9

ENERGY SYSTEMS

ADAPT WITH TECHNOLOGY AT A DISTRICT SCALE

INTRODUCTION

Energy is needed to support many aspects of a university campus--for example, lighting; heating, cooling, and ventilation; laboratory and classroom equipment; and all forms of technology. Energy can be distributed through the campus in the form of electricity, natural gas, heated hot water, or chilled water, depending on the need and infrastructure in each area of campus. Energy can be produced on site or procured from renewable sources that are by definition carbon neutral (sunlight, wind, and geothermal heat), from non-renewable non-carbon-neutral sources (natural gas, coal, petroleum), or from carbon neutral nuclear sources.

This chapter provides an outline for reducing demand for energy through energy efficient design and efficient technologies, and for developing campus energy supply and distribution systems that enable the campus to meet its carbon neutrality goals as the population and campus building square footage increase (stewardship). Treating the campus as a learning laboratory, CSUMB can provide educational signage about its commitment to renewable energy and carbon neutrality (placemaking). For information on creating potential public-private partnership strategies (partnerships) as a way to build district-scale energy systems, see the public-private partnership report in the appendix.

The campus seeks to meet its carbon neutrality goal by 2030 and strives for 105 percent net positive energy production, in alignment with the Living Community Challenge. Given the significant growth that will be experienced, the precise strategy, phasing, approach, and technology selection will need to be evaluated in greater depth. In order to develop the most cost-effective approach, a strategic energy plan should be developed to align growth, phasing, and infrastructure investment. As there are many options for achieving these overarching goals, this chapter aims to provide strategies, options, and guidelines for consideration toward these goals.

In addition, this master plan chapter focuses on the Main Campus and does not address the residential area in East Campus. Many energy-efficiency strategies for existing buildings have been applied to the East Campus, and additional strategies can be applied. As this area will not have significant growth, this master plan focuses efforts on the Main Campus.

GOALS

Achieve carbon neutrality and strive to achieve net positive energy

Achieve carbon neutrality for all energy used on campus (produced or purchased) by 2030; strive to achieve net positive energy as state regulations permit

Manage energy supply

Meet future demand for energy in a safe, reliable, and cost-effective manner

Design for energy efficiency

Design and retrofit infrastructure and buildings to minimize energy use

Promote resiliency

Design systems with the capacity to provide uninterrupted service, or to recover quickly, during extreme weather or natural disasters; aim to provide on-site energy generation and use the electrical grid as a backup source of energy

Utilize the campus as a living learning laboratory

Engage the campus community, particularly students, in living-learning opportunities regarding energy production and usage

BACKGROUND

Guiding Policies

Executive Order 987 (2006)

This policy statement on energy conservation, sustainable building practices, and physical plant management for CSU established priorities for energy conservation and sustainable buildings in June 2007.

Second Nature Climate Commitment (2007, reaffirmed 2016)

The original commitment asks that the campus develop a comprehensive climate action plan and set a target date for achieving carbon neutrality. In 2016 the campus signed the updated commitment, which incorporated adaptation to climate change.

Climate Action Plan (2013)

The Climate Action Plan was developed in response to the original Climate Commitment. It established a carbon neutrality target year of 2030 for a campus of 8,500 FTE. The 2013 Climate Action Plan includes the following strategies relevant to this energy strategy.

- Energy conservation in buildings and infrastructure
- Build a second 1MW grid-tied photovoltaic (PV) system
- Develop a green information-technology plan to assist with energy use monitoring
- Purchase and install a modular cogeneration plant
- Research thermal energy storage
- Buy green power or local carbon offsets to offset emissions
- Reduce natural gas usage

Green Building Standards

In addition, the CSU requires that new buildings aim for Gold and Platinum level LEED certification, and be designed to a minimum of a LEED Silver standard. CSUMB currently has three LEED Silver and one LEED Platinum certified building. LEED does not prescribe energy use benchmarks or generation targets, but is a strong support for meeting campus energy and carbon neutrality goals.

Existing Conditions

Current Energy Infrastructure

Central Plant and Hot Water

A gas-fired boiler plant supplies heating hot water to the campus core through underground piping. Approximately two-thirds of campus thermal demand is satisfied from this system; the balance is supplied by stand-alone gas-fired boilers and furnaces.

Chiller Plant and Chilled Water

An electric-powered chiller plant supplies chilled water to limited buildings along Divarty Street through underground piping.

Natural Gas

The campus owns a natural gas distribution system that extends to many building on campus. The natural gas is transported to campus via PG&E pipeline, metered to campus at a single location.

Electricity

The campus owns a medium-voltage electricity distribution system that extends to every building on campus. Electricity is procured both from a 1.0 MW solar tracking PV generation facility owned by SunEdison under a twenty-year contract, and from PG&E metered to campus at a single location.

Energy Use

The university has been tracking energy use for several years and thus has comprehensive data on energy use that can form a basis for projecting future demand. Using a benchmarking method, buildings were categorized into two major types: office/classroom and residential housing. Energy use for existing operations was calculated, and low energy use targets were set, informed by engineering and building design best practices. The current and projected energy usage by buildings on the CSUMB campus informs the master plan strategies.

