INSTITUTE FOR SUSTAINABILITY REPORT #2

CSUN Energy Analysis, 1990 - 2011

April 2012

California State University Northridge | Institute for Sustainability

CSUN Energy Analysis, 1990 - 2011

EXECUTIVE SUMMARY

California State University, Northridge (CSUN) is located on 353 acres in the heart of the San Fernando Valley, 23 miles northwest of the center of Los Angeles, the nation's second most populous city. The university, which is one of the fifty largest universities and colleges in the nation and the third largest in the 23-campus California State University system, serves more than 30,000 students a year with a faculty and staff of over three thousand. About 80 percent of CSUN students come from Los Angeles County. Within the campus, the University comprises six million square feet of facilities, including two dozen major buildings and more than 100 structures in total. Forty-four percent of building space houses the educational and administrative functions of the university, and the remaining fifty-five percent is dedicated to auxiliaries, which provide food, housing, recreational and student support services. The University has recently completed a $400 million campus renovation, including the construction of about a half dozen new buildings and upgrades to most existing facilities.

The university has strived to hold down energy costs and improve energy efficiency over the past two decades, whilst undergoing growth in both building area and its student population. In the massive re-building efforts following the January 1994 Northridge earthquake, energy consumption started to rise but was quickly addressed by major infrastructure changes to campus heating and cooling systems in 1998. In 2003 the campus installed its first set of solar panels, to be followed by an additional installation in 2005. In 2007 it made a significant investment in a 1 MW fuel cell plant, which has since supplied 15% of the campus's electricity demand. In addition, recent new building construction has placed emphasis on energy efficient design, with the most recent additions achieving LEED[1] gold certification for their environmentally-friendly designs.

This report documents historical trends in energy use over the past two decades and examines the relationships between energy consumption, building construction, infrastructure changes and student growth. The energy production and efficiencies of the campus's onsite energy generation facilities are analyzed and assessed.

Total electricity consumption on the campus was 4.71 million kWh/month in 2011, and at the current average price of 11.5 cents/kWh, purchased electricity costs the campus $427,000/month (2010) to $493,000/month (2011). Over the past fifteen years of growth, electricity consumption has increased by 0.9% per year[2], student numbers[3] by 2.8% per year[2], and equivalent building area[4] by 1.6% per year[2]. With the campus's investment in on-site electricity generation, the campus is purchasing less electricity now than it did fifteen years ago. Over the past five years electricity consumption on the campus has averaged 1.095 kWh/sqft per month, compared to an average efficiency for all types of commercial buildings in the western U.S. of 1.15 kWh/sqft per month, and 0.85 kWh/sqft per month for educational institutions[5]. Besides the efficiency of the cooling system and the thermal characteristics of the buildings, installed equipment and information technology play a significant role in electricity consumption.

Gas consumption amounted to 128,200 therms/month in 2011, and at the current price (75 cents/therm), gas consumption costs the campus $96,000/month (2011) to $105,000/month (2010). The campus consumes 0.030 – 0.033 therms/sqft per month (2011 and 2010 data). However, part of this gas is used as fuel for the fuel cell, without which gas consumption amounts to about 0.022 therms/sqft per month. For comparison, educational buildings in the U.S. average 0.03 therms/sqft per month, and those in the Pacific region, 0.029 therms/sqft per month[6]. Thus the university compares well with similar institutions in terms of its gas use.

CSUN's investments in on-site electricity generation have helped to reduce its electricity purchases over the past ten years with an installed solar capacity of 692 kW and a 1 MW fuel cell plant (four 250 kW fuel cells). The two photovoltaic installations have delivered power at an average load factor of 14% over their six to eight years of operation, together generating an average of 71,000 kWh/month of electricity to the campus. Their efficiency *at converting solar energy to electricity averages 8.6% over a year. The two solar installations were partially financed by local utility companies, leaving CSUN a net cost of $1.46 million. The campus has recovered almost a third of this in saved electricity costs of $471,000 over the past five years.*

In 2007 CSUN installed a fuel cell facility at a cost to the campus of $2.51 million, and has saved just over $1 million since then from avoidance of electricity costs after accounting for the cost of the fuel to run the plant. This amount does not include the fuel cost savings which result from co-generation of heat. In addition to the initial cost of the equipment and installation, the university pays a significant annual maintenance fee. Since start up, the fuel cell has generated almost 33.28 million kWh of electricity at an average efficiency of 37.17%, favorable when compared to the average efficiency of utility company power generation of 34% (31% after transmission)[7]. In 2011 the fuel cells suffered significant problems which resulted in extended shutdown periods and as a result, electricity generation for the year was only about half of that in 2010. In order for the campus's investment to pay off in the future, the plant's performance will need to return to or exceed its 2010 performance.

There is international consensus on the science of climate change and on the need for concerted action to address the global rise in greenhouse gas emissions. Under California law AB32, the Global Warming Solutions Act, greenhouse gas emissions must be reduced to 1990 levels by 2020 and to 80% below those levels by 2050. In the U.S. the energy sector is responsible for 80% of these emissions[8]. Thus reducing consumption of fossil fuels serves the multiple roles of reducing greenhouse gas emissions, reducing consumption of natural resources and their associated effects on the environment, and potentially saving on fuels costs.

In a 2007 report[9], McKinsey and Company assessed the costs and abatement potentials of more than 250 alternative strategies to reduce or prevent greenhouse gas emissions and found that almost 40% of these had negative marginal costs, such that over their lifetimes the cumulative savings in energy created by these options more than offset their costs. They determined the lowest average cost of abatement to be the category of "Improving the energy efficiency of buildings and appliances", largely due to the fact that buildings in the U.S. are relatively energy inefficient. The most potential savings come from replacement of inefficient lighting with CFLs (compact fluorescent lights) and LEDs (light emitting diodes). Under this category, CSUN can make significant improvements. A comprehensive analysis by a team of students under the direction of Dr. Ramin Vakilian calculated the savings resulting from a range of scenarios involving the installation of dimmers and LEDs in outdoor lighting[10]. Most have payback periods of less than 5 years and result in savings in lighting energy demand of up to 80% for specific installations. We recommend that the campus adopt the recommendations made, and support the ongoing efforts of this team to assess indoor lighting where the potential savings are even greater.

Electronic equipment provides the next most potential for savings in commercial buildings as a result of both increasing numbers and energy intensity of units. The campus has taken strides to address this category of energy use with its move to "thin clients" to replace classroom computers, and its research activities in control systems to enable remote (schedule and activity-based) powering on and off of equipment. Academic Affairs has also addressed the issue of increasing numbers of units through its efforts to centralize resources such as printers. We recommend that the university continue to support such initiatives and in addition, take greater consideration of energy consumption in the purchase of new equipment, which could be done through the distribution, incentivization or enforcement of a "green" products list, or a more centralized approach to purchasing in which such considerations are enforced.

Further potential for energy savings lie in heating, ventilation and air conditioning (HVAC) equipment and building shell improvements, which include the installation of reflective roof coatings, reduction of air leaks, greater insulation, dual paned windows, and window coatings for existing buildings. We strongly recommend that these potentials be evaluated, and that the campus make the appropriate investments in these improvements.

We further recommend that energy efficiencies in existing infrastructure, such as lighting and building shell improvements, be made before further solar installations are made, unless incentive monies improve the value of investments in renewable energy technologies.

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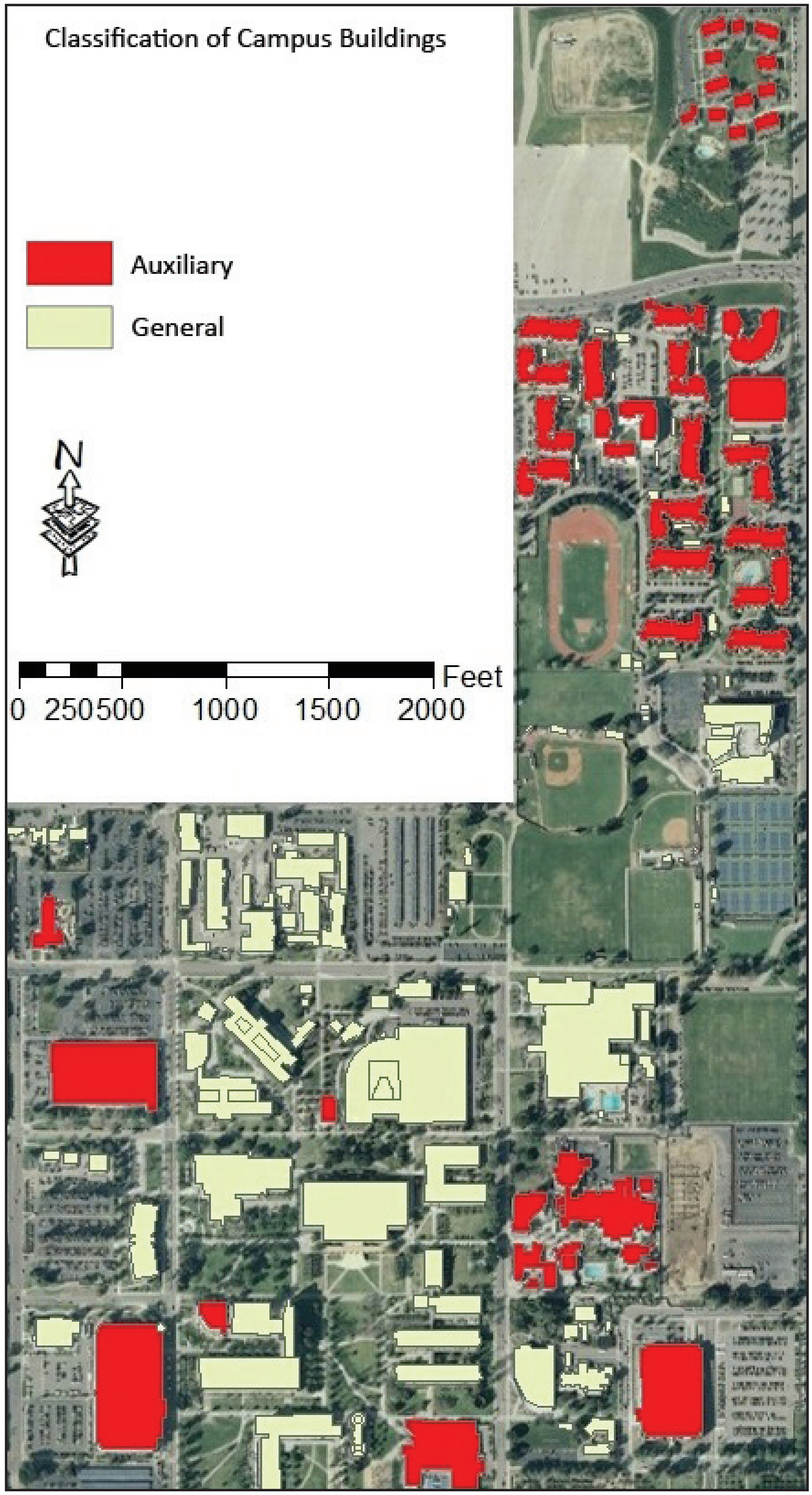
1. The CSUN Campus

Within the campus, the University comprises six million square feet of facilities, including two dozen major buildings and more than 100 structures in total. Building space (6,031,334 sq. ft.) is divided between two categories - General Funds, which include all the educational and administrative buildings (2,664,218 sq. ft.), and Non-general funds ("Auxiliaries"), which include student housing, the University Student Union (USU), the bookstore, eating establishments including the Sierra Center and Arbor Court, and other student support functions (3,367,116 sq. ft.).



