PNNL-15535

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

FY 2004 Energy Use and Recommended Energy Conservation Measures

Environmental Technology and National Security Buildings at Pacific Northwest National Laboratory

October 2003–September 2004

N. J. Olson
D. L. Hadley
R. D. Routh

December 2005

Prepared for
Bonneville Power Administration and
the U.S. Department of Energy
Federal Energy Management Program
under Contract DE-AC05-76RL01830

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Pacific Northwest National Laboratory
Richland, Washington 99352

(a) Routh Consulting Engineers, Inc.
Pasco, Washington

Summary

The purpose of this report is to determine why Pacific Northwest National Laboratory's (PNNL's) Environmental Technology Building (ETB) used nearly 600,000 kWh more electricity than the National Security Building (NSB) in fiscal year (FY) 2004. We determined that the difference in electricity use between the two buildings was primarily due to the large number of computers and related cooling systems in the basement of ETB. The computer-related usage of electricity in the ETB basement cannot be remedied since the number of computers in the building is still on the rise, and this will continue to be a problem until the computers can be relocated to a more suitable facility.

Using real-time FY 2004 energy-use data, the buildings were modeled to identify potential energy conservation measures (ECMs). No costs (to implement) ETB and NSB ECMs were identified that could save 714,410 kWh/year, exceeding the goal of 515,520 kWh/year. These potential cost-savings measures will be addressed by the landlord and staff education. Installing variable-frequency fan drives would save another 384,030 kWh and have a less than 10-year payback period. Turning off the parking lot lighting between midnight and 6:00 a.m. would save another 79,520 kWh/year, at little additional cost.

This study shows the value of real-time energy-use monitoring by use category (e.g., lighting, plug loads, HVAC systems). The no-cost operational ECMs identified add up to 13% of the total energy, or currently would save about $35,000 per year. In the past, it has been noted these buildings can easily drift an additional 10% to 15% in energy use during operational changes. Real-time energy monitoring is a desired asset for building energy management and should be installed in all future PNNL buildings.

We were unable to resolve the lighting energy usage discrepancy where ETB used significantly more lighting energy (5 to 20 kW) during off hours compared with NSB.

Neither ETB nor NSB have occupancy sensors in the conference rooms, cafeteria, or offices. ETB tends to host more staff functions after work hours and also schedules custodial services daily from 3:30 p.m. to midnight during the work week. We recommend that occupancy sensors be installed in the ETB conference and cafeteria rooms as soon as feasible and that building energy management work with custodial staff to see if more reasons for the kWh consumption differences can be identified.

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Introduction

The Environmental Technology Building (ETB) consistently uses about 20% more electrical energy than the nearly identical National Security Building (NSB). These two buildings are adjacent to one another on the Pacific Northwest National Laboratory (PNNL) campus in Richland, Washington (Figure 1). ETB has more energy conservation measures (ECMs) installed than NSB (e.g., T8 lighting and low-E windows) such that it would be expected that ETB would use less energy than NSB. However, just the opposite is true. It is believed the difference in energy consumption must be due to differences in the way the buildings are operated or there are unknown energy users in ETB.

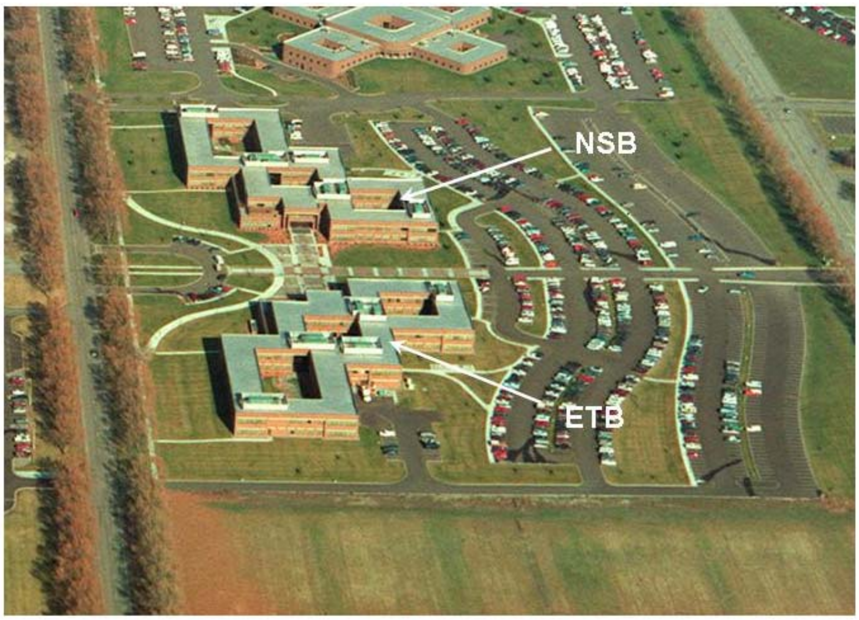

Figure 1. Aerial Photograph of ETB and NSB Buildings

This project was sponsored by the Bonneville Power Administration (BPA), DOE's Federal Energy Management Program (FEMP), and the Pacific Northwest National Laboratory (PNNL). The objective of this project was to continuously monitor energy usage in the two buildings and determine the reason(s) for the difference in their total electrical energy use, and then model the buildings so that ECMs could be identified and prioritized by return on investment. The goal was to identify ECMs that could save more than 515,520 kWh (difference between ETB and NSB in FY 2003) that could potentially be implemented at no cost. Then, recommend energy-savings measures to be implemented. Both buildings are described in the following sections.

Building Description – ETB

ETB is a two-story structure with a partial basement built of framed construction with a face brick exterior façade. Glazing is tinted double pane. Heating, ventilation, and air conditioning (HVAC) systems are primarily rooftop packaged air-handling units with variable air volume terminals with electric reheat coils. Five of the seven units have a nominal cooling capacity of 40 tons, while the other two units have a nominal cooling capacity of 50 tons, for a total capacity of 300 tons. The air-handling units also have electric heating coils to accommodate ventilation air loads. Volume control for the air-handling unit fans is accomplished with an inlet vane damper. Each of the HVAC systems has an economizer.

The HVAC systems and equipment were installed at the time of the original construction of the building in 1994. HVAC systems are controlled by a Carrier Comfort Network (CCN) central direct digital control system; however, only the standard controls packages have been installed. Operating personnel have been making periodic manual adjustments to equipment operating set points to improve building energy consumption. The HVAC systems generally operate from about 5:00 a.m. to about 10:00 p.m.; however, a few of the HVAC systems operate continuously.

Lighting inside the building is mostly fluorescent with F32T8 energy-saving (32W) lamps and energy-saving solid-state magnetic ballasts. Offices, conference rooms, and similar spaces have 2-foot by 4-foot, recessed, 2- or 3-lamp light fixtures. Offices and similar spaces with 3-lamp fixtures have multi-level switching for the room lighting. Compact fluorescent light fixtures are used for accent and special lighting. Lighting input wattage typically meets requirements of the Washington State Non-Residential Energy Code.[1] A few random measurements of office lighting levels were taken. Typical office illumination is about 50 to 65 foot-candles with all three lamps on, 35 to 50 foot-candles with two lamps on, and 15 to 25 foot-candles with one lamp on. Parking lot lighting uses high-pressure sodium fixtures.

Building Description – NSB

NSB is a two-story structure with a partial basement built of framed construction with a face brick exterior façade. Glazing is tinted double pane. HVAC systems are primarily rooftop packaged air-handling units with variable air volume terminals with electric reheat coils. Five of the seven units have a nominal cooling capacity of 40 tons, while the other two units have a nominal cooling capacity of 50 tons (300 tons total). The air-handling units also have electric heating coils to accommodate ventilation air loads. Volume control for the air-handling unit fans is accomplished with an inlet vane damper. Each of the HVAC systems has an economizer.