Figure 9.1 *Historic Main Campus Annual Energy Use, Gas and Electricity*

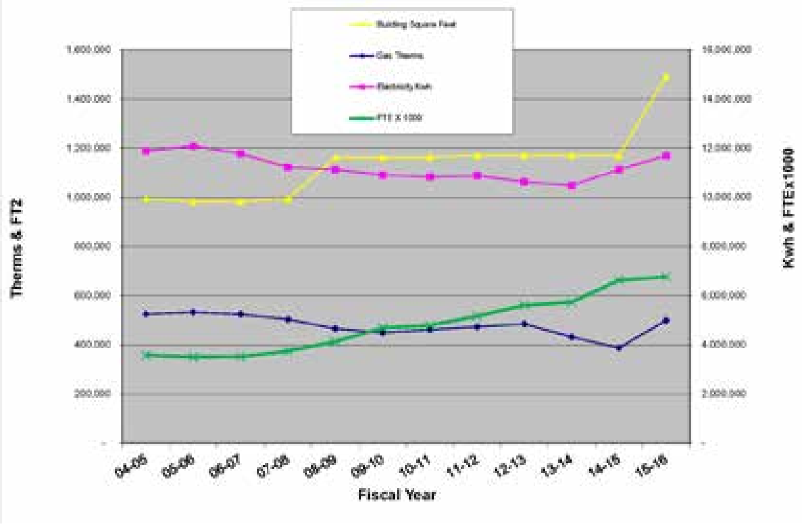


Figure 9.2 *Historic Campus Energy Use Intensity (EUI), Gas and Electricity*

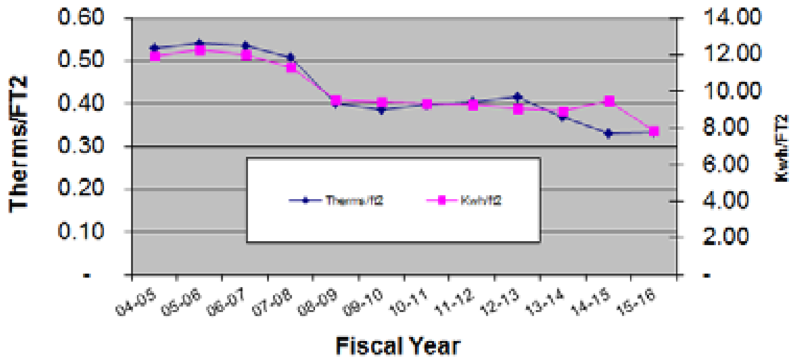


Figure 9.3 *Historic Main Campus GHG Emissions (Gas, Electricity, Total)*

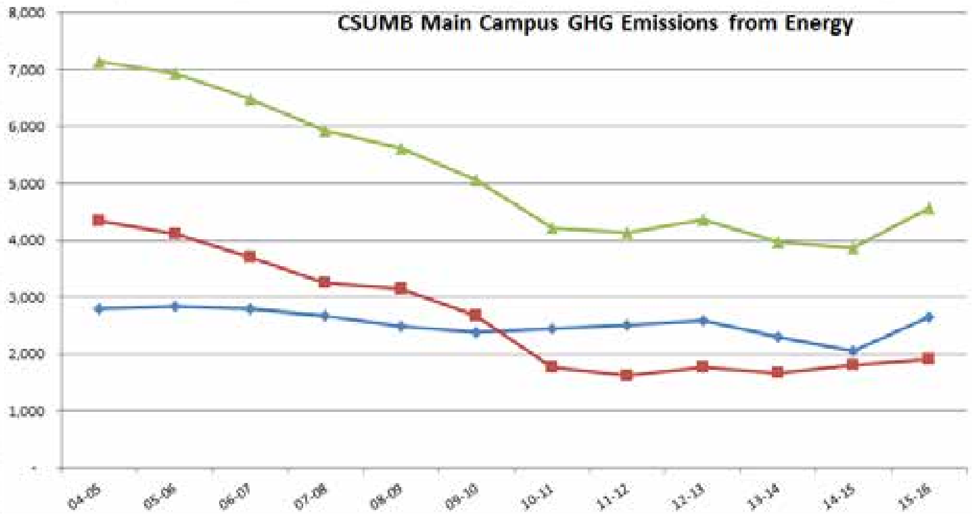


Table 9.1 *Historic and Projected Electricity and Gas Emission Factors*

California PG&E Emissions Factors
(lbs CO2 per kBTU)

Year	Electricity	Natural Gas
2010	0.139	0.117
2011	0.115	0.117
2012	0.130	0.117
2013	0.125	0.117
2014	0.121	0.117
2015	0.115	0.117
2016*	0.108	0.117
2017*	0.102	0.117
2018*	0.096	0.117
2019*	0.090	0.117
2020*	0.085	0.117

*Projected

Current and Historic Energy Use and Emissions

Figure 9.1 shows the current annual energy use by fuel type as well as total building square footage and FTE students. As is evident, efficient building design practices have been utilized as the campus has added buildings (and students), noting particularly that from 2014–2016 building square footage increased by roughly 300,000 square feet but electric and natural gas usage have increased at a lower rate. Also noteworthy is that fiscal years 2013-14 and 2014-15 were atypically warm; 2015-16 reflects a return to a colder winter in addition to new construction.

Energy use intensity (EUI), measured in kBtu/square foot/year, shows that energy use has been stable while adding significant square footage, as shown in Figure 9.2.

There has been an increase in greenhouse gas (GHG) emissions in the 2014-2016 period, as seen in Figure 9.3, due to an increase in natural gas usage from the new construction. Though electricity usage has also increased, the relative increase in emissions is minimized due to two important factors:

- The campus installed the 1.0 MW PV system in 2010
- The emissions factor of the grid-supplied electricity has decreased over time from 0.139 lbs CO2/kBtu in 2010 to 0.115 lbs CO2/kBtu in 2015. In general, emissions from grid-supplied electricity are decreasing due to the steep increase in renewable energy that has occurred on the grid and will continue to occur as the energy utilities meet California State Renewable Portfolio Standard goals.

In comparison, the natural gas emissions factor is 0.117 lbs CO2/kBtu, and this value does not change. Starting in 2015, the electricity supplied by the grid produces less emissions than natural gas and is expected to continue to decline. (See Table 9.1.)

Completed Energy Efficiency Measures

The campus has aggressively pursued energy efficiency in existing buildings by implementing projects that resulted in a 28 percent reduction in electrical consumption and an 18 percent reduction in natural gas consumption between 2006 and 2016 (see Figure 9.4 and Table 9.2). These gains have occurred with a 100 percent increase in the student body, and a 50 percent increase in building square footage over the same time period, such that efficiency gains were partially offset by usage associated with new construction and campus growth.

