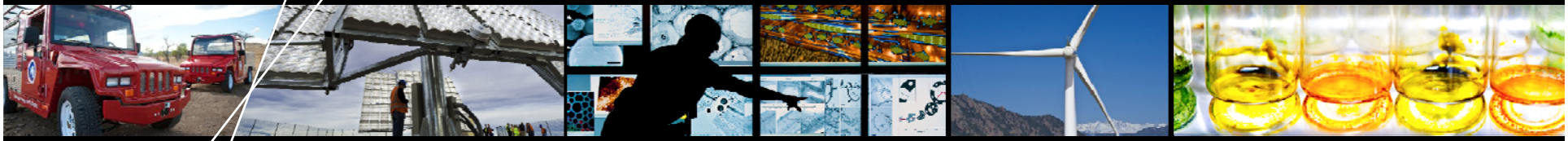
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEMP
Federal Energy Management Program

Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building:

NREL's Research Support Facility



NASA Net Zero Workshop

Michael Sheppy

June 6, 2012

What are Plug and Process Loads?

Definition: Plug and process loads are the miscellaneous loads that are not direct HVAC and lighting.

- **General lighting**
- **General heating**
- **General ventilation**
- **General cooling**
- **Water heating**

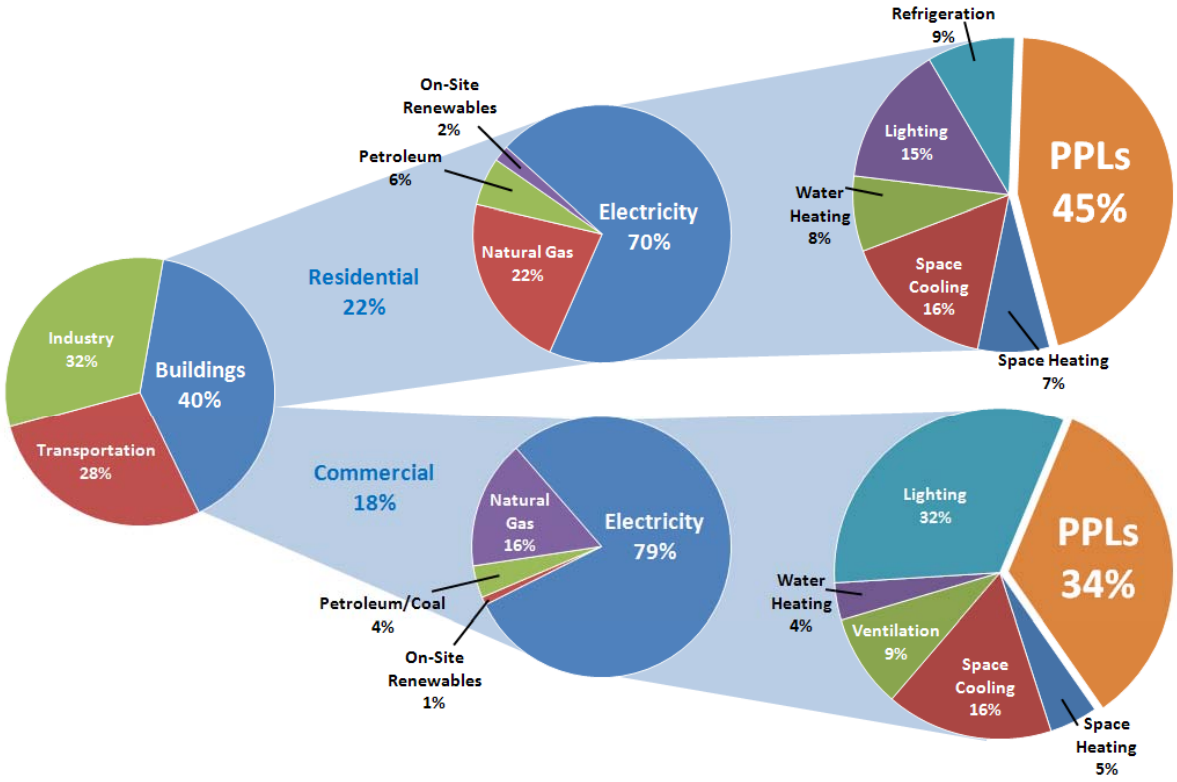


Figure Credit: Jeff Smith, Data: DOE Energy Data Book, 2009

Impact of PPLs:

- **12% of U.S. primary energy** (DOE Energy Data Book, 2009)

Challenges:

- Limited understanding of opportunities and equipment.
- No single decision maker can specify all efficiency strategies.
- Typically not addressed by building codes.

The Research Support Facility (RSF)

Facts

- *220,000-ft²*
- 800 occupants
- Design build process
- 50% savings over 90.1-2004

Energy Goal

- Whole-building demand-side energy use of a nominal **25 kBtu/ft²·yr**

Photo Credit: Patrick Corkery, NREL 17728

Day vs. Night Plug and Process Loads

Only occupied about ⅓ of the time

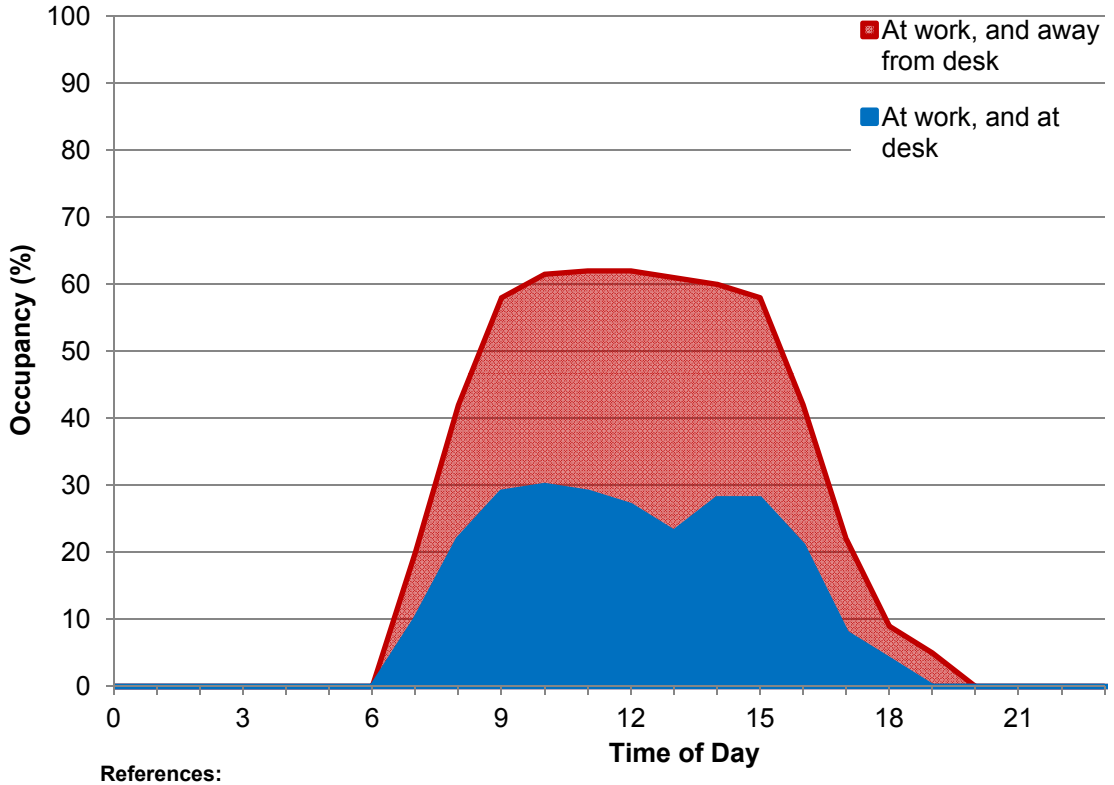
- Nights Unoccupied
- Weekends Unoccupied
- Holidays Unoccupied

