NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Eficiencia Energetica en la Republica Dominicana- Tecnologias Potenciales

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Promoviendo la inversión en eficiencia energética

- Objetivo general: movilizar la inversión del sector privado en energía limpia en la RD, centrándose en EE con grandes sectores comerciales e industriales (sector no hotelero), que se logrará mediante:
- Asociarse con grupos industriales públicos y privados para promover conjuntamente iniciativas compartidas para promover el despliegue de EE.
- Mejorar la comprensión entre las instituciones financieras de las oportunidades para invertir en eficiencia energética. Desarrollo de capacidades en el país entre empresas para comprender el caso comercial de las inversiones en eficiencia energética.
- Proyecto de unión de proyectos con instituciones financieras.

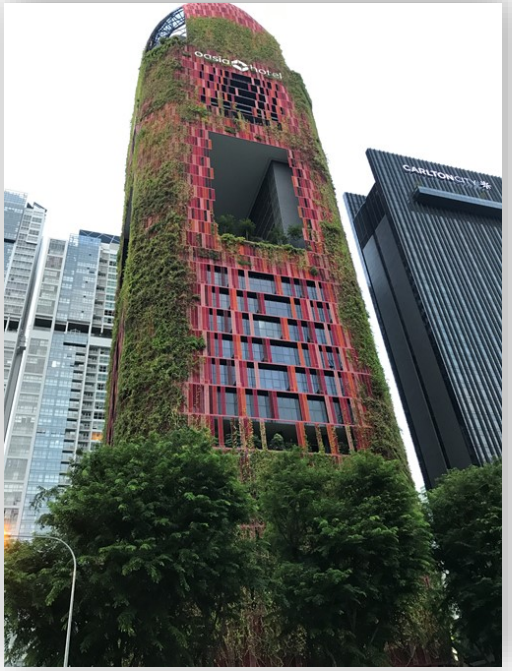

Photo: Jimmy Salasovich, NREL

Modelaje de Energia en Edificios

Visión general:

Modelización detallada de la energía del edificio para cualquier tipo de edificio.

Técnicas avanzadas de modelado energético:

Ventilación natural: Sistemas avanzados de climatización

Luz del día

Las herramientas de modelado de NREL:

OpenStudio

eQUEST

Beopt

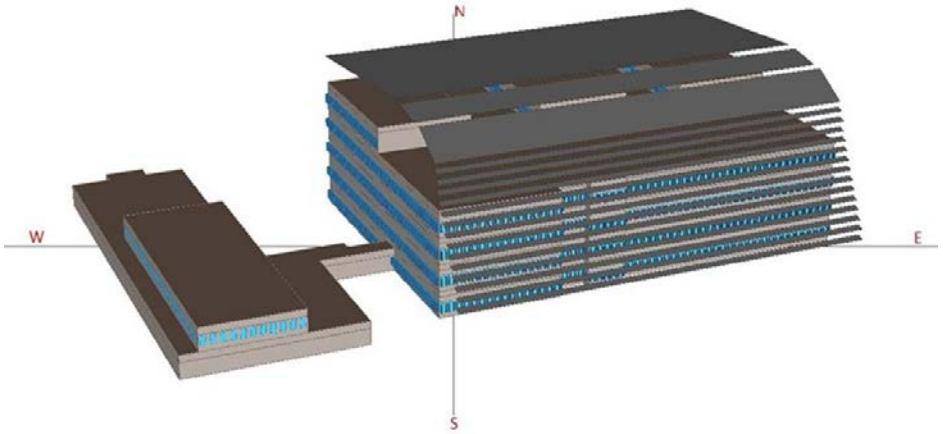

Photo: Jimmy Salasovich, NREL

Torres de radar con generación distribuida

Visión general:

Demostración de campo de tecnologías emergentes de EE / RE para evaluar el despliegue a gran escala.

Photo: Jesse Dean, NREL

TIRAS AVANZADAS PARA CONTROL DE CARGA DEL ENCHUFE

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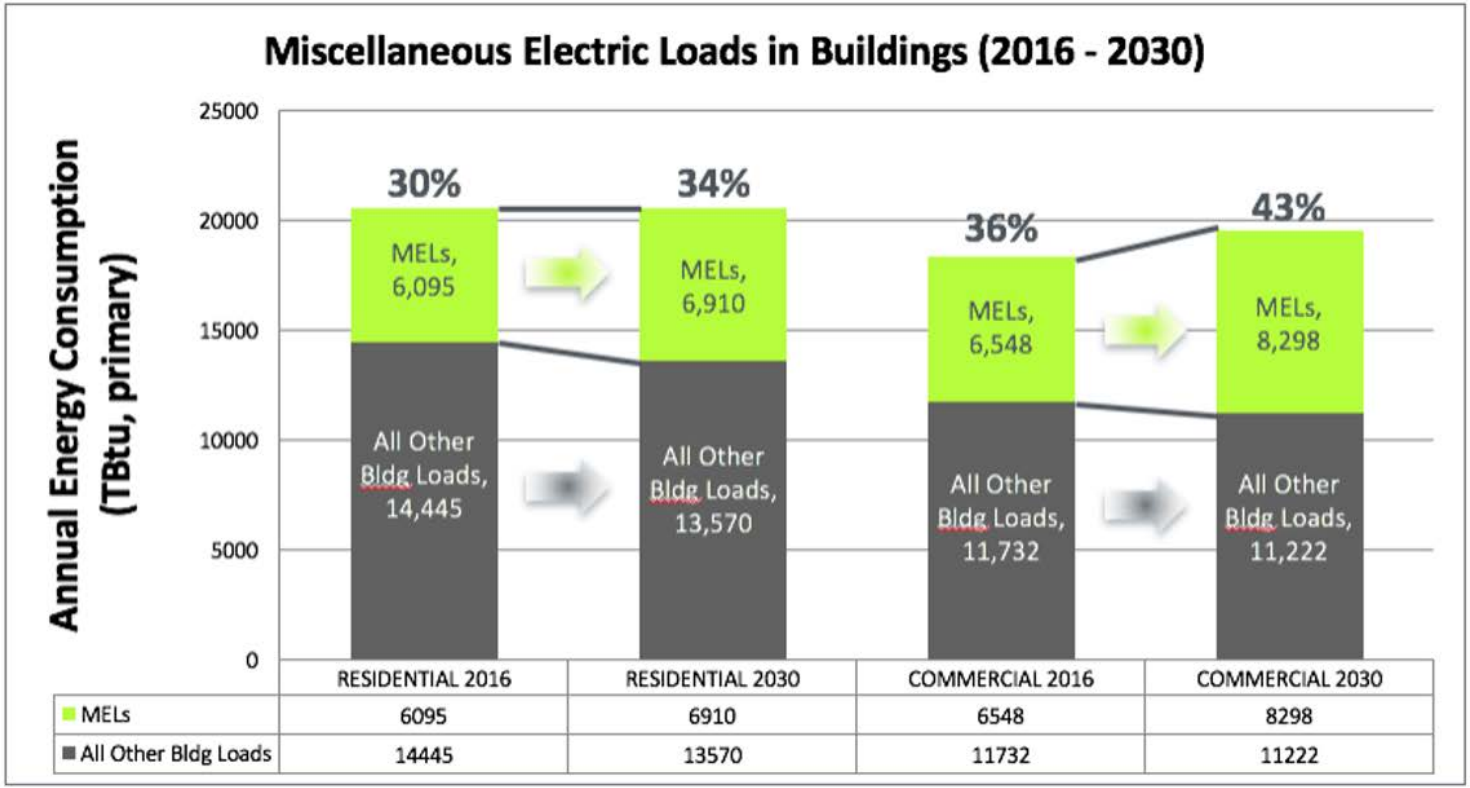
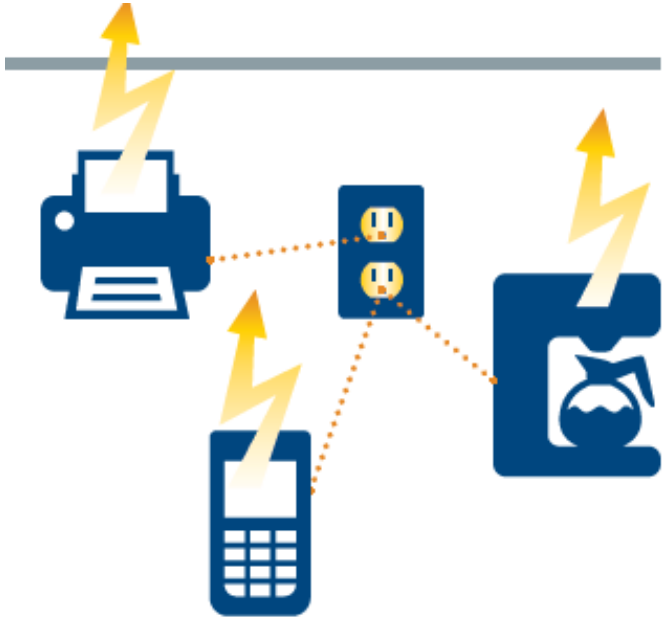


Data from: EIA Annual Energy Outlook, 2015.

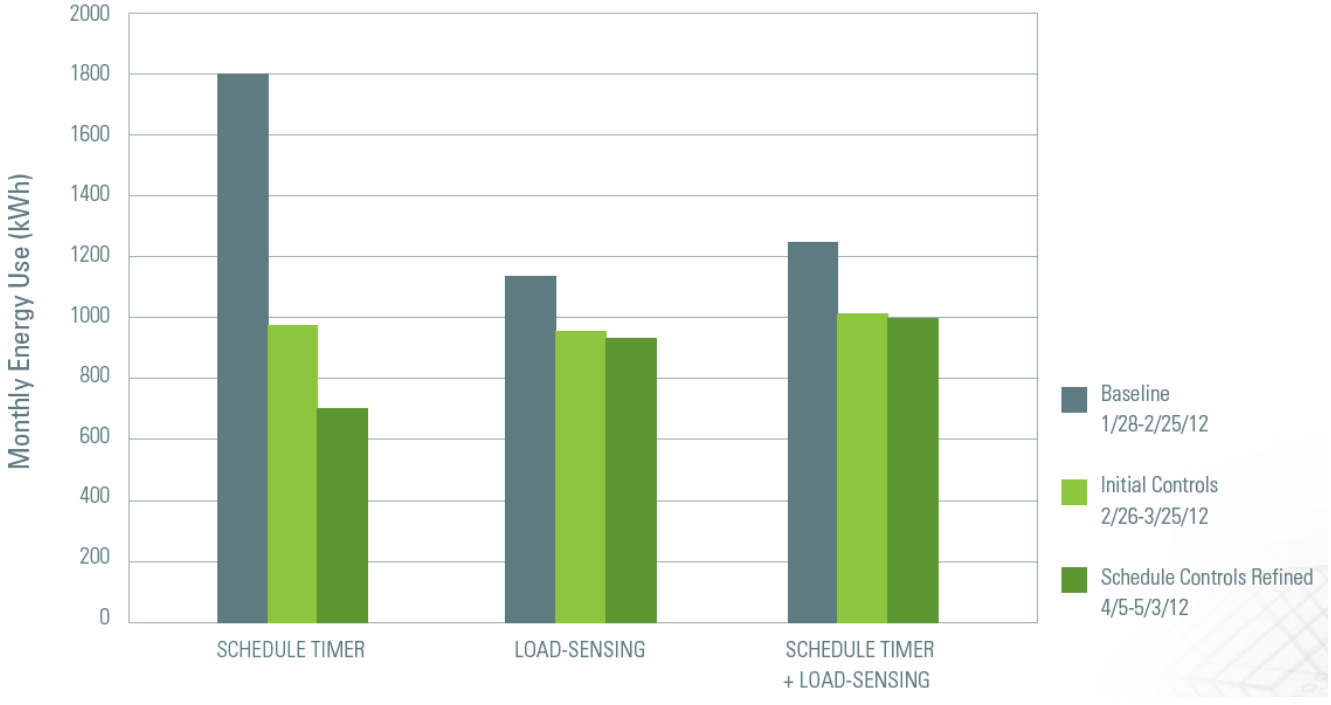
TIRAS AVANZADAS PARA CONTROL DE CARGA DEL ENCHUFE

- 25%de la electricidad se pierde por demanda fantasma.
- Desconecta circuitos basado en un temporizador, sensación de carga, o ambos
- 26% ahorros de energía en estaciones de trabajo con gestión avanzada de computadora
- 48% en cocinas y sala de impresora



TIRAS AVANZADAS PARA CONTROL DE CARGA DEL ENCHUFE

Schedule timer controls resulted in average-energy reduction of 48%

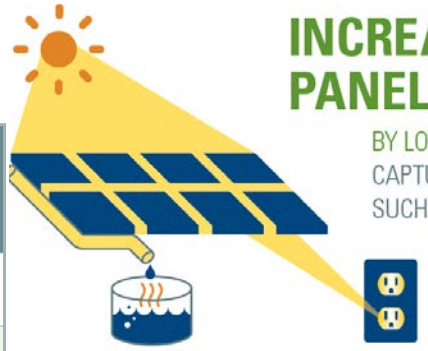


TIRAS HÍBRIDO FOTOVOLTAICO-TERMICO SISTEMA SOLAR

Energy Savings and Economics for PV-T

Cost-effective when electricity rates are high

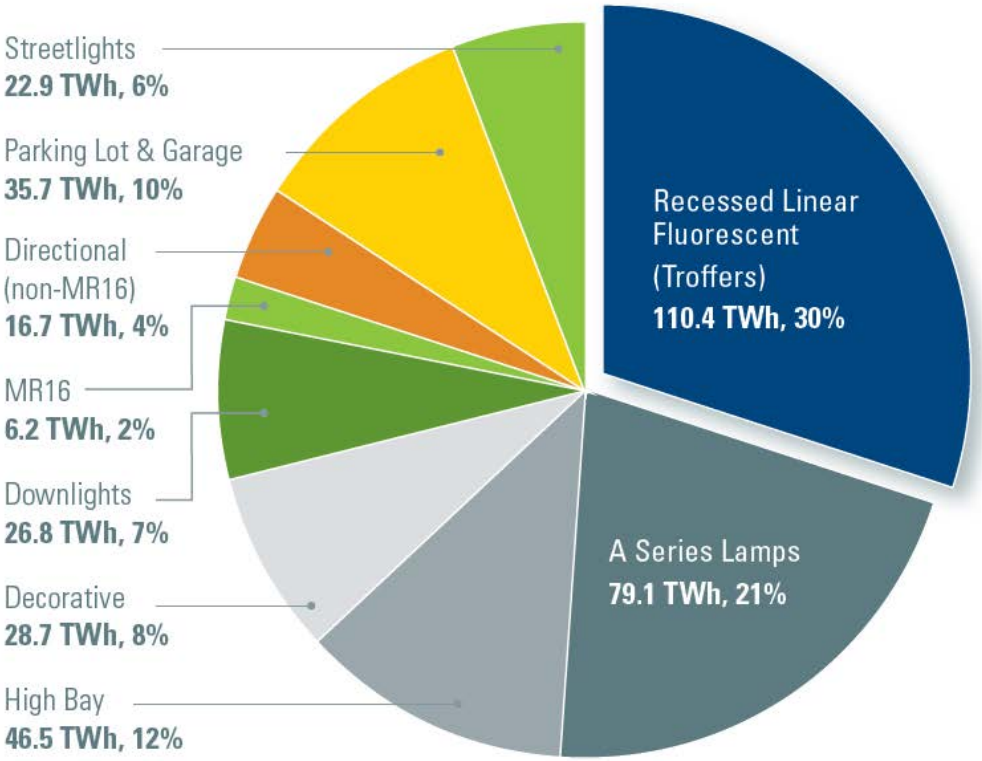
City	Electricity Rate ($/kWh)	City Cost Adjustment Multiplier	Solar Energy Production (kWh/yr)	Annual Cost Savings ($)	Installed Cost ($)	Simple Payback (yrs)	Payback with 30% Tax Credit (yrs)
Portland, OR	0.09	0.992	6,698	$581	$56,765	98	68
Boston, MA	0.15	1.172	6,331	$934	$67,065	72	50
Denver, CO	0.11	0.943	11,063	$1,198	$53,961	45	32
Honolulu, HI	**0.34**	**1.173**	**10,097**	**$3,488**	**$67,123**	**19**	**13**
Daggett, CA	0.18	0.996	11,824	$2,144	$56,994	27	19
Phoenix, AZ	0.10	0.887	11,783	$1,237	$50,757	41	29



INCREASES PV PANEL EFFICIENCY

BY LOWERING PV TEMPERATURE CAPTURES HEAT FOR OTHER USES SUCH AS DOMESTIC HOT WATER

ILUMINACIÓN LED CON CONTROLES INTEGRADO DE AVANZADOS



110.4

TWh SAVED[1]

EQUIVALENT TO 10 MILLION HOMES

1 TWh = average annual energy use of approximately 92,000 U.S. households

ILUMINACIÓN LED CON CONTROLES INTEGRADO DE AVANZADOS

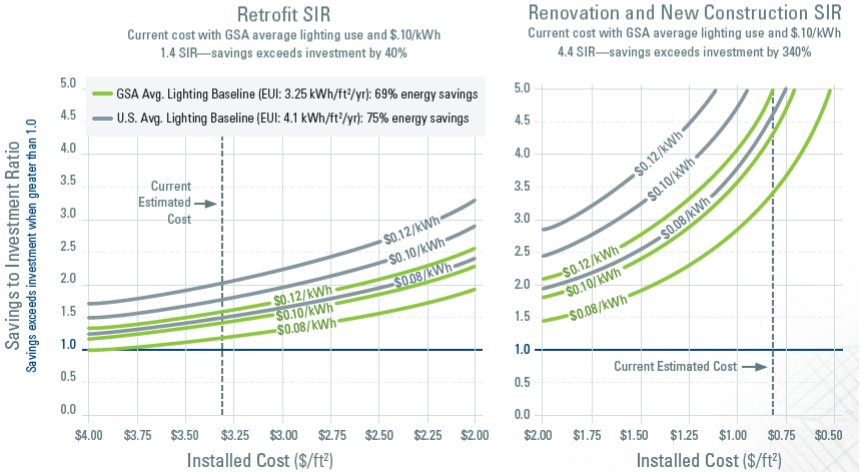
How did LED Fixtures with Integrated Controls perform in M&V?