Figure 9.4: *Completed Campus Energy Efficiency Projects*

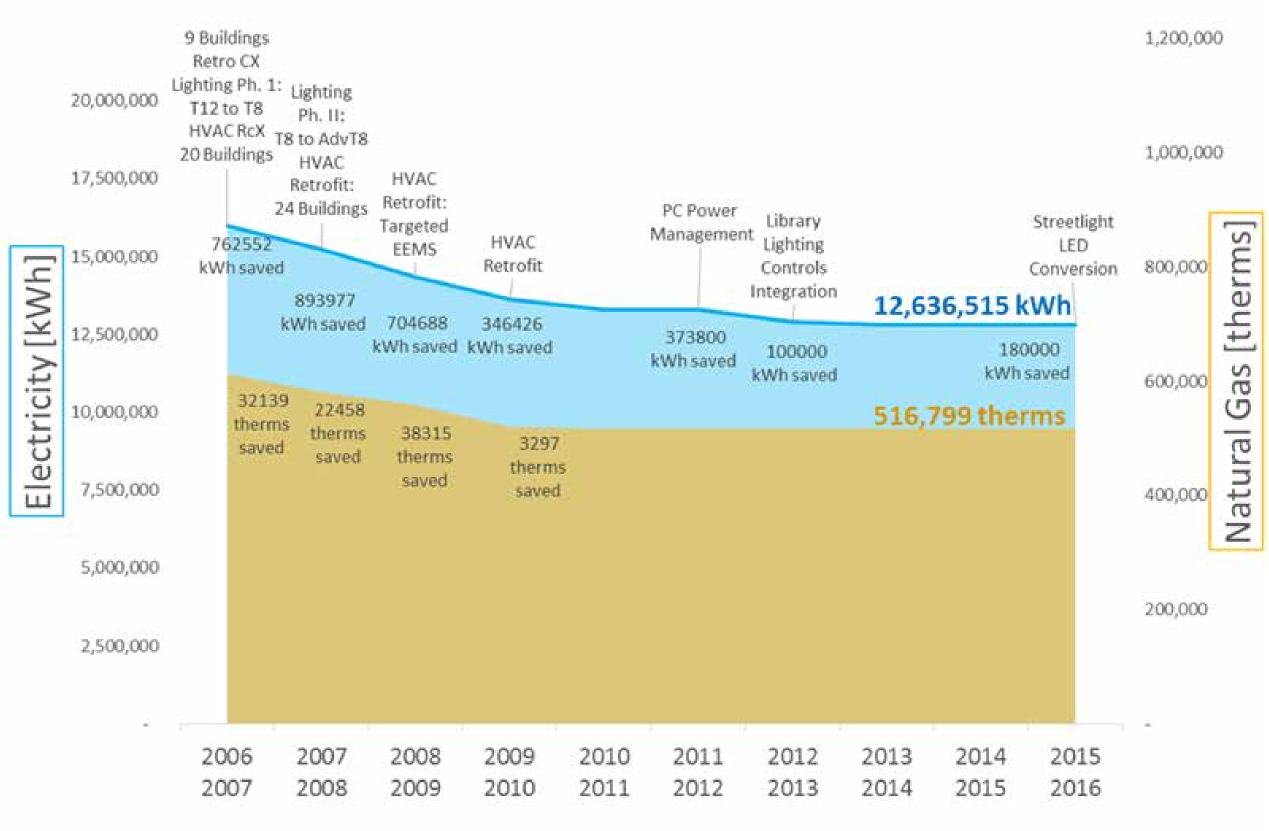


Table 9.2 *Completed Campus Energy Efficiency Projects*

Energy Efficiency Project Savings	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Building Recommissioning, 9 Buildings										
kWh saved	250,000									
Therms saved	6,000									
Lighting Retrofit Ph. 1: T12 to T8										
kWh saved	173,272									
HVAC Retrofit, 20 Buildings										
kWh saved	339,280									
Therms saved	26,139									
Lighting Retrofit Ph. II: T8 to Advanced T8										
kWh saved		360,772								
HVAC Retrofit, 24 Buildings										
kWh saved		533,205								
Therms saved		22,458								
HVAC Retrofit, Targeted Measures										
kWh saved			704,688							
Therms saved			38,315							
HVAC Retrofit, 2009										
kWh saved				346,426						
Therms saved				3,297						
PC Power Management										
kWh saved						373,800				
Library Lighting Controls Integration										
kWh saved							100,000			
Streetlight LED Conversion										
kWh saved										180,000
Total										
kWh saved	762,552	893,977	704,688	346,426	0	373,800	100,000	0	0	180,000
Therms saved	32,139	22,458	38,315	3,297	0	0	0	0	0	0
Cumulative Savings										
kWh	0	1,656,529	2,361,217	2,707,643	2,707,643	3,081,443	3,181,443	3,181,443	3,181,443	3,361,443
Therms	0	54,597	92,912	96,209	96,209	96,209	96,209	96,209	96,209	96,209

Building Energy Use, Energy Efficiency Targets, and Energy Demand Forecast

This analysis utilized the amount of energy used by current campus buildings and the projected energy needs of future campus buildings at full build-out to generate an energy needs forecast and the resulting carbon emissions levels produced throughout the planning horizon. The planning horizon is assumed to be 2030, consistent with carbon neutrality planning goals. This forecast incorporated updated energy use targets for:

- Existing buildings: create energy efficiency measures to reduce energy usage by at least 5 percent
- Continuously increasing efficiency standard: assume that every future building will be designed to reflect a 2.5 – 3 percent improvement over each previous year
- Decreasing carbon content of grid-sourced electricity: recognize that PG&E-sourced electricity will be increasingly renewable due to state-mandated renewable portfolio standards.

The recommended EUI targets by building type and key design strategies was used to develop an EUI model that will enable the campus to achieve its reduced energy use between now and 2030. Table 9.3 shows the EUI target numbers that are recommended by building type. The resulting energy forecast was predicated on a "Business As Usual" (BAU) modelling approach (i.e., natural gas for heat, electricity for other needs), alternative energy supply sources, and the potential to switch between energy fuel sources. These were then modeled to identify approaches to improve emissions outcomes. Information on key technologies and strategies to achieve these targets is detailed below.

Table 9.3: *Recommended Energy Use Intensity (EUI) Targets*

Building Type	US Average	Current CSUMB	EUI Target Existing Buildings	EUI Target, New Buildings 2020	EUI Target, New Buildings 2030
Offices/ Classrooms	100 kBTU/sf	64 kBTU/sf	53 kBTU/sf	49 kBTU/sf	22 kBTU/sf
Residence Halls	100 kBTU/sf	64 kBTU/sf	46 kBTU/sf	38 kBTU/sf	16 kBTU/sf

This master plan establishes targets for new construction for both 2020 and 2030. Residential new construction standards in California in 2020 will be net zero energy, and non-residential (commercial) construction will be net zero energy by 2030. Based on best practice, significant electrical savings can be achieved with high-efficiency lighting, better building envelopes, and improved HVAC equipment. For offices and classrooms, the study targets an EUI of 49 kBtu/sf, and this master plan recommends a stretch goal for new projects to target an EUI of 22 kBtu/sf by 2030. For residence halls, the study targets an EUI of 38 kBtu/sf and the master plan recommends a stretch goal for new projects to target an EUI of 16 kBtu/sf by 2030. While 2030 targets may seem aggressive, the market is trending quickly in this direction, and new technologies will become cost effective and will drive energy use downward sharply. Residential and non-residential buildings meeting these targets currently exist.

