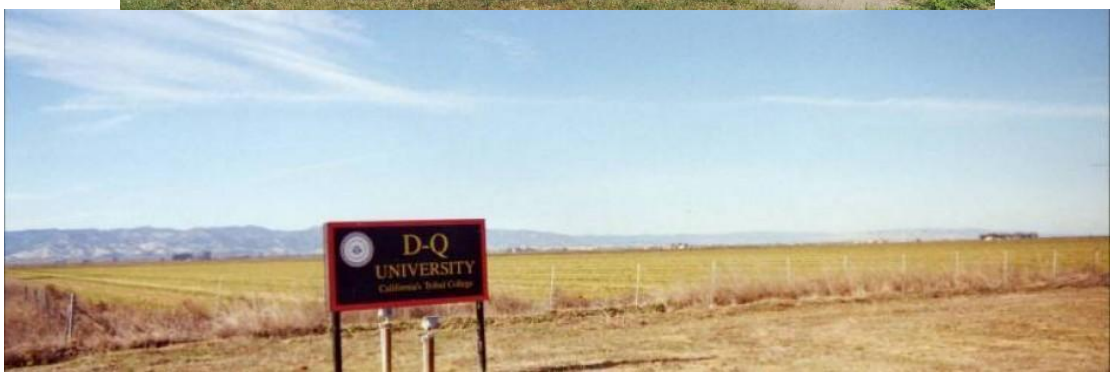


# Zero Net Energy at D-Q University

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A Path to ZNE

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**Zero Net Energy at D-Q University**

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## (0) Glossary

- **ZNE -** Zero Net Energy : In terms of cost, ZNE means that "the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year." (Torcellini et al. 2006)
- **DQU -** D-Q University : project site.
- **PV -** Photovoltaic : means of converting sunlight (also called insolation) into electricity.
- **PG&E -** Pacific Gas & Electric Company : DQU is a PG&E customer for electricity only.
- **ESM -** Energy Saving Measure : a broad term used to encompass both energy efficiency (same output for less energy input) and energy conservation (less output and less energy input).
- **eQUEST -** Quick Energy Simulation Tool : used to create a baseline model of energy use in a commercial building, as well as simulate and evaluate energy-saving measures.
- **CEUS -** California Commercial End-Use Survey : "a comprehensive study of commercial sector energy use...A stratified random sample of 2,790 commercial facilities was collected from the service areas of Pacific Gas & Electric, San Diego Gas & Electric, Southern California Edison, Southern California Gas Company, and the Sacramento Municipal Utility District. The sample was stratified by utility service area, climate region, building type, and energy consumption level." (CA Energy Commission 2014)
- **MyEnergy -** Online utility bill information for PG&E customers. For DQU, there is information for electricity use only.
- **EI -** Energy Intensity : energy use per square foot per year.
- **BTU/ft$^2$-yr -** a unit for quantifying propane use in British Thermal Units per square foot per year.
- **kW-hr/ft$^2$-yr -** a unit for quantifying electricity use in kilowatt-hour per square foot per year (Note: kW is a unit of power, kW-hr is a unit of energy and these are not interchangeable).
- **SPT -** Simple Payback Time : A metric to rank investments by the number of years it takes for a measure to pay for itself. It is computed by taking the dividing the initial cost by the annual savings.
- **setpoint -** the thermostat setting (e.g. 70 $^o$F) for a space heater or the dial setting (e.g. high) for a water heater.
- **fenestration -** openings in the building envelope such as doors and windows.
- **end-use -** the ultimate application or function for which the energy is used (i.e. the end destination or purpose).
- **discount rate -** is a multiplier that is used to convert a future value of money into a present value (now). This is essentially the time value of money, since the money can accrue interest when placed in a bank. For example, a discount rate of 8% per year means that the present value of a dollar one year from now would be approximately 93 cents.
- **T-8 fluorescent lamps -**The 'T' stands for tubular and '8' is for the number of 1/8ths of an inch in diameter. Therefore, a T-8 lamp is a tubular-shaped lamp that is one inch in diameter. Newer T-8 fluorescent lamps may be considered high efficiency when they require 28 or 25 watts of electrical power, whereas the ones at DQU require 32 watts. (PG&E 2014A)
- **TDV -** Time Dependent Valuation : TDV is an alternative measurement for valuing energy and "accounts for when energy is used. Under TDV the value of electricity differs depending on time-of-use (hourly, daily, seasonal), and the value of natural gas differs depending on season. TDV is based on the cost for utilities to provide the energy at different times." (CA Energy Commission 2004)

## (1) Executive Summary

D-Q University (DQU) operated on a former U.S. Army communications facility from 1971 until their loss of funding and accreditation in 2005. The campus has since been beset with issues of vandalism, idleness and high energy costs; however, has a renewed interest in opening its campus again. In re-opening, DQU is looking to achieve zero net energy costs (ZNE cost) and to become a model of sustainability for other tribal institutions to follow. DQU has partnered with UC Davis's Engineers Without Borders (EWB) and the Path to Zero Net Energy (PZNE) class to address these goals by conducting a study focused on the large dormitory building. The PZNE team performed an on-site field assessment, estimated energy use and costs for full occupancy, evaluated potential energy saving measures (ESMs), assessed the size of the solar photovoltaic (PV) system required for ZNE cost, and provided a list of potential resources to fund these endeavors.

For the on-site field assessment, we interviewed DQU staff, photographed major equipment/end-uses and documented any immediate concerns in the large dormitory building and on the campus. We used this information, combined with California Commercial End-use Survey (CEUS) data and floor area computations in Google Earth, to derive Best, High and Low Estimates for the large dormitory buildings' annual energy load, load profile and annual energy cost. Our Best Estimate found an electricity use of 84,300 kW-hr/yr and a propane gas use of 388.9 million BTU/yr. Most of the electricity went into cooling, ventilation and interior lighting end-uses, while for propane gas it was space and water heating. The combined annual electricity and propane usage cost DQU $23,400/yr. Although the results were similar between the Best and Low Estimates, there were disparities between the Best and High Estimates with annual electricity use, annual propane consumption and annual energy cost.

Using the findings from the previous step, we used eQUEST to model the energy and cost savings for water heating, roof insulation, lighting, space heating and window ESMs. We first had to estimate a baseline energy use and cost for comparison in eQUEST, which differed significantly with the CEUS Best, High, Low Estimates and reduced the percentage savings of the ESMs. For the five ESMs, modeled individually and in combination, the savings in electricity, propane gas and in energy cost generally ranged from 0% to 3% and the simple payback time was generally 0 to 16 years. These results suggest that eQUEST may need more detailed inputs for its model and/or the large dormitory building's degree of energy efficiency from the prior use may result in little savings with ESMs.

We used the PV Watts Calculator to estimate the size and cost of a solar PV system that could achieve ZNE cost. The benchmarks used for this computation were the CEUS High, Best and Low Estimates, because those estimates represent an energy efficient dormitory building relative to eQUEST's baseline estimate. In other words, we followed an efficiency-first approach before analyzing solar PV systems. Results indicate a wide variation of solar PV generation capacity and physical size required to meet the ZNE cost objective, starting from about 83 kW on the low end to a maximum of 287 kW and requiring about 3,900 to 13,500 square feet of roof space, respectively. Installation costs for these solar PV systems range from $215,800 to approximately $746,200 and the payback period was about 10 years. Although a sizable amount of roof area is required for these solar PV systems, we determined DQU has sufficient area to cover those demands.

PG&E, CA Energy Jobs Act (Proposition 39) and Second Nature offer incentives, rebates, professional and technical expertise to assist DQUs' efforts in becoming ZNE cost. PG&E offers a retro-commissioning incentive program and no-interest loans for energy efficiency improvements, while the CA Energy Jobs Act provides grant funding for planning energy efficiency and clean energy generation projects. Also, Second Nature provides outreach and education for building energy retrofits at under-resourced higher education institutions.

Taking into consideration all of the above, we made the following conclusions. First, CEUS's utilization of data from more energy efficient buildings led to a disparity between the CEUS and eQUEST estimates and a significant gap between the models and DQU's energy situation in reality. Second, the five ESMs, analyzed individually and in combination with eQUEST, had small percentages of energy and cost savings that suggest the eQUEST model may need further refinement and/or that these ESMs may be unworthy to pursue given the energy inefficiency of the large dormitory building. Third, to become ZNE cost and using the CEUS Low and High Estimates, DQU would need a roof-mounted PV system with a power output between 83 and 287 kW and occupies an area of approximately 3,900 to 13,500 square feet. This system would cost approximately $215,800 to $746,200 and have a 10-year payback time. However, DQU's first priority should be increasing their energy efficiency. Fourth, the best options for funding these efforts are through incentives, rebates and consultations offered by PG&E, the CA Energy Jobs Act and the non-profit group Second Nature. Lastly, the report contained four main sources of uncertainty: the use of hypothetical baselines, the possible underestimates of energy savings in eQUEST, the translation between energy savings and energy costs and the variables of weather and electricity generation with PV systems with respect to ZNE cost.

Ultimately, the PZNE team formulated the following six recommendations based on our research and findings. First, address the leaning electrical power transmission pole. Second, borrow metering equipment to assess the leaking main water pump. Third, reconsider the possibility of replacing the electrical transformer system. Fourth, create an inventory of major energy-consuming equipment. Fifth, explore PG&E's retro-commissioning service by requesting a representative for a site visit and a consultation.. Finally, focus on implementing ESMs before considering solar PV generation.

## (2) Project background

D-Q University (DQU), founded in 1971 after it gained control over federal surplus land once used as a radio transmitter station by the United States Army, became California's first indigenous-controlled institution for higher education outside of a reservation. Until this day, it remains the only successful attempt to open a Native American exclusive college in California, and it represents the collaborative effort of many different Native races. (Holdstock 2004) DQU's original mission statement is "to provide quality education, community involvement, and learning opportunities for all Native Americans in California and for all those that have a desire and ability to learn." (D-Q University 2013) However, after it lost funding and accreditation in 2005, it has been victim to vandalism and idleness.

