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LINC VAB SOLAR THERMAL RETROFIT CASE STUDY

An deep retrofit, Village at Beechwood housing, Lancaster California

2019 ACEEE Hot Water Forum, Nashville, TN

March 12, 2019 Joe Yenshiun Shiau, PE, CEM

Pop Quiz

1. How to size a solar thermal system, with evacuated tubes?
2. How does it work?
3. Any pictures for the internal guts?
4. How to protect from freeze damages?
5. What are the cost components? Incentives? Tax credits?
6. How can a low income apartment owner afford?
7. Are there multiple manufacturers on the market?
8. What the future holds for solar thermal?

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Project purpose & goals

- A deep retrofit in a low income apartment, to explore solutions for split-incentive and how Zero Net Energy (ZNE) can be achieved in multi-family rental properties
- Technology mix include traditional energy efficiency (EE), emerging, and renewable measures, as **balanced energy resources.**
- Focus: for a 30 home cluster sharing 3 natural gas-fired water heaters, a solar thermal system is added to assist pre-heating. Underground piping is replaced with modern insulation.
- Project duration 2014 - 2017

Acknowledgement & Credits

- Originally initiated by SoCalGas Emerging Technologies Program, later wrapped into a California Energy Commission (CEC) demonstration project
- Cofunded by CEC Public Interest Energy Research (PIER) grant $1.35MM, SoCalGas, SCE, HUD and others. Total project $2.46MM. Hot water ~10%.
- Project manager EPRI; engineering BIRA Energy
- Received the 2017 EPRI Technology Transfer Award, Power Delivery & Utilization sector
- Showcased in DOE Better Buildings Newsletter https://betterbuildingssolutioncenter.energy.gov/implementation-models/replicable-and-scalable-near-zero-net-energy-retrofits-low-income-housing

Better Buildings®
U.S. DEPARTMENT OF ENERGY

Top-10 Solutions

2016

Each month we recap the most viewed solutions shared by Better Buildings partners. Check out the Top-10 solutions in 2016 below.

Top-10 Solutions in 2016:

1. Energy Data Access: Blueprint for Action Toolkit
2. Toolkit: Implement Energy Management Information Systems in your Building Portfolio
3. SWAP Season 2: U.S. Naval Academy vs. U.S. Air Force Academy
4. Better Buildings Outdoor Lighting Accelerator: Decision Tree Tool
5. Better Buildings Financing Navigator: Online Tool to Help Identify Funding for Energy Efficiency Projects
6. Better Buildings Alliance Technology Specifications & Technology Team Activities
7. UC Berkeley Implementation Model: Tying Energy Costs to Building Occupants
8. LINC Housing Implementation Model: Replicable and Scalable Near-Zero Net Energy Retrofits for Low-Income Housing
9. City of Milwaukee, WI Implementation Model: Property Assessed Clean Energy (PACE) Program

Site, LINC Village at Beechwood, Lancaster, CA

Courtesy: LINC

Courtesy: EPRI

Site Description

- 28 buildings include a total of 100 dwelling units
  - (4) 10-plex buildings of 1- or 2-bedroom units
  - (2) 8-plex buildings of 2-bedroom units
  - (22) duplexes with a mix of 2- and 3-bedroom units
- All buildings are two stories. Each unit is on a single floor; 650 - 1,050 sq. ft.
- Multiple water heaters are shared by buildings in groups
  - Each duplex is provided by a shared 40 gallon, storage type natural gas fired water heater.
  - Two hot water central plants, each service 30 units in three adjacent buildings (one 8-plex, one duplex, and two 10-plex buildings.)

Challenges and Obstacles

- Split-incentive: Non-profit owner and low-income tenants
  - Natural gas is master metered. (Electric meters are per unit.)
  - Common laundry equipment is rental
- Vintage structure, built in 1975 era
- Desert climate with extreme temperatures, Zone 14
- Lack of Internet connections
- Some behavioral issues
  - Some tenants avoid running the RTU with forced air fan for heating/cooling
  - Tenant working odd-hours or staying home for long hours; taking more showers
  - Tenants not care about natural gas utility costs since not paying directly
  - Cooking by natural gas; some use may use for space heating at risks
  - Occasionally vandal risks in common facility
- 80% tenant cooperated in billing data releases
- Asbestos remediation is expensive and cost separate

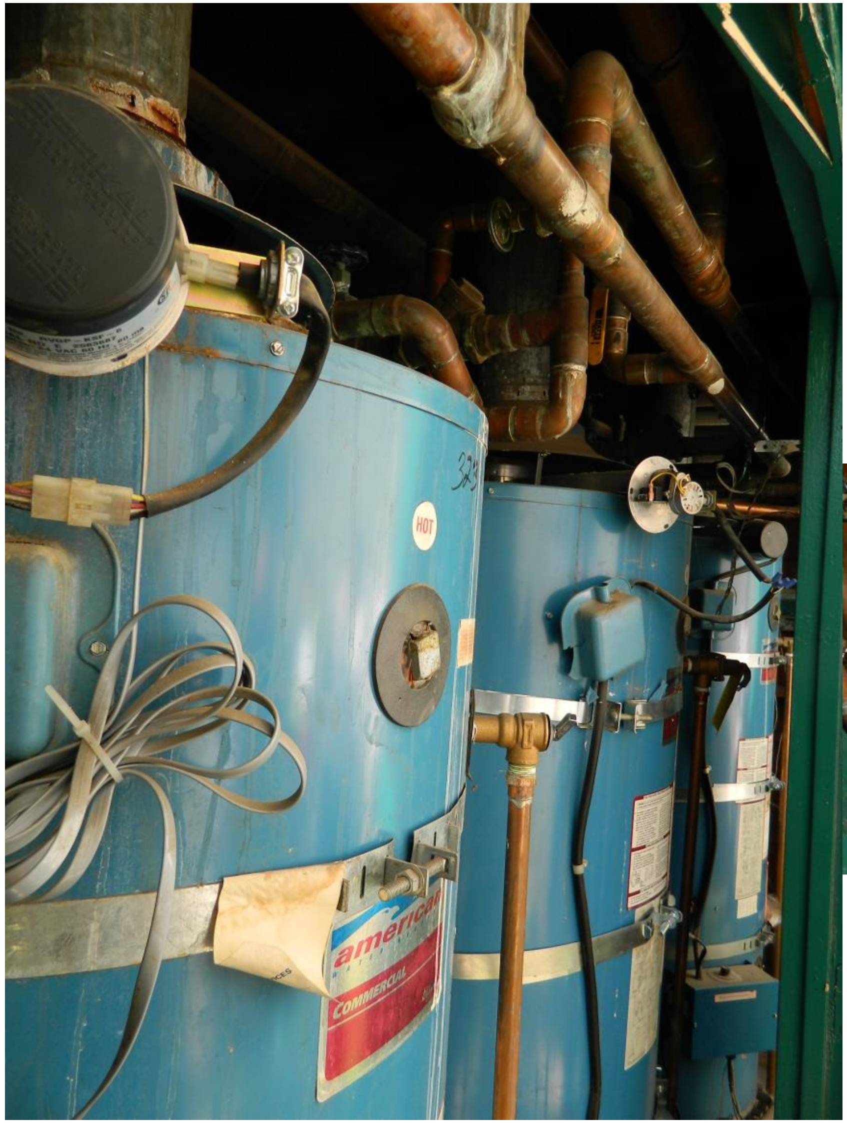
Overall Project Solutions & Unique Approaches

