FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

A Research Institute of the University of Central Florida

FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

Side by Side Testing of Water Heating Systems

Residential Energy Efficiency Stakeholder Meeting Austin , Texas

March 1st, 2012

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Hot Water Systems (HWS) Laboratory
FSEC Cocoa, Florida

2009 –Present (Currently in third testing rotation)

FSEC

Building America U.S. Department of Energy — Partnership for Improved Residential Construction — BA-PIRC

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Underground Circulation Loop

Solar Systems were evaluated under long plumbing conditions

- Solar circulation Loop 140+ feet of ½” copper tubing
- Encased in PVC tubing with R-2.4 insulation
- ICS to 50 gallon storage tank path need to overcome 70 ft travel.

Electric and Natural Gas Hot Water Baseline Systems

2009 – 2010 Testing rotation (Phase I)

Hot Water Systems (HWS) Laboratory
Improved HW systems

2010 – 2011 Testing Rotation (Phase II)

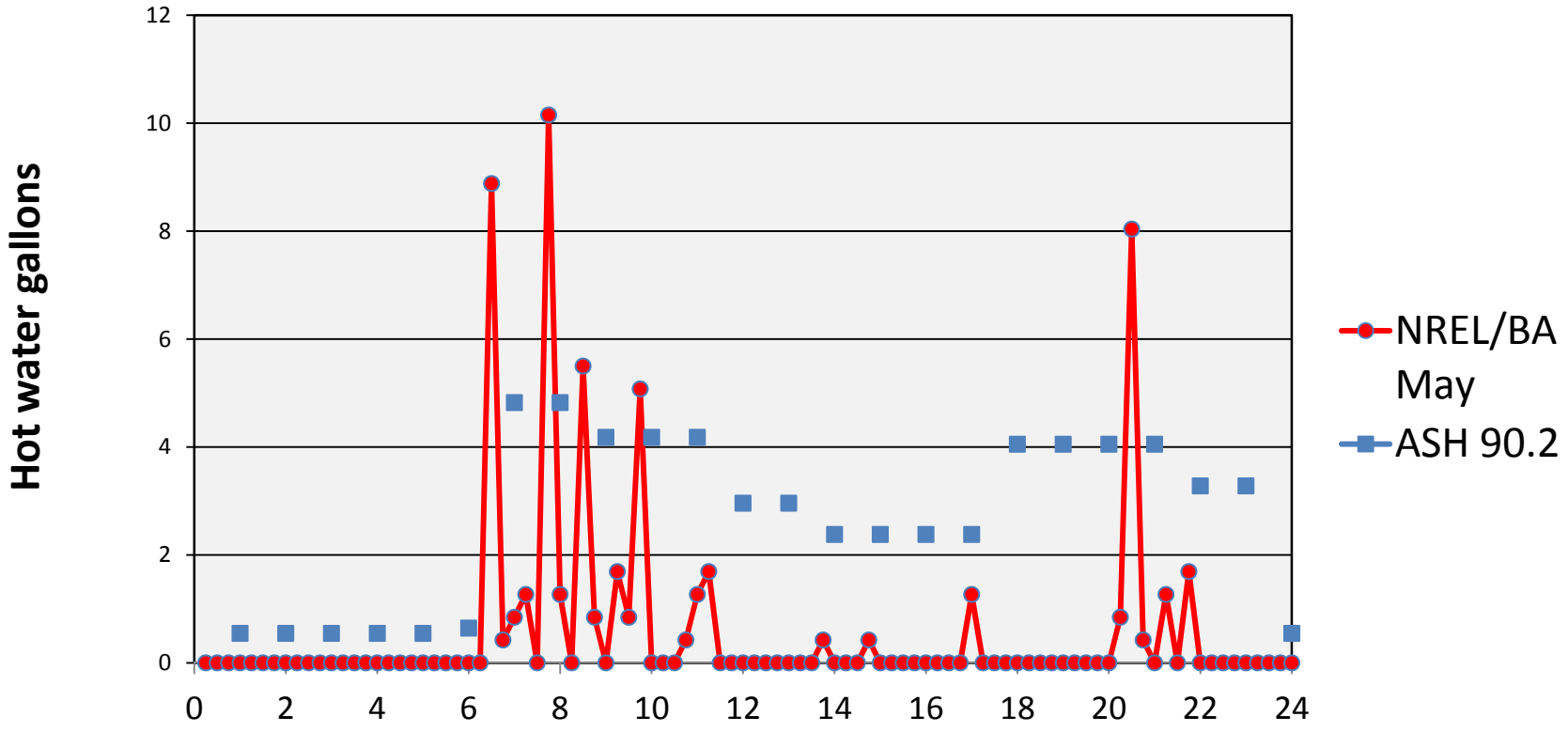
Review of Energy Factor Test Conditions

- 24 hour test, six draws totaling 64.3 gal/day
- Thermostat set to 135^{o}F (+/- 5 ^{o}F)
- Ambient test conditions at 67^{o}F
- Inlet water temperature of 58^{o}F
- Hot water draws at a rate of 3 gallons per minute (3 gpm)

HWS Lab Testing Conditions

- All systems thermostat set for hot water delivery of 120 ^{o}F
  - Solar systems utilize Mixing Valve
- Flow rate of 1.5 gallons per minute (gpm)
- Real mains inlet city water temperatures (Cocoa, FL)
- Ambient conditions in shed can exceed typical garage temperatures (six storage tanks together)
- Programmed Hot water draw schedules - alternated every two weeks (Ashrae 90. 2, NREL/BA)