1.1 Construction

CSUN's eight colleges are grouped around a quadrangle of landscaped green space and trees, which include the Oviatt library. Devastated by the 1994 Northridge earthquake, which damaged most of its major facilities, the campus has since completed a $470 million restoration of its buildings and infrastructure. Since 2000, the campus has achieved several milestones from its 1998 Master Plan, including the reconstruction of the campus loop road to improve vehicle circulation, parking pathways to allow universal access, and site lighting improvements throughout the campus. Recent major facility improvements have also been completed including a new Children's Center, the Brown Aquatics Center, the Physical Plant Management Facility, Sierra Center and Arbor Court food services complexes, three new parking structures, expansion and renovation of the USU, four new student housing facilities, and a

General funds			Non-General fund		
Date	**Facility**	**sq. ft.**	**Date**	**Facility**	**sq. ft.**
1991	Oviatt Library addition	108,838	**1991**	Satellite Student Union	32,882
1992	Citrus Hall	37,572		Lupine Hall	62,560
	Magnolia Hall	31,795		Saguaro Hall	65,836
	Sagebrush Hall	32,000		Heather Hall	63,165
1993	Education building	111,196		Rose Crown Hall	66,138
	Noski Auditorium	4,137		Bougainvillea Hall	67,306
	Juniper Hall	141,478	**1995**	University Student Union	82,876
2000	Sequoia Hall	83,850		Plaza Del Sol Performance Hall	19,490
	Art & Design Center Expansion	29,036	**2001**	Children's Center	12,275
	Main Distribution Facility	4,017	**2003**	Sierra Center	31,037
	University Hall	84,000		B5 Parking Structure	430,064
2001	Manzanita Hall	86,873	**2005**	B3 Parking structure	683,215
2003	Center for Adaptive Aquatic Therapy	18,000	**2007**	USU expansion-Sol Center	28,000
2004	Matador Hall	9,000		Arbor Court	4,320
2006	Parking and public safety admin	25,917	**2008**	G3 Parking structure	436,425
2009	Chaparral Hall	90,603	**2009**	Mariposa Hall	29,244
2010	Valley Performing Art Center	166,000		Toyon Hall	57,569
				Hawthorn Hall	5,849

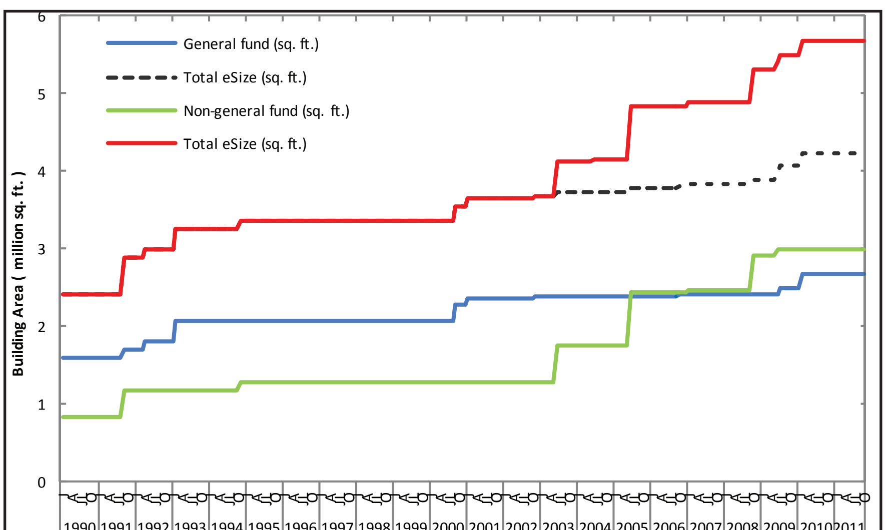


Figure 2. Campus construction projects and change in building floor area, 1990 - 2011. eSqFt = "equivalent" area, with reduced weighting for parking structures (see text).

new Science building. Building area growth associated with new construction since 1991 is shown in Figure 2 and listed in the accompanying table.

I.2 Students

After falling in the early 1990s, the number of Full-Time Equivalent Students (FTES)[3] climbed steadily throughout the second half of the 1990s and the 2000s following the recovery from the 1994 earthquake. It reached a record of almost 30,000 in Fall 2011, when there were 25,260 full-time and 6,244 part-time students enrolled at CSUN. The historical trend in student enrollment is shown in Figure 3[11].

1.3 Energy Consumption

The university is supplied utilities by the Los Angeles Department of Water and Power (LADWP) and the Southern California Gas (SCGas) Company. Electricity supply is supplemented by self-generation facilities which include four fuels cells and six microturbines which generate electricity from natural gas, and solar panels which utilize photovoltaics to generate electricity from sunlight. In the analysis which follows, energy consumption is broken down by fuel type and sector.

Monthly utility bills from LADWP (electricity) and SCGas (natural gas) dating back to 1990 were obtained from Physical Plant Management (PPM) and used in this analysis. Educational and administrative buildings on campus which are supported through campus general funds are, for the most part, on a single meter, although the newest buildings have their own sub-

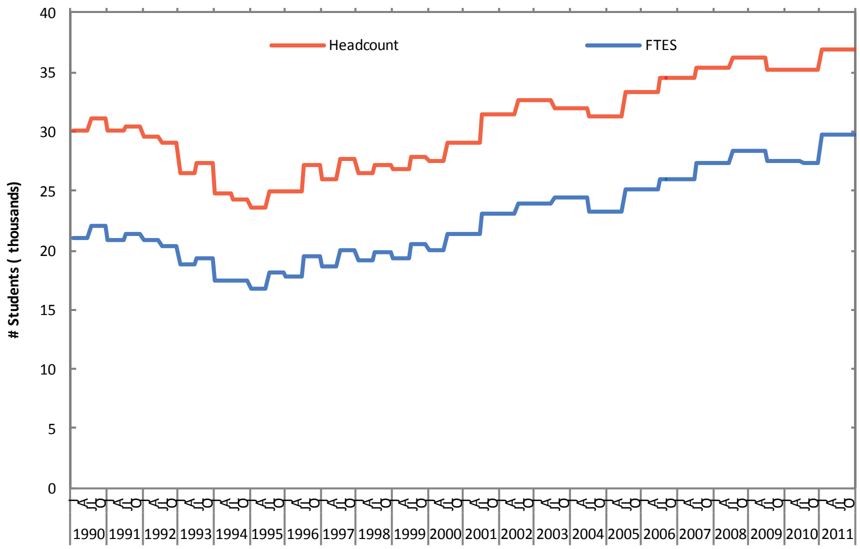


Figure 3. Number of Students, 1990 -2011.

meters. Thus data shown for the campus “general fund” include the total consumption from all such buildings together. Auxiliaries on the other hand, which are self-supporting, are individually metered and billed for utility use, so data can be broken down by sub-unit.

2. Electricity Consumption

Electricity use by sector for the campus is shown in Figure 4. Monthly consumption data are shown together with the moving average of the preceding 12 months. The moving average is useful for determining trends as it is not subject to the same seasonal variations which are apparent in the monthly records. Since these consumption data are taken from utility bills, they do not include electricity supplied by self-generation facilities (solar, fuel cell, microturbines). These totals will be considered later in the report. Cooling of campus buildings in hot weather is provided via chilled water which is pumped around the campus via underground pipes to provide air conditioning. In order to minimize the cost of cooling buildings, the water is chilled at night when utility rates are lowest and the cold water (39° F) is stored in a 2.3 million gallon tank from which it is pumped to buildings via a circling pipeline during the day. Electricity is distributed through four substations A-D to power lighting, IT, plug-in devices and appliances, laboratory and other equipment, and cooling for the buildings which are not connected to the chilled water loop (e.g. the University Club, Police Station, University Student Union).

Monthly consumption peaks mid-year between May and July as the demand for air conditioning increases and is lowest during the winter months. There is approximately a 2 million kWh difference in consumption between maximum and minimum, representing a 60% swing.

As can be seen in Figure 4, there was an increasing trend in the total campus electricity consumption between 1990 and 1993, which is broken by the earthquake in January 1994. Following the earthquake, consumption fell for about a year as the university re-built and then began to rise in late 1994 until the latter 1990s. In 1998, in an effort to control increasing energy consumption, PPM completed the construction of a new Central Plant which provides chilled water from the thermal storage tank. The tank is replenished with cold water generated at night and on weekends and provides chilled water throughout campus buildings at peak demand during the day. The improved efficiency of this air conditioning system led to a reduction in electricity consumption which fell until 2000 when demand again started to climb. In 1995-1997 PPM installed microturbines in the Central Plant facility, which use natural gas to drive turbine engines and generate electricity. They are rated with a nominal output of 180 kW, and operating at around 80% efficiency they are capable of injecting about 150 kW of power into substation D. An important factor in increasing the overall efficiency of these microturbines is the added heat recovery system. The hot exhaust from the microturbines is captured and used to heat the water flowing through the hot water loop which provides heating to buildings on campus.

In a joint undertaking by the engineering faculty and PPM in 2003, the campus installed its first photovoltaic project in parking lot E6. The installation includes more than 3,000 solar panels with a combined nominal capacity of 225 kW, sending the generated electricity to Substation B. Two years later, a second plant was completed in parking lot B2 with an additional 2,832 panels, supplying Substation C with up to 467 kW (nominal capacity) and increasing the campus's total solar capacity to nearly 700 kW. These projects have helped to control electricity purchase in the face of rising student numbers and building construction. In 2007, the campus completed construction of a new fuel cell plant containing four fuel cells, each with a capacity of 250 kW. This 1MW facility generates electricity through the chemical conversion of natural gas and utilizes a novel barometric trap, designed in-house, to capture and combine the waste gases in order to utilize their associated heat. The waste heat is used to heat water to 240° F which is then pumped into the campus hot water loop. The latent heat recovered from the fuel cell exhaust is used to heat the swimming pool. The waste water from the fuel cell water treatment system is stored in a 12,000 gallon tank and used to irrigate a quarter acre of rainforest, which was installed adjacent to the fuel cell plant for the purpose of sequestering its waste stream (water and carbon dioxide). The electricity generated by the fuel cell plant supplies power to campus Substation A. A marked decrease of more than 10% in purchased electricity is evident after the fuel cell was started up at the beginning of 2007 (Figure 4).

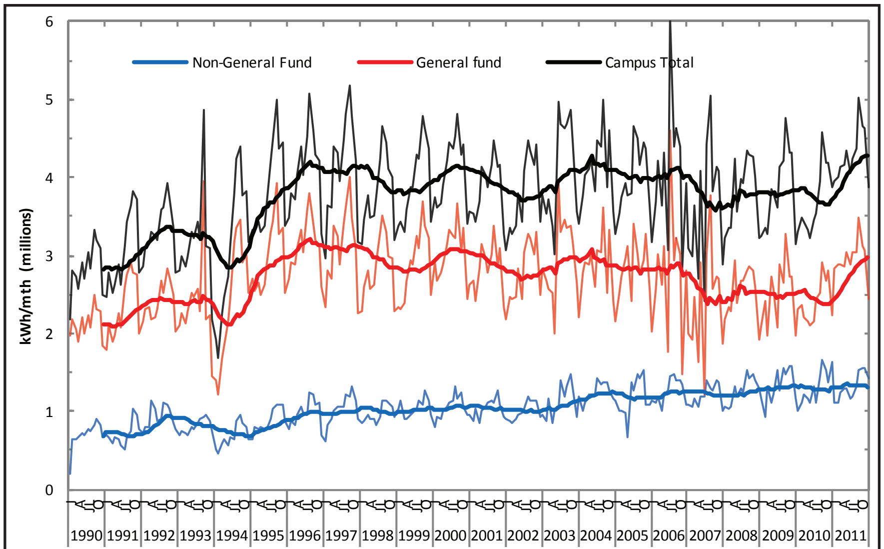


Figure 4. Purchased electricity, 1990- 2011

In Figure 4 one can see a clear difference in the consumption trends between General and Non-general Funds. Whereas General Fund electricity purchase has experienced many fluctuations during last 20 years, the Non-general fund use shows only small changes with a slow but steady increase over the past 15 years. Campus energy infrastructure changes (such as the installation of fuel cells and solar panels) have affected the amount of purchased electricity in the General Fund total, whereas auxiliary (Non-General Fund) purchases from LADWP are independent of internal campus energy generation.