- Owner & Operator LINC keeps facility and grounds well maintained
- LINC has been progressive in adopting new technologies
- Leveraged multiple grants and cofunding, including HUD
- Explored all retrofit options, conventional, emerging, and financial
  - Solar PV on common car ports
  - Evacuated tubes on roof
  - Aerosol duct sealing, thermostats, roof penetration insulation upgrade, etc.
  - Considered but not implemented:
    - Natural gas engine driven Heat Pump Water Heater
    - Staged burners for laundry dryers, etc.
- Modeling tool for individual unit: EnergyPlus™, BEoptE+ v1.3
- Submetering. Natural gas AMI meters data streaming.
- Construction test drilling and sampling to find existing conditions and retrofit options

M&V Site Plan

- Retrofitted are 30 units (1 duplex, 1 eight-plex, and 2 ten-plexes), retrofitted and monitored.
- Bldg. Cluster 4/5/6 (total of 28 units) has central water heaters (3) x 270k Btu/hr. Used as baseline for savings comparisons.
- Bldg. Cluster 1/2/3 had similar occupancy and central water heaters. Retrofit: Added solar evacuated tubes on roof and storage tanks on ground; 2 old water heaters removed.
- Gas submeters by SoCalGas advance meters
- Evacuated tubes vendor transmit the heat and flow data to Cloud, 5 years. (Not available.)

Hot Water System and Equipment, Before Retrofit



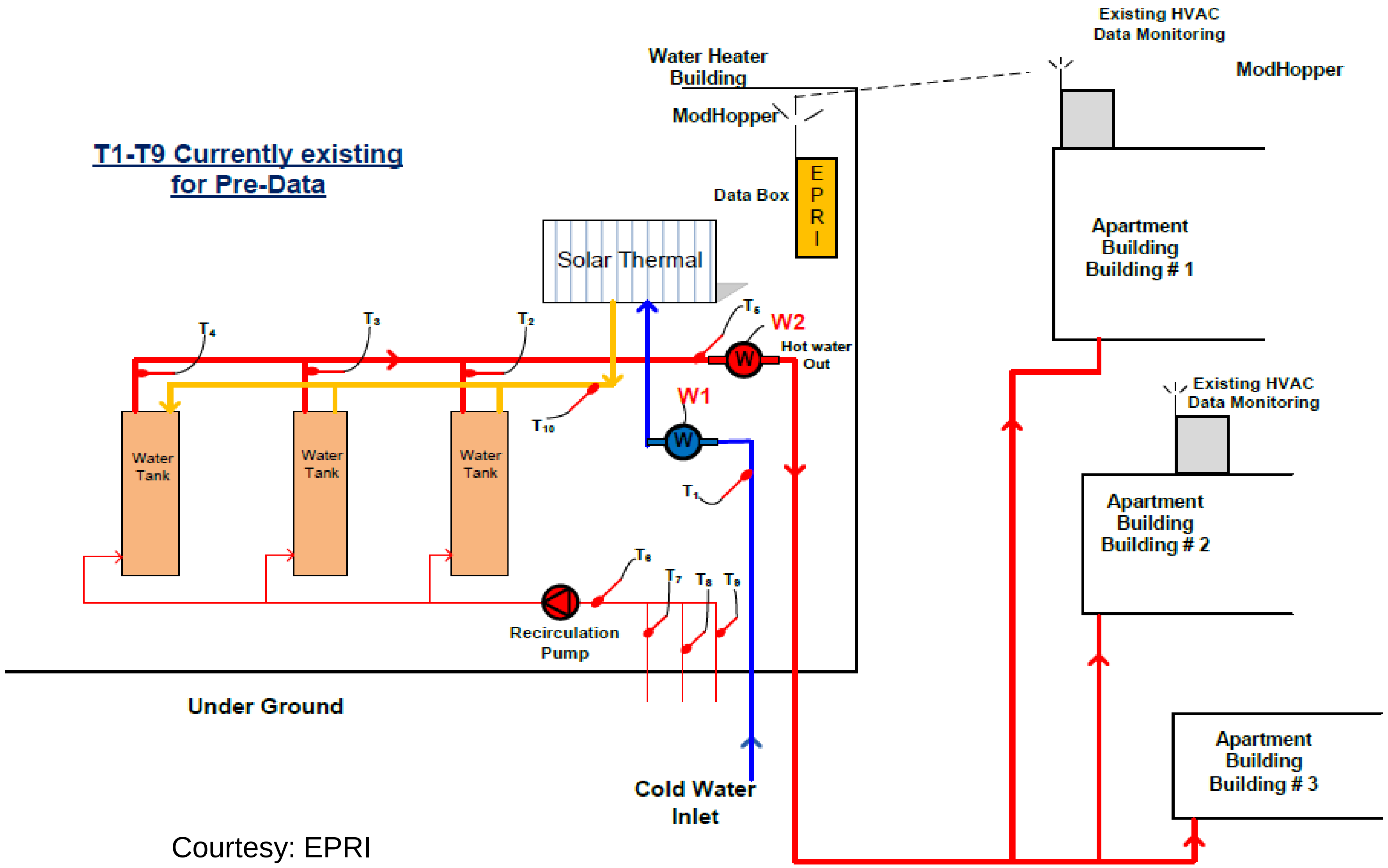
Water heaters for 30 units in Bldg. 1/2/3. (Typical for Bldg. 4/5/6)