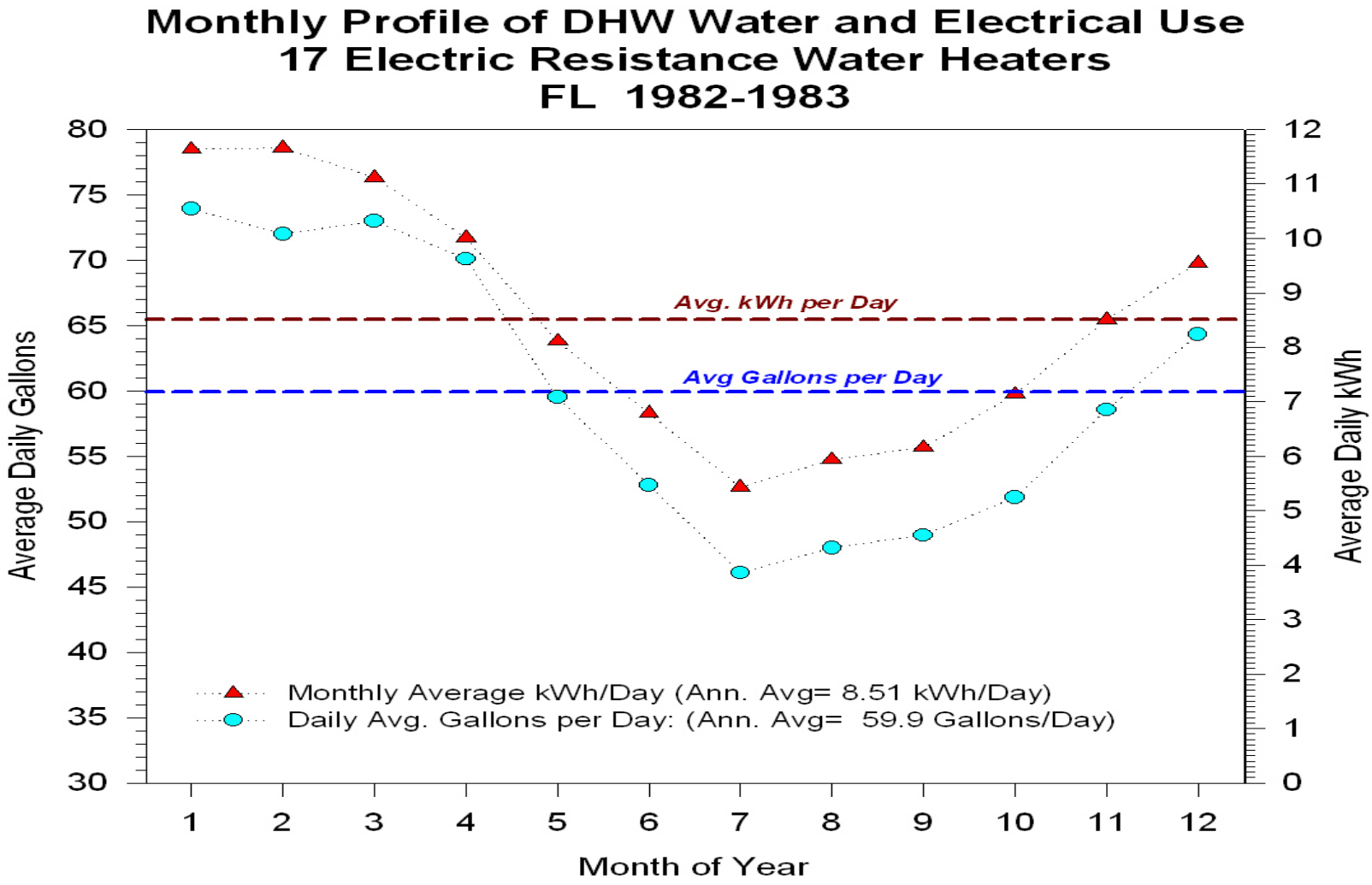
Two Hot Water Draws Compared



