Sector Focus:

Solar Hot Water Technologies for Higher Education Buildings

Renewable Heating & Cooling Webinar Series

U.S. Environmental Protection Agency

October 25, 2012

Agenda

1:00 – 1:10 pm	**Welcome**
1:10 – 1:25 pm	**Chris Beebe, BEAM Engineering** *Overview: Solar Hot Water Opportunities*
1:25 – 1:40 pm	**Doug Spengel, George Washington University** **Mark Ellis, George Washington University** *Residence Hall Projects*
1:40 – 2:05 pm	**Chris O'Brien, American University** *Residence and Dining Hall Projects*
2:05 – 2:15 pm	**Question & Answer Session**

Speaker

Chris Beebe

Chief Executive Officer

cbeebe@beamgrp.com

BEAM Engineering

BEAM Engineering is a Boston-based consulting firm specializing in delivering renewable energy technologies to market through policy and program advancement, project engineering, and industry engagement.

Chris brings an extensive and diverse knowledge base to the solar thermal heating and cooling community with experience in Mass., Calif., and New York.

Chris is a licensed Professional Engineer (PE), a LEED AP, and a Certified Energy Manager (CEM). He received his MSME and BSME in Mechanical Engineering from the University of Massachusetts - Amherst.

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Solar Heating and Cooling: Higher Education Facilities

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Chris Beebe, PE

cbeebe@beamgrp.com

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Outline

1. Solar Heating Overview
2. Higher Education Applications
3. Critical Design Considerations
4. Energy Savings and Financial Analysis
5. Evaluating Performance

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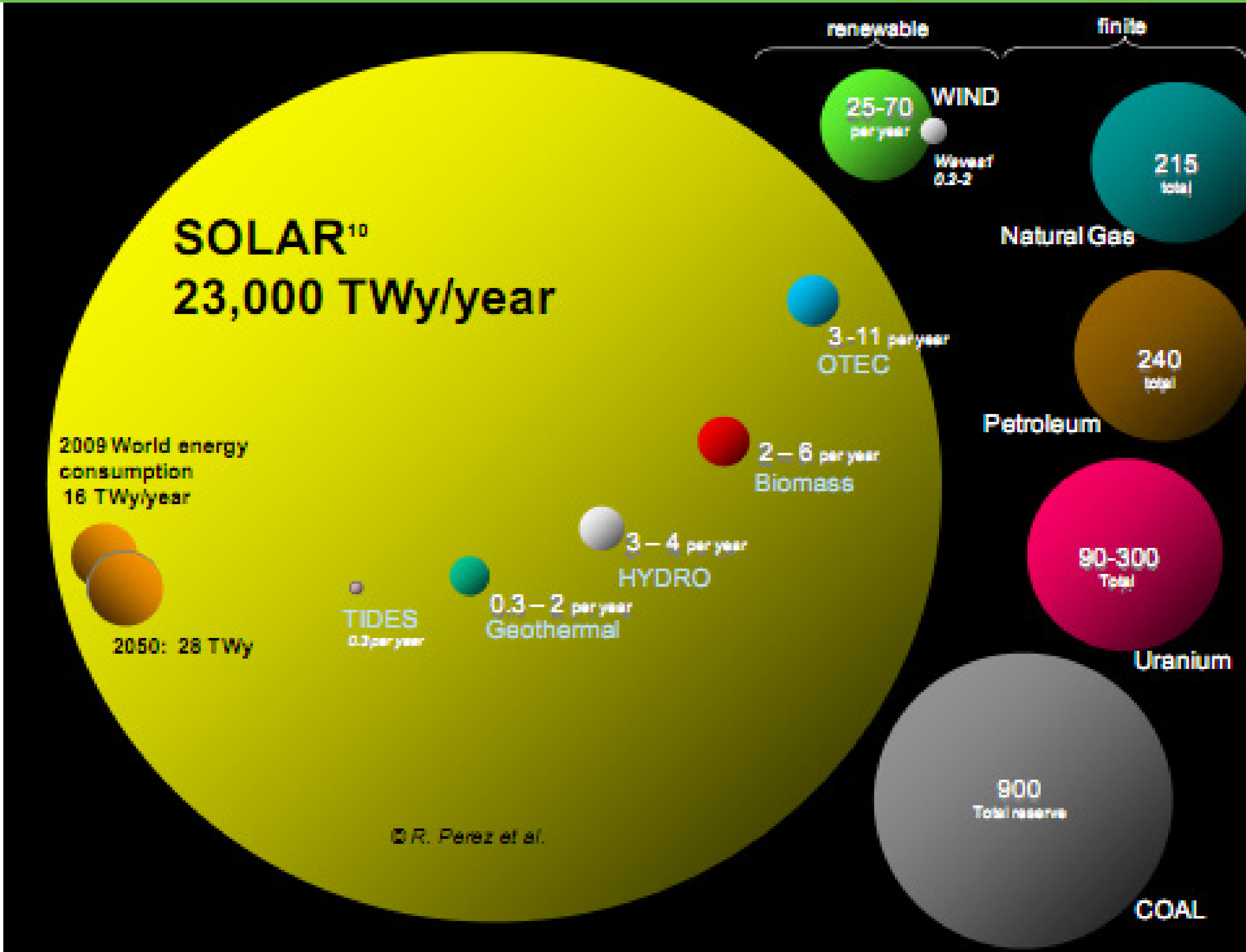
Solar Heating Overview

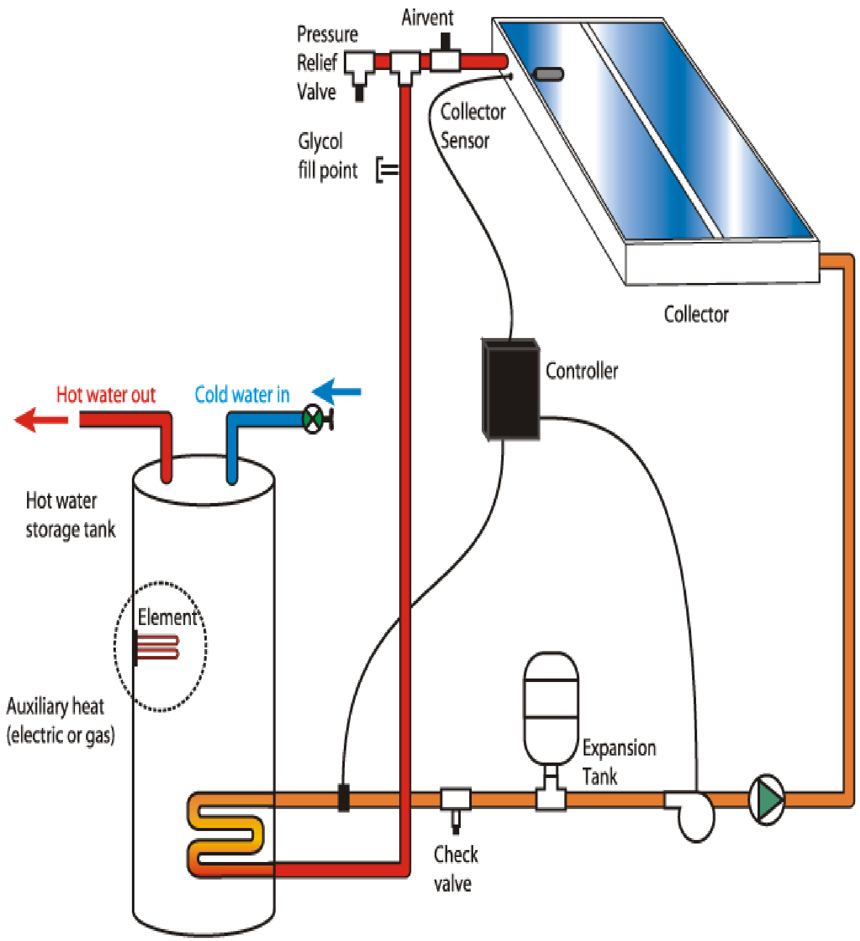
Solar Fuel Resource

- TW = Terawatt = 10^{12} watts
- Total power used by humans world wide in 2006 was 16 TW[2]
- 500,000 Btu/ft2/yr



Overview

- Collector
- Storage tank
- Pumps, Piping, Valves
- Heat exchangers
- Control Unit
- Freeze Protection
- Stagnation Protection
- Auxiliary Heat Source
- Monitoring Unit



Higher Education Applications

- Domestic Hot Water (DHW)
- Central Plant / Boiler Makeup Water
- Pool Heating
- Process Water Heating (Labs)
- Air Heating
- Solar Assisted Cooling (Absorption Chiller)

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Collector Technologies

- Unglazed Collector
- Flat Plate
- Evacuated Tube
- Concentrating Solar Collector
- Solar Air Heating

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Unglazed Flat Plate

Cost:

$15-$50/ft^2

Temperatures:

75°F to 95°F

Typical Applications:

Pool heating

Pros

Inexpensive

Cost-effective for low temperature applications

Great in Tropical climates

Cons

Low temperature applications only

High losses, especially in windy conditions

Freezing concerns in some climates

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Glazed Flat Plate Collector

Cost:

$90-$200/ft^2 total installed

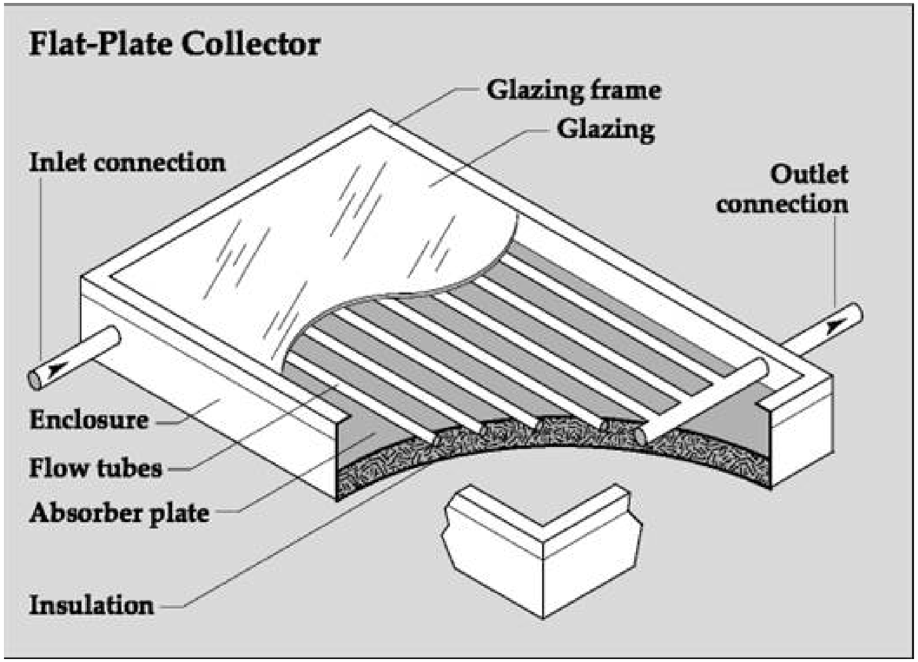
Temperatures:

