Not Too Fast, Not Too Slow: A Sustainable University Campus Community Sets an Achievable Trajectory toward Zero Net Energy

John Elliott, University of California, Merced
Karl Brown, California Institute for Energy and Environment, University of California

ABSTRACT

The new University of California, Merced campus has set a goal of zero net energy for stationary facilities and fleets by 2020. This is part of a triple zero commitment along with elimination of landfill waste and climate neutrality in the same timeframe. The campus has set progressive targets for deep efficiency as a foundation for this planning.

The measured performance of the first buildings is ahead of schedule with the campus operating at 70% of the annual energy requirement of equivalent 1999 California university building stock adjusted for climate. Two buildings are already operating below 65% of this benchmark, with peak power below 50%. A district chilled water thermal energy storage system further reduces peak power needs.

This initial success with deep efficiency has led the campus to consider an even more ambitious goal of buildings using just 25% of benchmark, requiring even less renewable energy to achieve zero net. The campus is pursuing renewable energy on a site-wide basis aided by California Energy Commission Public Interest Energy Research grant funding. The campus has constructed the first of its anticipated solar energy installations, a one-megawatt single-axis tracking PV array initially serving about half of the peak power and one-sixth of the annual electricity requirement of the campus.

Energy planning at the University of California, Merced is a demonstration of the feasibility of deep efficiency and zero net energy in a major research campus setting, along a trajectory consisting of progressively more challenging, but achievable steps.

Introduction

This paper describes past and current planning at the University of California (UC), Merced—an ongoing process that has enabled its main campus goal of zero net energy for stationary facilities and fleets by 2020. We begin by providing the external and the UC system-wide policy context for this goal, along with the internal context of campus planning for environmental stewardship and sustainability.

Deep Efficiency and Zero Net Energy Goals

Strong planning and policy goals are developing to reduce the adverse impacts of energy use, with recent advances spurred on by the imperative of climate protection. The most prominent external policy context for UC Merced includes California Assembly Bill (AB) 32, the American College and University President's Climate Commitment, and California Energy Efficiency Strategic Planning (CEESP) by the California Public Utilities Commission (CPUC). The first two are oriented toward climate policy; while the third is focused on energy use itself.

CPUC planning includes two zero net "Big Bold" energy efficiency strategies: 1) all new residential construction will be zero net energy by 2020, and 2) all new commercial construction will be zero net energy by 2030 (CPUC 2009). This mirrors the 2030 Challenge Targets supported by the leaders of the American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE), American Institute of Architects, and U.S. Green Building Council; along with the U.S. Conference of Mayors.

Definition of zero net energy. A good starting point for understanding the concept of zero net energy is a simple definition often ascribed to ASHRAE: "ASHRAE defines net-zero-energy buildings as those which, on an annual basis, use no more energy from the utility grid than is provided by on-site renewable energy sources. These buildings use 50 to 70 percent less energy than comparable traditional buildings, and the remaining energy use comes from renewable sources, like solar panels or wind turbines incorporated into the facility itself…" (Harrison 2008). Some experienced practitioners would argue for even deeper efficiency (for example, 75% less than traditional buildings to reduce the cost of on-site renewable energy).

UC system-wide and Merced campus policy. Initiation of Merced campus energy and sustainability planning preceded initiation of UC system-wide policy development. However, once UC system-wide policy development began in 2002 in response to student activism, the two planning and policy movements proceeded in parallel, supporting and strengthening each other.

Merced campus planning and policy development has provided "stretch goals" that have formed one reference point for the less aggressive policies intended as a minimum level of achievement system-wide. Merced campus planning and policy has also sought to fill in areas initiated by the sometimes more comprehensive system-wide policy. Finally, always seeking the leadership role, Merced campus policy has sought to stay ahead of UC system-wide policy in key areas such as energy efficiency.