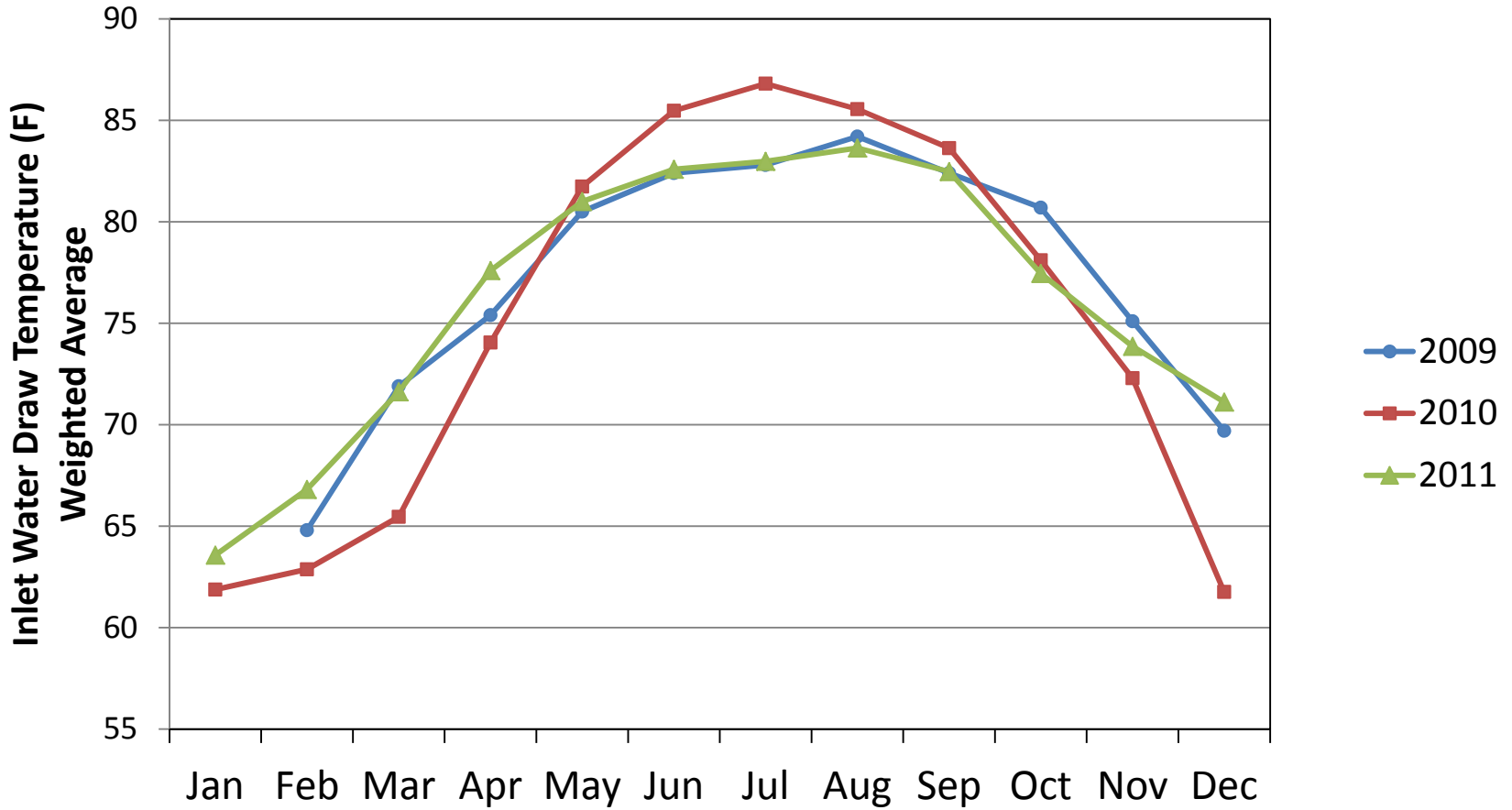
ASHRAE 90.2 Remains unchanged all year 64.3 gallons per day