Since the campus has grown over the past twenty years and continues to grow, it is instructive to examine normalized energy use (per unit building area) in order to assess the efficiency of new construction and infrastructure. Figure 5 shows monthly electricity purchase per gross square foot of floor space. (Figure 2 shows building square footage.)

In the case of Non-General electricity use, normalized consumption (per sq. ft.) declined significantly in the early part of the 1990s, increasing from the mid 90s until the end of 2004 and showing variability but falling slightly since then. The individual components responsible for these changes are examined in more detail in the following sections of this report but the latter decline presents a challenge of how to factor in the square footage associated with parking structures. Since parking structures do not require heating, air conditioning or plug-in loads, their energy use is expected to be significantly lower than other buildings and thus their inclusion in gross building area can be misleading. They can either be eliminated from calculations completely (which would lead to inaccuracy by virtue of their significant lighting requirements) or be given less weight. In this analysis we have applied a weighting of 7% to them in order to compute equivalent gross square footage (eGSF), as recommended by the campus energy manager. This area is shown as eSqFt in Figure 2. The resulting normalized consumption shows significantly less efficiency for the Non-General fund in comparison to the campus General fund. Most of this consumption takes place in the university student union (USU) and campus housing,

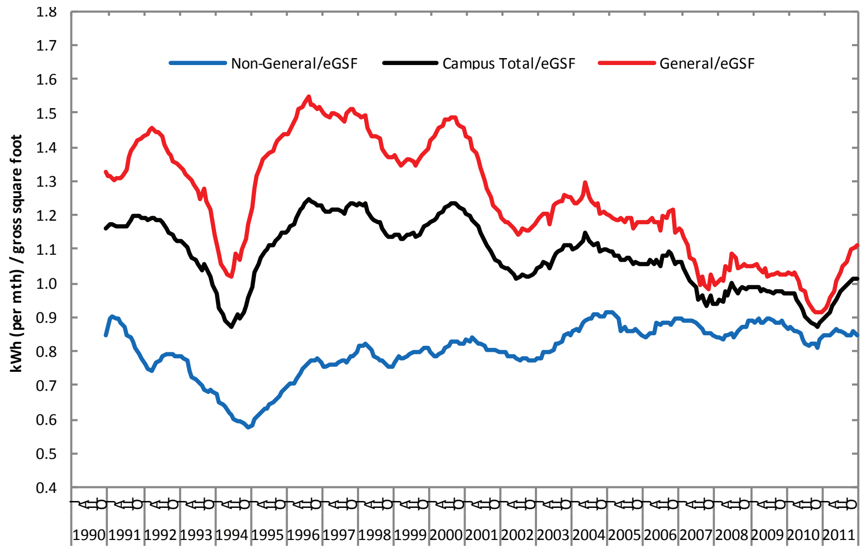


Figure 5. Purchased electricity per gross square foot of building space, 1990 - 2011

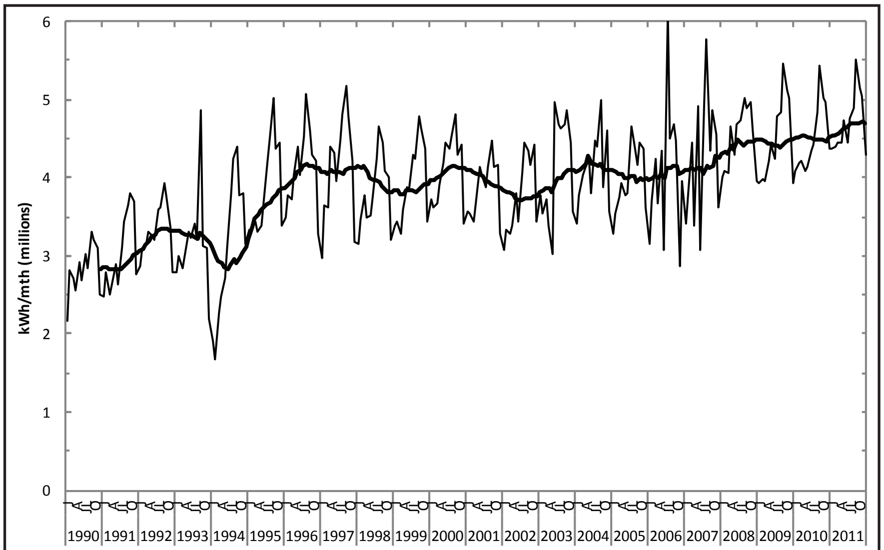


Figure 6. Consumed electricity (including on-site generation), 1990 - 2011 .

which are larger relative users of electricity than classrooms and administrative buildings.

Figure 5 shows how the campus total electricity purchase per unit area has fallen since the late 1990s, most notably in the periods 2001 – 2003 and 2007 – 2008, which correspond to periods of campus growth and to the installation of the fuel cell.

In 2011 campus electricity use per building sq ft rose ocnsiderably due to the partial shutdown of fule cell generation for much of the year. In order to examine how the pattern of overall consumption has changed, self-generated electricity is added to the purchased amount and shown in Figure 6. In comparing this to Figure 4 the dip in purchased electricity between 2007 and 2011 has been compensated for by self-generation and overall consumption has been constant over the past four years. Electricity use per sq ft of building area shows a slight improvement since the mid-1990s (Figure 7) to 1.1 kWh/sqft per month, currently. Use per FTES shows a more marked improvement since the mid 1990s, and a slight one over the past ten years, and currently stands at about 159 kWh/FTES per month.

2.1 Electricity Use by Auxiliaries

Consumption of electricity by Non-General funds can be broken down by unit because of the separate metering of each building. Figure 8 shows this breakdown by campus auxiliary.

Housing accounts for 43% of consumption so energy conservation measures and efficiency improvements should first be directed here. In a recent audit of campus housing it was noted that although energy efficiency measures have been installed in housing, student practices are poor and often negate these. Thus education is an essential component of any efficiency improvement effort. The USU is the next largest consumer of energy (23%) in the auxiliaries, followed by the bookstore (14%), the satellite student union (6%) and parking (almost 5%). The temporal changes in each of these units is examined below (Figures 9 and 10).

2.2 Housing

Campus housing accounts for nearly half of the Non-General fund electricity use. Utility bills for residential apartments are issued every other month and for the common areas, every month.

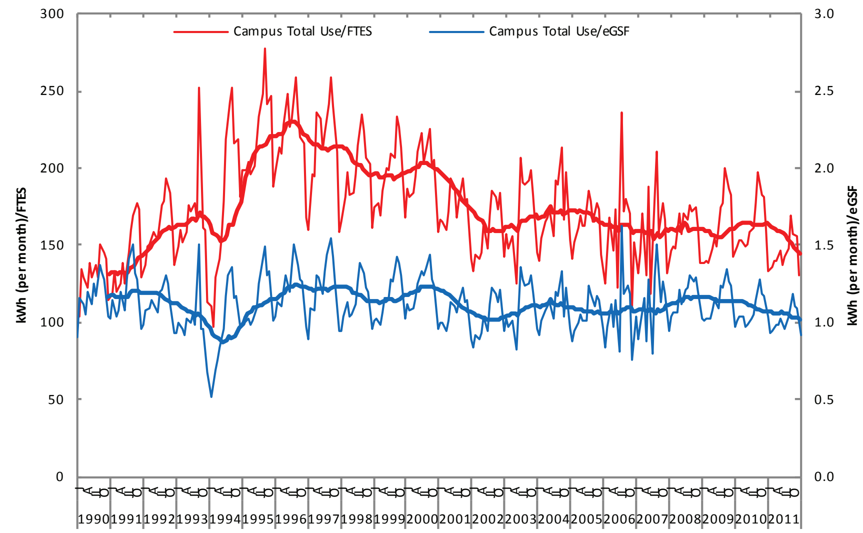


Figure 7. Consumed electricity (including on-site generation) per FTES and per sq ft of building area, 1990 - 2011.

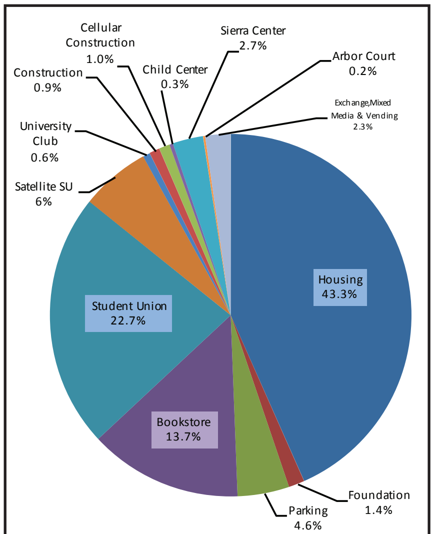


Figure 8. Electricity consumption by auxiliaries, 1990 - 2011.

In order to maintain consistency between data, the bi-monthly data is halved and added to the common area data to generate monthly consumption. The seasonality of the consumption shows up clearly with peak consumption occurring in September when students return to campus and the weather is hot. The overall trend of consumption in student housing shows a large reduction in 1994 due to the Northridge earthquake. The University Park Apartments suffered major damage which forced their temporary shutdown for a semester. During this time repairs were conducted which included the installation of central hot water to new buildings and retrofitting to the lighting. Some temporary dome structures were opened up in the housing area to host students during the construction period. University Village apartments were never closed because their wooden structure withstood the earthquake well. The Police Department and radio station were temporarily settled in the dormitories for few months immediately following the earthquake. An increase in electricity consumption occurred between 1994 and 1997, probably as a result of the rebuilding, and then consumption flattened out and has remained fairly constant from the latter 1990s to date.

2.3 University Student Union

The USU comprises food services (Subway, Freudian Sip and Sport Pub), the fitness center (now part of the Student Recreation Center), swimming pool, Wells Fargo Bank, convenience store, and conference facilities including the Sol Center, Northridge Center and Grand Salon. Before the earthquake in 1994 the average monthly electricity consumption for the USU was less that 150,000 kWh (Figure 9) but post-earthquake construction

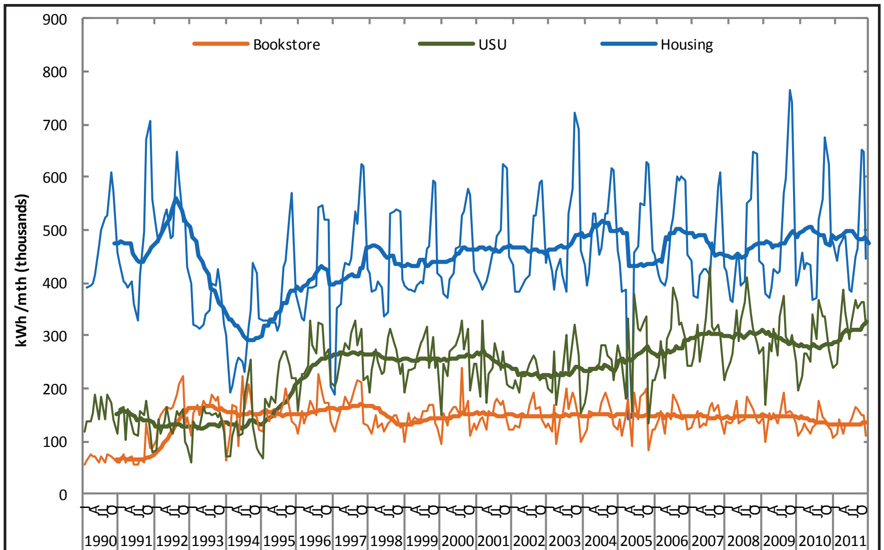


Figure 9. Electricity consumption in campus housing, the USU and the bookstore, 1990 - 2011.

raised consumption to more than 250,000 kWh/mth in the following years, rising to 300,000 kWh/mth by 2008. Over 100,000 sq ft of building space was added to the USU in 1995 and another 28,000 sq ft in 2007. With the exceptioon of the newly constructed Student Recreation Center, none of the USU buildings are connected to the campus hot/chilled water loop, so they are responsible for their own heating and air conditioning. Of the Non-General fund consumers, the USU is the second largest after housing.