69%
ENERGY SAVINGS
OVER GSA AVERAGE
41% from LED
28% from ALC[2]

40%
RETURN ON INVESTMENT
FOR GSA RETROFITS
1.4 SIR at current estimated cost and utility rate of $.10 kWh[3]

25%
OF COST SAVINGS
DUE TO REDUCED MAINTENANCE
LEDs last twice as long as fluorescent lamps[4]

Positive Return on Investment for Both Retrofits and Renovations



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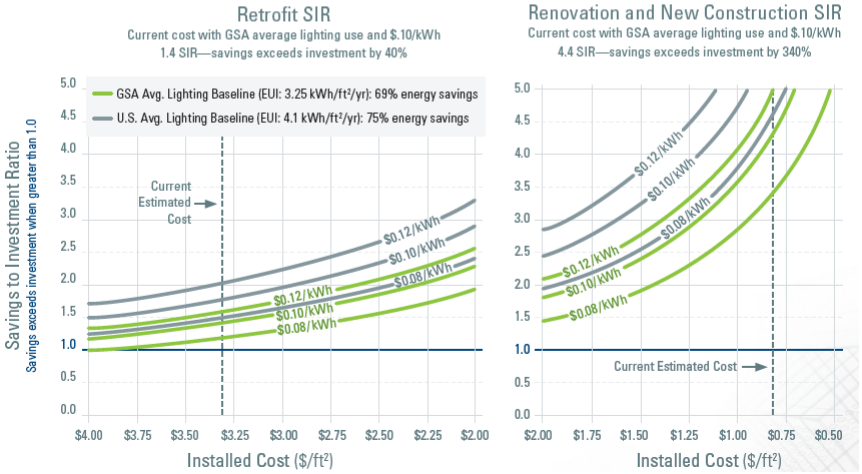
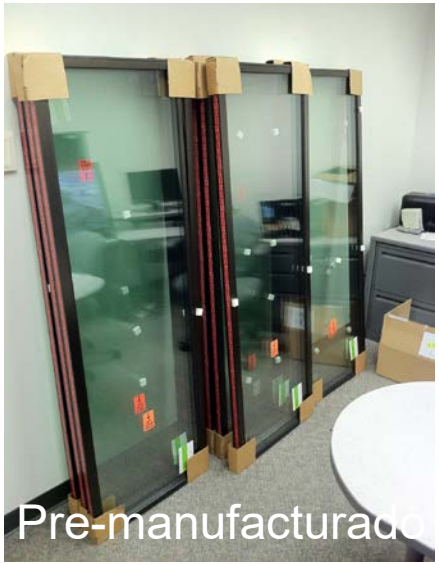


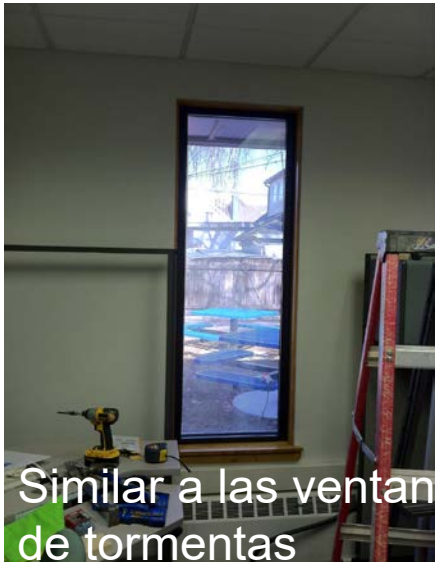
REMODELACIONES DE VENTANAS DE BAJO COSTO MEJORA EL RENDIMIENTO TÉRMICO

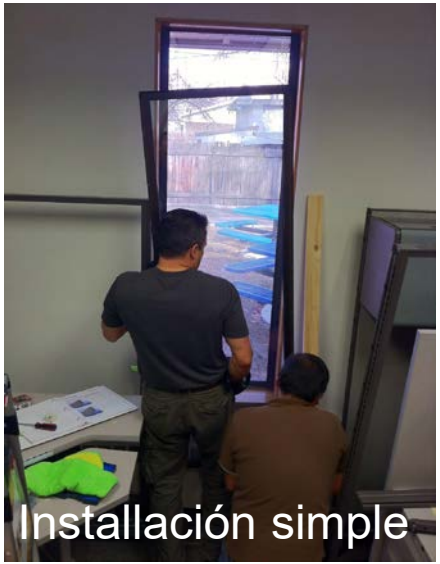
Oportunidad:

34%Energía HVAC enedificios comerciales se pierde a las ventanas

1.5% del total de EE.UU. consumo de energía







REMODELACIONES DE VENTANAS DE BAJO COSTO MEJORA EL RENDIMIENTO TÉRMICO

Ahorro de energía:

41% HVAC ahorro de energía

11% de ahorro en edificios completos estimado

Satisfacción de los ocupantes:

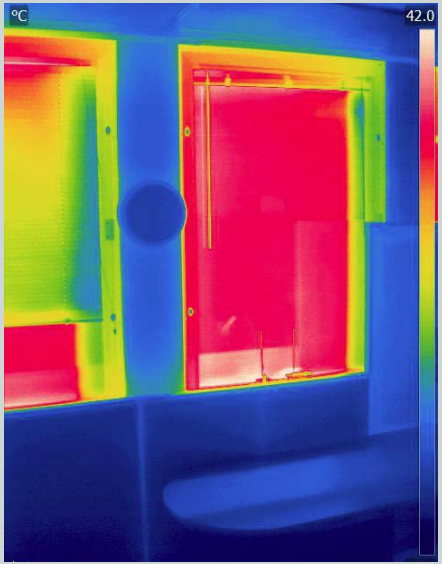
Instalación rápida y mejora del confort visual y térmico

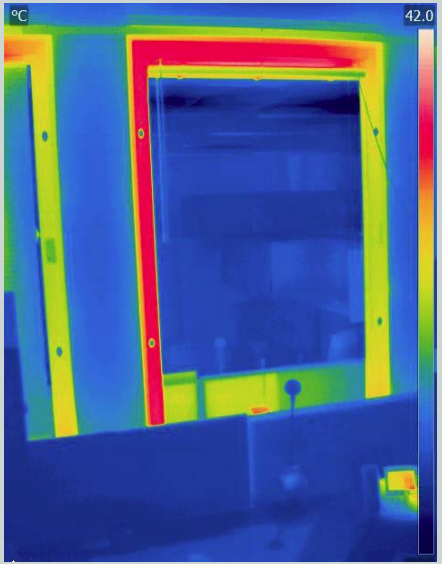
Efectividad de costo:

<9 años de amortización para el triple panel, el doble panel será más corto

REMODELACIONES DE VENTANAS DE BAJO COSTO MEJORA EL RENDIMIENTO TÉRMICO

Imágenes infrarrojas que comparan la energía radiante de la ventana durante condiciones





Película absorbente.

Ventana de baja emisivida

El confort térmico mejorado.

Los ocupantes no están expuestos a la radiación térmica del vidrio caliente (o frío).

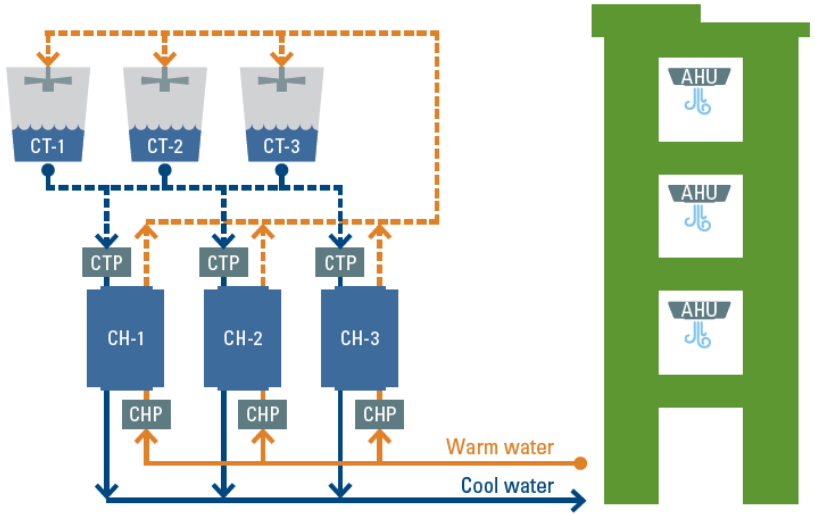
SITEMA DE CONTROL PARA LA OPTIMATIZACIÓN DE PLANTA

How does the Control Optimization System for Chiller Plants work?

OPTIMIZES SYSTEM PRESSURE AND TEMPERATURE DIFFERENCE (DELTA T)

MANAGES CHILLER LIFT AND FLOW BY MONITORING AND CONTROLLING FIVE INTERDEPENDENT SYSTEMS

Cooling Towers (CT), Chillers (CH), Condenser Pumps (CTP), Chilled Water Pumps (CHP), and Air Handler Units (AHU)



M&V

SITEMA DE CONTROL PARA LA OPTIMATIZACIÓN DE PLANTA

How did the Control Optimization System perform in M&V?

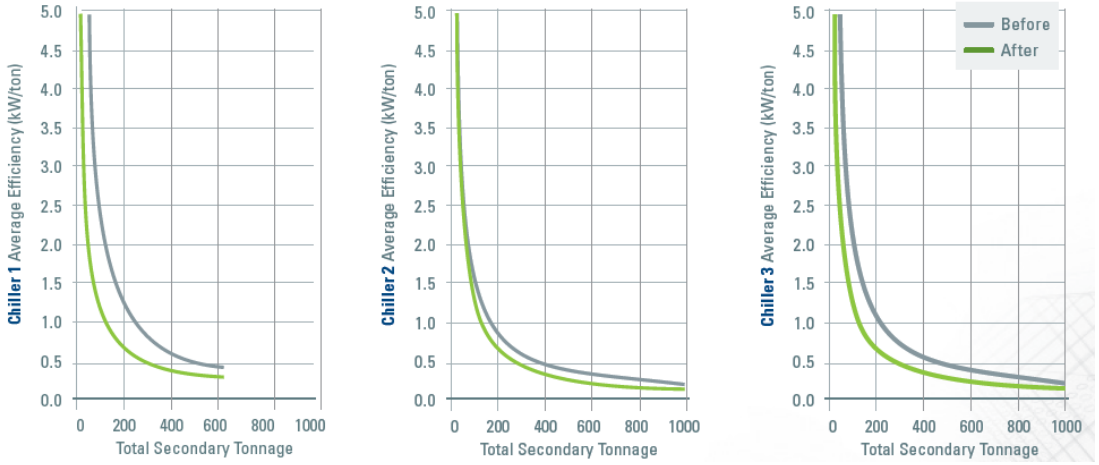
35%
COOLING SAVINGS
+/- 10% uncertainty
due to estimated baseline[1]

5 YR
PAYBACK
At avg. cost of $0.11/kWh[3]

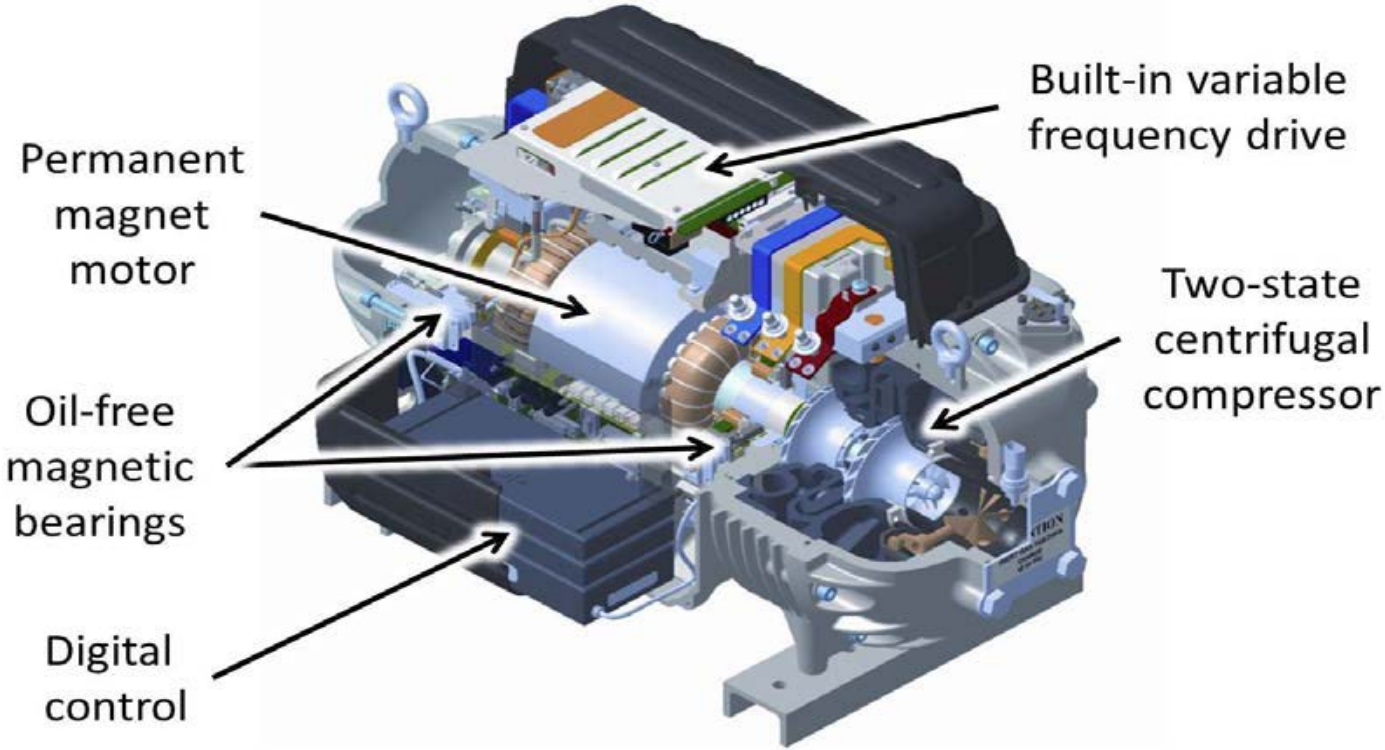
BETTER
VISIBILITY & CONTROL
FOR PLANT OPERATIONS[2]

Increased Efficiency, Especially at Part Loads

Performance averaged 0.64 kW/ton after control optimization



COJINETE MAGNÉTICO DE VELOCIDAD VARIABLE DE ENFRIADORA



COJINETE MAGNÉTICO DE VELOCIDAD VARIABLE DE ENFRIADORA

OPPORTUNITY

How much energy is used for space cooling in U.S. office buildings?

10%
OF ENERGY
GOES TO SPACE COOLING[1]

32%
OF COMMERCIAL BUILDINGS
RELY ON CHILLERS TO PROVIDE THIS COOLING[2]

TECHNOLOGY

How do maglev chillers save energy?

ELIMINATE FRICTION
WITH MAGNETIC BEARINGS

IMPROVE EFFICIENCY AT PARTIAL LOADS
WITH VARIABLE SPEED DRIVE

35%
MORE EFFICIENT
THAN FEMP-DESIGNATED HIGH-EFFICIENCY ROTARY SCREW CHILLERS

COJINETE MAGNÉTICO DE VELOCIDAD VARIABLE DE ENFRIADORA

$9,097 Reduccion annual del costo energetico

En el edificio federal George Howard Jr. Federal @ $0.073/kWh

Menos de 5 años de recuperación incremental

al final de la vida útil después de la normalización de la estructura de pago y los costos de servicios públicos y en comparación con el nuevo enfriador de tornillo rotativo designado por FEMP

COJINETE MAGNÉTICO DE VELOCIDAD VARIABLE DE ENFRIADORA

RESULTS

How did maglev chillers perform in M&V?

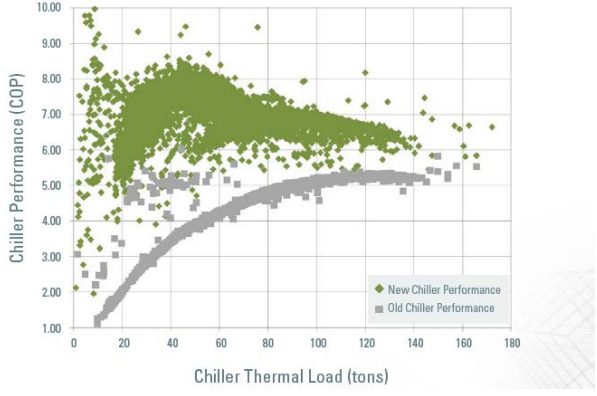
42%
ENERGY SAVINGS
AS COOLING LOADS DECREASE, EFFICIENCY INCREASES[3]

QUIET
PERFORMANCE
ALLOWS CHILLERS TO BE PLACED CLOSER TO OCCUPANT SPACES[4]

<5
YEARS
PAYBACK
after normalizing for payment structure & utility costs[5]

Efficiency of Maglev Chiller Increases as Load Is Reduced

Maglev chiller efficiency is highest between 40 to 50 tons (27 to 33% of nominal full load)
Incumbant chiller efficiency continuously decreases as chiller load is reduced



COJINETE MAGNÉTICO DE VELOCIDAD VARIABLE DE ENFRIADORA

Beneficios del compressor con cojinete magnetico:

- Compresores más pequeños y más ligeros que la capacidad similar.
- Enfriadores silenciosos, sin fricción, colocados más cerca de los espacios ocupantes.
- Refrigeración más eficiente a cargas parciales más bajas.

OTRAS AREAS POTENCIALES

- Incentivos fiscales a la importación de equipo eficiente, auditorías energéticas y monitoreo del consumo de energía, programa de EE en el sector público y privado.
- Auditorías energéticas Código de construcción que incluya: envolvente de edificio, uso de sensores de ocupación, uso de iluminación natural, uso de iluminación eficiente, cool roof, uso de refrigerantes naturales y calentamiento solar de agua.
- Sistemas de iluminación eficiente.
- Reemplazo de vehículos de combustión interna poco eficientes por vehículos eléctricos, o tecnologías más eficientes.
- Electrodomésticos eficientes.

OTRAS AREAS POTENCIALES

- Configuración de acondicionadores de aire.
- Alumbrado público.
- Motores eficientes y variadores de velocidad de motores.
- Sistemas de gestión de la energía.
- Diagnósticos energéticos.
- Cogeneración.
- Bombas de calor. - Calefones y termo tanques.
- Calderos.
- Medidas de eficiencia energética en el transporte carretero.

