Exploratorium Net Zero Energy Study:

Strategies to Reduce Peak Power Demand and Plug Load Energy Use

October 12th, 2012

Contents

EXECUTIVE SUMMARY

The results of this plug load reduction study found that with the right changes to equipment and due diligence of all the Exploratorium staff, plug load energy can be reduced to levels that predict the building will be net zero energy when fully occupied.

Net Zero Energy Performance

Based on the energy reductions made during the design and the plug load study, the project moved closer to the net zero annual energy goal. The predicted energy model uses 103% of the predicted solar energy provided by the PV system. Further savings in plug load energy up to 47% are possible.

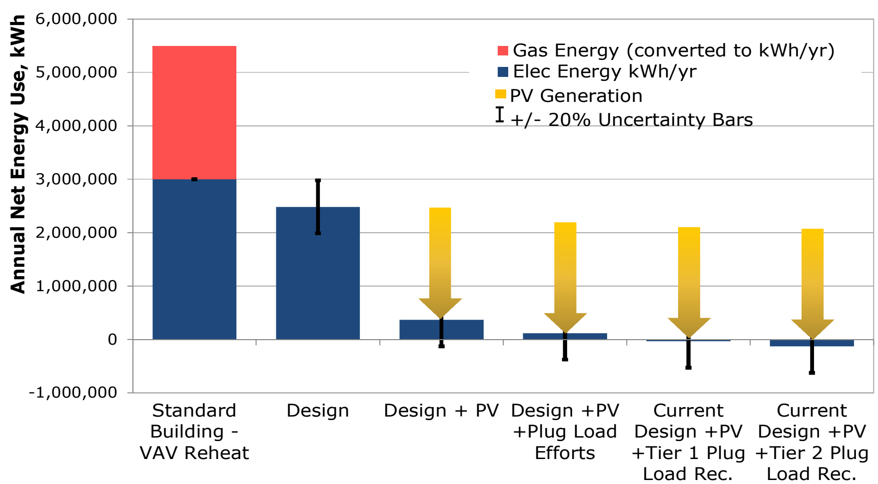


Figure 1: Annual Energy Use Reduction from a Standard Building Design

All estimates have a typical +/- 20% margin of error due to the both the software limitations of building simulation tools and the expected differences between actual operations as compared to the assumptions made in the models.

Plug Load Energy Reduction

Plug load annual energy was reduced by 24% from the design prior to this study. Further savings in plug load energy are possible by implementing the strategies described in our Tier 1 (39% savings) and Tier 2 (47% savings) recommendations.

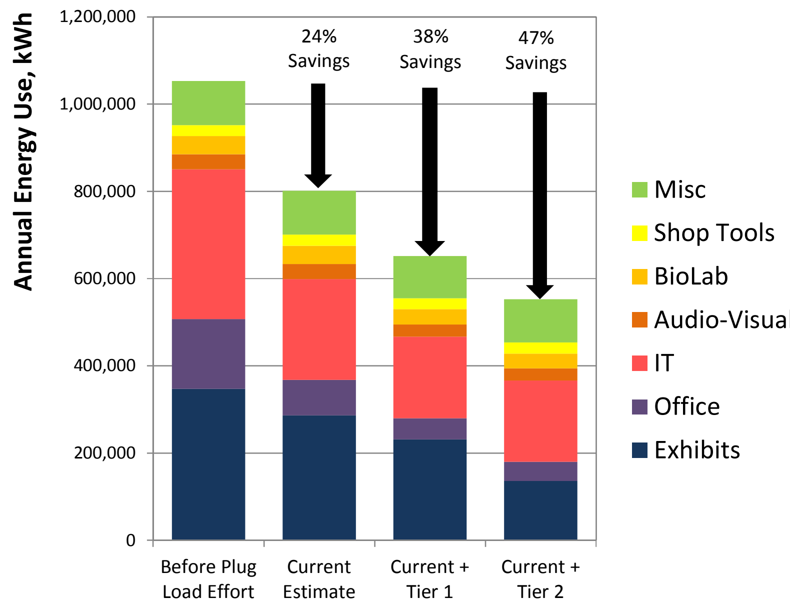


Figure 2: Plug Load Energy Estimates

Peak Power Building Demand Profile

The annual energy model was used to predict the peak power demand. This model is intended only for annual energy predictions; however these hourly results can help demonstrate the trends in power demand.

The demand profile shows the building peaking in winter months, when the building is in full heating. To understand the cost and operations implications of this analysis, we recommend the same third-party consultant that negotiated rates with PG&E should update their cost models with these revised building load models...

DISCLAIMER

The intent of this document is to predict the system performance of a building and/or mechanical systems for energy use and demand over a period of time. The contents of this report are based on engineering principles, energy modeling tools, and current best practices.

While this report makes estimates of performance and operations, the numbers presented here are only approximations and are built on several assumptions inherent to the software tools available and design information provided. Changes in building operation and usage can make drastic changes in energy use not anticipated in the model. Where additional information was needed, assumptions were made based on engineering practice and prior energy modeling experience.

Energy models of a building's performance should be used to help guide the design process and should not be considered or used as the basis of design or engineering calculations of record. Energy modeling tends to be most accurate as a tool for estimating the percent difference between two energy models, rather than predicting absolute energy use. An absolute energy question does present itself in the discussion of buildings trying to achieve a net zero energy standing.

Based on the assumptions and calculation methodology used, the estimates presented in this report are considered to have a margin of error of +/- 20% of actual building performance and energy consumption. For projects aiming for a net zero annual energy target, the industry best practice for sizing the energy generation components is to provide 20% more than the simulated annual energy consumption. The Exploratorium on-site energy generation was instead sized based on the available roof area of the building. Because of this limitation, the building will only achieve its net zero energy goal if the building operates within the limits of the modeled performance.

This report also discusses the peak electric demand profile of the building. These results were calculated using eQuest 3.64, a tool intended for annual energy simulations that averages loads over 1 hour time steps and is not intended for instantaneous peak load predictions. The results can be used to understand the relationship of the peak power demands over the year and where best to focus monitoring and control efforts. While peak power can be extracted from these analysis models, actual peak power may differ significantly.

Project Overview and Summary

The new Exploratorium building has had high goals in both energy efficiency and sustainability from the very beginning. The design team worked in full stead to incorporate these values into all elements of the work. The project aims to be net zero energy on an annual basis. Building towards this goal, the project selected to cover the south facing roof area with solar electric panels to balance the energy use.

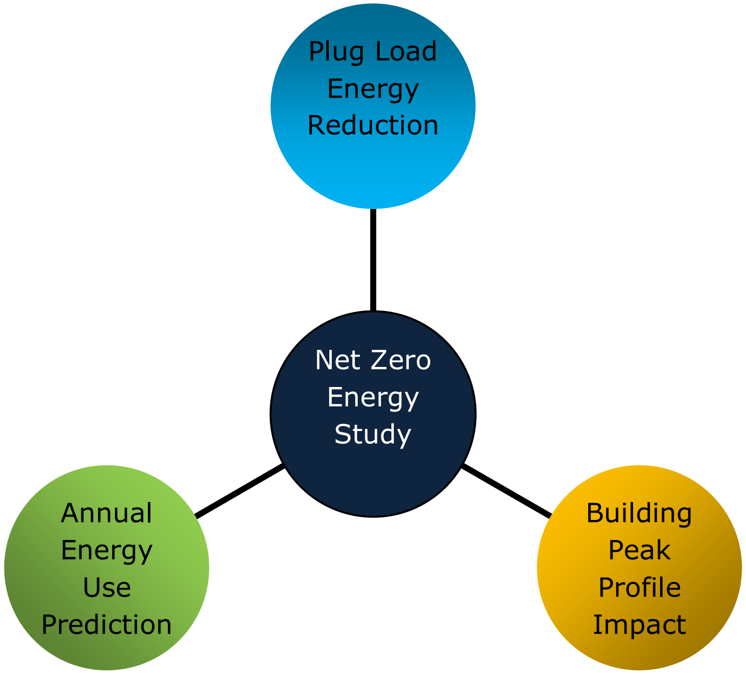
While many museums have exhibits on energy and sustainability, very few appear to have significant efforts on reducing energy usage for the exhibits themselves. The Exploratorium can lead the way for low energy museums by reducing exhibit energy usage.

This study surmises the findings of a plug load study, undertaken to further reduce annual energy use of electrical equipment and to better understand how the building is predicted to operate. The study focuses on three main discussions:

1. The annual energy prediction of the whole building
2. The plug load energy use by space type
3. A discussion of the peak demand profile

Each section will discuss the methods used and results found during the study. Based on the findings of these three areas of study, building level best practices are summarized at the end of this report.

As a part of their efforts to meet their net zero energy goals, the Exploratorium can use the strategies provided herein to reduce plug load energy use and peak power consumption.



Annual Energy Prediction

The annual energy prediction has been revised to include the reductions in plug load energy. The predicted energy model uses 103% of the predicted solar energy provided by the PV system. Further savings of plug load energy are possible. Specific measures have been surmised into two plans for the Exploratorium to consider:

- Tier 1 – Low Hanging Fruit Opportunities
- Tier 2 – More Difficult Opportunities

These plans are explained in detail in the **Plug Load Investigation Section** of this report.

Figure 3 summarizes these results in a graph and shows the PV energy generation. All estimates have a +/- 20% margin of error due to the both the software limitations of building simulation tools and the differences between actual building operations and our modeled assumptions.

These results are also shown in the cost per year of predicted energy in *Figure 4*. These results are based on the average electrical rate of $0.15/kWh for an A-6 Time of Use schedule specified for the Exploratorium. The actual energy cost and rates will be more complicated than this flat rate and were originally estimated by a third-party agency that accounted for the peak charges plus the sale of electrical energy back to the utility at a specified rate. For the purposes of understanding the general value of energy cost avoided, this simple rate was used. This translates directly into reduced solar power generation required to meet the net zero goal.

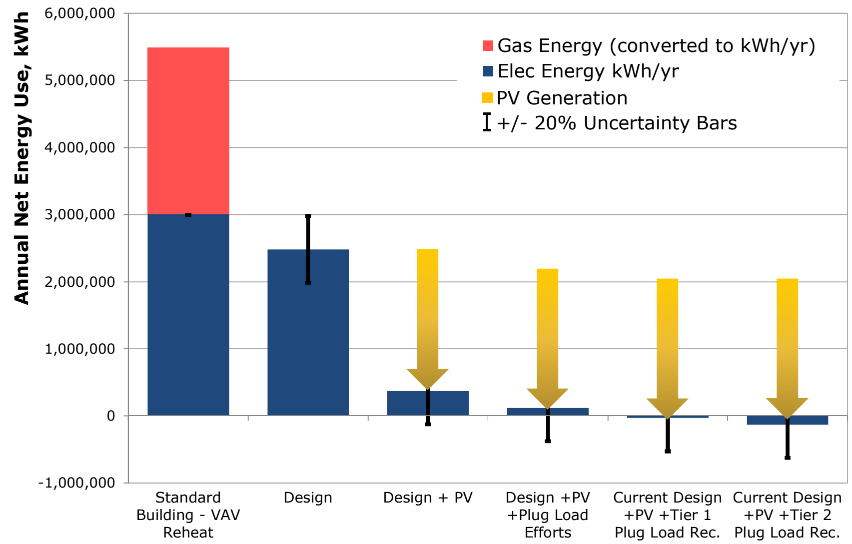


Figure 3: Pier 15 Annual Energy Use Estimations

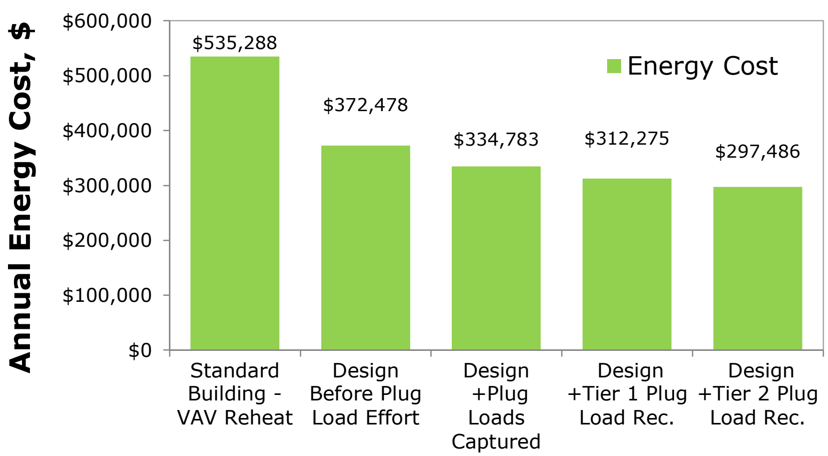


Figure 4: Pier 15 Approx. Annual Energy Cost Estimates

Plug Load Investigation

With assistance from the Exploratorium staff, estimated the energy consumption for the new Exploratorium by cataloguing each piece of equipment being installed. Additionally, the team measured the power use of nearly all existing exhibits in the facility. This resulted in a more refined plug load estimate, compared to the original estimate which was based on high level energy use intensity estimates.

