District to develop a request for proposal (RFP) to outline project requirements for Building 630's DER approach. A planning charrette was conducted shortly thereafter with a team of designers and stakeholders who gathered the information needed to develop a 10% concept design. The Presidio DPW staff provided a written owner's project requirements (OPR) document and the results of ERDC-CERL's energy modeling to help define the goals of the project and how to accomplish them. Because of the emphasis on energy and water savings, the RFP was iteratively refined and reviewed over the course of the following year to ensure that quantitative system performance targets were sufficiently specified and complemented by enough prescriptive instruction where necessary. The writing of the RFP was the most time-consuming part of the pre-award steps. Since we were breaking new ground, the DPW/USACE team spent months writing and revising the specification Section 011000, especially on the mechanical, plumbing, electrical, HVAC controls, and energy conservation sections.

Design Methodology

The Presidio pursued a design-build (DB) approach for the project instead of design-bid-build (DBB). This was done for four reasons:

- **Design Funding Constraints.** Because there was no guarantee that the project would be funded, Presidio did not want to pay for a full design, which would have cost from \$1M–\$1.5M. The cost to develop the Design Build RFP was \$450k.
- **Timing Constraints.** A full DBB design would have taken more than a year. Even if the funding had been provided on October 1, getting a full design done in-house by early spring (to allow for an adequate solicitation and award timeline to meet the September 30 deadline) would have been very difficult.
- **Technical Expertise Constraints.** Because this was to be the most ambitious energy project done at the Presidio, there was a desire to take advantage of the industry's expertise. The intent was to set stringent performance requirements and allow the contractor to design and build a solution. One major advantage to DB over DBB is that the contractor “owns” the design and is thus not likely to pursue design-related change orders.

Because we were pushing new boundaries with energy and water goals, the government team chose to minimize risk through the DB approach.

- **Renovation Constraints.** Because the project was a renovation of an existing building, developing an exact design would be very challenging. Floor-to-ceiling heights were a major constraint; seismic retrofits would depend on field conditions; fire sprinkler design would have to work around existing rooms in Wing C; and a mechanical room would have to stay in operation during Phase 1 since building occupants were still in Wing A while Wing B was under construction. Putting the onus of design on the contractor relieved the government from major risk of change orders while giving the contractor design ownership.

The decision to go with a design-build approach has yielded the following additional benefits:

- **Reduced Change Orders.** The request for information (RFI) and change order rate on this project have been estimated at less than half of that from recent DBB projects and has freed up the architect-engineer contractor to provide creative solutions to unforeseen challenges.
- **Improved Room Layout.** The RFP required 150 rooms to be provided. This was based on the 10% concept design done by USACE. Based on fire code, USACE determined that a third stairwell would be needed to meet the egress distance requirements. Due in part to the flexibility of the DB method, however, the contractor determined a way to design the room layout so that the third stairwell was not needed. This saved money, time, and freed up space in the building so that the Army will be able to add an additional eight rooms for a 5.3% increase in personnel at an estimated less than 1% impact to the EUI performance target.
- **HVAC Solutions.** The low clearances from interior concrete beams represented a design challenge, especially for the ventilation system. The contractor devised a solution with rooftop DOAS units with the primary ductwork outside the building in the external insulated chases. Fire dampers at entry points posed an additional challenge, but were overcome through precise three-dimensional modeling.

Contract Solicitation and Award

Awarding such a major project within 5 months of getting funding presented a real challenge.

Fortunately, a multiple award task order contract (MATOC) was in place with the USACE Huntsville office. This was an ideal contract vehicle since there was a prequalified list of contractors who had past experience with these types of contracts. This allowed the award process to go much faster than if the contract had gone to full and open competition.

Still, the Presidio wanted to request some additional evaluation criteria in the RFP intended to guide the source selection board (SSB) in the selection process. Criteria, which included DER experience, energy modeling approach, and greywater system knowledge, were intended to avoid contractor selection based solely on low cost. Including technical rating criteria should be considered a best practice for DER contract award.