Key Energy Modeling Design Assumptions to achieve these EUI targets include:

- Building envelope strategies:
  - Increased insulation
  - High performance glazing of windows
  - Thermal break windows and wall assemblies
  - Utilization of energy efficiency envelope strategies in current energy code
- Integrated lighting technologies and strategies:
  - Daylighting design strategies to reduce use of electric lighting

  - LED lighting for building and site lighting
  - Lighting controls
  - Daylight harvesting controls
- Energy efficient HVAC system technologies and strategies:
  - Radiant heating and cooling strategies using low temperature water (in-slab, panel, or supplied by central plant or distributed systems)
  - Variable Refrigerant Flow (VRF) systems (electric-fueled simultaneous heating/cooling, central condensing unit, fan coil units at each zone)
- Advanced HVAC system
  - Heat Pumps (electric fuel only providing both heating and cooling, or can be supplied by central plant or distributed systems)
  - Low temperature water system from central plant

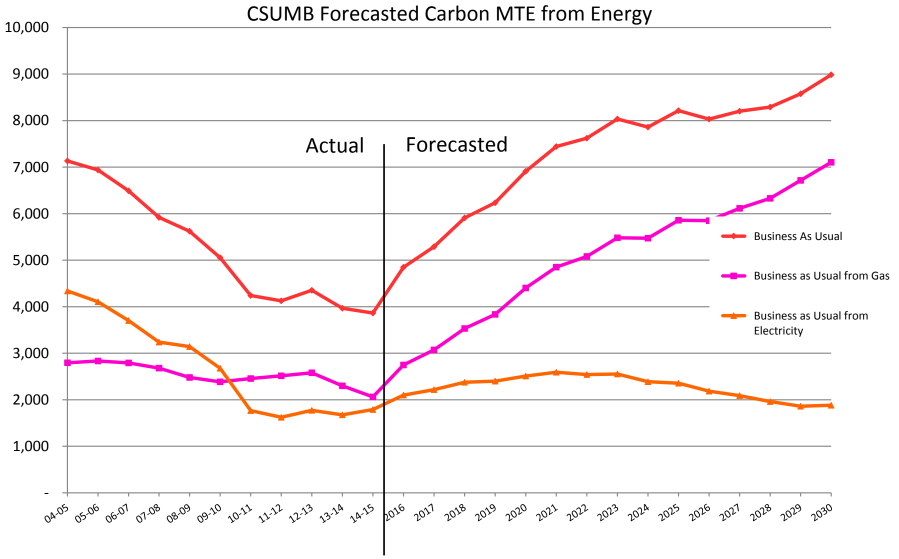
Detailed discussions of building technology systems are included in the Energy Use section of this chapter. Alternative supply methodologies and technologies aimed at reducing natural gas usage effectively shift the energy supply reliance between electricity and natural gas. Addressing natural gas usage tied to the heating demand will likely be more impactful than electricity demand in reaching the campus's sustainability goals. Alternative scenarios are modeled to identify different potential outcomes, which are discussed in the Energy Strategies and Technologies section of this chapter.

CSUMB Energy Use Modeling

Figure 9.5 shows the anticipated electricity, gas, and carbon emissions associated with pursuing the existing BAU energy strategy. This BAU strategy does not help the campus reach its carbon neutrality goal by 2030, and resulting emissions would need to be offset to meet the carbon neutrality goal.

Figure 9.5 shows the forecasted GHG emissions with the campus growing to 12,700 students between 2016 and 2030, using its current energy mix with new construction meeting Title 24 building code energy efficiency standards. The BAU case of current combined electricity and natural gas technologies results in the highest GHG emissions at roughly 9,000 MTE in 2030. The natural gas reliant technologies results in roughly 7,000 MTE by 2030, or a 22% reduction from BAU. The electric-reliant contribution results in 2,000 MTE by 2030, or a 77% reduction from BAU. Clearly, this is a wide range of outcomes and the decision of which path to take needs to be evaluated carefully through a strategic energy planning process.

Figure 9.5: *Business as Usual (BAU) Electricity, Natural Gas and GHG Emissions*



RECOMMENDATIONS

The California State University Executive Order 987, the 2007 and 2016 Second Nature Climate Commitments, and the resulting Climate Action Plan set ambitious goals for the university system and each individual campus. To achieve these goals CSUMB will need to develop an equally ambitious plan to reduce GHG emissions to the minimum possible, supply as much renewable energy from on-site resources as is economically feasible, and purchase offsets for any remaining GHG emissions. The options presented in this chapter provide a basis from which to develop a strategic energy plan that meets current and future needs in the most efficient, cost effective and environmentally sound manner possible.

Utilize a district scale approach to on-site energy production

To achieve its goals for carbon neutrality, the campus should approach on-site energy production projects on a campus-wide scale instead of building by building. A larger system is more efficient, easier to maintain, and takes advantage of available space and economies of scale. In addition, there is an existing hot and chilled water plant that still has years of life and is strategically located near the campus core.

Expand district scale chilled and hot water distribution

As on many UC and CSU campuses, district water loops can provide the most efficient, scalable, and low-carbon approach for long-term development that achieves carbon neutrality. A district scale, centralized system should be implemented to generate and distribute hot and chilled water to serve building heating and cooling needs. CSUMB's existing set of district heating and cooling piping loops in the main campus area should be expanded to serve future buildings.

Continue energy efficiency improvements in existing buildings

For existing buildings, design teams and the energy manager can research and adopt the best available technologies for high-performance building retrofits. Buildings can be retrofit with smart technology to quickly troubleshoot building system problems and to enable ongoing commissioning of the buildings. Buildings where lighting or HVAC commissioning has not been performed in the past five years should be recommissioned. For existing buildings, LED lighting retrofits may be cost effective and could be implementable with support of the UC CSU Energy Efficiency Partnership. Together these improvements alone should increase building efficiency beyond the 5 percent embedded in the BAU forecast.

Establish design standards for increasing energy performance for building level technologies

For new construction, building energy use should be targeted to a minimum of 15 percent better performance than current Title 24 code. Higher margins can be achieved in administrative buildings and some academic buildings. For existing buildings, building energy use should be targeted for a minimum of 5 percent improvement compared to existing usage, with higher goals for specific buildings that have greater opportunity for improvement. These increased opportunities would be best identified through a deep energy retrofit auditing process, which could be supported through the UC CSU Energy Efficiency Partnership.

Identify greenhouse gas emission offsets purchasing strategy

Depending on the strategies adopted and their combined success, achieving the university's carbon neutrality goal may require the purchase of carbon offsets to close any remaining gap at the end of the timeline, particularly if natural gas reliant strategies are adopted. If electricity reliant options are favored and a large proportion of on-site renewable energy is supplied, emissions will be much lower. Offsets could be procured in several ways:

- Participate in a local renewable energy offset or Community Choice Aggregation (CCA) program. Participation in a CCA may allow CSUMB to export surplus renewable electricity generated on campus on terms more favorable than those presently available. The campus will need to evaluate these benefits among other available options.
- Purchase renewable energy offsets from a certified green-e source in the quantity to offset remaining annual metric tons of carbon dioxide equivalent(MtCO2e) emissions associated with energy.

The related costs and benefits associated with CCA or offsets option should be considered when the Strategic Energy Plan is developed. Offsets can represent a significant added cost and should not be overlooked.

Participate in Programs That Provide Financial Incentives for Energy Efficiency

Savings by Design

Administered by California energy utilities, Savings By Design (SBD) encourages high-performance, non-residential building design and construction, and a variety of solutions to building owners and design teams. Incentives are available for owners and designers. Use of the Savings By Design program is a policy requirement for the CSU universities. This program can be accessed directly without participation in UC CSU Energy Efficiency Partnership, though incentive values will be lower.