85°F to 160°F

Typical Applications:

DHW Heating

Radiant Floor Space Heating



Pros

Proven technology

Long term functionality

High aperture area (0.97)

Cons

Temperature limitations – efficiency drop at high temperatures

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Evacuated Tube Collector

Cost:

$130-$250/ft^2 total installed

Temperatures:

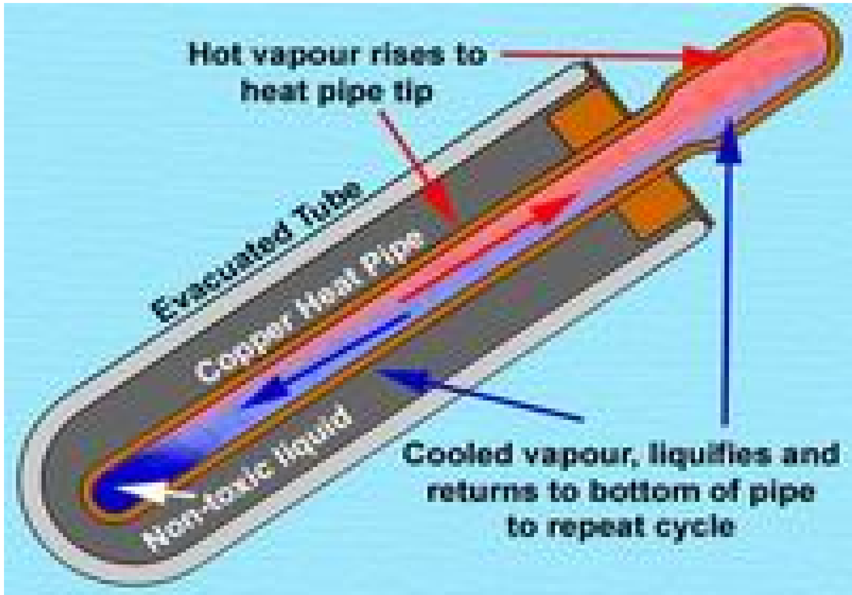
Up to 300°F

Typical Applications:

DHW

Low-temp Industrial

Space Heating



<u>Pros</u>

Higher temperature than flat plate

Improved efficiency at higher operating temperatures

Pipe bursting due to freezing is not such a concern as it is with flat plates

<u>Cons</u>

Vacuum may be lost over time – efficiency lost

Slightly higher initial cost vs. flat plate

Smaller aperture area (0.72)

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Concentrating Solar Collector

Cost:

$100-$300/ft^2

Temperatures:

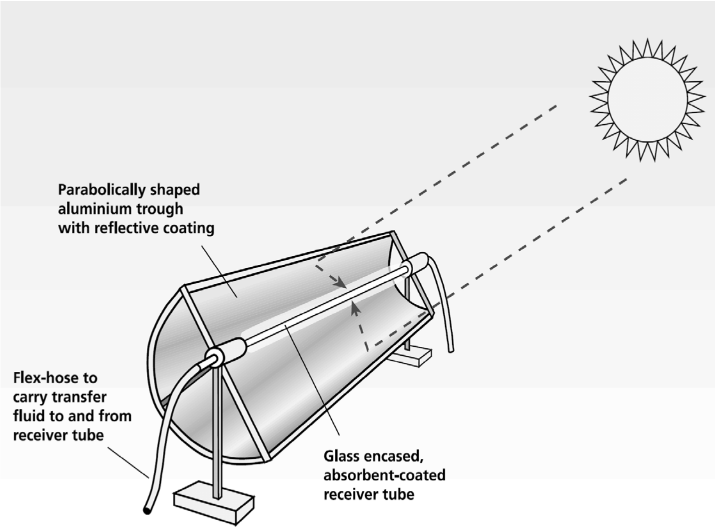
Up to 480°F

Typical Applications:

Large DHW

Industrial process

Boiler feedwater/makeup



<u>Pros</u>

High temperature applications

Can be lightweight and inexpensive

Higher efficiency at high temperatures

<u>Cons</u>

Can only use direct irradiation

Somewhat emerging technology

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Solar Air Heating

Cost:

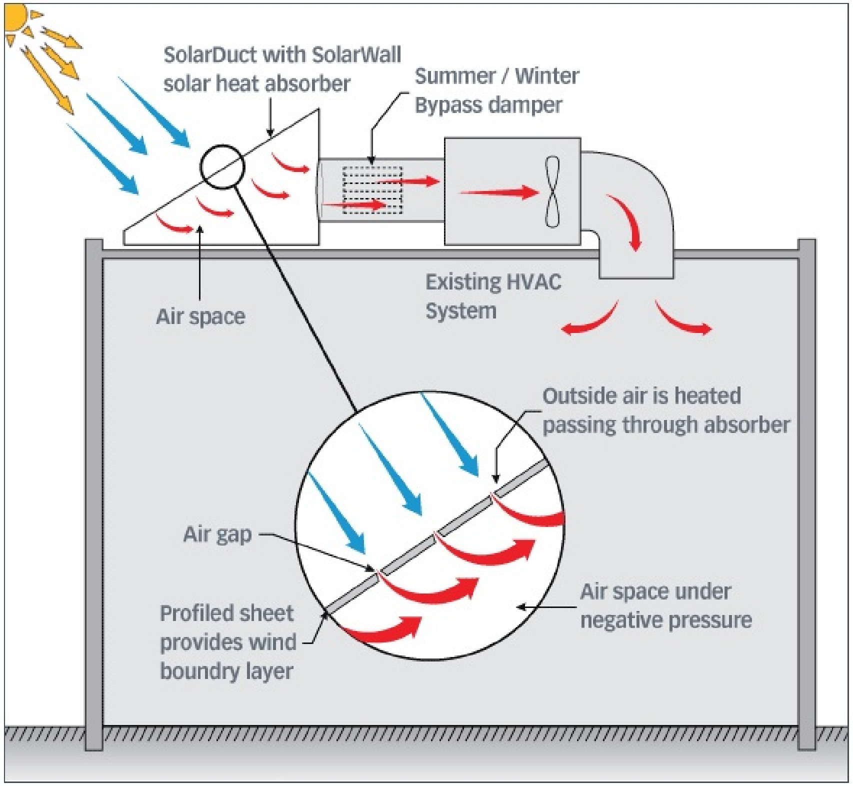
$100-$150/ft^2

Temperatures:

Up to 120°F

Typical Applications:

HVAC pre-heating



<u>Pros</u>

Potentially higher savings than solar DHW

<u>Cons</u>

Most useful when solar resource is at its lowest (winter)

Storage Tank

• Acts as a battery to hold the system's heat

• 50 gallons – 6,000 gallons +

• Size depends on desired storage length and usage patterns

• Constant usage facilities: small size requirement

• Daily spikes in water usage: large tank size requirement to store enough heat for daily spike

• Above or underground storage

• Insulation

Overheating & Freeze Protection

Stagnation is the condition in which heat transfer fluid boils off in the collector, due to prolonged solar exposure with no cooling flow. If Glycol is the heat transfer fluid, it can degrade to glycolic acid which has no freeze protection properties and can degrade system components.

Freeze Protection –

- Indirect Forced Circulation (Closed Loop)
- Active closed loop glycol
- Drainback

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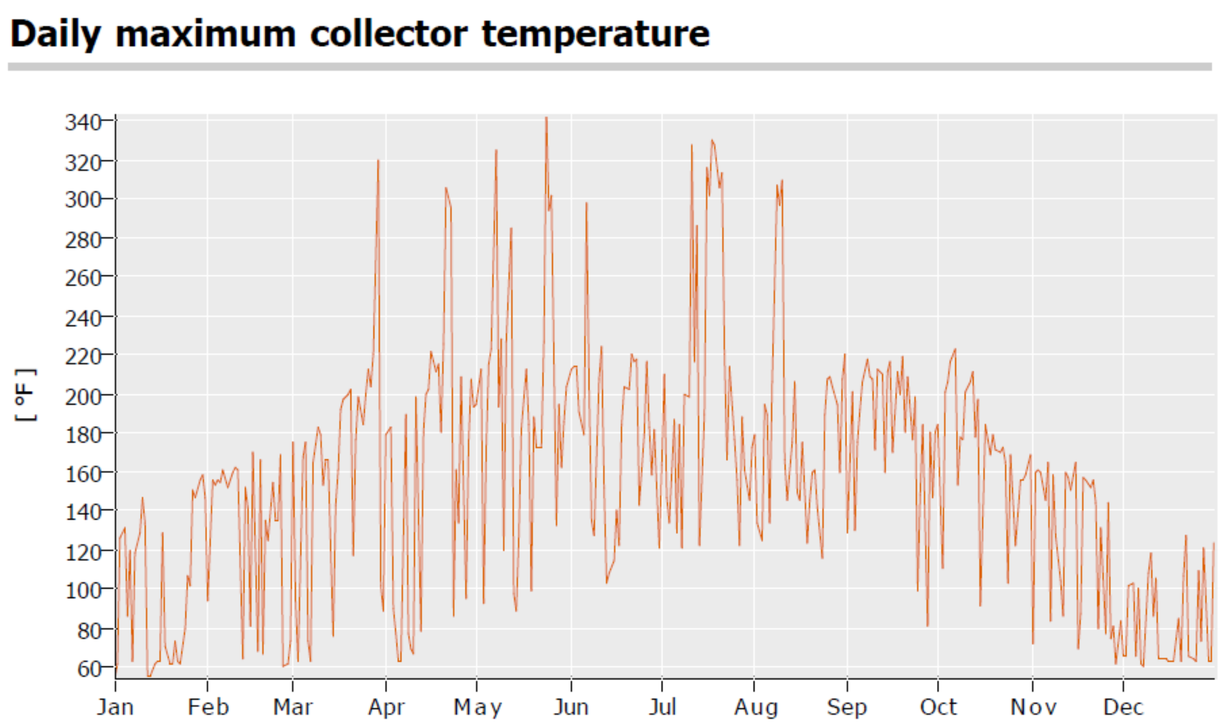
Overheating

- Glycol can turn into glycolic acid at high temperatures which can cause premature breakdown of system components
- Stagnation protection can be built in with proper sizing, storage capacity, as well as drainback, advanced controllers, or steamback systems