The original UC system-wide policy preceded the mid-decade milestone when zero net energy or "climate neutrality" targets gained momentum, so there was no allusion to such a visionary goal. With an update to the policy in 2007, a climate neutrality provision was added: "By December 2008, the University will develop an action plan for becoming climate neutral which will include: a feasibility study for meeting the 2014 and 2020 *(intermediate)* goals[1] stated in the Policy Guidelines, a target date for achieving climate neutrality[2] as soon as possible while maintaining the University's overall mission, and a needs assessment of the resources required to successfully achieve these goals." (UCOP 2009). In actual implementation, this provision is being met by having each campus produce such an action plan.

At this writing, all campuses have produced action plans. However, only the Merced, San Diego, and Santa Barbara campus action plans include a target date for climate neutrality, with the Merced campus plan also providing a target date for zero net energy.

[1] "… voluntarily meeting the State of California's goals, pursuant to the "California Global Warming Solutions Act of 2006" that is, by 2020 to reduce GHG emissions to 1990 levels. In addition…the University will pursue the goal of reducing GHG emissions to 2000 levels by 2014 and provide an action plan for becoming climate neutral…

[2] "Climate neutrality means that the University will have a net zero impact on the Earth's climate, and will be achieved by minimizing GHG emissions as much as possible and using carbon offsets or other measures to mitigate the remaining GHG emissions."

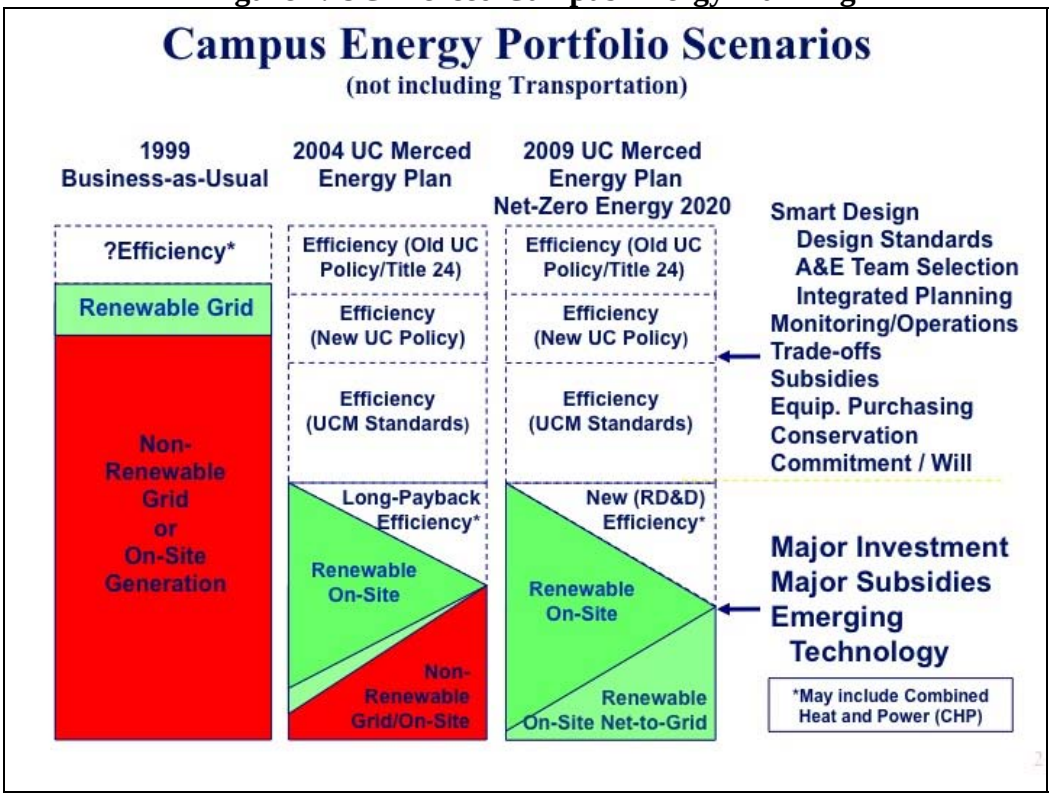
UC Merced's Path to the Present

Early energy planning for UC Merced from 1999 through 2004 coincided with energy load forecasting, campus master planning, and design of the first buildings. More recent energy planning has been in conjunction with feedback from performance measurement of the first buildings, the activities of a Chancellor's Advisory Committee on Sustainability and a 2009 update of the campus Long Range Development Plan