UC CSU Energy Efficiency Partnership

The University of California and California State University systems have developed a joint program to offer energy efficiency programs to the UC and CSU campuses in partnership with the statewide energy utility programs. The new construction element of the program is based on the SBD program but is tailored for optimal uptake by the UC and CSU campuses. An incentive to participate of $0.10/kWh is added to the SBD incentive rates for energy savings in this program. Enhanced incentives are also available for energy efficiency retrofit projects. The program is administered by a single subcontractor statewide, direct to the UC and CSU systems, thereby improving program service and response. CSUMB has participated in the past and is eligible to participate in the current program.

Develop Plan for Financing Infrastructure and Building Improvements

Despite uncertainties regarding future construction budgets, advanced energy-saving systems should be incorporated in new construction, and attention should be paid to improving performance in existing buildings as well. Energy efficiency strategies have a well-established positive return on investment, and costs of renewable energy systems and storage continue to decline. Financing mechanisms such as group solar solicitations, power purchase agreements, and public-private partnerships could be beneficial financially. A capital financing plan should be developed along with and consistent with the strategic energy plan.

Table 9.4 includes a rough early estimate of the first cost of technologies described in this chapter. Figure 9.11 shows the rate of return on investment compared to business as usual (BAU).

ENERGY STRATEGIES AND TECHNOLOGIES

Campus-Wide System Strategies and Technologies

With a campus that inherited a number of disparate former military buildings, CSUMB must continue to standardize campus-wide systems and approaches over time. Because most of the increase in program area will be new construction, the university has an opportunity to apply high-performance building standards campus-wide. The strategies below include systems that should be considered, as they are cost effective and high performance, and they meet the campus goals stated above.

Upon initial analysis, pursuing the water-sourced heat pump strategy appears the most cost effective and feasible district-scale solution, one that would meet the university's goals to partner with local agencies, be a leader in innovative technologies, and produce on-site energy.

District scale heat pump-provided energy strategy

Two types of heat pump energy supply systems are available to the campus. The first, a solar-sourced heat pump, has a number of advantages and disadvantages. While this system would help meet the carbon neutrality target, the initial capital outlay, lack of affordable scalability, and project risk should be evaluated as the technology matures.

The second, a water-sourced heat pump utilizing reclaimed water in partnership with Marina Coast Water District, may be a cost effective and efficient option. It would allow the university to be a responsible steward of its natural resources, and it would provide an excellent opportunity to partner with the local water district on a mutually beneficial landmark project.

Heat pump generated energy supply

The heat pump strategy aligns best with on-site renewable energy production and carbon neutrality goals. It is also the most efficient way to provide heating and cooling for the campus. To prepare for either the solar or water heat-pump supply scenario, the campus should develop and expand its district-scale water distribution system and design building systems to circulate hot water at lower temperature. Plans for campus expansion need to take into account this infrastructure improvement.

Ultra-clean natural gas fired cogeneration as an interim step

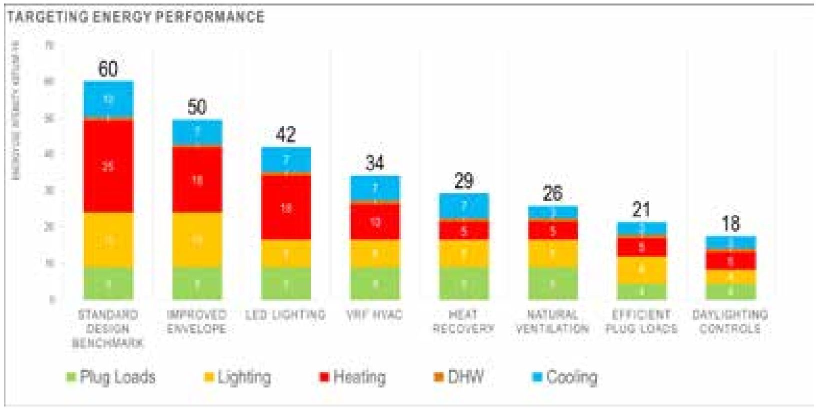
A cogeneration plant would use natural gas to produce both electricity and district-scale hot water for the campus. This technology is well established, and the economics are understood. The GHG impacts are, however, higher than other technologies available to the campus. Nevertheless, some form of natural gas generation will still be required, even in the long term, for stability of the California grid, even after the renewable mandates are met. As an interim step, therefore, the university may want to explore the feasibility of a natural gas-fired cogeneration plant.

Building System Strategies and Technologies

Because building energy use significantly affects both electricity and natural gas usage, reducing it is the key means of achieving net zero energy and carbon neutrality. CSUMB has implemented many energy efficiency measures and has already recognized a reduction in electricity and gas usage. Building energy use is rapidly changing as more data on existing operations becomes available, the price of energy increases, and the state of California moves toward achieving Zero Net Energy residential buildings by 2020 and commercial buildings by 2030. These targets are actively being met throughout the state on projects using market-ready technologies and strategies that can be replicated at CSUMB. High-performance building strategies for new construction are outlined below, as well as recommendations for building energy systems.

The pathway to a low-carbon campus requires high-performance buildings utilizing many energy efficiency strategies that together contribute to a low EUI. Shown below is a pathway to a low EUI target that buildings often undergo during a design process. Building envelope, lighting technologies and strategies, daylighting strategies, energy efficient HVAC systems, and plug loads are driven down through a rigorous design and modeling process. Currently, the CSUMB buildings use 60 EUI per year on average. This is not unusual for existing buildings constructed under previous energy codes. New construction in California is continually bringing this average down; new buildings built to code operate at an EUI of 42 or lower. Proven technologies and holistic design processes can reach an EUI in the mid-20s through passive and energy-efficient design approaches. As an example, in its first year of operation, the Joel and Dena Gambord Business and Information Technology Building had an EUI of 28. This same process and holistic approach were used to establish the low energy stretch goals for each building type. (Figure 9.6)

Figure 9.6: *Building Systems Energy Performance Targets*



Low Energy Heating Standards

Where there are HVAC related considerations, the most effective strategy is utilizing a decoupled ventilation, heating, and cooling system. These systems by design utilize lower temperature heating water and can directly tie into a campus-wide heating system in the future. Low energy and low carbon building technologies include radiant heating and cooling, Variable Refrigerant Flow (VRF) heating and cooling, and heat pumps. (Figures 9.7 and 9.8)