Origins of NREL/BA Draw Schedule

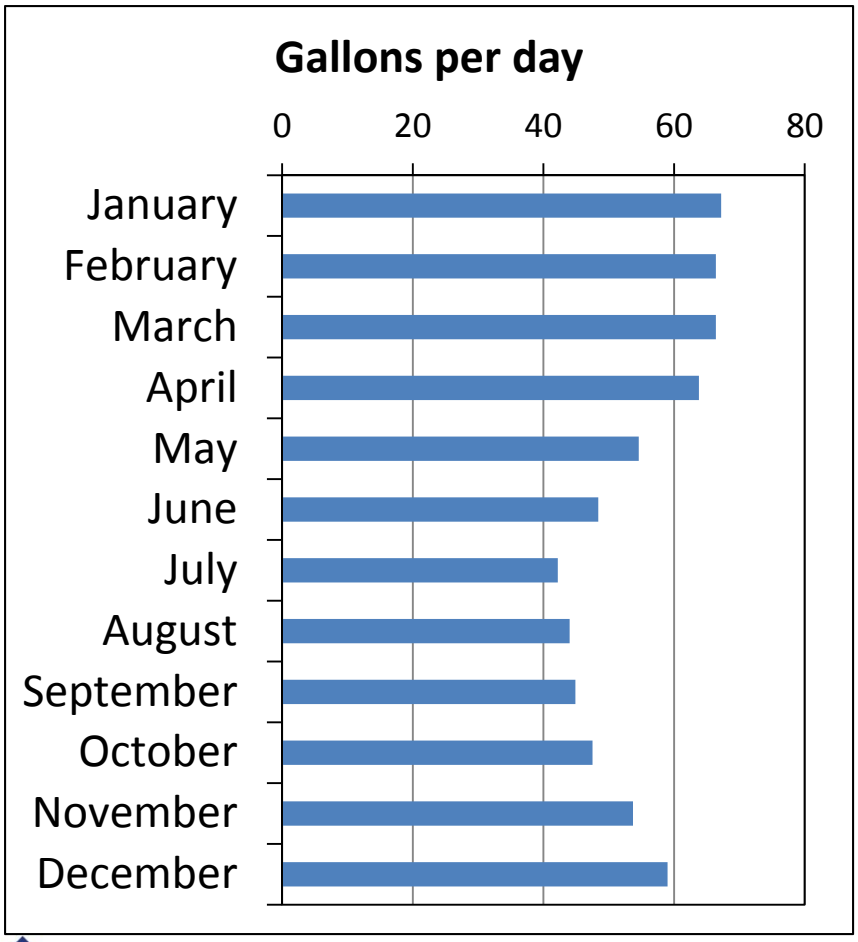
- NREL – Building America Research Benchmark guidance (Paper by Hendron, Burch) http://www.nrel.gov/docs/fy08osti/40874.pdf
- Created by a software tool (DHW Calc) developed by the Kassel University, Germany
- Adjusted monthly based on data obtained from a field study (1986) of 16 sites monitored throughout Florida - 3.5 person household avg.