Plug load usage was divided into eight different areas to help focus the data collection, analysis, and recommendations. These areas were selected based on the wide variety of equipment types and the Exploratorium staff who have control and knowledge over these areas. A summary of major equipment types and contacts are shown in *Table 1*.

Table 1: Plug Load Space Types

Space Type	Major Equipment Types	Main Contact
Exhibits	Motors, Lighting, Displays, etc	Ray Gruenig
IT	Servers, Network Gear	Chris Axley
Office	Computers, Displays, Printers, Appliances	Jennifer Fragomeni
BioLab	Microscopes, Freezers, Incubators	Angela Armendariz
Audio/Visual	Speakers, Projectors	Nicole Minor
Shop	Power Tools, Dust Collection	Chuck Mignacco
Café	Kitchen equipment (electricity & gas)	Clay Reynolds
Miscellaneous	Elevators, Warming Plates	n/a

The currently estimated plug load energy incorporates changes in the equipment and operation from the existing facility to the new building at Pier 15. The two sets of recommendations, with increasing levels of aggressiveness, are presented to move towards net zero operation.

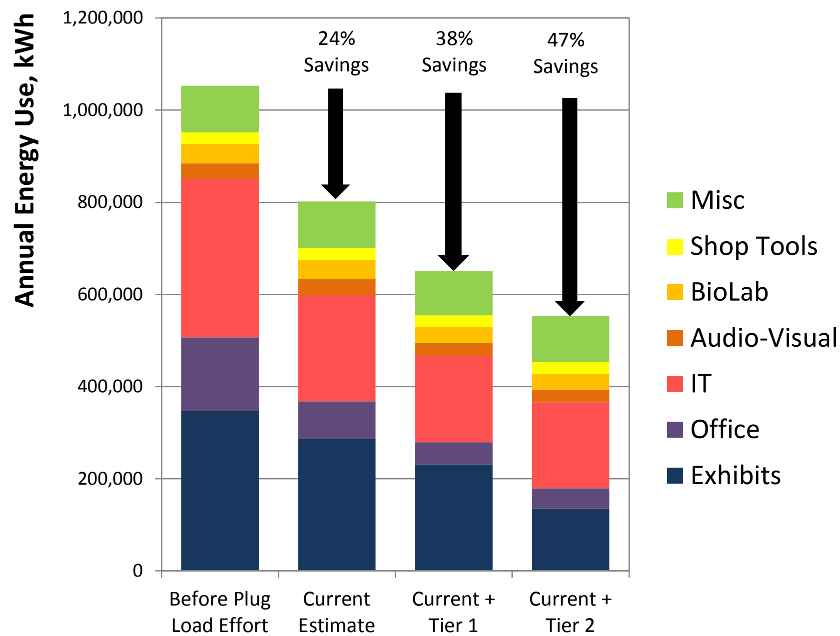


Figure 5: Plug Load Energy Use by Space Type

The estimated energy use for each space type is shown in *Figure 5*.

Data sheets were distributed to each contact who collected information about the equipment including model numbers, nameplate data, and quantity. When possible, actual power demand was collected onsite. Since the exhibits are primarily custom built, nearly all of the data in this area was based on actual power usage during active and idle states. Runtime for equipment was based on discussions with the key staff contacts, with consideration for expanded hours at the new Pier 15 facility. Assumed hours of operation are provided in Appendix 1. While a net zero facility requires energy efficiency and conservation across the board, space types with highest energy usage (Exhibits, IT, and Office) received the most attention. The café and exterior lighting is not included in the net zero energy goal, but equipment recommendations and best practices are provided for the tenant.

There were many pieces of equipment that could be considered part of two or more space types. These devices were assigned to which leads controlled the selection and operation of the equipment. Duplicates were eliminated when identified on more than one datasheet. Due to the sheer number of devices – over one thousand – there may still be duplicates and unidentified equipment.

What follows is a discussion of each space type and the recommendations for reducing plug load energy use. Following all the sections is the summation of all the recommendations as surmised into two plans for the Exploratorium to consider:

- Tier 1 – Low Hanging Fruit Opportunities
- Tier 2 – More Difficult Opportunities

Exhibits

Exhibits are the most visible, distinct, and largest energy user among all plug load categories, consuming an estimated 35% of plug load energy use. This includes old exhibits that have been operating for years, new exhibits in testing, and future exhibits that are in concept development and will eventually arrive in the new facility.

From spot measurements and surveys of current designs, a small number of exhibits are responsible for a large portion of energy usage. The top 10 exhibits, as seen in *Figure 6*, are estimated to consume over 30% of the energy for all existing exhibits. The top ten new exhibits, shown in *Figure 7*, are estimated to consume 67% of the energy for all new exhibits, but two of these – "Nakaya Fog" and "Thermal Mixing" – are on different meters and not included in the net zero goal.

The goal of studying the energy use of exhibits was first to produce a short-list of immediate items to focus on and second to help define a culture of design that considers the options and impacts with regards to energy.

What follows is a brief description of the process used, the findings, and the recommendations for the exhibit area.

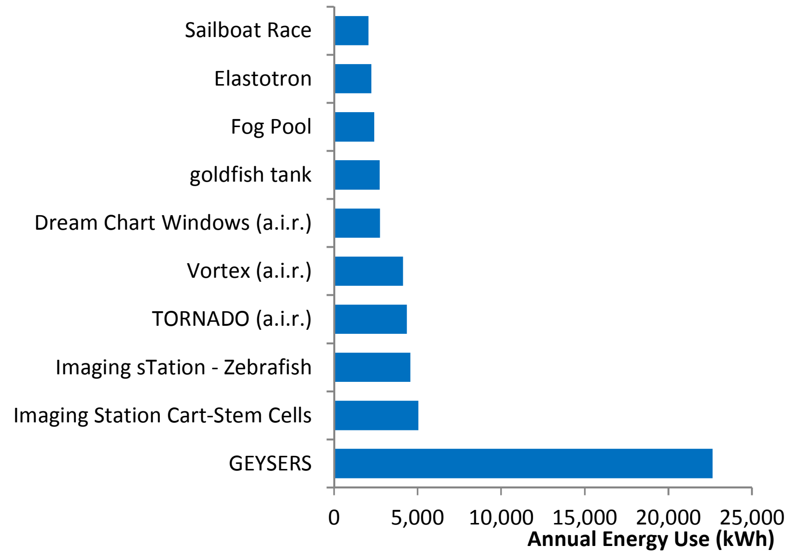


Figure 6: Top Ten Energy Users in Existing Exhibits

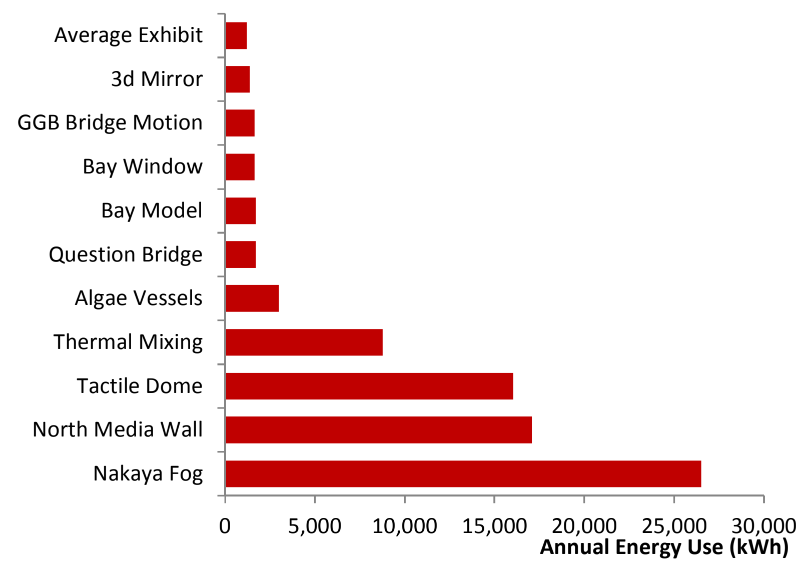


Figure 7: Top Ten Energy Users in New Exhibits

Inventory and Estimation Process

Existing estimates for the exhibits were developed with a bottom up strategy. The team and the Exploratorium measured actual power draw of each of the available exhibits for both active and idle modes. Usage profiles for each exhibit were developed with the user groups, identifying how many hours per day each exhibit was active, idle, or off. Tools used to measure:

- Kill-a-Watt Meters
- PowerSight Meter

There were several exhibits that were not available to be measured. Larger exhibits in this category ("Geysers" and "Vortex") were estimated based on nameplate information provided by the Exploratorium. Nameplate information is often much higher than actual power usage, which may result in a conservative estimate. The rest of the unmeasured exhibits were estimated to have the same energy consumption as an average exhibit.

Energy usage for the new facility was estimated by scaling the hours of operation for the new facility's hours and taking event usage into consideration. There are several dozen new indoor and outdoor exhibits that are being developed for the new facility. Power draw for these exhibits was estimated by the Exploratorium based on the exhibit components and existing exhibits. Hours of operation for indoor exhibits were based on the average current indoor exhibit runtimes. Outdoor exhibits were estimated to have a 40% duty cycle, which is close to the average indoor exhibit runtime. Outdoor lighting for unpaid spaces is assumed to have a 75% duty cycle.

Findings

As anticipated, exhibits are a significant energy user among plug loads, consuming an estimated 36%. Existing exhibits are anticipated to consume nearly 54% of exhibit energy, with new interior exhibits using 24% and exterior exhibits using 20% (see *Figure 8*).

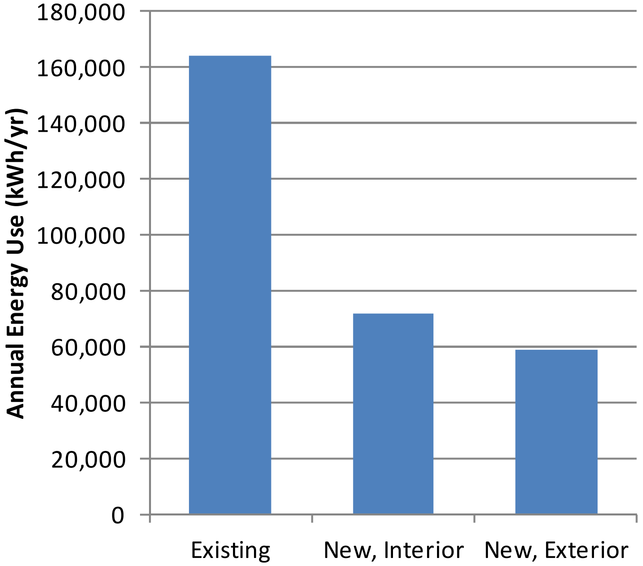


Figure 8: Exhibit Energy Use by Category

While we expected some exhibits to use more than others, we were surprised by the vast distributions between the largest and smallest users. One percent of existing exhibits, just three exhibits, are estimated to use 20% of exhibit energy. The top fifty exhibits consume 60% of exhibit energy, with the next fifty consuming only 15%. *Figure 9* demonstrates this phenomenon by showing the energy consumed by groups of fifty exhibits. A list of the top fifty energy users is available in Appendix 2.

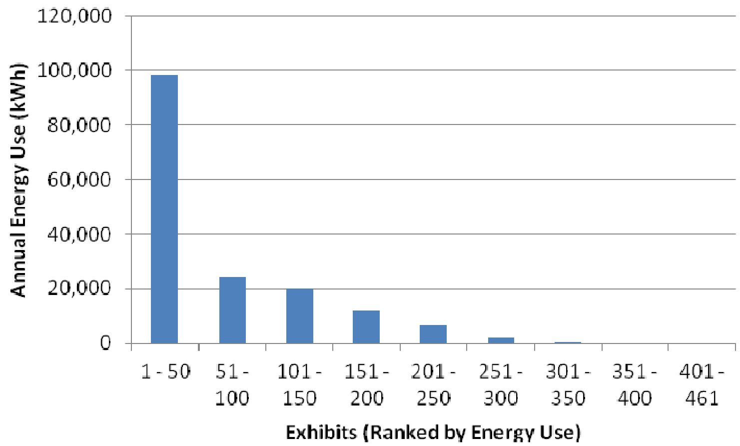


Figure 9: Energy Use Distribution across Existing Exhibits

In *Figure 10*, a similar disparity in seen in new exhibits. The top ten exhibits consume 67% of new exhibit energy. This includes the Nakaya Fog piece which will be on the Pier 17 meter and the Thermal Mixing piece which will be on the café submeter.