Critical Considerations

Five Key Development Elements

1. Measure Target Hot Water Load – Right Size
2. Structural Assessment – Avoid Cost Surprises
3. Consistent Bids – Compare Apples to Apples
4. Clear Construction Plan – Coordinate Multiple Trades
5. Ensuring Production – Performance Monitoring

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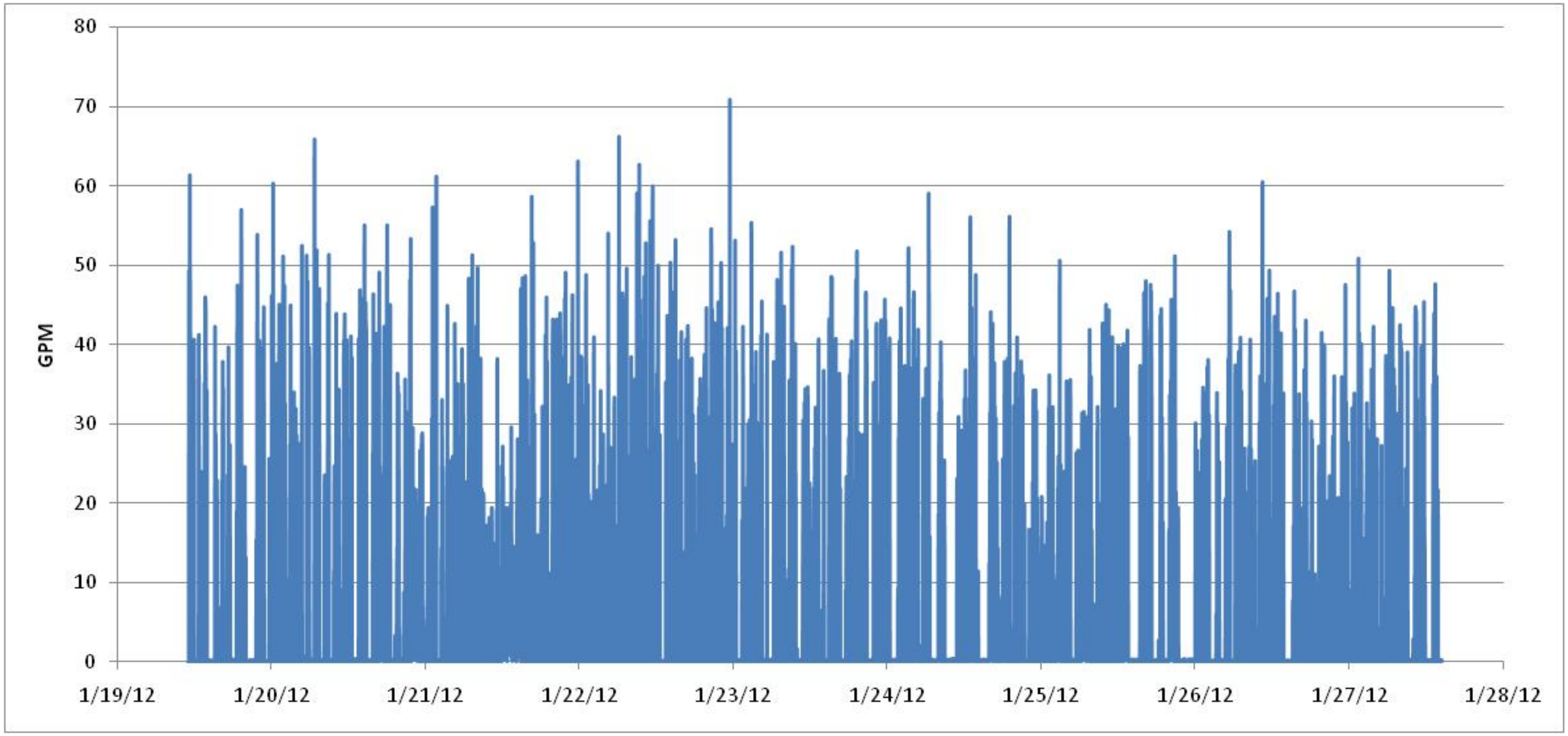
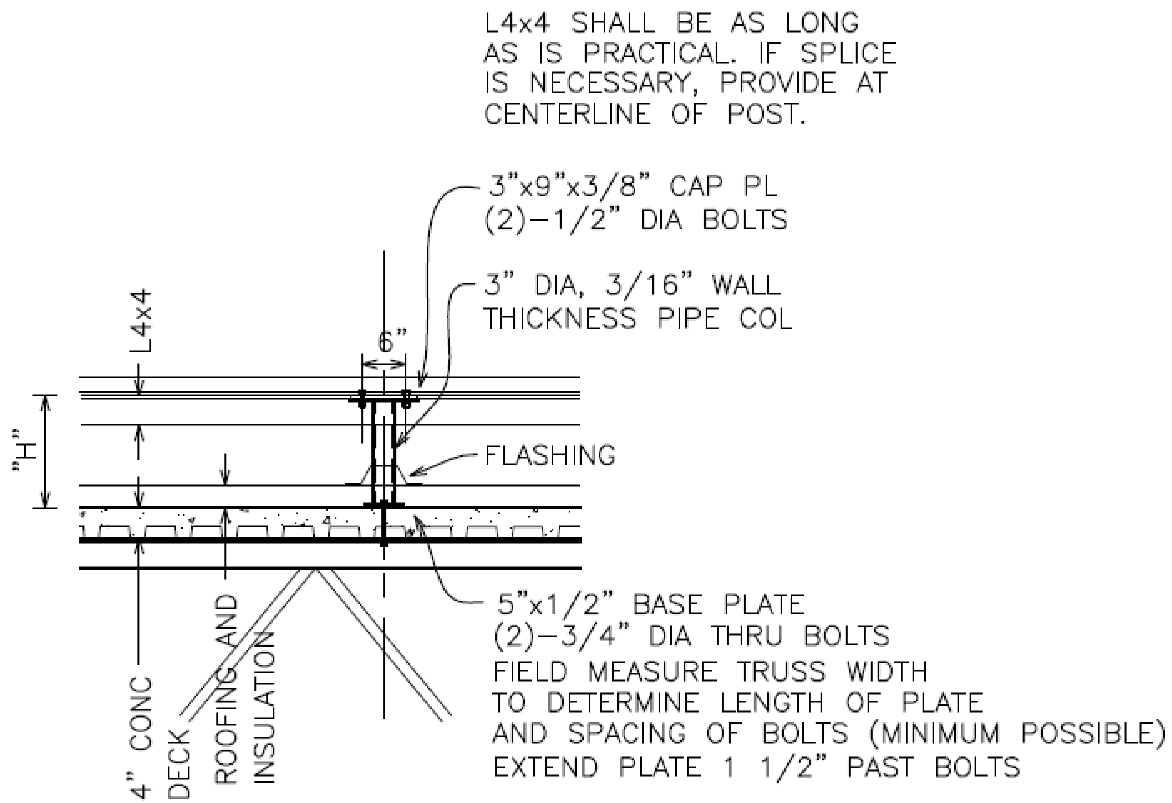
Hot Water Load

- Water Usage per day (i.e. 8,966 GPD)
- Peak flow rates (i.e. 50-70 GPM)
- Temperature requirements (i.e. 118 F)



Structural Assessment

- **Structural upgrades can be a big source of cost surprises**
- **Address early during feasibility phase, not post-contract**



Typical Costs

Component Type:	Manufacturer	Model	Quantity	Warranty (years)	Material Cost	Labor Cost	Comments / Additional Information
Flat Plate Collectors:							
Flashing, Carrying Beam, and Collector Frame:							
Heat Exchanger(s) - Collector-Side:							
Heat Exchanger(s) - DHW-Side:							
Electric and Controls							
Controller:							
Performance Monitoring System:							
Pumps:							
Electrical Conduit Run & Interconnection							
Piping							
Collector-side Piping Total							
DHW-side Piping Total							
Insulation – Piping							

- Eliminate missed components
- Can compare and understand bids more easily
- Allows for independent component cost analysis
- Nearly eliminates change orders

Energy Savings and Financials

- Reduce Heating Loads up to 80%
- Grants can substantially reduce costs
- Paybacks typically range from 3 to 12 years
- Net Present Value (NPV) positive, and higher than fossil fuel systems
- Delivered energy cost of $0.50-$2.00 / therm
- Consider non-energy educational benefits:
  - Enrollment
  - Marketing
  - Grants

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Evaluating Performance

Verifying Saving

Option	Measurement & Verification Approach	Pros	Cons
1	Energy Model	- Accurate assuming system conditions don't change and model is accurate to begin with	- Assumes ideal 'typical' conditions - Easy to miss small things that have big impact on modeled savings
2	Utility Bills	- Reflects cost savings - Most 'real' to customer	- Year to year usage variations and other factors must be accounted for
3	Monitoring	- Reflects actual conditions - Used to ensure operation	- Can add cost, though investment typically recouped by higher system uptime

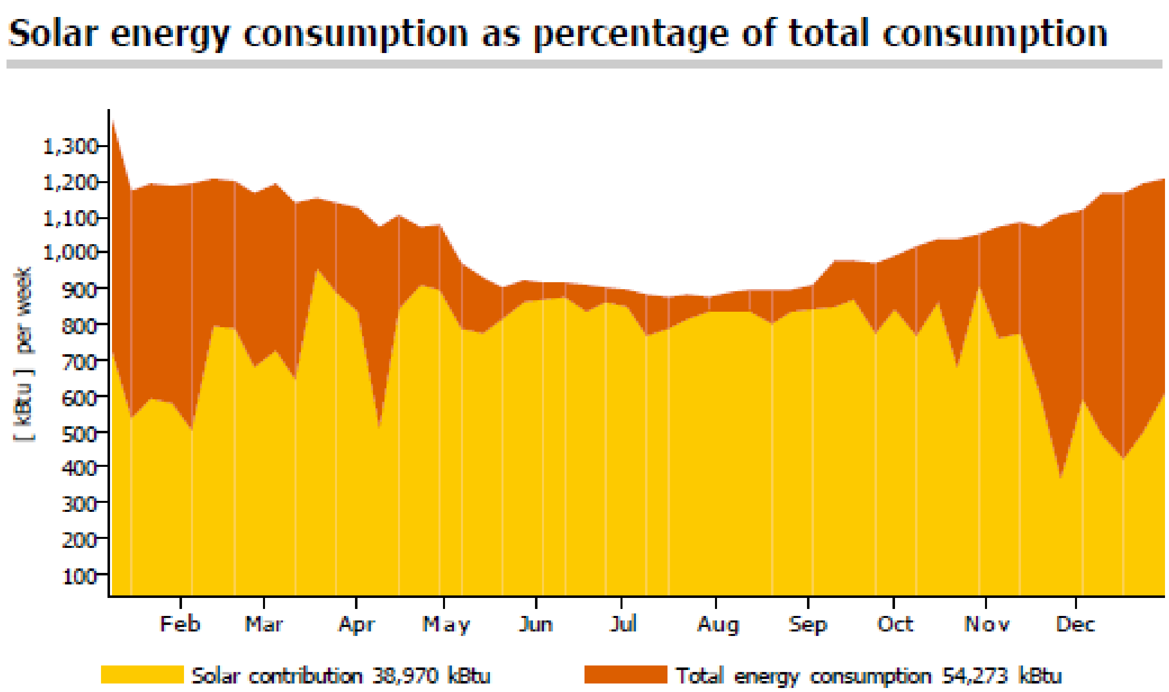
Expected vs. Actual Savings

- Monitored Performance data (green bars) vs. Expected Data (yellow line)