Early Campus Energy Planning and Sustainability Goals

Early campus energy planning was focused on attaining the deepest efficiency possible with the available budget for buildings and infrastructure, capturing the associated energy operating cost savings, stretching that infrastructure to cover as much of the future campus as possible, and addressing long-term limits on the burden the campus could put on the regional energy infrastructure. At that time, the literature indicated that a target of energy use and peak demand of 50% of business-as-usual was achievable with minimal additional first costs (Brown 2002).[3] The original (2004) campus plan is presented along with a business-as-usual case and the updated (2009) campus plan in Figure 1.

Figure 1. UC Merced Campus Energy Planning



Source: Karl Brown, California Institute for Energy and Environment

[3] Planning has since included collaboration with the New Buildings Institute's "Getting to 50 and Beyond" Program.

A system of benchmark-based energy performance targets was established through a load study of existing UC and California State University (CSU) campuses. Campus energy targets are referenced to equivalent UC/CSU building stock circa 1999. This system of targets is described in detail in an earlier paper (Brown 2002). Table 1 shows the reduced energy use, peak load, energy costs, and infrastructure requirements that result from the 50% goal combined with a full thermal storage system that shifts all cooling load off peak.

Table 1. UC Merced Energy Plan Summary Analysis (2004)

University of California, Merced Long Range Development Plan: 25,000 Students Planning Estimate: 35% Laboratory Buildings Utility Energy (not including Transportation)		
	Baseline (BAU)	Efficient Design
Annual Energy Cost (millions 2004$)	$27	$13.5
Maximum electric Demand (Megawatts)	46	18
Annual Electric Use (million kWh)	205	110
Annual Gas Use (million therms)	7.1	3.9
Chiller Plant Capacity (thousand tons)	19	10

Source: Karl Brown, California Institute for Energy and Environment

Getting to 50% with progressive energy efficiency targets. In the early 2000s, campus personnel and design team members lacked the confidence to immediately pursue a 50% savings goal. A progressive set of energy efficiency targets was established to allow the campus to work toward the 50% goal, learning from its experience with each building. The plan called for the first 600,000 gross square feet (gsf) of buildings to use 80%, the next 600,000 gsf to use 65%, and finally all buildings thereafter to use 50% of the benchmarks.[4] These targets are enforced through campus design standards. For the first time, designers are asked to do energy analysis that reflects the actual expected use of the building, rather than to model code compliance. Details of this paradigm shift are also discussed in a companion paper (Brown et al. 2010). The footprint resulting from this original progression plan is shown in Figure 2 (2004 Planning).