Hot water circulator

Demand control

Aquastat for hot water temperature setting & sequencing

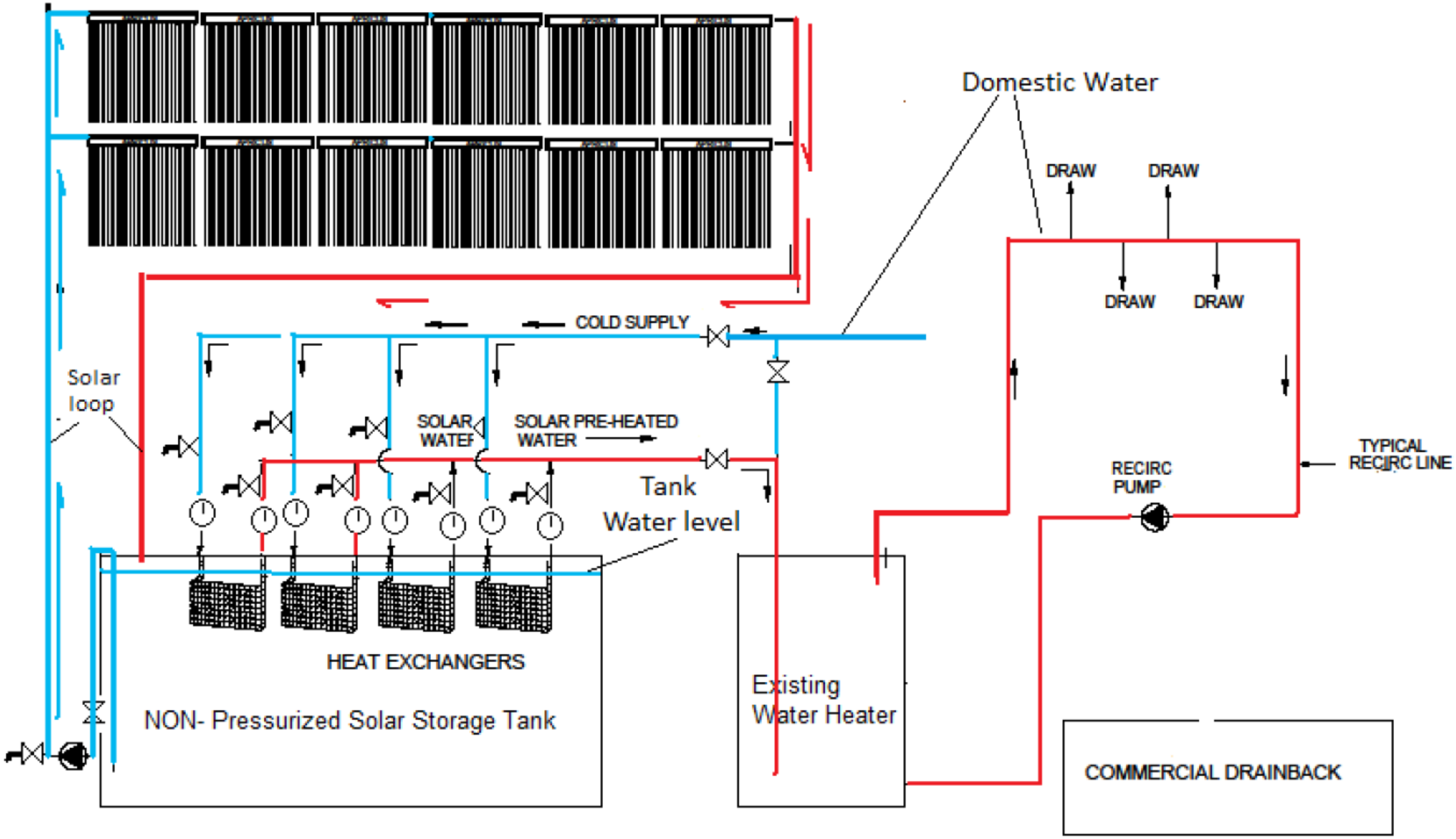
Retrofit Schematic: A Solar Thermal Assisted HW System



Courtesy: EPRI

The Addition of Solar Assisted

Pre-heating Cold Makeup Water



Courtesy: Arnold Solar Inc

Project Design/Cost, California Solar Initiative (CSI)
Drainback system with evacuated tube collectors