The HVAC systems and equipment were installed at the time of the original construction of the building in 1992. HVAC systems are controlled by a CCN central direct digital control system; however, only the standard controls packages have been installed. Operating personnel have been making periodic manual adjustments to equipment operating set points to improve building energy consumption. The HVAC systems generally operate from about 5:00 a.m. to about 10:00 p.m.; however, a few of the HVAC systems operate continuously.

[1] Washington Administrative Code (WAC) 51-11, Chapters 11-20.

Lighting inside the NSB is mostly fluorescent with F40T12 energy-saving (34W) lamps and energy-saving solid-state magnetic ballasts. Offices, conference rooms, and similar spaces have 2-foot by 4-foot, recessed, 2- or 3-lamp light fixtures. Offices and similar spaces with 3-lamp fixtures have multi-level switching for the room lighting. Compact fluorescent light fixtures are used for accent and special lighting. Lighting input wattage typically meets requirements of the Washington State Non-Residential Energy Code. A few random measurements of office lighting levels were taken. Typical office illumination is about 50 to 65 foot-candles with all three lamps on, 35 to 50 foot-candles with two lamps on, and 15 to 25 foot-candles with one lamp on. Parking lot lighting uses high-pressure sodium fixtures.

Data Collection

In a previous study, PNNL invested $62K into building metering instrumentation in late 1994. A total of 16 data loggers were installed in the two buildings for recording 15-minute time-series records of the following energy uses:

- whole building
- space heating
- space cooling
- interior lighting
- exterior lighting
- domestic hot water
- miscellaneous equipment (general office equipment, personal computers, printers, task lighting, small appliances, LAN, elevators)

The data collection program for these two buildings continues, with approximately 10 years of detailed historical data available for analysis.

In 1998, an analysis of data collected over 4 years indicated that energy use in ETB had increased 42% since the first year of building occupancy and NSB had increased 13%. Operational changes related to recommissioning were completed in January 1999. These changes significantly reduced the energy consumption in both buildings, but did not explain why ETB consumes significantly more energy than NSB, or why both buildings consume significantly more energy than expected. The instrumentation in place does indicate the city of Richland meters are operating satisfactorily and the billings are accurate (i.e., faulty meters are not the cause).

The incentive for action now is to determine why the difference in energy consumption between the two buildings is increasing (515,520 kWh in FY 2003 and 591,520 kWh in FY 2004 – city of Richland metering/billing) as is the price of energy. To do this, the instrumentation and data loggers in place were checked for accuracy and the FY 2003 and FY 2004 data were downloaded such that energy end use (lighting, HVAC, fans, etc.) could be quantified in 15-minute time intervals. Modeling (DOE 2.1 is the model of choice) provided the energy use baselines (adjusted for weather) to allow real-time evaluation of metered data in the future and help sustain energy savings through operational adjustments.

Results and Discussion

The downloaded internal metering results for the ETB and NSB buildings by end-use category in FY 2004 are shown in Table 1. Due to lack of access, we know we are not monitoring some usage; but it appears we are monitoring ~98% of the whole building energy usage. Other than this, the internal monitoring agrees well in total with the whole building meters the city of Richland uses for billing purposes.

Table 1. Metered Results by End-Use Category for FY 2004 (kWh)

Use Category	ETB	NSB	ETB-NSB
Interior Lights	327,927	240,604	87,322
Equipment	743,702	546,915	196,787
Heating	754,135	668,297	85,838
AC/AHU	970,486	733,238	237,248
Exterior Lights	70,390	92,090	(21,701)
LAN	38,250	47,643	(9,392)
Other	14,060	12,043	2,017
Total	**2,918,949**	**2,340,830**	**578,119**
City of Richland Total Building Meter	2,984,960	2,393,440	591,520

In order to model the buildings (particularly ETB) so that energy-efficiency savings options could be quantitatively assessed, we first had to determine why there were differences in the ETB and NSB energy usage categories. As discussed previously, ETB energy usage could not be modeled with the initial design/build parameters and instrumentation well enough to evaluate the consequences of changing operating conditions. Therefore, the reasons for the differences in interior lighting, equipment, exterior lighting, and Local Area Network (LAN) energy usages had to be determined before evaluating the differences related to HVAC. Interior lighting, office-related equipment, and the HVAC systems are the primary systems where energy savings can be achieved as well as the areas where a better understanding of energy usage will lead to better modeling of the buildings.

Interior Lighting

There are 1,339 and 1,348 light fixtures in ETB and NSB, respectively. ETB has T8 lighting/solid-state magnetic ballasts (105 watts, 70 watts for 3- and 2-lamp fixtures, respectively) compared with the less energy-efficient NSB T12 lighting/solid-state magnetic ballasts (108 watts, 72 watts for 3- and 2-lamp fixtures, respectively). The office occupant can control lighting by 1-2-3 lamps on, depending on the particular office lamping. Typical office illumination is about 50 to 65 foot-candles with all three lamps on, 35 to 50 foot-candles with two lamps on, and 15 to 25 foot-candles with one lamp on. For reference, 35 foot-candles is the design standard for schools. During walk-throughs in the two buildings, it was noted that staff are more overlit in ETB and practice less energy conservation than NSB staff, because of a larger number of ETB staff leaving the lights on in the unoccupied offices during work hours. In contrast, NSB enjoys a southern exposure to the reception center, which significantly reduces both the lighting and heating needs in the high ceiling reception area. The action recommended is to inform staff of the savings available by being energy stewards.

Neither ETB nor NSB have occupancy sensors in the conference rooms, cafeteria, or offices. ETB tends to host more staff functions after work hours as well as scheduling custodial services daily from 3:30 p.m. to midnight during the work week. We recommend that occupancy sensors be installed in the ETB conference and cafeteria rooms as soon as feasible.

There is 14.5 kW of continuous lighting (in each building) – illuminated exit signs and egress (unswitched) lighting that remain on continuously. Continuous lighting usage was included in the NSB metered results, but 14.5 kW was subtracted off for the following comparison with ETB. The lighting usage for the highest winter and summer demand, coldest (January 5th) and second hottest (June 23rd) days in 2004 is plotted versus time of day in Figures 2 and 3, respectively. In NSB, all interior lighting (including egress and exit signs) was monitored together, so 14.5 kW was subtracted to compare with the ETB lighting results. Note that ETB lighting usage has much more variation than NSB, but it is not clear why ETB is so much higher during off hours, even on holidays and weekends. There is also considerable variation compared to NSB (Figures 2 and 3) at all hours, which appears randomly from day to day (Figure 4).