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www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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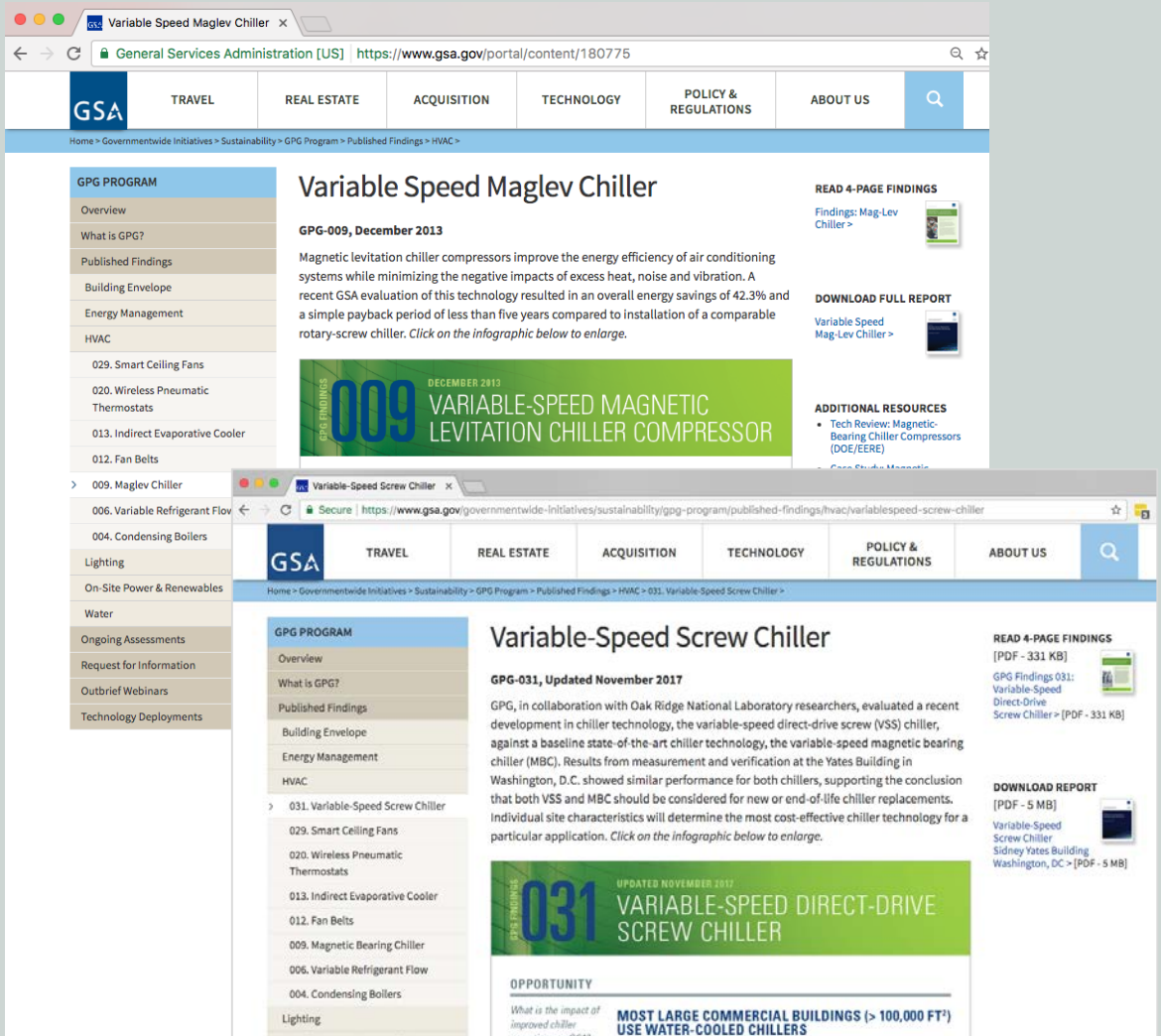
Reports Online

- Infographic
- 4-page Findings
- Full Report
- Additional Resources

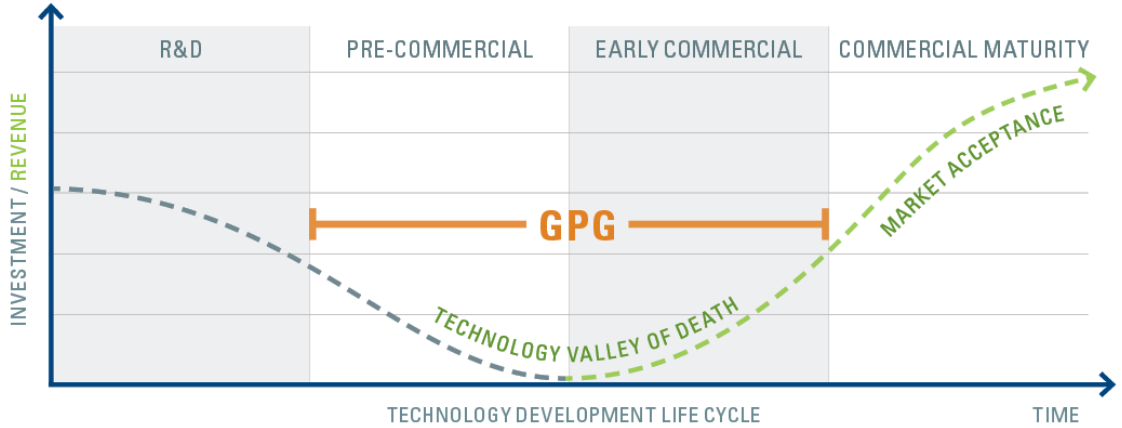


Emerging Technologies' two programs — GSA Proving Ground (GPG) and
Pilot to Portfolio (P2P) — enable GSA to make sound investment decisions in next generation building technologies based on their real world performance

Leading by Example

GSA's Proving Ground accelerates market acceptance by objectively assessing innovative building technologies in real-world environments, and deploying those that deliver. To date, GSA has installed 9 technologies across more than 200 buildings.

In aggregate, these technologies are delivering $7.4 Million in annual O&M savings



GPG Process

Identify promising technologies at the edge of commercialization

Pilot technology installations within GSA's real estate portfolio

Partner with Department of Energy national laboratories to objectively evaluate real-world performance

Identify technologies with broad deployment potential for GSA, coordinate results with broader federal and CRE community.

Introduction to Plug Load Control

Thanks to:

- Region 3 for conceptualizing the study and bringing it to GPG
- NREL for designing a study that tested all the strategies and allowed us to use a technology that had 80% of the value at 20% of the cost
- OFM team for leading a deployment campaign throughout 200 facilities
- FAS for leveraging Federal procurement buying power

What Are Plug Loads?







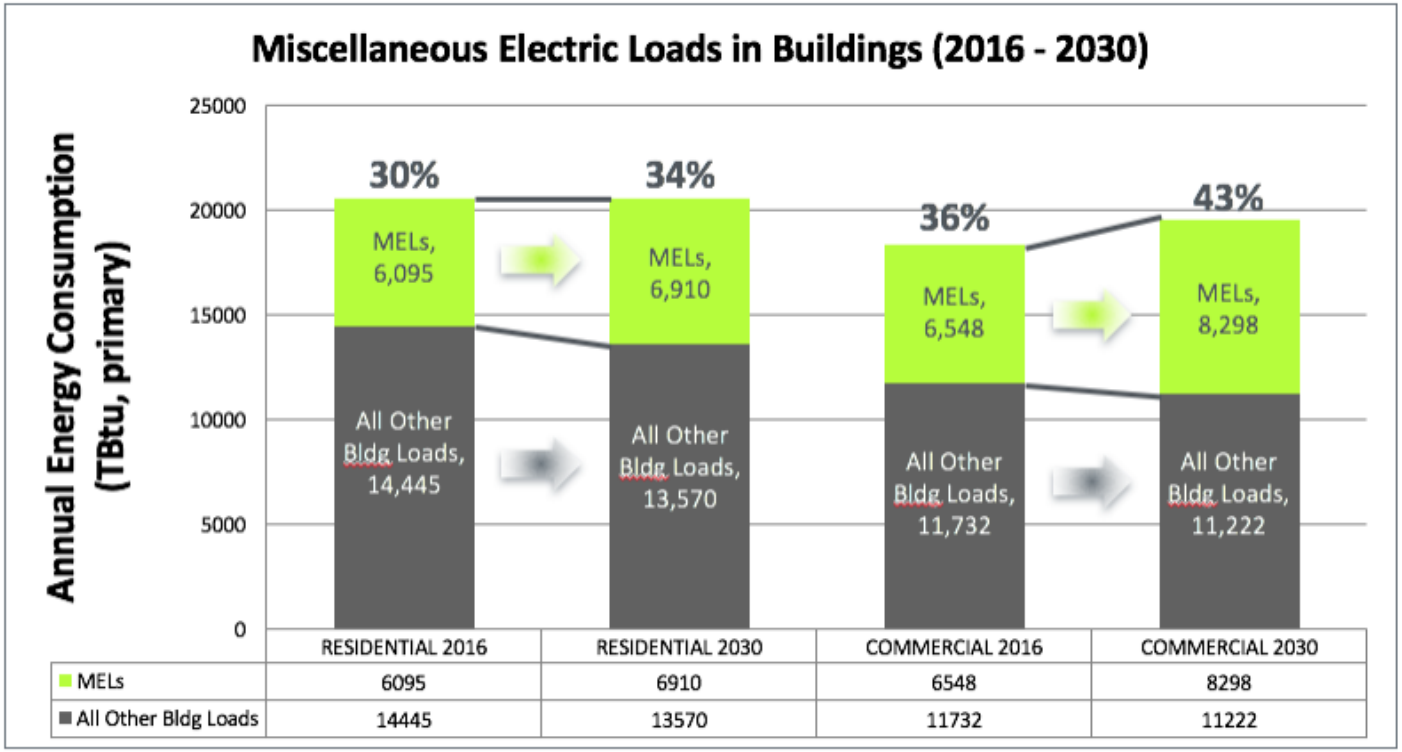








Plug Load Energy



Data from: EIA Annual Energy Outlook, 2015.

Typical Energy Savings

Translates to approximately

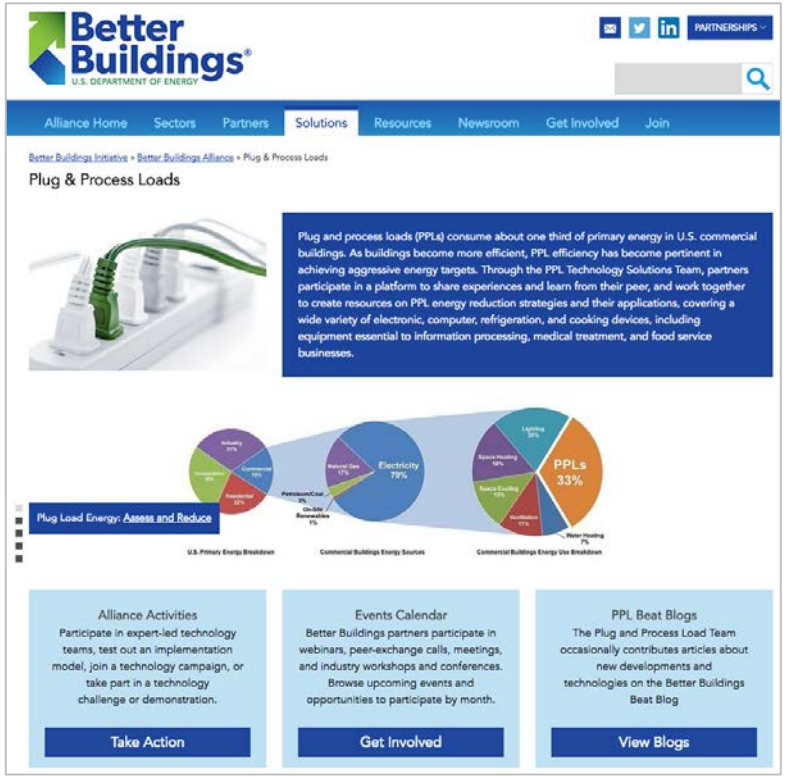
10%

of whole building energy consumption

Better Buildings Initiative

Better Buildings Initiative

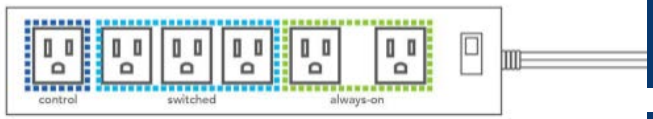
Plug & Process Loads Team

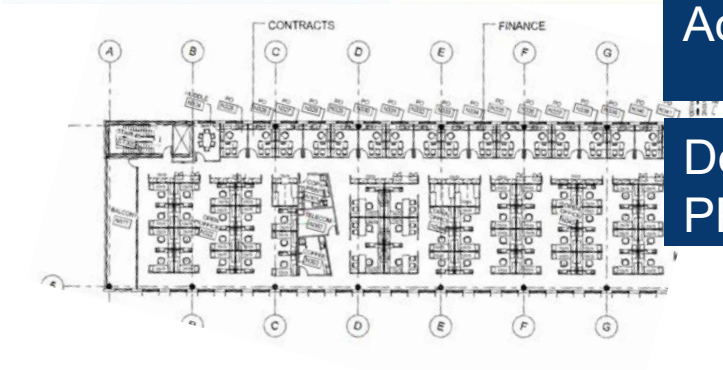


https://betterbuildingsinitiative.energy.gov/alliance/technology-solution/plug-process-loads

Plug Load Resources

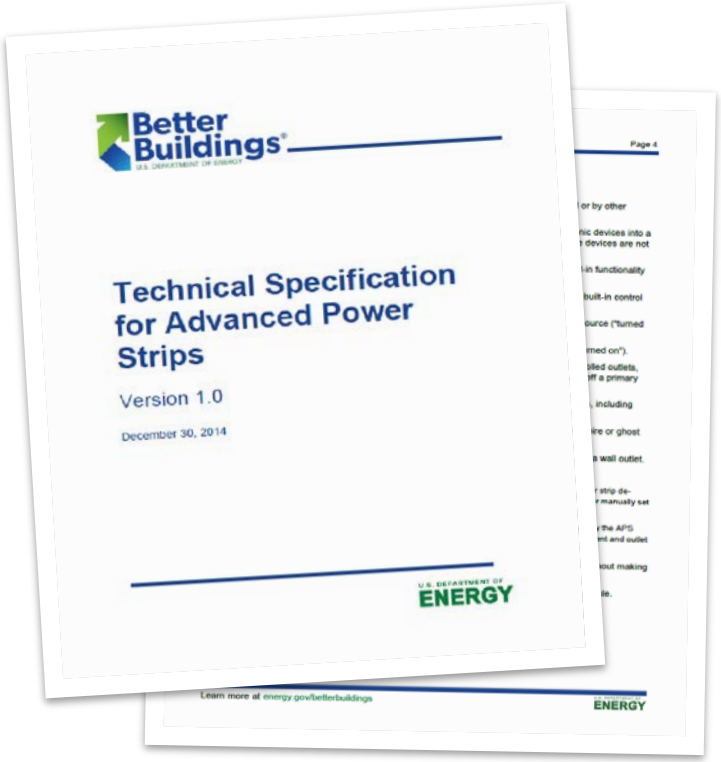
Established PPL Energy Management Solutions

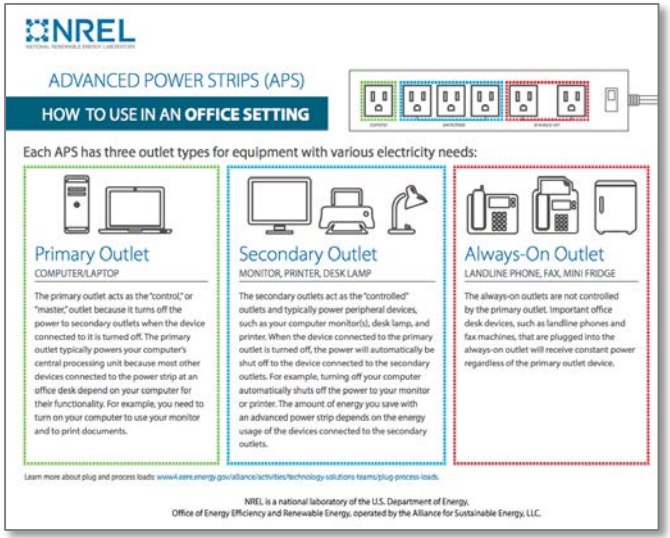




- “Turn It Off!” Campaigns
- Upgrade Equipment, ENERGY STAR
- Built-In Low Power States
- Advanced Power Strips
- Design Strategies for Consolidating PPLs

Plug Load Resources



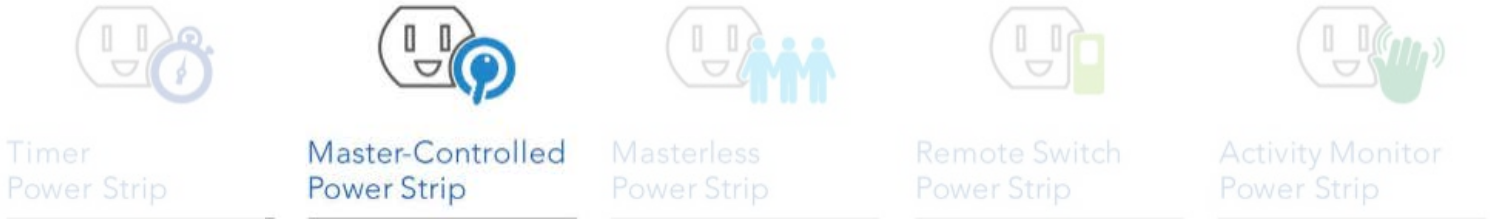


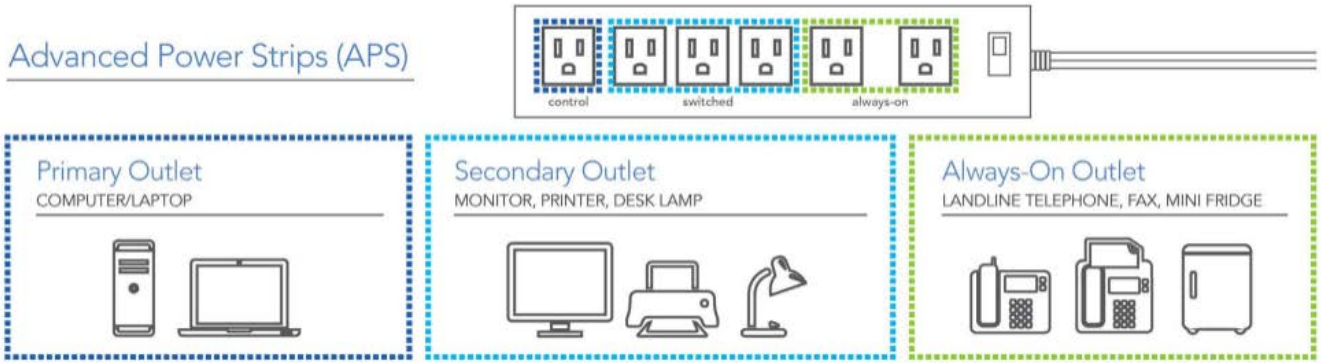
Advanced Power Strips

Advanced Power Strips

- Power strip automatically turns off outlets based on a pre-set schedule

Advanced Power Strips





Advanced Power Strips

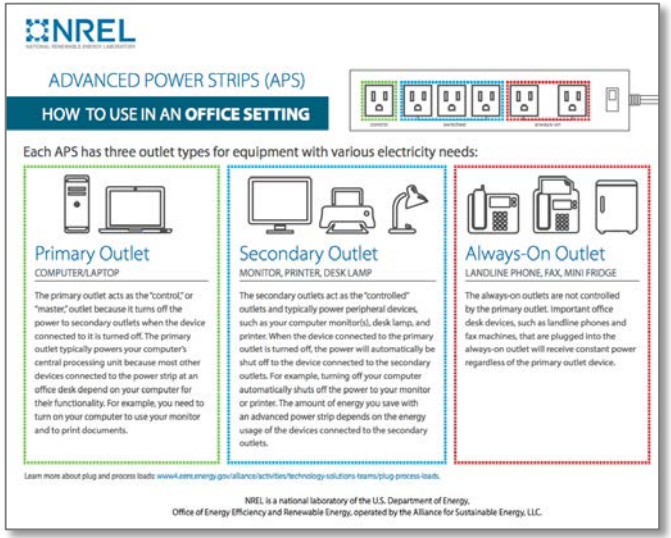
Timer
Power Strip

Master-Controlled
Power Strip

Masterless
Power Strip

Remote Switch
Power Strip

Activity Monitor
Power Strip



Advanced Power Strips

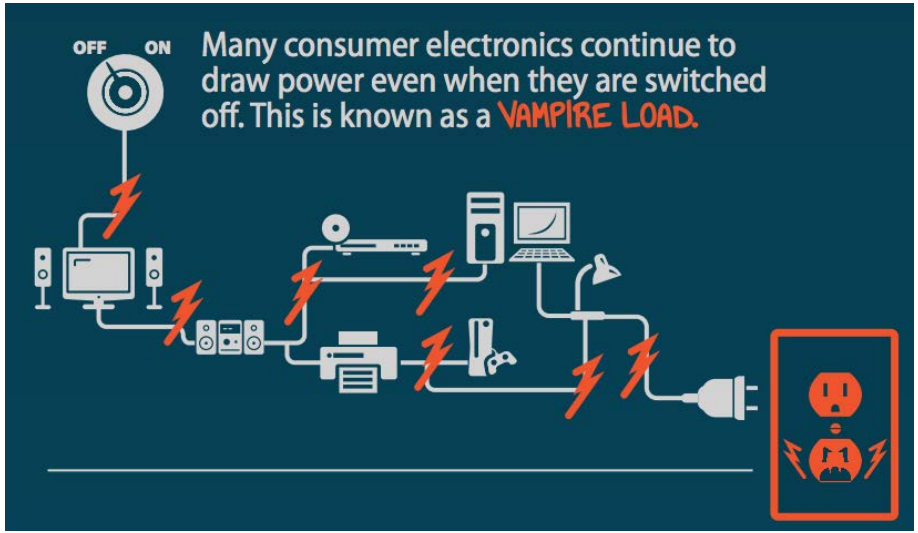
Timer Power Strip

Master-Controlled Power Strip

Masterless Power Strip

Remote Switch Power Strip

Activity Monitor Power Strip



Advanced Power Strips

Timer Power Strip

Master-Controlled Power Strip

Masterless Power Strip

Remote Switch Power Strip

Activity Monitor Power Strip

Advanced Power Strips

Timer Power Strip

Master-Controlled Power Strip

Masterless Power Strip

Remote Switch Power Strip

Activity Monitor Power Strip

A Tale of Two Tiers

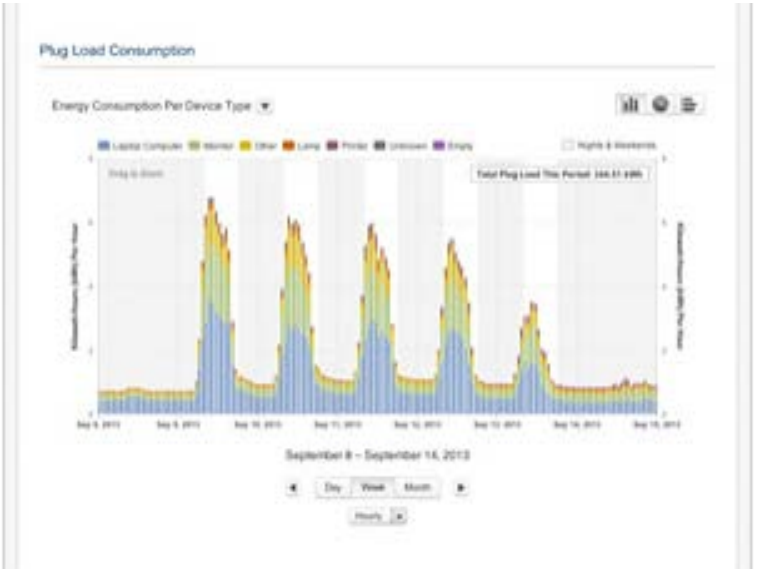
Tier 1 = Typical APS

Timer Power Strip | Master-Controlled Power Strip | Masterless Power Strip | Remote Switch Power Strip | Activity Monitor Power Strip