LESSONS LEARNED

Quality Assurance

An enhanced quality assurance process is needed to ensure that critical DER milestones are achieved. Given the advanced technologies and more stringent performance requirements associated with this project, standard quality assurance and commissioning methods have at times been insufficient. A more comprehensive and deliverables-based approach known as Product Delivery Quality Assurance (PDQA) is recommended (Mørck et al. 2016). The PDQA process recognizes the need for evaluation criteria specific to DER projects and is comprised of five phases, as defined in Table 4.

An example of a PDQA task that would be additional to standard construction project deliverables, but beneficial to the DER approach is the job-site window mock-up shown in Figure 7. This deliverable can be considered a critical milestone in ensuring that enhanced envelope air tightness and thermal leakage performance requirements are met by allowing all quality assurance personnel the opportunity to review or approve the mock-up version. In this way, fenestration products or installation deficiencies can be identified in the mock-up rather than with all windows during subsequent inspection and testing. While Presidio formalized this requirement in the project RFP, a lesson learned involved how to best use the mock-up. While the mock-up clearly showed the quality assurance staff that backer rod and sealant were elements of the air barrier, Building 630 design drawings did not include appropriate sealing methods. Additional RFP requirements on how to best construct and utilize the window mock up are required for future DER RFPs, including sealing methods, exposed section layers for QA transparency, and commissioning team validation of mock-up assembly prior to window installations.

Prescriptive RFP Content. Several DER features at Building 630 may have benefited from shifting the balance towards more prescriptive and less performance-based RFP requirements. Similar to the requirement for specific HVAC system types that were determined to meet energy targets and base maintenance preferences, other areas of the RFP could have been expanded to cover system features known to be desirable for Presidio. Interior lighting technology, for example, would have better aligned with campus retrofit efforts if interior LED fixtures had been specified, just as bi-level dimming LEDs were required for exterior fixtures. Similarly, the RFP could

Table 4. PDQA Can be Used to Identify DER Roles and Responsibilities Associated with DER Milestones

Product Delivery Phase	Description
Development Phase	Clear and concise documentation of RFP, energy modeling reports, and OPR that formalizes DER expectations into biddable project requirements to be references throughout the product delivery phases.
Procurement Phase	Clear and concise documentation of RFP, energy modeling reports, and OPR that formalizes DER expectations into biddable project requirements to be references throughout the product delivery phases.
Design Phase	A whole-building design approach to meet the prescriptive and performance-based project requirements outlined and with additional deliverables including energy modeling to verify performance targets at each design iteration.
Construction Phase	Enhanced construction quality assurance from government staff trained and experienced in DER-type construction and independent commissioning specialists engaged throughout project phases and enforcing DER-specific deliverables.
Post-Occupancy Phase	Evaluation of energy and comfort criteria established at the development phase at predetermined intervals after occupation to verify project performance goals are being continuously met.



Figure 7 PDQA process deliverables like window mock-ups can be effective quality assurance tools when used correctly.

have defined electrical circuits supporting critical vs. non-critical loads to best facilitate future power generation efforts or integration of load management technologies like addressable receptacles. Table 5 summarizes some of these system-specific considerations when including prescriptive RFP content for DER projects.

One particular challenge for Building 630 has been the acquisition of a building automation system (BAS). This is another area where more specific RFP language could have avoided disturbances during the construction phase and better accommodated Presidio's BAS needs. Relying on a campus-wide management system that was not ready for connection to Building 630, the DER contract had to be modified to allow temporary standalone functionality. In hindsight and commensurate with the importance of a robust and reliable

BAS, a better approach would have required building-level controls that met project needs for fine interval commissioning trends, adequate operational memory, and informational energy sub-meter displays in corridors while using separate contract means to later integrate to the base-wide front-end when ready.

Yet many of the issues encountered were more foundational and came down to basic disagreements with the A-E designer on their RFP-required energy modeling. The RFP required the contractor to demonstrate that minimum EUI targets were met at each design iteration; however, much of what contributed to the EUI calculation was unclear. Thus slight differences in which square footage values were applicable, what weather files were selected, whether to remove laundry hot water usage, and how to adjust the site-to-source factors to match utility generation sources rendered energy modeling comparisons somewhat less valuable. For future projects, it is recommended to either specify each known modeling constraint in the RFP along with the performance targets, or to use the pre-design model to list each of the prescriptive requirements for system selection and operation without mandating additional energy modeling from the contractor.