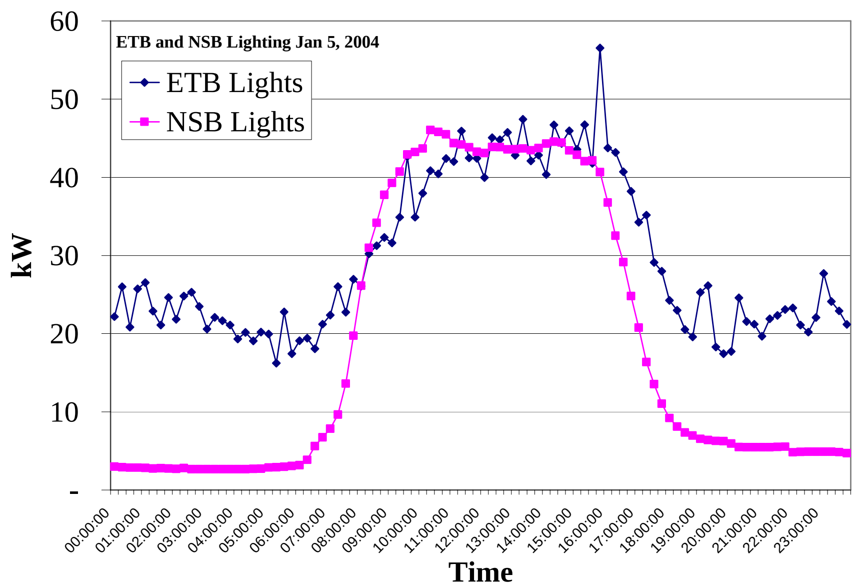

Figure 2. Comparison of ETB and NSB Interior Lighting Energy Usage

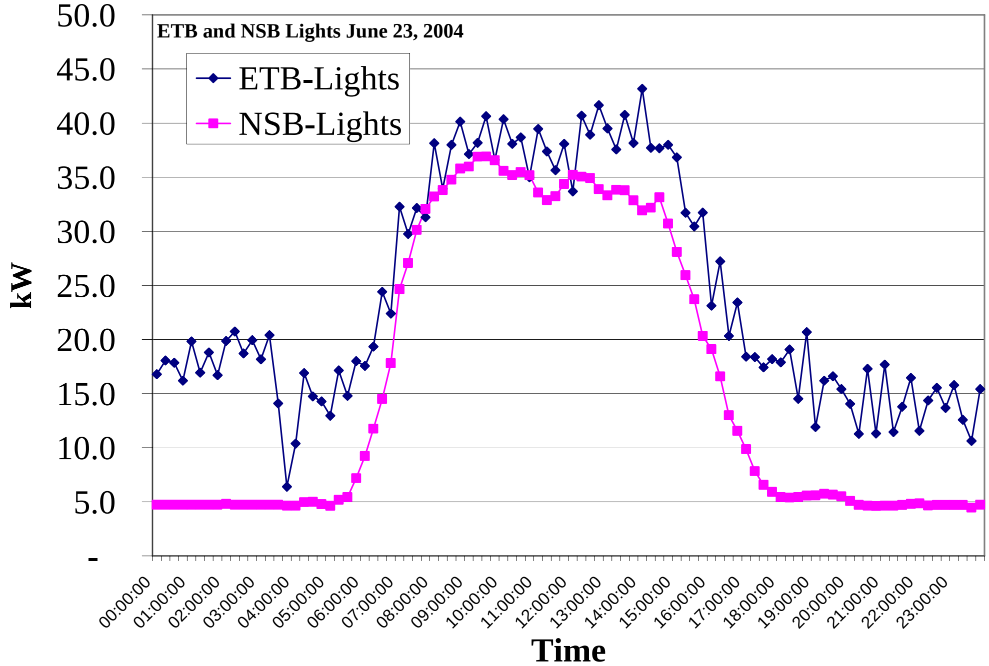

Figure 3. ETB and NSB Lighting Usage on June 23, 2004

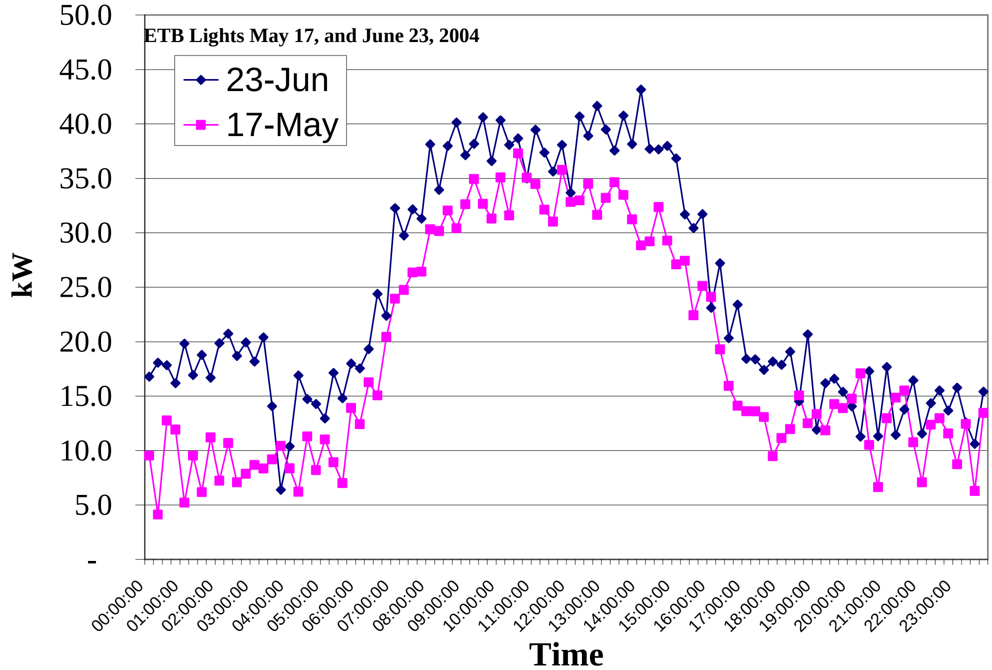

Figure 4. ETB Lighting Usage on May 17 and June 23, 2004

The typical lighting power usage of a work day versus a non-work day is shown in Figure 5. It appears there is about 7 to 10 kW more lighting usage in ETB during non-work days than in NSB. During work days, the off-hours lighting usage doubles non-work days usage (Figures 2 and 3). Walk-throughs did not identify sources other than during the off-hours custodial service from 3:30 p.m. to midnight, but no other sources of this magnitude were found. There are 1% more fixtures in NSB, and ETB has about 3% more energy-efficient lighting. As observed, it would be expected that the peak lighting loads during work days would be similar for ETB and NSB, but that ETB's lighting loads would be less than NSB instead of more. Therefore, it is concluded there may be extraneous power loads being monitored through the NSB lighting panel that are not connected with lighting and/or the lighting stewardship may be more effective in NSB. The lighting will be periodically monitored to attempt to determine the reason for the differences between NSB and ETB.

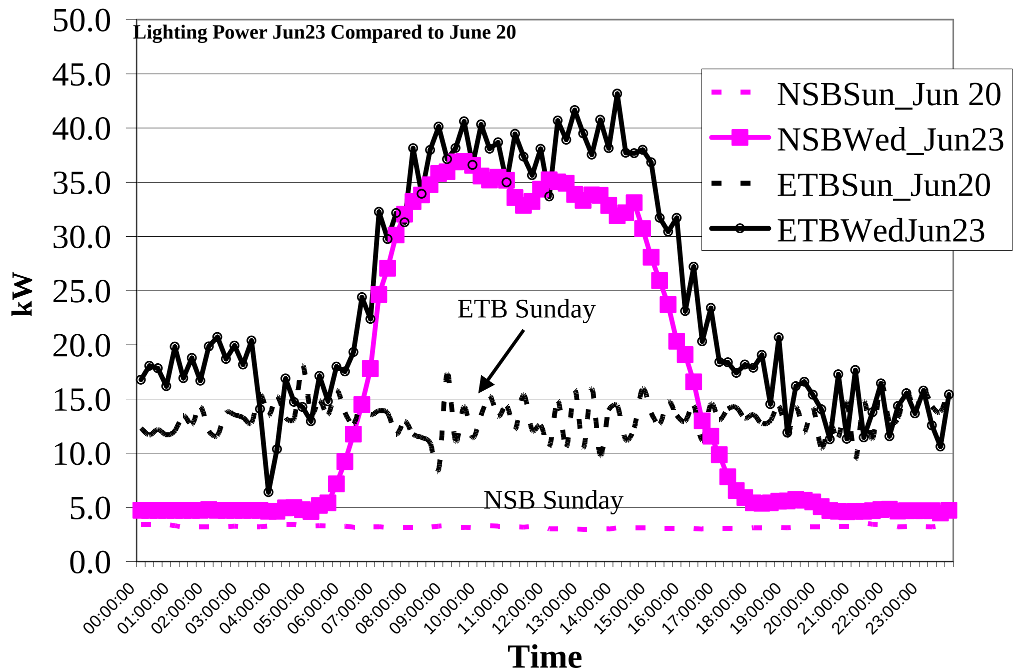

Figure 5. ETB and NSB Lighting Usage, Wednesday, June 23, 2004, Compared with Sunday, June 20, 2004 (non-work day)

Equipment

This category is basically plug-in power such as task lighting, office computers, computer displays, computer servers, printers, scanners, personal data assistants, space heaters, and refrigerators. In the case of ETB, it was found that electrical energy consumption attributable to computer equipment in Rooms 103 and 104 based on continuous operation could be as high as 479,300 kWh/year. The annual electrical energy consumption attributable to the Liebert HVAC units serving these rooms if the loads are true could be as high as 193,000 kWh/year. Obviously, from the Table 1 data, this worst case may not be true (672,300 kWh/year), but goes a long ways toward explaining the energy use difference between NSB and ETB. From the monitoring results, the difference between equipment loads in ETB and NSB is only 30% of the worst case ETB basement computers without considering their impact on central (zone) air conditioning.