Tier 2 = APS with Occupant Sensing

Connected APSs

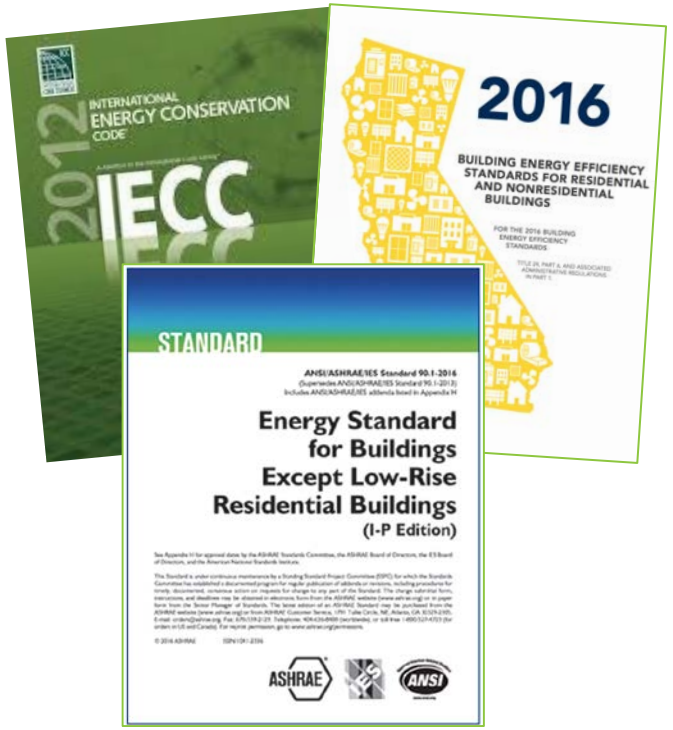
Hardware + Software + Services



Building Standards & Codes

Standards Require Plug Load Controls (…since 2010!)

- ASHRAE 90.1
- California Title 24
- 50% of outlets in specified spaces must have automatic shut-off control
  - Workstations
  - Private offices
  - Conference rooms
  - Print/copy rooms
  - Break rooms
  - Classrooms
- Plug-in control devices are not allowed



Wireless Meter & Controls —”Smart Outlets”

BUDDERFLY

Better Buildings Initiative

Data analytics = informed decisions

- Set schedules
- Monitor device health for efficiency and failure
- Inform policies
- Control equipment and manage data remotely
- Engage occupants

GPG-003 Advanced Power Strips for Plug Load Control

General Services Administration
Public Buildings Service

GSA

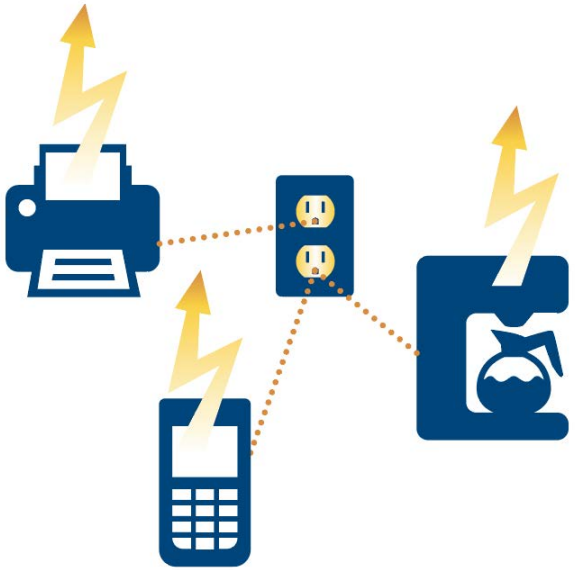
GPG-003 | SEPTEMBER 2012

ADVANCED POWER STRIPS

Advanced Power Strips Decrease Energy Consumption

Desk-based technologies and other electronics that plug into office building receptacles draw a considerable amount of power, some of it 24/7. In fact, "plug loads" account for roughly 25% of total electricity consumed within office buildings. GSA currently owns and leases more than 370 million square feet of building space in some 9,600 buildings nationwide. The size of this real estate portfolio alone suggests the possibility of enormous energy savings, if plug loads can be reduced. With this in mind, GSA's GPG program recently assessed the effectiveness of advanced power strips (APS) in managing plug-load energy consumption in eight of its buildings. Three types of plug-load reduction strategies were evaluated: schedule timer control, which allows the user to set the day and time when a circuit will be energized and de-

Opportunity



25% of electricity end use in office buildings goes towards plug loads (in 2012) and this has continued to increase

Advanced Power Strips

De-energize circuits

Based on a timer, load-sensing or both

Measurement & Verification, GSA's Mid-Atlantic Region

Veterans Administration Center Building – Philadelphia, Pennsylvania
William J. Green, Jr. Federal Building – Philadelphia, Pennsylvania
Cohen Complex – Camden, New Jersey
Clarkson S. Fisher Federal Building and U.S. Courthouse – Trenton, New Jersey
Spottswood W. Robinson III and Robert R. Merhige, Jr., U.S. Courthouse – Richmond, Virginia Edward A. Garmatz U.S. Courthouse – Baltimore, Maryland
William S. Moorhead Federal Building – Pittsburgh, Pennsylvania
Robert C. Byrd Federal Building and U.S. Courthouse –

NREL assessed Advanced Power Strips throughout GSA's Mid-Atlantic Region

Technology Installed and Measurement and Verification applied by Mid-Atlantic.

Test Plan

- 3 control strategies: load-sensing, schedule-timer, both
- Different space types: workstations, printer rooms, kitchens

Monitored for 12 weeks

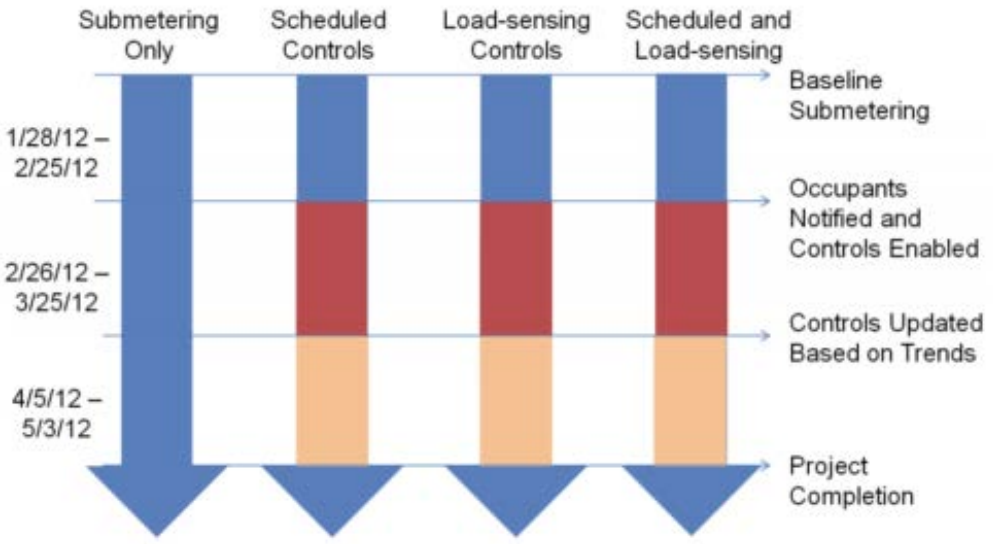
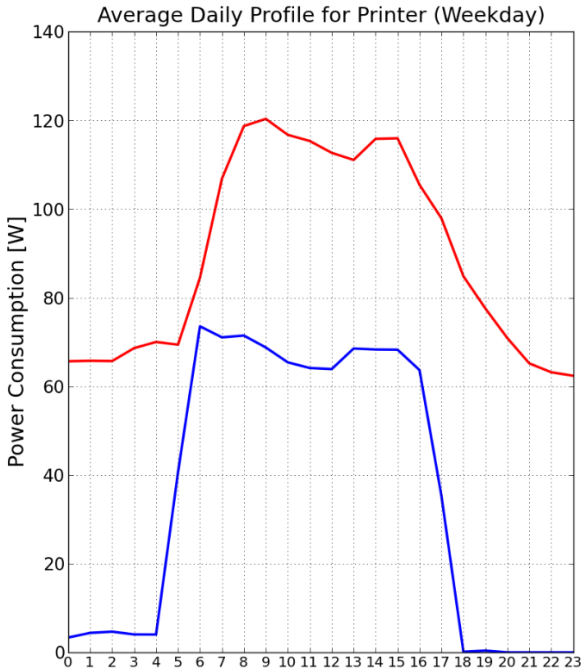
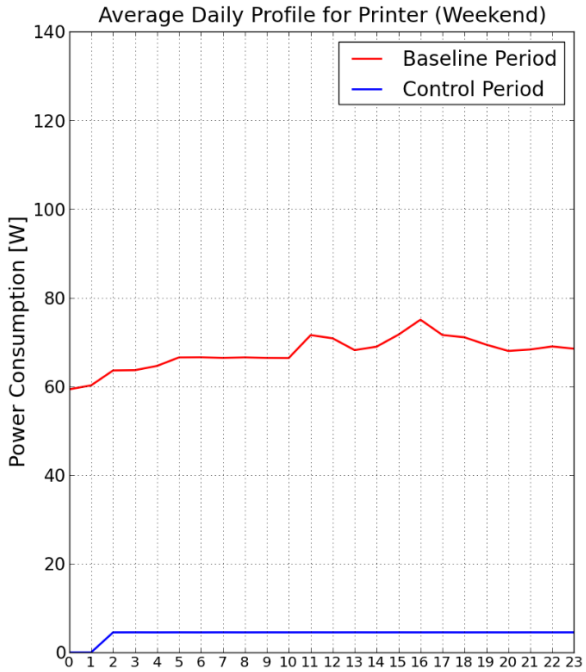


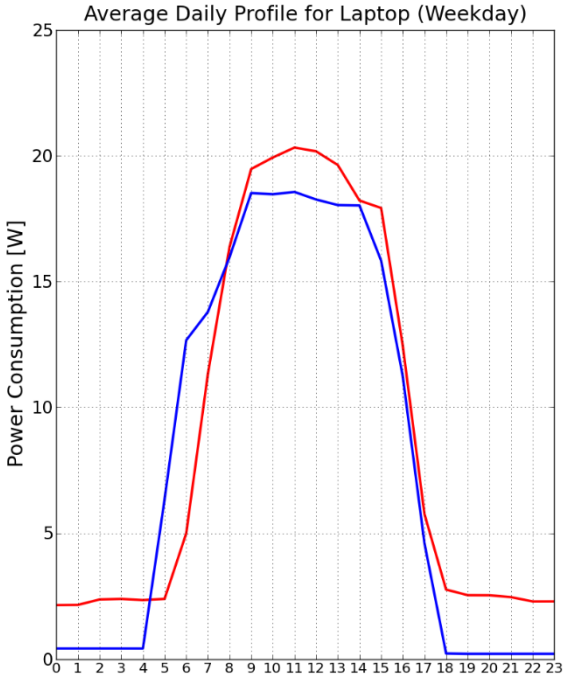
Figure IV-4: Diagram of project timeline

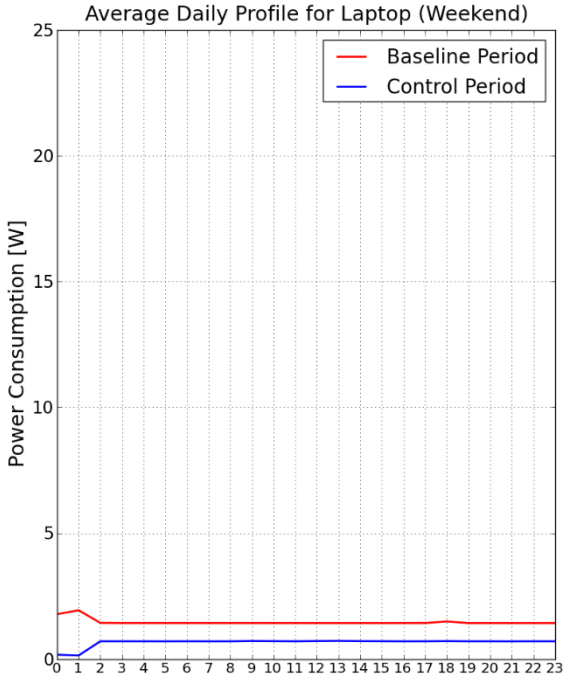
Printers


Average Daily Profile for Printer (Weekday)
Power Consumption [W]
0
20
40
60
80
100
120
140
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

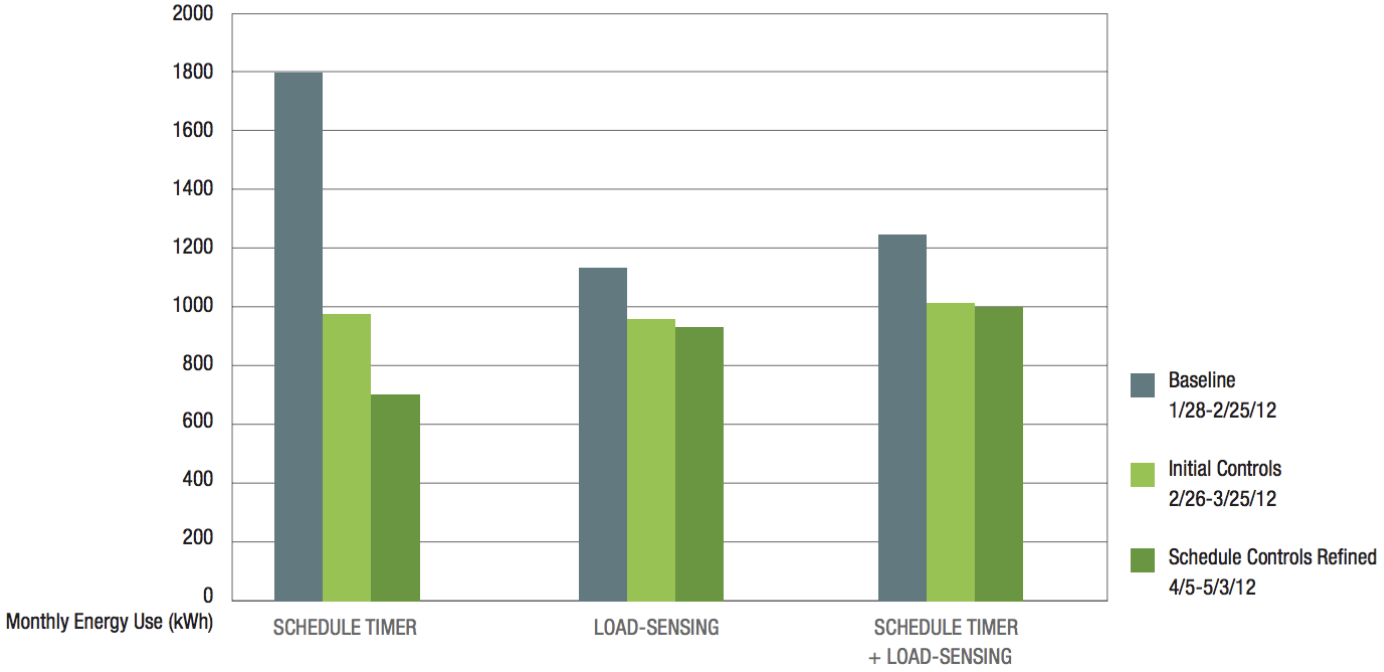

Average Daily Profile for Printer (Weekend)
Baseline Period
Control Period
Power Consumption [W]
0
20
40
60
80
100
120
140
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Laptops


Average Daily Profile for Laptop (Weekday)
Power Consumption [W]
0
5
10
15
20
25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23


Average Daily Profile for Laptop (Weekend)
Baseline Period
Control Period
Power Consumption [W]
0
5
10
15
20
25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

Energy Savings



26%

ENERGY SAVINGS

AT WORKSTATIONS with advanced computer management in place

48% IN KITCHENS & PRINTER ROOMS

Simpler and Lower-Cost Schedule Timer Most Effective

- Largest savings with devices powered 24/7 such as printers, copiers and kitchen appliances
- Majority of users did not wish to have more control over their individual APSs
- Load-sensing might be worth pursuing for individual workstations when occupants have a variety of desktop appliances and unpredictable schedules

Payback

GSA Estimated Energy Savings

77.23 kWh/yr for Workstations
Annual savings of $8.50

466.2 kWh/yr for Common Areas
Annual savings of $51.29

3
YEARS
PAYBACK
for workstations
@$22 per device
.5 years for
common areas

Recommended Broad Deployment

Best suited for all locations

- Energy savings and low payback support deployment throughout GSA's portfolio

Test-Bed Experience

Timer tested was powerful

- Each plug programmed separately, wifi accessible, logged plug electricity use
- IT security issues prevented connecting to GSA's network
- Savings weren't as high as initially expected because most offices had already gone from desktop to laptop computers

Test-Bed Experience

User experience

- Users didn’t like big brother aspect of logging when electricity was being used
- Users had issues with printers being turned off when they needed them
- Override switch wasn’t easy to use, users had to get on hands and knees to access