Cooling and Natural Ventilation

Cooling loads at CSUMB are significantly lower than heating loads because of the moderate climate. Regardless, cooling is needed in heavily occupied academic buildings and in residences in the early fall, when the cooling season spikes and students are back on campus. In building design, cooling loads should be determined through annual energy modeling. Natural ventilation strategies such as operable windows, cross ventilation, and stack ventilation are highly effective and should be prioritized. Remaining cooling loads that cannot be met by natural ventilation strategies can be met by mechanical ventilation such as DOAS (Dedicated Outdoor Air Supply) systems with partial cooling of just the required ventilation air, using effi-

Figure 9.7: *Low Energy Building HVAC Strategies - Variable Refrigerant Flow Heat Pumps*

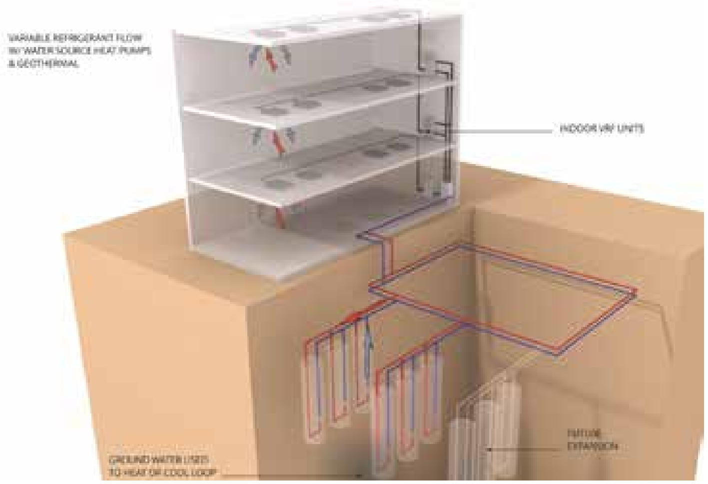
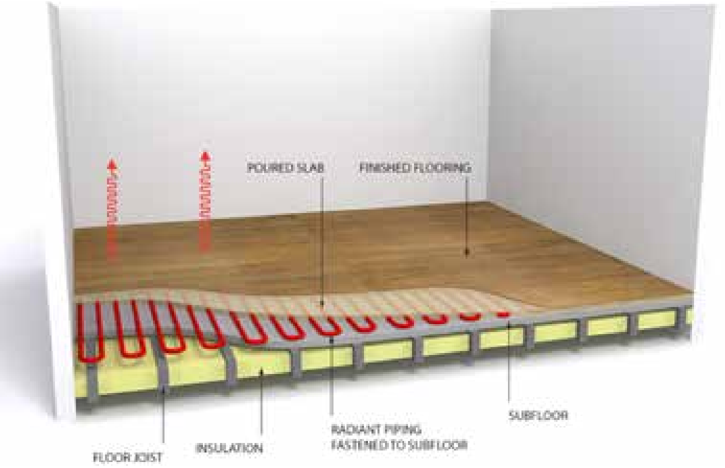


Figure 9.8: *Low Energy Building HVAC Strategies - Radiant Heating/Cooling*



These systems work on the principle of moving heat from the ground into a building or from the air into a building. Like a refrigerator running in reverse, heat pumps use electricity to move heat and are orders of magnitude more efficient than natural gas.

cient heat pump technology. This strategy is consistent with the decoupled ventilation strategy described in the Low Energy Heating Standards above.

Daylighting Strategies and Lighting Technologies

Natural daylight is a resource in academic, administrative, and residential buildings that should be optimized through design. Daylight is free, and it is the highest quality lighting available. The many daylighting strategies that are available include side lighting (windows), top lighting (skylights), light shelves, and light tubes. Design practice for new construction should include daylight strategies and daylight modeling. Once the daylight contribution is known, artificial lighting should be carefully designed to augment daylighting needs and fill gaps that daylight cannot provide, such as occupancy beyond daylight hours, non-daylit areas, egress and emergency lighting, task lighting, and specialty lighting. Daylight harvesting controls, including occupancy sensors and photo sensors, should be integrated into daylighting design.

LED lighting technologies have progressed rapidly in quality, color rendering, and cost effectiveness and are now embedded in California's Title 24 energy code. LEDs are therefore a requirement for new construction, and lighting loads as a fraction of total loads will decline. New buildings should take advantage of LED lighting technologies. Existing buildings can also be retrofit for LED technologies, and this might be considered for an additional energy efficiency project. The UC CSU Energy Efficiency Partnership provides incentives for LED retrofits.

Domestic Hot Water Systems

The mild climate in Monterey is ideal for a heat-pump-based domestic hot water heating storage system, with solar thermal backup for high-energy load spaces, such as residential, food preparation, and dining facilities. Offices and classroom buildings with distributed low-use fixtures and overall low hot water demand, such as hand washing lavatories in restrooms, would benefit from distributed point-of-use domestic hot water heaters. This strategy avoids excessive distribution losses associated with long runs and intermittent use, and it reduces overall system cost.

Plug Load Management

Hard-wired plug load controlling outlets tied to occupancy sensors should be installed to at least meet current code. Plug load controls help to reduce energy use by equipment such as computer monitors, desk lamps, TVs, and other accessories when dorm rooms, offices, conference rooms, and other spaces are unoccupied. Permanently on plugs will continue to provide power to devices which should not be turned off. In addition to the devices themselves, signage should be included to educate users on which outlets are appropriate for which types of devices.

Energy Supply Strategies and Technologies

To address the heating requirements of the campus, this master plan proposes several strategies which generally follow two themes:

- Natural Gas Reliant Technologies: BAU with gas boilers and cogeneration
- Electricity Reliant Technologies: air sourced heat pump, solar sourced heat pump, water sourced heat pump, with various levels of crossover and bridging potential between some of these technologies

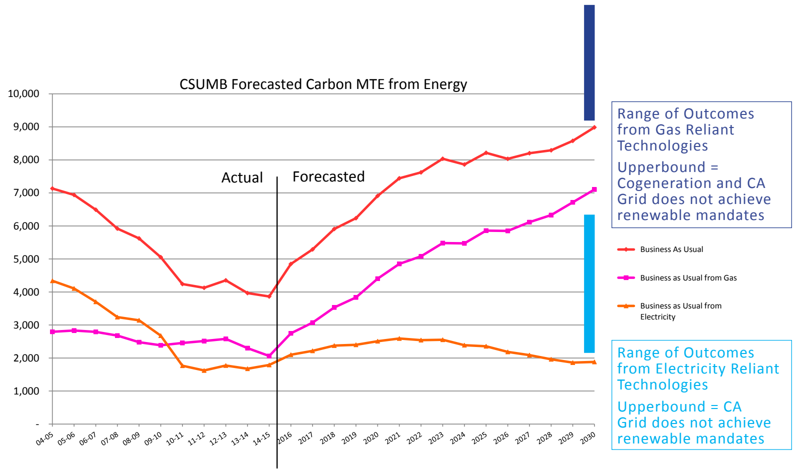
Each strategy and underlying technology has operational and financial advantages, as well as limitations and risks. If California is successful in achieving its mandates to reduce the carbon content of grid electricity by the year 2030, it appears that the electricity reliant strategies will be far more likely to position the campus to achieve its carbon neutrality objectives over the long term. (Figure 9.9) In fact, in 2015 the GHG emissions of the PG&E electricity utility grid was equal to the emissions of natural gas on a lbs/CO2 basis, with future electricity emissions projected to be far below natural gas by 2020. (Table 9.1)

Following is a discussion of the concepts of both the natural gas and electricity reliant Technologies, as well as probable advantages and disadvantages of each.