More and more computer equipment is being placed in office locations without paying attention to energy-efficient design. For example, overcooling (or overheating) one office location impacts the entire zone supplied by one of the seven air handlers for each building, or around 14,000 square feet more than the office location being addressed. The solution is to involve Facilities and Operations staff in the design of such facilities and to design for the application before proceeding. As a tenant of these facilities, we have no control over wasted energy usage due to poor systems design unless design engineering is addressing the need. The recommendation to bring solution is to monitor such facilities and charge energy costs directly to programs if the proper energy design needs are not addressed.

Equipment is something that will be difficult to control. While energy conservation technology has been advanced in office equipment such as computers, computer displays, and printers (Energy Star), we see a significant increase in this type of equipment. As the laboratory grows, the equipment and number of staff per building grow. It has been observed that some staff have multiple printers, computers, and as many as three video screens for their computers. And they are all on continuously for various reasons. Both ETB and NSB have off-hours and large equipment loads as evidenced by the data in Figures 6 through 8.

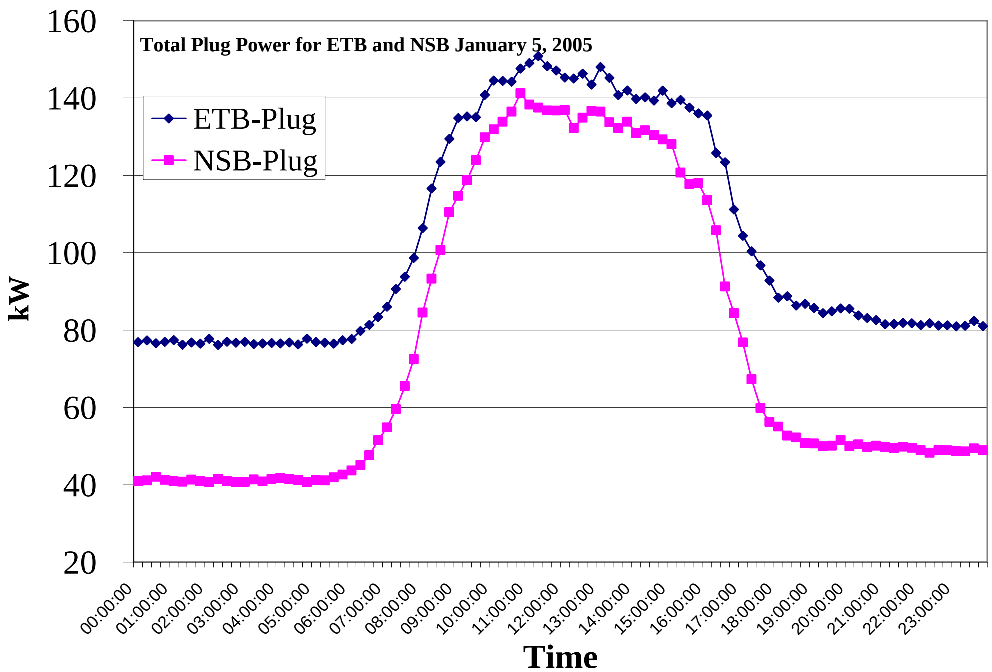

Figure 6. ETB and NSB Plug Power Usage, January 5, 2004

Examples of the growth in the equipment items connected to the PNNL network and left on 24/7 are shown in Figures 9 and 10. Examples of equipment items that can be counted during the PNNL network sweeps are printers and MS Windows-operated computers. Unix, Apple, and MS-NT operating system computers cannot be counted at any given time. About 90% of the staff leave their computers on continuously so that they can be automatically backed up at night and to be able to work from home or on travel with the resources on their work computers. Since backups can be done at any time selected by staff, it is believed at least 50% of the computers and related equipment could be turned off by staff members during off-hours.