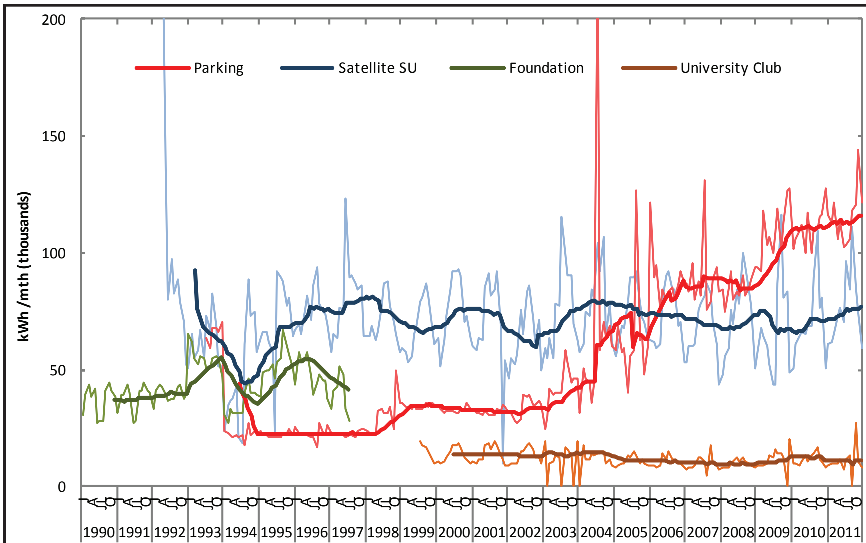


Figure 10. Electricity consumption in the Satellite Student Union, Parking, the Foundation and the University Club, 1990 - 2011

2.4 Book Store Complex

In late 1991, 108,838 sq. ft. of floor space was added to the bookstore which increased its electricity consumption dramatically. Since 1992 the bookstore has shown a fairly constant electricity demand, apart from a drop in 1998 which resulted from its connection to the campus's hot and chilled water loops. This caused consumption to fall almost 20% from an average of 160,000 kWh/mth to about 130,000 kWh/mth. Within two years it had risen back to an average of 150,000 kWh/mth, a level which it has stayed just under for the last decade.

2.5 Satellite Student Union

The satellite student union comprises a dining facility that serves student housing, a computer lab. and meeting rooms. Electricity consumption has amounted to around 60,000-80,000 kWh/mth for the past 15 years or so (Figure 10).

2.6 Parking

Since the construction of the first multi-storey parking structure in 2003, electricity use for that sector has risen and tripled in less than 6 years (Figure 10). Because of safety concerns lights in the structures are left on all night. During the day, natural light is supplemented by lighting from about a third of the available lights. The lighting requirements of the structures have resulted in parking overtaking the bookstore complex to become the third largest electricity consumer in auxiliaries at 120,000 kWh/month, costing about $15,000 per month. This is an area where there is potential for energy and cost savings.

2.7 Foundation

'Foundation' was the name assigned to a series of auxiliary sectors including the vending machines, food services, convenient stores and copy shops pre-1997. After 1997, the foundation became The University Corporation (TUC) and was split into different segments. Food services (Sierra Center and Arbor Court) became independent (and currently account for less than 5% of the electricity consumption of auxiliaries), vending machines are now assigned fixed billing based of the number of the machines and the operating hours per month and billing is combined with the convenience store (the "Exchange") under the title "Exchange, Mixed Media and Vending", which accounts for about 2% of electricity use.

2.8 University Club

Since 2000 the University Club has served as a dining service for the campus community and hosts community and campus events. The seasonal change in electricity consumption is clear (Figure 10) but the annualized average shows a fairly constant consumption rate over many years, but with a slow decline starting in the mid 2000s of about 20%.

3. Gas Consumption

Gas use by sector for the campus is shown in Figure 11. Monthly data are shown together with moving averages for the preceding 12 months. These data exhibit a strong seasonal cycle, peaking in mid winter when temperatures fall and heating is in demand around the campus, and falling in summer when gas is only used for hot water and cooking.

Gas consumption by General Fund operations declined from 1990 for about 5 years, rising again with rebuilding efforts after the earthquake. In 1998, in an effort to improve energy efficiency, PPM completed the construction of a new Central Plant which provides heating to the campus via hot water boilers, which replaced the old steam boilers. The three hot water boilers work on demand, controlled by a computerized Siemens energy management system located in the Central Plant. Water is heated to 190-200^{o} F and pumped into the hot water loop around campus where it is fed into heat exchangers within the buildings to provide hot air to offices and classrooms. By the time the hot water returns to Central Plant after its loop around campus its temperature has fallen to about 150^{o} F and must be re-heated before it is re-circulated. The efficiency of the boilers is very much higher than the older steam boilers and as a result, has reduced the campus gas consumption significantly since their installation in 1998.

In the mid-late 90s PPM installed microturbines in the Central Plant facility. These use natural gas combustion to drive turbine engines and generate electricity. They are rated with a nominal total output of 180 kW, and operating at around 80% efficiency they inject about 150 kW of power into campus substation

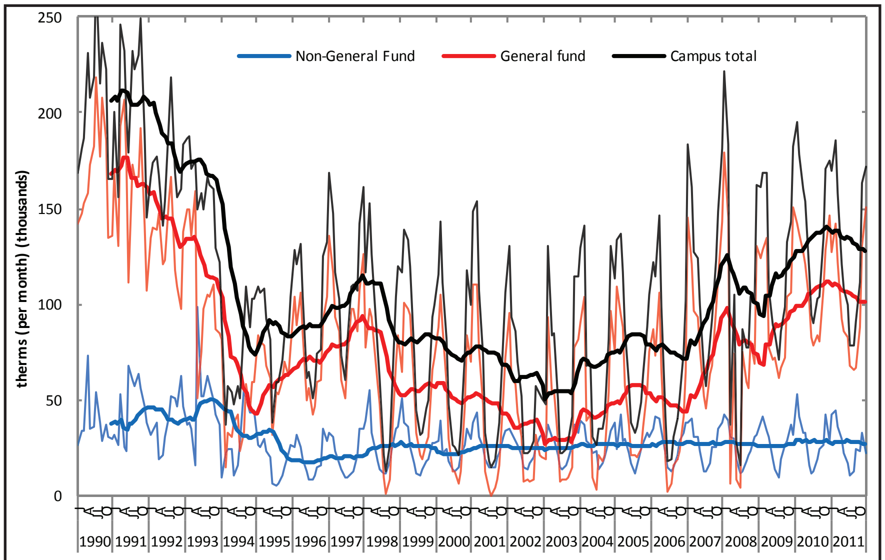


Figure 11. Gas consumption, 1990 - 2011.

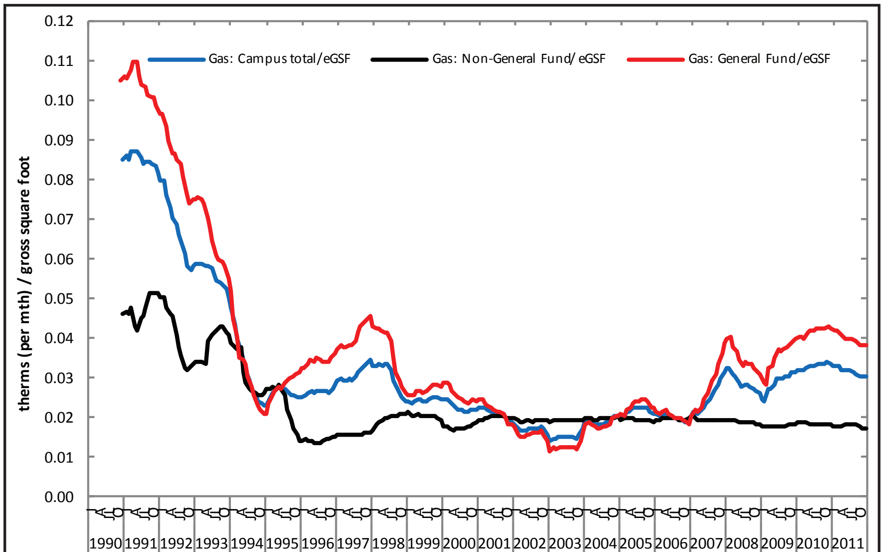


Figure 12. Gas consumption per gross sq ft of building area, 1990 - 2011.

D. This had a slight effect on gas consumption. Consumption rose suddenly after the fuel cell (which converts gas to electricity) started its operation in 2007. The jump in early 2007 was due to adjustment and testing, and later consumption increased but has varied depending on the number of fuel cells in use. In 2010 all four fuel cells were working full load, but in 2011 there were periods of shutdown.

Gas consumption by auxiliaries increased for a short period in the early 1990s and then stayed fairly constant for 3 years, decreasing significantly after the 1994 earthquake. Since rebuilding, gas consumption in auxiliaries has risen slowly then remained consistently at its 2000 level, which is lower than pre-earthquake consumption.

Figure 12 shows how there has

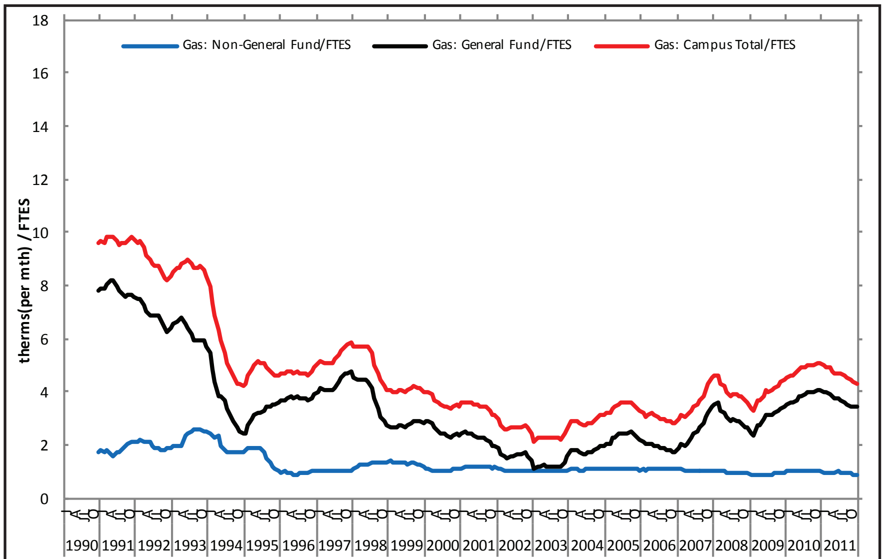


Figure 13. Gas consumption per FTES, 1990 - 2011.

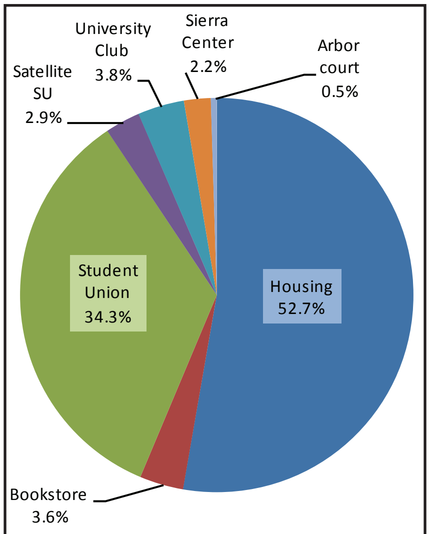


Figure 14. Gas consumption within auxiliaries, 1990 - 2011.

been a significant improvement in energy efficiency with regard to gas consumption per sq ft of building area since the early 1990s.

Construction in 1992 and 1993 together with the efforts to reduce energy consumption on campus through the construction of the new Central Plant improved the heating efficiency of buildings throughout the 1990s until 2007. A rise in consumption was caused by the installation of the fuel cells in 2007, and consumption per sq ft has remained almost constant since then as both usage and building area have increased together. Gas consumption per FTES (Figure 13) follows a very similar trend.

3.1 Gas Use by Auxiliaries

Gas use within the Non-General fund is broken down by unit in Figure 14, from which it can be seen that student housing (52%) and the University Student Union (35%) dominate consumption.