Additional Drawing and Details. Despite the substantial effort defining RFP requirements, there were still issues with the design team's interpretation of what was needed that additional drawings or details could have mitigated. There is a need to clarify in the RFP what is required for an air barrier shop drawing, and how the subcontractor(s) installing the various components of the air barrier must demonstrate compliance with the shop drawings. More specifically, there is a need to improve the specification for the detailing and installation of window systems. A combination of written requirements and prohibitions coupled with clear drawings of acceptable examples should be included in future RFPs. For example, the use of caulk as a component of the air barrier should be prohibited

Table 5. Summary of Prescriptive RFP Considerations for DER Projects

DER System	Presidio RPF Approach	Future RFP Considerations
Greywater tank sizing	Tank size required was estimated at 2000 gal (7570 L) based on initial calculations of 4000 gal (15,140 L) per day of greywater .	For bidding clarity, either specify tank sizing or provide all sizing assumptions to be used, including domestic water usage profiles, gender ratios, showering times, and whether to include washing machines.
Solar thermal system sizing	Requirement to meet 70% of domestic hot-water load based on 20 gal (75 L) per person of 120°F (49°C) supply and 140°F (60°C) storage at 10 min shower durations.	Include additional modeling assumptions such as horizontal irradiance available, tilt angle, panel load temperatures, and domestic hot-water diversity or total daily load expected. Include DER quality assurance team members experienced in renewable energy modeling programs.
Window type	Requirement for dual pane thermally broken windows with U-value less than or equal to 0.30.	Be specific with how U-value is determined. Without specifying center-of-glass U-value vs. assembly U-value, poorer than expected window performance may be provided.
Window details	Requirement for airtightness maximums and procedures however no window details provided.	Provide window details to more prescriptively indicate air barrier and thermal break components to be later used during window mock up quality assurance.
Interior lighting type	Lighting power densities (LPD) and foot-candles requirements provided for each space type with some exterior lighting technologies required.	If other organizational buildings are transitioning to interior linear tube LEDs, as is Presidio, require this technology in the RFP in addition to LDP and illuminance requirements.
Noncritical electric loads	Only emergency circuit criteria provided.	For load shedding or on-site power generation goals, consider requiring differentiation between critical and noncritical electric circuits.
Radiant heating systems	Requirement for overhead hydronic radiant heating in dwelling unit ceiling. No requirement given for imbedded versus radiant panels.	Radiant systems paired with dedicated outside air units can accommodate low ceiling spaces in tighter renovation projects. Embedded versus paneled radiant systems have implications on hydronic distribution sizing, occupant comfort, and maintenance access.
Ductwork type	ANSI/ASHRAE/IES Standard 90.1 (ASHRAE 2010) performance criteria, ASHRAE Advanced Energy Design Guide recommendations, UFGS 23 05 93 testing requirements provided (DoD 2015). No requirement for round versus square duct provided.	Duct leakage test requirements at Building 630 were eventually met using an aerosol interior duct sealant. Consider specifying round duct for first-cost savings and better leakage test results.
HVAC controls sequences	Requirements for duct static pressure, mixed air temperature, and hot-water temperature set point resets. Requirements for demand controlled ventilation and recirculation pump scheduling.	Consult with maintenance team to limit sequence of operation complexity to strategies that are applicable, desired, and supportable. Consider including requirements for special commissioning trend intervals to assist quality assurance of advanced sequences or even providing points schedules to be completed by contractor.
HVAC controls infrastructure	Requirements given for integration into planned campus front-end. Change order was required to establish temporary building-level front-end.	Select open protocols that support all sequences of operation. Ensure RFP includes requirements for local interfaces to accommodate testing and maintenance of the controls system.
Energy submetering	Floor-by-floor water and electricity metering requirement for tracking and energy awareness purposes.	Specify metering intervals required (e.g., 15 min.) and provide details on any monitoring kiosks in the building. Hot-water metering may require three flow meters to calculate usage: domestic cold, domestic hot, and domestic return.
Heat recovery: Air-side	Requirement for air-side heat recovery without cross-leakage.	Reference ASHRAE Standard 62.1 (2016) to specify cross-leakage rates. Require control sequences to enable heat recovery based on outside air or space demand criteria.
Heat recovery: Domestic hot water	Requirement for drain-water heat recovery system on showers to preheat cold-water supply. No requirements on piping configurations.	Ensure vertical space is available for drain-water systems and specify insulation requirements in crawlspaces. Specify parallel piped heat recovery devices, whether bypass loops are acceptable, and how to enable bypass pumps.