Annual Plug Load Energy Use Intensity (kBtu/ft²)

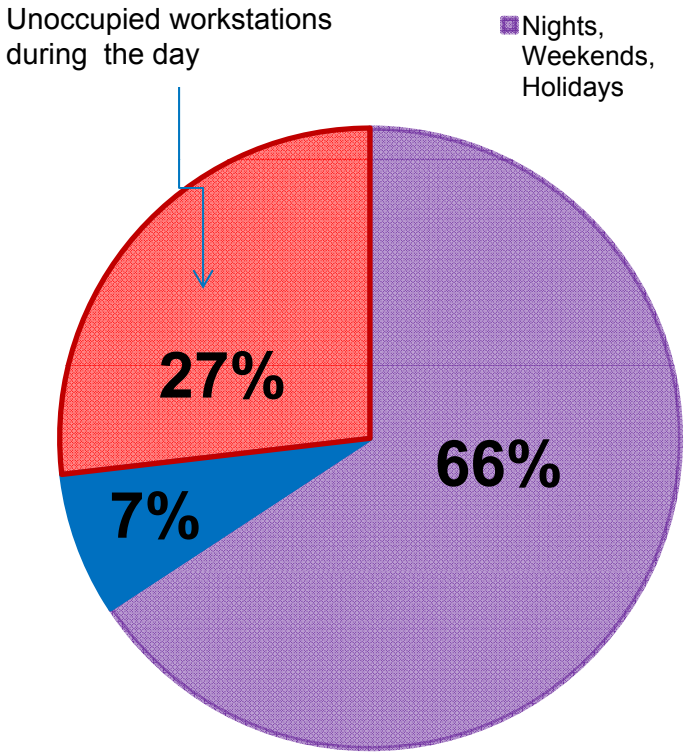
Occupied Hours Power Density (W/ft²) \ Unoccupied Hours Power Density (W/ft²)	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50
0.10	3.0	5.2	7.4	9.7	11.9	14.1	16.3	18.6	20.8	23.0	25.2	27.4	29.7	31.9	34.1
0.20	3.8	6.0	8.2	10.4	12.7	14.9	17.1	19.3	21.5	23.8	26.0	28.2	30.4	32.7	34.9
0.30	4.5	6.8	9.0	11.2	13.4	15.6	17.9	20.1	22.3	24.5	26.8	29.0	31.2	33.4	35.6
0.40	5.3	7.5	9.7	12.0	14.2	16.4	18.6	20.9	23.1	25.3	27.5	29.7	32.0	34.2	36.4
0.50	6.1	8.3	10.5	12.7	15.0	17.2	19.4	21.6	23.8	26.1	28.3	30.5	32.7	35.0	37.2
0.60	6.8	9.1	11.3	13.5	15.7	17.9	20.2	22.4	24.6	26.8	29.1	31.3	33.5	35.7	38.0
0.70	7.6	9.8	12.0	14.3	16.5	18.7	20.9	23.2	25.4	27.6	29.8	32.1	34.3	36.5	38.7
0.80	8.4	10.6	12.8	15.0	17.3	19.5	21.7	23.9	26.2	28.4	30.6	32.8	35.0	37.3	39.5
0.90	9.1	11.4	13.6				22.5	24.7	26.9	29.1	31.4	33.6	35.8	38.0	40.3
1.00	9.9	12.1	14.4	16.6	18.8	21.0	23.2	25.5	27.7	29.9	32.1	34.4	36.6	38.8	41.0
1.10	10.7	12.9	15.1	17.3	19.6	21.8	24.0	26.2	28.5	30.7	32.9	35.1	37.3	39.6	41.8
1.20	11.4	13.7	15.9	18.1	20.3	22.6	24.8	27.0	29.2	31.4	33.7	35.9	38.1	40.3	42.6
1.30	12.2	14.4	16.7	18.9	21.1	23.3	25.5	27.8	30.0	32.2	34.4	36.7	38.9	41.1	43.3
1.40	13.0	15.2	17.4	19.6	21.9	24.1	26.3	28.5	30.8	33.0	35.2	37.4	39.7	41.9	44.1
1.50	13.7	16.0	18.2	20.4	22.6	24.9	27.1	29.3	31.5	33.8	36.0	38.2	40.4	42.6	44.9

Key Strategy: Provide Power when Equipment is Needed

- **Nights, weekends, and holidays account for 66% of the year**
  - A typical office building is unoccupied during this time
- **During a typical work day, building occupants are only at their desk less than 30% of the time**
  - Workstations are vacant and should be powered down during more than 70% of business hours
- **Workstations should only be powered 7% of the year!**