Example Monitoring Results

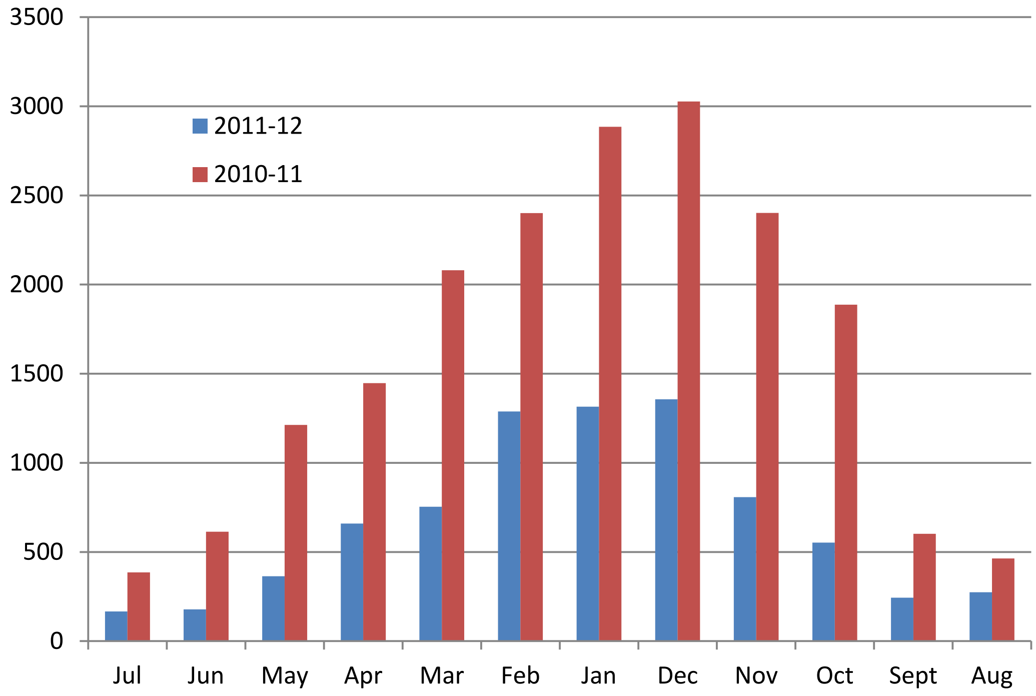
Project	Compared to Expected
1	76%
2	124%
3	115%
4	91%
5	88%
6	116%
7	88%
8	95%
9	115%
10	75%
12	78%
13	100%
14	132%

- Energy Model: RETScreen, TSOL, Polysun, F-Chart, etc
- Conditions: Heat load, orientation, equipments, etc.
- Solar Fraction: % load met by solar



Utility Bills

- 50-70% reduction in gas year over year
- Went from being one of the most inefficient buildings to 32% more efficient than average.



"I received a call from the Gas utility in July because they wanted to check to make sure everything was okay - they noticed that we had used NO gas over the previous month and we worried that something was wrong. I was happy to report that our solar panels were meeting all our needs! It was a great day."
~Facilities Director

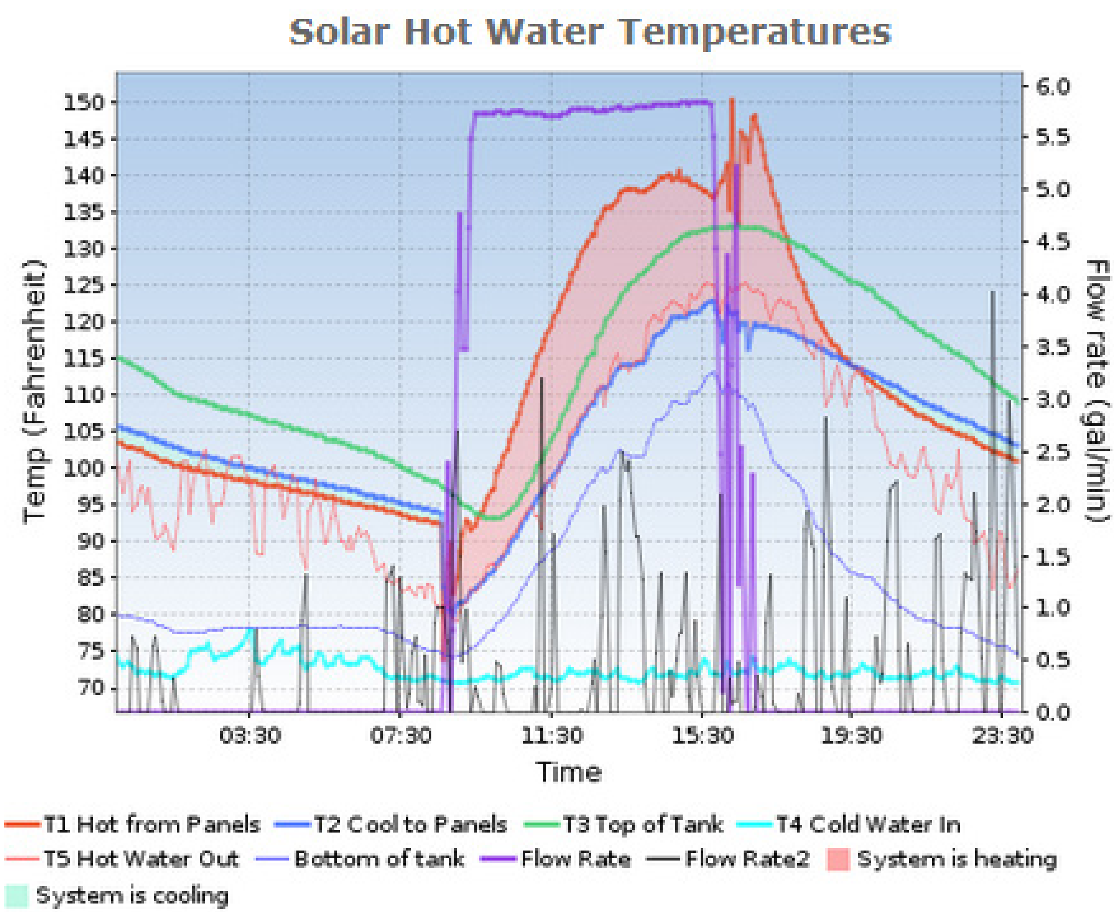
Solar Heating and Backup

- The backup heating system will generally heat water to set temperature, regardless of solar contribution, making no interruption in service.
- Thus when solar heating systems are not functioning it is rare for it to be caught.
- Single biggest benefit of active monitoring system:

Is it generally operating as it should be?

Case Study – Normal

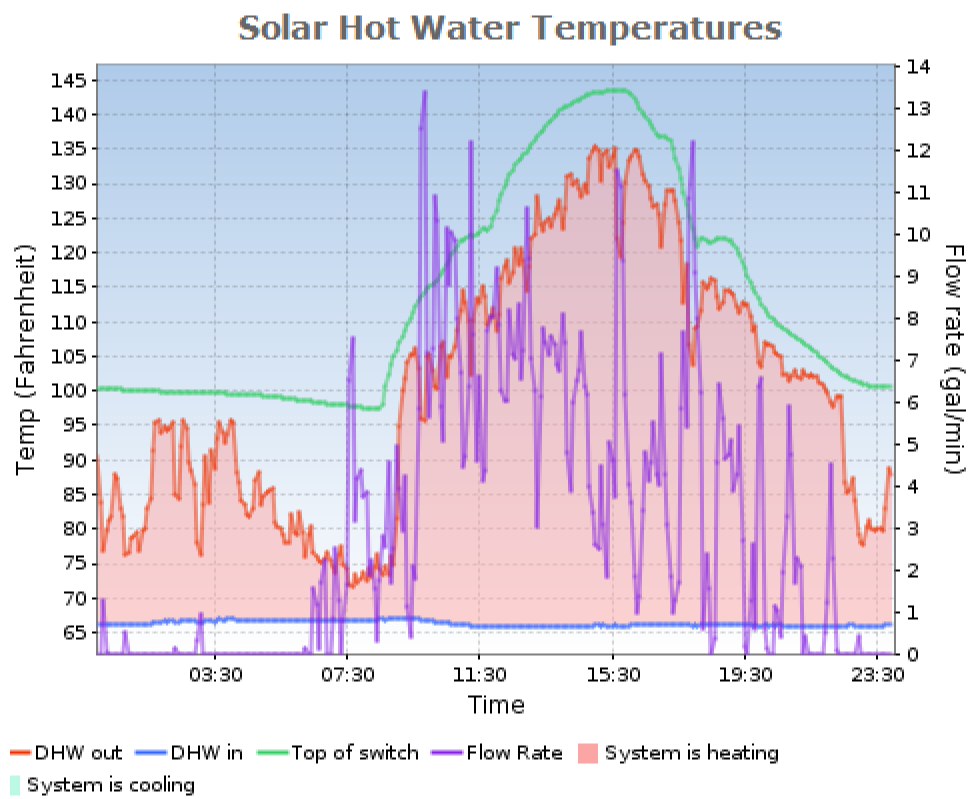
- Looks good
- Over 100% of expected production
- Easily understood:
  - Rise in tank temp
  - Potable flow rate
  - Collector flow rate
  - Delivered water temp



Refresh

Case Study – Temperature Gain

Potable Water Temperature Gain

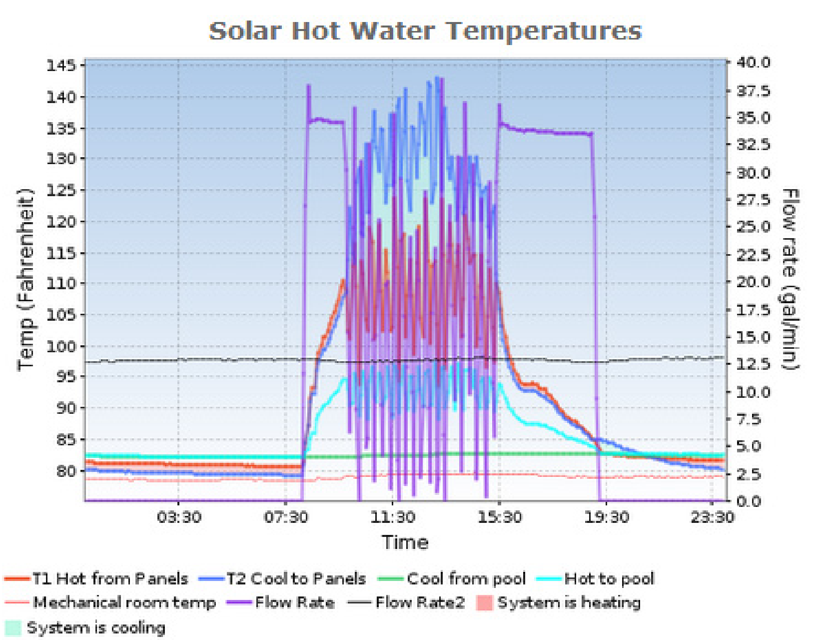


- Incoming DHW street water from 66 F heated up to 135 F.
- 6,000 gallon tank heated from 100 F to 144 F daily to store energy.