in writing. The use of positive seals with tape between the window system and the rough opening should also be explicitly stated and shown in example details. Requirements for window systems such as U-values (for the window system, not the glass) should be clear and non-ambiguous in the specification. If slider windows are not desired by the government, then that should be explicitly stated. (One note on this subject is that our maintenance crews are much more in favor of sliders than casement windows because of their concern about constant repairs; awning windows may be another low-maintenance window that provides better air sealing than sliders).

Improvements to the existing air barrier design drawing include air barrier testing such as blower door tests as prescribed in USACE airtightness testing procedures, application of paint-on air barriers at the window, and improved window details. These drawings are needed to identify additional thermal barrier, air barrier, and installation requirements that could have prevented issues such as the later attempted use of caulking as an air barrier product (Figure 8).

Clarity on thermal bridging requirements should also be improved with additional drawings that standardize DER approaches to balancing the additional cost of less thermal bridging with the energy penalty incurred from bridging. Structural thermal isolation pads between the building structure and exterior steel stairs should be required whereas isolating basement staircases or bringing exterior insulation several

feet below grade may require a life-cycle cost analysis and other evaluation methodologies to determine economic viability. Thermal bridging to the earth for renovations, which is especially challenging due to the cost and impact of disturbing earth along an existing foundation wall, typifies the need for improved clarity on continuous insulation requirements. Building 630's RFP required insulation to be in compliance with Standard 189.1 (ASHRAE 2011). This code included references that did not require exterior insulation below the grade. If insulation should continue below grade to the top of the footing, it should be explicitly stated in the RFP.

Additionally, the methods used to install exterior insulation should be clarified. Rasping of rigid foam is a method used to smooth joints between panels. This method is labor intensive and causes tiny expanded polystyrene foam particles to scatter down to the ground and potentially off the jobsite. This was particularly problematic at Presidio where the storm-water has the potential to carry stray expanded polystyrene foam particles from the hillside campus into the nearby marine sanctuary. As a best practice, DER RFPs should prohibit on-site rasping, shaving, sanding, or shaping the rigid foam after installation.

In the RFP development, the government team envisioned using round or oval ducts because those have the lowest leakage characteristics. But because of very tight clearances from floor to ceiling, and to allow the transitions from the exterior