3.2 Housing

Figure 15 shows a very strong seasonal component to gas consumption in housing, wherein winter monthly consumption more than doubles that in the summer. After a decline in the early 1990s there was an additional drop following the 1994 earthquake when the gas distribution to housing was completely shut down for an extended period of time. By 1996, gas consumption in the dormitories started to rise dramatically as evacuated buildings were being put back into use after repair. Use rose until 2007 when a retrofit project in which tankless water heaters were installed in the dormitories caused a slight decline. For most of the past decade consumption held fairly steady at around 16,000-17,000 therms/mth until the end of 2009, when 92,000 sq ft of new dormitory

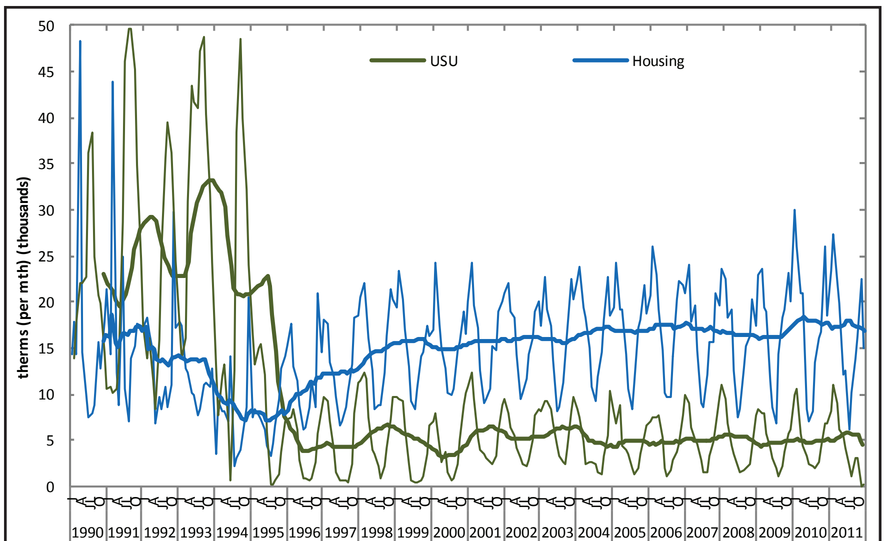


Figure 15. Gas consumption within auxiliaries, 1990 - 2011.

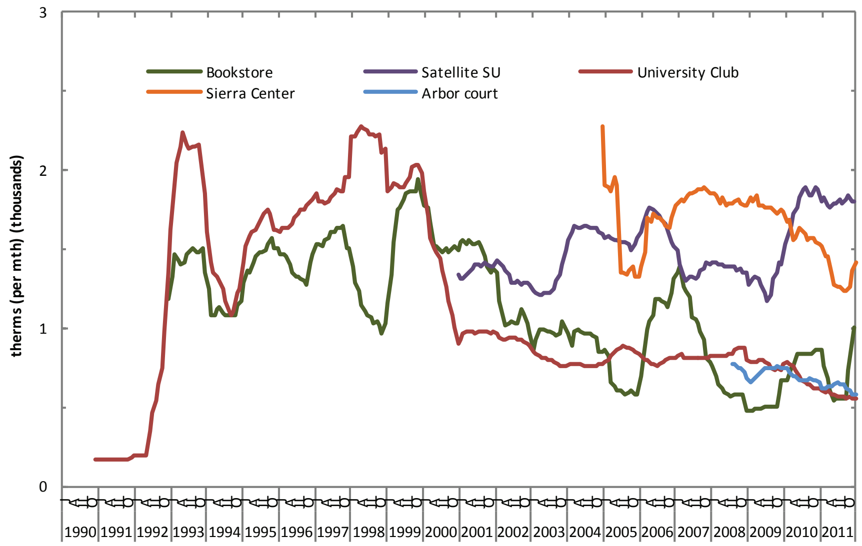


Figure 16. Gas consumption in the Bookstore, Satellite Student Union, University Club, Sierra Center, Arbor Grill, 1990 - 2011.

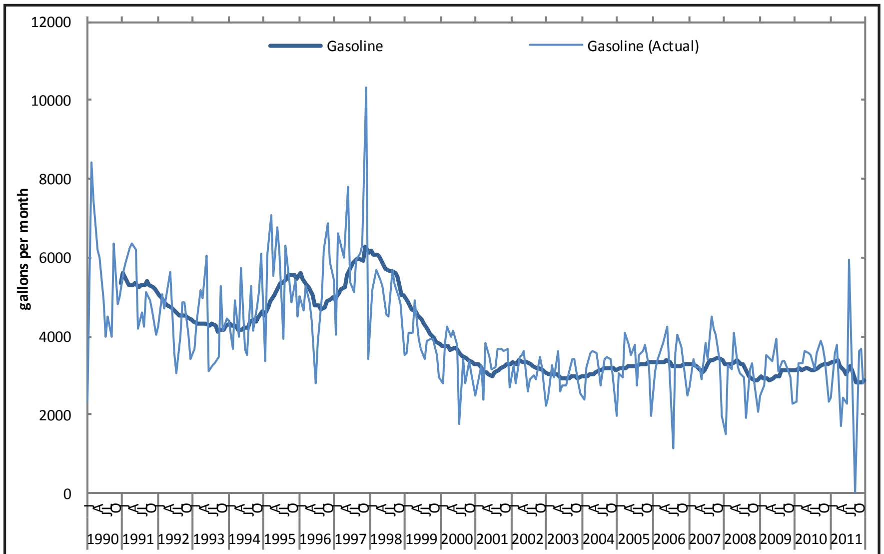


Figure 17. Gasoline consumption, 1990 - 2011.

space was added and consumption rose again. Gas consumption per unit area in housing has actually declined a little over the past two years.

3.3 University Student Union

As shown in Figure 15, gas consumption in the USU fell abruptly in January 1994 when the gas was shut down completely for a few months. Soon after, the USU chef retired and the USU decided to close its restaurant in 1995. Consequently gas consumption fell from 20,000 therms/mth to about 5,000 therms/mth, where it has remained since.

Figure 16 shows gas consumption data for the remaining auxiliaries. The bookstore was one of the only auxilaries which was not damaged significantly by the 1994 earthquake. Gas consumption is low (only about 4% of the Non-General total) and decreasing. The average gas usage is low for all these sub-units (less than 2,000 therms/mth) and there is considerable variability according to the number and type of meals served, and the weather.

4. Gasoline Consumption

CSUN owns and operates 222 vehicles (136 carts and 86 other vehicles). Ninety-four of these are used by PPM for construction projects and maintainance. Forty-eight of the vehicles are trucks, which are gradually being transitioned from diesel to gasoline and/or being replaced by smaller electric vehicles where possible. In addition to using electric golf carts to get around campus, PPM personnel use bicycles to minimize fuel usage.

A result of the move to electric vehicles and pedal power has been a gradual decline in the number of gallons of gasoline purchased as shown in Figure 17. Currently the university vehicles consume about 3,000 gallons of gasoline per month. The remainder of the vehicles, thirty-eight in total, are “exempt“ and are used by police department and parking services.

5. On-site Energy Generation

5.1 Fuel Cell

In 2007 a 1 MW fuel cell, installed at CSUN’s old steam boiler plant, began operation. The plant specifications were written by personnel from the university’s Facilities Planning, Design and Construction together with faculty and students from the College of Engineering and Computer Science. The installation included four 250 kW stacks (now upgraded to 300 kW), installed in-house by CSUN Physical Plant personnel. The fuel cell plant provides electric power to two 1000-ton chillers, located in the chiller plant directly beside the fuel cell stacks. PPM staff worked with engineering faculty and students to design and construct an integral barometric trap, a unique and innovative mechanism to combine and recover heat from the waste gases from the four separate stacks. These gases exit the fuel cells at temperatures between 650°F and 750°F, and are fed into a heat recovery system. PPM, faculty and students collaborated on the design and construction of an adjacent quarter acre of rainforest to sequester the carbon dioxide and waste water from the fuel cell plant. The gases are sprayed into the rainforest area through a system of pipes and diffuser towers controlled by valves within the plant building.

The fuel cell facility was installed at a total cost of $5.26 million, partially funded by incentives of $500,000 from the Los Angeles Department of Water and Power (LADWP) and $2.25 million from the Self Generation Incentive Program (SGIP)[12]. The SGIP is a California Public Utilities Commission (CPUC) program administered by the gas utility, Southern California Gas Company, in CSUN's case. The net cost to CSUN was $2.51 million. The university contracts with the fuel cell manufacturer, FuelCell Energy, Inc., for annual maintenance, which includes stack replacements. There is a substantial annual maintenance fee associated with this.

CSUN was the first institution in the world to have a grid connected fuel cell, which upon startup became only the eleventh operating 1 megawatt fuel cell plant in the world and the only one of that size operating in any college, institution or school (as of 2011). In addition the fuel cell is unique in that its emissions are recycled for sequestration and rainforest productivity, and used for research purposes by departments within the university.

Fuel cells produce electricity via chemical reaction rather than the conventional combustion process. Their advantage over conventional fossil fuel combustion is their increased efficiency (typically 40 – 60%) versus traditional power

Figure 18. Fuel Cell installation

Figure 19. Inside chiller plant facility adjacent to fuel cells.

Figure 20. Rainforest controls inside chiller plant adjacent to fuel cells.

plant efficiencies of 34%[7]. When the waste heat from the fuel cell is captured in a CHP (combined heat and power) system, as is done at CSUN, the combined efficiency can be as high as 80%. Mobile fuel cell systems designed for vehicles ("hydrogen cars") use hydrogen as a fuel and a proton exchange mechanism/polymer electrolyte membrane (PEM) to generate electricity at relatively low temperatures (typically around 80° C). The heat from these is wasted. In high temperature fuel cells such as those at CSUN, the operating temperature is several hundred degrees and the heat generated is captured and used for other purposes, thus raising the overall efficiency of the system. Other advantages of fuel cells over fossil fuel combustion are the reduced emissions associated with electricity generation. Fuel cells produce virtually no nitrogen oxides (NOx), carbon monoxide (CO), sulfates (SOx), volatile organic compounds (VOCs) or particulates (PMs). Conventional electricity generation in California produces 0.62 lb NOx and 0.53 lb SO_2 per MWh of electricity generated[13]. In addition fuel cells emit lesser amounts of greenhouse gases compared to conventional power generation, 520 – 680 lbs CO_2 per MWh for a system like CSUN's[14] which utilizes heat recovery compared to the average for utility companies in California of 724 lbs/MWh[13].

The plant at CSUN comprises molten carbonate fuel cells (MCFCs) which operate at a temperature of around 650° C and use lithium potassium carbonate salt as the electrolyte. One advantage of this type of fuel cell is its flexibility with regard to fuel choice, since the higher temperature of operation allows hydrogen to be formed internally from a range of fossil fuels. At CSUN, natural gas (or methane), CH_4, is used. At the high operating temperature the electrolyte melts and allows the negative carbonate ions produced by it to flow through the cell and combine with hydrogen from the fuel (natural gas) at the anode. This chemical reaction produces water, carbon dioxide, and electrons at the anode. The electrons then travel around an external circuit (wire) to the cathode, producing an electric current. At the cathode, carbon dioxide (from the anode) reacts with oxygen (from the air) and the arriving electrons to produce carbonate ions and replenish those consumed from the electrolyte.