Case Study – Set Points

- Problem: Poor performance with excessive pump cycling causing substantial electric consumption.
- Solution: Increase load setting 'off' point, smoothes operation.

Before



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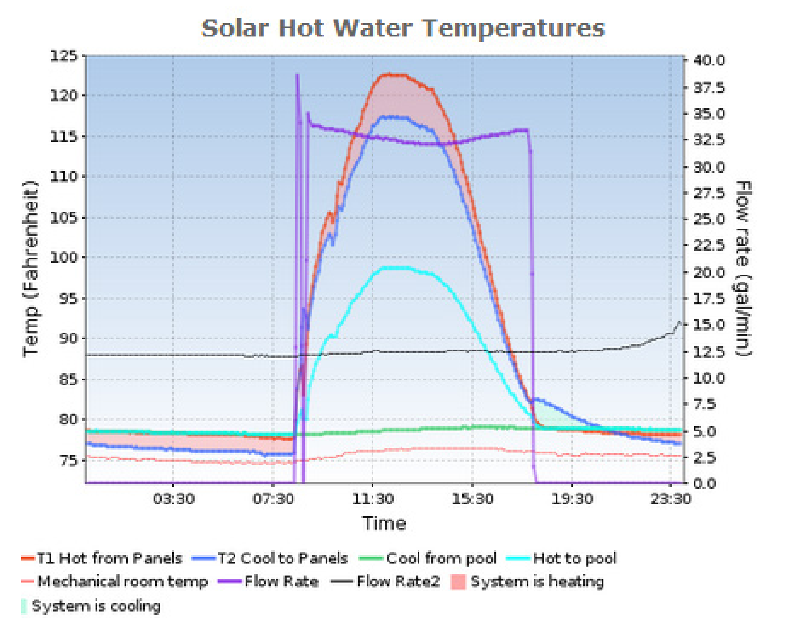

Summary

1. Substantial reduction in heating costs possible.
2. Carbon and GHG goals may be unattainable without solar heating technologies.
3. Universities can be excellent applications due to high water usage, favorable siting conditions, and strong facilities departments.
4. Explore grants
5. External benefits of renewable energy in education setting can be substantial.

Questions:

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Speaker

George Washington University

Doug Spengel

Energy and Environmental Mgr.

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202-994-6067

- Mr. Spengel has tracked energy and water usages and emissions for GW's buildings for 10 years, and he served as the internal project manager for installation of GW's three solar thermal systems in 2011
- His prior work experience includes 12 years as an environmental consultant for U.S. EPA
- He earned a MBA from George Washington University, a MS ChE from Carnegie Mellon University, and a BS ChE from Lehigh University, and three professional certifications: PE, CEM, and LEED AP

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Speaker

George Washington University

- Mr. Ellis works across the institution supporting a diverse set of sustainability projects – such as renewable energy, energy efficiency, and procurement – to help achieve GW's GHG reduction targets
- Mark's prior experience includes nearly 10 years as an energy and environmental consultant in the areas of energy efficiency, energy reliability, and technology delivery
- Mr. Ellis holds an MBA/MS dual-degree in Sustainable Enterprise from the University of Michigan, and a BS in Environmental Science & Policy from the University of Maryland – College Park

Sustainable GW

Mark Ellis

Sustainability Project Facilitator

markellis@gwu.edu

Sustainable GW

Solar Thermal Systems

One step toward climate neutrality

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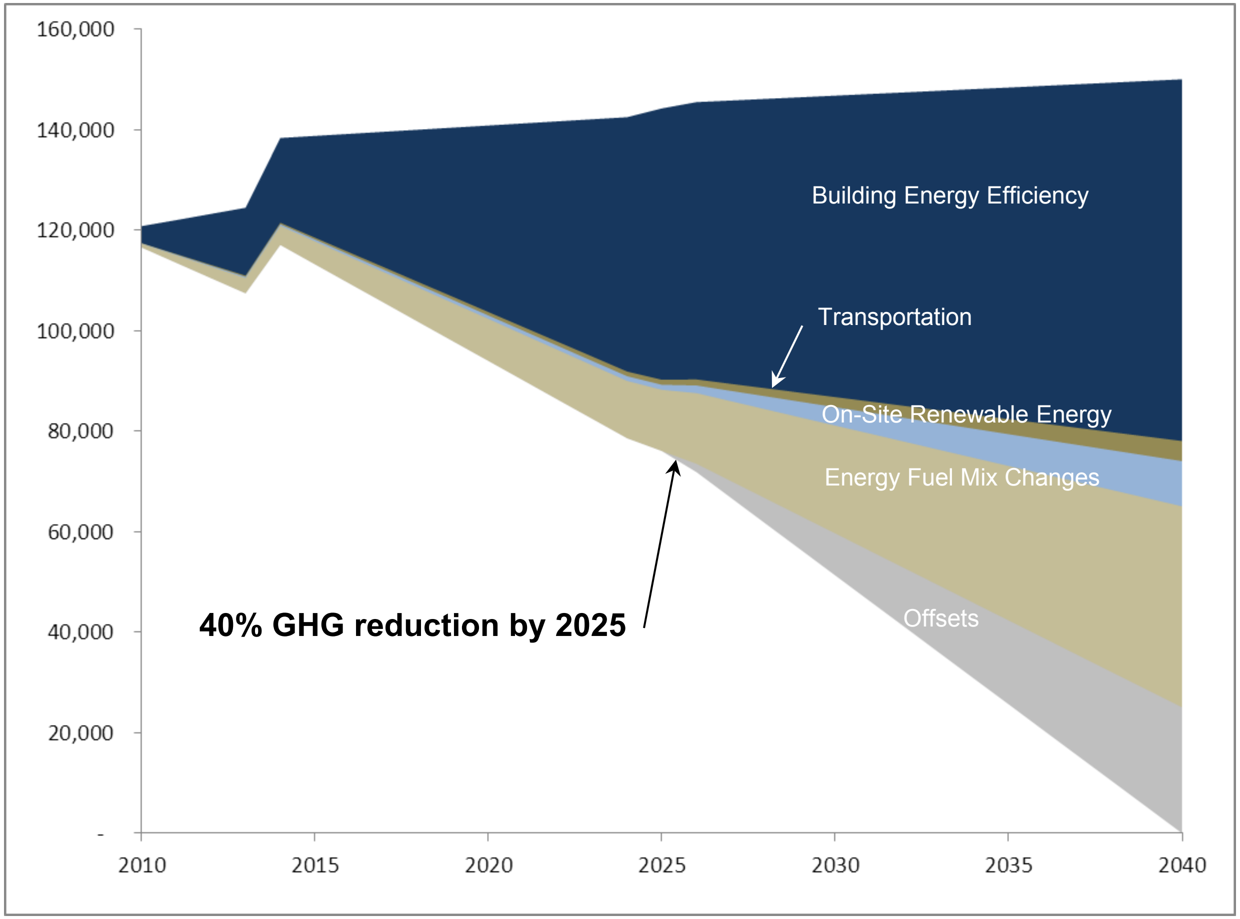
Climate Action Plan Pathway



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Climate Action Plan Goals

Key Targets

- *GOAL*: By 2025 GW targets a 40% reduction in campus-wide GHG emissions from 2008 baseline via conservation and optimization, new construction, and behavior change initiatives.
- *GOAL*: By 2040 GW targets carbon neutrality, from energy demand reductions, on-campus low-carbon electricity generation, transportation reductions, and changes in utility supplier fuel mix.
- Achieve through three high-level strategies: reduction, innovation, and partnership.