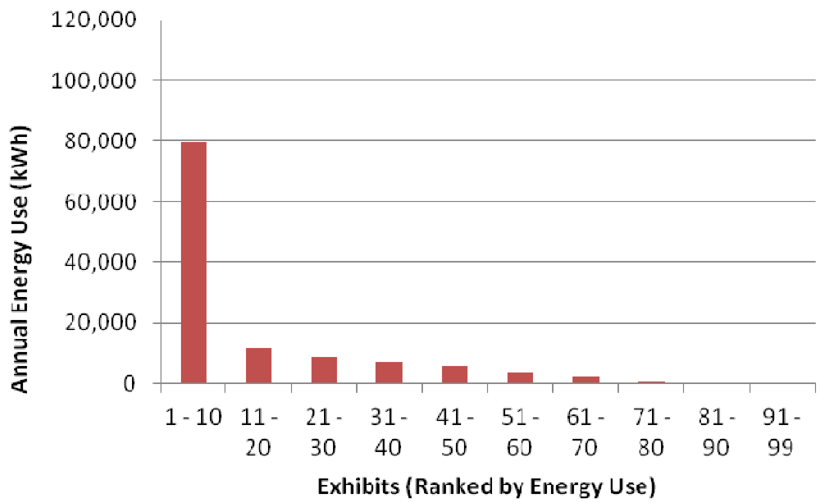
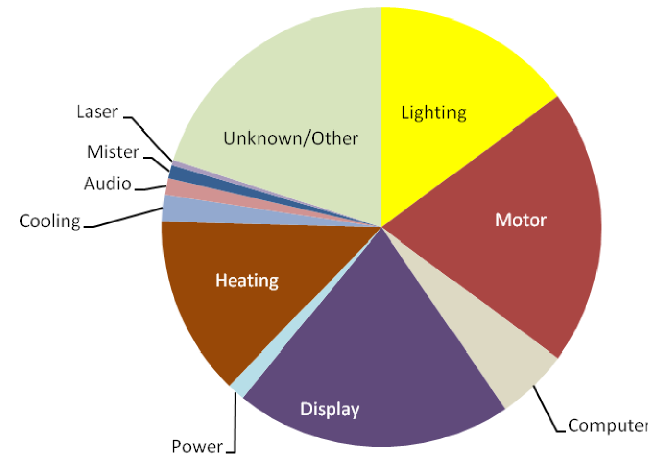


Figure 10: Energy Use Distribution across New Exhibits

When breaking down the energy usage by component type in *Figure 11*, displays and motors use the most energy, followed by lighting and heating elements. There is also a significant portion of exhibits with unknown or other component types. This category is thought to be primarily made up of all the others in a similar balance of consumption.



Component	Annual Energy Use (kWh/yr)			Percent of Total
	Existing	New	Total	
Lighting	29,834	12,150	41,984	15%
Motor	26,564	31,044	57,608	20%
Computer	8,690	6,425	15,115	5%
Display	23,034	34,810	57,844	20%
Power	3,729	0	3,729	1%
Heating	28,674	8,760	37,434	13%
Cooling	3,623	1,947	5,570	2%
Audio	2,359	1,114	3,473	1%
Mister	2,816	0	2,816	1%
Laser	1,099	0	1,099	0%
Unknown	33,780	22,922	56,703	20%

Figure 11 and Table 2: Exhibit Energy Use by Component

Recommendations

Measure 1: Reduce Geyser event frequency

We recommend retrofitting the exhibits with more efficient technologies when possible. “Geysers” is the most energy intensive exhibit, using four times as much as the next largest exhibit. The exhibit consists of three large electric resistance elements and a pump. The electric resistors operate continuously during operating hours to replicate the natural cycle of a geyser. The exhibit designer suggested replacing the heating elements from 2.2kW to 1kW or below, reducing associated electricity use by 50% or more. This would lengthen the eruption frequencies, but maintain the integrity of the exhibit.

Measure 2: Retrofit components of other exhibits

There are several exhibits using inefficient lighting which should be replaced with more efficient lighting (unless the existing lighting type is integral to the exhibit). The greatest opportunity for lighting reduction is by replacing MR16 halogen lights, shown in *Figure 12*. LED options are now available and can reduce power output by nearly 90%. A less efficient alternative is the halogen infrared (IR) MR16 lights, which reduce energy output by 30%, but look identical to the originals. Any remaining incandescents and halogens should be replaced with CFLs, like at the “Olvera Clock”. A small number of exhibits have T12 fluorescent tubes that should be replaced with Super T8 lamps and electronic ballasts, reducing power output by 40%. Any probe start metal halides and magnetic ballasts can be replaced with a lower wattage pulse start metal halide and electronic ballast.

There may also be opportunities to replace motors with more efficient motors or variable frequency drives. “Turntable” and “Vortex”, *Figure 13*, were identified as the best candidates for installing a variable frequency drive (VFD) to vary the speed and power draw of a motor. The VFD would efficiently reduce motor speed when not being used and quickly ramp up on command. Working systematically through the top energy users will help prioritize exhibits that would benefit most from this retrofit. A list of identified opportunities is in Appendix 3.

Figure 12: MR16 Lighting – Halogen (L) and LED (R)

Figure 13: VFD Candidates “Turntable” and “Vortex”

Older computers and displays are still connected to a handful of the exhibits, like “Talk to Daisy”. Replace these with the new office standards or another efficient selection appropriate to the exhibits.

Measure 3: Add idle mode to additional exhibits

Many exhibits already have an idle mode incorporated into their operation, which we estimate reduces their total energy consumption by about 37%. During the site visit, several other exhibits were also identified to have idle potential. Portions of or complete exhibits can be controlled with occupancy sensors when not being used. Other exhibits may benefit from a timer to reset settings or turn off after not being touched for several minutes. Exhibits identified during the site visit are provided in the Appendix 4, though many others may be candidates.

A great example is the “Blow Your Toaster” exhibit, which was recently retrofitted by the Exploratorium staff. The exhibit allows a visitor to turn up an electric resistance heater. Visitors would crank up the heater and then walk away, leaving the setting unchanged indefinitely. A timer was installed to reset the setting when the dial was untouched for a length of time. Encourage exhibit designers to share stories like this about their efforts to create more efficient exhibits. Praise and reward exhibit designers and other staff who reduce energy consumption, both internally and externally, by identifying these exhibits.

Measure 4: Group 24/7 exhibits on the same panel

A small minority of exhibits run continuously, due to life support or time-telling requirements. We recommend grouping these exhibits onto the same electric panel. This will make it easier to shut off non-critical banks of exhibits at once.

Measure 5: Only run outdoor exhibits while open

The outdoor exhibits in the unpaid space are currently estimated to operate 18 hours a day, much longer than the visiting hours. Running these exhibits only during visiting hours would save energy, but may also reduce the amount of public engagement.

Measure 6: Turn off exhibits during events

Several events are anticipated every week. Turning off exhibits during events will save about 15% of the exhibit energy, but may detract from the appeal of the Exploratorium space. Other options for dealing with event usage include holding events in less energy intensive exhibit areas or turning off exhibits when event goers are seated or away from the exhibits.

Measure 7: Turn off six highest energy users

Just as more efficient exhibits should be praised, exposing the least efficient exhibits may also be valuable. A small amount of exhibits consume large amounts of energy. Shutting down the top six energy users would reduce exhibit energy usage by 25%. Since this may remove popular exhibits, it may be preferable to limit their hours of operation, improve the efficiency of their components, or cull other exhibits. A less extreme measure would be to publicize the energy hogs (perhaps with small pig statues) to encourage more efficient design.

Measure 8: Exclude Nakaya Exhibit from NZE goal

The Nakaya fog piece will be a large energy user, but will be on the electric meter for the Pier 17 building and will run for less than a year. Excluding the exhibit from the goal will make it easier to track progress and better reflect the long term building energy use.

Measure 9: Exclude other exterior exhibits from NZE goal

While the recommendations above will reduce energy consumption, excluding certain exhibits from the net zero goal may be warranted. The thermal mixing exhibit will be located within the café and included on their submeter. Since the café has not been included in the net zero goal, it is reasonable to not include either of these exhibits in the goal. Another possibility is to remove the paid and/or unpaid exterior exhibits from the goal. This is not as attractive, but may allow for the Exploratorium to meet their indoor, non-tenant spaces if the initial estimates were low.

IT

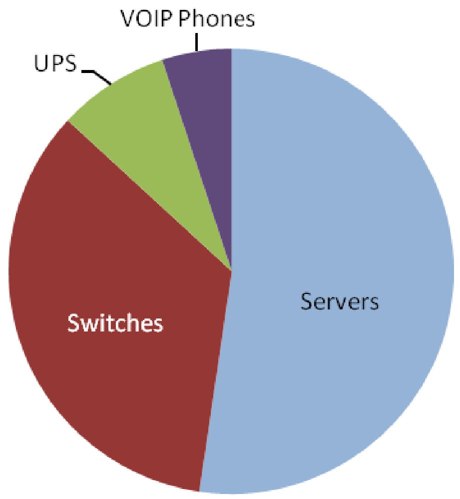
IT equipment is the second most demanding plug load space type, accounting for 30% of the plug load energy. The IT manager has already begun to virtualize servers, leading to a significant reduction in energy, and plans to continue the effort at the new facility. However, there may be opportunities to further reduce energy consumption in the IT realm. Personal office equipment was originally included in the IT section, but was moved to the Office section to reflect the physical location of the equipment and the broader staff interaction.

Inventory and Estimation Process

IT equipment usage was estimated based on the existing and proposed set of server and networking gear provided by the IT lead. When possible, energy usage was based on manufacturer information for typical energy consumption. In other cases, the rated power was used. This may result in an estimate higher than actual usage if the equipment goes into idle mode frequently. All of the equipment is estimated to run every hour of the year.

Findings

Although much effort has been made to reduce server energy consumption through virtualization, servers are the largest consumer of IT energy. Network switches are the next largest component, followed by uninterruptible power supplies and voice-over-internet phones. The breakdown of IT energy use by category is shown in *Figure 14*.



Component	Annual Energy Use (kWh/yr)	Percent of Total
Servers	120,662	52%
Switches	79,516	34%
UPS	18,660	8%
VOIP Phones	11,689	5%

Figure 14 and Table 3: IT Energy Use By Component

Changes from Initial Estimate

The initial estimate did not take into account the actual and planned virtualization of the servers. Server energy consumption was originally based on the rated power of the server, while the new estimate uses testing data from an ENERGY STAR study[1]. Energy use estimates for some equipment was based on existing equipment. These figures were updated based on the list of proposed equipment.

[1] http://www.energystar.gov/ia/products/downloads/ES_server_case_study.pdf

Recommendations

Measure 10: Enact Dynamic Power Management on servers

The HP servers (and possibly others) can utilize Dynamic Power Management, which matched the power output to the actual server load. Enacting these settings can dramatically reduce energy consumption during idle and partial loading, without a major impact on network speed. For example, the HP servers running in idle mode use more than 60% less energy than servers running at full load.

Measure 11: Turn off switching gear at night

The Cisco Catalysts consume most of the network switching energy and have nearly identical energy use in full load and idle modes. There may be an opportunity to turn off some of the switching gear at night. This would require experimentation once the network is established. These switches have EnergyWise capability, which allow power ports such as VOIP phones to be shut down when not in use. EnergyWise can also control power management on individual computers. We recommend exploring the full capability of EnergyWise to manage power on the various network devices.

Office

The office space type includes desktop computers, laptops, displays, printers, task lights and appliances. The anticipated computer and monitor fleet's energy efficiency has been greatly improved since the study began. However, there is still opportunity to improve the older stock and ensure that new appliances will be highly energy efficient.

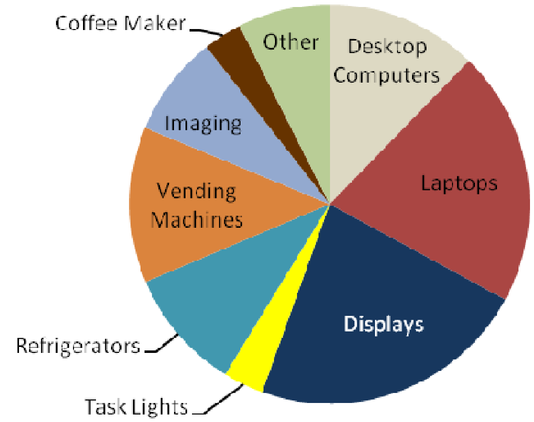
Inventory and Estimation Process

Office equipment estimates are based on an equipment inventory provided by the Exploratorium. Power draw was based on the ENERGY STAR database or the manufacturer. Nameplate data was used in some cases, which will result in an overestimate of those devices. Some new appliances were not yet selected; estimates for these devices were based on standard equipment.