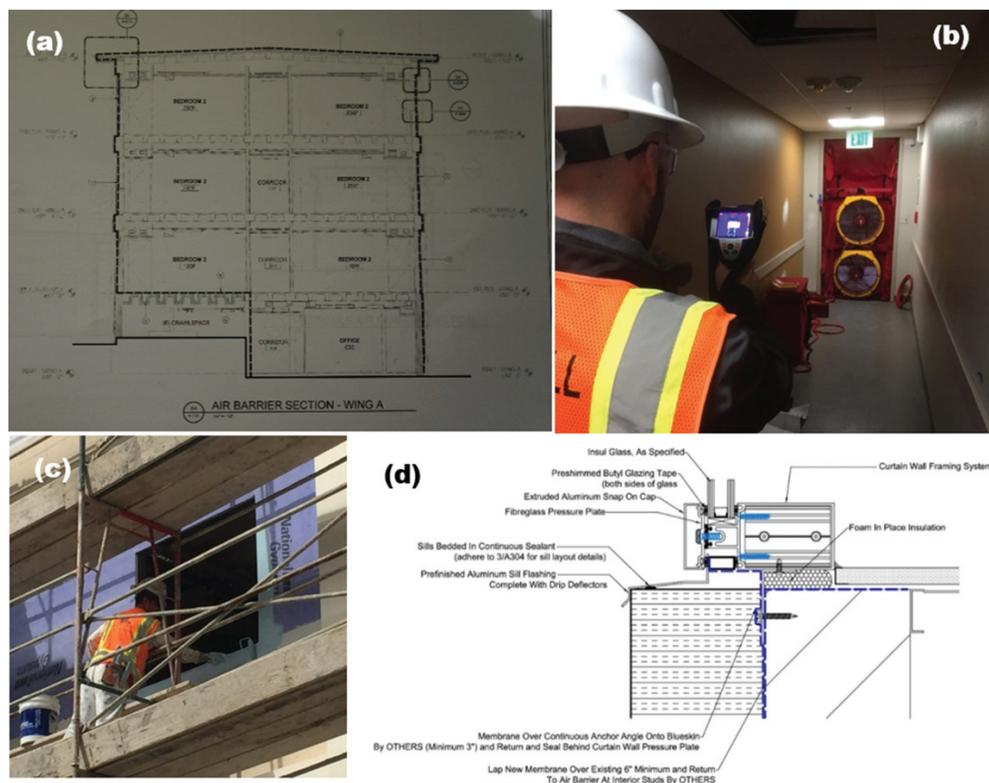


Figure 8 (a) Improvements to the existing air barrier design drawing required: (b) air barrier testing, (c) paint-on air barriers at the window, and (d) improved window details.

shaft to the inside, the contractor opted for rectangular duct. During duct air leakage testing (DALT), the performance criteria of 3 cfm of leakage per ft² (15.24 L/s/m²) of ducting was initially not met. Ductwork joint seals alone were not enough to meet DALT performance criteria (Figure 9). After trying to seal joints and connections that were accessible from the outside, the contractor still could not meet the requirement. Eventually, they used an aerosol gel system that sealed from the inside. The whole process delayed the project and cost the contractor extra money. Future RFPs will benefit from clarification on leakage class ratings for round versus square duct, a requirement for immediate ductwork testing prior to gypsum wallboard installation, and additional information on DALT testing procedures to include limitations on duct section lengths tested and quality assurance sample rates.

For complex HVAC systems configurations, system diagrams can be extremely valuable tools that schematically untangle otherwise disordered HVAC layouts to identify key system components and their interactions. Although system diagrams were not required for the Building 630 design, Presidio Public Works staff drafted the design shown in Figure 10 in an attempt to better discuss design issues discovered in the flow diagram plan sheet shown in Figure 4. The original hydronic flow diagram, while itself a diagrammatic simplification of the building's complex piping infrastructure, does not easily support certain design review tasks. In this case, reorganizing the chaotic flow diagram into the more familiar primary dual-secondary configuration made several design errors related to flow control immediately evident. System diagrams simplify complex piping schematics and can serve as valuable communication and diagnostic tools (Figure 10).



Figure 9 Ductwork joint seals (a) alone that did not meet DALT criteria and (b) insulation provided.