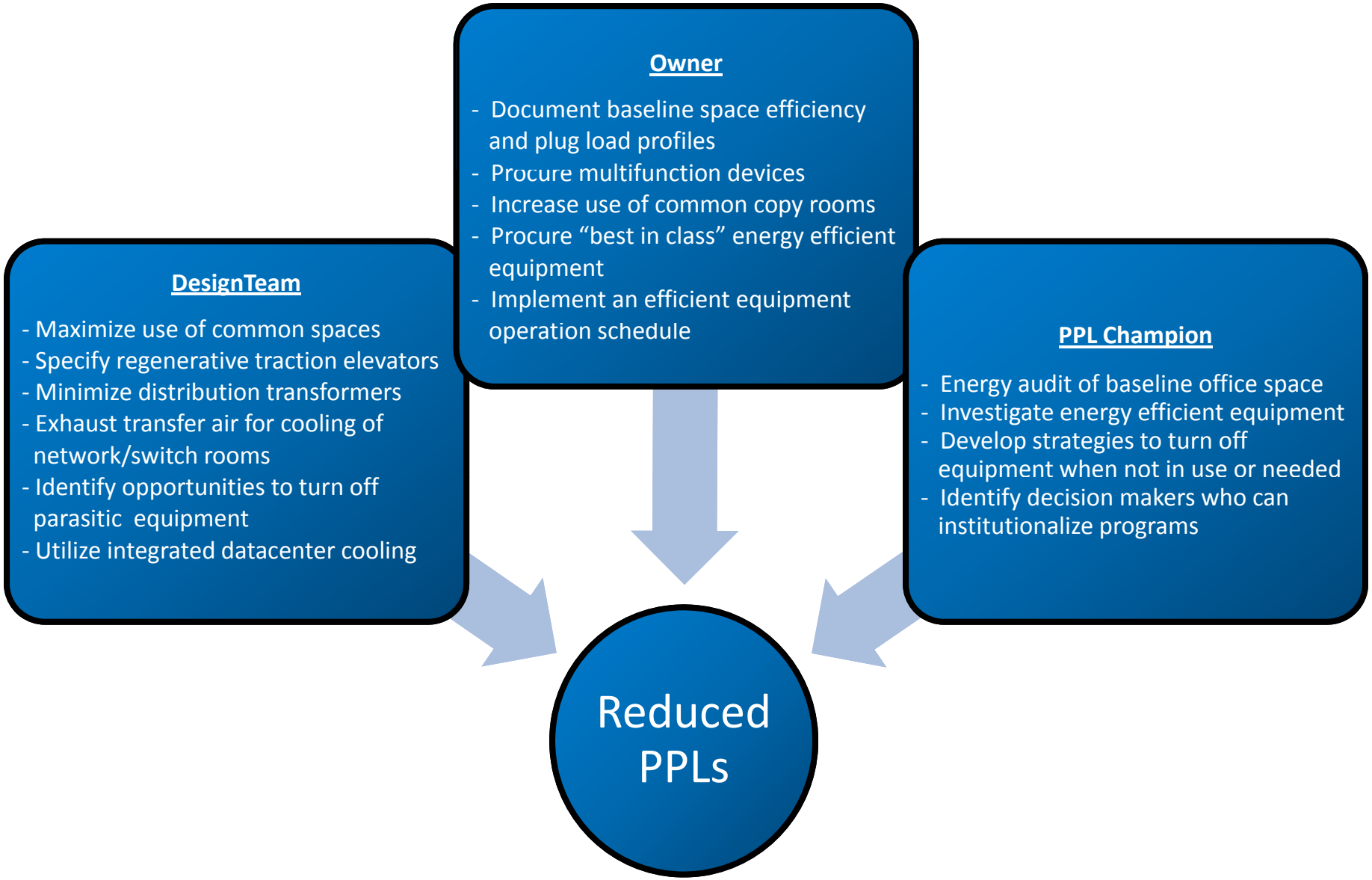


References:
http://www.gsa.gov/graphics/pbs/WorkPlace_Matters_FINAL508_lowres.pdf