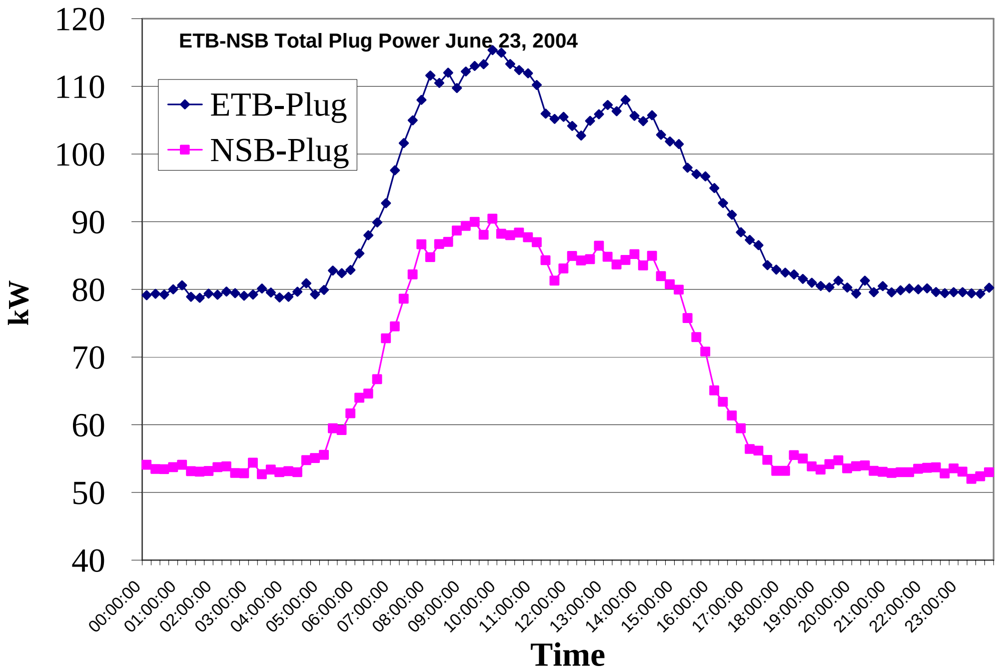

Figure 7. ETB and NSB Plug Power Usage, June 23, 2004

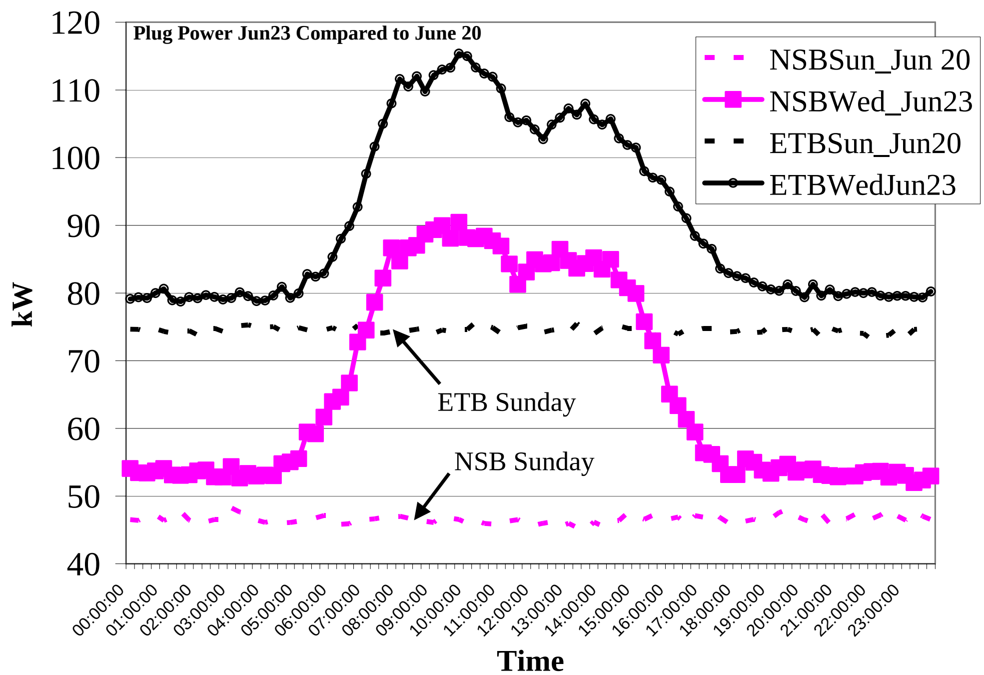

Figure 8. ETB and NSB Plug Power Usage on June 23, 2004, Compared with Sunday, June 20, 2004 (non-work day)

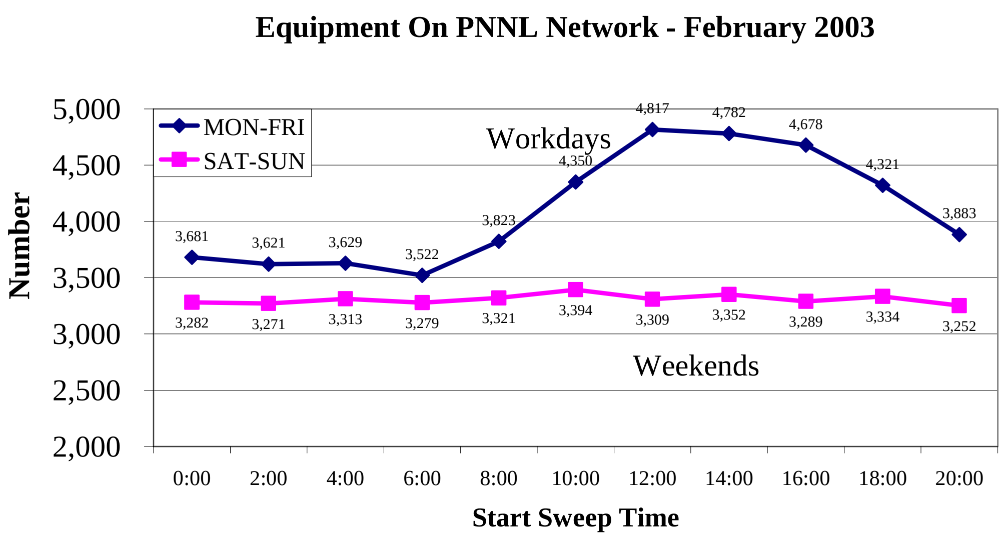

Figure 9. Average Number of Equipment Items Connected to the PNNL Network vs. Time During February 2003

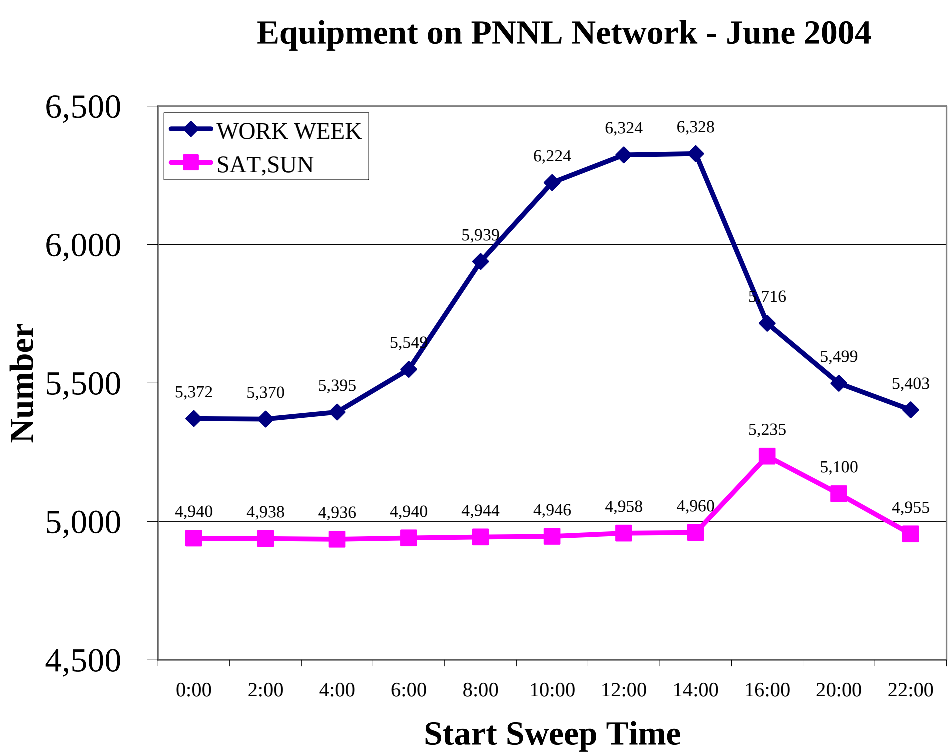

Figure 10. Average Number of Equipment Items Connected to the PNNL Network vs. Time During June 2004

A couple years ago, PNNL staff were introduced to the Watt Stopper, a device to turn off unneeded equipment when staff left their office locations (e.g., everything but computers, coffee pots, and refrigerators). Unfortunately, a high percentage of staff change locations every year and their Watt Stoppers do not go with them. One solution is to reintroduce the Watt Stopper and energy conservation education to staff.

Heating, Ventilation, and Air Conditioning Systems

For the past few years, three of the HVAC systems at ETB have been operating continuously rather than being shut down or set back during unoccupied periods. Only one HVAC system has been operating continuously at NSB. This operating strategy has largely been implemented in response to tenant feedback regarding comfort conditions in the buildings. It is not known whether the conditions that prompted the scheduling of HVAC system still exist. The building manager has recently adjusted the operating schedules of two of the three HVAC systems in ETB similar to the operating schedules of the other HVAC systems in the building. The difference in energy consumption attributable to this operating difference is approximately 70,000 kWh. There are additional energy savings available in both buildings by operating all of the HVAC systems on occupied/unoccupied schedules. If certain areas of the buildings require continuous HVAC system operation, such as central computer rooms, consideration should be given to removing these areas from the building HVAC systems and installing smaller, individual HVAC systems for these areas.

The static pressure set points of HVAC systems at ETB are typically higher than those at NSB. Based on an average difference of 1 inch on the water gauge in set point conditions, the difference in energy consumption attributable to this operating difference is approximately 87,000 kWh. The minimum ventilation air set points of HVAC systems at ETB are also higher than those at NSB. ETB's set points are typically 10% whereas NSB's are 0%. Both building's HVAC systems are equipped with carbon dioxide sensors that reset the minimum ventilation air set points upward as necessary to maintain concentrations at 1,000 ppm or less, but do not reset them below the minimum set points. The difference in energy consumption attributable to this operating difference is estimated at approximately 45,000 kWh.

The leaving air temperature set points of the HVAC systems in both buildings are adjusted seasonally and periodically by the building operating staff. Adjustments are sometimes made in response to tenant feedback regarding comfort conditions in the buildings. These adjustments are also sometimes made to only the HVAC system serving the area of the building from where this feedback has been received. Differences in when and to what degree these adjustments are made between the two buildings, and between HVAC systems within each building, are not known specifically but are suspected of being accountable for some of the difference in energy consumption between the two buildings, perhaps in the range of 50,000 kWh or more.