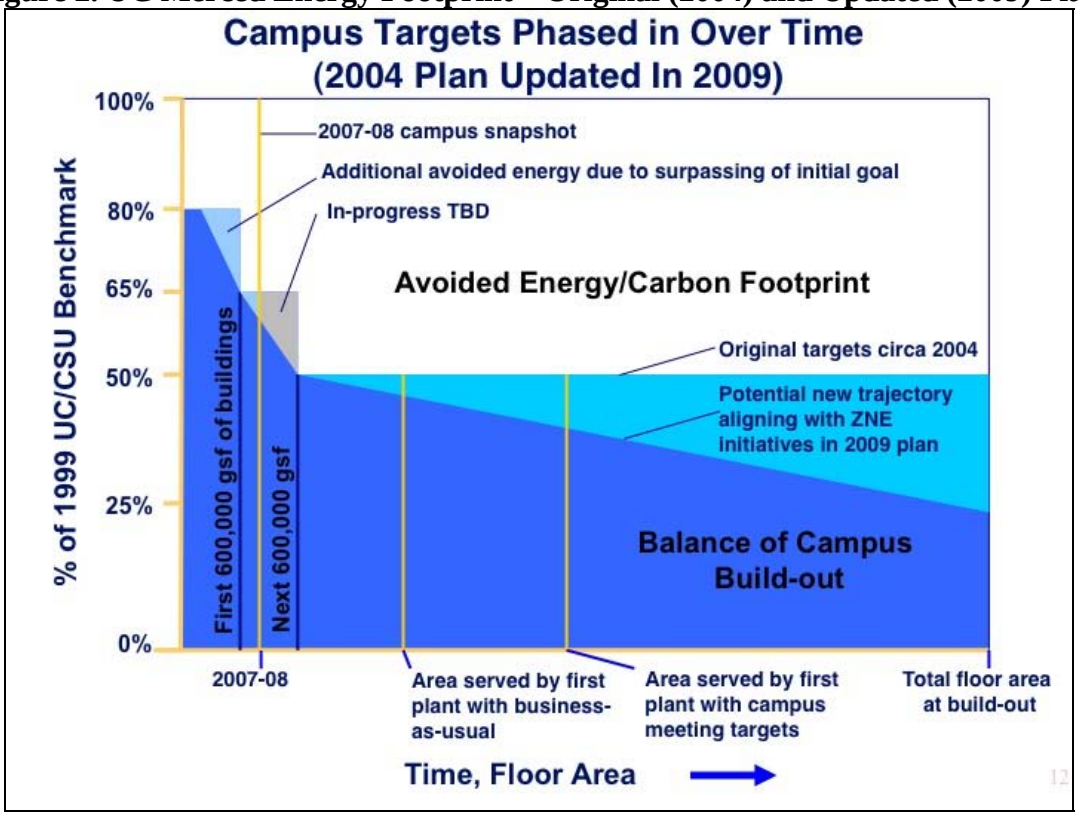
Integrated building and infrastructure planning. Early campus energy planning had the vision to integrate the efficiency goals with energy budget and infrastructure planning. This may seem the natural thing to do, but the authors observe there is nothing in building rating systems, building standards, or conventional thinking about efficiency that compels it. So it is actually more common for infrastructure planning to make assumptions of business-as-usual goals rather than planning for efficiency.

UC Merced campus planning sized the first phase of the district heating and cooling plant using actual usage data from existing campuses adjusted for building type, climate, and efficiency goals. An explicit margin of safety was agreed upon by the owner and design team, as opposed to a compounded margin of safety resulting from unstated conservative assumptions at

[4] The first 600,000 gsf of floor area included a classroom and office building, a library, a laboratory building, a cooling and heating plant, and a housing and dining complex. Originally a timeframe was used to delineate the progression of goals (e.g., 2004-05, 2006-07, thereafter).

every stage of load estimation.[5] The building design process included goals for reduced maximum electric, cooling and heating load in addition to reduced annual energy use.

Figure 2. UC Merced Energy Footprint—Original (2004) and Updated (2009) Plan



Source: Karl Brown, California Institute for Energy and Environment

"All-in" and peak load goals. The integrated planning approach carried with it some advantages that eventually gave the campus a leg up on zero net planning. First, the importance of addressing all energy use at the facility, rather than only those building systems regulated by energy-related building codes, was recognized at the outset. This recognition occurred because of the intent to manage operating costs, reduce greenhouse gas emissions, and plan the infrastructure needed to support the buildings.

Second, planning for infrastructure also drew attention to the peak electricity, chilled water, and hot water loads. Thus, the "all-in" and peak load planning needed for zero net energy planning has always been present in the UC Merced process. Designers rely on professional judgement regarding plug loads and other model inputs, assuming the campus will follow-through on commitments to procure efficient office equipment and otherwise manage loads. Details of the UC Merced design and analysis process are discussed in a companion paper (Brown et al. 2010).

Planning for measured performance verification. Measured performance verification was also part of campus energy planning from the outset. This was a result of the intent to achieve

[5] The plant sizing process was more effective for the cooling plant than for the heating plant because better data was available for maximum cooling loads from existing campuses.

continuous improvement in designs as the campus moved toward its ultimate efficiency goals, as well as the need to actively mange operating costs. This "as-operated" validation plan preceded both the movement toward greenhouse gas accounting spurred by California AB 32 and the emergence of LEED® "existing building" ratings.