Credit: Chad Lobato/NREL

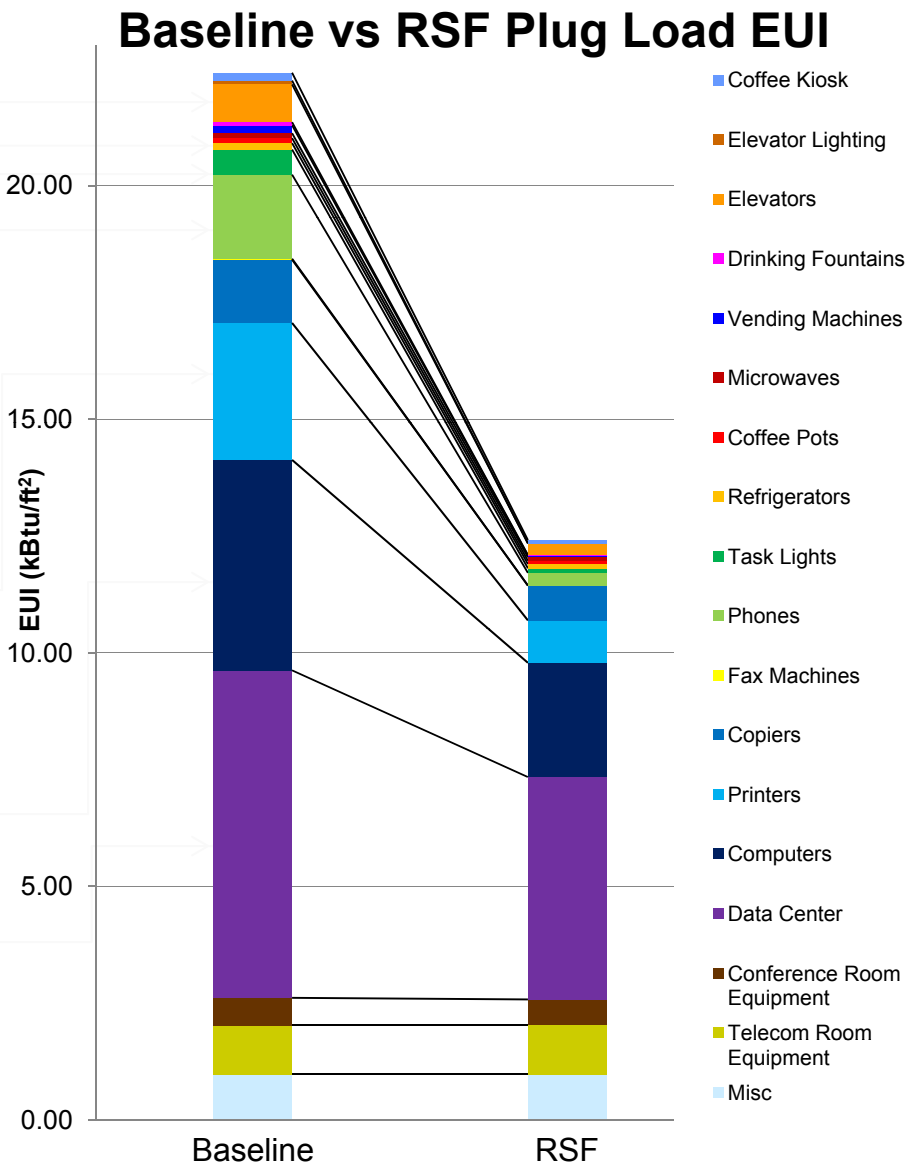
Key Players in Reducing PPLs



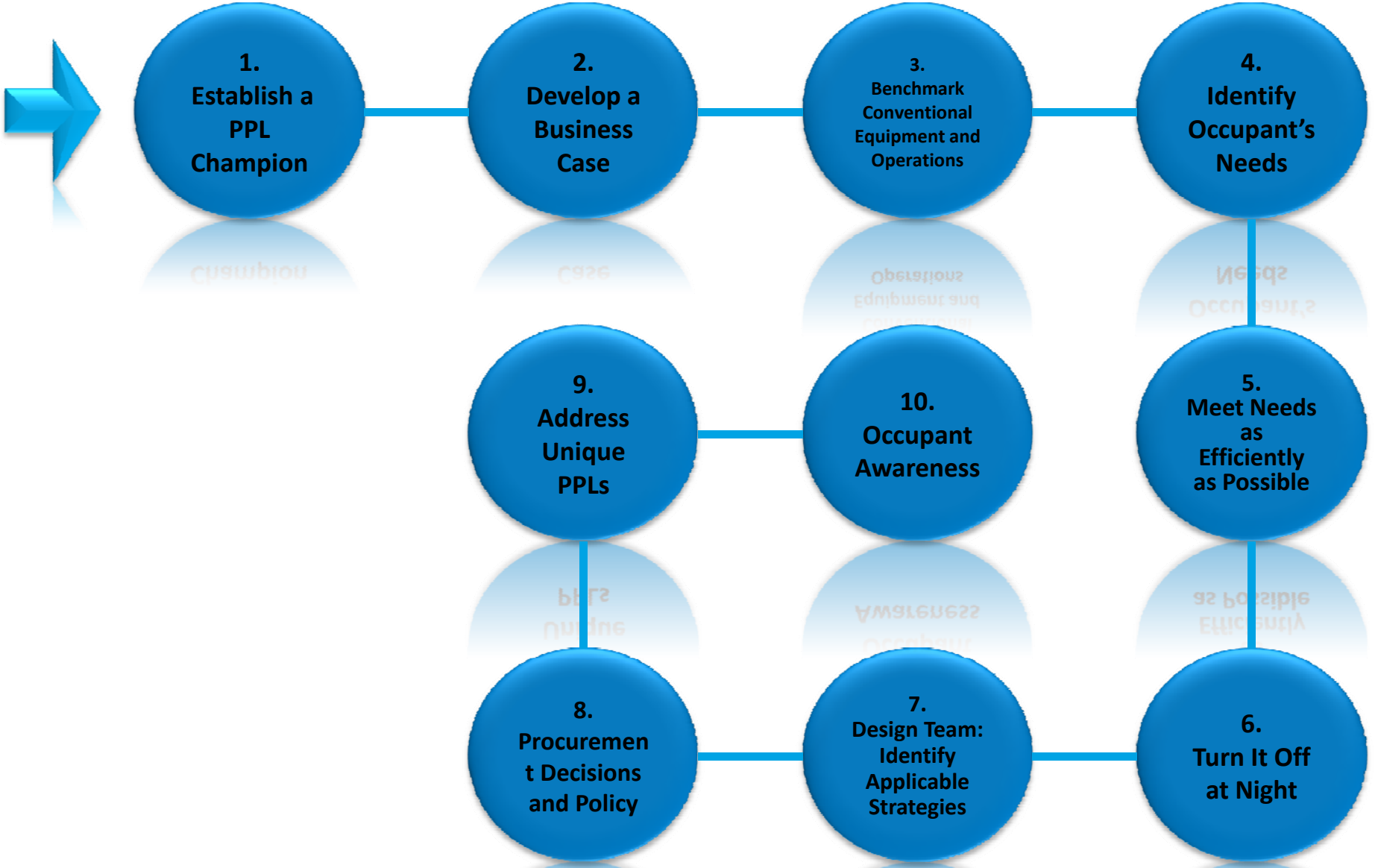
RSF Plug Load Reduction Strategies

- **Elevators**
  - Use energy efficient traction elevators
  - Change elevator lighting to energy efficient fluorescent lighting
  - Turn off elevator lighting when the elevator is unoccupied
- **Break Rooms**
  - Increase the number of people that use each break room from approximately 40 to 60
  - Eliminate the cooler on the drinking fountain
- **Task Lights**
  - Move from 35W fluorescent task lights to 6W LED task lights
- **Phones**
  - Go from 1000 standard phones to 1000 VOIP phone that consumes 2W each
- **Copiers, Printers, Fax Machines**
  - Decrease the number people that use individual copiers, printers and fax machines
  - Increase the number of people that use common, or group, copiers, printers and fax machines from 15 to 20
  - Increase the use of all-in-one machines
- **Computers**
  - Go from approximately 260 laptops, 33% of staff, to 720, 90% of staff, ensure standby mode works for all workstations
- **Data Center**
  - Blade Servers with Virtualization
  - High efficiency UPS
  - 65W/employee current to 48W/employee in RSF

- **The result of these strategies is a 47% reduction in plug loads**

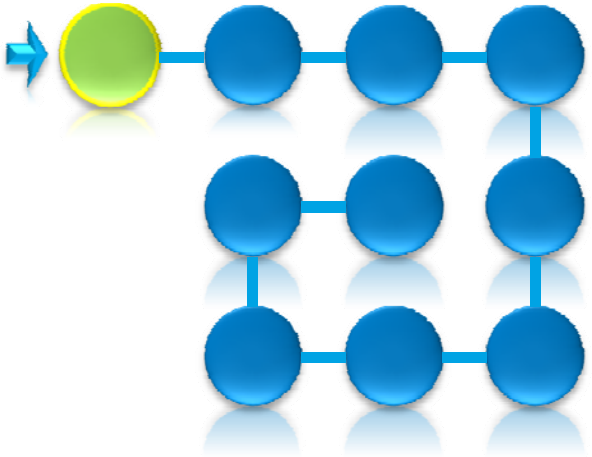


10 Steps to Address PPLs



Step 1: Establish a PPL Champion

- **Purpose:**
  - To initiate and help implement PPL strategies.
- **Skills needed:**
- Understanding of:
  - technical energy efficiency opportunities
  - design strategies
- Ability to:
  - apply business model
  - question operations, institutional policies, and procurement processes



Step 2: Develop a business case for addressing PPLs

- **Avoided Cost of Renewables (ACR):**
  - Equates the cost of PPL efficiency measures to avoided renewable costs.
  - Gives all parties a financial incentive to investigate PPLs.
- **ACR for the RSF:**
  - Used to justify demand-side efficiency measures.
  - 1 Watt continuous saved – $33 worth of PV was avoided. Additional loads must be offset with renewables.

The PV cost avoided by PPL reductions exceeded $4 million.

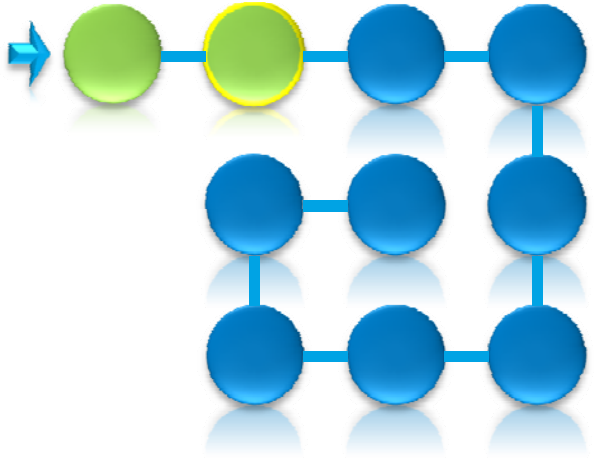
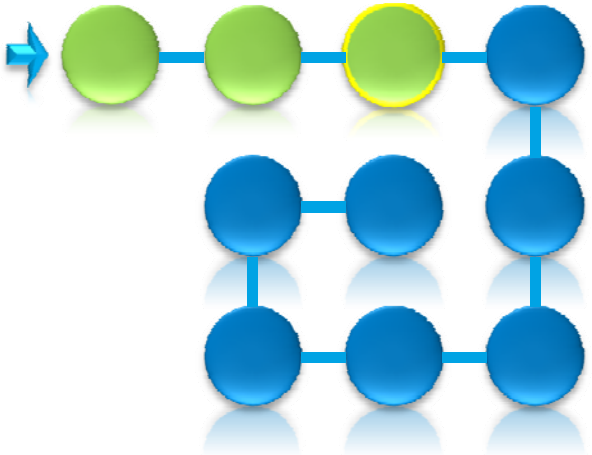


Photo Credit: Dennis Schroeder PIX 17842

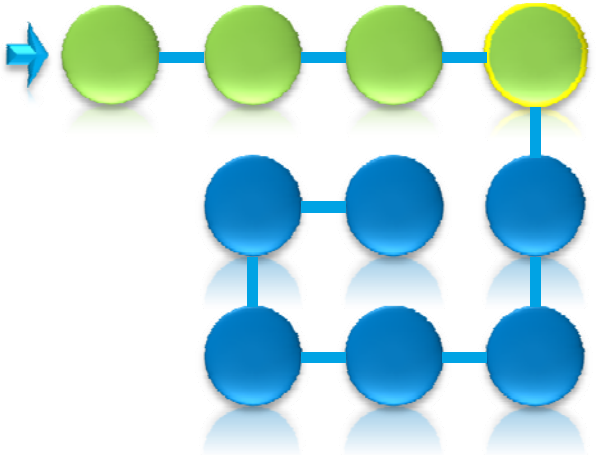
Step 3: Benchmark your conventional equipment and operations