Natural Gas Reliant Technologies

The 2004 CSUMB master plan update, which predated the Campus Climate Commitment, anticipated supplying the campus energy needs for heat and electricity using a cogeneration energy supply strategy (further explained below) that was heavily reliant on natural gas. In pursuing this strategy the campus invested in a district hot water distribution system (operated at 170 degrees F) and a central boiler plant. The cogeneration component was deferred until the thermal load could justify the investment; a solicitation for this cogeneration component was attempted unsuccessfully in 2013. However, construction of additional buildings on campus and conversion of existing buildings to the district hot water system has continued through

Figure 9.9: *Forecasted GHG Emissions from Energy*



2016, and approximately two thirds of the campus annual heat loads is now being supplied by the district hot water system. This system is robust and has significant capacity to supply new buildings in the campus core from existing hot water piping.

Gas Fired Boilers

In the BAU case the university would continue to use its existing central plant boilers to supply heat to new buildings. These boilers burn natural gas in high performance, high efficiency burners to heat hot water, which is then circulated throughout the district heating system. Significant capacity exists in this plant to supply the campus build-out; the addition of new boilers would be driven more by a desire to maintain redundancy and reliability (versus rationing during a breakdown) than by a requirement to meet peak need. The boilers are reliable and low maintenance.

Advantages:

- The technology is commercially readily available and well understood
- The technology can be purchased incrementally

Disadvantages

- This approach results in higher GHG emissions than other alternatives

Cogeneration

Cogeneration for the campus would be the conversion of natural gas into two useable forms of energy: electricity and heating hot water. Installing a cogeneration plant would increase the amount of natural gas consumed on campus while reducing the amount of electricity purchased from the grid. The cogeneration plant uses natural gas to produce both electricity and hot water, reducing the natural gas burned in the central plant boilers. The plant would consist of one or more reciprocating engines driving electric generators tied to the campus electrical distribution system, with heat recovery to the campus district heating system on the engine exhaust.

This form of energy production is more efficient than procuring electricity from the grid and producing hot water in boilers because the cogeneration plant can make better use of its heat output than the average grid-tied, natural gas-fueled power plant.

Advantages:

- The technology is commercially readily available and well understood
- The upfront capital investment may be lower than other options
- The cogeneration can be scaled up as campus grows

Disadvantages

- Reciprocating engines require high levels of maintenance
- The GHG emissions associated with the combustion process are higher than other alternatives when viewed at a campus level
- Investment in cogeneration may become a sunk-cost

Electricity Reliant Technologies

Heat pump systems take energy from a heat source and store it in a "heat sink." Heat pumps are an electric technology that supplies both heating and cooling in one piece of equipment. They are advantageous in conditions with low-carbon or carbon-neutral goals because they supply heating and cooling without the use of natural gas, and the equipment uses only small amounts of electricity. Criteria for considering heat pump options for district scale energy supply scenarios include:

- Reliability and service life of technology
- Cost
- Maintenance

Heat sources considered include air, solar, and water. A general discussion of each source follows; however, the solar and water options are the most feasible for the CSUMB location and are evaluated in more detail.

Air-Sourced Heat Pump

An air-sourced heat pump system relies on extracting energy from the essentially infinite reservoir of outdoor ambient air, and using this electricity to heat indoor spaces.

Advantages:

- The technology is commercially readily available and well understood
- The technology can be purchased incrementally
- The technology provides both heating and cooling and does not require a large investment in interconnecting infrastructure

Disadvantages

- This approach is a distributed system, entailing many small units that must be maintained by certified technicians. Each unit contains regulated refrigerants that could potentially leak, to the detriment of the environment.

- The system has an inherent inefficiency because it is needed most when the outdoor air is cold. As the amount of electricity required for heating is proportional to the temperature difference between the ambient and conditioned space the system must work harder to achieve its objective.
- CSUMB's close proximity to the Pacific Ocean, with its onshore winds and moisture, pose extreme corrosion challenges. The required contact and heat exchange with air can drastically shorten the service life of exposed equipment and make the sustainability of this strategy questionable.

Solar Sourced Heat Pump

A solar-sourced heat pump system would capture energy from sunlight through thermal solar panels that circulate hot water. Part of this energy would be distributed directly for use in buildings via a district hot water distribution system, and the other part of the captured energy would be stored for use in tanks during times when there is insufficient sunlight due to time of day, cloud cover, coastal fog, and seasonal variation. Times when energy would be withdrawn from storage would therefore include each morning, evening, and night; during prolonged overcast; and daily in winter when sunlight is limited and the heating need is greatest.

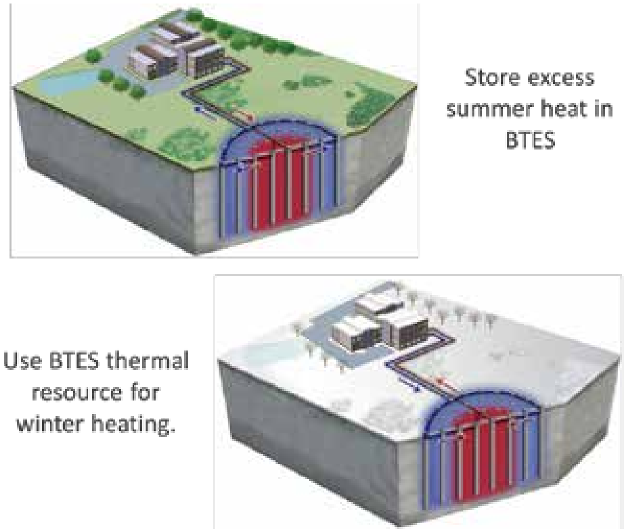
Solar energy technologies are prevalent and affordable in today's energy market. Solar PV systems, which directly translate solar radiation into electricity, are most prevalent. These are also the lowest-cost systems available today, but their efficiency, which tops out around 23 percent, is low.

Newer technologies couple solar electric creation with solar hot water (solar thermal) and are known as Photovoltaic Thermal (PVT) collectors. These systems are best utilized at locations where hot water can be readily utilized, such as the district scale HHW system at CSUMB.