Success with the first buildings. UC Merced's aggressive energy planning was validated by the design and construction process for the first buildings. Designers were often able to achieve eight to ten out of the available ten LEED® energy efficiency credits and maximum Savings-By Design incentives, as well as meet or surpass the benchmark-based deep efficiency targets (Taylor Engineering 2002). Gold LEED® ratings were achieved for all but one of the first buildings, surpassing the goal of silver ratings.

Some buildings achieve deeper efficiency than planned. A 2007-08 measured performance snapshot of the campus and two of the first buildings further validates early campus energy planning. Two of the buildings - a classroom and office building and a laboratory facility - measured at less than 65% of benchmark energy use and at just 50% of benchmark peak electric power. Details of as-designed achievements and measured performance are presented in case studies (CIEE 2009, NBI 2009a, NBI 2009b) and the companion paper (Brown et al. 2010).

Measured performance versus benchmarks provides valuable feedback. During the 2007-08 snapshot the campus as a whole operated at 69% of benchmark energy use and at 51% of benchmark peak power. Total campus energy use has since increased to 73% of benchmark with peak power now at 57% of benchmark. Though the long-term trend is still within planning bounds and on the zero net energy trajectory, such a short-term increase is of concern. The campus will respond by investigating if the increase is due to deviations from campus design standards, operating issues, variation in weather, or increased intensity of use. The existence of the benchmark-based metric is providing the campus an earlier chance to mitigate potential issues. The simpler metric of energy use per unit floor area does not show the same strong signal.

Early results suggest a more aggressive trajectory toward deep efficiency. Building on the good energy performance identified in the performance snapshot, several opportunities remain to improve or correct control strategies in the buildings and further improve energy performance. Thus, it is possible that the original deep efficiency goal of 50% of benchmark might eventually be met by two of the original buildings. Technology advances have occurred since the design of these buildings, further suggesting that a target of less than 50% of benchmark is possible[6]. This may enable the steeper trajectory toward zero net energy discussed in a following section.[7]

Evolution of Campus Energy and Sustainability Planning and Goal Setting

Within the last few years, campus energy and sustainability planning has evolved. This has occurred primarily through activities associated with a Chancellor's Advisory Committee on Sustainability and the development of a new Long Range Development Plan for the campus.

[6]Advances include wireless controls and new light-emitting diode applications.

[7]In another confidence-building process, achieving an original commitment to LEED® Silver building ratings eventually helped to establish a higher commitment to Gold ratings.

This evolution has also been facilitated by achievements in starting renewable energy generation on campus through the construction of a one-megawatt (MW) photovoltaic array, and directing research to the campus zero net energy goal.

Chancellors Advisory Committee on Sustainability (CACS). The CACS was convened in fall of 2007 and has been successful in creating a clear and consistent vision of sustainability for the campus and facilitating communication between and among staff, faculty and students to advance sustainability. The committee has developed a set of twelve "sustainability stakeholders" in areas such as energy, procurement, and water. Each stakeholder has identified a sustainability goal for their area and two to three of the highest priority objectives required to achieve the goal. Finally, stakeholders have developed quarterly milestones to achieve the objectives. The sustainability strategic plan expressed by these goals, objectives, and quarterly milestones (CACS 2010) has provided a clear and scalable process to advance sustainability broadly and provide the context to strengthen the original commitments to building energy performance targets and green building.

Triple zero commitment. As the CACS was developing a vocabulary to discuss sustainability on campus in early 2008, the campus was preparing a new Long Range Development Plan (LRDP) to guide the development of the campus from its current footprint of approximately 100 acres to over 800 acres, accommodating 25,000 students over the coming decades. Influenced in part by discussions with the committee and broadening support for sustainability objectives, the LRDP authorship group chose to identify key campus sustainability goals as a defining element of the plan. The plan, which was approved in March 2009, established a "triple zero commitment" of zero net energy, zero landfill waste, and climate neutrality, all by 2020. This commitment, along with other progressive elements to increase building density and reduce commuting miles, helped the plan to win the 2009 Governor's Leadership in Governor's Environmental and Economic Leadership award.