- **Methods:**
  - Submeter panels (if properly organized)
  - PPL power meters
  - Combination of submetering and equip. spec. sheets can be used
- **Data:**
  - Understand when equipment is used
  - Highlight opportunities to turn off
  - Basis of comparison for financial calculations



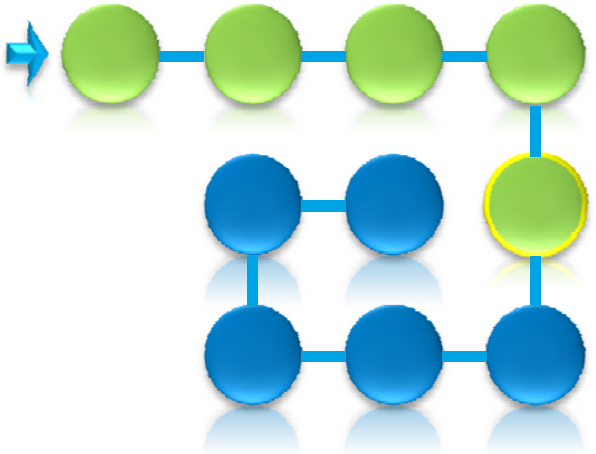
Step 4: Be willing to identify occupants' true needs

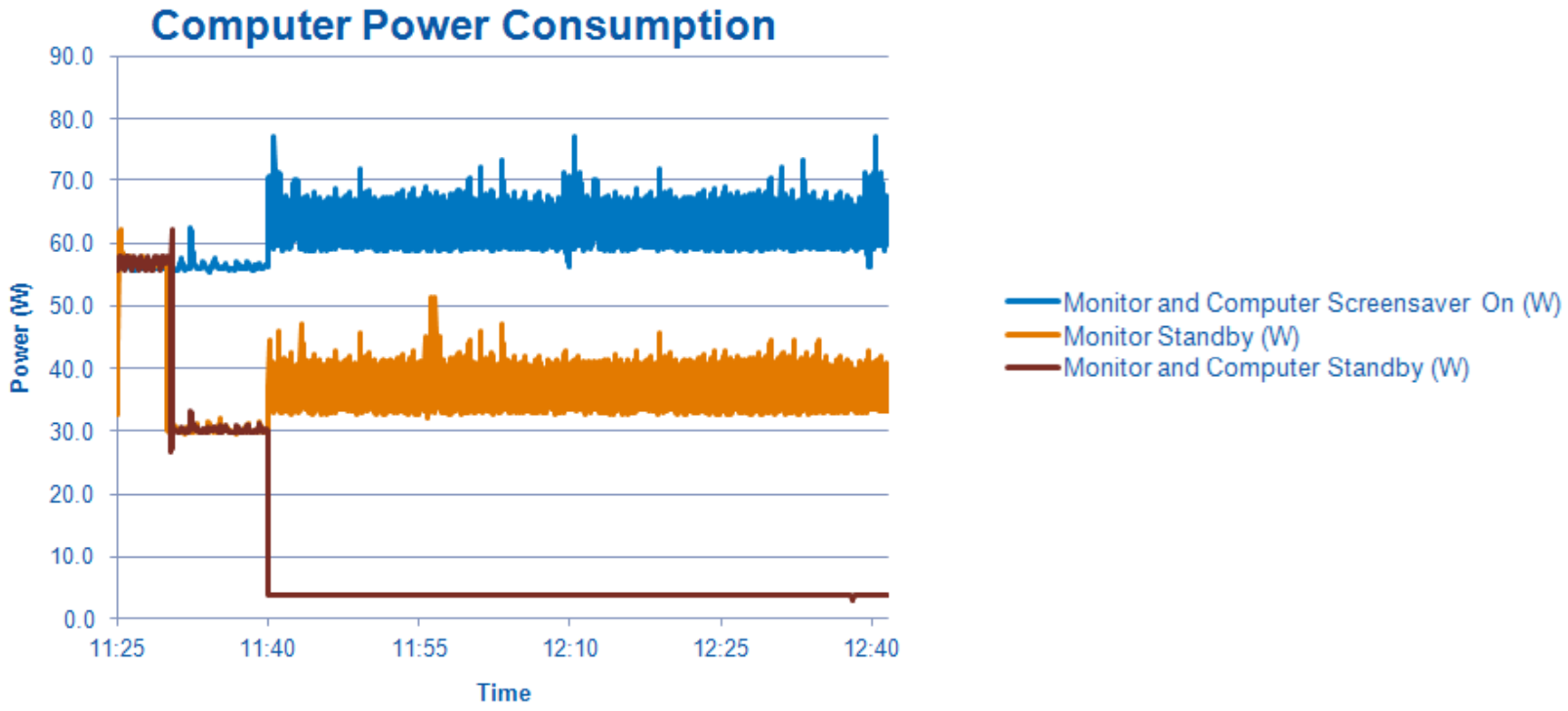
- **True need:**
  - Equipment or procedure required to achieve a given business goal or an assigned task.
- **Understand:**
  - What do occupants produce as part of their jobs and what tools do they require?
  - Every occupant, including those working in sensitive operations must be accounted for.
- **Nonessential equipment:**
  - A business case must be made for continued use.



Step 5: Meet needs as efficiently as possible

- **Search energy efficient equipment databases.**
- **<u>Nonrated equipment:</u>**
  - Investigate the most efficient model
  - Turn off when not in use (if possible)
- **Pay attention to parasitic loads.**