We assumed computers and displays were on when employees are in the office and powered down on nights and weekends. Task lights were assumed to be on for half of the work week. Imaging equipment and appliances were assumed to be on for all six working days.

Findings

Displays and laptops are estimated to be the largest energy user among the office equipment. Even though they are being replaced with more efficient devices and assumed to turn off at night, the great number of laptops, displays, and desktops still use more than 50% of all office energy. Larger appliances, like refrigerators and vending machines, are the next largest energy user. These findings are summarized in *Figure 15*.



Component	Annual Energy Use (kWh/yr)	Percent of Total
Desktop Computers	11,000	13%
Laptops	16,831	20%
Displays	20,218	25%
Task Lights	2,602	3%
Refrigerators	6,290	8%
Vending Machines	10,046	12%
Imaging	6,957	8%
Coffee Maker	2,496	3%
Other	5,938	7%

Figure 15 and Table 4: Office Energy Use By Component

Changes from Initial Estimate

Since February 2012, the Exploratorium has made an effort to improve the current and proposed set of computers and displays. The new purchasing standard calls for devices with power consumption far below the average ENERGY STAR rating. Many older desktops have been or will be replaced by efficient laptops. The initial estimate also assumed each computer and display would be on for six days per week, when in reality these devices are assigned to users who typically work five days a week.

Recommendations

Measure 12: Implement monitor power management

Our analysis assumes that monitors and computers are on during the entire working day and off during unoccupied hours. Enact aggressive monitor power management settings that turn off the monitor after a certain amount of inactivity of time (as low as 5 minutes). Screen savers are not an energy efficiency measure and can actually result in increased energy consumption. We recommend either enacting this through the network or assigning one person to ensure everyone has enabled these settings on a per monitor basis.

Measure 13: Implement computer power management

This expands the monitor power management recommendation to computers as well. We recommend sending computers into standby or hibernation in as few as fifteen minutes.

Measure 14: Replace older monitors with new standard

Replace older monitors with the new Dell 2011H standard. While these monitors will be replaced over time, expediting this process will help the facility achieve net zero more quickly.

Measure 15: Replace older laptops and desktops with new standard

Expediting the replacement of laptops and desktops to the new standard will help the facility achieve net zero more quickly. Desktop users should be placed on the most efficient model when possible (Mac Mini and Dell Optiplex 990). The current set of standard equipment is shown in *Table 5* below, with a chart of their energy consumption in *Figure 16*.

Table 5: Current Computing Standards

Equipment Type	Model
Monitors	Dell E2011H
Laptops (PC)	HP Elitebook 8470p and 8560w
Laptops (Mac)	Macbook Pro 13" and Macbook Pro 15"
Desktops (PC)	Dell Optiplex 990 and HP xw 4600 workstations
Desktops (Mac)	Mac Pro and Mac Mini

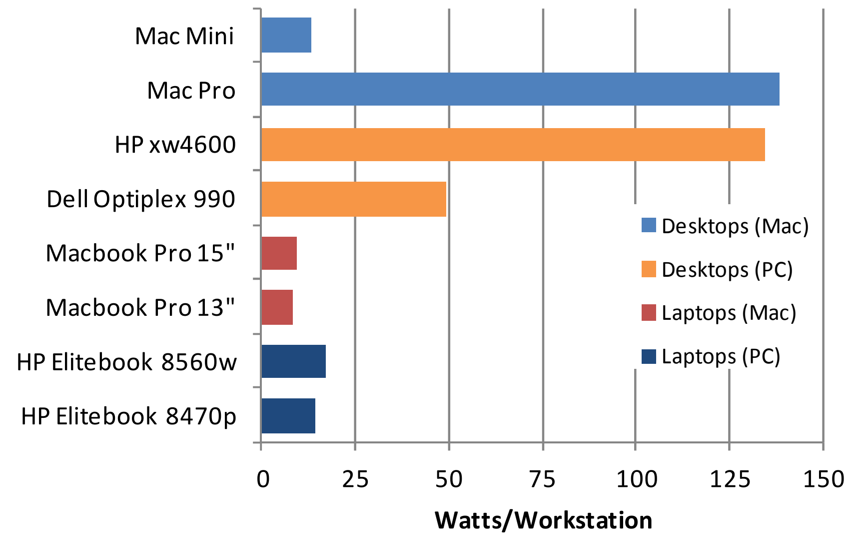


Figure 16: Power Draw by Workstation Model

Measure 16: Replace desktops with laptops or thin clients

Although the number of desktops has decreased, they still consume much more energy per user. Consider replacing desktops with laptops or even thin clients. Since desktops are typically provided for users with high performance needs, this is a less likely scenario.

Measure 17: Power Strip Control

We recommended occupancy sensor controlled power strips for task lights, monitors, chargers, and other equipment. These provide a low-cost solution that can help reduce random plug loads found in office environments. The LED task light has an occupancy sensor built in and monitors can be controlled with power management settings, which can be enacted network wide through the EnergyWise capability already available.

There has been interest within the Exploratorium for the Teknion furniture with Enmetric power bars built in (*Figure 17*). These devices can monitor power use on each individual plug. Energy consumption for each category of energy use can be tracked, and users can see how their energy use compares to the office average. The system can also be programmed to shut off different types of equipment at various times of day or when other equipment is turned off. Since most devices have other control mechanisms and the Enmetric system has a high first cost, it is not anticipated that there is enough hard savings to justify this system. However, there is an unquantifiable value for users to be aware of their energy consumption and for the Exploratorium to track energy use by device type. A pilot study of the Teknion/Enmetric system should be pursued if the costs are acceptable to the Exploratorium.

Figure 17: Teknion/Enmetric Plug Monitoring System

Measure 18: Efficient Printer Selection and Operation

Most of the existing printers are older ENERGY STAR qualified models, with high standby losses compared to today's models. Existing printers have standby losses of about 20W, while newer ENERGY STAR printers can have standby losses of less than 5W.

Purchase new printers and place more staff on the same printer when possible, to reduce standby losses. Select full-size copiers

that are enabled to turn off when not in use. The current copiers vary in power draw, but have standby losses of up to 185W during standby and 100W during sleep mode.

Standby power losses can also be reduced by external controls. Individual printers can be turned off with Smart Strips or the Enmetric system by turning off printers when the associated computer is turned off. Shared printers and copiers can be turned off when all associated computers are turned off, if the Enmetric system is selected. The EnergyWise feature in the network switches may also be able to provide similar control.

Measure 19: Select high efficiency refrigerators

For the eight new refrigerators, we recommend high efficiency Sun Frost units[2] which use 50% less energy than the than federal standard. Typical ENERGY STAR mid-range refrigerators are only 20% better. Consolidation of refrigerators would provide additional benefits. Additional savings can be attained by keeping the refrigerators stocked and cleaning the condenser coils.

For the under counter refrigerator, we recommend the Paykel RB36S, which uses 63% less energy than the federal standard.

Measure 20: Select ENERGY STAR rated Vending Machines and Incorporate Vending Misers

Two new vending machines will be acquired, which we recommend have ENERGY STAR rating. Models with lower vendible capacity have lower energy usage, but may also require more frequent servicing. Vending Miser occupancy sensors are also recommended to further reduce energy consumption[3].

[2] http://www.sunfrost.com/refrigerator_models.html

[3] http://www.usatech.com/energy_management/energy_vm.php

Measure 21: Select coffee makers with insulated carafes and tankless water heaters

Four coffee machines will be acquired for the new facility. ENERGY STAR does not yet rate coffee machines. We recommend coffee machines with an insulated carafe rather than a hot plate. Most coffee makers are on standby and have a tank of hot water on standby. We recommend Newco Coffee ECO or AKH family, depending on specific needs. These machines heat water instantaneously rather than keeping a hot water reserve. This is not an ideal model for tea or hot chocolate. You could brew a carafe of hot water by not putting any coffee in the device, but this may require some behavioral change.

http://www.newcocoffee.com/family-akh.htm#eco

Measure 22: Select high efficiency dishwasher

If a compact dishwasher is acceptable, then Fisher & Paykel (DD24STI7 or DD24SHTI7) is recommended. This model uses 50% less electricity and water than required than federal standard.

If a standard dishwasher is required, Bosch (SHE8ER55UC or SHX8ER55UC) is recommended. It has 35% more electricity and 10% more water use than the compact Fisher & Paykel. Larger capacity would make up for most of the additional electricity use if fully loaded.

SHE8ER55UC

SHX8ER55UC

Biolab

The Biolab consumes an estimated 5% of the building's plug load energy. Major equipment includes microscopes, freezers, incubators, and grow lights. There are a few opportunities to reduce energy consumption, including more efficient equipment and smaller freezers.

Inventory and Estimation Process

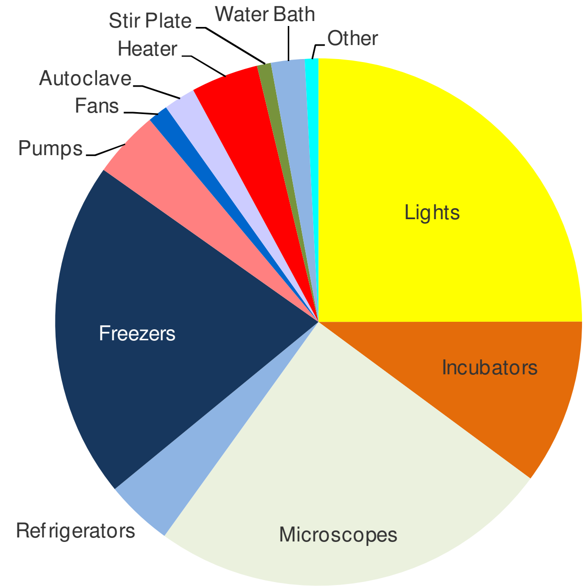
Equipment energy use was primarily based on nameplate and manufacturer information. The hours of operation were provided by the Exploratorium and vary considerably. Some equipment, like the freezers and incubators must run at all times, while others run infrequently, like the mushroom fogger. There are also several components that run only during operating hours.

Findings

While the Biolab is fairly energy intensive, its smaller area results in relatively lower total energy consumption. Lighting is the largest contributor to energy consumption, followed by microscopes, freezers, and incubators. The component level energy breakdown is shown in *Figure 18*.

Changes from Initial Estimate

The initial estimate used energy intensity for a typical lab. The refined estimate incorporates the full inventory and estimated hours of operation to better reflect this specific lab.



Component	Annual Energy Use (kWh/yr)	Percent of Total
Lights	10,527	25%
Incubators	4,281	10%
Microscopes	10,470	25%
Refrigerators	1,747	4%
Freezers	8,736	21%
Pumps	1,737	4%
Fans	524	1%
Autoclave	819	2%
Heater	1,747	4%
Stir Plate	353	1%
Water Bath	874	2%
Other	354	1%

Figure 18 and Table 6: Biolab Energy Use By Component

Recommendations

Measure 23: Replace grow light and light boxes

We recommend upgrading the process lighting. The grow lights should be replaced with lower wattage pulse start metal halides with electronic ballasts. The light box with T12 fluorescent lamps should be replaced with Super T8 fluorescent lamps and electronic ballasts. The new facility is currently considering high wattage CFLs for the grow lights. However, both pulse start metal halide/electronic ballast and Super T8 linear fluorescent systems are more efficient. If these options are acceptable, they should be considered for the new facility. Incorporate photosensors to turn off artificial lighting when daylighting is plentiful.

Measure 24: Replace existing computers and monitors

Replace the microscope computers and monitors with the new facility standard to reduce Biolab energy by an estimated 10%.

Measure 25: Restrict use of sub-80 freezers

The current sub-80 freezer was being used to store dry ice, in addition to lab samples. A smaller lab freezer was selected for the new lab and will use 70% less energy, with the dry ice deliveries stored in the shop.

Measure 26: Retrofit microscopes with LEDs

One of the microscopes has LED lighting, but others still use halogen lighting. Check with the microscope servicer to see whether these microscopes could be retrofit with LEDs. Microscopes in the Clean Room are used infrequently and not prime candidates for retrofit.

Audio Visual

The Audio Visual (A/V) space type includes all equipment in the Theatre and Webcast Studio and the exhibit audio system. Components include speakers, projectors, playback devices, antennas, monitors, and controls. The Audio Visual space type itself is one of the smaller plug load segments, but similar components are captured elsewhere. Select ENERGY STAR rated equipment and de-energizing devices through cultural shifts and automated controls.