First on site renewable generation. To support its zero net energy goal, the campus sought to build on its energy efficiency efforts and begin generating renewable power. By spring of 2008, the campus had identified the most cost-effective sites for solar photovoltaic development on campus and had released a request for proposals to develop a photovoltaic system through a third party power purchase agreement. An eight-acre one-megawatt tracking photovoltaic array was completed in November 2009. The system as designed is anticipated to supply about 12% of total current campus source energy for stationary facilities and fleets including 17% of campus electricity, as well as meet about half of 2010 summer peak power demand.

Strengthening ties between facilities, teaching, and research to create a living laboratory. The campus has recognized that facility-driven sustainability goals will have limited success if they are not incorporated into the key mission of the university: teaching and research. To this end, the campus has pursued opportunities to strengthen ties between efforts to achieve zero net energy and campus teaching and research. This integration between facilities, teaching, and research is increasingly identified with the concept of the campus as a living laboratory.

For the past two years, students of thermodynamics have visited the campus central plant, explored the building energy management system, and completed semester projects based on actual performance data collected from the campus monitoring network. For example, one term,

student groups calculated the chilling plant efficiency for every month of the year and interpreted the results. Discussions are underway to create longer-term service learning or undergraduate theses that "chip away" at research questions posed by the campus goal of zero net energy.

An original commitment to archive extensive monitoring data on all of the campus buildings has created a valuable data set and facilitated joint research projects between facilities management and researchers. For example, the campus has pursued research projects with Berkeley Lab and United Technologies Research Center on chilling plant optimization, building performance visualization, occupancy controls, and demand response. Availability of extensive monitoring data also supported collaboration between the campus, Berkeley Lab, the California Institute for Energy and Environment, and the New Buildings Institute to analyze building energy performance and prepare case studies. Finally, facilities management and researchers at the UC Merced School of Engineering were awarded a $1 million Renewable Energy Secure Communities grant from the California Energy Commission (CEC) Public Interest Energy Research (PIER) program to investigate integration of renewable energy technologies toward the campus goal of zero net energy. This project advances research to integrate energy efficiency, solar power, and plasma gasification into an operational renewable campus energy portfolio.

As these collaborations grow, the campus is beginning to see a natural synergy between sustainability and the core mission of the university to pursue teaching, research and attract students, faculty, staff, and research dollars. In fact, the UC Merced Energy Research Institute has chosen to organize its research agenda around a zero net energy concept. The university is uniquely positioned as a living laboratory that can integrate education and research with practical implementation experience.

The Path to 2020

Campus planning for zero net energy is currently proceeding toward deeper efficiency as well as scenario building and optimization. Specific activities are proceeding within a broader effort to strengthen the living laboratory as described above.

Deeper Efficiency

Campus experience with the benchmark-based building energy performance goals to date has validated them as achievable without significant additional cost. This suggests that the campus can achieve greater savings through deeper efficiency.