Currently, the campus' use is limited to monthly powwows in the cultural building (Building A in Figure 1) and periodic trainings. There is one caretaker who lives on site, Sky Road Webb, and a dedicated team of individuals who work on facility repairs. As of 2012, the University Board of Trustees has signed a commitment with the Inter-Tribal Council of California to "[strengthen] the administrative capacity of the University" and work towards re-opening the institution. (D-Q University 2013)

This history outlines the project's context and the greater purpose for DQU: (1) to re-open the university with zero energy costs, and (2) to become a model of sustainability for other tribal institutions to follow. The Path to Zero Net Energy (PZNE) class has partnered with Erik Porse of Engineers Without Borders UC Davis chapter (EWB) to assist DQU in meeting these goals. The EWB team consists of approximately 15 students and is split into two focuses: water and energy. Porse, along with ten of the students from the EWB team, concentrates on addressing water concerns at DQU; while the other five students from EWB, and the PZNE team, will focus on the energy problems. With this in mind, and in consultation with our clients Erik and Sky, we outlined the problem and generated our scope of work. Our understanding of DQU's problem, in specific terms, is unreliable, unpredictable, inefficient, and highly expensive energy consumption. Furthermore, our client has expressed concern over a phantom load of energy that is causing sporadic spikes in the energy bills. To address these issues within the PZNE class's timeframe and in accordance with our team's expertise, we decided to focus on a single building, the larger dormitory building (Building B in Figure 1), and produced the following scope of work:

- On-site field assessment at DQU.
- Create estimates of energy consumption and cost if DQU were fully operational (i.e., projected baseline estimate)
- Evaluate different energy saving measures (ESMs) to reduce this projected baseline estimate.
- Estimate on-site solar photovoltaic (PV) generation needed to meet the remaining load and to achieve zero net energy in terms of energy cost (ZNE cost).

- Provide a list of potential funding sources to facilitate the implementation of ESMs and solar PV generation.

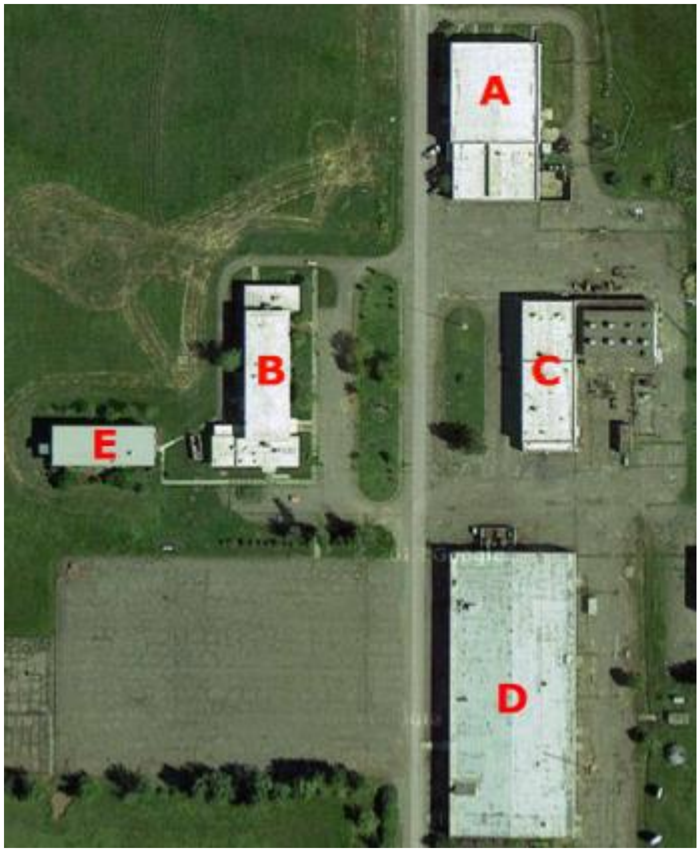


**Figure 1: Aerial View of DQU (Google Maps)**

***Building A: Cultural building***
***Building B: Large dormitory building***
***Building C: Mechanic shop***
***Building D: Administration building***
***Building E: Small dormitory building***

## (3) Methodology

Our approach to the scope of work was shaped by the following considerations, constraints and assumptions outlined in Table 1. The implications of these items are further discussed in the results and uncertainty sections.

**Table 1: Summary Table of Main Considerations, Constraints and Assumptions**

| Considerations | Constraints | Assumptions |
|---|---|---|
| High energy costs as an idle facility; PG&E customer for electricity but buys propane for gas use independently | Time and technical expertise, especially with metering large equipment and efficiency measures. | Same energy consumption for propane gas-based equipment as natural gas-based equipment, namely the water heater and stove. |
| Desire to re-open as a model of sustainability for tribal institutions. | One electricity meter for DQU; no sub-metering to pinpoint energy uses and no metering of propane gas use. | Use of default values in eQUEST for variables where information was not collected from the field visit. |
| Need for outside funding to finance energy efficiency projects. | The age of DQU's infrastructure (site and buildings), its past use as a military communications facility and a mixture of old and new equipment. | For monetary computations: no discount rate; no defined project lifetime; and fixed prices of electricity and propane gas. |

**Equipment & Procedure:**

Throughout the course of ten weeks we utilized the following methods to address the project purpose and scope of work:

I. DQU Field Assessment
II. Estimate Annual Energy Loads, Load Profiles, and Annual Energy Costs
III. Evaluate Energy Saving Measures and Simple Payback Time
IV. Estimate On-Site Solar PV Generation for ZNE Cost
V. Identifying Funding Opportunities for DQU

I. DQU Field Assessment:

To begin, we visited DQU in early May and assessed the large dormitory, the cultural building, two water pump houses, and two power transformers. This endeavor had three main components: (1) interviewing DQU Board of Trustees Treasurer Joe Saulque, Sky Road Webb, and staff to understand occupant behavior, (2) creating a photo inventory of large energy-consuming devices for the entire site and (3) taking notes of any immediate concerns. The findings from this assessment directed our efforts at the large dormitory building and later influenced the creation of the projected baseline estimate and consequential computations.

II. Estimate Annual Energy Loads, Load Profiles and Annual Energy Costs:

*California Commercial End-use Survey (CEUS)*

This part involved multiple steps to calculate the following: annual electricity and propane gas consumption (i.e., the annual energy load), the distribution of annual energy consumption among end-uses (i.e., a load profile) and the annual energy costs. First, we used the CEUS data to generate three different scenarios - High, Low, and Best estimates - which provide a range of values and account for the uncertainty inherent in working with a model rather than on-site measurements. We used CEUS survey data for health care, lodging, and restaurant buildings, because the large dormitory building shares characteristics with each of these building types. That gave three values for energy intensity (EI) for each building type and for each energy end-use, such as cooking and lighting, which were given as BTU/$ft^2$ per year for propane gas and kWh/$ft^2$ per year electricity. The High and Low Estimates took the highest and lowest EIs from the three building types, whereas we attempted to use the EI that most closely matched the conditions at DQU when calculating the Best Estimate. The EI multiplied by end-use square footage (e.g., kitchen floor area and residential floor area), which were computed with Google Earth's measurement tool, produced estimates of the annual energy consumption of that end-use component. For instance, we took the EI for refrigeration and multiplied it by the square footage for the kitchen space only, rather than for the entire dormitory building, to determine the total annual energy consumption required by the refrigeration equipment. Summing up the end-use components produced an estimate of the annual energy consumption for electricity and propane gas end-uses. Measuring each component's percentage contribution to the total annual energy consumption gave an estimated load profile.

*eQUEST*

We generated a fourth estimate of annual energy load and load profile using eQUEST, which is based on the characteristics of the DQU dormitory building rather than surveys of various building types as with CEUS. We used the Schematic Design (SD) Wizard to input the characteristics of the building envelope and equipment based on the findings from our field assessment. The SD Wizard then simulated the dormitory building's operations and produced a table of annual energy usage and load profiles for electricity and propane gas end-uses.

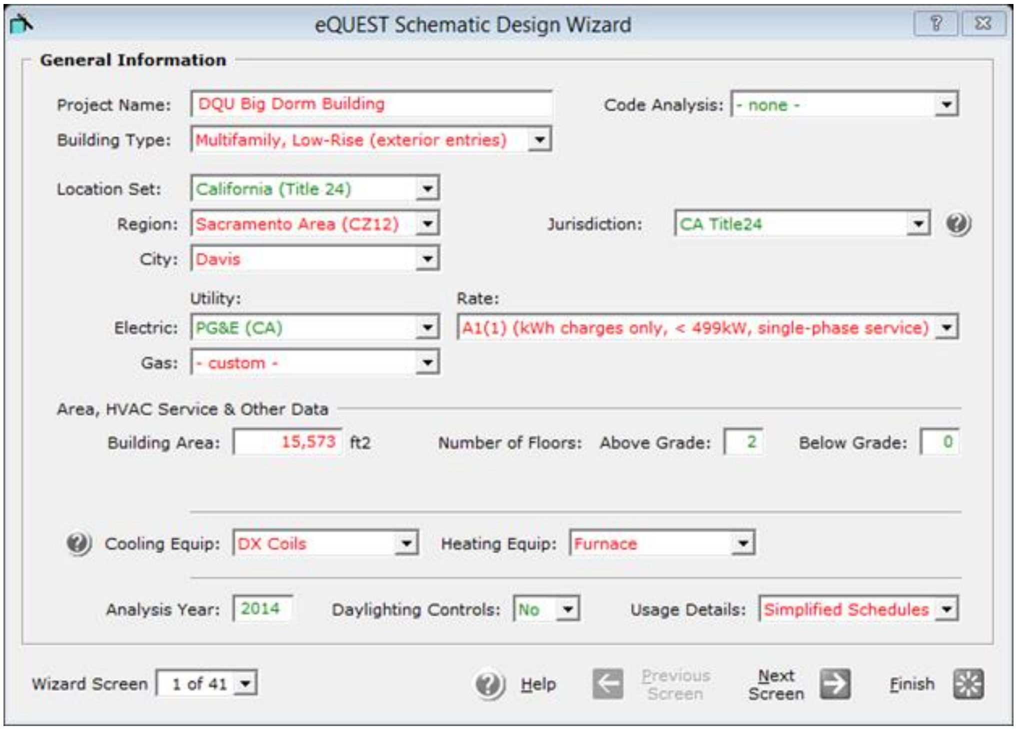


**Figure 2: Screenshot of eQUEST's Schematic Design Wizard**

*CEUS & eQUEST*

To estimate annual energy costs, we took the annual energy load of each scenario and multiplied the quantity of energy - kilowatt-hours (kW-hr) for electricity and British Thermal Units (BTUs) for propane gas - by the price of electricity and propane gas, respectively. DQU's monthly PG&E utility bill provided the electricity price and the U.S. Energy Information Administration (EIA) provided the price of propane gas in California. (US EIA, 2014) Using the prices of electricity and propane gas, we computed the annual costs in terms of each fuel for all four estimates of annual energy use.