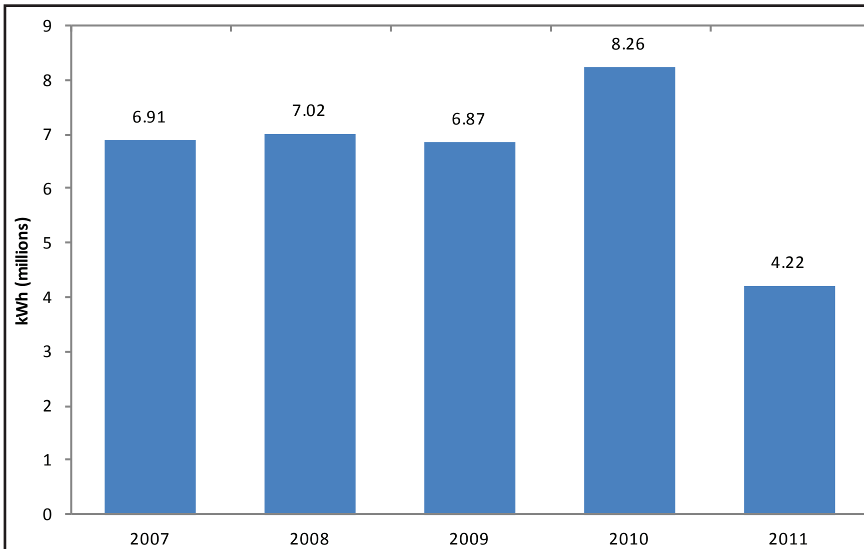


Figure 21. Annual electricity generation by fuel cell.

The fuel cells release hot waste gases – carbon dioxide and water vapor – at a temperature of 650°F -750°F. These are captured and travel through a heat exchanger, where most of their heat is transferred to the campus's hot water loop, reducing the temperature of the waste stream down to 170°F. In this first heat exchange the hot gases provide heating for buildings around the campus. Following that first exchange, a second exchanger recovers the latent heat of condensation, heating water to 140°F for use in the adjacent (USU) swimming pool and for domestic hot water in the dining services within the USU. The resulting (cooled) waste water and carbon dioxide are then used to irrigate the adjacent rainforest through eight cooling towers placed within the site.

After start up and an initial testing process, the fuel cell officially began operating in July 2007 and has been operating continually since then, although the maintenance of the cells and replacement of stacks has led to their operation at less than maximum capacity periodically during this time. Figure 21 shows the annual amount of electricity generated by the plant since installation.

Figure 22 shows the monthly fuel cell electricity output, input gas energy content, and net efficiency since operations started up. As can be seen, the electricity generation has shown significant variability (depending largely on the number of fuel cells operating). In 2007 the plant generated around 6.9 million kWh of electricity from natural gas having an energy content of 65,301 MMBtu (19.13 million kWh) for a net efficiency of 36.1 % (Annual efficiency averages are shown in Figure 23).

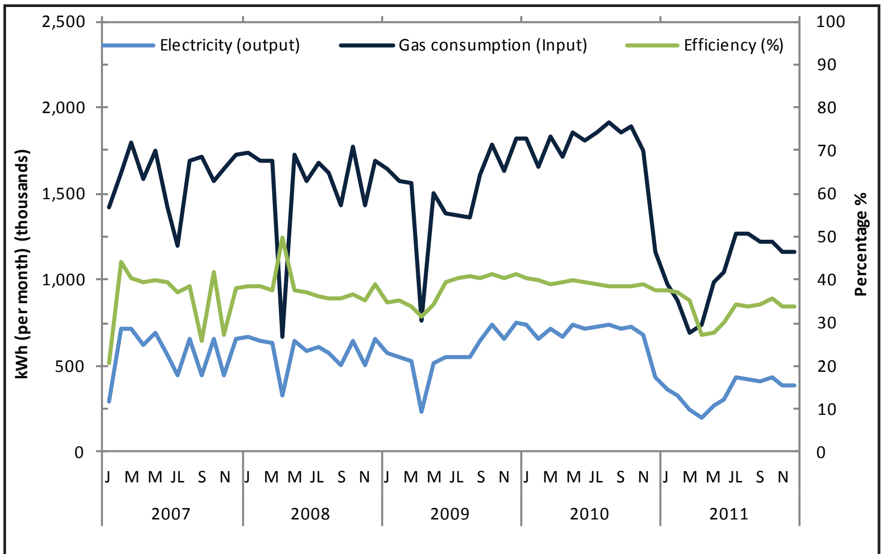


Figure 22. Monthly electricity generated by fuel cell (kWh), energy consumed in power production (kWh), and resultant efficiency (%, see RH axis).

In 2008, the output electricity of the plant was approximately 7 million kWh, and the gas consumption 63,799 MMBtu (18.69 million kWh), resulting in a slightly increased efficiency of 37.6%. There was an abrupt fall in electricity generation in April 2008, when maintenance operations caused one of the generators to be shut down.

In 2009 the fuel cell plant efficiency rose to 38.1% but the generated amount of electricity decreased to 6.87 million kWh, and the amount of gas consumed fell to 61,513 MMBtu (18.02 million kWh). As in 2008, one of the generators in the plant was shut down in April. This drop can be easily seen in both

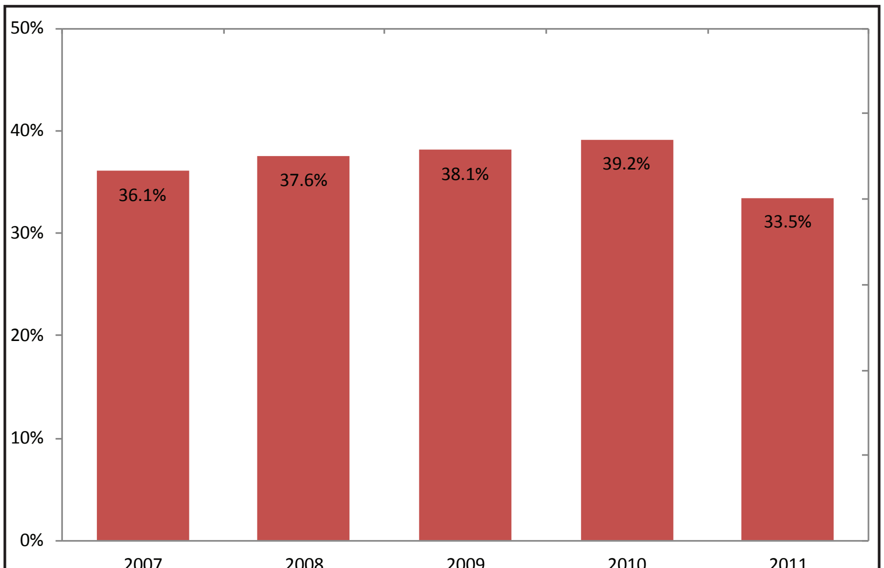


Figure 23. Annual electricity production efficiency from fuel cells.

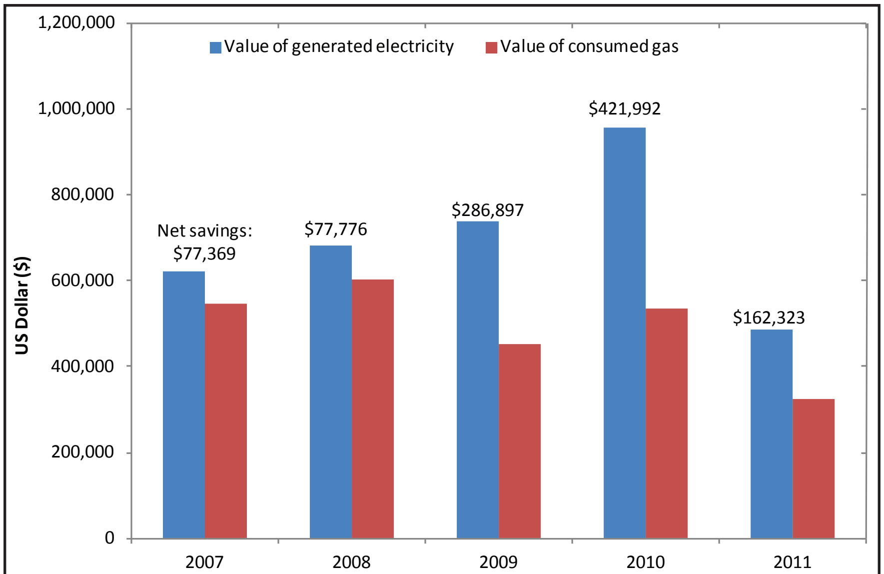


Figure 24. Annual fuel costs and savings associated with fuel cells since startup

input and output in Figure 22.

In 2010 the fuel cells operated without any shut downs until the end of the year and reached a record efficiency of 39.2% for the year. They generated 8.26 million kWh of electricity and consumed 71,952 MMBtu (21.1 million kWh) of natural gas.

In 2011 the fuel cell plant suffered partial shut downs for much of the year and generated only 4.22 million kWh of electricity whilst consuming 43,028 MMBtu (12.61 million kWh) of natural gas. Its efficiency was also down at 33.5% for the year.

Since start up, the fuel cell has generated almost 33.28 million kWh of electricity at an average efficiency of 37.17%.

The fuel cost savings to the university as a result of the campus fuel cells can be computed as the value of the electricity generated minus the cost of the natural gas consumed. This calculation was performed on a monthly basis since the start of fuel cell operation. Actual monthly costs of natural gas and electricity were employed in these calculations, thus month to month variability results from gas consumption changes, variation in amount of electricity generated, and variations in the prices of natural gas (costs) and electricity (savings). Fuel cost and the value of the electricity generated by the fuel cell are shown in Figure 24. The difference between adjacent bars shows the annual fuel cost savings. The large variability is as dependent on utility prices as on fuel consumed or energy produced. Since the beginning of 2007, the university has saved $ 1,026,358 in energy costs from the fuel cells.

5.2 Rainforest

A quarter acre of rainforest (Figure 25) was constructed on an area adjacent to the campus fuel cell for the purpose of sequestering its waste stream. Even though carbon dioxide emissions are lower than would be the case with conventional power generation, there is still some CO_2 in the waste stream. After passing through the latent heat-recovery coil, this CO_2-rich exhaust is directed into a recovery chamber and then, together with the waste water, to a series of eight diffuser towers distributed within the rainforest. Waste water from the fuel cells collects at a rate of about 6.3 gallons per minute (9,000 gallons per day) in a 12,000 gal

Figure 25: Rain forest during construction, 2007

Figure 26. Water and carbon dioxide irrigation taking place from rainforest tower.

storage tank and is used to irrigate the rain forest through a gravity flow system. The warm, humid air is drawn down through the towers and pumped out in all directions around the towers during the day (when photosynthesis is taking place) to help the plants grow bigger and faster (Figure 26). BioChar was added to the soil to promote growth of the tropical plants. BioChar also assists in the natural sequestration of CO_2 from the atmosphere by the soil as well as promoting the natural consumption of the CO_2 by the foliage.

5.3 Photovoltaic (Solar) Energy

In 2003 California State University, Northridge undertook its first solar photovoltaic (PV) installation in the E6 parking lot, where the panels serve the dual purpose of generating electricity whilst providing shade to parked vehicles (Figure 27). This installation comprises 3,024 solar panels, manufactured by Shell Solar Industries, each of which can generate up to 75 watts of power, producing a peak generating capacity (“nameplate capacity”) of 225 kilowatts. Much of this power is generated when it is needed most, between 1 p.m. and 5 p.m. during summer months. In addition to saving energy, the use of photovoltaic cells reduces greenhouse gas emissions and reduces the campus’s impact on the environment. This $1.8 million project was developed through a partnership with the university’s Physical Plant Management, the College of Engineering and Computer Science, Los Angeles Department of Water and Power (LADWP), Southern California Gas Company (SCGas) and Shell Solar Industries. The public utility companies provided more than 80% of the cost in incentive funding.

The second solar photovoltaic installation at CSUN was completed in 2005 and includes 2,832 densely configured 165-W Sharp solar PV panels installed in the B2 parking lot (Figure 28). At peak capacity these can generate 467 kW of power from a similar ground area to that employed in lot E6. This project cost $3.4 million, with $2.3 million being provided in incentives from the same two utilities (LADWP and SCGas). For this installation, the engineering team provided an educational opportunity for CSUN students through a large glass window within the structure which allows for viewing of the plant operation and displays the amount of electricity being generated by the sun in real-time.

Figure 27. First PV array at California State University, Northridge. Installed in parking lot E6.

Figure 28. Second PV array at California State University, Northridge. Installed in parking lot B2.

Figure 29. Electricity generation by two photovoltaic plants, 2007 - 2011.