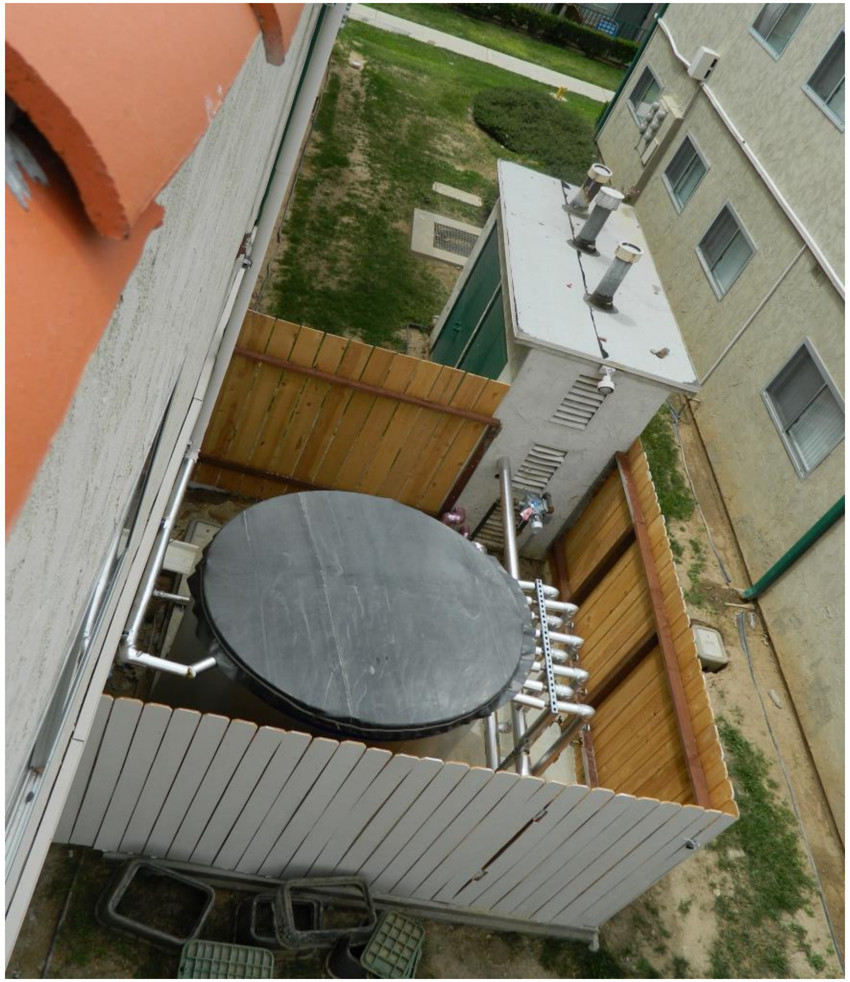
- Contract amount ………………… $90k
- CSI Incentive, Climate Zone 14: $49k (MFR Low Income $19.23 /Th)
- Net cost without tax benefit $41k
- Sizing 64k kWh/yr (2,182 Th/yr in natural gas, CSI estimate/allowed)
- Collector tilt 45°, 12 modules x 56.4= 677 sq ft, 30 tubes/panel, freeze protected, drain back.
- Atmospheric tank 1,250 gal. Heat Exchanger: immersed, load side.
- Estimated output 1,120 Gal/day delivered at 120°F
- Max aux. heat capacity 600k (Btu/hr)

Solar Thermal System in Construction

Courtesy: EPRI

Hot Water System and Equipment, After Retrofit

Solar collectors and Storage Tank, integrated to existing Water Heaters



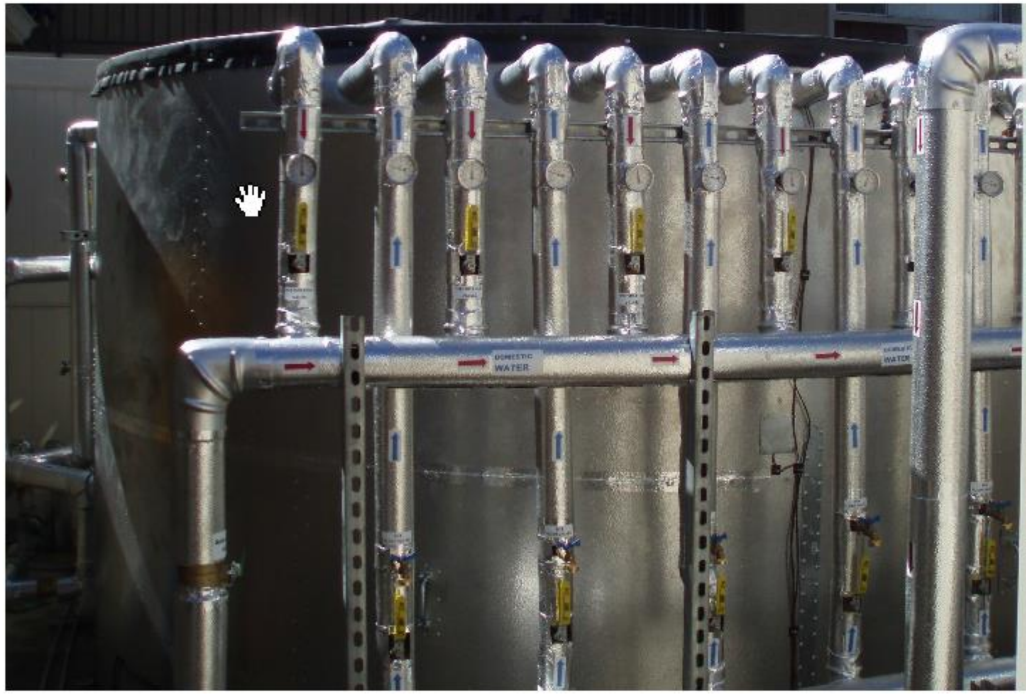
Solar Thermal System Sequence of Operation

1. The sun shines on the collector(s). The collector(s) heat up.
2. The sensor mounted on the collector sends a temperature signal to the pump controller.
3. The controller receives the temperature signal from the collector sensor and compares it to the temperature of the tank sensor.
4. If the temperature of the collector is 15°F or more higher than the bottom of the tank, the controller turns on the pump.
5. This cycle continues until the solar storage tank has reached its maximum set temperature of 140°F.
6. When the maximum solar tank temperature is reached, the controller turns off the pump and all the heat transfer fluid (water) drains out of the collectors and back into the solar storage tank.

Courtesy: Arnold Solar Inc

Solar Thermal Tank and Heat Exchangers

Controller



Heat Exchanger with Temperature Gages

Heat Exchangers
304 SS 1"Dia.x100ft each
Corrugated, immersed

Courtesy: Arnold Solar Inc

Evacuated Tubes & Underground Hot Water Piping

Courtesy: SCE

- Pipe special ordered
- Rigid insulation to withstand the weight of the ground.
- Protective layer moisture barrier is water tight; against the corrosion from soil.
- Contribution to savings estimated **1/3** by reducing distribution loss
- Contribution to savings estimated **2/3** from solar thermal

Solar Thermal Savings

- » Estimated indirectly from gas reduction, not normalized
  - Bldg.'s 1/2/3 compared with itself, before and after
  - Bldg.'s 1/2/3 compared against similar Bldg.'s 4/5/6
  - Feb-June 2016 (post-retrofit vs. 2015 (pre-retrofit) is 1,275 Therms
- » A rough estimate of annual savings, 1,275 * (12mo/5mo) = **3,060** Therms/yr