III. <u>Evaluate Energy Saving Measures (ESMs) with Simple Payback Time (SPT)</u>:

We identified the largest energy end-uses based on the findings from the field assessment, the CEUS and the eQUEST models. Then, we chose ESMs that would reduce the energy consumption of those end-uses and simulated their impact using the ESM Wizard in eQUEST. There were several options within each category of ESM and we chose to model the following: adding roof insulation, replacing windows, lowering the setpoint for space heating, lowering the setpoint for water heating and adding occupancy sensors for lighting. Also, there was a variety of options for addressing those building components and equipment, and we selected measures that ranged from no-cost (e.g., reducing setpoints for space and water heating) to measures with a high, upfront cost (e.g., replacing windows). For measures with monetary costs, we used homewyse.com to estimate material and labor costs, while eQUEST provided estimates of the annual electricity and propane gas savings from the ESM or the combination of ESMs. (Homewyse, 2014A & 2014B) We determined annual energy cost savings of the ESMs in eQUEST by multiplying the annual energy savings by the prices of electricity and propane gas; then, we divided those cost savings by the cost of implementation to determine the SPT of the ESM.

IV. Estimate On-Site Solar PV Generation for Zero Net Energy Cost:
In order to offset total annual energy costs and meet DQU's cost-based definition of ZNE, we used the PV Watts Calculator (NREL 2014) to estimate the size of a solar photovoltaic (PV) system or array that would be required to meet DQU's annual energy costs. Even though PV systems generate electricity only, we included annual propane gas costs in our benchmarks in order to model a 100% ZNE building in terms of cost. After consulting our mentors Kurt Kornbluth and Magdalena Brum, we used the annual energy costs represented by the CEUS High, Best, and Low value estimates generated previously because they represent an ideal, energy-efficient dormitory building. Furthermore, such practice follows the "reduce-before-produce" or "efficiency first" strategy for minimizing energy consumption before pursuing renewable energy generation. Accordingly, pursuing all cost-effective ESMs first to reduce the energy load helps to minimize the size and cost of a solar PV system needed to meet the new, smaller load.

We had to convert the estimates of energy consumption (High, Best, and Low Estimates) into units of power in order to use the PV Watts Calculator. (NREL 2014) Next, we estimated the requisite PV system size--the size needed to offset total annual energy costs for the dormitory building--through trial and error by adjusting the amount of power (kW). We recalculated the PV system's requisite size, however, by adjusting the solar insolation value downward to account for dust and plant debris from nearby farms as well as high temperatures that were not sufficiently accounted for in the PV Watts Calculator. (NREL 2014) Also, we inflated the installation cost estimates of the ground-based system by 10% to account for underground power line installation, since PV Watts Calculator (NREL 2014) did not appear to consider this.

V. Identifying Funding Opportunities for DQU:
Erik Porse (EWB-UC Davis) suggested during our first meeting that we explore funding sources to assist DQU finance improvements to achieve Zero Net Energy. We searched online through Google with the terms "sustainability and dorm buildings", "energy efficiency and dorm buildings", "sustainability and schools", and "energy efficiency and schools". Local funding sources were examined first, before broadening the search to include sources outside California.

## (4) Results & Discussion

**DQU Field Assessment Findings:**
Our visit of the large dormitory building (see Figure 2 and building B in Figure 1) revealed the following:

- Floor area of 15,500 square feet contained in 2 floors.
- Building envelope is cinder-block construction with an un-insulated wooden roof.
- Fenestrations: all east- and west-facing windows are double-pane, while all north and south-facing windows are single-pane; doors are mostly glass and are single-pane.
- Multiple uses of building, including: cafeteria and large kitchen/food storage; residential; computer lab; and education.

- Multiple energy sources: propane gas for water heating, cooking equipment, and furnace; electricity for all other energy end-uses
- Approximately 30 rooms total, with the majority of them being residential.
- Approximately 55 students at full occupancy, with the number remaining roughly constant year-round; 0 right now.
- The students bring a low-to-moderate quantity of plug loads (mainly electronics).

**Figure 3: DQU's large dormitory building**

Continuing with the assessment, we found:

- Mixed age of site infrastructure, buildings and equipment, with older elements (e.g., single-pane windows) and newer ones (HVAC equipment).
- Three high-power step-down transformers (12 kV to 480 V and (480 V to 220 V or 120 V) for low-power uses, which means much of the electrical energy gets dissipated as heat. One transformer was broken (burnt out).
- About 0.8 miles north of the main buildings, there was a large water pump leaking inside the pumphouse and in the fields surrounding the building, resulting in a swamp.
- A power outage at DQU may result if the leaning power pole falls over and the 12 kV power line disconnects.

The findings above have the following implications. (1) Continued high electricity usage and costs despite low occupancy at DQU (unknown loads). Metering and monitoring are necessary to quantify the unknown loads' impacts on electricity use and costs. (2) There is a wide range of ESMs given the multiple uses of the large dormitory building. For example, DQU can replace food service equipment with EnergyStar-certified ones to reduce the kitchen's electrical loads/costs and add insulation to the water heaters to reduce propane gas use/costs. (3) The absence of occupants makes it challenging to determine current usage patterns (any baselines are hypothetical), to identify potential ESMs and to analyze the impacts of behavioral changes.

**CEUS Findings:**

There are similarities and differences between the results for the Best, High, and Low Estimates obtained using CEUS data on energy intensity (EI). All three scenarios indicate that the top three end-uses of electricity are cooling, ventilation and interior lighting uses; water heating and then space heating are the top two end-uses of propane use. However, there is a large difference in total annual energy consumption and cost between the three scenarios (Table 2). The total annual energy cost of the Best Estimate, including electricity and propane gas, amounts to approximately $23,400, based on an estimated annual electricity consumption of 84,300 kW-hr/yr and annual propane gas use of 388.9 million BTU/yr.

**Table 2: Summary of CEUS Scenarios**

| CEUS Scenario | Electricity (kW-hr/yr) | Propane Gas (kBTU/yr) | Total Energy Cost ($/yr) |
|---|---|---|---|
| High Estimate | 303,200 | 895,500 | $74,700 |
| Best Estimate | 84,300 | 388,900 | $23,400 |
| Low Estimate | 76,300 | 353,300 | $21,200 |

**Table 3: CEUS Best Estimate End-Use Load Profile Breakdown**

| **Electrical End-Use** | **kW-hr/yr** | **%** |
|---|---|---|
| *Cooling* | *31,183* | *36.97%* |
| *Ventilation* | *21,897* | *25.96%* |
| *Refrigeration* | *5,433* | *6.44%* |
| *Ext. lighting* | *1,796* | *2.13%* |
| *Int. lighting* | *18,532* | *21.97%* |
| *Office Equipment* | *430* | *0.51%* |
| *Misc.* | *5,070* | *6.01%* |
| **Total** | **84,341** | **kW-hr/year** |
| **Total Electricity Cost** | **$23,436.48** | **$/year** |
| **Propane End-Use** | **kBTU/yr** | **%** |
| *Space Heating* | *72,615* | *18.67%* |
| *Water Heating* | *306,462* | *78.80%* |
| *Cooking* | *9,830* | *2.53%* |
| **Total** | **388,908** | **kBTU/year** |
| **Total Propane Cost** | **$7,411.64** | **$/year** |