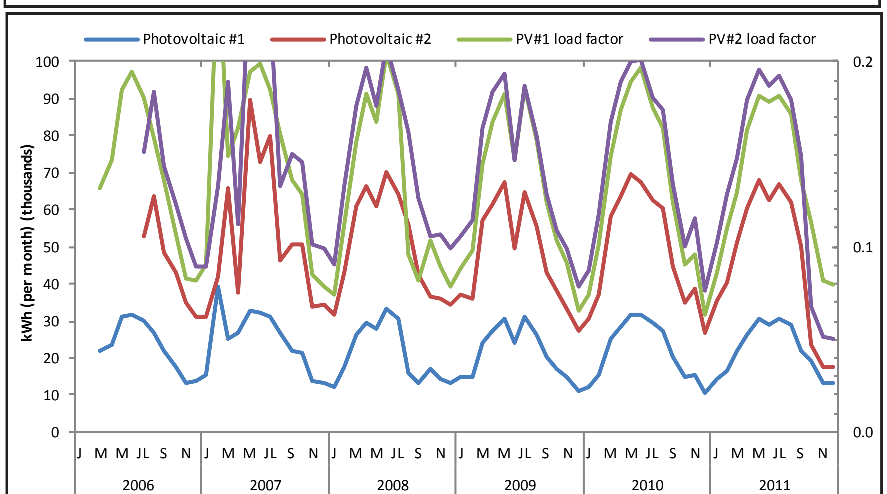


Figure 30. Seasonal change in electricity generation by two photovoltaic plants, 2006 - 2011

Photovoltaic cells work by absorbing the sun's rays on to semiconductor materials which create direct current. Inverters then convert this current to alternating current and direct it to a substation operating at 4,160 volts, from which it is fed into a power grid that distributes electricity throughout campus. The efficiency of the solar cells in converting sunlight into electricity is limited by the electrical properties of the semiconductor materials, which require a certain threshold of energy (or frequency of light) to trigger the flow of electrons. A portion of the solar spectrum contains light of a lower frequency (or longer wavelength) than this, and this part cannot be used to produce electricity. Amorphous silicon-based cells average around 8% efficiency, single crystal silicon cells around 18%, and multi-crystalline up to about 20%. Because different materials are sensitive to different parts of the solar spectrum, new multiple junction devices are being developed by researchers in which each junction is responsive to a different band within the solar spectrum. In this way the efficiency of multiple junction devices can be improved upon those offered by single junction ones. The CSUN solar panels are first-generation devices which employ amorphous silicon-based cells.

Figure 29 shows the total amount of electricity generated by each of the PV installations since installation. These two plants together generated 932,000 kWh in 2007, slightly decreasing to 854,000 kWh in 2008. In 2009 the amount of generated electricity dropped down again to 826,000 kWh, and then rose in 2010 to 856,000 kWh. In 2011 it totalled 820,000 kWh.

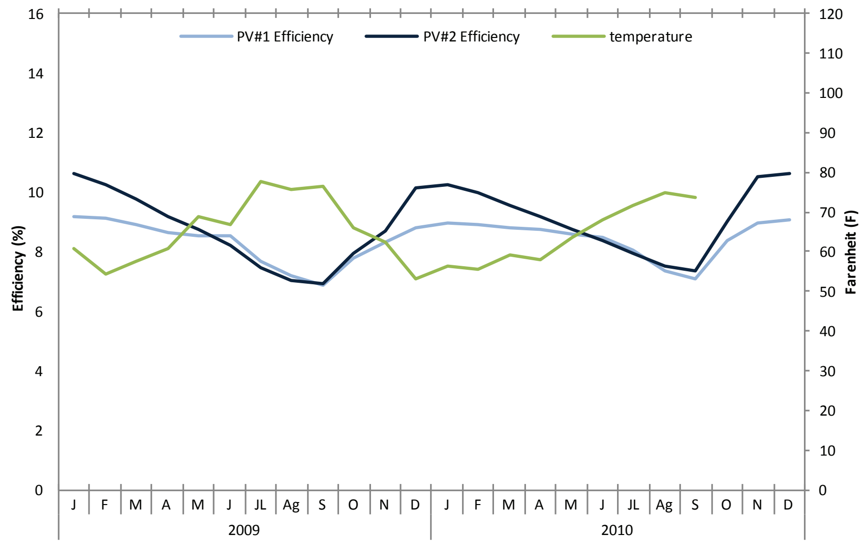


Figure 31. Efficiencies of two photovoltaic installations, 2009 - 2010

The variation in the generated electricity is a function of both the efficiency of the panels (which varies with temperature, amount of sunlight, and cleanness) and the amount of incoming sunlight (which depends on time of year/season, time of day, cloud cover and air pollution).

The monthly variation in the amount of generated electricity is shown in Figure 30. Although the second solar installation consistently produces more than twice the amount of electricity than the first one (as expected from the capacities of the two installations), their monthly variation mimics each other closely, indicating that the output variation is primarily a function of change in incoming solar energy. The exception is mid-2007 when it appears that the PV2 installation (parking lot B2) suffers a much greater proportional reduction than PV1 (parking lot E6). Figure 30 also shows the load factors for the two PV installations (RH axis). These rangle between 0.08 and 0.20 depending on the time of year and amount of sunlight. The maximum load factor occurs in summer and reaches a peak of about 20%. The average load factors of the two installations since startup average 14%. There has not been any noticeable decline in this factor over the past 6 years.

It is instructive to calculate and compare the efficiencies of the two sets of panels at converting solar energy to electrical energy. PV efficiency can be calculated by dividing the electrical energy output (kWh) by the input solar energy. The incoming solar energy is obtained using data from the campus weather station, which incorporates a Campbell Scientific pyranometer measuring hourly solar radiation between 400 and 1100 nm. Since the area of the panels is known, the total energy arriving on each panel each hour (J or kWh) can be calculated, and totaled per day and per month. Using these data, monthly efficiencies for the PV panels were computed. (These show net efficiency after all losses, including the DC to AC conversion, are accounted for.)

As can be seen in Figure 31, the efficiency of the panels drops during the summer period, falling to its minimum of 6.9% in early September, the hottest time of the year. In winter, the efficiency of the panels is highest (10.6%). The average annual efficiency is 8.6%. Also shown in Figure 31 is the monthly average (24-hr)

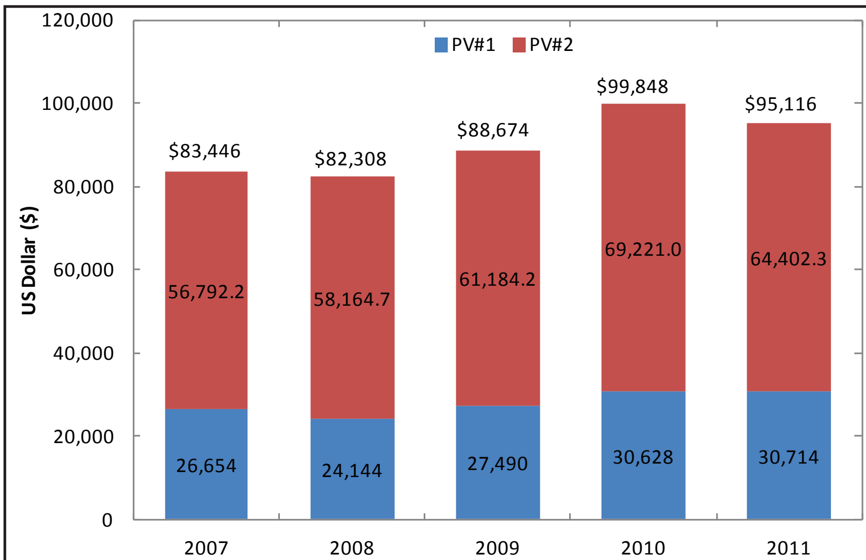


Figure 32. Electricity cost savings from solar generation, 2007-2011.

temperature. The strong inverse relationship between efficiency and temperature is evident. Heat increases the resistance of wires, and since the panels are connected together by wires, their higher resistance in summer will increase energy loss and reduce efficiency at that time of year.

The annual cost savings to the university depend on the net amount of electricity generated and the cost of electricity. Utilizing monthly data on energy generation and prices, these savings were computed and are shown in Figure 32. In 2007 these plants saved more than $83,000 in electricity costs and almost the same amount the year after. Since the price of electricity has risen since, the value of the savings was higher in 2009 and 2010 even though the amount of electricity generated fell. In 2009 the savings amounted to more than $88,000 , almost $100,000 in 2010 and $95,000 in 2011.

5.4 Microturbines

CSUN's first co-generation project was the installation of six natural gas-fired 30 kW Capstone microturbines (Figure 33) between 1995 and 1997. The turbines were donated to CSUN under a grant from the South Coast Air Quality Management District by the National Fuel Cell Research Center (NFCRC) at UC Irvine. Under the agreement, NFCRC arranged for the installation and subsequent testing of the microturbines' performance. CSUN agreed to be the host site, to pay for the fuel (natural gas) and to maintain the equipment. Each microturbine is capable of operating at a load factor of 74% to 85%, and of producing between 10,000 and 19,300 kWh of electricity each month. The 530° F exhaust heat is recovered and pumped into the hot water loop used to heat campus buildings. Although the microturbines performed well in the early years of installation, in recent years several problems have developed and the original generation promise of 1,400,000 kWh a year has not been met. Monthly electricity generation from these units since 2007 is shown in Figure 33. In 2010 the units successfully produced 453,000 kWh of electricity, but in 2011 the units failed.

5.5 Summary of On-site Generation

CSUN has installed three different types of on-site energy generation facilities in the past decade in its effort to explore sustainable alternatives to conventional electricity generation from utility-

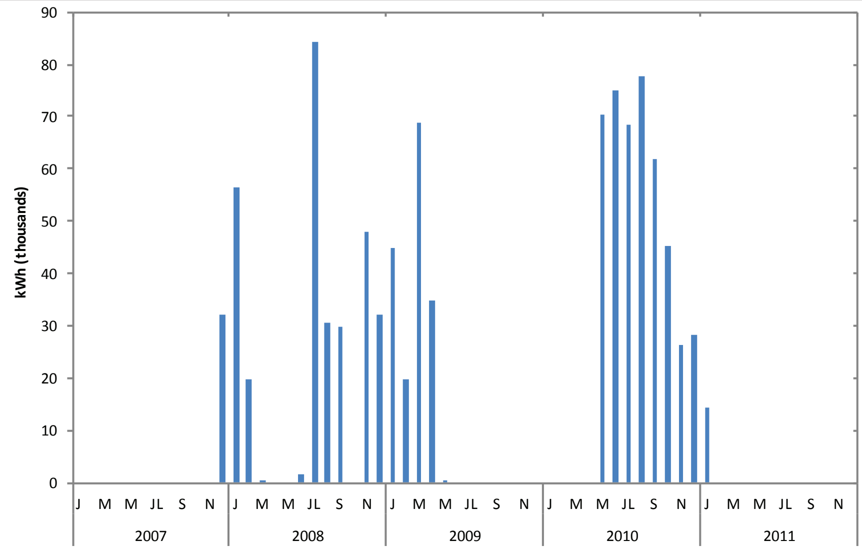


Figure 33. Monthly electricity generated from microturbines since 2007

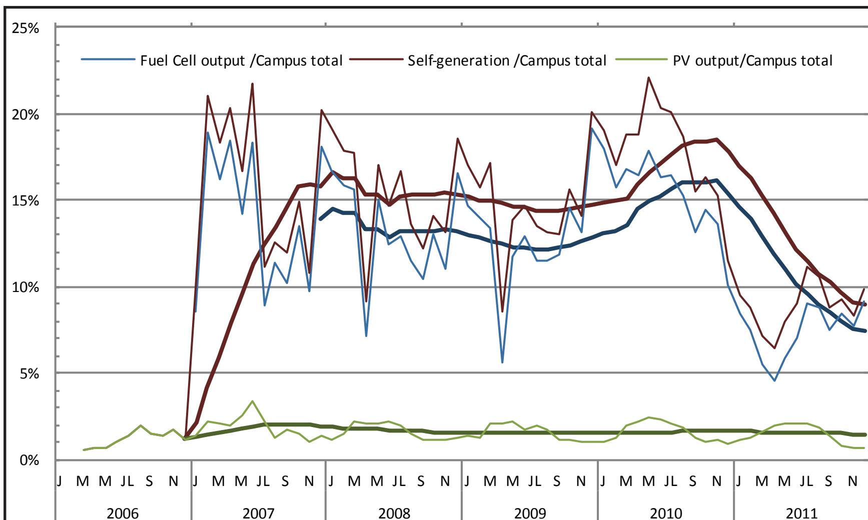


Figure 34. Proportion of campus electricity use supplied by on-site generation

operated power plants, which utilize primarily fossil fuel combustion. These alternatives have lesser pollutant emissions and reduced greenhouse gas emissions. In taking a leadership role, CSUN explored innovative alternatives at relatively early stages in their commercial deployment. This approach allowed the university to take advantage of financial incentives and install energy alternatives at relatively low costs. The disadvantages of an early-adoption approach are that the technologies are not always fully proven at a commercial/ institutional scale beforehand. CSUN has always felt that as an educational institution it should lead by example, and for the most part, its investments in alternative energy technologies have proved to be good ones.