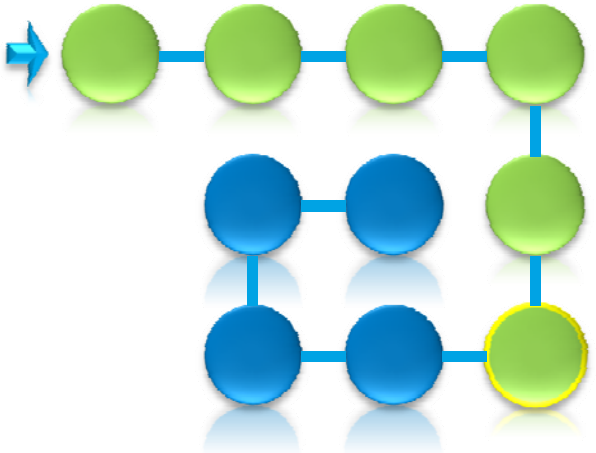


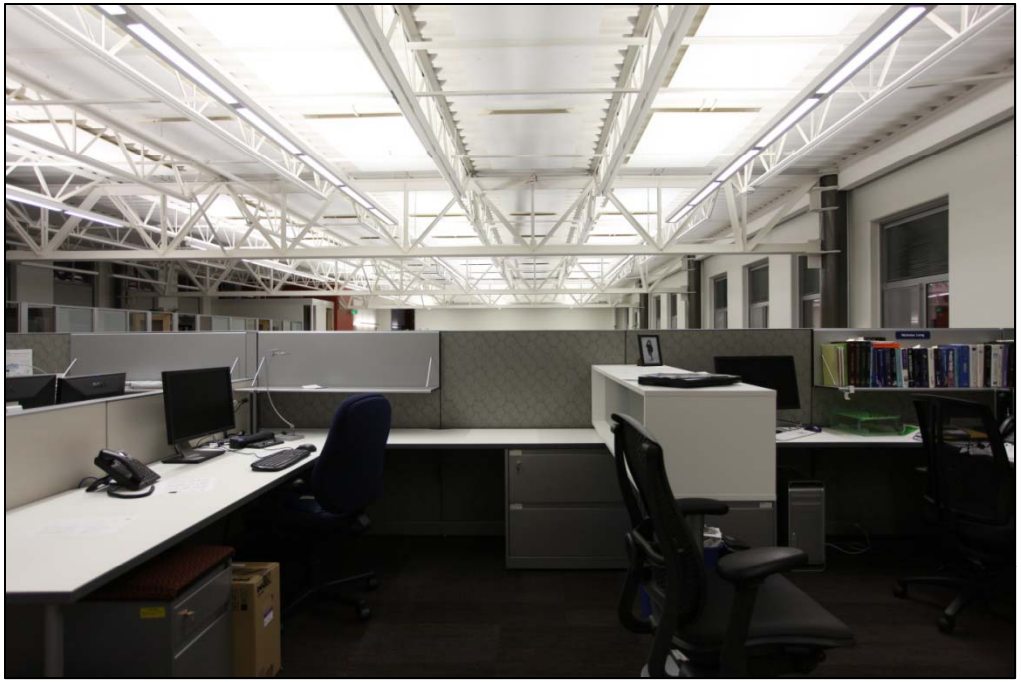


Step 6: Turning it all off

Office buildings are typically unoccupied **66%** of year.

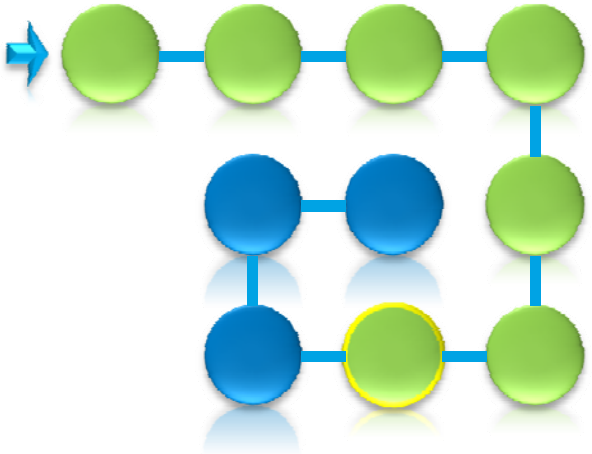
KEY: Reduce power density during nonbusiness hours.





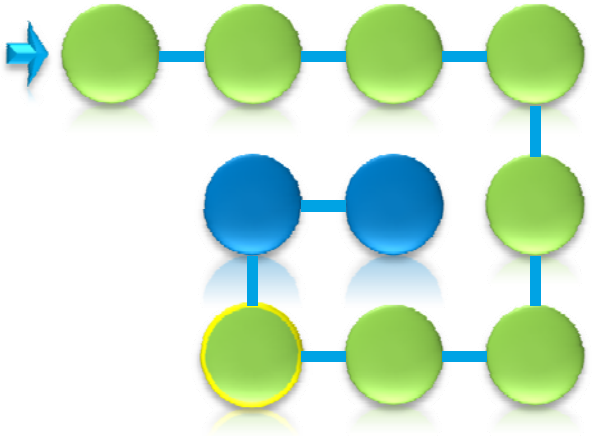
Step 7: Encourage the design team to identify all applicable PPL strategies

- **Question standard specifications, operations, and design standards.**
- **Maximize space efficiency.**
- **<u>Integrate PPL control strategies into the building's electrical system:</u>**
  - Switches
  - Vacancy sensors
  - Timed disconnects for outlets
  - Controlling outlets through the Building Management System (BMS)
- **<u>Other loads:</u>**
  - Elevators
  - Transformers
  - Process cooling systems
  - Data centers



Step 8: Institutionalize procurement decisions and policy programs

- **Day-to-day energy efficiency:**
  - Depends on the decisions of occupants, facility managers, and owners.
- **Identify decision makers who can:**
  - Institutionalize PPL measures through procurement decisions and policy programs.
  - Promote buy-in.
  - Identify unbreakable and unchangeable policies.



Step 9: Address unique miscellaneous PPLs

- **<u>EXAMPLE:</u> Contractors and food service areas.**
  - Building owner can contractually require or provide the most efficient equipment available.
- **<u>Case-by-case evaluation:</u>**
  - Energy-efficient equipment may not be available and may be restricted from being turned off (e.g. ATM)
  - Manufacturers may be able to recommend alternatives.

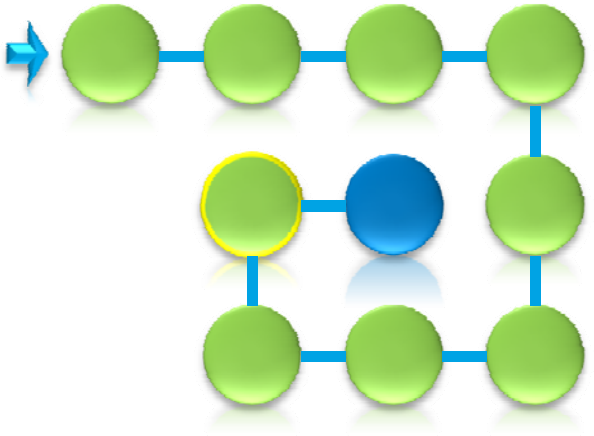


Photo Credit: Chad Lobato

Step 10: Occupant awareness

- Encourage and allow to “do good”.
- PPL strategies should counteract “bad users.”
- Emphasize importance of turning off personal electronics when leaving a workspace.

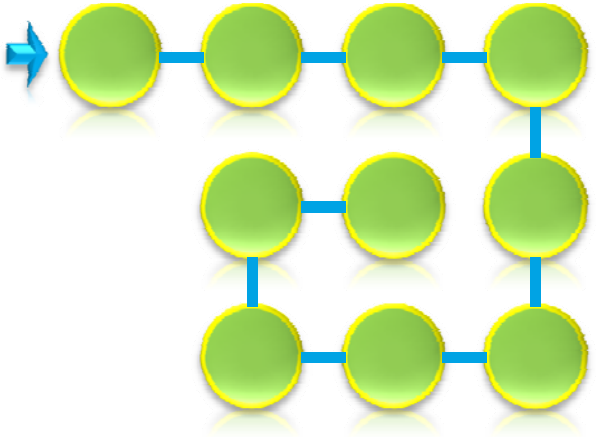


Photo Credit: Jennifer Scheib

References

- 1. U.S. Department of Energy. *Buildings Energy Data Book*. Energy Efficiency and Renewable Energy. 2009.
- 2. Pless, S., Torcellini, P., Shelton, D. (2010). *Using an energy performance based design-build process to procure a large scale low energy building*. Golden, CO: National Renewable Energy Laboratory.
- 3. KONE Corporation. 2006. *KONE Green Calculator – Compare Hydraulic Elevators with KONE EcoSpace*. Finland. http://www.kone.com/media/en_US/green/index.html.
- 4. Torcellini, P., Pless, S., Deru, M., Griffith, B., Long, N., Judkoff , R. (2006). *Lessons Learned from Case Studies of Six High-Performance Buildings.* Golden, CO: National Renewable Energy Laboratory, Report No. TP-550-37542.