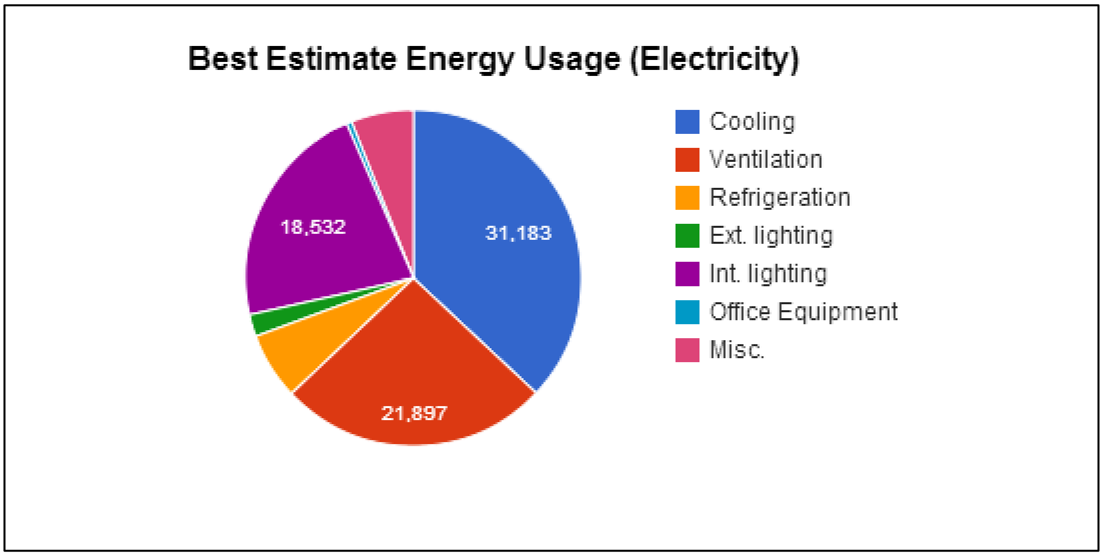


**Figure 4: CEUS Best Estimate Electricity Load Profile**

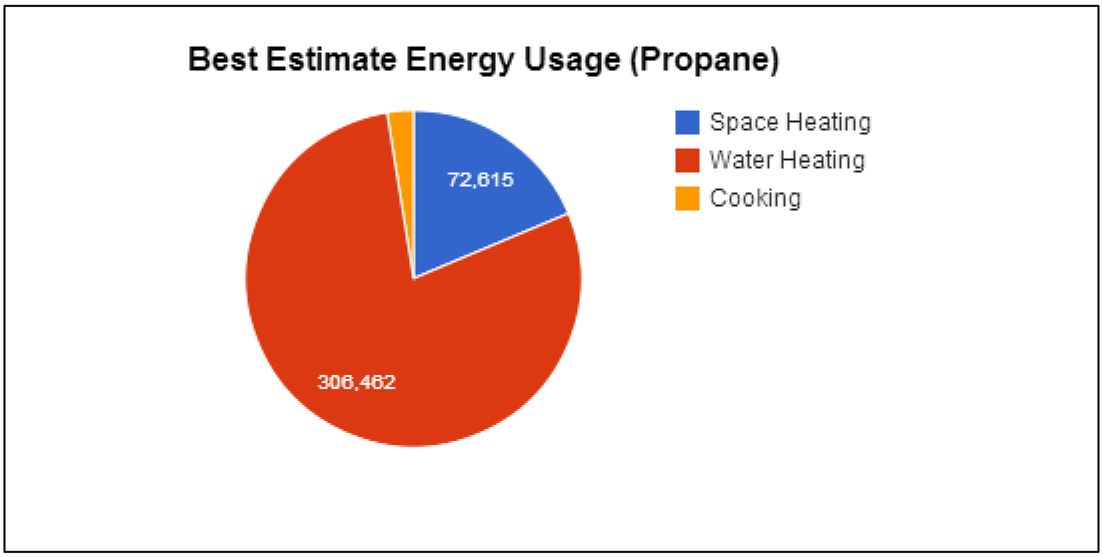


**Figure 5: CEUS Best Estimate Propane Gas Load Profile**

These results suggest that, for the large dormitory building, DQU should direct their energy efficiency projects to lighting, cooling, and ventilation in terms of electricity usage, and to water heating and space heating in terms of propane usage. The next step would be sub-metering with PG&E to pinpoint and verify major end-uses of electricity and propane gas before deciding on the types of ESMs to implement.

The High Estimate may approximate the large dormitory buildings' annual energy consumption and cost at full occupancy without ESMs. This High Estimate may be the baseline energy usage and cost for this building. In contrast, the Best and Low Estimates may approximate the large dormitory buildings' annual energy use and cost at full occupancy with ESMs implemented.

Our Best Estimate was much closer to the Low Estimate than the High Estimate of electricity and propane gas use, which the team anticipated. However, there was a wide disparity between the Low and High Estimates of energy costs, electricity and gas use (Table 2). This is not surprising, since we used three categories of CEUS data and there was considerable variation between the EIs of the end-use components among the categories, like refrigeration and cooking.

**eQUEST Findings:**

The five individual ESMs discussed below are as follows: (1) lowering the water heater set point from 135 $^{o}$F to 105 $^{o}$F, (2) adding 2” of polystyrene insulation to the roof, (3) adding lighting sensors and improving occupant behavior with regards to lights, (4) reducing the space heating temperature from 68 $^{o}$F to 63 $^{o}$F and (5) replacing all remaining single-pane windows with double-pane ones.

In terms of electricity savings, eQUEST predicts ESM (3) saves about 3% or 10,500 kW-hr/yr and about $300/yr in energy costs, with an implementation cost of $1,500 for lighting sensors and a Simple Payback Time (SPT) of 6 years. However, since that measure reduces the heat output from the lights, it entails additional space heating use and thus increased propane gas consumption. Also, the potential for additional electricity and cost savings is limited, since the large dormitory building already uses T-8 fluorescent lamps, which PG&E considers energy efficient. In terms of propane gas savings, eQUEST predicts ESM (4) saves about 3% or 66.7 million BTU/year and $1,700/year in energy costs with an immediate payback and no implementation costs. Reducing the space heating set point below 63 $^{o}$F will save more propane, but it may make the large dormitory building’s interior temperature uncomfortable. The combination of ESMs (1) through (5) saves about 4% in electricity (15,200 kW-hr/yr), about 5% in propane gas (109.5 million BTU/yr) and $3,400/year in energy costs with a SPT of 15 years and an implementation cost of $51,600. See Table 4 for more details.

**Table 4: Summary Table of eQUEST ESMs**

| Energy Saving Measure | Electricity Savings (kW-hr/yr) | % Savings | Propane Savings (kBTU/yr) | % Savings | Implementation Cost ($) | Total Savings ($/yr) | Simple Payback Period (yr) |
|---|---|---|---|---|---|---|---|
| *eQUEST baseline* | *373,500 (Total)* | *n/a* | *2,174,700 (Total)* | *n/a* | *n/a* | *$112,400 (Cost)* | *n/a* |
| Water heating, reduce 30 $^{o}$F | 0 | 0.00% | 50,500 | 2.32% | No Cost | $1,000 | 0 |
| Add roof insulation, 2" thick | 50 | 0.01% | 5,100 | 0.23% | $25,100 | $100 | 236 |
| Lighting sensors & behavior | 10,500 | 2.82% | -7,300 | -0.34% | $1,500 | $300 | 6 |
| Space heating, reduce 5 $^{o}$F | 2,000 | 0.54% | 66,700 | 3.14% | No Cost | $1,700 | 0 |
| Double-pane all windows | 3,600 | 0.97% | 46,000 | 2.25% | $25,000 | $1,600 | 16 |
| Combination of the 5 ESMs* | 15,200 | 4.07% | 109,500 | 5.05% | $51,600 | $3,400 | 15 |

*Note: Water heating temperature reduced from 135 $^{o}$F to 110 $^{o}$F (25 degrees $^{o}$F).

Since DQU plans to operate on a long-term basis, the ESMs worth pursuing here may be the ones with a SPT of less than 30 years. This leaves the roof insulation ESM, by itself, as the only measure unworthy of implementation, since the payback time is over 200 years. Do note the combination of measures has an SPT of 15 years, which shows SPTs are not additive (i.e., putting two ESMs with SPTs of 5 years each in combination does not mean an SPT of 10 years). In reality, the payback times are most likely greater than the values listed in the table, since money in the future is worth less than at present (the discount rate), in the absence of incentives and rebates.

The low percentage of savings for electricity and propane suggest the following: the default values used in the eQUEST model may not be correct or the building is energy-inefficient to the degree that ESMs would not amount to much savings in energy and costs. We believe both are partially valid, since we worked with limited data for modelling--hence, the use of default values--and the dormitory building was originally used for military communications purposes, where energy efficiency was not considered.

Also, the high value of total energy consumption with the eQUEST baseline estimate understates the percentage of savings in electricity and propane gas under the various ESM scenarios. For the combination of five ESMs, the electricity and propane percent savings are approximately 20% and 30%, respectively, with the CEUS Best Estimate as the baseline. The next section further discusses the disparity between the CEUS and eQUEST estimates of annual energy consumption.

**eQUEST & CEUS Comparison:**

We did not find an electricity or propane gas meter specifically for the large dormitory building, which meant the utility bill data could not be used to determine energy end-uses for this building. Additionally, much of the commercial-sized food service equipment was too large to measure energy consumption using watt-monitoring equipment. Therefore, we used eQUEST and CEUS models to estimate baselines of annual energy consumption.

The results indicate a significant difference between estimates of annual energy consumption, and thus cost, depending on the model used. Annual energy consumption (electricity and propane gas) is significantly lower in all CEUS-based scenarios compared to the baseline estimate generated by eQUEST: electricity consumption is between 19 and 80 percent lower, and propane gas consumption is between 59 and 84 percent lower. A more detailed comparison of results from eQUEST and CEUS is presented in Table 5.

**Table 5: CEUS & eQUEST Estimates Comparison**

| Scenario | Electricity (kW-hr/yr) | Difference in Electricity from eQUEST Baseline (%) | Propane Gas (kBTU/yr) | Difference in Propane Gas from eQUEST Baseline (%) | Total Energy Cost ($/yr) | Difference in Total Energy Cost from eQUEST Baseline (%) |
|---|---|---|---|---|---|---|
| Baseline Estimate (eQUEST) | 373,500 | n/a | 2,174,700 | n/a | $112,400 | n/a |
| High Estimate (CEUS) | 303,200 | 19 | 895,500 | 59 | $74,700 | 34 |
| Best Estimate (CEUS) | 84,300 | 77 | 388,900 | 82 | $23,400 | 79 |
| Low Estimate (CEUS) | 76,300 | 80 | 353,300 | 84 | $21,200 | 81 |

It is expected that, results from a model will differ from measurements of actual energy consumption at a single, specific facility. Therefore, we present the large dormitory building's annual energy cost baseline as a range from approximately $75,000 to over $110,000 per year rather than as a single value. One possible explanation for this disparity is that the CEUS includes more energy efficient buildings compared to the large dormitory, which was not constructed with energy efficiency considerations.

**PV Watts Calculator Findings:**

The estimated requisite size, in terms of power output and physical area, of the solar PV systems to meet ZNE cost on the large dormitory building varied based on the different scenarios modeled (CEUS: High, Best, and Low Estimates). To meet the Best Estimate case, DQU would need a 90 kW solar PV array with an installation cost of approximately $234,000 and occupying about 4,250 square feet. This installation cost, including equipment and labor, can be reduced by securing grants, which are discussed in the next section on funding. The table below shows the difference in solar PV system size and cost for the three scenarios modeled, as well as the uniformity in the payback period of about ten years.