Monthly Profile of DHW Water and Electrical Use
17 Electric Resistance Water Heaters
FL 1982-1983
Average Daily Gallons
Average Daily kWh
Avg. kWh per Day
Avg Gallons per Day
Monthly Average kWh/Day (Ann. Avg= 8.51 kWh/Day)
Daily Avg. Gallons per Day: (Ann. Avg= 59.9 Gallons/Day)
Month of Year

Weighted Average Inlet Water Temperatures at HWS Lab (Cocoa, FL)

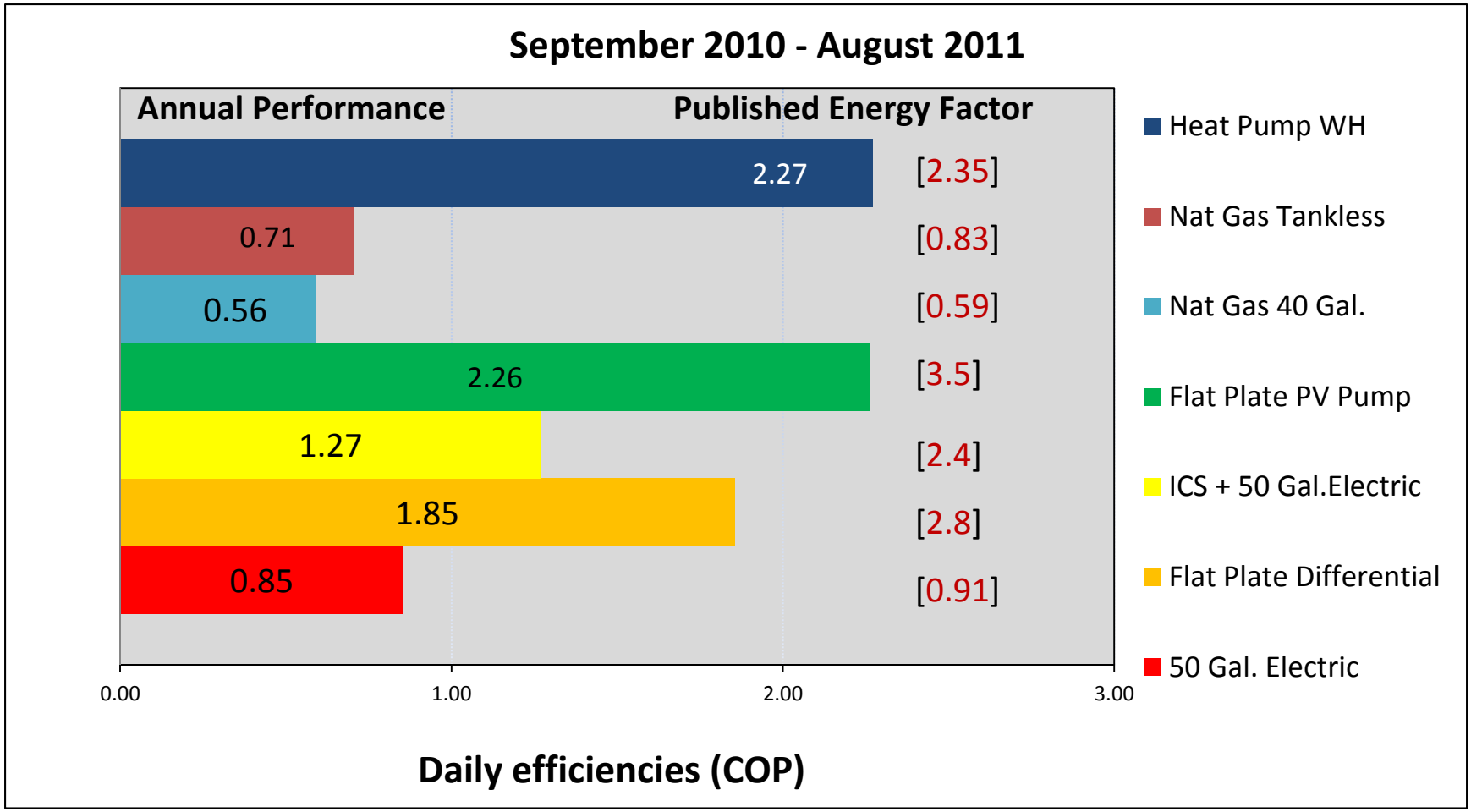


NREL/BA Draw Profile

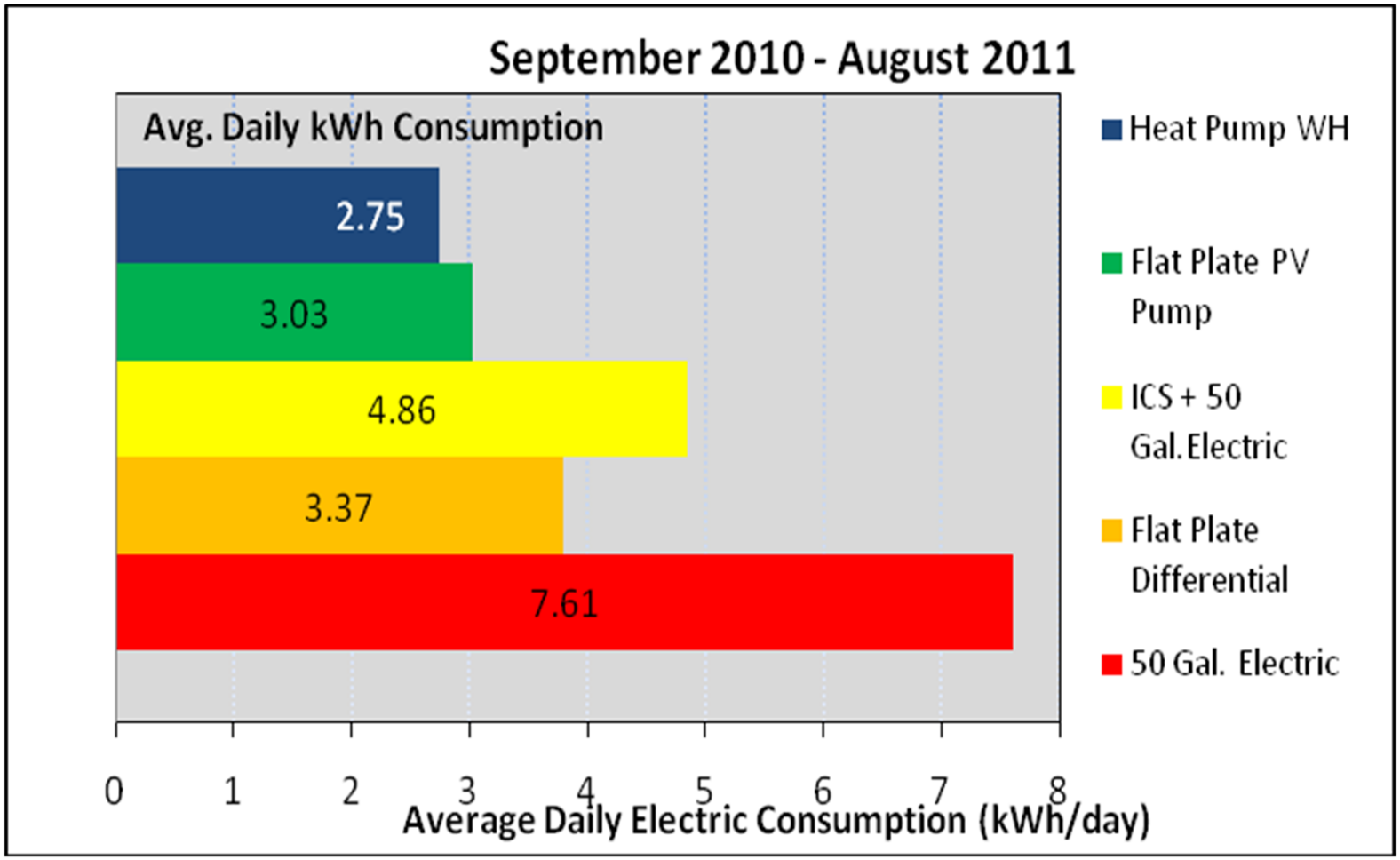


January	67.2
February	66.4
March	66.4
April	63.8
May	54.6
June	48.4
July	42.2
August	44
September	44.9
October	47.5
November	53.7
December	59