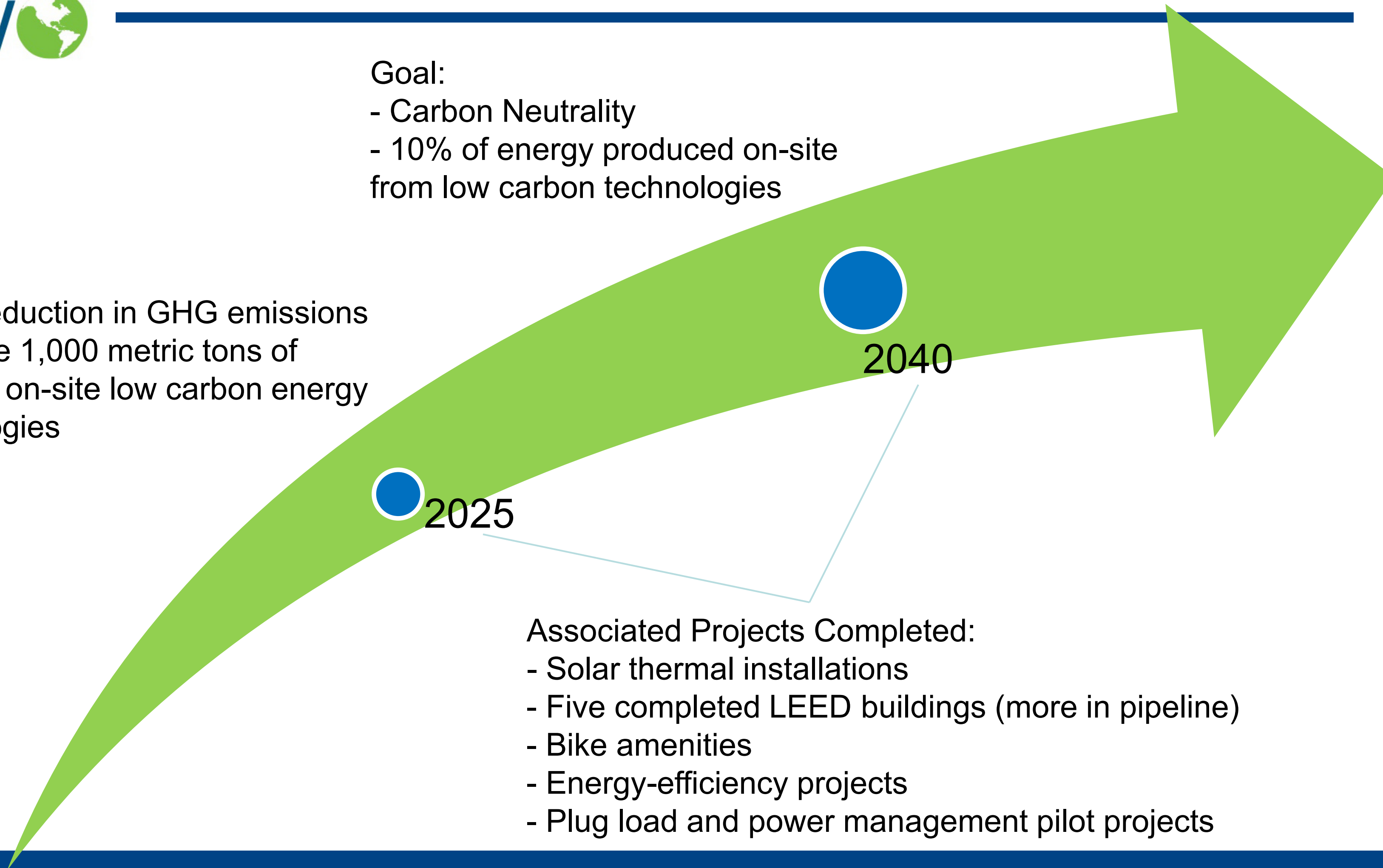
Innovation – Where Solar Thermal Fits In

- GW will use its campuses as testing grounds for green energy technologies and integrate the performance of these options into learning and research opportunities for students and faculty.
- *GOAL*: By 2025 GW targets at least 1,000 MTCO2e reduction in emissions due to use of on-site low-carbon technologies.
- *GOAL*: By 2040 GW aims to obtain 10% of its energy needs through on-site low-carbon technologies.

Climate Action Overview

Goal:
- Carbon Neutrality
- 10% of energy produced on-site from low carbon technologies

Goal:
- 40% reduction in GHG emissions
- Reduce 1,000 metric tons of CO_2 via on-site low carbon energy technologies

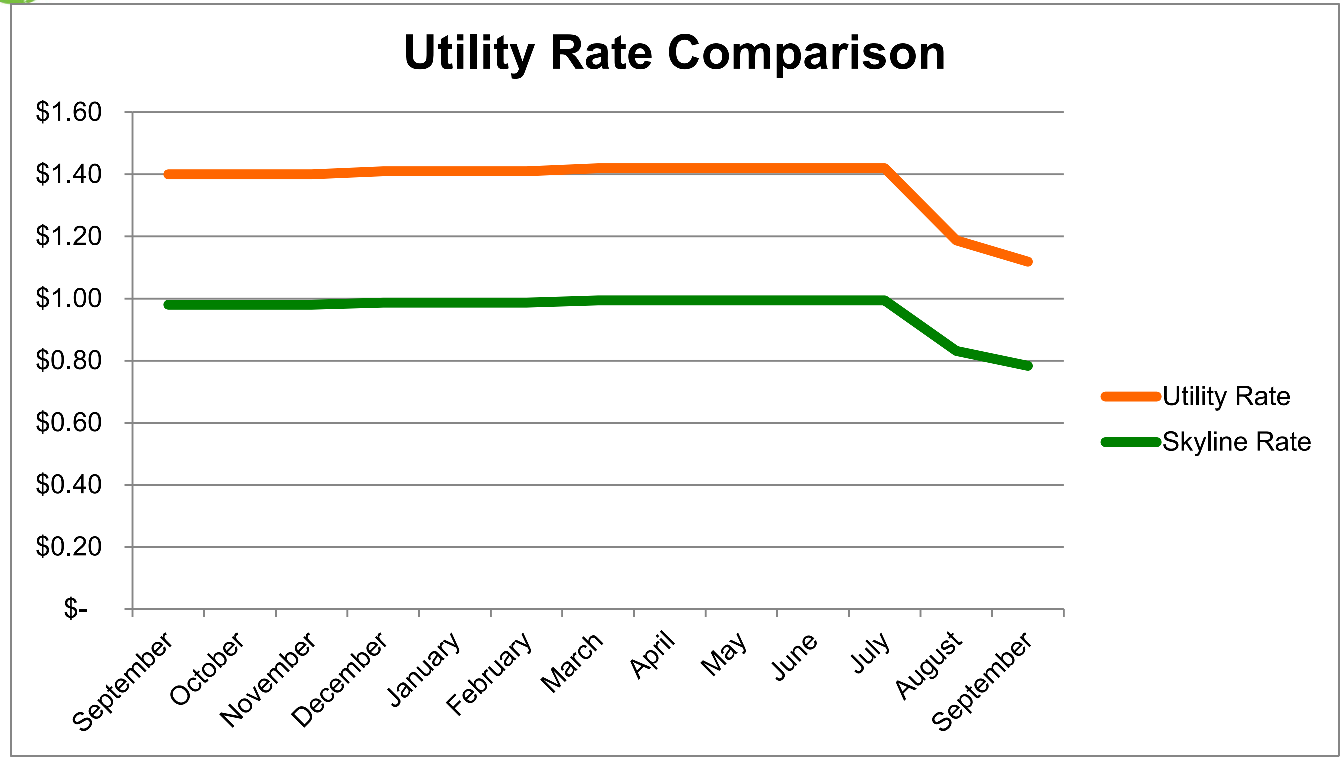


Associated Projects Completed:
- Solar thermal installations
- Five completed LEED buildings (more in pipeline)
- Bike amenities
- Energy-efficiency projects
- Plug load and power management pilot projects

Procurement

- Solar thermal RFP issued in August 2010
- Skyline Innovations selected as project financier and developer:
  - 10 year contract after which GW takes ownership
  - No upfront investment from GW
  - Solar hot water priced at fixed discount to utility rate
  - Skyline covers all O&M expenses for contract term
  - Early buy-out options available in contract

Financing



Price-indexed power purchase agreement provides solar water heating at a fixed discount to the fluctuating utility rate

Construction

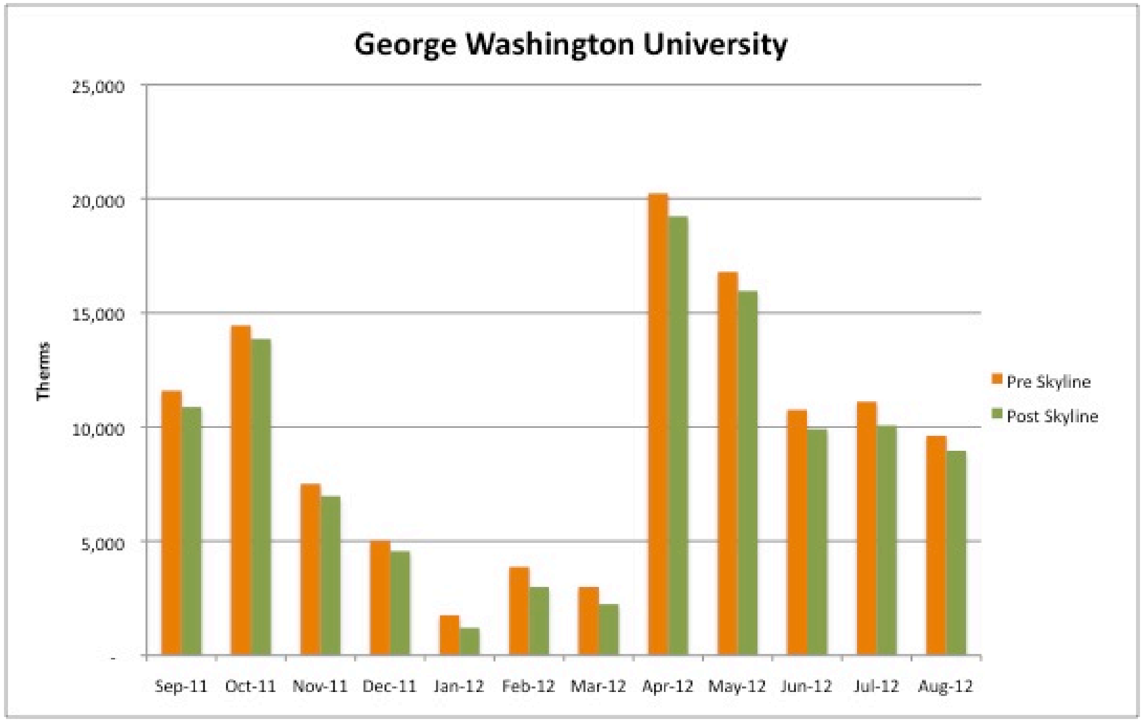
- Used an existing hot water storage tank pair each time
- Repurposed one tank of pair for solar pre-heating
- Used ballasted systems to limit roof penetrations and maintain roof warranties
- Systems can operate independently from BASs
- Later added a heat dump for low-occupancy periods

System Information

- Commissioned 7/27/2011
- System Value: $411,000
- System Generation: 2.8 MBTU per day
- System Size: 94 collectors total (Kingspan and AET)
- Storage Size: 5,120 gallons
- System Locations:
  - Ivory Tower, 616 23rd St, NW, Residence Hall: 723 beds
  - 1959 E St, NW, Residence Hall: 188 beds
  - 2031 F St, NW, Residence Hall: 27 beds

System Performance

Utility vs. Solar Energy Consumption



- Solar system addresses domestic hot water usage only (not building heat)
- Total savings since March 2011: $3,470 and 10,407 therms