The PVT panels are highly efficient and can harvest up to 90% of the solar energy on a clear day. They utilize evacuated tubes to make very high temperature water (up to 180 degrees F). This coupling of thermal heat in water boosts the electric PV panels as well, improving their output and extending their service life. Solar PV electric panels work best in cold, clear, climates like high deserts in the winter; however, given their high efficiency, PVT is still a highly viable energy source in locations such as the CSUMB campus.

This PVT system relies on significant infrastructure to store and reclaim the energy (heat) that is captured. One system which has widespread use is Borehole Thermal Energy Storage (BTES). BTES is the equivalent of a battery using the constant ambient temperature of the earth for heating and cooling. Similar to a geoexchange system, BTES can store excess heat in summer for low-carbon heating in winter, as shown in Figure 9.10. It can store heat from PVT and cogeneration if these systems are on site. This technology is used to balance heating resources for lowest cost and lowest carbon.

Figure 9.10: *Borehole Thermal Energy Storage (BTES)*



BTES can be located in open space or under parking lots as available. It comprises a series of vertical wells drilled in close proximity to create what is called a thermal field. When needed, energy is extracted from these wells in the ground by a heat pump, which supplies heat to the district hot water distribution system, thus cooling the ground and warming the district heating system. These systems are most efficient when all buildings linked to the system can operate with the lowest water supply temperature possible (130-140 degrees F).

Advantages:

- The heat pump is centralized and not in contact with air, thus improving maintainability
- Because it relies on district water distribution it can be backed up or peak-shaved by the campus's existing boiler plant.
- An opportunity exists to use PVT panels that would produce both heat and electricity thus offsetting some of the heat pump electrical consumption.
- BTES and heat pumps provide carbon-free heating and cooling

Disadvantages:

- The solar arrays and borehole will be large and capital intensive, and it will be challenging to size and finance these to match the campus energy demand. These demands will be a moving target, driven by incremental funding of buildings and development..

Water-Sourced Heat Pump

A third heat pump solution relies on another source of ambient heat—water. Similar to the air-sourced heat pump, this system extracts energy from a steady source of water. In an unusual coincidence, the Monterey Peninsula is seeing the development of a new water source, one which is planned to be pumped through the CSUMB campus on a steady basis. The Marina Coast Water District (MCWD) and the Monterey Regional Water Pollution Agency (MRWPCA) have teamed with FORA to assist in the development of the Monterey Pure Water Project. The proposed project will treat various community wastewater streams at the MRWPCA treatment plant north of the campus, and inject the resulting "product water" into the Seaside groundwater basin to the south of the campus for later extraction as potable water.

One version of this project uses an existing pipeline through campus to convey the 68 degree F product water at flow rates between 1,000 and 2,400 gallons per minute (depending on drought levels and month of the year) to the injection field. The opportunity for a water sourced heat pump arises from the potential to extract energy from this product water flow (lowering the water's temperature) as it is piped through campus. Calculations indicate that significant portions of current and future campus thermal demand could be supplied from this source by imposing nominal temperature changes on the order of 4 to 15 degrees F on the product water.

Advantages

- The technical design of the heat pump component would be essentially the same as that in the solar sourced alternative, but the water-sourced system would require heat exchange equipment in lieu of the solar panels and the borehole.
- The product water flows are forecast to be highest in winter, thus aligning the energy supply and demand, and minimizing the expenditure of capital on oversized equipment or storage.
- The heat exchange equipment would be less capital intensive than the solar panels and boreholes. By eliminating the need for solar thermal, it would also simplify the procurement of future solar PV.
- The heat exchange equipment could be installed incrementally as the campus grows.

- Lowering the temperature of the source water would extend the lifespan of the piping system.
- The system would be backed up by the district boiler plant, allowing for incremental build-out and peak load shifting. At the extreme, if the cost relationships between electricity and gas diverged, a fuel switching strategy could be implemented.
- Achieving multi-agency cooperation to add a greenhouse gas reducing energy component to a water project could garner best practice recognition on a statewide or national scale.

Disadvantages:

- The product water is not in the control of the university and the ability and extent to which the product water temperature can be changed would need to be negotiated with outside agencies.

Table 9.4: *Rough Cost Scenario Comparison of Technologies on an Annual Basis*

	FY15-16 Estimated	2030 Business as Usual Boilers	2030 Cogeneration	2030 Bore Hole Solar Thermal	2030 Water Sourced Heat Pump	2030 Water Sourced Heat Pump w/PV
Energy Quantities						
Heat Therms (as Gas)	516,799	1,333,000	1,768,944	-	-	-
Electricity Grid + 1MW Solar Kwh	12,636,515	26,000,000	16,470,000	29,000,000	33,200,000	29,060,000
HCF Water	68,232	136,464	136,464	136,464	136,464	136,464
Energy Costs						
$ Gas	$ 363,587	$ 937,815	$ 1,244,517	$ -	$ -	$ -
$ Electricity	$ 1,757,346	$ 3,615,791	$ 2,290,465	$ 4,032,998	$ 4,617,087	$ 4,041,342
$ Water & Sewer	$ 561,727	$ 1,123,454	$ 1,123,454	$ 1,123,454	$ 1,123,454	$ 1,123,454
Financed Capital Investment	$ 4,259,001	$ -	$ 3,500,000	$ 35,000,000	$ 8,000,000	$ 19,000,000
$ P&I Expense of Capital	$ 410,322	$ -	$ 337,198	$ 3,371,980	$ 770,738	$ 1,830,503
$ Salaries & Benefits	$ 241,230	$ 241,230	$ 241,230	$ 241,230	$ 241,230	$ 241,230
Total	$ 3,334,212	$ 5,918,290	$ 5,236,864	$ 8,769,662	$ 6,752,510	$ 7,236,530
Annual Cost Difference vs. Business as Usual			$ (681,426)	$ 2,851,372	$ 834,220	$ 1,318,240
Grid Kwh Carbon Content Forecast Lbs/MWI	427	167	167	167	167	167
Mte Carbon from Gas	2,749	7,090	9,409	-	-	-
Mte Carbon from Electricity	2,099	1,833	1,111	2,060	2,379	2,065
Total Carbon Mte	4,848	8,924	10,521	2,060	2,379	2,065
Cost to Offsett to Zero at $50/Mte	$ 242,391	$ 446,180	$ 526,027	$ 103,021	$ 118,929	$ 103,248
Total Carbon Neutral Cost	$ 3,576,603	$ 6,364,470	$ 5,762,891	$ 8,872,683	$ 6,871,438	$ 7,339,778
Annual Cost Difference vs. Business as Usual			$ (601,579)	$ 2,508,213	$ 1,108,547	$ 975,308