**Table 6: Summary Table for Solar PV Generation**

| CEUS Scenario | Energy Cost w/o Solar PV ($/yr) | Roof-Mounted Solar PV Array (kW) | Space Requirement (square feet) | Energy Value of Solar PV Array ($/yr) | Initial Cost (Equipment & Labor) | Simple Payback Time (yr) |
|---|---|---|---|---|---|---|
| **Best Estimate** | $23,400 | 90 | 4,228 | $23,500 | $234,000 | 10 |
| **High Estimate** | $74,700 | 287 | 13,482 | $75,100 | $746,200 | 10 |
| **Low Estimate** | $21,200 | 83 | 3,899 | $21,700 | $215,800 | 10 |

Note: All figures rounded up.

The results indicate that the more energy efficient DQU's dormitory building is, the smaller the solar PV array needed to meet total annual energy cost. Therefore, DQU should reduce its energy load via ESMs before planning for a solar PV system. Such a strategy will minimize the area required and the initial cost of a solar PV system. At the same time, we found sufficient space available on the roofs of DQU buildings for roof-mounted systems and sufficient surface (ground) area for ground-mounted systems. The figures presented above are for roof-mounted PV systems only; figures for ground-mounted PV systems are presented in Appendix D. We chose to present estimates of roof-mounted systems only, because they tend to be cheaper than ground-mounted PV systems. Further analysis would compare the feasibility of roof and ground-mounted solar PV systems at DQU. This analysis would also include site-specific considerations, such as shading, and determine if the building roofs have the requisite strength for solar PV panels.

**ZNE Funding and Financing Sources:**

We found three resources helpful to DQU's efforts towards ZNE cost. The resources include public and private sources of funding - e.g., rebates, financial incentives, grants, and no-interest loans - as well as professional and technical assistance. To start, DQU should contact their account representative at Pacific Gas & Electric (PG&E) to explore retro-commissioning, which is a comprehensive audit of electricity consumption, electrical end-uses, and potential ESMs. Propane gas consumption and end-uses would not be covered under retro-commissioning, because DQU purchases propane independently and is not a gas customer with PG&E. Consequently, Second Nature may be the most helpful resource for addressing propane gas consumption and end-uses at DQU. Once DQU further analyzes its energy use and develops an energy-saving plan, then DQU should apply for grant funding through the CA Clean Energy Jobs Act. Each of the resources are explained in detail below, and please note that website addresses are provided in the references section at the end of the report.

<u>PG&E</u>:

DQU is a PG&E customer for electricity only and thus is eligible for rebates and incentives for this energy type only. See PG&E (2014B) for an overview of rebates and incentives for business customers.

*Incentives for retro-commissioning existing equipment*

PG&E offers a retro-commissioning (RCx) incentive program, which PG&E defines as a "systematic process for identifying less-than-optimal performance in your facility's equipment, lighting and control systems and making the necessary adjustments. While retrofitting involves replacing outdated equipment, RCx focuses on improving the efficiency of what's already in place." (PG&E 2014C) Therefore, an RCx project would be most fitting when HVAC, lighting, or other major equipment is relatively new. In addition to providing a financial incentive ($0.08/kWh) based on actual energy savings, PG&E will connect DQU with experts to help ensure that RCx projects save energy and extend equipment lifetime.

This financial incentive has detailed eligibility requirements, such as a minimum of 50,000 square feet of conditioned space. (PG&E 2014C) Given that the large dormitory is only about 15,000 square feet, DQU should pursue retro-commissioning for all campus buildings in unison. See PG&E (2014C) for detailed information on eligibility, program guidelines, and contact information for a PG&E Account Representative.

*Rebates for retrofitting equipment*

Rebates are available for replacing existing equipment with ones that use less electricity. (PG&E 2014D) In the large dormitory building, examples include: food service equipment, refrigeration, lighting, as well as cooling and ventilation. Further research is required to determine the best time to replace existing equipment with more energy-efficient models that qualifies for PG&E rebates. See PG&E (2014D) for more detailed information on eligibility, program guidelines, and equipment catalogs. Appendix E includes a sample inventory for tracking major appliances and equipment at DQU that could qualify for rebates when replaced.

*On-bill Financing for Energy Efficiency*

PG&E (2014E) offers customers no-interest loans between $5,000 and $100,000 to eliminate the upfront or initial costs of energy efficiency investments or improvements. Investments are structured so that they can be repaid within 5 years, and may include PG&E rebates to reduce initial costs and the size of the loan. Financing may cover a wide array of energy efficiency improvements, such as lighting, food service equipment, water pumps, electric motors, and HVAC equipment. See PG&E (2014E) to see a short introductory video and for more information about on-bill financing for energy efficiency.

<u>The California Clean Energy Jobs Act (Proposition 39)</u>:

The CA Clean Energy Jobs Act established a dedicated, annual grant fund with about $550 million available to schools throughout the state for eligible energy efficiency and clean energy generation projects on school buildings. (CA Energy Commission 2014B) The grant program will last for five years, beginning with the current 2013-2014 fiscal year. Grant requests during the first year can include funds for planning purposes, which may be helpful for DQU given the wide scope for energy-saving measures and solar PV generation throughout the campus.

The California Energy Commission (CEC) manages this program and offers assistance to "Eligible local education agencies (LEAs)" (CA Energy Commission 2014B) through the application process. See CA Energy Commission (2014B) for detailed information, including program guidelines, application materials, as well as links to webinars and contact information.

<u>Second Nature</u>:

Second Nature (2013), a nonprofit organization advancing sustainability in the higher education sector, launched the Advancing Green Building in Higher Education Initiative, a strategic outreach and education program. This program assists under-resourced higher education institutions, such as many Minority-Serving Institutions, community and technical colleges, and small inner-city, rural, or religiously affiliated institutions to “build green” on their campuses. The Campus Green Builder web portal is one of the principal activities offered through this initiative, and can be explored at: http://www.campusgreenbuilder.org/node/8/.

**Sources of Uncertainty & Additional Studies:**

This section outlines the uncertainties with our results for the annual energy consumption baseline, the ESMs' energy and cost savings and the requisite sizes of solar PV systems to help achieve ZNE cost.

Comparing the baseline estimates to bill data from a fully functional DQU campus may show if the eQUEST and CEUS estimates are representative of actual energy consumption and costs for this dormitory building; however, only roughly because the bill data available is not specific to the large dormitory building. Additionally, the comparison might help clarify the disparity in eQUEST and CEUS results. Attaining this bill data will entail two processes of accessing electrical bill data from PG&E who has maintained these records, and the more challenging process of obtaining the propane data which is not connected to PG&E. Furthermore, propane gas bills will contain fuel purchase and quantity data, but may not reflect the usage patterns of propane consumption, especially if the fuel goes to storage.

We are uncertain about eQUEST's estimated savings from implementing the ESMs since these measures were evaluated against a high baseline of annual energy consumption and cost. In terms of percentages, the ESMs would have greater savings in annual energy consumption and cost if the baseline values were lower, like if the CEUS Low Estimate were used. In addition, an error may be present in eQUEST since the model did not show any propane gas savings from lowering the water heater set point by 5 to 20 degrees $^{o}$F. Nonetheless, given the variety of ESMs available to model in eQUEST, the tool is still useful for examining potential ESMs for reduced consumption and costs.

Reductions in energy consumption do not necessarily translate 1-for-1 into energy cost savings, because a change in fuel price can offset or mask the reduced energy use. The assumption of fixed prices for electricity and propane gas ($0.19 per kW-hr and $1.82 per gallon propane) may not hold in the long term. While the energy cost savings from ESMs rise as fuel prices increase, these “savings” are hidden since the increase in cost is multiplied through the remaining energy use, while the savings are multiplied by the energy not used. Typically, the savings in energy use are a fraction of the remaining energy usage, so the increase in energy price offsets the additional cost savings from ESMs. This shows the importance of disaggregating the energy use and cost data when measuring energy savings. It also shows why using utility bills to indirectly “measure” energy savings (“Folk Quantification of Energy”) should be avoided. (Kempton & Montgomery, 1982)

Electricity production from solar PV systems varies with weather conditions. For example, cloudy skies and very high temperatures reduce the quantity of electricity generated. Also, a solar PV system may not meet all of electricity load if there is a spike in consumption, such as the cooling load on extremely hot summer days. Together, these weather and electricity variables contribute to time-dependent valuation (TDV), which means that solar PV systems are not ZNE under certain conditions.

## (5) Conclusions & Recommendations

**Conclusions:**

1. Modeling results from CEUS data and eQUEST show a wide range of estimates for annual energy consumption and cost for the large dormitory building. Comparing the CEUS Low Estimate with the eQUEST estimate, the electricity usage ranges from 76,300 to 373,500 kW-hr/yr, while propane consumption ranges from 353.3 to 2,174.7 million BTU/yr and the total energy cost varies from $21,200 to $112,400 annually. This five-fold difference may be explained by CEUS's inclusion of more modern buildings in its database compared to DQU's large dormitory building.
2. The five ESMs, individually, saved anywhere from about 0% to 3% in electricity, in propane gas and in energy cost, compared to the eQUEST baseline, with a SPT ranging from 0 (now) to 200+ years. Similarly, the combination of five ESMs saved about 4% in electricity, 5% in propane, 3% in energy cost, and had a SPT of 15 years. These low percentages suggest that eQUEST may need more detailed building materials and equipment inputs to better model the energy and cost savings. This also suggests that the building may be energy-inefficient to the degree that ESMs may not save much energy and costs, since its original construction did not consider energy efficiency.
3. Using the CEUS Low and High Estimates, meeting ZNE cost would require a PV system between 83 and 287 kW, occupy an area of approximately 3,900 to 13,500 square feet, cost approximately $215,800 to $746,200 and have a 10-year payback. While the campus contains plenty of roof and ground area for solar arrays, the results suggest the PV systems' power output, physical size and installation cost are lower with a more energy efficient dormitory building.
4. PG&E, CA Energy Jobs Act (Proposition 39) and Second Nature offer incentives, rebates, professional and technical expertise to assist DQUs' efforts for ZNE cost. PG&E offers a retro-commissioning incentive program and 0% interest loans for energy efficiency improvements, while the CA Energy Jobs Act provides grant funding for planning energy efficiency and clean energy generation projects. Also, Second Nature provides outreach and education for building energy retrofits at under-resourced higher education institutions.
5. There are four main areas of uncertainty in this study. The first is the use of hypothetical energy usage and cost baselines since the large dormitory is not fully occupied. The second pertains to the possibility of eQUEST underestimating the energy usage and cost savings. Third, energy savings may not translate 1-for-1 into energy cost savings because the prices of electricity and propane gas may not be fixed in the long term. Fourth, weather and power output variables mean that a solar PV system is not ZNE cost under certain conditions.