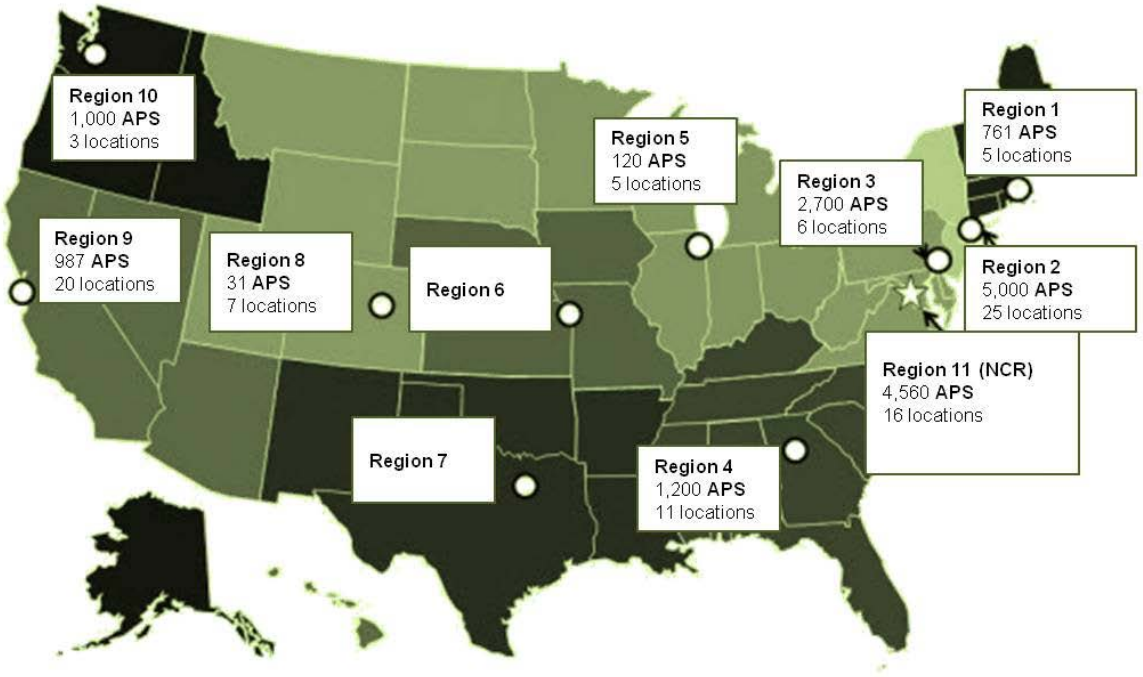
Current APS

Decided on a much dumber timer-controlled APS

- Most of these are still being used
- At first, the thought was that it would be hard to give these away but then everyone wanted one

APS National Deployment

16,000 timer-controlled devices in over 80 facilities across GSA



Deployment Details

Bulk Purchase of APS

- Off the shelf, no customization, Belkin, Conserve Surge with Timer
- On GSA Schedule & TAA compliant
- 35% discount from GSA Schedule

Deployment

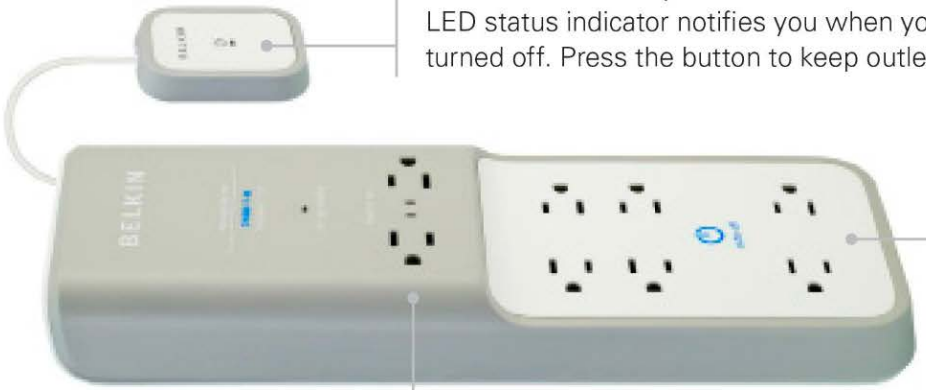
- 90% workstation
  10% kitchen/print room

Cost Effective

- Over $200,000 savings annually
- 1.7 year overall payback
  - Workstations
    2.6 years
  - Common Areas
    0.4 years

Image source: Comfy

Timer-Controlled APS Functionality



One-Touch Desktop Button

Use the Desktop Button to turn your Timed Outlets on and off. These outlets automatically turn off after 11 hours to save power. The blinking LED status indicator notifies you when your outlets are about to be turned off. Press the button to keep outlets on for another 11 hours.

6 Auto-Off Timed Outlets

Timed outlets automatically turn off after 11 hours. Use these outlets for devices that don't require constant power (24/7), such as laptop computers*, monitors, phone chargers, printers, and desk lights.

2 Always-On Outlets

Use these outlets for devices that require power at all times, such as desktop computers, phones and clocks.

Emerging Technologies' two programs — GSA Proving Ground (GPG) and
Pilot to Portfolio (P2P) — enable GSA to make sound investment decisions in next generation building technologies based on their real world performance

GPG-027

Honeycomb Solar Thermal Collector

General Services Administration
Public Buildings Service

GSA

GPG-027 | AUGUST 2016

HONEYCOMB SOLAR THERMAL COLLECTOR

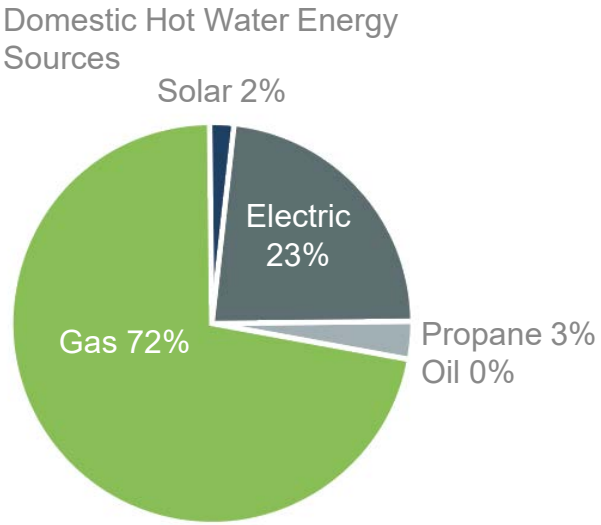
Cost-Effective for Facilities with Electric Water Heaters and Large Consistent Loads

The Energy Independence and Security Act of 2007 (EISA) requires new federal buildings and major renovations to meet 30% of their hot water demand with solar energy, provided it is cost-effective over the life of the system. In response to this mandate, GSA's GPG program commissioned the National Renewable Energy Laboratory (NREL) to assess a unique solar hot water (SHW) collector technology, the Honeycomb Solar Thermal Collector (HSTC). The HSTC uses a honeycomb insulating layer to minimize heat loss, making it particularly effective, manufacturers say, in cold climates, where many GSA facilities are located. The technology was installed at two test-bed locations, the Major General Emmett J. Bean Federal Center in Indianapolis, Indiana, and the GSA Regional Headquarters Building in Auburn, Washington. Researchers found that, for most domestic hot water applications in which mains water is heated by an array of solar collectors and stored in a tank, the HSTC technology was up to 8% more efficient

Requirement for Solar Hot Water

30% of Solar Hot Water Required–EISA 2007

- For new construction and major renovation. Provided it is cost-effective over the lifetime of the equipment. Technology life for SHW systems is typically 25 years.
- When the law was written, SHW was more cost effective than PV. Since then PV has dropped 80% in price and natural gas prices are 48% lower.[1]

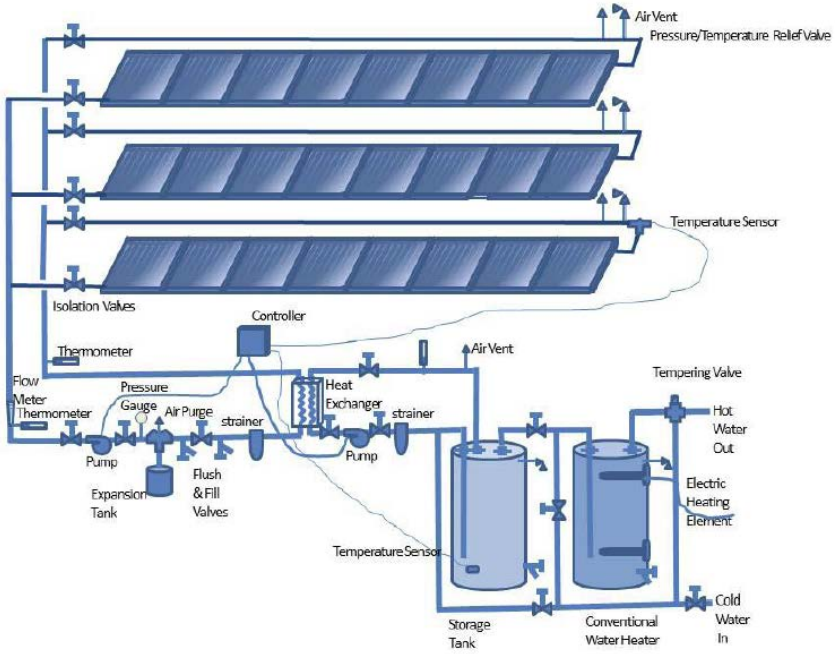


[1] Natural Gas per 1,000 cubic/ft 2007=$7.31; 2017 $3.52, https://www.eia.gov/dnav/ng/hist/n3045us3a.htm

How It Works

- The collector captures sunlight energy with solar panels and heat a fluid (sometimes but not always water).

- Heated fluid flows from the collector to a storage tank for use in service applications, space heating and cooling, and process heat.

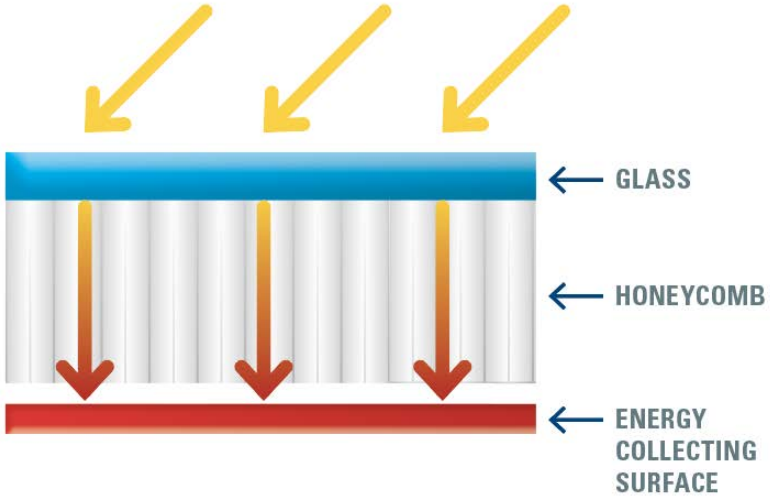


How HSTC Differs from Typical Flat-Plate Collectors

Claim of Higher Operating Efficiency in Cold Climates

MINIMIZES HEAT LOSS

Honeycomb insulating layer allows solar energy to enter the collector while reducing heat loss from the energy collecting surface



Measurement & Verification

Researchers Monitored Performance at Two Demonstration Sites in Cold Climates

Bean Federal Center, Indianapolis

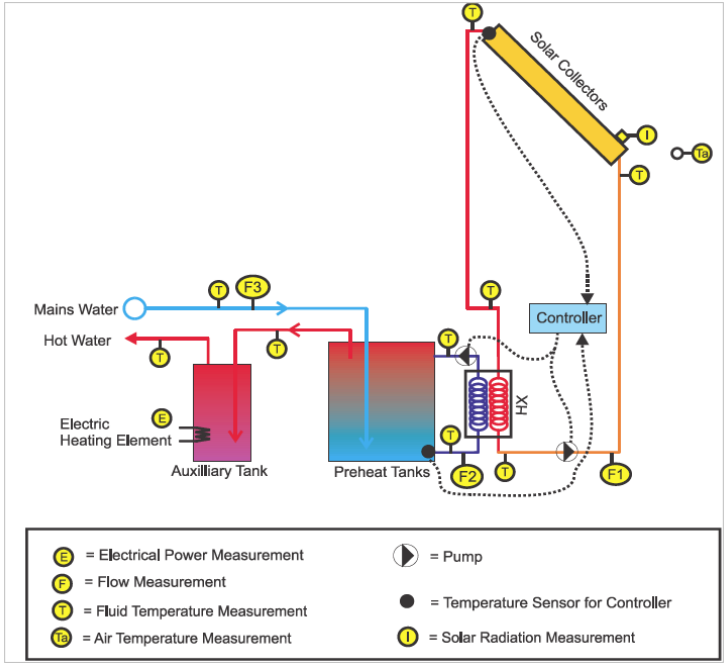
Cold winters, hot summers, average solar resource

GSA Regional Headquarters, Auburn

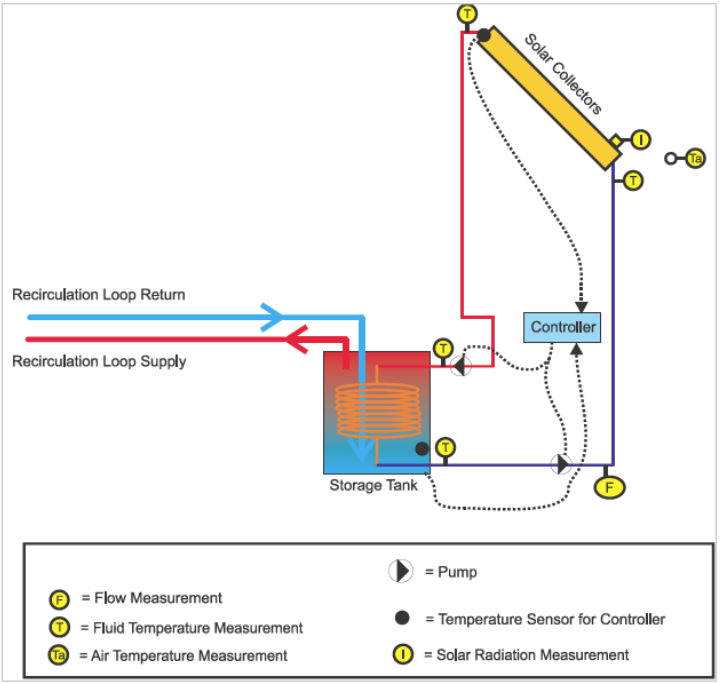
Mild winters and summers, low solar solar resource

Technology for test-bed measurement and verification provided by Tigi Solar

System Design



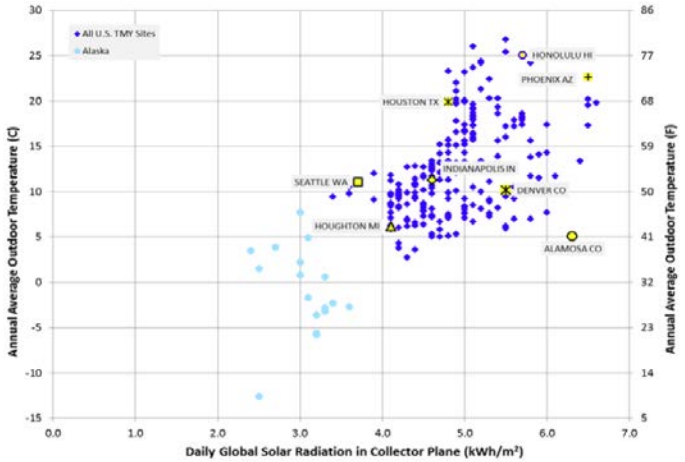
Bean Federal Center



Auburn Regional Headquarters

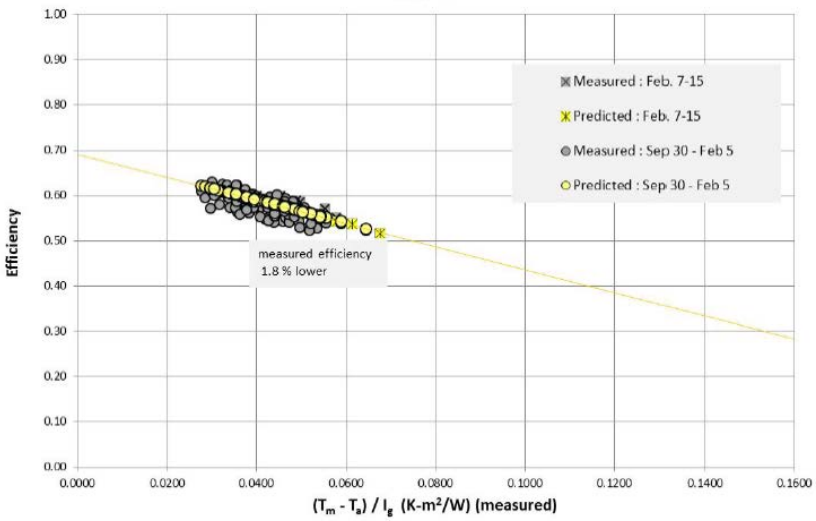
Performance Objectives

- Was collector performance within +/-10% of manufacturer's claims?
- What was efficiency compared to incumbent technologies?
- Did the overheat protection work as expected?
- What is the expected

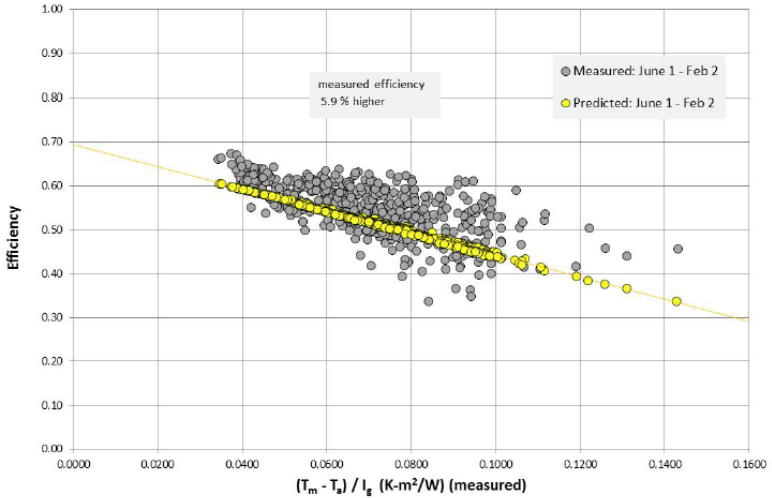


U.S. Locations Used in the Simulation Study

Measured Efficiencies Within 2% of Manufacturer's Estimate



Bean Federal Center
Comparison of Measured to Predicted Collector Array Efficiency

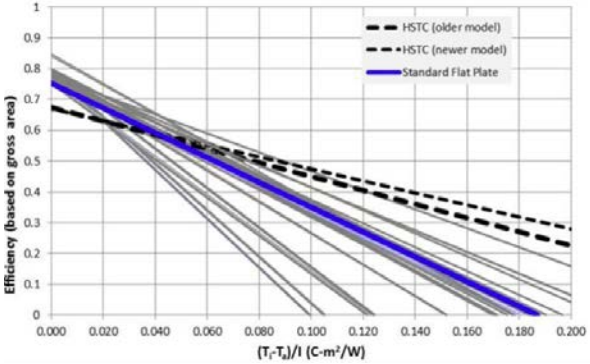


Auburn Regional Headquarters
Comparison of Measured to Predicted Collector Array Efficiency

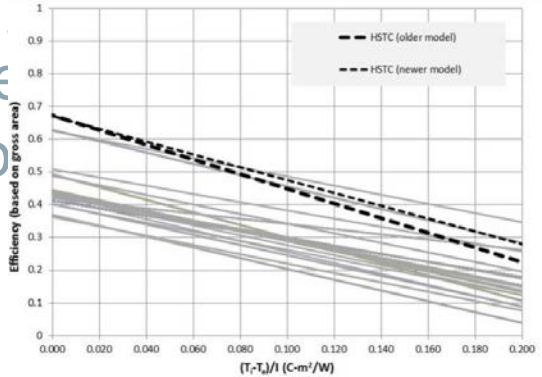
Comparable to Flat-Plate Collectors—Up to 8% Greater Efficien

Little difference between hot & cold climates when using a temporary storage tank.

Should outperform flat-plate in systems without a storage tank, particularly in cold climates. SHW age n b ve.