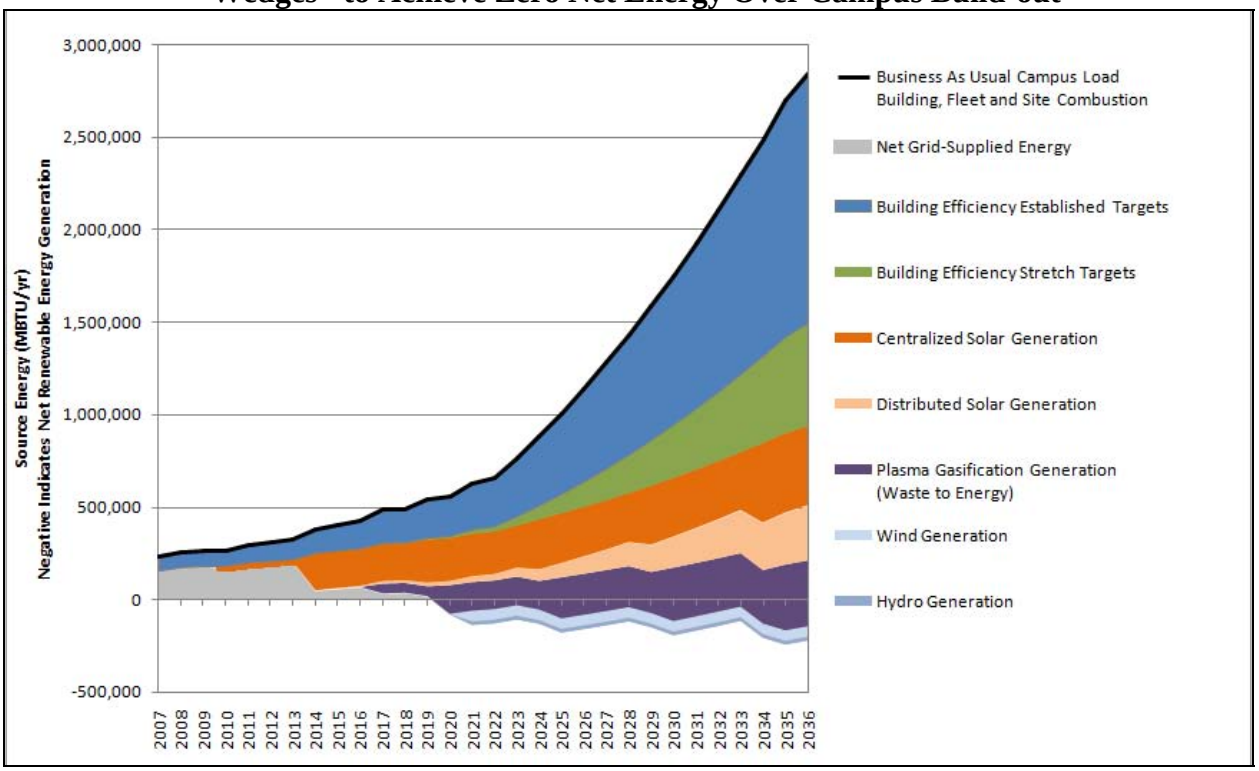
Striving to 25%. The campus is considering implementing a goal of "Striving to 25" - that is, working towards a goal that buildings are designed to use just 25% of the campus energy performance benchmarks. This may represent a more cost-effective level of energy efficiency, which would minimize lifecycle costs for construction and operations over a reasonable planning horizon (for example, 20 years). Since 2010 marks the first year that buildings will be designed to 50% of the benchmark, a path to 25% will not likely be implemented until actual performance data validates that the 50% goal is regularly achievable. Further work is needed to validate the economically optimal level of efficiency investment and ensure that data are being collected to evaluate the relative marginal costs of efficiency and energy generation. Figure 2 illustrates a potential new campus footprint with the steeper trajectory toward very low energy buildings including the early success and the possible new 25% goal (2009 Planning).

Ongoing monitoring-based commissioning. With increasing emphasis on efficiency as part of a portfolio deployed to reach zero net energy, there is greater need to have a monitoring system in place to ensure that efficiency as part of a building design is maintained over time. As part of its CEC PIER grant, the campus is developing a monitoring-based commissioning protocol that will be implemented for all future buildings. Specifically designed to identify whether energy performance is being maintained, a comprehensive set of indicators will be developed and used for dispatching campus facilities staff to actively maintain building efficiency. The monitoring protocol will be implemented on an energy performance platform developed by Berkeley Lab and United Technology Research Center, and now installed on School of Engineering servers. This platform uses an extract of data from the campus energy management system and is intended to make the existing warehouse of performance data more accessible and actionable.