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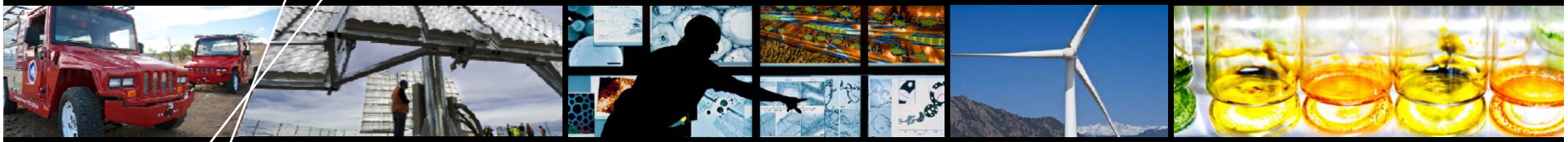


Best Practices

Summary of Energy Efficiency Measures in the RSF and Their Expected Effects

Areas		Current Consumption kBtu/ft²·yr (kWh/m²·yr)	Strategies	RSF kBtu/ft²·yr (kWh/m²·yr)	Energy Savings kBtu/ft²·yr (kWh/m²·yr)	PV Cost Savings
Data Center	Servers	19.43 (61.22)	• 35W per occupant blade servers replaced 65W per occupant standard servers • Servers receive power from a 96% efficient UPS and a 98.6% efficient power distribution unit • Blade servers are virtualized to save energy • Up to 20 virtualized servers can be run on one physical server	10.56 (33.27)	8.87 (27.95)	$2,189,689
Work Station	Copiers	1.34 (4.22)	• Multifunction devices replaced single-function copiers, printers, and fax machines • Eliminate personal copiers and fax machines • Decrease the use of personal printers by 75% • Increase the number of users from 40 to 60 per multifunction device • Monitoring to ensure standby modes are operational and effective	0.74 (2.33)	0.60 (1.89)	$149,645
	Printers	2.92 (9.20)		0.90 (2.84)	2.02 (6.37)	$497,060
	Fax Machines	0.02 (0.06)		0.00 (0.00)	0.02 (0.06)	$5,513
	Computers and Monitors	4.49 (14.15)	• 30W laptop computers replaced 100W desktop computers • 15W - 18W 22” - 24” (56cm – 61cm) LED backlit LCD monitors replaced older 25W - 50W 19” - 24” (48cm - 61cm) fluorescent backlit LCD monitors and 70W CRT monitors (one, 18W 24” (61cm) monitor or two, 15W 22” (56cm) monitors are used per occupant) • Power management surge protectors eliminate parasitic losses when space is unoccupied • Monitoring to ensure standby modes are operational and effective	2.43 (7.66)	2.06 (6.49)	$506,335
	Task Lights	0.54 (1.70)	• 6W LED task lights replaced 35W fluorescent task lights • Power management surge protectors eliminate parasitic losses when space is unoccupied • Monitoring to ensure standby modes are operational and effective	0.10 (0.32)	0.44 (1.39)	$107,990
	Phones	1.79 (5.64)	• 2W VOIP phones replaced 15W standard phones	0.28 (0.88)	1.51 (4.76)	$375,038
Breakroom	Refrigerators	0.27 (0.85)	• The most efficient continuous 48W ENERGY STAR refrigerators were specified • Increase number of users from 40 to 60 per breakroom	0.18 (0.57)	0.09 (0.28)	$22,051
	Coffee Pots	0.22 (0.69)	• Increase number of users from 40 to 60 per breakroom	0.14 (0.44)	0.08 (0.25)	$17,699
	Microwaves	0.21 (0.66)	• Eliminate equipment with parasitic loads, such as status LEDs • Monitoring to ensure standby modes are operational and effective	0.14 (0.44)	0.07 (0.22)	$17,398
	Vending Machines	0.17 (0.54)	• Most efficient ENERGY STAR vending machines were specified and delamped • Increase number of users from 100 to 400 per vending machine	0.12 (0.38)	0.05 (0.16)	$11,971
	Drinking Fountains	0.07 (0.22)	• Water coolers were eliminated from drinking fountains • Bottled water coolers were eliminated by providing filtered water at the tap	0.01 (0.03)	0.06 (0.19)	$14,294
Elevators	Elevators	0.80 (2.52)	• Regenerative traction elevators replaced hydraulic elevators	0.25 (0.79)	0.55 (1.73)	$137,015
	Elevator Lighting	0.08 (0.25)	• The elevator lighting and fans turn off when the elevator is unoccupied	0.00 (0.00)	0.08 (0.25)	$19,940

Summary of Energy Efficiency Measures in the RSF and Their Expected Effects

Areas	Current Consumption kBtu/ft2·yr (kWh/m2·yr)	Strategies	RSF kBtu/ft2·yr (kWh/m2·yr)	Energy Savings kBtu/ft2·yr (kWh/m2·yr)	PV Cost Savings
Telecom Room Equipment	1.05 (3.31)	• Power and enable individual Ethernet switches based on occupant needs	1.05 (3.31)	NA[1]	NA[1]
Conference Room Equipment	0.58 (1.83)	• 120W 55" (140cm) LED backlit LCD TVs replaced older 200W - 300W 55" (140cm) fluorescent backlit LCD TVs in conference rooms	0.55 (1.73)	0.03 (0.09)	$7,931
Coffee Kiosk					
Espresso Machine	0.06 (0.19)	• An efficient espresso machine with built in standby mode replaced an older, uninsulated espresso machine that was powered 24/7 • Monitoring to ensure standby modes are operational and effective	0.02 (0.06)	0.04 (0.13)	$8,885
Refrigerators	0.04 (0.13)	• The most efficient continuous 48W ENERGY STAR commercial refrigerators were specified • Refrigerators with solid fronts were specified instead of refrigerators with glass fronts	0.01 (0.03)	0.03 (0.09)	$5,677
All Equipment	0.08 (0.25)	• A full-size refrigerator replaced multiple mini refrigerators • Eliminate equipment with parasitic loads, such as status LEDs • Provide switches to disconnect all non-essential equipment during non-business hours. Include contractual requirement for operator to disconnect all non-essential equipment. • The most efficient ENERGY STAR commercial chest freezer was specified • Monitoring to ensure standby modes are operational and effective	0.03 (0.09)	0.05 (0.16)	$10,119
Miscellaneous	0.97 (3.06)	• Motorized compact shelving was replaced by hand crank compact shelving • Motion sensors/time clock outlets are used to turn off miscellaneous loads when not in use (lobby energy monitors, ice machine, exercise equipment, etc.) • Implement management policies to minimize or eliminate use of personal electronic equipment (personal coffee makers, fans, heaters, mini refrigerators, decorative lighting, etc.) • Miscellaneous workstation equipment will be controlled by smart power strips, such as head set chargers, cell phone chargers, label makers, radios, etc. • IT recommended USB-powered peripherals rather than standard 120V devices (external hard drives) • Computer standby settings are used to lock out idle computers instead of using screen savers	0.97 (3.06)	NA[1]	NA[1]
TOTAL	**35.13 (110.69)**		**18.48 (58.23)**	**16.65 (52.46)**	**$4,104,251**

Questions?