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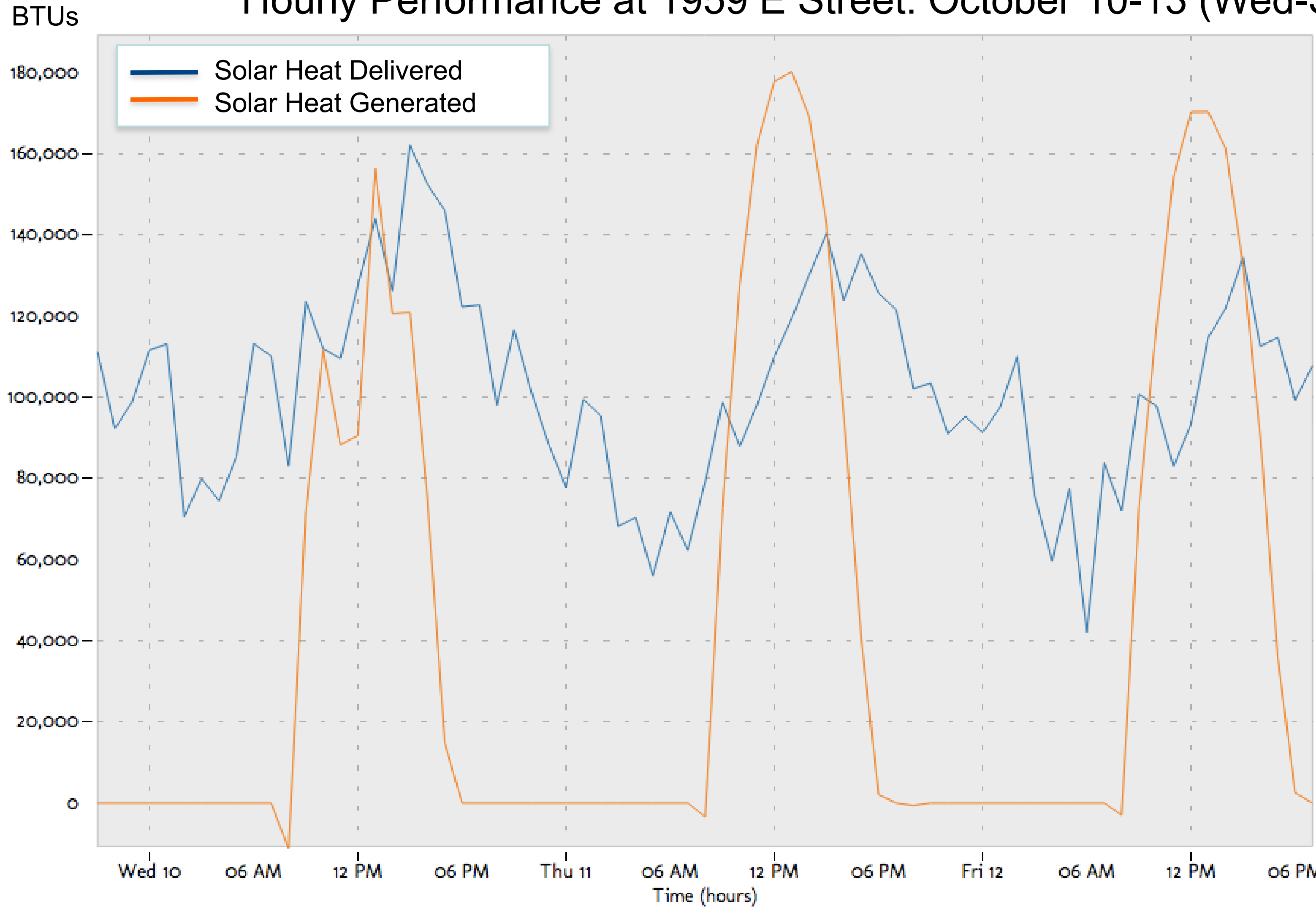
System Performance

Hourly Performance at 1959 E Street: October 10-13 (Wed-Sat)



Conclusions

- Solar thermal systems make sense for facilities with large hot water usages: residence halls, restaurants, and pools
- Using a power purchase agreement eliminates the first-cost-investment hurdle
- System design should consider existing equipment, conditions, and variable occupancy levels

System Photos

Speaker

American University

Chris O'Brien

Director of Sustainability

cobrien@american.edu

- Chris is AU's Director of Sustainability and is responsible for policy, planning, outreach and implementing the university's commitment to climate-neutrality by the year 2020, green buildings, zero waste, and green procurement.
- Previously, Chris was the director of the Responsible Purchasing Network, Managing Director of the Green Business Network and the Fair Trade Federation; Treasurer of the Fair Trade Resource Network; and co-owner of the Seven Bridges Organic Brewing Supply Cooperative.
- Advisor to: Electronic Products Environmental Assessment Tool (EPEAT), Green Advantage, and the Association for the Advancement of Sustainability in Higher Education's STARS Steering Committee.
- Author of Fermenting Revolution: How to Drink Beer and Save the World (New Society, 2006).
- Twitter: twitter.com/GreenAU

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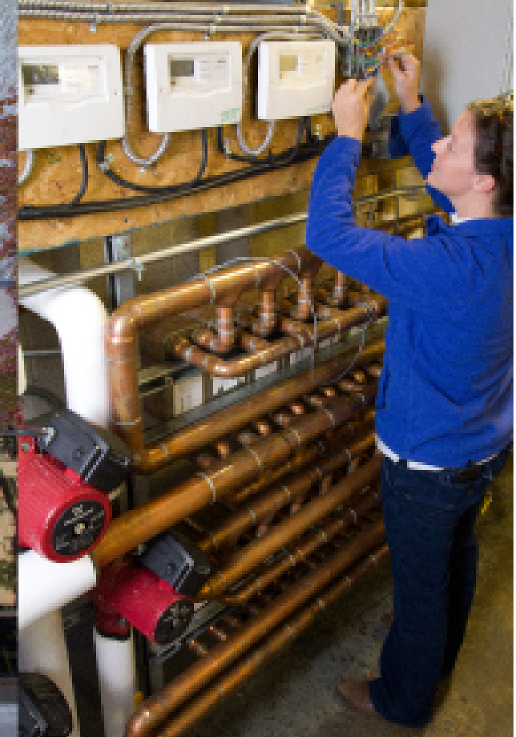
THE AMERICAN DREAM IS GREEN

Solar Hot Water
American University

Chris O’Brien, Director of Sustainability

EPA Webinar

October 25, 2012



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Project Profile

- Commissioned 10/20/2011
- Value: $393,000
- Capacity: 6.1 MBTU (45 kBTU per collector)
- Energy: 17,385 therms annually
- Panels: 136 Kingspan Thermomax Collectors
- Storage: 10,000 gallons of solar hot water
- Locations (American University, Washington D.C.)
  - Anderson-Centennial Hall: 1,400 residents
  - Letts Hall: 400 residents
  - Mary Graydon Center (dining hall)

Financing Options

1. Direct Purchase

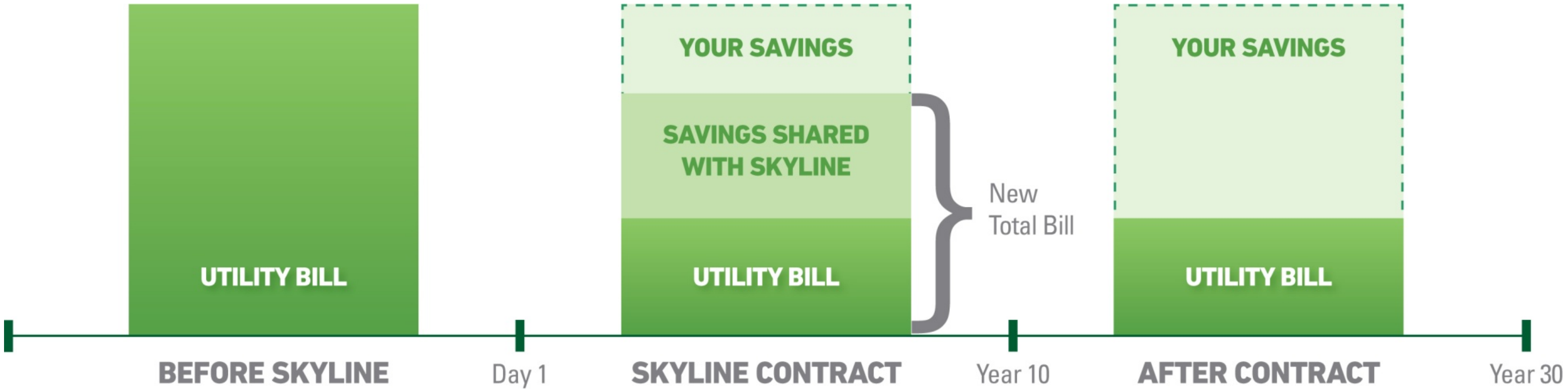
Pros	Cons
Retain all financial savings	Significant capital investment
Eligible for local grant s (see dsireusa.org)	Ineligible for tax incentives
Retain Solar Renewable Energy Credits (SRECs) to retire or market	Responsible for O&M (can also be a pro)
~6 year payback on 25 year lifecycle	

2. Power Purchase Agreement

Pros	Cons
No capital investment	Forfeit ownership of SRECs
Cash-flow positive on day one	Forfeit most financial savings to PPA owner
No O&M for 10 years	
PPA owner eligible for tax incentives	