Small remaining differences in energy consumption between the two buildings are attributable to fixed differences such as differences in the direction of exterior exposure of similar spaces because the orientation of the buildings is mirrored, differences in the amount of parking lot lighting that is supplied by one building versus the other, and minor differences in the distribution and arrangement of HVAC system zoning. The difference in energy consumption attributable to the minor variations is estimated to be in the range of 30,000 kWh.

The total HVAC energy usage versus time for the coldest and second hottest day (highest winter and summer demands) in FY 2004, respectively, are shown in Figures 11 and 12. It is interesting to note in Figure 11, the heating started an hour earlier in ETB. As staff-related equipment and lighting loads increased, the HVAC energy usage decreased during the day. The opposite occurs during the hot summer day cooling needs shown in Figure 12. As the lighting and equipment loads increased during the day, the HVAC cooling also increased to keep staff comfortable with building temperatures.

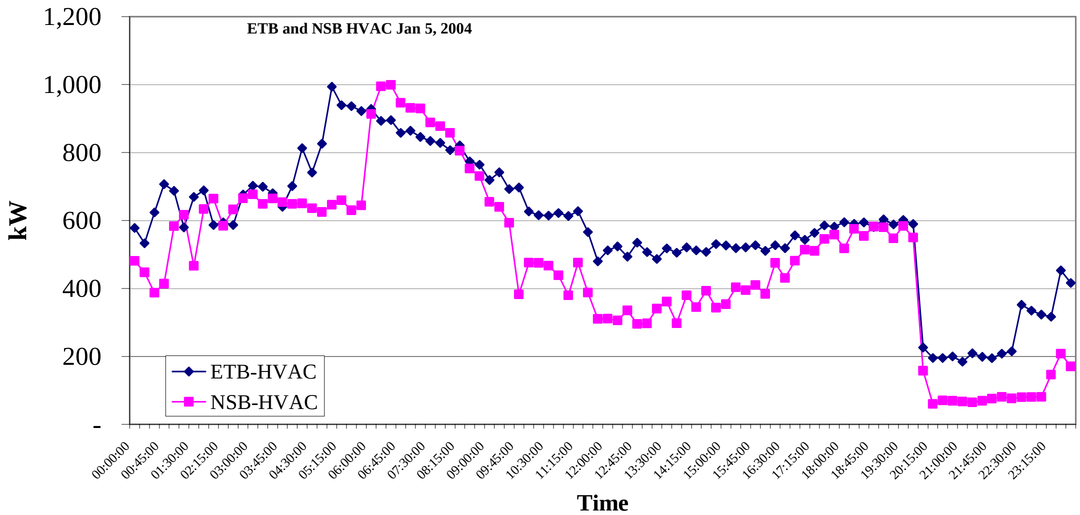

Figure 11. HVAC Energy Usage Comparison of ETB and NSB on January 5, 2004

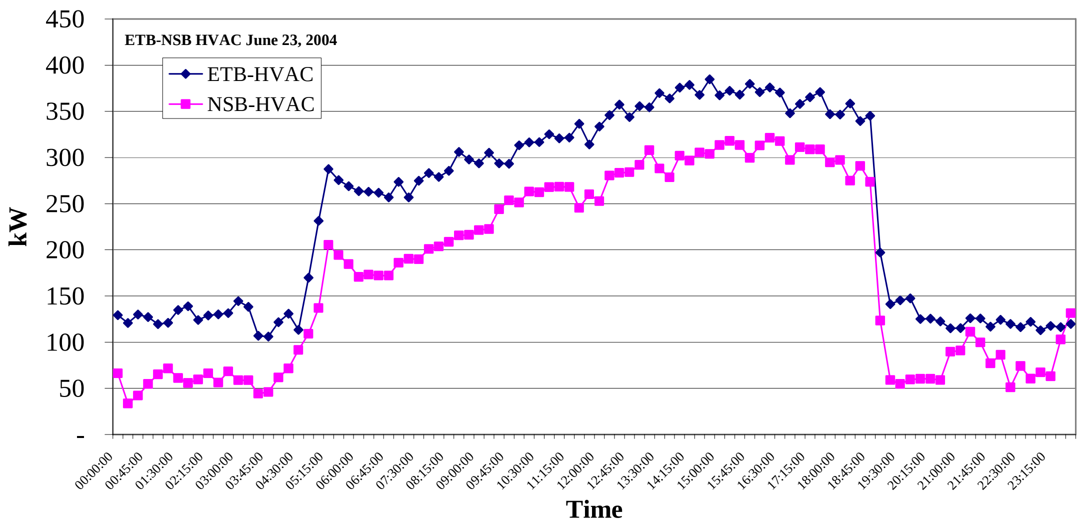

Figure 12. HVAC Energy Usage Comparison of ETB and NSB on June 23, 2004

Energy-Conservation Measures

Using the metered energy usage data from FY 2004, both NSB and ETB could be modeled well using DOE 2.1 (Figures 13 and 14). The energy usage distributions for the buildings are shown in Figures 15 and 16. Using the models, the energy savings were estimated for the energy conservation measures (ECMs) discussed in the following sections.