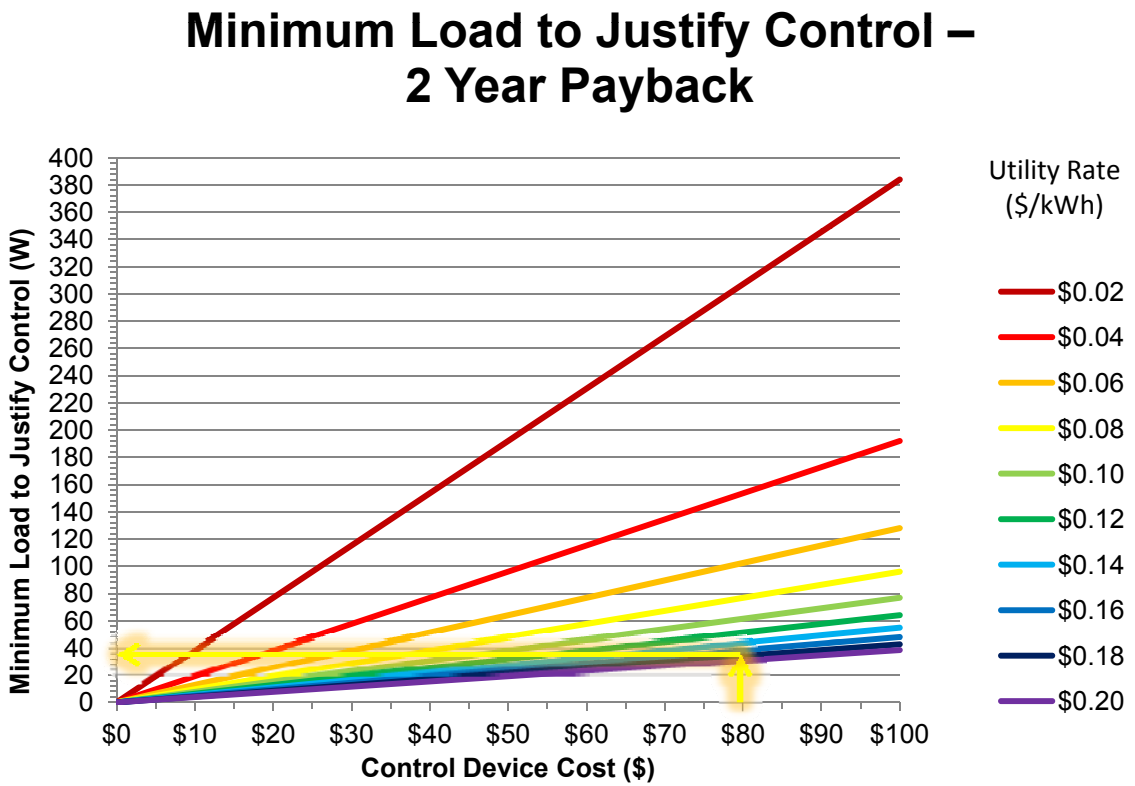
Backup Slides

New and Emerging Technologies

- **Load sensing: automatically energizes/de-energizes outlets based on the load of the attached devices.**
- **Scheduling/Timer: applies user programmed schedules to energize/de-energize outlets.**
- **Occupancy/Vacancy: energizes outlets only when users are present and de-energizes them when vacant.**
- **Manual: energizes/de-energizes electrical outlets based only on manual input.**

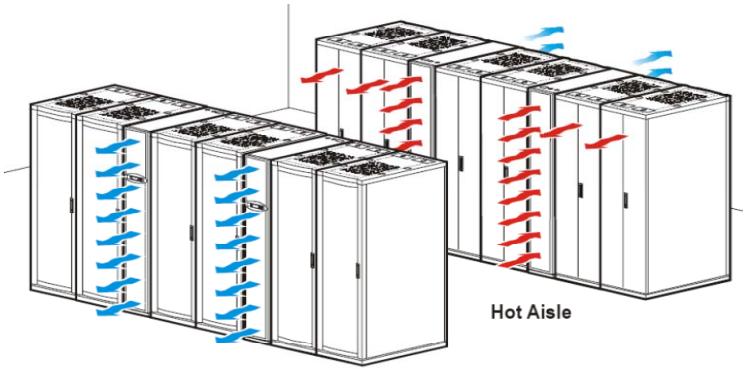
Business Case for Advance Power Strip Investments

- **Utility Rate: $0.22/kWh**
- **For every 1 Watt continuous load that you reduce, you save $1.93 annually.**



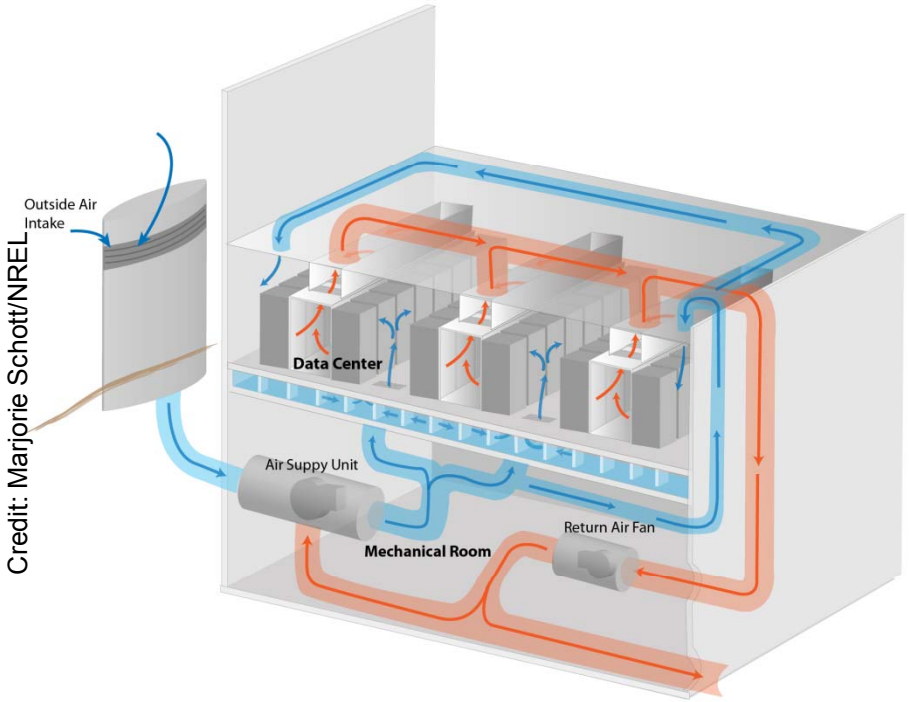
RSF Data Center

- **Moving towards high-density blade servers**
  - Highly efficient power supplies
  - Variable speed fans
  - Wake-on-LAN
- **Server virtualization**
  - Ratio: 4-8 to 1
- **Dynamic Workload management**
  - Server resources go from “always on” to “always available”
  - Resources are powered up or down as resources are needed
- **Hot aisle containment with airside economizer and evaporative cooling**
- **Target PUE of 1.1 vs. legacy PUE of 2.5**
- **Expected reduction of 65% in total data center power consumption**



Operational Lessons- Datacenter

- **Fully containing hot aisle difficult**
  - Custom aisle floor and door seals
  - Ensure equipment designed for cold aisle containment
    - And installed to pull cold air
      - Not hot air…
- Have run ~1.1-1.15 PUE
  - A few hot spots were driving up PUE…
  - Summer time PUE of 1.20 because of increased cooling
- **Starting to control hot aisle based on return temperature of ~80F**
- **65 Watts/person to 38 Watts/person**
  - But NREL has doubled in size
  - Modeled 65 watts/person for 1200 people
  - Using 38 watts/person for 2300 people



Credit: Marjorie Schott/NREL

NREL/PIX 17897

Monthly Average PUE