Figure 34 shows the percentage of campus electricity which is generated on-site from the fuel cell, the solar arrays, and the microturbines. The PV installations are the most reliable source, consistently supplying about 2% of the electricity use annually. The fuel cells reliably supplied between 12 and 16% of the campus's use until 2011 when they had to be shut down for much of the year. At the end of 2011, only 7% of the electricity came from this source. The fuel cell stacks are due for replacement so their contribution is expected to improve to and beyond 2010 levels by the end of 2012. When all fuel cells are operational, as was the case in 2010, the campus is able to provide almost 18% of its total electricity use.

6. Summary

Both electricity consumption and gas consumption have risen at CSUN since the early 1990s together with student numbers and building area. There was an interruption in all of these as a result of the 1994 earthquake, since which time FTES has increased by 75% and building square footage by over 25%. When normalized by either student number (FTES) or building area (eSqFt) the energy consumption of the campus has decreased post-earthquake, showing that with the growth of the campus has come improved energy efficiency. The university, however, is still burdened with older buildings which are energy inefficient and require a significant investment to bring up to new standards of efficiency.

Total electricity consumption on the campus increased from an average of 2.82 million kWh/ month in 1990 to 4.71 million kWh/ month by 2011, but most of this rise took place in the mid nineties. By the end of 1996 the average electricity consumption was 4.12 kWh/month so the rate of increase has been small, 0.9% increase per year over the last fifteen years. During the same period of time, FTES has grown by 2.8% per year and equivalent square footage of building area by 1.6% per year. With the campus's investment in on-site electricity generation throughout the 2000s, the campus is actually purchasing less electricity now than it did fifteen years ago. The biggest change came as a result of the installation of the fuel cell plant in 2007, since which the amount of purchased electricity dropped by 15 – 18 % until 2011 when fuel cells were forced to shut down for long periods, increasing the amount of electricity that the campus had to purchase. Over the past five years electricity consumption on the campus has averaged an efficiency of 1.095 kWh/sqft per month and 158.86 kWh/FTES per month. For comparison purposes note that in the area served by LADWP, total electricity consumption amounts to 550 kWh/month per person, and of this, residential electricity consumption accounts for 185 kWh/ month per person[15]. In the western U.S. the average efficiency of commercial buildings is 1.15 kWh/ sqft per month, but educational institutions average well below that at around 0.85 kWh/sqft per month[5]. At the current average cost of 11.5 cents/kWh, purchased electricity costs the campus about $427,000 - $493,000/month (2010 and 2011 averages).

Gas consumption fell from 206,000 therms/mth in 1990 to 128,200 therms/mth in 2011 but was lower than both of these in the intervening years, reaching a historical low of only 50,000 therms/mth at the end of 2002. The most significant changes were seen as a result of the earthquake, a fall from an average of 160,000 therms/mth in 1993 to 74,000 therms/mth in 1994, and then a rise to 115,000 therms/mth in 1997. Consumption has never reached pre-earthquake levels thanks to the construction of the new Central Plant facility in 1998 which reduced consumption to 80,100 therms/mth in 1998. After 1998, gas consumption continued to fall until 2003 it started to increase again as a result of campus growth. At current prices (75 cents/ therm), gas consumption costs the campus $96,000 -$105,000 per month (2010 and 2011 averages). The campus consumes 0.030 – 0.033 therms/sqft per month (2011 and 2010) and 4.3 – 5.1 therms/

FTES per month. However, part of this gas is used as fuel for the fuel cell. If that amount is subtracted from the total, gas consumption is considerably reduced, at 0.019 – 0.022 therms/mth per sqft. For comparison, note that commercial buildings in the U.S. consume on average 0.036 therms/mth per sqft, and educational buildings average below this at 0.03 therms/mth per sqft. Educational buildings in the Pacific region average 0.029 therms/mth per sqft[6]. Thus the university compares well with similar buildings.

In 2003 CSUN began its investment in renewable energy with the installation of its first PV array. This was followed by a second installation in 2005. The cost of the two solar installations to CSUN was $1.46 million. Since installation, the campus has saved about $471,000 in electricity costs over five years. Thus the panels are expected to pay for themselves in well under the nominal 20-year payback period that is commonly used in PV cost-benefit assessment. The PV panels have delivered power at a capacity factor of 14% over their six to eight years of operation. This factor is a useful indicator of expected power delivery in considering the viability of future installations. A new installation with a nominal capacity of 1 MW might thus be expected to deliver an average of 102,200 kWh/mth, or perhaps a little more since newer technologies are expected to have somewhat improved efficiencies. This is equivalent to 2.2% of CSUN's total electricity consumption, and would save the campus approximately $11,750/mth in utility charges.

In 2007 CSUN installed a 1 MW fuel cell facility at a cost to the campus of $2.51 million. In addition to the startup cost the campus pays an annual maintenance fee which includes periodic stack replacement. So far the campus has saved just over $1 million from avoidance of electricity costs as a result of fuel cell power generation. This amount does not include the savings in gas purchases which result from co-generation of heat. The cost-benefit of the fuel cells is largely determined by the cost of the maintenance agreement and the reliability of the cells. Until 2011 it appears that the fuel cells were a good investment. In looking forward, their performance will need to return to 2010 levels in order for the campus to benefit from the expected return on its investment.

In the case of the microturbines, these were donated so there were no upfront costs associated with their installation. Although they saved the campus on fuel costs for many years, they are no longer functioning in a sustainable manner.

7. Recommendations

There is international consensus on the science of climate change and on the need for concerted action to address the global rise in greenhouse gas emissions. Under California law AB32, the Global Warming Solutions Act, greenhouse gas emissions must be reduced to 1990 levels by 2020 and to 80% below those levels by 2050. In the U.S. the energy sector is responsible for 80% of these emissions[8]. Thus reducing consumption of fossil fuels serves the multiple roles of reducing greenhouse gas emissions, reducing consumption of natural resources and their associated effects on the environment, and potentially saving on fuels costs. Reduction in fossil fuel consumption and emissions can be achieved by reducing overall energy consumption, transferring to more efficient and less polluting technologies (e.g. fuel cell, microturbines) and/or the use of renewable technologies for energy generation (e.g. solar). The most cost-effective of these are conservation measures.

McKinsey and Company[9] assessed the costs and abatement potentials of more than 250 alternative strategies to reduce or prevent greenhouse gas emissions and found that almost 40% of these had negative marginal costs, such that over their lifetimes the cumulative savings in energy created by these options more than offset their costs. (Costs include capital, operating and maintenance costs, and calculations assume no price for carbon.) Of the general clusters of opportunity, the #1 (lowest) average cost of abatement is the category of "Improving the energy efficiency of buildings and appliances". A primary reason for this is that residential and commercial buildings in the U.S. are relatively energy inefficient.

The most potential savings come from replacement of inefficient lighting with CFLs (compact fluorescent lights) and LEDs (light emitting diodes). CFLs are about 30% more efficient than traditional incandescent lights and last eight times longer; LEDs use an eighth the amount of energy of incandescent lights and last forty times longer. A team of CSUN students, working under the guidance of Dr. Ramin Vakilian[10] calculated that the installation of dimmers and LEDs in outdoor lighting at CSUN would have payback periods of 1 – 10 years depending on type, extent and location, and save between 6% and 85% of current lighting energy use. A series of recommendations were made including the implementation of network controls, the replacement of T8's with T5 fluorescent tubes, the installation of bi-level dimmer controls, and small scale LED replacements. The team is currently conducting a similar analysis of indoor lighting. We recommend that the campus adopt these recommendations.

According to the McKinsey report, the second most energy savings potential for buildings is from electronic equipment. Whereas commercial energy use is expected to rise by 1.6% per year, the rate of increase in energy use from office equipment is expected to more than double that as a result of both an increase in the number and in the energy intensity of units. CSUN is currently taking measures and should continue to do so, in both these areas. Over the past two years Academic Affairs, in cooperation with Information Technology, has been deploying "thin clients" to replace all 365 classroom computers throughout the campus. In a move to save even more energy, 43 "zero client" computers are being installed in a computer lab this summer in a pilot project. Virtually all processing and storage for these takes place remotely, with a net savings in overall energy consumption. A graduate student in the Pioneering Technology Group, working under the direction of Rink and Wiegley, is designing a control system to manage the power to plug-in devices so that computers (and other network capable devices) can be powered off (or on) remotely. This would allow overnight shutdown, activity-based shutdown with time scheduling control, class scheduling-based powering on and off, etc. The system will also have the potential to control other equipment with internet capability. We recommend that these efforts be supported, encouraged and adopted.

Another area that CSUN should continue to address is the sheer number of units (computers, printers, copiers) on campus. Wherever feasible and without introducing unreasonable inefficiencies in the use of faculty and staff time, units should be shared. A further recommendation is that energy consumption and other sustainability criteria, such as manufacturing and disposal, should be a consideration in the purchase or lease of new equipment. We recommend that only Energy Star products be purchased and that a list of recommended "green" products be established for use in purchasing decisions.

The remaining categories of negative abatement potential for commercial buildings pertain to HVAC (heating, ventilation and air conditioning) equipment, combined heat and power applications, and building shell improvements. CSUN has invested considerably in the first two of these over the past two decades with its new Central Plant facility, fuel cells, Siemens energy control system and ongoing improvements in heating and cooling infrastructure. However, it is saddled with old equipment in many campus buildings including Sierra Hall, Santa Susana Hall and Redwood Hall which should be considered for replacement with more efficient systems. There is considerable potential for improvements in building shells of existing buildings through retrofits. These include the installation of reflective roof coatings, reduction of air leaks, greater insulation, window coatings and dual paned windows. We recommend that cost-benefit analyses be conducted for each of these potentials, and that the campus invest in making these beneficial improvements which will likely result in long-term energy and cost savings.

Whereas most energy efficiency measures such as those outlined above have negative marginal costs, the Kinsey report finds positive costs associated with many renewable energy installations, including distributed solar photovoltaics. The cost-benefit of such installations depends largely on funding and incentives. In CSUN's case, much of the funding for the PV installations came from utility companies and thus as demonstrated in this report, the investments by the campus were good ones. In order for future investments in PV to be sound, similar incentives or reduced costs would be necessary. We recommend that energy efficiency improvements in existing infrastructure, such as lighting and building shells, be made before further PV is installed, unless incentive monies improve the value of such an investment.

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2. compounding annually

3. Student numbers in this report are given in terms of FTES (Full-Time Equivalent Students). This is the equivalent number of students served assuming that all undergraduates took 15 units and all graduate students, 12 units per semester.

4. Equivalent building area (eSqFt) is the total floor space of buildings with parking structures given a weighting of 7% that of other buildings.

5. Data from the U.S. Energy Information Administration (http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set10/2003html/c15.html)

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