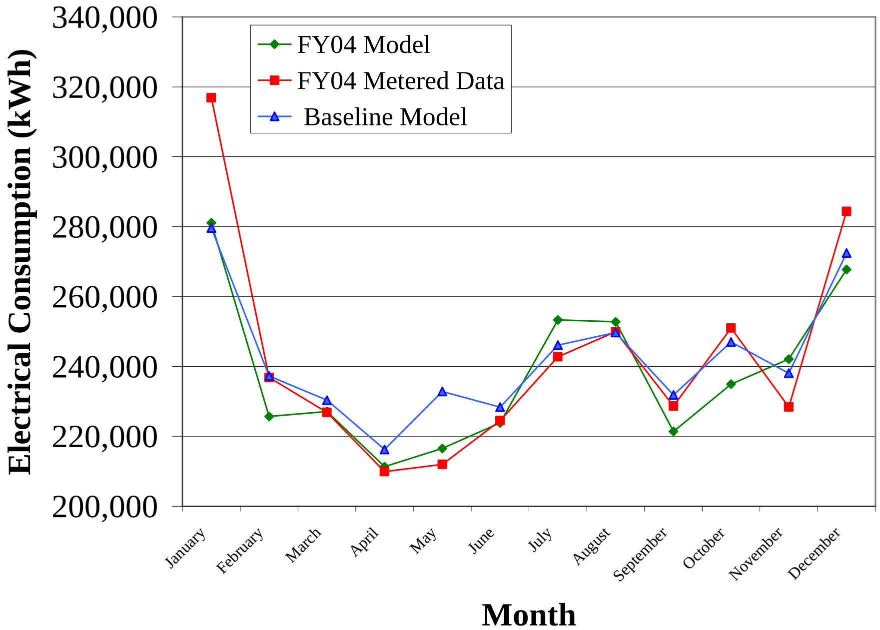

Figure 13. ETB Energy Consumption by Month, FY 2004

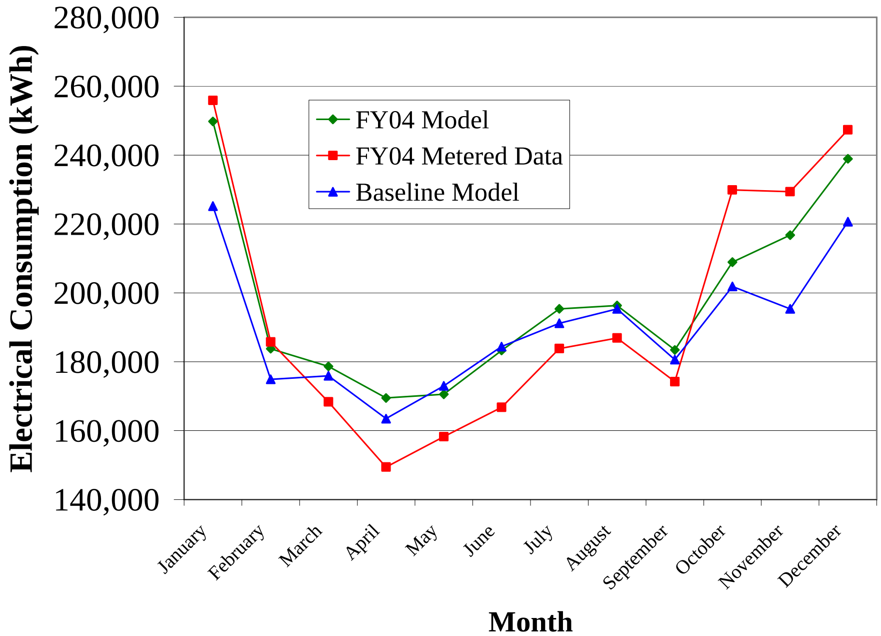

Figure 14. NSB Energy Consumption by Month, FY 2004

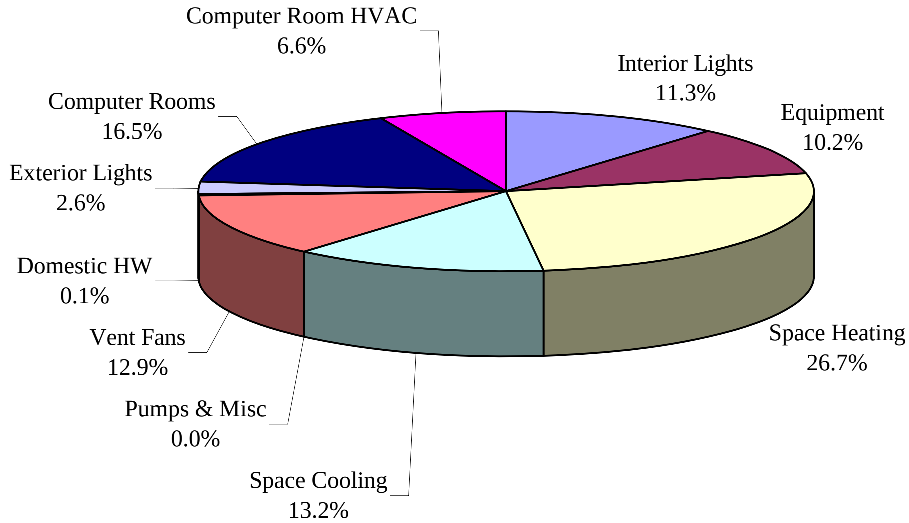

Figure 15. ETB End-Use Electrical Consumption, FY 2004

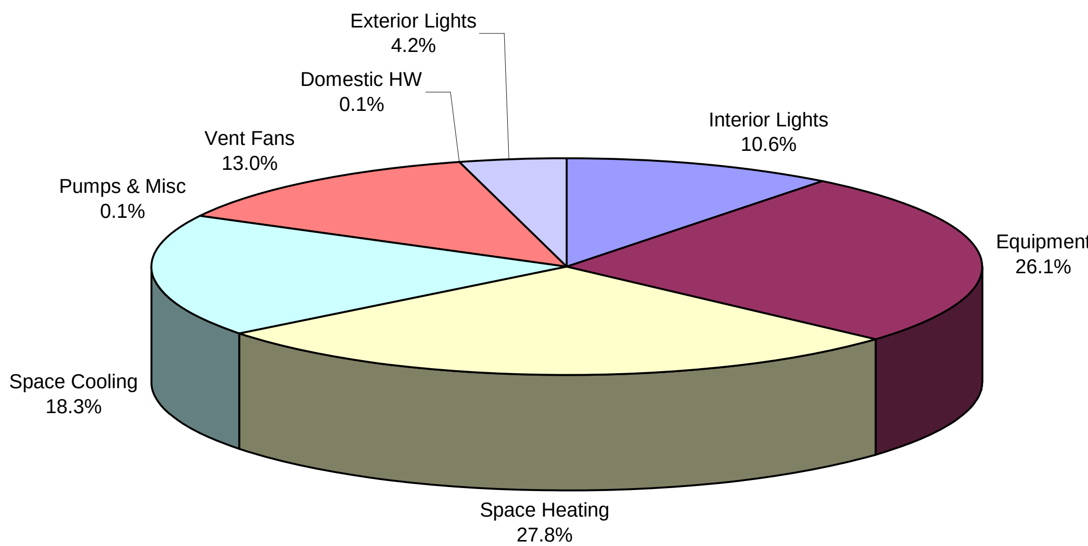

Figure 16. NSB End-Use Electrical Consumption, FY 2004

ECM 1 – Shut Down/Set Back All HVAC Systems During Unoccupied Periods

This measure changes the operating schedules for the HVAC systems that are currently operating continuously to operate from 5:00 a.m. to 10:00 p.m., similar to the other systems in each of the buildings. Modeling was accomplished by adjusting the operating schedule of HVAC systems to hours noted. This measure will reduce electrical consumption by about 168,920 kWh/year at ETB and 91,460 kWh/year at NSB. This will result in electrical energy cost savings of about $4,090 and $3,640 per year, respectively. This ECM is subject to administrative control so there are no significant installation costs.

ECM 2 – Turn Off Office Lighting During Unoccupied Periods

This measure estimates the savings potentially available by having building occupants turn off all controllable lighting when they leave for evenings and weekends. For purposes of this analysis, 14.5 kW of lighting has been identified as illuminated exit signs and egress (unswitched) lighting that remains on continuously. Modeling was accomplished by adjusting the operating schedule of office lighting to reduce lighting during unoccupied periods to this amount. This measure will reduce electrical consumption by about 56,530 kWh/year at ETB and 23,230 kWh/year at NSB. This will result in electrical energy cost savings of about $2,550 and $1,550 per year, respectively. This ECM is subject to administrative control, so there are no significant installation costs. However, actual savings may vary depending on the habits of the building occupants.

ECM 3 – Replace T12 Lamps (NSB Only) and Replace Solid State Magnetic Ballasts with Electronic Ballasts (Both Buildings)

At ETB, this measure replaces all solid-state magnetic ballasts with electronic ballasts. Input wattage for 3-lamp fixtures is reduced from 105 watts per fixture to 93 watts. Input wattage for 2-lamp fixtures is reduced from 70 watts per fixture to 62 watts. At NSB, this measure replaces all T12 fluorescent lamps and solid-state magnetic ballasts with T8 lamps and electronic ballasts. Input wattage for 3-lamp fixtures is reduced from 108 watts per fixture to 93 watts. Input wattage for 2-lamp fixtures is reduced from 72 watts per fixture to 62 watts. Modeling was accomplished by adjusting the lighting input wattage for each zone based on the number and type of fixtures installed. This measure will reduce electrical consumption by about 23,570 kWh/year at ETB and 24,090 kWh/year at NSB. This will result in electrical energy cost savings of about $1,230 and $2,760 per year, respectively. There are 1,339 light fixtures that will be retrofitted at ETB and 1,348 light fixtures that will be retrofitted at NSB. Installation costs to implement this ECM are estimated at $58,960 and $74,140, respectively.

ECM 4 – Install Occupancy Sensors in Individual Offices, Conference Rooms, and Restrooms

This measure installs occupancy sensors in individual offices, conference rooms, and restrooms to turn off room lighting when unoccupied. In general, occupancy sensors will be passive infrared types. Individual offices will receive sensors that directly replace the room light switch. Other spaces will receive pendent-type sensors to afford better coverage of the room and, where necessary, to control rooms with multiple light switches. The sensors will have an adjustable time delay to control how long the lights remain on after last sensing room occupancy. For purposes of this analysis, the occupancy sensors replace the multi-level switching of room lighting. This measure has been modeled by adding a user-defined function in each zone that adjusts the scheduled lighting operation. The function is calculated for each zone for each hour of the model simulation. For any hour that more than half the lighting is otherwise scheduled to be on, randomly 50% of the time lighting input is reduced 20%. This roughly correlates to lights in about one of five offices being turned off for the hour. This measure will reduce electrical consumption by about 8,490 kWh/year at ETB and 10,220 kWh/year at NSB. This will result in electrical energy cost savings of about $660 and $1,120 per year, respectively. There are about 329 rooms at ETB where occupancy sensors could be installed and about 360 rooms at NSB. Installation costs to implement this ECM are estimated at $54,340 and $59,400, respectively.