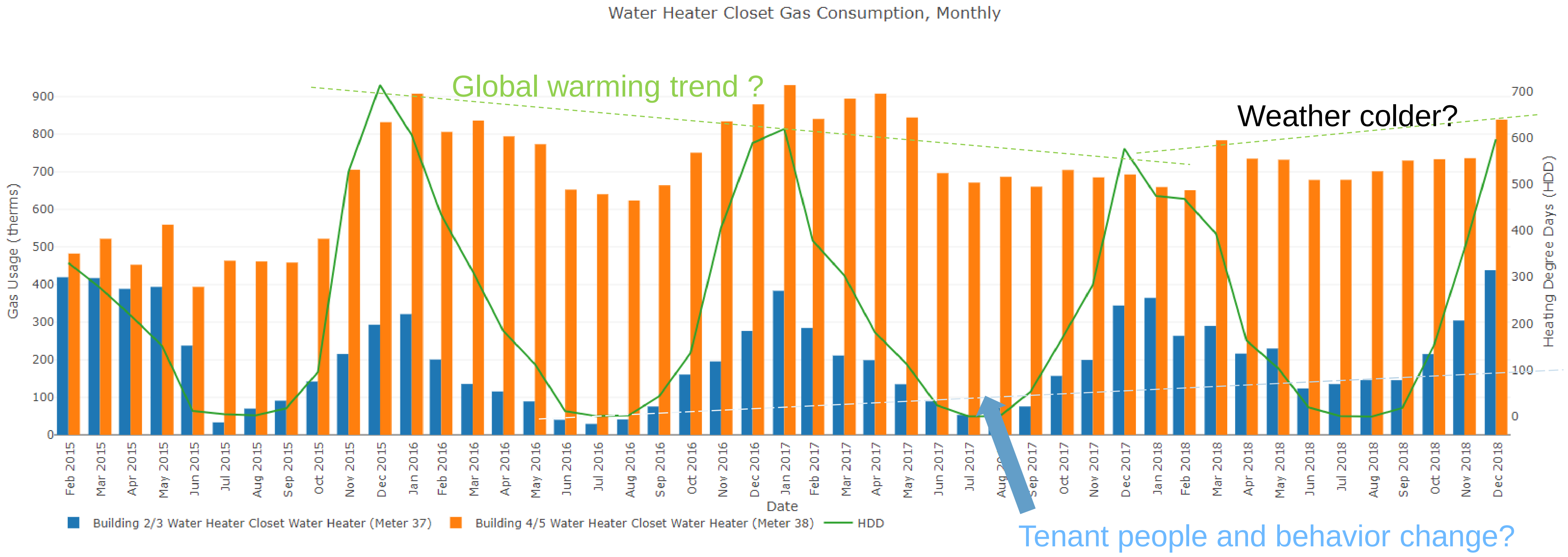
  Assume 1/3 by pipe insulation; 2/3 by solar thermal is ………………….. **2,040** Therms
- » So happened to be close to what CSI model estimated ……………….… **2,182** Th/yr

- » Simple payback, with CSI incentives, $41k / $2,040 = **20.1** years
- » Deduct federal tax credit 30%, net owner's cost $14,101 / $2,040 = **6.9** years

- » As an arbitrary comparison, if natural gas costs the same as electricity per Btu
  - Assume Electricity/Natural Gas cost ratio 3
  - Simple payback = 6.9 / 3 = **2.3** years

Monthly Savings, Comparing 2 Building Clusters

Blue: Cluster 1/2/3 Orange: Cluster 4/5/6

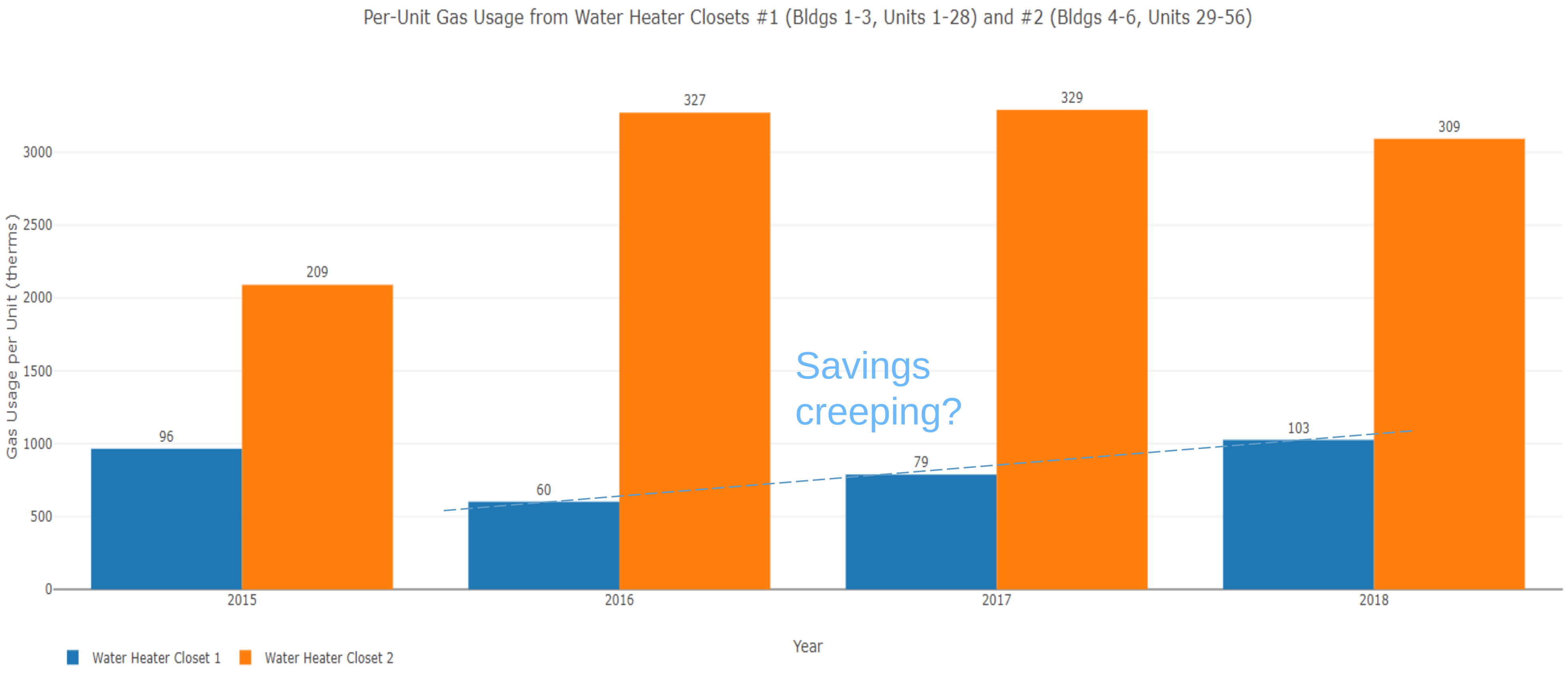


Note: No HDD normalization was performed.