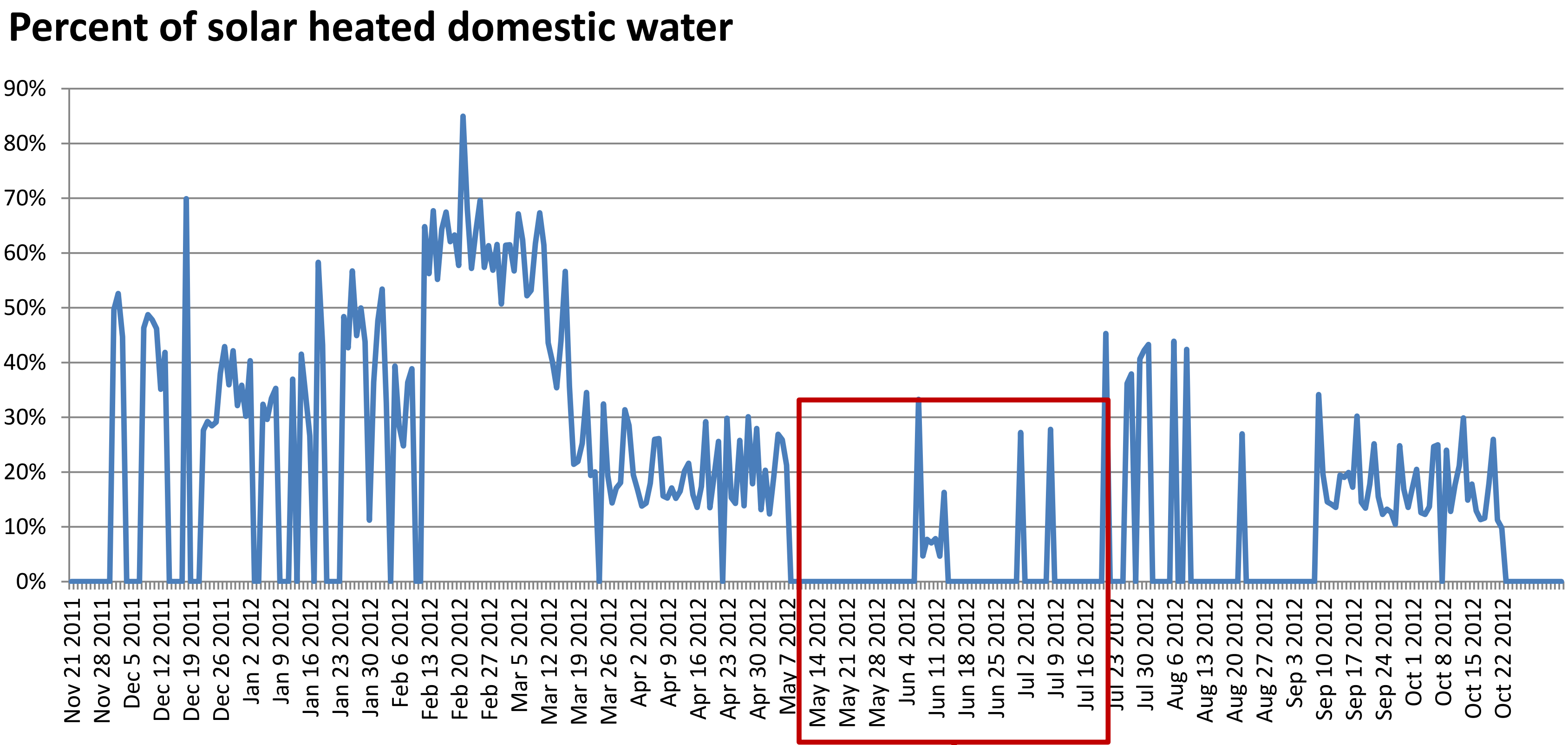
Onsite Solar Power Purchase Structure

Price-indexed solar Power Purchase Agreement (PPA) structure from Skyline Innovations



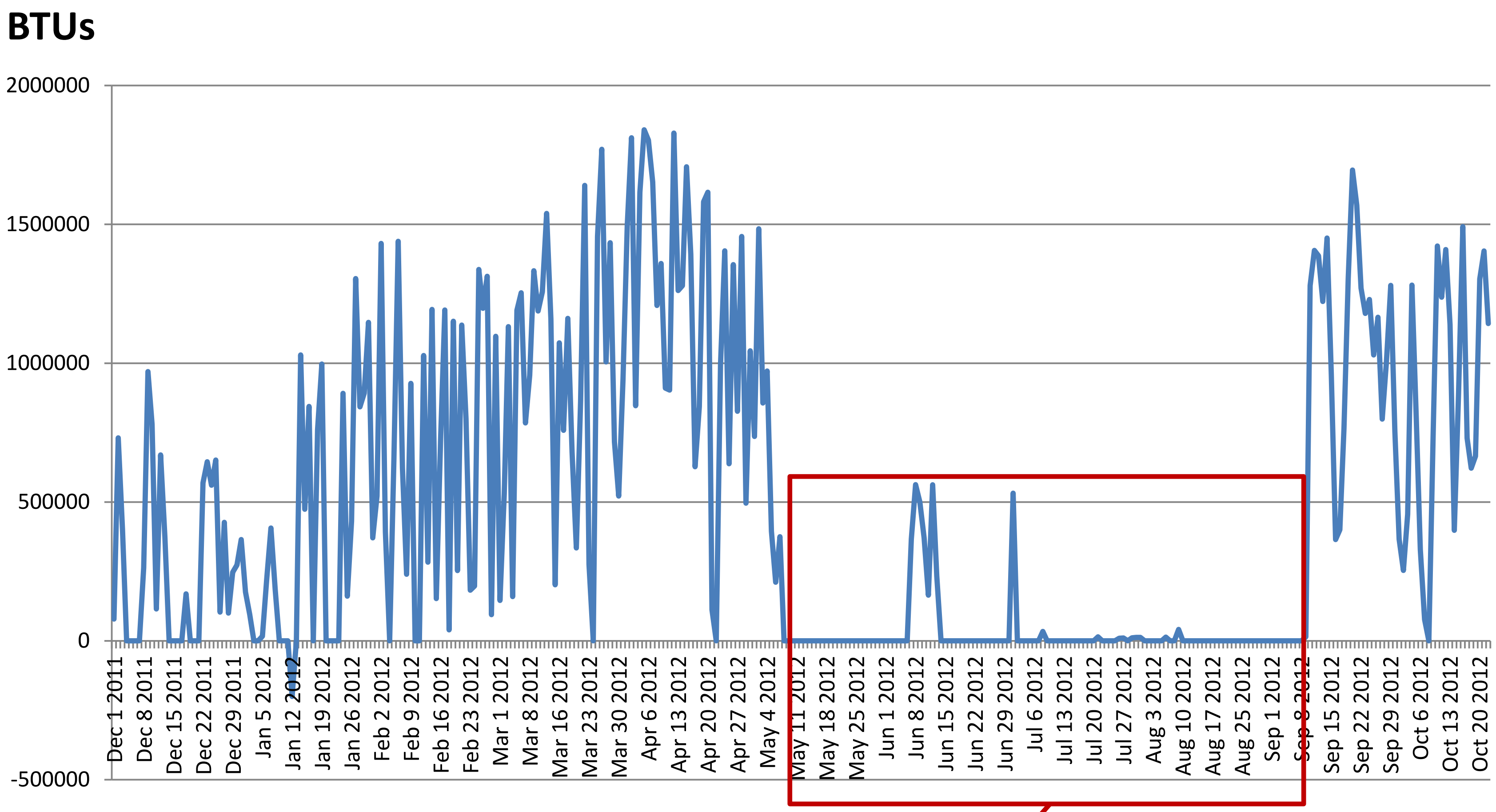
- Solar hot water delivered at a fixed discount to utility rates
- PPA owner provides O&M for 10 year contract term
- After 10 years, AU owns system and keeps all savings

Solar Fraction—Letts Hall



Low occupancy. System in safety mode to prevent overheating.

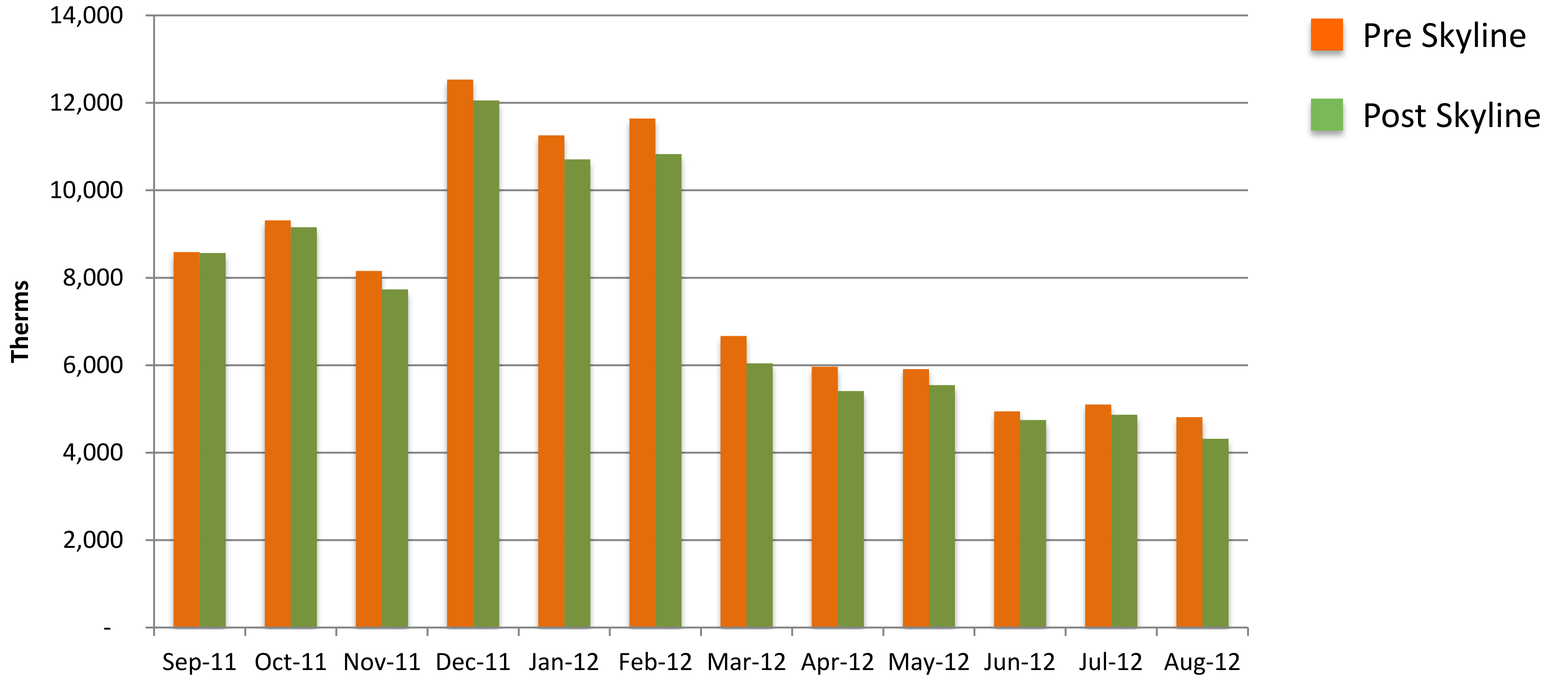
BTUs Generated—Letts Hall



Low occupancy. System in safety mode to prevent overheating.

System Performance

Utility vs. Solar Energy Consumption for Entire Campus



- Total gas utility bill savings in year one = $1,613
- Solar system covers domestic hot water usage
- 117,550 lbs of CO_2 offset, or 91 Trees

Innovations

- One of the largest, urban solar hot water systems on the East Coast
- Custom fabricated ballasted mounting system integrated with green roof

Lessons Learned

- Projected annual system savings = $10,000
- Actual savings in year one = $1,613
- Reasons:
  - System design didn't account for seasonal occupancy
  - Overheating caused down time; heat dumps installed
  - Gas prices 50% lower than projected
- Savings will increase with less downtime & higher gas prices
- PPA eliminates capital investment & O&M effort but also forfeits most of the financial upside
- Now considering direct purchase of solar hot water systems on additional buildings (~6 year payback; 12% IRR)

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Solar Hot Water Technologies for Higher Education Buildings

Question and Answer Session

Please type your questions into the Q/A window on your screen.