Inventory and Estimation Process

A list of anticipated A/V equipment was provided by the Exploratorium. Power draw was estimated by researching rated or typical wattage on manufacturers' datasheets. Speakers and amplifiers were estimated to use only 10% of their rated power, since their normal operation has much less demand, due to variations in volume and signals. Hours of usage was based on information from the team lead. Most equipment was assumed to be operating during all visiting hours, though many items like webcasting gear and performance equipment will be used sparingly.

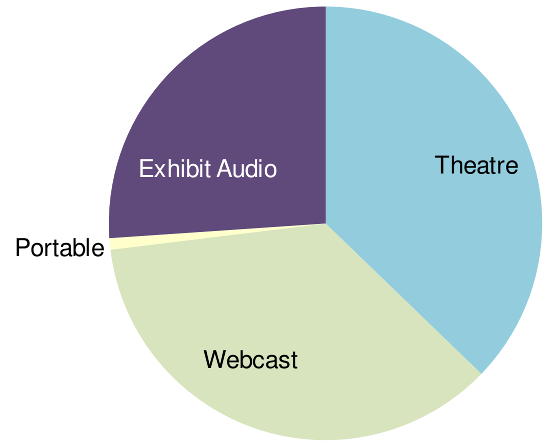
Only the general exhibit audio was included in this space type. Audio and visual equipment for individual exhibits were kept in the exhibit category.

Findings

We found a fairly even distribution of energy use between the Theatre and Webcast Studio, with a somewhat lower use from the general exhibit audio system (

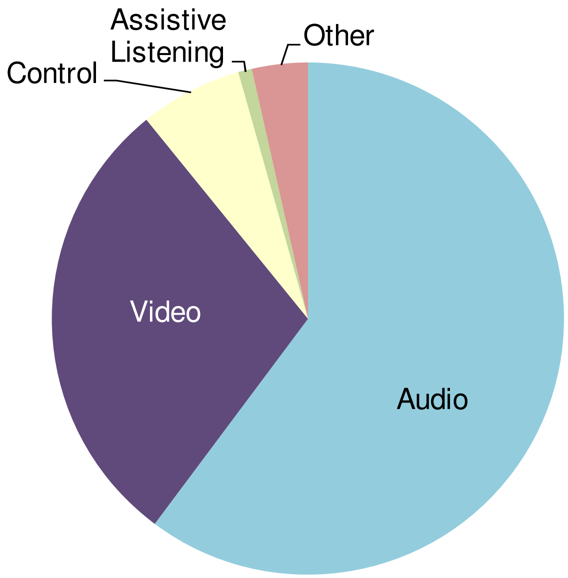
Figure 19). Audio equipment consumes more power than the video equipment, with controls and other components far behind (

Figure 20).



Area	Annual Energy Use (kWh/yr)	Percent of Total
Theatre	12,823	37%
Webcast	12,333	36%
Exhibit Audio	8,987	26%
Portable	292	1%

Figure 19 and Table 7: Audio Visual Energy Use By Area



Component	Annual Energy Use (kWh/yr)	Percent of Total
Audio	20,731	60%
Video	9,967	29%
Control	2,228	6%
Assistive Listening	300	1%
Other	1,210	4%

Figure 20 and Table 8: Audio Visual Energy Use By Component

Changes from Initial Estimate

The original estimate used a top down method based on power density for similar spaces. The new estimate utilizes a bottom up approach that looks at each piece of equipment and its associated power draw and annual hours of operation.

Recommendations

Measure 27: Select ENERGY STAR equipment

The wide diversity and needs of audio and visual equipment makes it difficult to make concrete model recommendations. We recommend selecting ENERGY STAR rated equipment when available. These devices have high amplifier efficiency, low power usage when idle, and auto power down.

Measure 28: Connect peripherals to Smart Strips

There may be several pieces that could benefit from a Smart Strip, as seen in *Figure 21*. Smart Strips shut down peripherals when the large, master equipment is off. This reduces both active and vampire energy usage. For example, when a computer shuts off, the associated display, speakers, and transmitters turn off as well. This is especially important for devices that are not ENERGY STAR rated and may use significant amounts of energy when idle or "off". The Enmetric system can provide similar capability, but would require additional staff effort to program the rules. Turning off power strips manually is also effective, but may be less reliable.

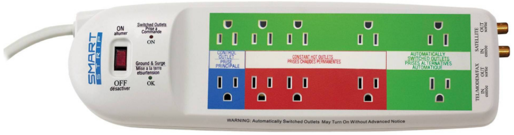


Figure 21: Smart Strip

Shop

Shop equipment consists of power tools and related equipment in the machine, welding, and wood shops. Though the shop space type is the smallest contributor to plug load use, there are still opportunities to reduce energy use by selecting efficient equipment and turning tools off when not in use.

Inventory and Estimation Process

Shop equipment was estimated based on measured amps, supply voltage, and an assumed power factor of 80%. Shop personnel provided information about estimated weekly runtime for each of the devices.

Findings

Due to the relatively low energy use of the shops and wide variety of equipment, our efforts did not focus on the shop. While power tools have a large power draw, each individual device is used infrequently. The woodshop uses the most energy, mostly from the table saw and dust collection system. The machine shop is the next largest user, followed by the welding shop. Energy use by component is shown in *Figure 23*.

Changes from Initial Estimate

No changes were made from the initial estimate.

Recommendations

Measure 29: Reduce charging losses

Make sure equipment is shut off when not in use. Many power tools require a charging station, which may still draw power after the charging is complete. Energy saving charging stations (*Figure 22*) shut off the charger when batteries are fully charged. ENERGY STAR does rate portable chargers for power tools, which should be specified in the purchasing policy.

Figure 22: Smart Charging Station

Measure 30: Shop tool best practices[4]

Use hand tools when possible

Keep tools sharp and clean

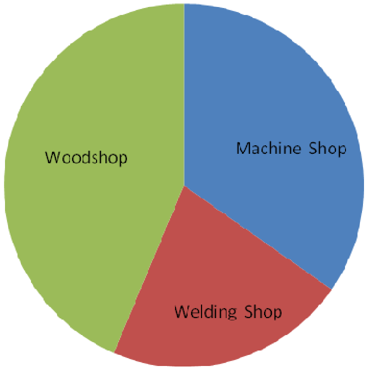
Let equipment cool down

Use 220V equipment to reduce line losses

Use corded tools instead of chargers

Select large gauge extensions

Use thin kerf blades for saws



Area	Annual Energy Use (kWh/yr)	Percent of Total
Machine Shop	8,727	35%
Welding Shop	5,448	22%
Woodshop	10,976	44%

Figure 23 and Table 9: Shop Energy Use By Area

[4] http://frugalwoodworking.com/techniques/energy-efficient-woodshop/

Miscellaneous

Any identified equipment that does not fit the space types, HVAC, or lighting is included in this category. This is almost entirely composed of the elevators, with a small portion due to the warming plates outside of the café submeter.

Inventory and Estimation Process

Energy use for the five elevators was estimated based on the rated loads, elevator speed, and several other assumptions.

The warming plates were based on the rated load and estimated runtimes provided by the Exploratorium.

Findings

Elevators alone are estimated to use a significant amount of energy, about 4% of total building electricity use. The American Council for an Energy-Efficient Economy considers elevator use to account for 5% of North American office building energy consumption, which is close to the Exploratorium estimate. The calculation is highly sensitive to estimates of capacity and usage frequency. There is a chance we overestimated the elevator energy usage, but our estimate should be used for planning purposes.

Changes from Initial Estimate

There are no changes in the elevator estimate. Other elevator calculators were used to estimate the energy use, with most being smaller than the original estimate. The warming plates were not specifically included in the initial estimate.

Recommendations

Measure 31: Encourage use of stairs over elevators

Elevators are a major electrical load. Encourage staff and public to use stairs to reduce energy use and promote healthy activity. We recommend signage encouraging visitors and staff to use the stairs when possible. Although elevators do have a substantial standby load, most of the energy is used to move people. Ensure that the fans and lights are turned off when the elevator is not being used.

Café

While the café will not be run by the Exploratorium or included in the initial net zero energy goal, it is still important to decrease all energy consumed within the building. If the building operates more efficiently than predicted, adding the café to the net zero goal would further increase the Exploratorium's standing in the green building community. The estimated electricity usage of café components is shown below, but is not included in net zero estimates.

Table 10: Café Energy Use By Component

Component	Annual Energy Use (kWh/yr)
Lighting	20,480
Domestic Hot Water	28,336
Fans	52,111
Thermal Mixing Exhibit	8,760

Recommendations have been made to the café operator and are included below, along with best practices.

Inventory and Estimation Process

The café operator provided a cutbook of the proposed set of equipment, but did not provide information on specific models or anticipated runtime. Since the café was not included in the scope of the goal, no additional effort was made to further estimate the equipment consumption. The café submeter will simplify future estimates of equipment usage.

Findings

The proposed set of kitchen equipment includes a wide variety of electricity and gas consuming devices. Some of the models are ENERGY STAR rated while others are not, even though they fall into categories of equipment rated by the organization.

Changes from Initial Estimate

There are no changes from the initial estimate due to lack of information and scope of the study.

Recommendations

We recommend selecting ENERGY STAR rated or rebate qualified equipment[5]. Even within these ratings, there is a wide range in energy efficiency. The most efficient piece of equipment meeting the café needs should be selected. When we were provided with enough information on these needs, e.g., volume or heating capacity, specific recommendations were made.

Measure 32: Increase Cold Storage Insulation

The cold storage unit initially had an estimated insulation R-value of 22. We recommended increasing the insulation: the kitchen designers have selected units with insulation of R-34, a large improvement from the draft cutbook.

Measure 33: Select ENERGY STAR Freezer

The currently specified freezers are not ENERGY STAR qualified. ENERGY STAR options available, but we need more information for a specific recommendation.

[5] http://www.fishnick.com/saveenergy/rebates/

Measure 34: Select ENERGY STAR Hot Holding Cabinet

The currently specified hot holding cabinets are not ENERGY STAR qualified. Based on the dimensions of the currently specified units, we recommend the Cambro CMBH1826L for Item 18 and the Cambro UPCH400, UPCHD400, or UPCHW400 for Item 66. If these models do not meet the café's needs, another ENERGY STAR unit should be specified.

Cambro CMBH1826L

Cambro UPCH400/UPCHD400/UPCHW400

Measure 35: Exhaust Hood Control

We recommended demand control ventilation on exhaust hoods, like the Melink Intelli-hood shown in *Figure 24*. This device adjusts ventilation based on opacity of smoke and occupancy to reduce fan and cooling costs. Demand control ventilation has been incorporated into the design.

Figure 24: Melink Intelli-hood

Measure 36: Select ENERGY STAR Refrigerators

The currently specified under counter refrigerators are not ENERGY STAR qualified. ENERGY STAR options available, but we need more information for a specific recommendation.

Measure 37: Purchase finned-bottom pots and pans

We recommend finned-bottom pots and pans (like Turbopots) to reduce associated energy consumption by 30% and decrease cooking time. An example is seen in *Figure 25*.

Figure 25: Turbopot

Measure 38: Select Low Demand Coffee Maker

We suggest getting the lowest possible kW rated model of the options shown in the cutbook. This would decrease throughput but reduce demand (which could be as high as 12 kW).

Measure 39: Select Water-Cooled Ice Machines

We recommend selecting water-cooled ice machines rather than air-cooled machines to reduce associated energy consumption by more than 30%.

Efficient Kitchen Practices

Once the equipment is selected and installed, even more energy can be saved by following best practices. The Food Service Technology Center is a resource for efficient equipment and operation. We recommend following their energy savings tips.[6,7]

A few selected tips are below:

- Turn off equipment (especially broilers) when not in use. During downtimes, turn down or off extra burners.
- Fully load dishwashers to reduce the number of washes.
- Set Water Heater to Proper Temperature. Only heat water to the temperature required for specific tasks in your operation. Typically this means either 110°F or 140°F for the dishwashing machine.
- Clean dirty refrigeration condenser coils often (saves energy and reduces service calls). Clean coils with a vacuum or coil brush - avoid brooms and caustic chemicals.
- Turn Off Door Heaters on Reach-In Refrigeration. Heaters should only be used if condensation appears around doors. Look carefully since the switches are sometimes hidden.

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[6] http://www.fishnick.com/saveenergy/energytips/natural_gas_10_ways.pdf

[7] http://www.fishnick.com/savewater/bestpractices/Water_Conservation_in_CFS.pdf

Summary

A summary of plug load reduction measures are shown in *Table 11: Summary of Recommendations* below. Plug load measures that have already been incorporated into the design are shown as Tier 0. Recommendations are marked as either Tier 1 or 2, based on our judgment of ease of implementation, cost, and impact on staff and visitors. To avoid double counting savings, the total energy savings for Tier 1 and Tier 2 includes interaction between measures. The energy savings of some measures were not quantified, due to scope or certainty in estimation methods. These measures are identified as not calculated (n.c.).