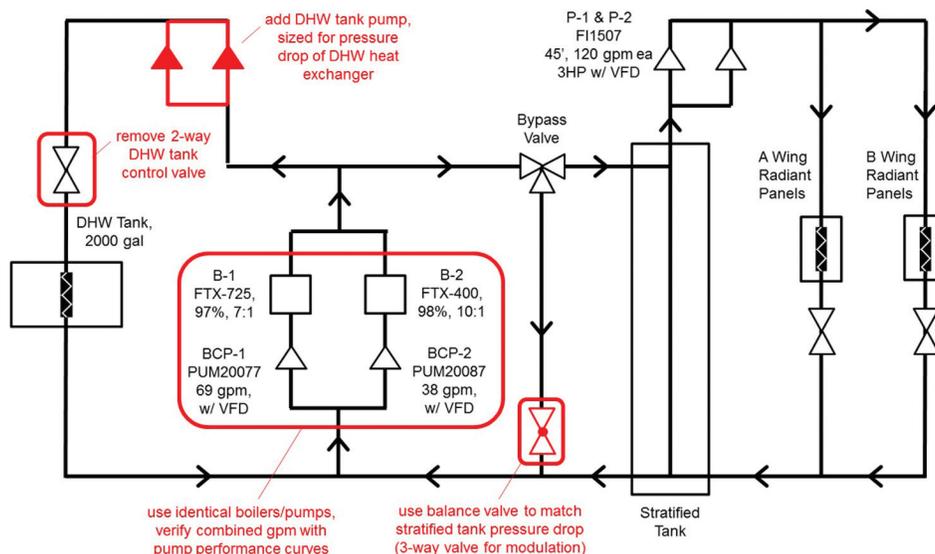


Figure 10 System diagram of Building 630's closed-loop hydronic system (design errors shown in grey).

Presidio Public Works plans to add system diagram submittal requirements for all hydronic systems in future DER projects.

Construction Phase Improvements

Many buildings to be renovated will contain hazardous material (HAZMAT). A good process to identify HAZMAT in the RFP will lead to more accurate estimates by the bidders and fewer change orders. For Building 630, DPW contracted for sampling and analysis during the RFP development. Asbestos samples were taken in both wings at floor tiles and base boards; however wallboard material samples were not taken. This was because the walls of Wing B, where the site walk was held, were concrete masonry unit and would not contain asbestos. But, Wing A was built about 5 years after Wing B and used wallboard. The lesson here was to do a better job in determining where to take samples.

Another challenge with renovations is delineating the project boundaries. In the 630 Barracks project, Wing C was not in the project scope, with the exception of fire sprinklers. However, because the boilers that were being replaced in the project also provided hot water to Wing C's heating system, an additional project was needed to provide heat to Wing C. Because Wing C was not in the project, the electrical loads were not initially counted. This led to concerns with the sizing of the main electrical panels and almost required upsizing the building transformer. With respect to DER projects, defining energy boundaries is especially important since the energy intensity target was a performance specification and the potential for dual funding from Energy Savings Performance Contracts (ESPCs) may introduce additional collocating of on-site trades.

While building and duct airtightness requirements have been met (Lamb 2016), there is still room for improvement. Slight air leakage was found at the roofline overhang that could be further minimized by closer adherence to the design details (Figures 11a and 11b) and improved continuous air

barrier application. At windows, thermal imaging and smoke testing revealed additional slight air leakage (Figures 11c and 11d) and missing weep covers that have since been installed. Though not drastic enough to prevent successful air barrier testing, certain areas of localized leakage such as that at windows represent valuable lessons learned. Exterior stair-

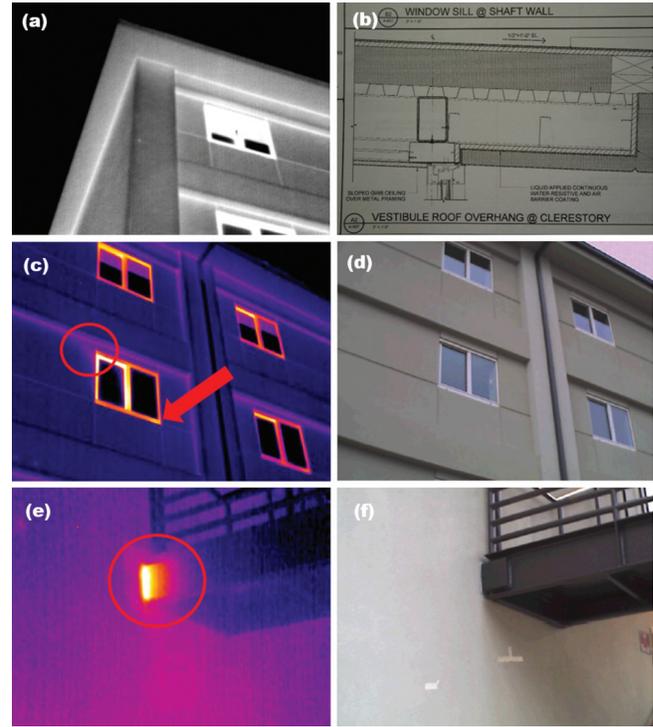


Figure 11 Areas for improvement: (a, b) roof air barrier detail as compared was included in the design, (c, d) slight leakage at the overhang, and (e, f) contact of thermal barrier and exterior stairway steel supports still acts as thermal bridge.