**Recommendations:**

1. *Address electrical transmission pole.* One of the electrical transmission poles northeast of the main water pumphouse is leaning at a 30 degree angle from vertical. Electricity service for the DQU campus may be cut off completely if the pole falls over and could pose a fire hazard. Therefore, addressing the leaning transmission pole is imperative. An immediate remedy would be to brace the pole so that it does not fall over completely and consult experts for a more permanent solution. PG&E may not repair the leaning transmission pole, because of jurisdictional issues stemming from DQU's status as a commercial customer and/or the pole's location on DQU's property (i.e., tribal land). It may be helpful to have access to pertinent laws and regulations covering electrical transmission systems. http://www.pge.com/myhome/customerservice/other/treetrimming/lawsregulations/, http://www.pge.com/safety/gaselectricsafety/powerlines/
2. *Borrow metering equipment for main water pump.* We discovered a major water leak inside and just north of the main water pumphouse during the field assessment. The leak may cause the water pump to turn on and run more frequently than necessary. Accordingly, the water pump could be a significant contributor to the high energy costs at DQU, despite low occupancy and water use levels. Metering the water pump for electricity usage should help clarify the water pumps' impacts on energy consumption and cost, and metering equipment can be borrowed from the Tool Lending Library maintained by the Pacific Energy Center. To access the lending library online: http://www.pge.com/pec/tll/.
3. *Reconsider replacing the electrical transformer system.* DQU has three electrical transformers throughout its campus, which reduce the power transmission voltage from 12 kV to 480, 220 or 120 V to safely power campus buildings and equipment. The transformer system was designed originally to meet the large power needs of the U.S. Army communications facility and was never retrofitted when the site was converted to a tribal college campus. We learned from the interview that a contractor had proposed replacing the transformer system when they were asked to replace a blown-out transformer, but the proposal was deemed cost-prohibitive at that time. It may be appropriate to reconsider replacing and downsizing the existing transformer system if there is the potential for significant energy savings. Also, the cost of replacing the transformer system may be easier to cover as part of a broader energy-saving plan for the campus. DQU should contact Harreld's Hi-Voltage, Inc. to discuss the benefits and costs of replacing the transformer system. (http://harreldshivoltage.com/)
4. *Create an inventory of major energy-consuming equipment.* DQU contains commercial-sized equipment, including: the air conditioning unit and furnace, water heaters, lighting, and food service equipment (refrigerators, coolers, dishwasher, and ventilation). An inventory will be very useful for evaluating the benefits and costs of replacing the equipment and for determining eligibility for PG&E rebates for energy efficiency improvements. A sample of an equipment inventory is provided in Appendix E.
5. *Explore Retro-commissioning services with PG&E.* Pursuing Zero Net Energy campus-wide may be more cost-effective than addressing one building at a time. Therefore, DQU should contact its PG&E Account Representative and explore retro-commissioning to begin developing a comprehensive energy-saving plan for the

entire campus. Note that PG&E's retro-commissioning will cover electricity consumption and end-uses only, because DQU is a PG&E customer for electricity only.

6. *Focus on ESMs first and then explore a solar PV system.* It is best practice to pursue all cost-effective ESMs before exploring solar PV generation. That is because ESMs will reduce the energy load thereby minimizing the size and cost of a solar PV system needed for ZNE cost at DQU. The energy cost savings from ESMs could be used to fund the solar PV system.

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## (7) Appendices

**Appendix A: CEUS & Google Earth Data and Computation Sheets**

**Appendix B: CEUS Results for Best, High and Low Estimates**

**Appendix C: Summary Table of ESMs**

**Appendix D: Solar PV Summary Table and Potential Locations at DQU**

**Appendix E: Sample Inventory of Major Energy-consuming Equipment**

## Appendix A: CEUS & Google Earth Data and Computation Sheets

CEUS End Use EUI & EIs for Electricity & Gas for Health, Lodging and Restaurant Buildings:

| Category | Health (electric) | | Health (gas) | | Lodging (electric) | | Lodging (gas) | | Restaurant (electric) | | Restaurant (gas) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | EUI | EI | EUI | EI | EUI | EI | EUI | EI | EUI | EI | EUI | EI |
| **Heating** | 0.89 | 0.29 | 22.56 | 22.22 | 0.79 | 0.79 | 5.29 | 2.64 | - | - | 19.62 | 15.65 |
| **Cooling** | 3.7 | 3.64 | 0 | 0 | 1.24 | 1.24 | 0 | 0 | 5.59 | 4.54 | - | - |
| **Ventilation** | 2.61 | 2.57 | 0 | 0 | 0.81 | 0.81 | 0 | 0 | 4.63 | 3.76 | - | - |
| **Water Heating** | - | - | 42.76 | 42.76 | - | - | 25.71 | 25.71 | - | - | 29.96 | 29.96 |
| **Cooking** | - | - | 16.27 | 12.92 | - | - | 0 | 0 | - | - | 124.15 | 68.84 |
| **Refrigeration** | 0.4 | 0.4 | - | - | 0.44 | 0.44 | - | - | 7.83 | 15.66 | - | - |
| **Ext. lighting** | 0.52 | 0.52 | - | - | 2.18 | 2.18 | - | - | 2.81 | 2.81 | - | - |
| **Int. lighting** | 4.89 | 4.89 | - | - | 2.38 | 2.38 | - | - | 6.99 | 6.99 | - | - |
| **Office Equipment** | 0.29 | 0.29 | - | - | 0.22 | 0.22 | - | - | 0.81 | 0.74 | - | - |
| **Misc.** | 2.5 | 2.57 | 3.13 | 1.15 | 0.35 | 0.35 | 0.53 | 0.26 | 2.08 | 0.33 | - | - |
| **Process** | 0 | 0 | 33.17 | 9.81 | - | - | - | - | - | - | - | - |
| **Motors** | 5.15 | 1.74 | - | - | 0.2 | 0.2 | - | - | - | - | - | - |
| **Air compressor** | 0.48 | 0.16 | - | - | - | - | - | - | - | - | - | - |
| **Segment TOTAL** | - | 17.55 | - | 88.86 | - | 8.78 | - | 28.61 | - | 35.83 | - | 114.44 |

| Legend | Electric | Gas |
|---|---|---|
| **EUI = Energy Use Index** | Low | Low |
| **EI= Energy Intensity** | Medium | Medium |
| | High | High |
| **Units** | kWh/ft$^2$-yr | kBTU/ft$^2$-yr |

Floor Areas of Large Dormitory Building in Google Earth:

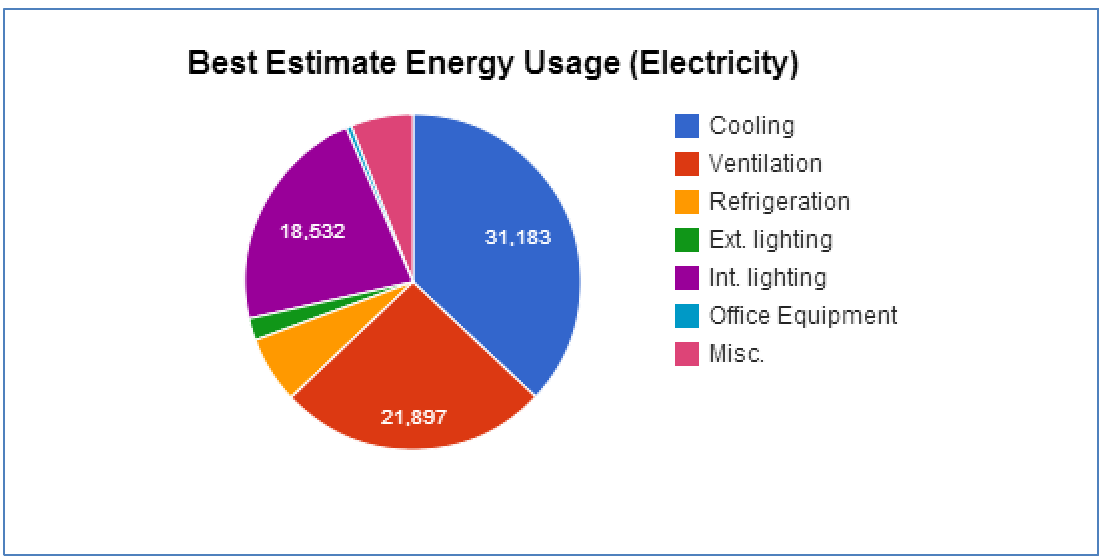
| Area | Length (ft) | Width (ft) | Floor Area (ft$^2$) | % Total Area |
|---|---|---|---|---|
| South Hall | 62.67 | 31.44 | 1,970.34 | 12.65% |
| Kitchen | 24.20 | 31.44 | 760.85 | 4.89% |
| Walk-in Fridge | 30.37 | 10.72 | 325.57 | 2.09% |
| Residence L1 | 44.80 | 123.14 | 5,516.67 | 70.85% |
| Residence L2 | 44.80 | 123.14 | 5,516.67 | |
| North Hall | 54.14 | 27.39 | 1,482.89 | 9.52% |
| TOTAL | n/a | n/a | 15,573.00 | ft$^2$ |