Table 11: Summary of Recommendations

Measures Already Incorporated Into Design			
Measure ID	**Measure Name**	**Estimated Energy Savings (kWh/yr)**	**Tier**
A	Initial computer and monitor recommendations	22,275	0
B	Initial display recommendations	34,962	0
C	Task lighting recommendations	20,628	0
D	Night exhibit reduction	60,917	0
E	Server virtualization	112,515	0
Exhibits			
Measure ID	**Measure Name**	**Estimated Energy Savings (kWh/yr)**	**Tier**
1	Reduce Geyser event frequency	11,326	1
2	Retrofit components of other exhibits	6,390	1
3	Add idle mode to additional exhibits	10,224	1
4	Group 24/7 exhibits on the same panel	n.c.	1
5	Only run outdoor exhibits while open	6,904	2
6	Turn off exhibits during events	23,488	2

7	Turn off six highest energy users	52,910	2
8	Exclude Nakaya Exhibit from NZE goal	26,515	1
9	Exclude other exterior exhibits from NZE goal	23,740	2
IT			
Measure ID	**Measure Name**	**Estimated Energy Savings (kWh/yr)**	**Tier**
10	Enact Dynamic Power Management on servers	17,831	1
11	Turn off switching gear at night	25,723	1
Office			
Measure ID	**Measure Name**	**Estimated Energy Savings (kWh/yr)**	**Tier**
12	Implement monitor power management	5,769	1
13	Implement computer power management	4,285	1
14	Replace older monitors with new standard	5,455	1
15	Replace older laptops and desktops with new standard	8,083	1
16	Replace desktops with laptops or thin clients	9,804	2
17	Power Strip Control	n.c.	
18	Efficient printer selection and operation		
19	Select high efficiency refrigerator	3,559	1
20	Select ENERGY STAR rated Vending Machines and Incorporate Vending Misers	5,696	1
21	Select coffee maker with insulated carafe and tankless water heater	1,248	1
22	Select high efficiency dishwasher		
Biolab			
Measure ID	**Measure Name**	**Estimated Energy Savings (kWh/yr)**	**Tier**
23	Replace grow light and light boxes	2,702	1
24	Replace existing computers and monitors	4,179	1
25	Restrict use of sub-80 freezers		
26	Retrofit microscopes with LEDs	1,048	2

			Audio Visual
Measure ID	Measure Name	Estimated Energy Savings (kWh/yr)	Tier
27	Select ENERGY STAR A/V equipment	3,444	1
28	Connect A/V peripherals to Smart Strips	3,444	1
			Shop
Measure ID	Measure Name	Estimated Energy Savings (kWh/yr)	Tier
29	Reduce charging losses	n.c.	1
30	Shop tool best practice	n.c.	1
			Miscellaneous
Measure ID	Measure Name	Estimated Energy Savings (kWh/yr)	Tier
31	Encourage use of stairs over elevators	4,183	1
			Café
Measure ID	Measure Name	Estimated Energy Savings (kWh/yr)	Tier
32	Increase Cold Storage Insulation	n.c.	1
33	Select ENERGY STAR Freezer	n.c.	1
34	Select ENERGY STAR Hot Holding Cabinet	n.c.	1
35	Exhaust Hood Control	n.c.	1
36	Select ENERGY STAR Refrigerators	n.c.	1
37	Purchase finned-bottom pots and pans	n.c.	1
38	Select Low Demand Coffee Maker	n.c.	1
39	Select Water-Cooled Ice Machines	n.c.	1
	Total - Tier 1	**150,055**	
	Total - Tier 1 + 2 (includes interaction)	**251,435**	

Figure 26 visualizes the estimated annual energy savings for the quantified measures in each of the tiers.

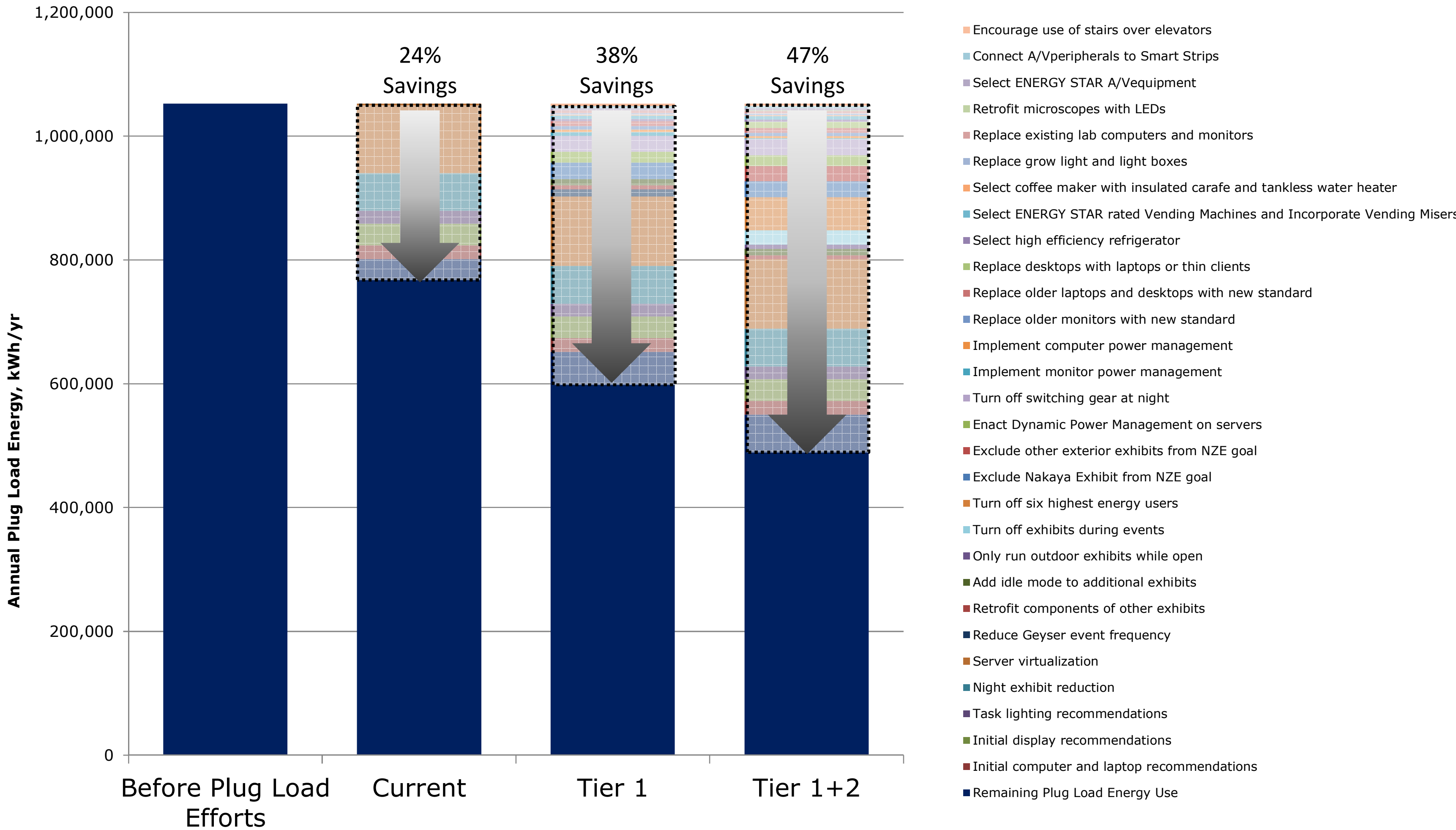


Figure 26: Annual Energy Savings for Plug Load Reduction Measures

Peak Power Building Demand Profile

The annual energy model originally used to predict the peak power demand was revised. The model is built in a tool intended for annual energy predictions (eQuest 3.64); however these hourly results can demonstrate the trend in power demand profile.

The demand profile shows the building peaking in winter months, when the building is in full heating mode.

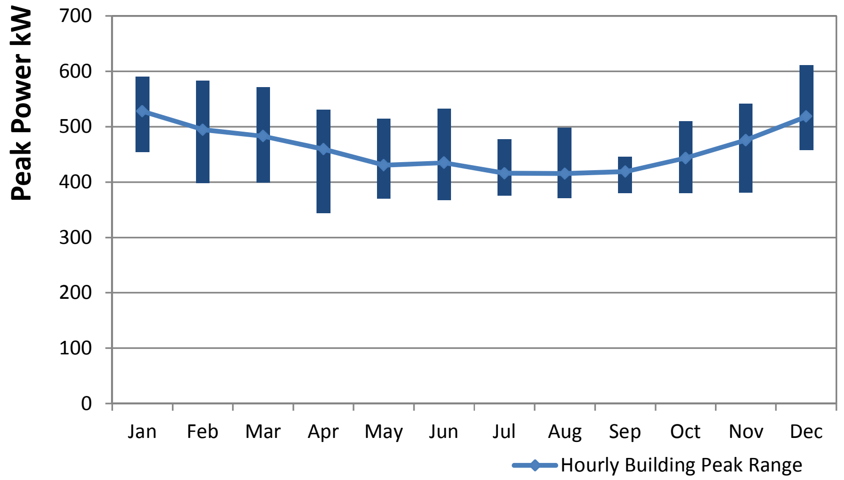


Figure 27: Building Peak Demand Profile

This result is a prediction of the design and operations of the building and should be considered a guiding tool for understanding relationships between the building demand and the environment and use during those peaks.

The building demand profile was previously predicted by a third-party consultant who took an energy profile from the energy model and combined this with the annual PV output to predict the facility's rate structure and the annual energy cost and risk. The numbers here can only be used to understand the simulated profile of energy demand. For a full update to this analysis, the same third-party consultant who was hired to estimate the utility rate structure and peak should update their analysis with this new model.

A quick PV calculation was done using PV-Watts (created by NREL) based on the size, location and orientation of the designed system. Figure 28 shows the PV production and building demand graphed together. The building demand varies a little each month, shown in dark bars. The PV can vary significantly in production based on the position of the sun throughout the year.

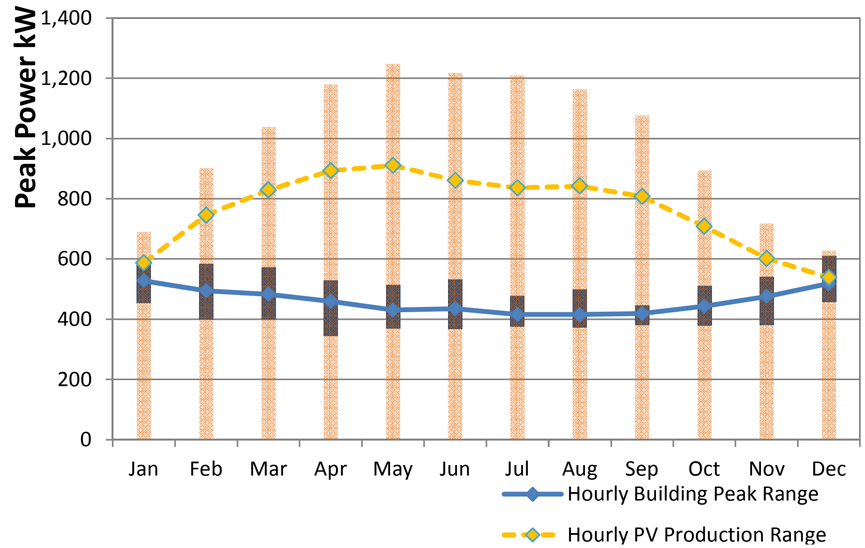


Figure 28: Building Demand with Rough monthly PV Production Estimate

The building profile can help to understand how the building is anticipated to operate over the year and where to expect the bulk of the demand to come from. Over the whole year, the energy model shows that most of the energy use is in the heating system and in the plug load energy.

We recommend verifying the peak heating loads in the winter season of 2012 when the building will be functional but not fully occupied. The simulation relies heavily on the assumed operating schedule of the facility. General energy modeling software for buildings currently do best when predicting loads for air-based heating systems and require special care and approximations for radiant concepts. Of all mechanical heating systems, radiant heating can offer the most flexibility in operations to avoid peaks demands.

What follows is a discussion of the peak plug load predictions and diversities and then monthly typical-day graphs of the building demand profile.