Scenario Building and Optimization

The campus is working to develop models that will identify necessary milestones to meet zero net energy and help refine understanding of how a renewable energy portfolio can be achieved most cost-effectively. Figure 3 shows an example path to zero net energy over campus build-out through a series of efficiency goals and renewable energy projects. The black trend line reflects business as usual loads included in the zero net energy commitment, while the colored wedges represent opportunities to reduce grid-supplied energy through energy efficiency or renewable energy generation.

Figure 3. UC Merced Example Analysis Showing Business As Usual Loads and "Wedges" to Achieve Zero Net Energy Over Campus Build-out



Notes: The data for 2007, 2008, and 2009 are measured values; "Wedges" concept originated by Pacala & Socolow.
Source: John Elliott, University of California, Merced

The simple spreadsheet model underlying Figure 3 is critical for clarifying the magnitude of effort required and identifying milestones necessary to achieve zero net energy. This model also identifies key variables that must be refined to better target zero net energy activities. A summary of initial planning conclusions drawn from this model is summarized in Table 2.

While such a model can illuminate a possible path to zero net energy, it cannot identify whether such a path is cost effective. The cost effectiveness of a renewable energy portfolio designed to achieve zero net energy is driven by seasonal and hourly generation and load profiles and the costs for efficiency, renewable power generation, and grid power that will be used to meet loads during those times when loads still exceed generation capacity.

For example, UC Merced's tariff for grid power (PG&E E-20P) has significant demand charge components based on a peak demand during a billing month for various time-of-use periods. As part of its grant funded by the CEC, the campus is developing an optimization model to identify the cheapest allocation of renewable resources (including storage) to minimize costs and exposure to such demand charges.

Table 2. Renewable Energy Assumptions for Initial Planning Conclusions

Renewable Resource	Description	Benefits	Drawbacks	Next Steps
Most Critical Systems				
Additional Centralized Solar Generation	Development of 100 to 200 acres of campus-related land	Plentiful resource, potential for storage, more cost effective than distributed	Variable resource, low capacity factor	Identify partners and projects
Distributed Solar Generation	Photovoltaic on rooftops	Plentiful resource, scalable with load	Variable resource, low capacity factor	Investigate and develop building standards and funding sources
Plasma Gasification	Conversion of campus solid and sewage waste to steam, syngas, or electricity	Dispatchable, contributes to zero waste, ties goal to core mission (research)	Uncertainty (not commercially ready), potential permitting issues	Refine process to better estimate potential, piloting activities, seek funding
Less Critical Systems				
Hydro Generation	Purchase of 1 MW facility within campus boundary	Low cost, generates at night	Low capacity factor (uses irrigation flows)	Investigate feasibility with resource owners
Wind Generation	15 turbines, ~ 40m hub height	Potential low cost	Variable resource, few viable locations	Collect wind data, investigate technologies

Source: John Elliott, University of California, Merced

Conclusions and Recommendations

Experience at UC Merced is demonstrating that development of a zero net energy campus is feasible and that strategies being piloted may be applicable to other growing communities. While each campus will operate under unique circumstances, the experience at UC Merced suggests several recommendations for consideration by other campuses pursuing similar goals:

1. **Start with energy efficiency.** Energy efficiency will be the cheapest resource for the foreseeable future and deep efficiency is necessary to make a zero net energy goal feasible.

2. **Set bold, but achievable goals, then build on them.** At UC Merced, success in achieving a phased commitment of "Getting to 50" (50% of benchmark energy use) has gained general acceptance of the performance targets and has set the stage for a potential effort to "Strive to 25."

3. **Collect data to cultivate a living laboratory.** At UC Merced, early attention to widespread collection of building performance monitoring data helped facilitate efforts to create a living laboratory, where specific facilities-driven goals, such as zero net energy, are integrated with activities that advance the core teaching and research mission of the university.

4. **Create an organizational structure and a process to further sustainability.** The activities of the Chancellor's Advisory Committee on Sustainability at UC Merced have been critical to developing a vocabulary to discuss sustainability across the university and facilitating the conversations and actions that will help the campus achieve zero net energy.

Acknowledgements and Disclaimer

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