Table 6. Testing Results Indicate Air Barrier Tightness Requirements Have Been Met Despite Slight Leakage at Windows and Roof Areas

	Required	Pressurization	Depressurization	Combined Average	Pass/Fail
Actual leakage at 75 Pa, cfm (m ³ /min)	<11,578 (<324.18401)	6978 (195)	7276 (204)	7127 (200)	PASS
Actual leakage rate at 75 Pa, cfm/ft ² (L/s/m ²)	0.15 (0.76)	0.09 (0.46)	0.48 (0.094)	0.092 (0.47)	PASS
Effective leakage area at 75 Pa, ft ² (m ²)	—	5.3 (0.49)	5.5 (0.51)	5.4 (0.50)	—
Pressure exponent, <i>n</i>	0.45 < <i>n</i> < 0.8	0.720	0.639	0.680	PASS
Air leakage coefficient, cfm/Pa ^{<i>n</i>} (L/s/Pa)	—	311.7 (147)	461.0 (218)	386.3 (182)	—
Squared correlation coefficient	<i>R</i> ² > 0.98	0.9988	0.9975	0.9982	PASS

wells, while designed to minimize the contact between the envelope and steel supports, still showed heat transfer bridging at this reduced interface (Figures 11e and 11f) during testing that could have been further reduced with the installation of a thermal break. Another area of slight performance loss was at interior ducting where ANSI/ASHRAE/IES/USGBC Standard 189.1 (ASHRAE 2011) levels of insulation were provided per the RFP, but had been compressed to accommodate low ceilings.

CONCLUSIONS AND RECOMMENATIONS

Table 5 summarizes lessons learned by indicating where more prescriptive design and construction criteria are recommended in future DER projects. Additional recommendations include the need for better DER quality assurance documentation and training, as well as standardized guidance on sizing DER systems such as solar thermal and greywater storage systems. The quality assurance process itself needs to extend to all project phases, from commissioning and subject matter expert input during RFP development to postoccupancy performance data evaluation and remediation during the warranty period. For the Army, we recommend that a Center of Expertise (COE) be established to house experienced architects, engineers, and technicians that can better support DER RFP standardization, critical quality assurance milestone acceptance, and transitioning of non-U.S. approaches and technologies to Army projects.

With the completion of the first wing at Building 630 (Figure 12), Presidio has accumulated a number of best prac-

tices and lessons learned to support future DER endeavors within the Department of Defense (DoD). By coordinating the DER of its Army barracks with a scheduled renovation to modern living standards, Presidio has established a cost effective method for procuring high performance buildings in pursuit of its net zero energy goals and at shared costs. Relative to the funding required to support a standard retrofit project, the DER-specific portions of Building 630's renovation have been estimated at less than 10% of overall project costs. This was accomplished in part by an innovative approach to DER efforts that bundles sustainable technologies into overall life-cycle-cost-effective packages that are demonstrated during preaward energy modeling and formalized as project requirements and performance targets in the RFP. Recognition also goes to the organizations responsible for facilitating and implementing this approach, including U.S. Army Garrison Presidio for its initiative, U.S. Army Installation Management Command for its approval and oversight, U.S. Army Corps of Engineers for its technical support, and contractor AECOM for its expertise and partnership.

Execution of these DER acquisition best practices and partial completion of construction have led to the reporting of DER strategies that have worked and others that require fine tuning. As part of the commissioning of the first wing and central plant, stringent testing criteria and system efficiencies are being successfully implemented to maintain the trajectory to meet the 86% energy intensity reduction targets and the ultra-low site EUI performance requirement of 18 kBtu/ft² (56.73 kWh/m²). Subsequent occupation or measurement and



Figure 12 Completed first wing of Presidio Building 630: (a) actual versus (b) rendered.

verification phases may reveal additional takeaways, but Building 630 already provides Presidio, DoD, and the greater sustainability community with a wealth of documented success and knowledge for how to best approach large DER projects.

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