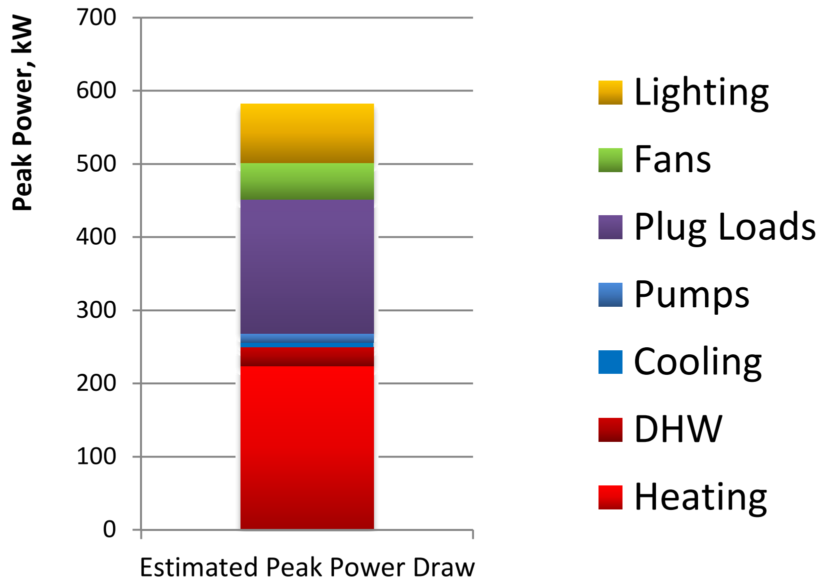


Figure 29: Simulated Peak by Component

Plug Load Peak Predictions and Diversities

To understand the peak power of the building model, the assumptions around the plug loads and the assumptions made about how they will operate is a critical piece. In the plug load study, information was gathered for all the equipment possible being installed when the building is fully occupied. Based on the data gathered, conversations with the users and estimations, a diversity of peak power use simultaneously for each area was applied. These diversities may be high for some areas and quite possibly low for others. The café for example has a number of small-to-large pieces of equipment where the data provided was not clear on what they will be installing.

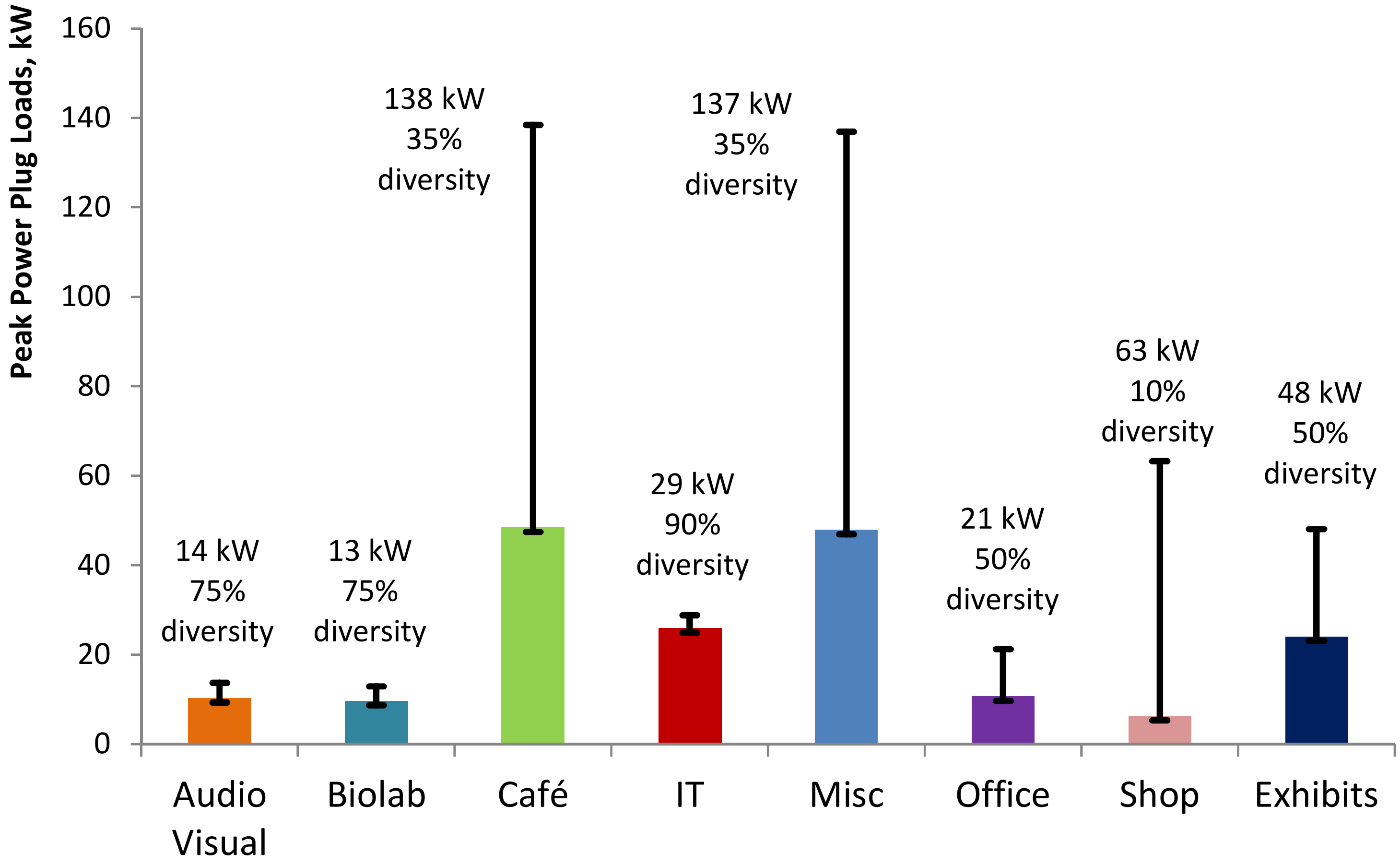


Figure 30: Plug Load Total Installed Power and Diversity Estimations

Peak Day Profiles

Two winter peak days are shown here to demonstrate the component contribution to the building peak profile on cold days.

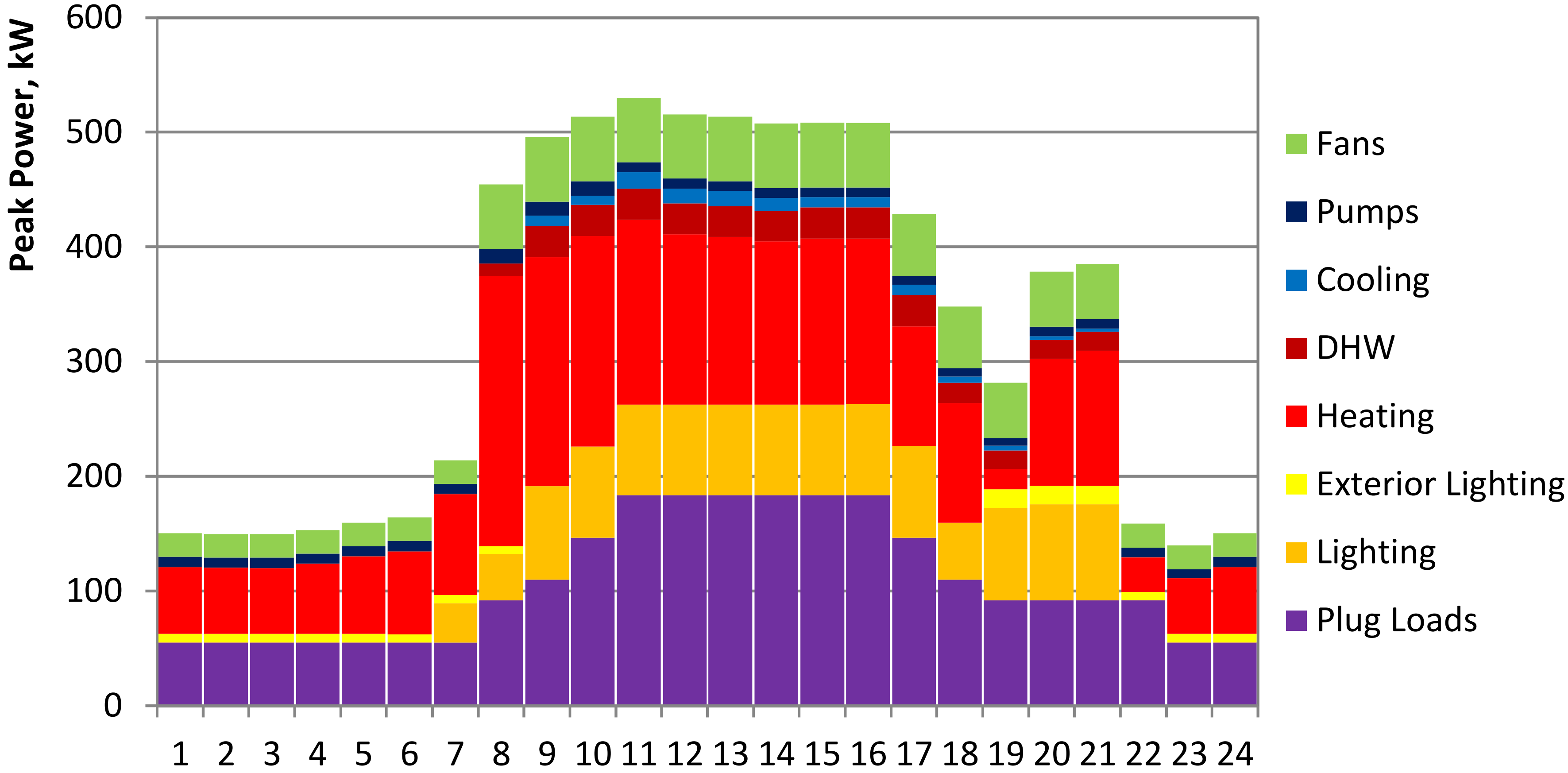
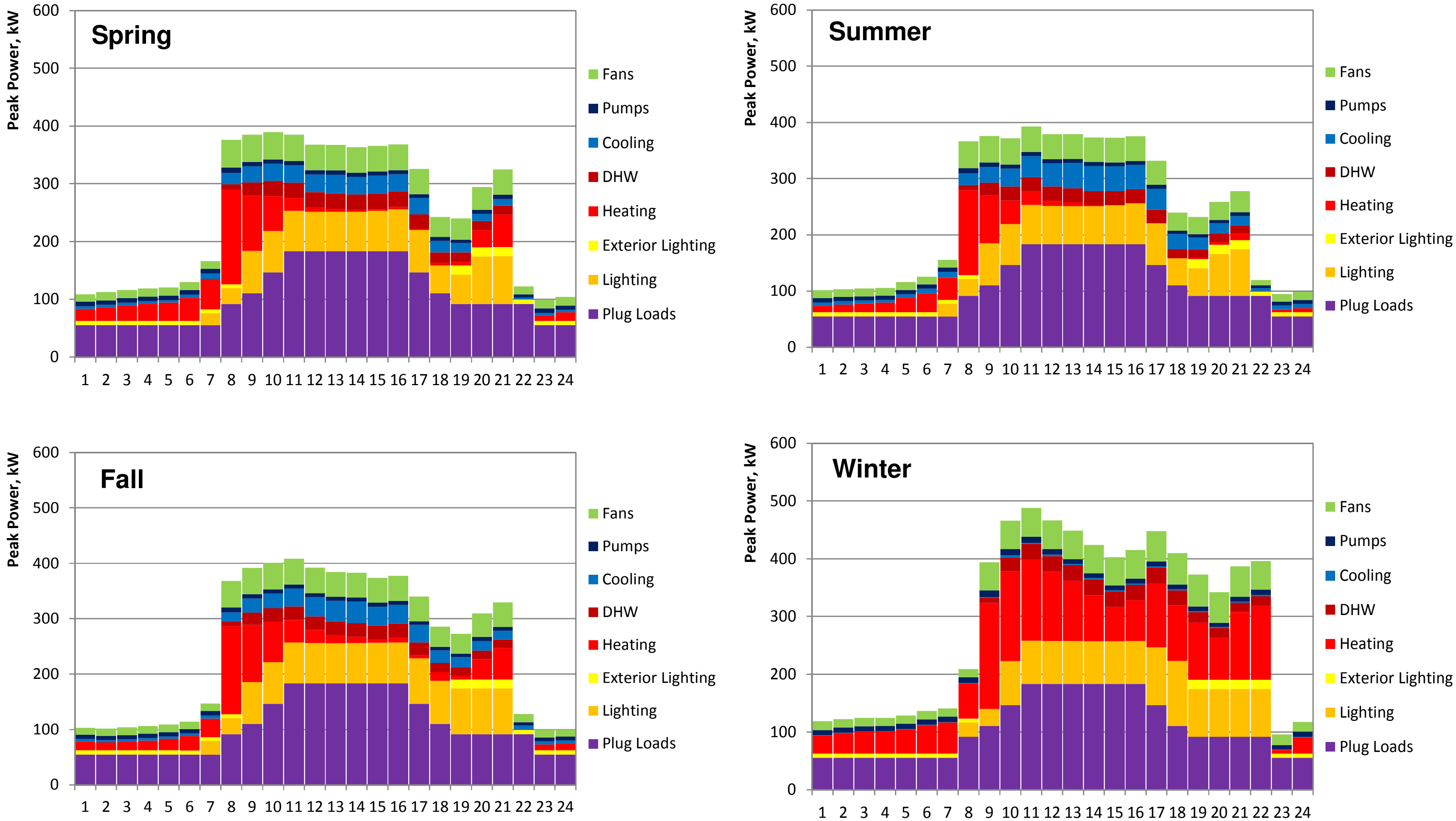


Figure 31: Peak profile of power demand on extreme day in April.