Comparing Two Building Clusters

Average Per MFR Dwelling Unit Water Heating

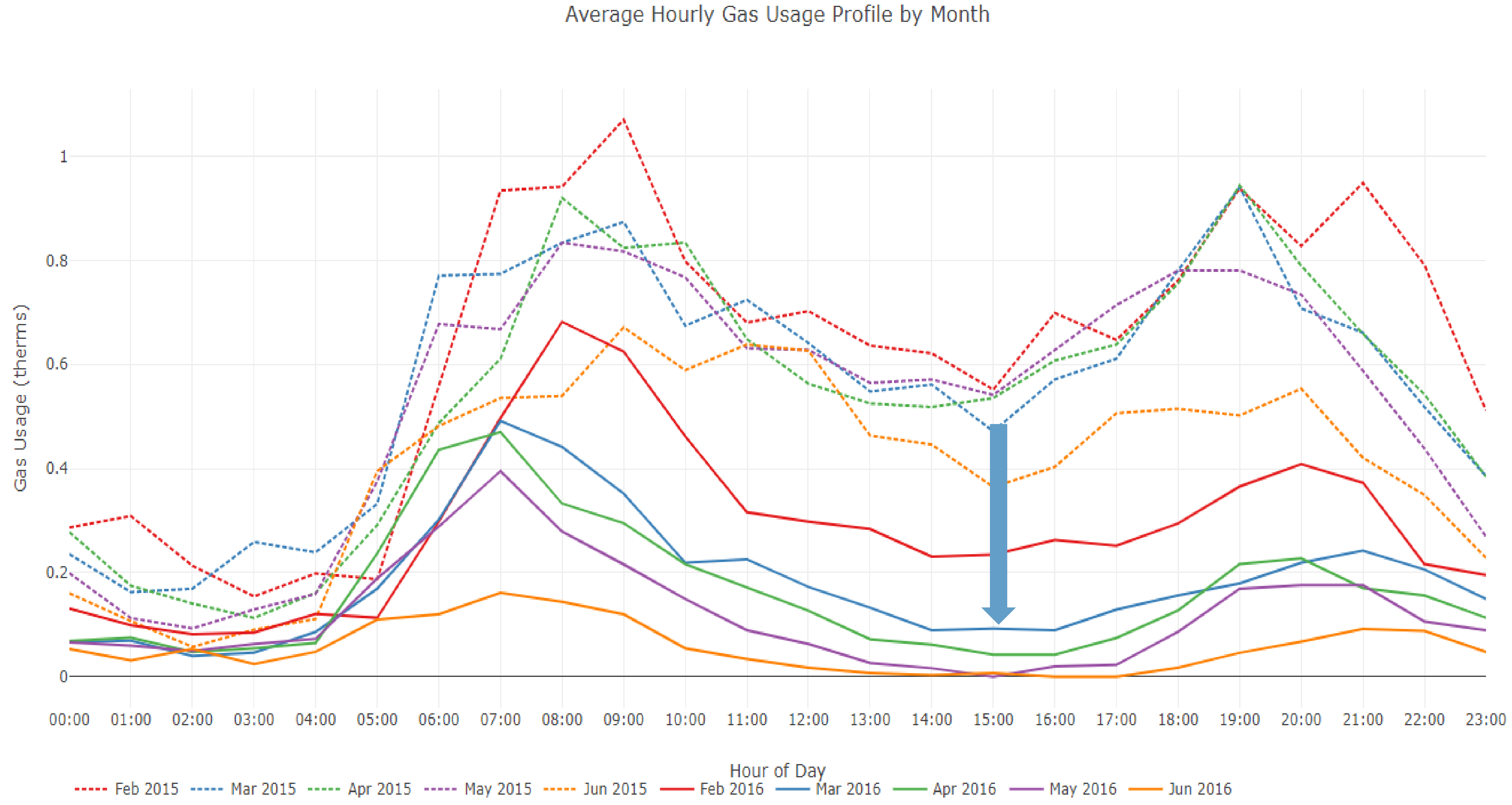
Blue: Cluster 1/2/3   Orange: Cluster 4/5/6



- Before: 3X of the CA RASS model, 110 th/yr/unit
- After: in line and lower
- What is changing?
  - HDD
  - Occupancy
  - Behavior