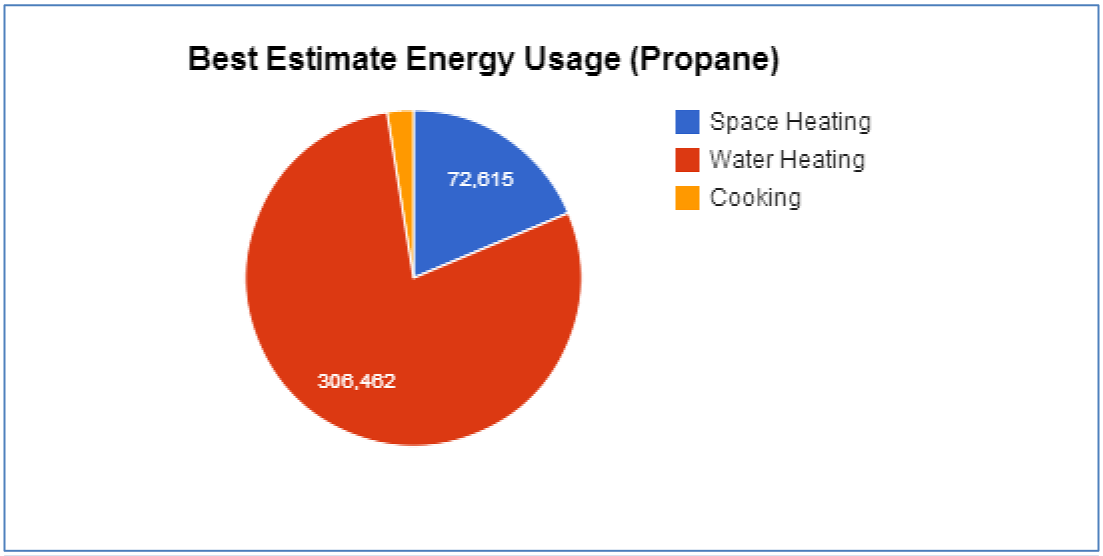
**Appendix B: CEUS Results for Best, High and Low Estimates**

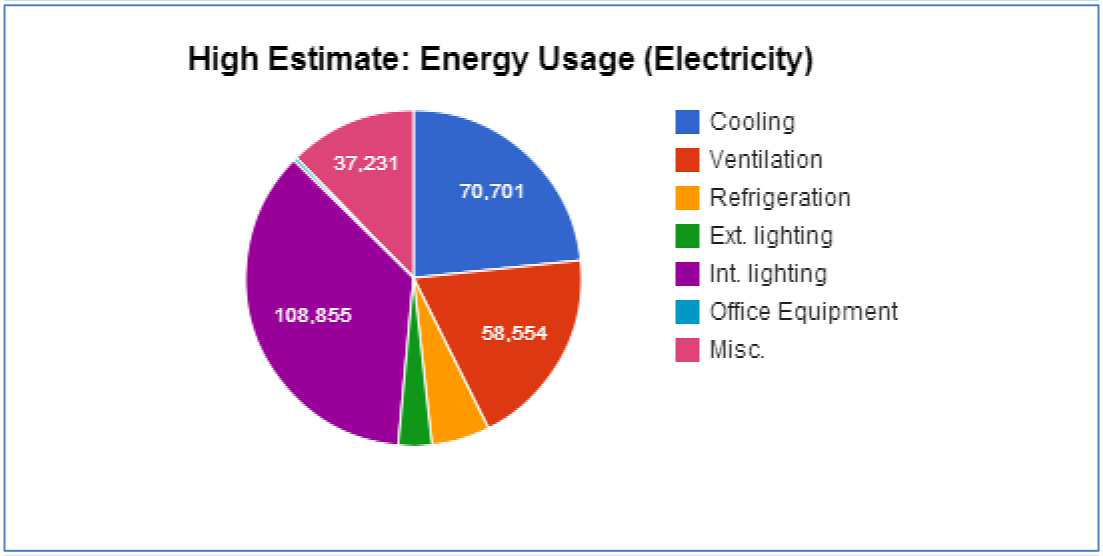
Load Profile Table for the Best, High and Low Estimates:

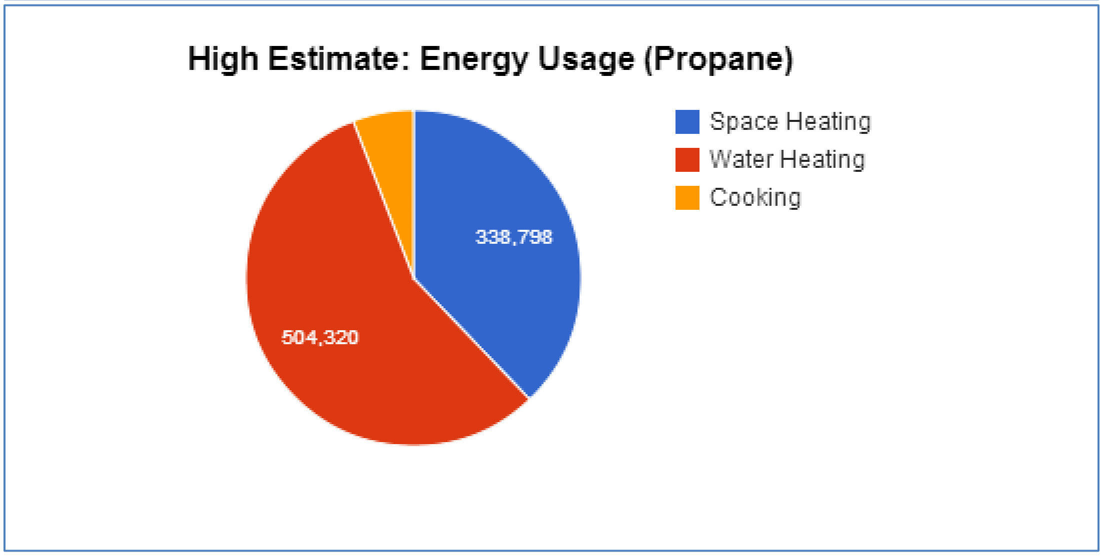
| CEUS Best Estimate | | | CEUS High Estimate | | | CEUS Low Estimate | | |
|---|---|---|---|---|---|---|---|---|
| **Electrical End Use** | **kW-hr/yr** | **%** | **Electrical End Use** | **kW-hr/yr** | **%** | **Electrical End Use** | **kW-hr/yr** | **%** |
| *Cooling* | *31,183* | *36.97%* | *Cooling* | *70,701* | *23.32%* | *Cooling* | *19,311* | *25.30%* |
| *Ventilation* | *21,897* | *25.96%* | *Ventilation* | *58,554* | *19.31%* | *Ventilation* | *12,614* | *16.53%* |
| *Refrigeration* | *5,433* | *6.44%* | *Refrigeration* | *17,013* | *5.61%* | *Refrigeration* | *435* | *0.57%* |
| *Ext. lighting* | *1,796* | *2.13%* | *Ext. lighting* | *9,704* | *3.20%* | *Ext. Lighting* | *1,796* | *2.35%* |
| *Int. lighting* | *18,532* | *21.97%* | *Int. lighting* | *108,855* | *35.91%* | *Int. Lighting* | *37,064* | *48.56%* |
| *Office Equipment* | *430* | *0.51%* | *Office Equipment* | *1,097* | *0.36%* | *Office Equipment* | *326* | *0.43%* |
| *Misc.* | *5,070* | *6.01%* | *Misc.* | *37,231* | *12.28%* | *Misc.* | *4,781* | *6.26%* |
| **Total** | **84,341** | ***kW-hr/year*** | **Total** | **303,156** | ***kW-hr/year*** | **Total** | **76,325** | ***kW-hr/year*** |
| **Propane End Use** | **kBTU/yr** | **%** | **Propane End Use** | **kBTU/yr** | **%** | **Propane End Use** | **kBTU/yr** | **%** |
| *Space Heating* | *72,615* | *18.67%* | *Space Heating* | *338,798* | *37.83%* | *Space Heating* | *40,253* | *11.39%* |
| *Water Heating* | *306,462* | *78.80%* | *Water Heating* | *504,320* | *56.32%* | *Water Heating* | *303,229* | *85.82%* |
| *Cooking* | *9,830* | *2.53%* | *Cooking* | *52,377* | *5.85%* | *Cooking* | *9,830* | *2.78%* |
| **Total** | **388,908** | ***kBTU/year*** | **Total** | **895,494** | ***kBTU/year*** | **Total** | **353,312** | ***kBTU/year*** |

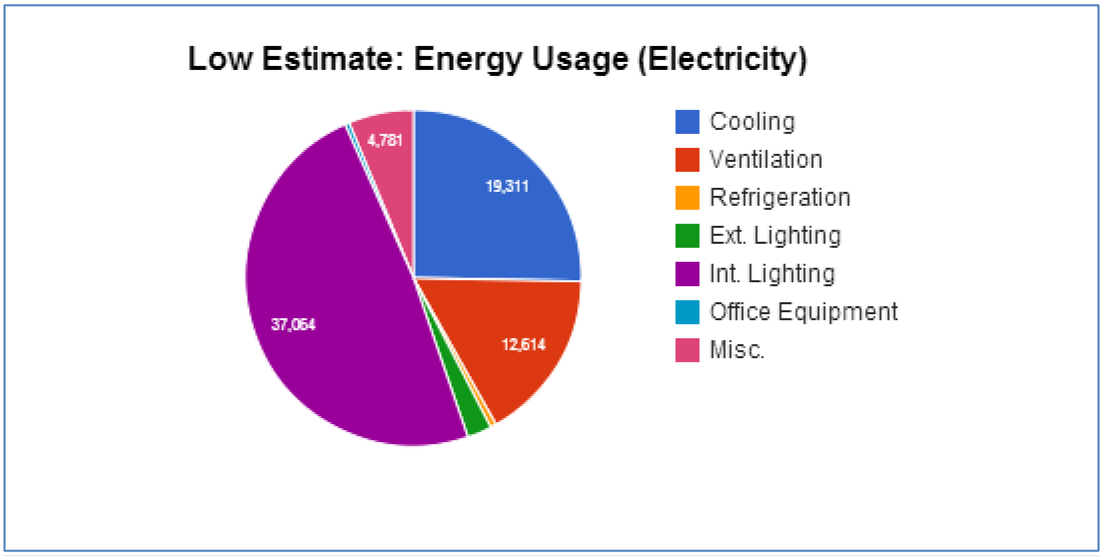
Pie Charts for the Load Profile of the Best, High and Low Estimates:

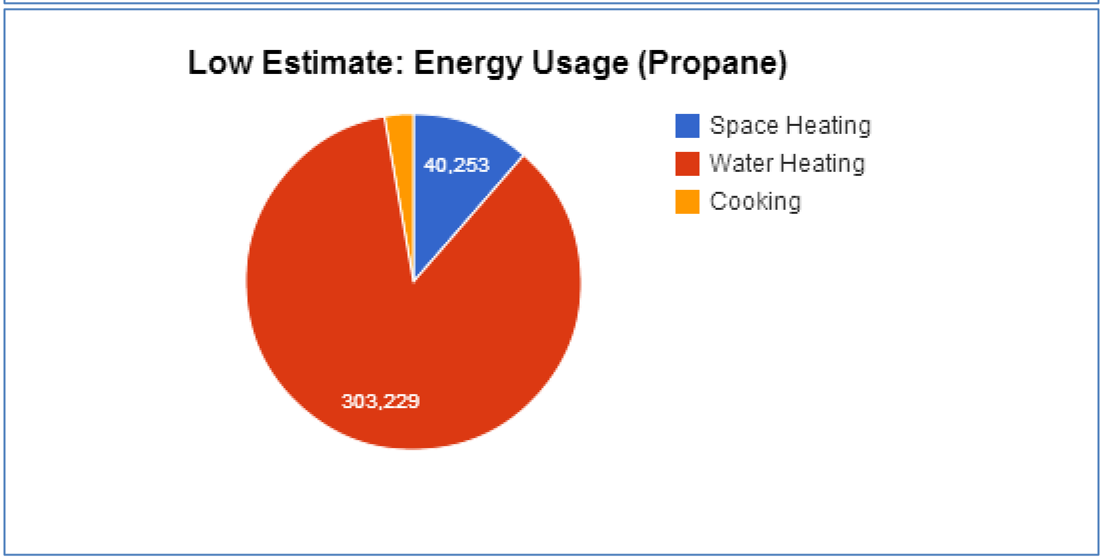



Best Estimate Energy Usage (Propane)
Space Heating
Water Heating
Cooking
72,615
306,462


High Estimate: Energy Usage (Electricity)
Cooling
Ventilation
Refrigeration
Ext. lighting
Int. lighting
Office Equipment
Misc.
37,231
70,701
108,855
58,554


High Estimate: Energy Usage (Propane)
Space Heating
Water Heating
Cooking
338,798
504,320


Low Estimate: Energy Usage (Electricity)
Cooling
Ventilation
Refrigeration
Ext. Lighting
Int. Lighting
Office Equipment
Misc.
4,781
19,311
37,054
12,614


Low Estimate: Energy Usage (Propane)
Space Heating
Water Heating
Cooking
40,253
303,229

## Appendix C: Summary Table of ESMs

| Scenarios | Energy Efficiency Measure (EEM) | Electricity Consumption (kW-hr/yr) | Gas (propane) Consumption (kBTU/yr) | Electricity Cost ($/yr) | Propane Gas Cost ($/yr) | Electricity Cost Savings ($/yr) | Gas (propane) Cost Savings ($/yr) | Total Annual Energy Costs | Total Annual Energy Cost Savings | Cost Estimate of ESM | Simple Payback Time (yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Baseline (eQuest)* | *n/a* | *373,500* | *2,174,700* | *$71,000* | *$41,400* | *n/a* | *n/a* | *$112,400* | *$0* | *n/a* | *n/a* |
| Scenario 1 | Lowered setpoint of water heater by 10 °F (135 to 125) | 373,500 | 2,174,500 | $71,000 | $41,400 | n/a | ~$0 | $112,400 | ~$0 | No cost to implement | Now |
| Scenario 2 | Lowered setpoint of water heater by 20 °F (135 to 115) | 373,500 | 2,174, 500 | $71,000 | $41,400 | n/a | ~$0 | $112,400 | ~$0 | | |
| Scenario 3 | Lowered setpoint of water heater by 30 °F (135 to 105) | 373,500 | 2,124,200 | $71,000 | $40,500 | n/a | $1,000 | $111,400 | $1,000 | | |
| Scenario 4 | Lowered setpoint of water heater by 40 °F (135 to 95) | 373,500 | 2,043,100 | $71,000 | $38,900 | n/a | $2,500 | $109,900 | $2,500 | | |
| Scenario 5 | Add 2" polystyrene R-8 exterior insulation (none in baseline) | 373,400 | 2,169,600 | $71,000 | $41,300 | ~$0 | $100 | $112,300 | $100 | $25,100 | 236 |
| Scenario 6 | Increased lighting efficiency by 10% via occupancy sensor | 363,000 | 2,182,000 | $70,600 | $41,500 | $400 | -$100 | $112,100 | $300 | $1,500 | 6 |
| Scenario 7 | Lowered setpoint of space heating by 8 °F (68 to 60) | 370,400 | 2,070,600 | $70,400 | $39,500 | $600 | $2,000 | $109,800 | $2,600 | No cost to implement | Now |
| Scenario 8 | Lowered setpoint of space heating by 5 °F (68 to 63) | 371,500 | 2,108,000 | $70,600 | $40,200 | $400 | $1,300 | $110,700 | $1,700 | | |
| Scenario 9 | Replace remaining single-pane with double-pane, low-E windows | 369,900 | 2,128,700 | $70,300 | $40,500 | $700 | $900 | $110,800 | $1,600 | $25,000 | 16 |
| Scenario 10 | Combine Scenarios 5, 6, 8, 9 | 358,300 | 2,075,200 | $69,700 | $39,500 | $1,300 | $1,900 | $109,200 | $3,200 | $51,600 | 15 |
| Scenario 11 | Set water heater to 110 °F and Scenario 10 combo | 358,300 | 2,065,200 | $69,700 | $39,400 | $1,300 | $2,100 | $109,000 | $3,400 | $51,600 | 15 |

## Appendix D: Solar PV Summary Table and Potential Locations at DQU

Solar PV Summary Table:

| Solar PV System Characteristics | Best Estimate | High Estimate | Low Estimate |
|---|---|---|---|
| ***Open Rack or Ground-mount system*** | | | |
| Annual Total Energy Costs, without solar PV system | $23,400 | $74,700 | $21,200 |
| Annual Energy Value, with solar PV system (i.e., cash flow in terms of energy costs) | $23,700 | $75,200 | $21,600 |
| Solar Requirement-fixed, open rack (kW) | 89 | 282 | 81 |
| Array Area (sq. ft.) | 4,181 | 13,247 | 3,805 |
| Initial Cost of Solar PV System (materials & labor)* | $254,500 | $806,500 | $231,700 |
| Initial Economic Comparison (without incentives)* | $0.12 per kW-hr | | |
| Initial Economic Comparison (with incentives) | $0.03 per kW-hr | | |
| Simple Payback Time (no discount rate) | 11 years | | |
| ***Roof-mount system*** | | | |
| Annual Total Energy Costs, without solar PV system | $23,400 | $74,700 | $21,200 |
| Annual Energy Value, with solar PV system (i.e., cash flow in terms of energy costs) | $23,500 | $75,100 | $21,700 |
| Solar Requirement-fixed, roof mount (kW) | 90 | 287 | 83 |
| Array Area (sq. ft.) | 4,228 | 13,482 | 3,890 |
| Initial Cost of Solar PV System (materials & labor) | $234,000 | $746,200 | $215,800 |
| Initial Economic Comparison (without incentives)* | $0.12 per kW-hr | | |
| Initial Economic Comparison (with incentives)* | $0.04 per kW-hr | | |
| Simple Payback Time (no discount rate) | 10 years | | |

* Note: The comparison is with $0.19 per kilowatt-hour (kW-hr), which is DQU's electricity rate as of May 2014.

Potential Locations for Solar Array System at DQU:

| Area Name | Area ($ft^2$) | Dimensions (ft) | Approximate Longitude | Approximate Latitude |
|---|---|---|---|---|
| Potential Rooftop Locations for Solar Arrays @ DQU | | | | |
| Cultural building | 4,30 | 66 X 66 | 38°34'5.75"N | 121°53'11.87"W |
| Administrative building | 20,200 | 82 X 246 | 38°33'59.76"N | 121°53'11.64"W |
| Potential Ground Location for Solar Arrays @ DQU | | | | |
| Grassy areas south of parking lot | 55,700 | 147 X 377 | 38°33'56.31"N | 121°53'16.28"W |
| Total Area | 80,200 | n/a | n/a | n/a |

Note: Dimensions account for non-solar panel uses like inverters.

**Appendix E: Sample Inventory of Major Energy-consuming Equipment**

| **HVAC** | |
|---|---|
| Model # and Unit type | |
| Rated Power (kW) | |
| Location of unit | |
| Rooms served | |
| Annual usage estimation (h/day*days/year) | |

| **WATER HEATER-#1** | |
|---|---|
| Model # and Unit type | |
| Rated Power (kW) | |
| Location of unit | |
| Rooms served | |
| Annual usage estimation (GAL/day*days/year) | |
| Hot water temperature set point | |
| **WATER HEATER-#2** | |
| Model # and Unit type | |
| Rated Power (kW) | |
| Location of unit | |
| Rooms served | |
| Annual usage estimation (GAL/day*days/year) | |
| Hot water temperature set point | |

| **MAJOR APPLIANCES & PLUG LOADS** | | | |
|---|---|---|---|
| **Type** | **Location** | **Model #** | **Rated Power (kW)** |
| *Food Service Equipment* | | | |
| Range | | | |
| Microwave | | | |
| Conventional refrigerator | | | |
| Freezer | | | |
| Beverage cooler | | | |
| Walk-in cooler | | | |
| Milk dispenser | | | |
| Commercial dish washer | | | |
| *Electronics* | | | |
| Computer | | | |
| Printer | | | |
| Laptop | | | |
| Phone | | | |
| Printer | | | |
| Wi-fi Router | | | |
| TV | | | |
| Exhaust fan (kitchen) | | | |
| Other appliances/equipment | | | |