ECM 5 – Turn Off Parking Lot Lighting Between Midnight and 6:00 a.m.

This measure installs controls to override photocell operation of the parking lot light fixtures and shut lighting off between midnight and 6:00 a.m. It is anticipated that few, if any, people will be in the buildings during these hours, so lighting will not be required for transit from the building to parked automobiles. This schedule should allow for people working late into the evening to safely leave the building. After the override period, lighting will turn back on if photocell sensors would have otherwise had the lighting on to accommodate people arriving early in the morning. Modeling was accomplished by adjusting the operating schedule of the exterior lighting. This measure will reduce electrical consumption by about 34,950 kWh/year at ETB and 44,570 kWh/year at NSB. This will result in electrical energy cost savings of about $1,100 and $1,410 per year, respectively. Installation costs to implement this ECM are estimated at $1,500 for each building.

ECM 6 – Automatic Air-Handling Unit Leaving-Air Temperature Reset Control

This measure upgrades controls to reset the leaving-air temperature of the air-handling units automatically based on multiple zone sensors. Currently, the leaving-air temperature is generally constant except for standard return air temperature reset capability. Also, operating personnel adjust the set point manually at their discretion when cooling load conditions warrant. Automatic control will continuously monitor building temperatures in the zones served by the respective air-handling unit, and raise or lower the leaving-air temperature set point so that it is just cool enough to accommodate the area that is furthest above its temperature set point. This reduces the amount of cooling and reheat energy required to maintain all zones served by the system at their set point conditions. This measure has been modeled by changing the control type for the air-handling unit cooling leaving-air temperature from a minimal reset based on return air temperature to automatic control based on conditions in the zones associated with the air-handling unit. This measure will reduce electrical consumption by about 109,750 kWh/year at ETB and 152,110 kWh/year at NSB. This will result in electrical energy cost savings of about $8,590 and $15,550 per year, respectively. Nine zone sensors will be installed for each air-handling unit and wired in an averaging configuration. HVAC unit control firmware will be upgraded to accommodate the new zone sensors. Installation costs to implement this ECM are estimated at $52,500 for each building.

ECM 7 – Install Variable Frequency Drives on Variable Air-Handling Unit Fans

Currently, inlet vane dampers are used for variable air volume control for the HVAC system fans. This measure installs variable frequency drives for volume control of the variable air volume air-handling units. Modeling was accomplished by changing the fan volume control type from an inlet vane damper to a variable-speed drive. This measure will reduce electrical consumption by about 238,420 kWh/year at ETB and 152,110 kWh/year at NSB. This will result in electrical energy cost savings of about $8,700 and $5,940 per year, respectively. There are seven main air-handling units in each building that will be converted to variable frequency drives. Installation costs to implement this ECM are estimated at $57,750 for each building.

ECM 8 – Turn Off Office Computer-Related Equipment During Unoccupied Periods

This measure estimates the savings potentially available by having building occupants turn off their personal computers when they leave for evenings and weekends. For purposes of this analysis, it has been estimated that about half the personal computers and related equipment in the building that are currently left on overnight and on weekends can be turned off. Office computer-related equipment consists of computers, display screens, printers, personal data assistants, etc. Modeling was accomplished by adjusting the operating schedule of office equipment to reduce current equipment use by half during unoccupied hours. This measure will reduce electrical consumption by about 139,710 kWh/year at ETB and 146,930 kWh/year at NSB. This will result in electrical energy cost savings of about $6,130 and $9,170 per year, respectively. This ECM is subject to administrative control, so there are no installation costs. However, actual savings may vary depending on the habits of the building occupants.

ECM 9 – Reduce HVAC System Static Pressure Set Points (ETB Only)

This measure changes the static pressure set point for the HVAC systems at ETB to match those modeled for NSB. Modeling was accomplished by reducing the static pressure of the supply fans by 1 inch on the water gauge. This measure will reduce electrical consumption by about 87,630 kWh/year, resulting in an electrical energy cost savings of about $3,460 per year. This ECM is subject to administrative control, so there are no installation costs.

Table 2 summarizes ECMs identified for ETB, the energy savings afforded by each ECM, the estimated installation costs to implement each ECM, and the simple payback period for installation costs. Table 3 summarizes ECMs identified for the NSB, the energy savings afforded by each ECM, and the estimated installation costs to implement each ECM, and the simple payback period for installation costs.

Table 2. ETB Energy Savings Implementing ECMs

ECM	Electrical Savings (kWh)	Electrical Cost Savings	Install Cost	Simple Payback Period (yr)
ECM 1 – HVAC System Setback	168,920	$4,090	$0	0
ECM 2 – Office Lighting Reduction	56,530	$2,550	$0	0
ECM 3 – Electronic Ballasts	20,720	$1,410	$58,960	>25
ECM 4 – Occupancy Sensors	8,490	$1,000	$54,340	>25
ECM 5 – Parking Lot Lighting	34,950	$1,140	$1,500	1.3
ECM 6 – Automatic LAT Reset	69,360	$3,805	$52,500	13.8
ECM 7 – Variable Frequency Fan Drives	223,210	$8,250	$57,750	7.0
ECM 8 – Office Computer-Related Equipment Reduction	139,710	$6,130	$0	0
ECM 9 – Static Pressure Reduction	87,630	$3,460	$0	0
Total energy savings for no install cost ETB ECMs = 452,790 kWh/year.				

Table 3. NSB Energy Savings Implementing ECMs

ECM	Electrical Savings (kWh)	Electrical Cost Savings	Install Cost	Simple Payback Period (yr)
ECM 1 – HVAC System Setback	91,460	$3,640	$0	0
ECM 2 – Office Lighting Reduction	23,230	$2,780	$0	0
ECM 3 – T8 Lamps/Electronic Ballasts	24,090	$2,760	$74,140	>25
ECM 4 – Occupancy Sensors	10,220	$1,120	$59,400	>25
ECM 5 – Parking Lot Lighting	44,570	$1,410	$1,500	1.1
ECM 6 – Automatic LAT Reset	152,110	$15,550	$52,500	3.4
ECM 7 – Variable Frequency Fan Drives	160,820	$5,940	$57,750	9.7
ECM 8 – Office Computer-Related Equipment Reduction	146,930	$9,170	$0	0
Total energy savings for no install cost NSB ECMs = 261,620 kWh/year.				

Conclusions

The primary reasons for the nearly 600,000 kWh (FY 2004) higher ETB energy usage (compared with the NSB during the same period) are the computers and cooling systems in the ETB basement. There is additional impact of the basement equipment on the central cooling systems, which could not be quantified. The computer-related energy usage in the ETB basement cannot be remedied since the number of computers in the building is still on the rise, and this will continue to be a problem until the computers can be relocated to a more suitable facility. In the future, PNNL should strive to design dedicated space for specialized computer servers and related equipment to minimize the impact on central HVAC systems.

The second objective of this study was to identify no installation cost ECMs that would save more than 515,520 kWh/year. The ETB/NSB no/low cost ECMs 1, 2, and 8 (plus ETB ECM 9) (Tables 2 and 3) could save 714,410 kWh/year and should be implemented immediately. Installing variable frequency fan drives (ECM 7) would save another 384,030 kWh and have a less than 10-year payback period. Turning off the parking lot lighting between midnight and 6:00 a.m. would save another 79,520 kWh at little additional cost.