Typical Daily Profiles for Each Season



Managing the Peak Demand of the Building

Peak power demands of a building is a process of ongoing operations and maintenance both in careful monitoring and understanding of how energy use rises and falls.

Simple strategies for alarms in the building management system can alert staff when peak power is approaching a limit. However the management of this information and understanding how to shed load by turning off extraneous services is beyond the scope of this study.

We recommend:

1. Have 3rd Party re-visit the utility rate estimates to evaluate the risk using the latest building demand profile.
2. Monitor building loads and utility net demand as soon as possible in real-time.
3. Monitor the heating peak to understand better
4. Develop a plan for load shedding with an implementation strategy

Best Practices

Several more recommendations cross space type boundaries. While these measures are difficult to quantify, they can have a huge impact on the building's energy consumption and are a crucial component to operating a net zero energy building.

Measurement and Verification

Most buildings that achieve net zero perform continuous measurement and verification during their first year of operation to ensure the building achieves net zero status. While each individual system will be commissioned, the M&V process focuses on optimization of these systems and determining whether the building is on track to meet its goal. The facility has a set of milestones as the Exploratorium moves into its new home. Monitor the energy consumption between these milestones with the appropriate adjustments in operational assumptions (discussed further in the Peak Load section).

Sustainability/Energy Manager

We recommend appointing one person in the Exploratorium with the specific duty of sustainability and energy management. While this person might have other roles at the Exploratorium, this task should be their main responsibility. Monitoring whether the net zero goal is being achieved will be a major task itself. The Sustainability/Energy Manager can monitor progress, make energy conservation recommendations, and help the Facilities Manager make adjustments to the Building Automation System. This Manager can assist exhibit designers to design and operate energy efficient equipment and assist with knowledge transfer throughout the facility. Additional duties may include grant writing and developing sustainability-oriented educational programs for the general public.

Purchasing Guidelines

Develop purchasing guidelines that direct staff to select the most efficient piece of equipment in each category. Oftentimes, a new piece of equipment is needed quickly, without warning, due to a failure or other event. Preselecting an efficient replacement avoids a rushed, inefficient purchase. While ENERGY STAR rated equipment is recommended, there is a wide range within this categorization. Make sure the sustainability/energy manager and/or someone appointed from each space type knows how to look through the ENERGY STAR website and look for the most efficient piece of equipment[8]. For each device type, there is a spreadsheet with specifications and energy usage.

Develop specific guides for exhibit designers to create energy efficient exhibits. Include guidelines for the equipment itself (lighting, motors, etc) and controls (when to switch to idle, whether to incorporate occupancy sensors, Smart Strip, etc).

Information Exchange

Foster a culture of sustainability that encourages staff to share how they have reduced energy efficiency in their exhibit or workspace. There are already exhibits that have lowered their energy consumption drastically. Develop channel, perhaps workshops, to share these successes and empower other staff to do the same. Consider expanding this to the public; create a way for them to provide energy efficiency suggestions to the Exploratorium and each other.

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[8] http://www.energystar.gov/index.cfm?c=products.pr_find_es_products

Appendices

Appendix 1 – Operating Schedule Assumptions

Typical operation assumptions are shown below. Certain exhibits have a smaller duty cycle during visiting hours, while others must be on at all times. Equipment in other space types is also anticipated to experience some variation, but the schedule below represents the vast majority of identified equipment.

Space Type	Category	Days/Wk	Hrs/Day	% On
Exhibits	Public	2	12	100%
Exhibits	Public	4	8	100%
Exhibits	Event	4	4	50%
Exhibits	Unpaid Space	7	18	100%
IT	All	7	24	100%
Office	Computers & Monitors	5	9	100%
Office	Task Lights	4	4	100%
Office	Shared	6	9	100%
Office	Refrigeration	7	24	100%
Office	Other	6	1	100%
Biolab	Life Supporting	7	24	100%
Biolab	Grow Lights	7	12	100%
Biolab	Clean Room Microscope	7	1	100%
Biolab	Other Microscopes	7	8	100%
Biolab	Microscope Computers	7	24	100%
Audio Visual	General	6	10	100%
Audio Visual	Webcasting Gear	0.5	10	100%
Audio Visual	Full Theatre Equipment	2	4	100%
Shop	Varies from 1 to 25 hours per week based on typical usage			
Misc	Tray Warmers	2	6	100%
Misc	Elevators	7	2	100%

Appendix 2- List of Largest Exhibit Energy Users

ID	Exhibit Name	Annual Energy Use (kWh/yr)	Cumulative Energy Use (kWh/yr)
6040	GEYSERS	22,651	22,651
6722	Imaging Station Cart-Stem Cells	5,048	27,699
6714	Imaging sTation - Zebrafish	4,556	32,255
6292	TORNADO (a.i.r.)	4,366	36,620
6318	Vortex (a.i.r.)	4,118	40,738
5996	Dream Chart Windows (a.i.r.)	2,746	43,484
6765	goldfish tank	2,733	46,217
6955	Fog Pool	2,402	48,620
7080	Elastotron	2,231	50,850
6591	Sailboat Race	2,059	52,910
6071	Hot Spot	2,001	54,910
7087	Watch Mushrooms Grow	1,945	56,855
6354	Blow Out Your Toaster	1,751	58,606
6235	How a Steam Engine Works	1,613	60,219
6740	Imaging Station-worms/flies Storage (the cart)	1,603	61,822
6047	Glow Discharge	1,579	63,401
5962	Colored Shadows	1,544	64,945
6182	POLARIZED LIGHT ISLAND PLAYGROUND	1,493	66,438
6494	Living Color	1,445	67,883
6025	Fluttering	1,441	69,324
6396	Change Blindness	1,414	70,738
6412	Floating Objects	1,373	72,111
6545	Cell Models	1,363	73,474
7095	Plankton Ballet	1,340	74,814
6016	Falling Feather	1,201	76,015
6786	Sonic Storytelling	1,201	77,216
6386	Seeing Demo	1,167	78,383
6238	Skillets	1,153	79,536
6676	Theater of the Mind	1,098	80,635
6892	who Lives Here	1,064	81,699
7117	Water Drop Photography	1,030	82,728
6368	Hot-Cold Coils	1,030	83,758
6466	Chick Embryo time-lapse	1,030	84,787
6209	Rift Zone	1,004	85,792
6794	Center of Attention	995	86,787
5980	Curie Point	971	87,758
6375	Colored Rooms	963	88,721
6145	No Sound Through Empty Space	896	89,617
6868	Imaging Station Media Pods	831	90,447
5912	BERNOULII LEViTATOR	824	91,271
7107	Salty Tanks	803	92,074
6823	Auditory Transduction video	789	92,863
6001	Eddy Currents	782	93,646
7099	Monochromatic Room	755	94,401
6353	INVISIBLE LIGHT	721	95,122
6367	Heat Camera	700	95,822
6273	STROBE FOUNTAIN	692	96,513
7121	Strobe-O-Scope	686	97,200
6311	Vibrating Pinscreen (a.i.r.)	659	97,859
6052	GREEN LIPS ("Chromoscope")	652	98,511

Appendix 3 - Identified Exhibit Retrofit Opportunities

A list of identified exhibit retrofit opportunities is provided below. Additional internal discussions about energy efficiency and a concerted effort to improve component efficiency would reveal even more savings.

Exhibit Names	Retrofit Category	Estimated Energy Savings (kWh/yr)	Efficiency Measure Description
Bone Stress	Lighting	52	T12->T8
Camera Obscura - Such Ruins Give the Mind a Sense of Sadness (a.i.r.)	Lighting	80	T12->T8
Colored Shadows	Lighting	463	If probe start, replace with 320W pulse start and electronic ballast.
Confused Sea (a.i.r.)/"A Nourishing Wind"	Lighting	103	MR16->MR 16 Infrared (more savings if LED/CFL is possible)
Floating Objects	Lighting	111	Halogen->CFL
Geysers	Heating	11,326	Replace heating elements with lower wattage versions.
Olvera Clock (Light)	Lighting	152	Inc ->CFL
PERIPHERAL VISION	Lighting	55	MR16->MR 16 Infrared (more savings if LED/CFL is possible)
PUPIL	Lighting	124	Replace with LED
Rift Zone	Lighting	26	MR16->MR 16 Infrared (more savings if LED/CFL is possible)
Sound Spectrogram	Computer/Display	360	Replace with MacMini and new Flatscreen
Spinning Blackboard	Lighting	214	Halogen->CFL
Stereo Viewers (Old and New)	Lighting	86	MR16->MR 16 Infrared (more savings if LED/CFL is possible)
Talk to Daisy	Computer/Display	416	Replace with MacMini and new Flatscreen
Two as One	Lighting	463	Replace with LED
Two Wheels and a Ball	Lighting	150	MR16->MR 16 Infrared (more savings if LED/CFL is possible)
Vibrating Pinscreen (a.i.r.)	Lighting	253	MR16->MR 16 Infrared (more savings if LED/CFL is possible)
Zoetropes (a.i.r.)	Lighting	88	MR16->MR 16 Infrared (more savings if LED/CFL is possible)

Appendix 4 - Exhibits that can go idle

A list of identified exhibits that could go idle, but not currently, has been provided below. Only some of the teams identified these types of exhibits, so there are likely many more that could be equipped with an idle mode.

Exhibit Name	Comments
Sailboat Race	
Floating Objects	VFDs can NOT be cycled on/off -- they take too long to boot. Might be able to tie occupancy sensor to VFDs, ramp blowers down if nobody present.
Plankton Ballet	Air/temp control must be kept running 24/7 to keep plankton alive. Lights can be turned off when unoccupied.
Water Drop Photography	Maybe put monitor in sleep mode, but then lose attractive nature of exhibit
Rift Zone	
Curie Point	
Salty Tanks	
Eddy Currents	Idle mode power draw is low; not impactful to add occupancy sensor.
Strobe-O-Scope	Allowing monitor to enter sleep mode will allow largest savings, but dark screen does not attract viewers.
Vibrating Pinscreen (a.i.r.)	
Circles of Magnetism	
Jacob's Ladder	
Dancing Drops	
Animal Camera video	
Two Wheels and a Ball	
Beat Bounce	Occupancy sensor would save 40W.
PhotoBacteria	Water has to be kept at temperature, but may be able to turn off air pump when exhibit is unoccupied.
Self Balancing stick	Can't turn computer off; takes too long to boot. What about sleep mode -- how fast can it wake? Put only the monitor in sleep mode?
Confused Sea (a.i.r.)/"A Nourishing Wind"	
Pendulum and A Turntable	
Stripped Down Motor	
Water Cannon	
Liquid Litmus	
Electric Flame	
Magnetic Clouds	
Seismic Sand	
Thermal Impressions	

Zero to Sixty	
Simple Motions / Complex Patterns	
Olvera Clock (Light)	Motor lifts weights; can't be turned off if clock is to keep time. Light could be turned off w/ occupancy sensor.
Camera Obscura - Such Ruins Give the Mind a Sense of Sadness (a.i.r.)	
Giant Electroscope	
Daisy Dyno	
Museum of wear and tear	Not practical to turn displays off; takes too long to reboot. Do displays have sleep mode capability? Lights could be controlled by occupancy sensors.
Slowly Revolving Bench	
Photoelectricity	
Phototube	
Magnetic Domains	
Gas Model	
pulley table ("Make Your Own Pulley System")	
Circling Wave Umbrella	
Floating in Copper	
MAGNETIC SUCTION	
Hysteresis Motor	
magnetic labyrinth	
Musical Lockers	
TRANSISTOR	
FADING MOTION	
Transformer	
Magnet + Electricity = Motor (a.i.r.)	
Zeeman Effect	
Turntable	Turntable is heavy; large power draw when spinning up to speed; turning on/off not practical, but ramping up/down with VFD may be.
Vortex (a.i.r.)	Probably not practical to turn on/off - ramp up/down with VFD.
Magnetic Field Stone	
Magnetic Spinners	