Comparing with Itself - Bldg. 1/2/3 Hourly Natural Gas Use Profiles

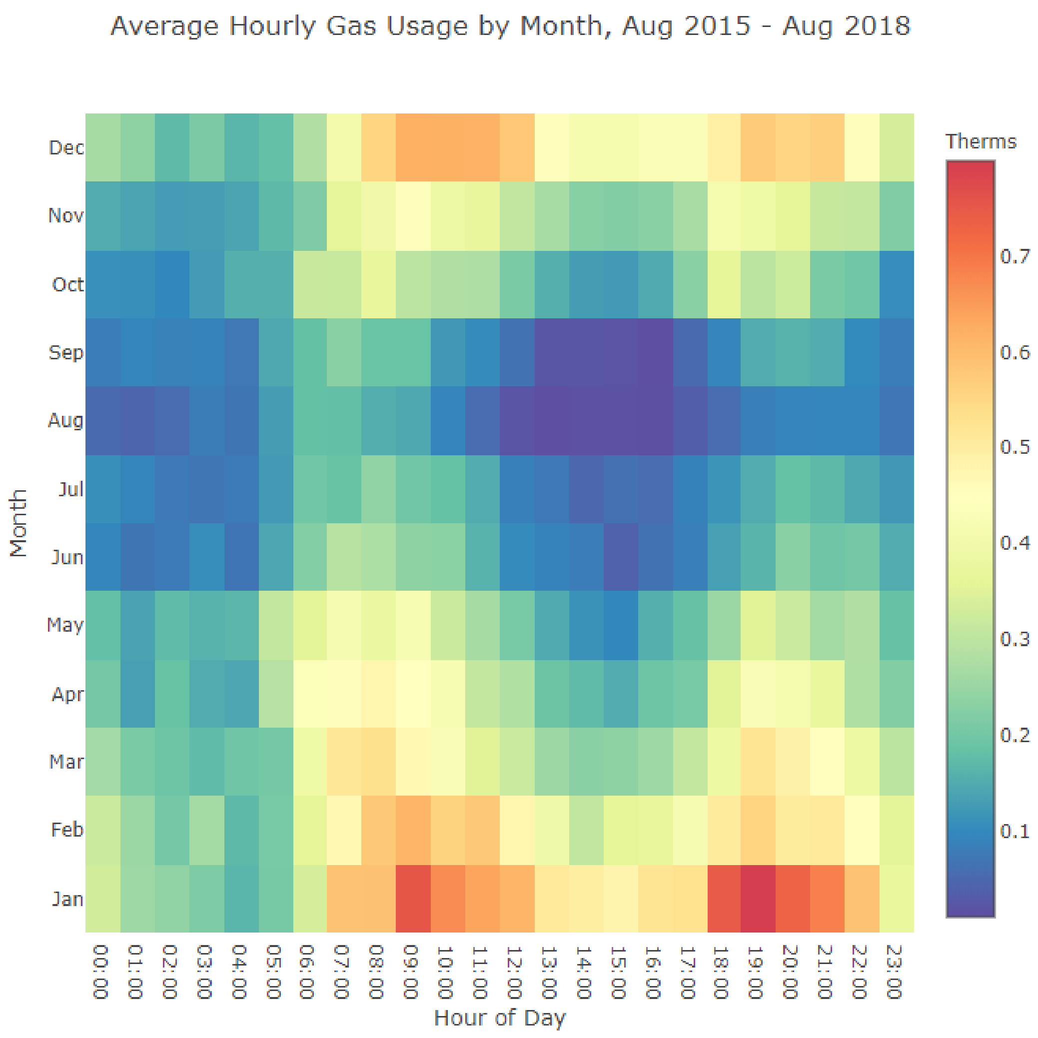
Dashed line = Before solar thermal (2015); Solid line = With solar thermal (2016)



- Two daily peaks around 9 a.m. and 8 p.m., a typical tenant behavior
- Large savings post retrofit is obvious

Heat Map, Average Hourly Natural Gas Usage by Month

Building Cluster 1/2/3

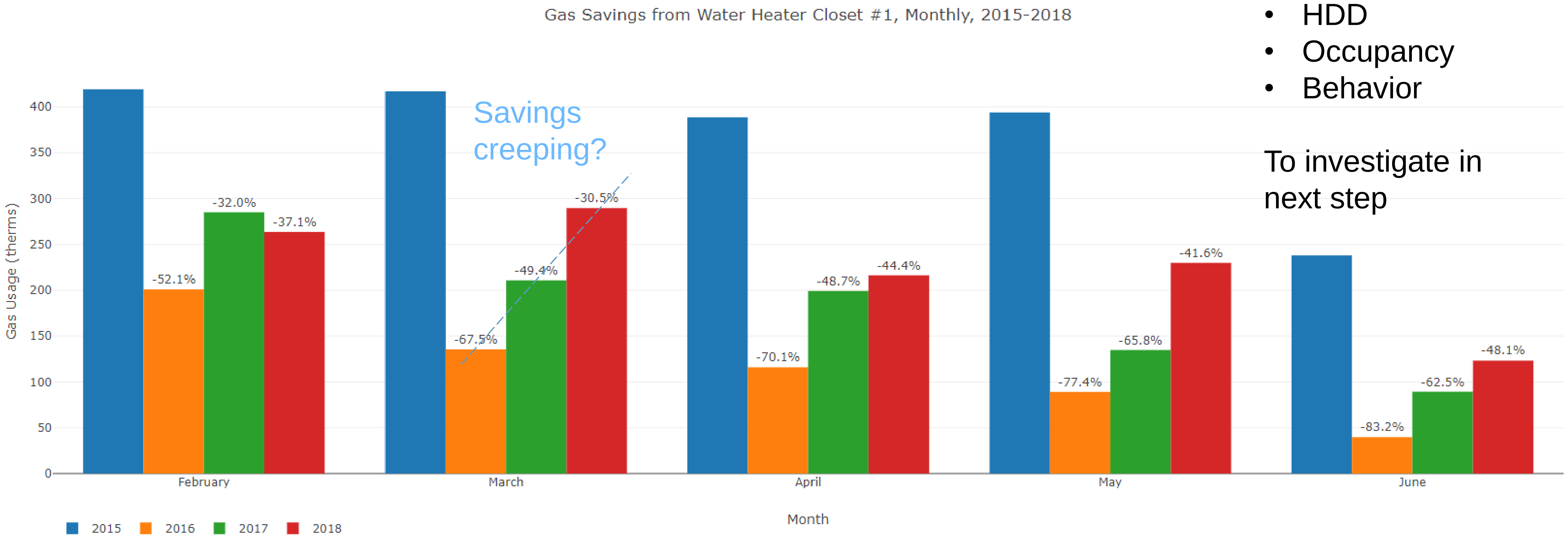


Aug 2015 – Aug 2018, after solar thermal was installed

- There is a morning (about 9 a.m.) and evening peak (about 7 p.m.)
- **Seasonality:** January experiences the highest usage. The natural gas usages gradually decrease into summer and goes back up in autumn.
- Expect ~1 Therm/home in So Cal average single family. ½ for multi-family.

Comparing with Itself in Different Years

Building Cluster 1/2/3
Energy Savings, Feb through June
Before retrofit, baseline is 2015



What is changing?