Flat-Plate Collectors



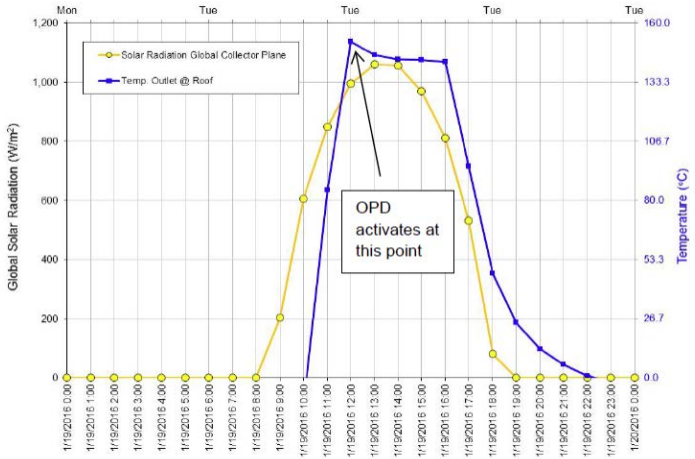
Evacuated Tube Collectors

Sample of Efficiency Curves from the SRCC Database

Overheating Protection Worked

Maximum Stagnation Temperature of 152°C (306°F)

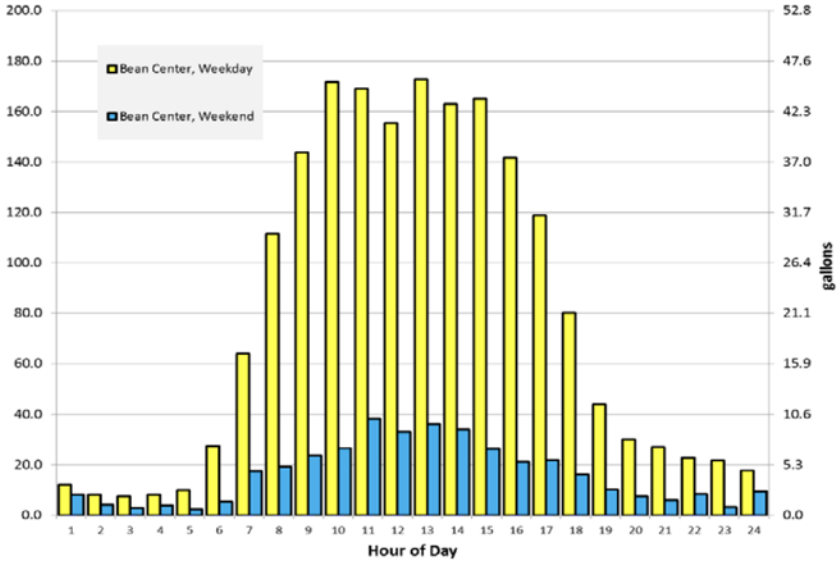
HSTC OPD might decrease SHW maintena costs
over its lifetime.



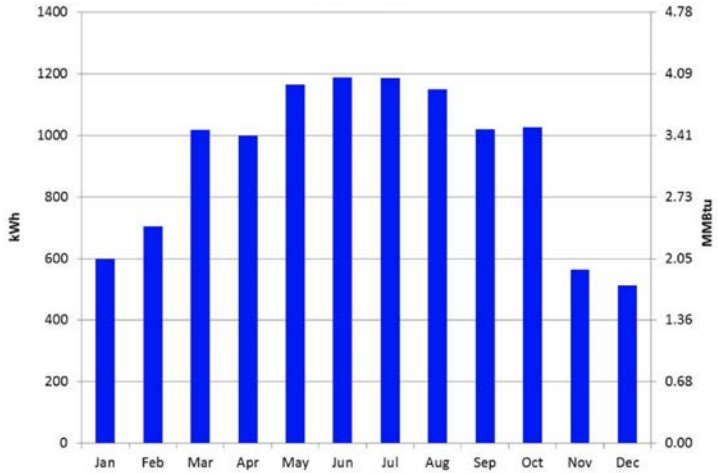
Measured Stagnation Temperature During a Clear Day in January. Outdoor Temperature Was About -9°C (16°F).

Energy Savings—Bean Federal Center

11,100 kWh/year



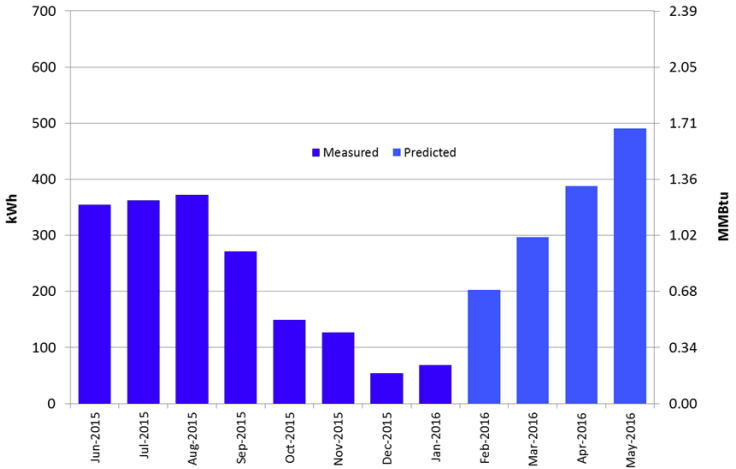
Weekday and Weekend Hot Water Usage



Monthly Electrical Energy Savings

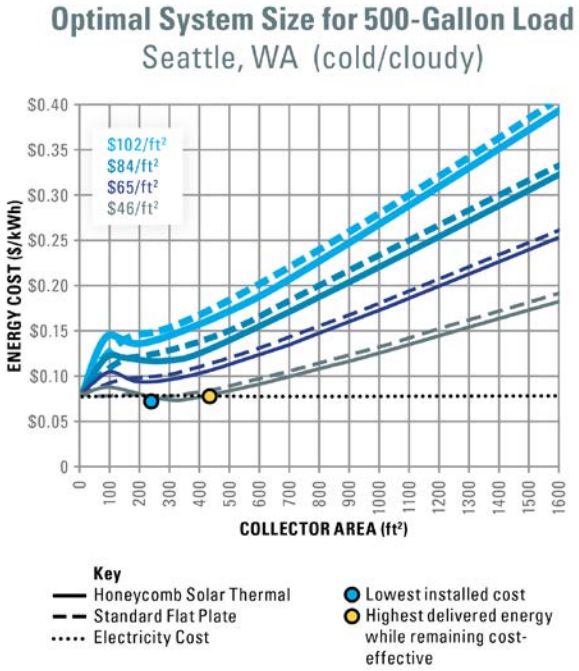
Energy Savings—Auburn Regional Headquarters

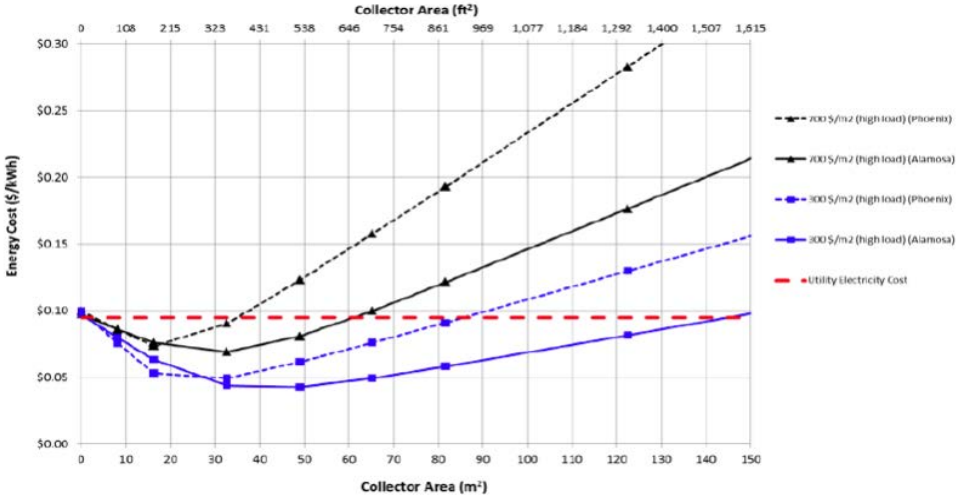
3,155 kWh/year



Monthly Electrical Energy Savings

Climate Important to Cost Savings and System Sizing





Delivered Energy Cost for Two Very Sunny Climates, One Very Hot (Phoenix, AZ) and One Very Cold (Alamosa, CO), With Similar Unit Energy Costs

Large Loads are Critical for Positive ROI

Positive ROI With Electric Reheat, 500-Gallon Weekday Load and 46/ft^2 Installed Cost

City	Hot Water Load (gal/day)	System Unit Cost ($/ft^2)	Collector Area (ft^2)	Solar Fraction*	Annual Energy Savings (kWh/yr)	Payback (years)	SIR
Seattle, WA cold/cloudy annual solar radiation 5.0 gigajoule/m^2/yr	125	$102	88	0.44	3,154	40.0	0.26
	500	$102	175	0.32	8,937	26.8	0.56
	500	$46	175	0.32	8,937	13.0	1.15
Indianapolis, IN cold/partly cloudy annual solar radiation 5.9 gigajoule/m^2/yr	125	$102	88	0.51	3,638	29.0	0.42
	500	$102	175	0.38	10,448	19.2	0.81
	500	$46	175	0.38	10,448	9.3	1.68
Denver, CO cold/sunny annual solar radiation 6.8 gigajoule/m^2/yr	125	$102	88	0.60	4,291	24.5	0.54
	500	$102	175	0.44	12,343	16.2	0.98
	500	$46	175	0.44	12,343	7.8	2.03
Phoenix, AZ warm/sunny annual solar radiation 8.5 gigajoule/m^2/yr	125	$102	88	0.54	2,757	21.4	0.50
	500	$102	175	0.71	13,556	15.0	1.06
	500	$46	175	0.71	13,556	7.3	2.20

Collector cost is only 20% of installed system cost, a more expensive collector has a relatively small impact on overall costs.

Guidelines for Deployment

- Implement Efficiency First Applicable water conservation and energy efficiency opportunities should be implemented before sizing a solar thermal system.
- Use Accurate System Design Tools to Optimize Cost Effectiveness Using the approach outlined in NREL's report to determine system design, a detailed sub-hourly simulation program should be used and the system should be modeled accurately with SRCC-rated solar thermal panel performance data. Life-cycle cost, rather than efficiency, should drive system selection.
- Use a Trained Solar Hot Water Installer There are several unique features of SHW systems with which experienced plumbers may not be familiar, such as calculating the required pressure of collector fluid to avoid boiling under stagnation conditions.

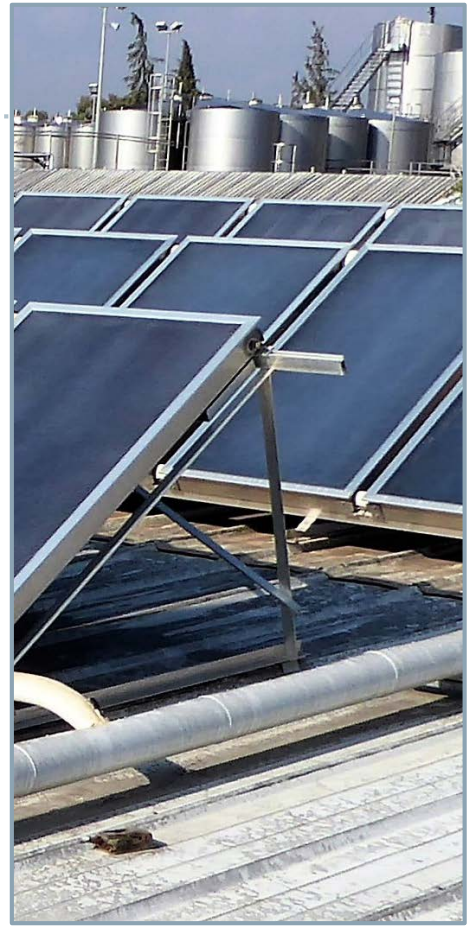
Target Locations

- Large, Consistent Weekday Hot Water Loads The larger the load being offset, the more cost-effective the system (facilities with workout facilities, kitchens, laundry).
- Central Hot Water Systems Facilities with centralized domestic hot water systems should be targeted for SHW. Facilities with small de-centralized point-of use domestic hot water systems are not suitable for solar thermal installations.
- Roof Availability Facilities with roofs that won't need to be replaced for 20 to 25 years, have sufficient space available to accommodate an SHW system, and won't need expensive structural modifications to carry the increased load.
- High Solar Resource Sunny locations are more cost-effective.
- High Energy Costs The unit cost of electricity ($/kWh) is seven times

Deployment

Consider for Facilities with Electric Water Heaters and Large, Consistent Loads

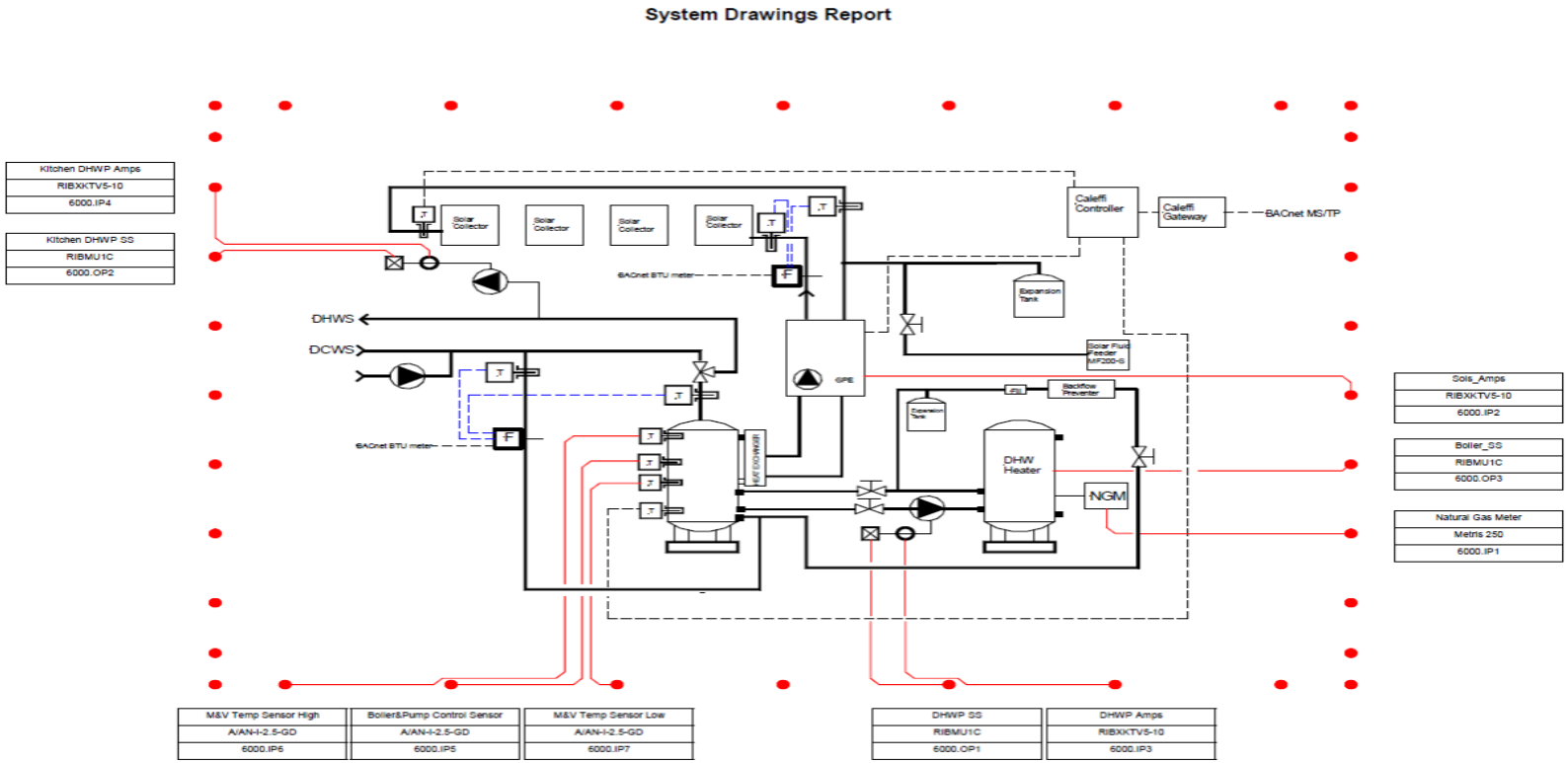
- Natural gas prices in the U.S. are generally too low to make SHW cost-effective.
- Life-cycle cost, rather than efficiency, should drive system selection.



GSA Regional Headquarters, Auburn

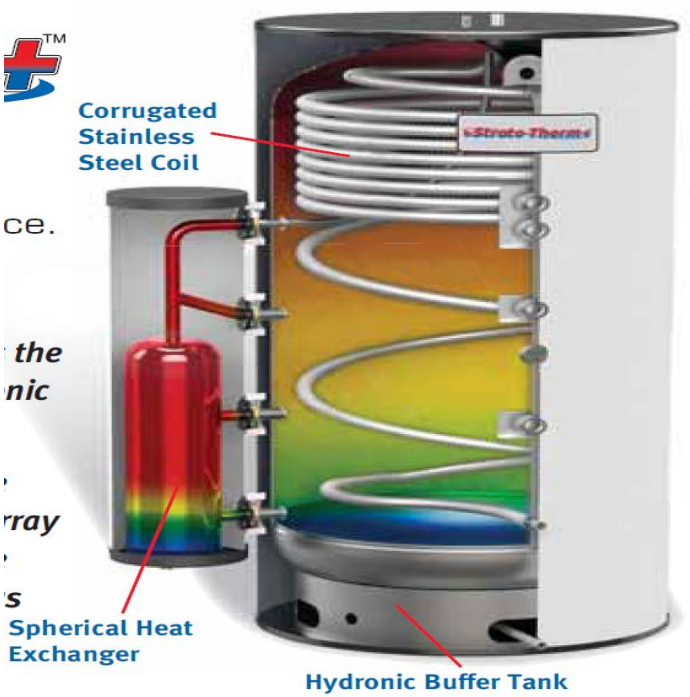
- Installed as design build
- The mechanical system installer engaged a solar expert for this installation
- A year after the installation was completed, our cafe was closed, which impacted the payback
- Works well in summer, but has limited application in winter

Process and Instrumentation Drawing



Solar Controller

Thermal Storage Tank



Bean Federal Center

Not currently operating, need to consult with a local solar thermal system installer and re-examine:

1. Concentration of glycol (antifreeze)
2. Set point of pressure relief valve
3. Pressure of fluid in system

Bean Federal Center—Preliminary Recommendations

- Change from 30% to 50% antifreeze
- Increase system pressure from 15 psi to 78 psi in the mechanical room (70 psi at the roof)

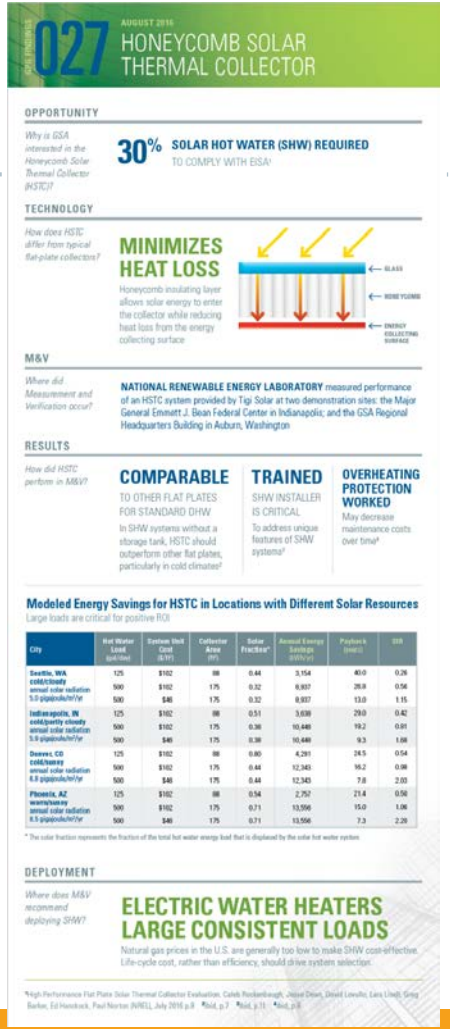
Note: desired pressure estimates on the roof but pressure is being measured in the mechanical room, 2 floors down, pressure change is 0.4 psi per foot.