Combined Draw Performance



Average Daily Electric Energy Use

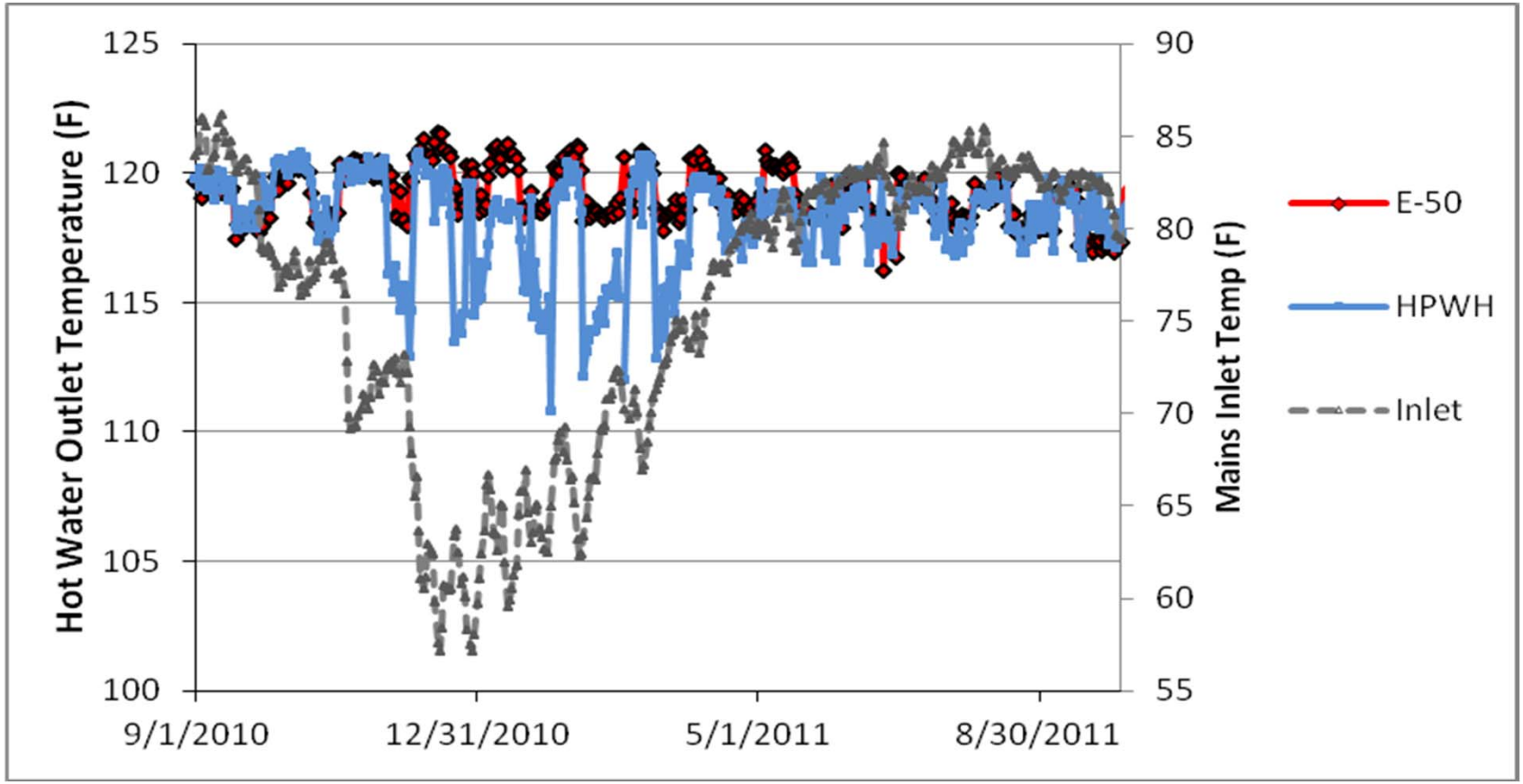