- HDD
- Occupancy
- Behavior

To investigate in next step

Market Potential

A. Typical natural gas end use for the CA RASS report
B. MFR population in the SoCalGas service area
C. Potential MFR units

   assume 10%,186,000
D. Avg. 206 Th/unit/yr savings in Bldg. 1/2/3

   (309-103=206 Slide #22)

The potential is large

   206x186,000=38.3 MMTh/yr

End-Use	UEC	Saturation	Intensity
Therms			
Normal Weather	2009	2009	2009
Space Heat	121	95%	115.0
Water Heat	110	79%	86.9
Cooking	26	81%	21.1
Clothes Dryer	30	38%	11.4
Spa Heat	99	2%	2.0
Gas Barbeque	14	8%	1.1
Gas Fireplace	16	8%	1.3
Total			238.7

Dwelling Type	2009 RASS Total Sample Count	2009 Mkt Share
Single Family	3,912,905	92%
Multiple Family	1,861,248	90%
Total	5,774,153	92%

Lessons Learned for Solar Thermal Retrofit

- The roof area is large enough for solar thermal to reduce at least one-half of the natural gas use. Sizing correctly.
- Ground space is necessary for tanks
- Central plant has benefit of scale and diversity
- Solar evacuated tube system is reliable - 3 year experience
- The actual output may exceed what CSI model estimated
- Key to success: Simplicity in controls; quality installation; training
- Long term monitoring and verification to sustain savings

Think Again the Roles of CSI Program for the Industry

Solar Thermal Installed Cost Structure 2015

Schedule of Value

Description	Value
12 - Sunrain Model TZ 58/1800-30R collectors	$ 14,400.00
1 - 1200 gallon STSS solar storage tank W/4 SS HX	$ 18,000.00
direct Labor	$ 20,300.00
domestic manifold and pump station	$ 5,000.00
Engineering and permitting	$ 3,500.00
Slab and Fence	$ 9,000.00
Electrical circuit	$ 1,000.00
Travel cost	$ 6,000.00
System monitoring	$ 1,500.00
BOS	$ 7,728.00
Sales Taxes	$ 3,552.00
Totals	$ 89,980.00

$1,200 ea. Avg.

Courtesy: Arnold Solar Inc.

What the Future Holds

A Random Glance of a 2019 Listing on Internet

Click image to open expanded view

XXX Solar 30 Tube Water Heater Collector Slope Roof Frame Evacuated Vacuum Tubes SRCC Certified Hot

by Duda Solar

Be the first to review this item

Price: $1,546.55 & **FREE Shipping**

Pay **$148.85 per month or less** in 12 monthly payments (plus S&H + tax). Learn more

Size: **30 Tube**

15 Tube | 20 Tube | 25 Tube | **30 Tube**

Color: **Slope Roof**

Installation options: **Get expert installation** Details

Without expert installation | Expert installation **+$396.80** per unit

See more

- Hailstone Resistance: up to φmm (1"), Max Operating Pressure: 87psi, Max Flow Rate: 5.25 gpm
- 14mm TU1 Copper Heat Pipes, Manifold insulation: 45mm 93 Kg/m^3 Rockwool, Rated Best Heat Retention
- φ58mm x 1800mm Three-Target Cu/SS-ALN(H)/SS-ALN(L)/ALN Vacuum Tubes, High Boron Silicon 3.3 Glass
- Sun Absorption Efficiency: 93-96%, Vacuum Rating: Less than 5.0 x 10^3 Pa, Lifespan:70% @ 15 Years
- OG-100 SRCC Certificate Number: 10001880, Eligible for 30% Federal Tax Rebate, Winter Resistant

Per panel material cost

$1,200/ea.(2015) $1,547 (2019)

…Equivalent to a 6.5% inflation

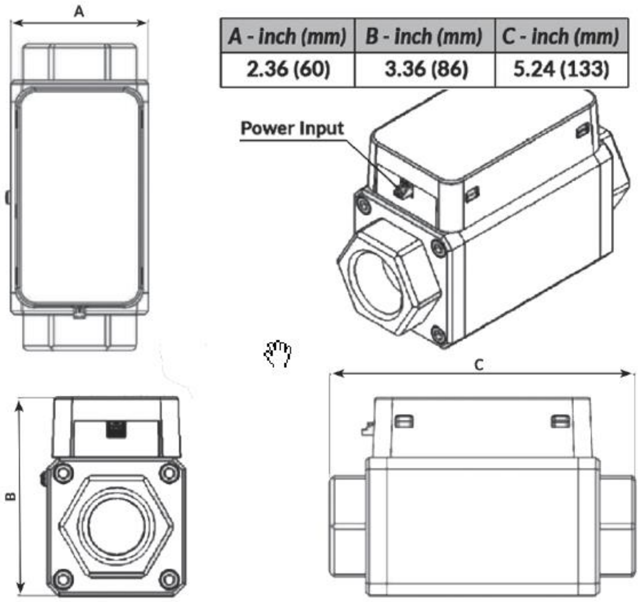
Not an apple-to-apple comparison.

Uncertainties and variables:

- Equipment price may become more competitive? Similar to the solar PV price trend? Trump tariff impact?
- Inflation - certain
- Labor and integration costs
- CSI rebates going away?

Next Steps

- To reconcile with direct M&V data stored in the Cloud with the indirect method using natural gas sub-metered data
- A behavioral study is on-going, led by EPRI
  - Natural gas submetering: Additional compact and low cost real-time flow meters are used for selected end users
- SoCalGas is continuing the AMI meter data gathering support till the end of 2019
- Deep retrofit may be replicated in other locations
  - Long term owners/operators, such as LINC
  - Public sectors



A - inch (mm)	B - inch (mm)	C - inch (mm)
2.36 (60)	3.36 (86)	5.24 (133)

Q&A

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Project Overall Lessons Learned
for Owner & Contractors

- Deep retrofit improves quality of life for tenants, as learned from interviews
- Specialty contractor is chosen to perform the work, it is critical to the success
- It is imperative that qualified PM is onsite while all critical work is being performed
- Older buildings are in dire need of energy upgrades, in addition to costly hazardous (lead, asbestos, mold) material remediation
- Use a pilot and research phase to discover unknowns and allow adjustments and control of the surprises and costs
- Modeling is a robust tool; and peer review is necessary
- It is hard for an HVAC team used to 5 ACH50 to make 3.5ACH50.

Miscellaneous Overall Projects Lessons Learned

- HVAC & Envelope Upgrade Side benefits: Indoor air quality can improve, tenant satisfaction can increase dramatically, and tenant turnover may decrease. Property value increases.
- Similar benefits in hot water services: larger storage capacity and faster recovery
- Tenant education is needed for advanced thermostats
- Maintenance crew training is needed for specialty systems
- Tenant education is needed to know ZNE does not always equal to no utility bills.