Assigning Pressure

Concentration Propylene Glycol (%)	Gauge Pressure (psi)	Boiling Temperature (deg F)	Freezing Temperature (deg F)	
50%	34.8	292.0°	-23.2°	
50%	39.2	297.3°	-23.2°	
50%	43.5	302.2°	-23.2°	min. pressure = 47.9 psi
50%	47.9	306.7°	-23.2°	
50%	52.2	311.0°	-23.2°	
50%	56.6	315.0°	-23.2°	
50%	60.9	318.8°	-23.2°	
50%	65.3	322.4°	-23.2°	recommended = 69.6 psi
50%	69.6	325.8°	-23.2°	
50%	74.0	329.0°	-23.2°	
50%	78.3	332.1°	-23.2°	
50%	82.7	335.0°	-23.2°	
50%	87.0	337.8°		

Going Forward

- AE firm to talk with report authors.
- Emerging Technologies to provide support for operations.



AUGUST 2016

027 HONEYCOMB SOLAR THERMAL COLLECTOR

OPPORTUNITY

Why is GSA interested in the Honeycomb Solar Thermal Collector (HSTC)?

30% SOLAR HOT WATER (SHW) REQUIRED TO COMPLY WITH EISA[1]

TECHNOLOGY

How does HSTC differ from typical flat-plate collectors?

MINIMIZES HEAT LOSS

Honeycomb insulating layer allows solar energy to enter the collector while reducing heat loss from the energy collecting surface

M&V

Where did Measurement and Verification occur?

NATIONAL RENEWABLE ENERGY LABORATORY measured performance of an HSTC system provided by Tigi Solar at two demonstration sites: the Major General Emmett J. Bean Federal Center in Indianapolis; and the GSA Regional Headquarters Building in Auburn, Washington

RESULTS

How did HSTC perform in M&V?

COMPARABLE TO OTHER FLAT PLATES FOR STANDARD DHW

In SHW systems without a storage tank, HSTC should outperform other flat plates, particularly in cold climates[2]

TRAINED SHW INSTALLER IS CRITICAL

To address unique features of SHW systems[3]

OVERHEATING PROTECTION WORKED

May decrease maintenance costs over time[4]

Modeled Energy Savings for HSTC in Locations with Different Solar Resources

Large loads are critical for positive ROI

City	Hot Water Load (gal/day)	System Unit Cost ($/ft²)	Collector Area (ft²)	Solar Fraction*	Annual Energy Savings (kWh/yr)	Payback (years)	ROI
Seattle, WA cold/cloudy annual solar radiation 5.0 gigajoule/m²/yr	125	$102	80	0.44	3,154	40.0	0.26
	500	$102	175	0.32	8,937	20.0	0.56
	500	$46	175	0.32	8,937	13.0	1.15
Indianapolis, IN cold/partly cloudy annual solar radiation 5.0 gigajoule/m²/yr	125	$102	80	0.51	3,638	29.0	0.42
	500	$102	175	0.38	10,446	19.2	0.91
	500	$46	175	0.38	10,446	9.3	1.88
Denver, CO cold/sunny annual solar radiation 6.0 gigajoule/m²/yr	125	$102	80	0.60	4,291	24.5	0.54
	500	$102	175	0.44	12,343	16.2	0.99
	500	$46	175	0.44	12,343	7.8	2.00
Phoenix, AZ warm/sunny annual solar radiation 6.5 gigajoule/m²/yr	125	$102	80	0.54	2,757	21.4	0.56
	500	$102	175	0.71	13,556	15.0	1.06
	500	$46	175	0.71	13,556	7.3	2.29

* The solar fraction represents the fraction of the total hot water energy load that is displaced by the solar hot water system.

DEPLOYMENT

Where does M&V recommend deploying SHW?

ELECTRIC WATER HEATERS LARGE CONSISTENT LOADS

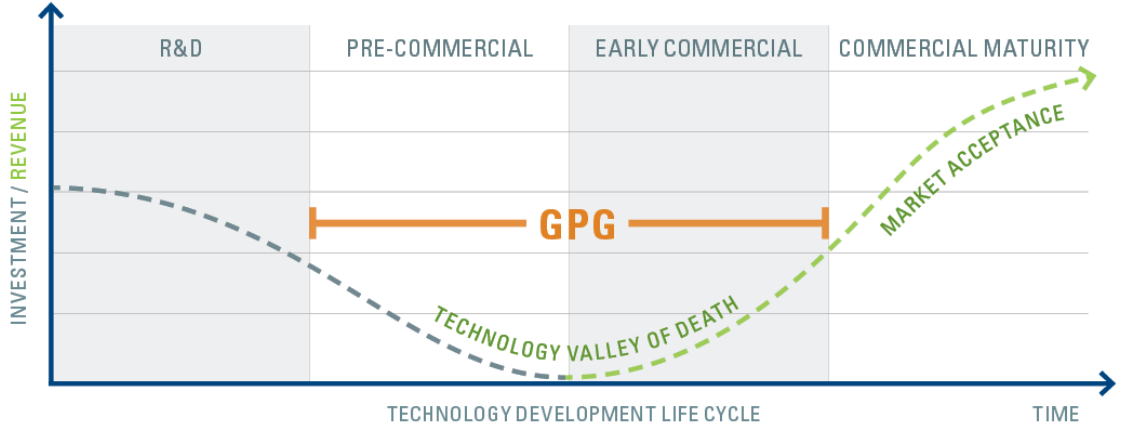
Natural gas prices in the U.S. are generally too low to make SHW cost-effective. Life-cycle cost, rather than efficiency, should drive system selection.

[1] High Performance Flat Plate Solar Thermal Collector Evaluation, Caleb Rockenbaugh, Jesse Dean, David Lovullo, Lars Lindl, Greg Barker, Ed Hancock, Paul Norton (NREL, July 2016, p.8 [2] Ibid, p.7 [3] Ibid, p.11 [4] Ibid, p.8

Emerging Technologies' two programs — GSA Proving Ground (GPG) and
Pilot to Portfolio (P2P) — enable GSA to make sound investment decisions in next generation building technologies based on their real world performance

Leading by Example

GSA's Proving Ground accelerates market acceptance by objectively assessing innovative building technologies in real-world environments, and deploying those that deliver. To date, GSA has installed 9 technologies across more than 200 buildings. In aggregate, these technologies are delivering $7.4 Million in annual O&M savings



GPG Process

Identify promising technologies at the edge of commercialization

Pilot technology installations within GSA's real estate portfolio

Partner with Department of Energy national laboratories to objectively evaluate real-world performance

Recommend technologies with broad deployment potential for GSA

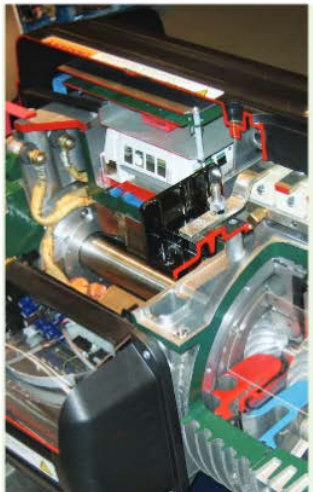
GPG-009

Variable Speed Magnetic Bearing Chiller

GSA Public Buildings Service

GPG-009 | OCTOBER 2013

MAGNETIC LEVITATION CHILLER COMPRESSOR



Magnetic Levitation Chiller Compressor Reduces Space Cooling Energy Consumption

In the U.S., space cooling accounts for 9.6% of energy consumption in office buildings. Because space cooling is primarily driven by electricity—a higher cost energy source—it can account for an even greater percentage of a facility's annual energy bill.[1] Chillers, used frequently in larger facilities, provide cooling in 31% of office building floor space within U.S. commercial buildings.[2]

GSA's Green Proving Ground (GPG) recently evaluated the effect of new, more efficient chiller compressor technology on energy cost and consumption by assessing a magnetic levitation ("maglev") chiller compressor at the George Howard, Jr. Federal Building and U.S. Courthouse in Pine Bluff, Arkansas. This new chiller compressor technology offers quieter, more efficient cooling at lower partial loads than positive displacement chillers, due to its ability to reduce friction, operate at variable speeds,

Opportunity

10%

OF ENERGY

GOES TO SPACE COOLING

32%

OF COMMERCIAL BUILDINGS

RELY ON CHILLERS TO PROVIDE THIS COOLING

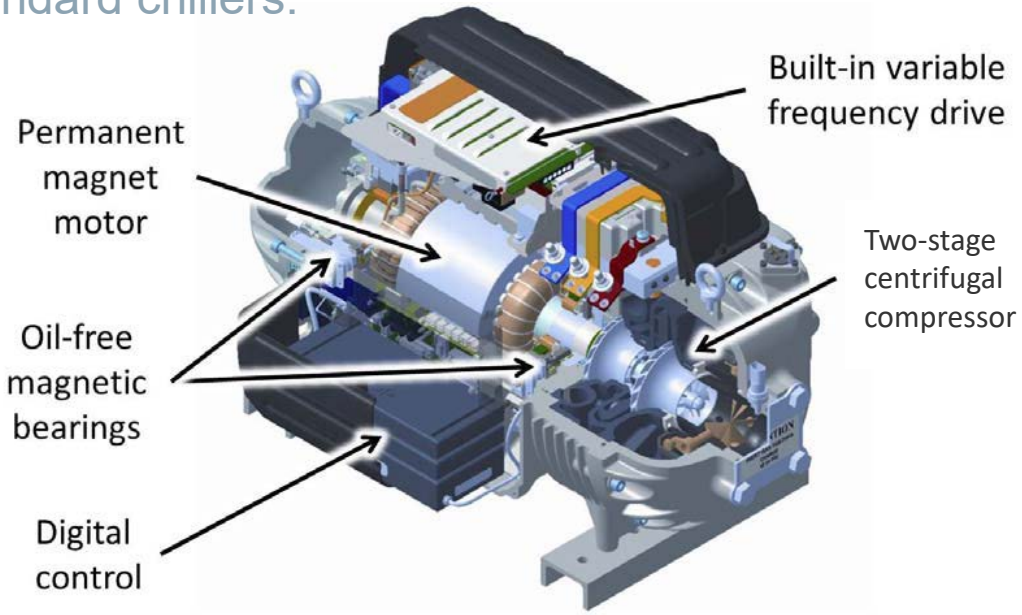
GSA Opportunity

GSA FLOOR SPACE	BUILDINGS >100,000 SF
 Large Buildings	Most Use Water-Cooled Chillers

GPG-009. Variable Speed Magnetic Bearing Chiller

Improves Efficiency when Operating Under Small and Partial Loads

Uses magnetic levitation to eliminate heat, noise and vibration associated with standard chillers.

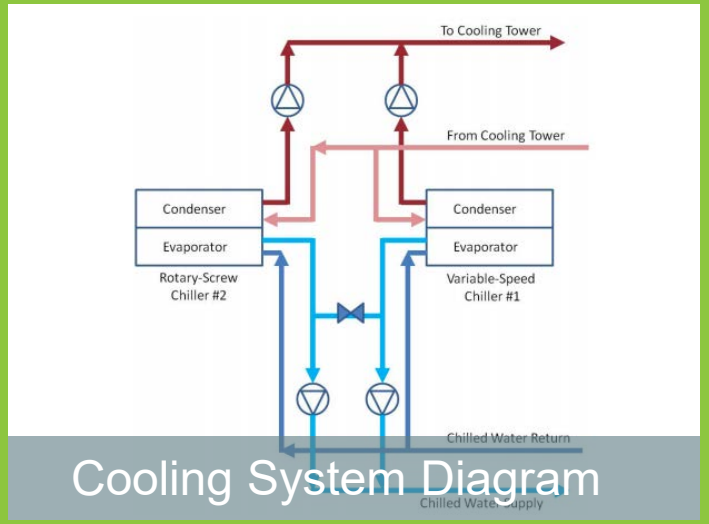


Measurement & Verification

Experts monitored performance of old and new chillers over a six-month period

George Howard, Jr. Federal Building—a four-story, 108,000 square foot courthouse and office building

George Howard Jr. Federal Building



Cooling System Diagram

Basecase at the George Howard Federal Building, Pine Bluff AR

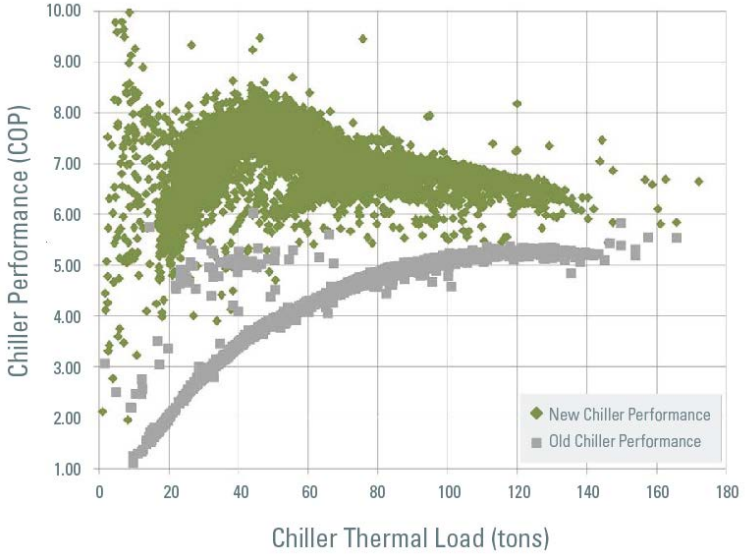
- 150-ton rotary-screw chiller installed in 1993 (Before variable-speed chillers, smaller chillers needed to be rotary screw)
- Rotary-screw compressor used R-22 refrigerant; MBC used R-134A.

Description	Original Chiller	New Chiller
Nominal Capacity	150-tons cooling	150-tons cooling
Minimum Circuit Rating	460-volt, 185-amp, 3-phase	460-volt, 166-amp, 3-phase
Maximum Circuit Rating	480-volt, 300-amp, 3-phase	480-volt, 225-amp, 3-phase
Compressor Rating	1 unit 460 volt 148 run-load amps (RLA)	2 units 460 volt 72 RLA (each)
Oil Tank Heater	2 units 115 volts 2 RLA	Not applicable
Refrigerant	R-22 330 pounds	R-134A 531 pounds
Oil	35 pints	Not applicable

Efficiency of Magnetic Bearing Chiller (MBC) Increases at Low

MBC chiller efficiency is highest at low loads (27 to 33% of nominal full load)

Incumbent chiller efficiency continuously decreases as



42%

ENERGY SAVINGS

AS COOLING LOADS DECREASE, EFFICIENCY INCREASES

Cost-Effectiveness

$9,097 energy cost reduction per year

at the George Howard Jr. Federal Building @ $0.073/kWh

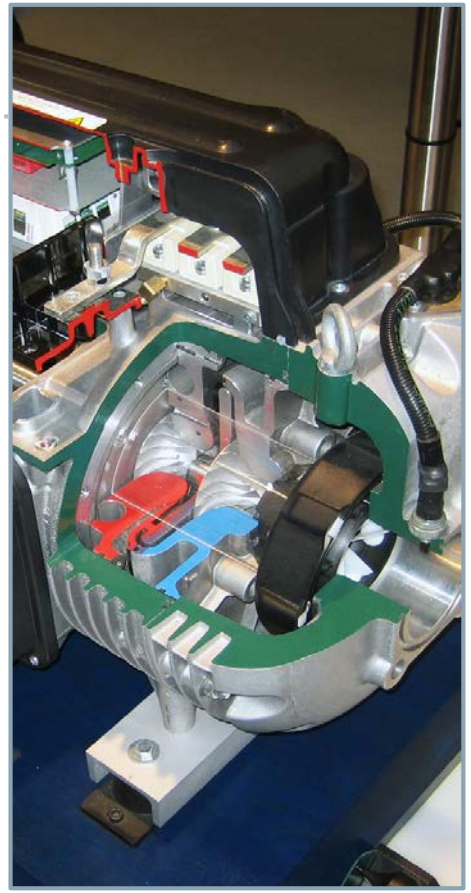
Less than 5 year incremental payback

at end-of-life replacement after normalizing for payment structure & utility costs
and as compared to new FEMP-designated rotary screw chiller

Operations & Maintenance

Magnetic bearing compressor benefits:

- Smaller and lighter than similar capacity compressors.
- Quiet, frictionless chillers placed closer to occupant spaces.
- More efficient cooling at lower partial loads.



Additional GSA Deployments MBC Chiller

R1: 4 deployed
R2: 6 deployed
R4: 46 deployed
R5: 50 deployed
R6: 20 deployed
R7: 68 deployed, 4 pending
R8: 1 deployed, 3 pending
R9: 5 deployed
R10: 6 deployed
NCR: 4 deployed
210 total

GSA Region 7 Experience

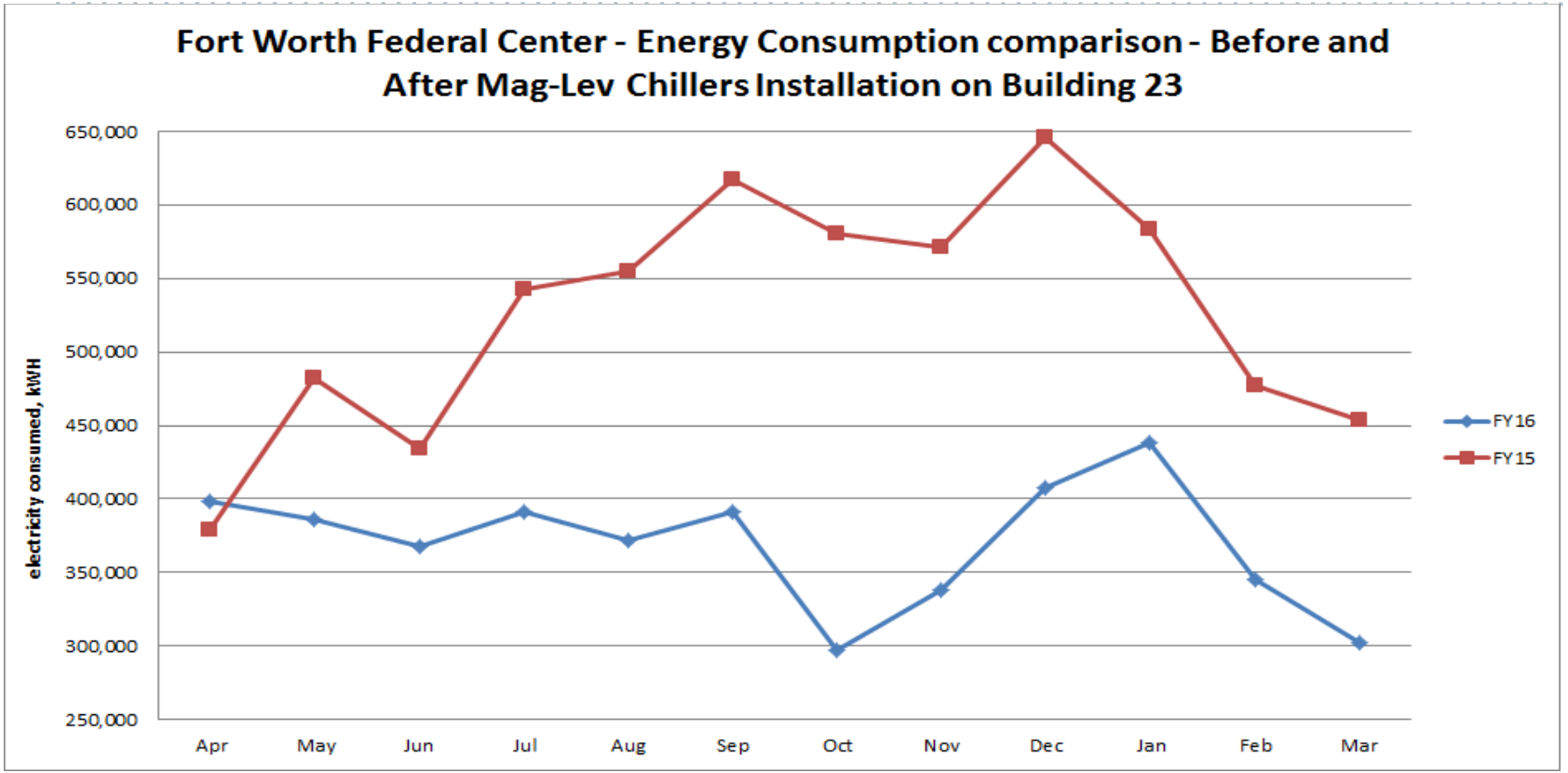
⅓ of R7 Chiller Inventory is MBC

- Range of tonnage
  - From 60-ton with 1 compressor to 750-ton with 4 compressors
  - Majority water-cooled, a few air-cooled
- IPLV values (in kW/tons) for water-cooled MBC typically range from 0.3 to 0.35
- Recommended IPLV values of various water-cooled chillers
  - Rotary screw (greater than 150 tons) - 0.49 or less
  - Centrifugal (150-299 tons) - 0.52 or less
  - Centrifugal (300-2000 tons) - 0.45 or less

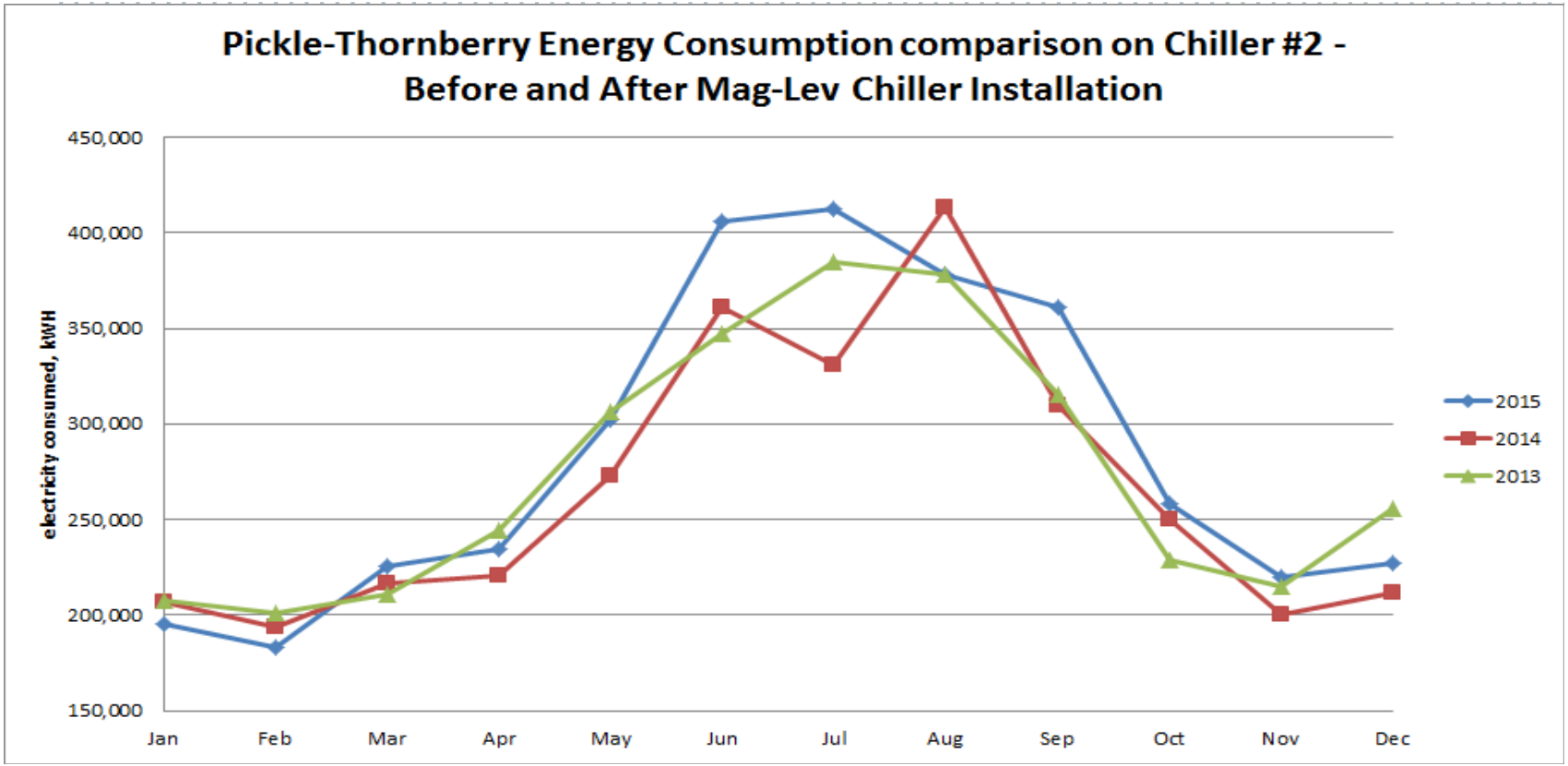
Lessons Learned

- MBC chiller needs to be operated differently, most efficient at lower partial loads, stage chillers to get maximum efficiency.
- Essential that O&M contractor is trained.
- In most cases, chiller-replacement projects are incentive-eligible

Examples from the Field — Whole Building Energy Use



Examples from the Field : Whole Building Energy Use



GPG-031 Variable-Speed Direct-Drive Screw Chiller

General Services Administration
Public Buildings Service

GSA

GPG-031 | JANUARY 2017

VARIABLE-SPEED DIRECT-DRIVE SCREW CHILLER

Variable-Speed Screw Chiller Delivers Energy Savings Across a Wide Range of Operating Conditions

Over the past 15 years, chillers have become more efficient, more flexible and easier to operate. Most contemporary chillers will outperform the late 20th century models they are replacing, but there are significant differences to consider among chillers now on the market. The Green Proving Ground program, in collaboration with researchers from Oak Ridge National Laboratory, evaluated the most recent development in chiller technology, the variable-speed direct-drive screw (VSS) chiller, alongside the current state-of-the art chiller technology, the variable-speed magnetic levitation (maglev) chiller.[1] The test bed design at the Sidney R. Yates Building in Washington, D.C. connected both chillers to the same chilled water and condenser water loops, creating operating conditions as close to identical as possible within a real-world environment. Measurement and verification from the Yates Building showed that the VSS further raised the bar on chiller performance, consuming 11% less

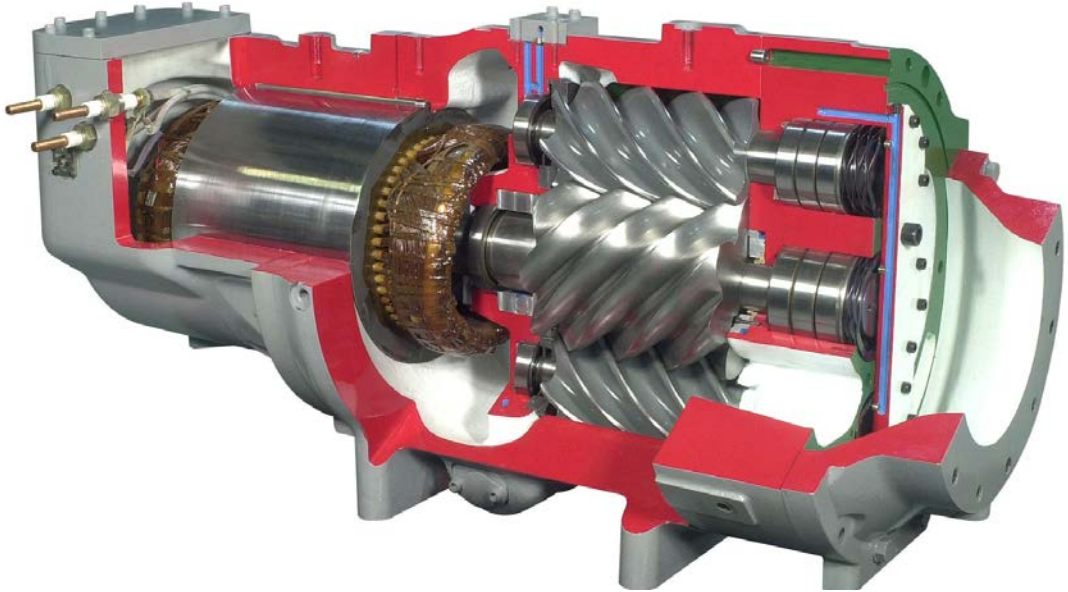
Report Reissued after Third-Party Review

- Report originally released in December 2016. In February 2017 Daikin (MBC Vendor) and Danfoss (OEM of MBC compressor) submitted letters raising concern about the accuracy of the published findings.
- GPG commissioned both internal and third-party review to validate the substance of these concerns. As an outcome of this review, language in the report has been clarified to better characterize test bed design, chiller selection, and measurement uncertainty. The report's substance and overall

GPG-031. Variable-Speed Direct-Drive Chiller

Capacity Controlled by Motor Speed Alone

Three screw rotors and a variable-speed motor are the only major moving parts.



Measurement & Verification

Both Connected to the Same Chilled and Condenser Water Loops

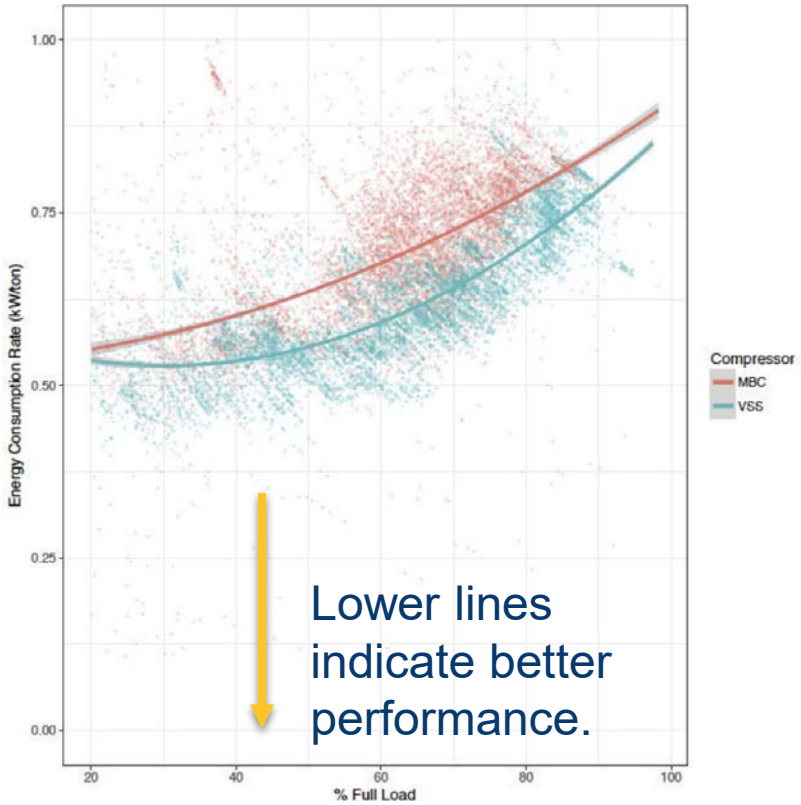
Real-world operating conditions as identical as possible in the Sidney R. Yates Building, Washington, D.C.

Carrier VSS

Daikin MBC

Technology for test-bed measurement and verification provided by Carrier and Daikin/Danfoss

Chiller Energy Use

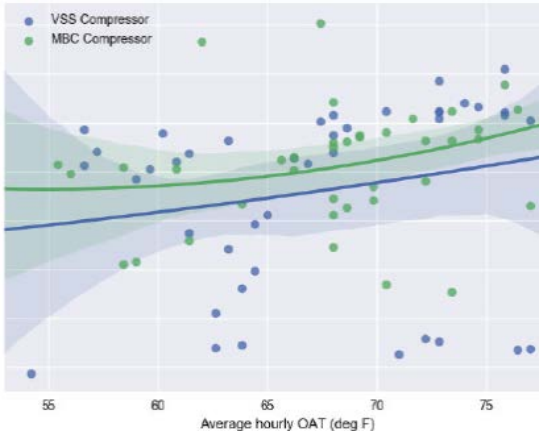


Chillers Have Comparable Energy Use

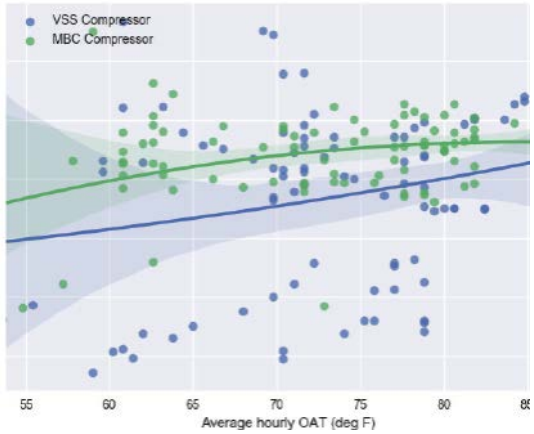
VSS 11% Lower Energy Consumption Rate at Test Bed

Savings could range from +24% to -4% due to measurement uncertainty

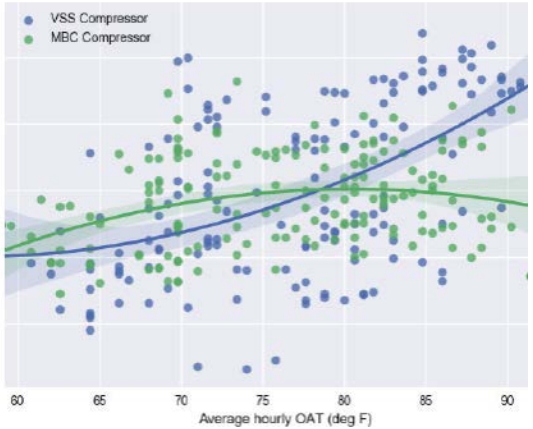
Average hourly —energy consumption vs outside air temperature



Energy consumed (in kilowatt-hours) per hour when condenser EWT is between **67.5°F and 72.5°F**



Energy consumed (in kilowatt-hours) per hour when condenser EWT is between **72.5°F and 77.5°F**



Energy consumed (in kilowatt-hours) per hour when condenser EWT is between **77.5°F and 82.5°F**

Operating Conditions

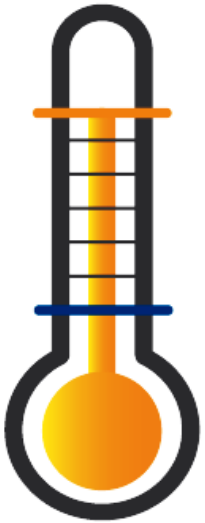
VSS able to handle swings in condenser water temperature outside the design parameters

Vendor states that MBC can be built to accept wider range of temperatures

VSS Entering Condenser Water Temperatures

July 2016, 95°

March 2016, 55°



Noise Ratings

78–83 Decibels for Both VSS and MBC

Sound level comparable to a vacuum cleaner, conversation is possible in the mechanical room.

VSS Load	DBA
100	83
75	83
50	77
25	77

MBC Load	DBA
100	83.5
75	82.5
50	81
25	77

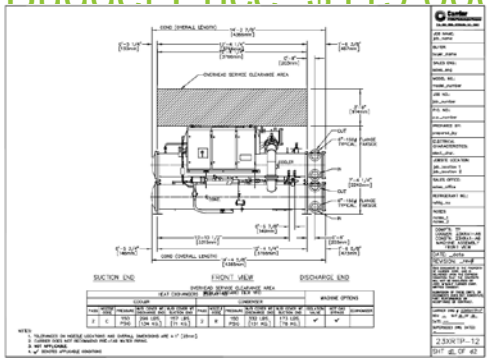
Yates Test Bed – 275 Ton Load Specified

VSS
275 ton chiller

14.4 ft length

18,857 lbs.

Budget Price: $119,000[1]



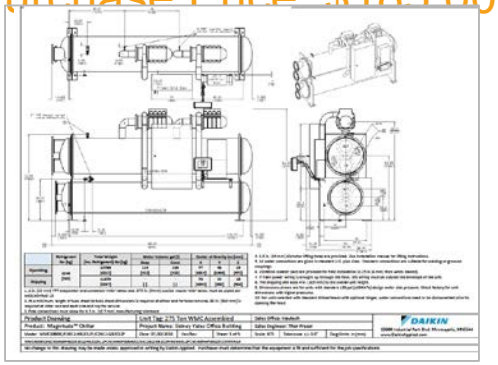
[1]Budget price was verified by using a third-party to “ghost shop” the vendor.

MBC
400 ton shell/2-200 ton compressors[2]

14.1 ft length

13,800 lbs.

Purchase Price: $185,000



[2]During design phase, vendor confirmed that this configuration was “selected for the most efficient” at a 275-ton capacity.

Deployment Opportunity

Consider VSS and MBC for End-of-Life Replacement for Water-Cooled Chillers

While VSS and MBC both provide improved operating performance compared to chillers meeting minimum FEMP performance criteria, the VSS chiller's ability to tolerate swings in condenser water temperature make it more robust and especially attractive for mission critical applications like data centers.

Facility Manager Feedback - Yates Test Bed

Thumbs Up to Both Chillers

- VSS runs more in shoulder season accepts lower condenser water temperatures — 55°F for VSS, 65°F for MBC.
- You can shut down one of the compressors on the MBC.
- VSS chiller is a little noisier at low loads.

Facility Manager Feedback - Yates Test Bed

VSS Best for Our Unique Set-Up

- Cooling tower sump is 25-feet in the ground with no heater.

BEST PRACTICES

Best Practices for Chillers

Chiller Plant Design and Commissioning

Employ a mechanical engineer to do a thorough economic and technical analysis for all facets of the chiller plant design. Consider the control optimization system for chiller plants that GPG evaluated in September 2016 (GPG #028) in the chiller plant analysis.

Peak Cooling Load

When replacing an old chiller, perform a new heat gain/loss calculation to size the new chiller correctly.

Best Practices for Chillers

Cooling Load Profile

If the building spends most of the time at partial loads, prioritize the energy consumption rate (kW/ton) at part load. If a facility operates 24/7/365 with a fairly high and constant internal load focus on a chiller's efficiency at maximum

Load	VSS Rated kW/ton	MBC Rated kW/ton
100	0.615	0.543
75	0.414	0.412
50	0.278	0.295
25	0.303	0.265

Best Practices for Chillers

Condenser Water Supply Temperature

Centrifugal compressors are custom designed to meet site-specific condenser water temperatures. For effective performance of MBC centrifugal chillers, water temperature must be considered during design.

The variable-speed screw compressor is a universal design; the same compressor can be used in Phoenix, AZ or Fargo, ND.

Best Practices for Chillers

Local Electricity Rate Structure

Look at both consumption and demand charges. If demand charges are high, thermal storage or some other method of load shifting might be a cost-effective part of a new chiller plant design.

Chiller Manufacturer Presence

When choosing a chiller, consider whether or not the manufacturer operates in your locale. Some manufacturers might be able to provide better service because of having a stronger local presence.