Average Hot Water Draw Temperatures

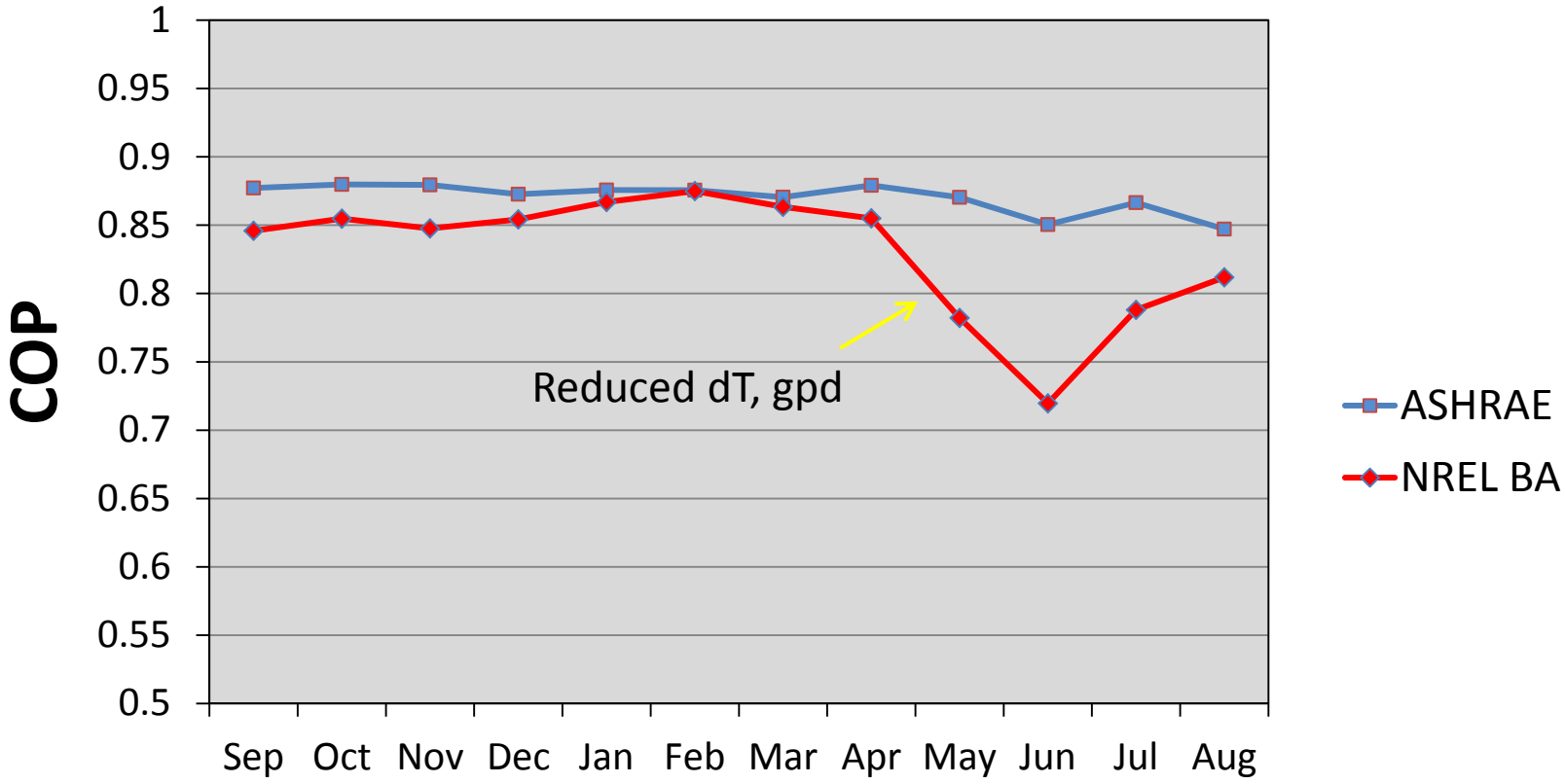
	All Draws (°F)	NREL/BA (°F)
Electric 50 gal.	119.4	118.4
FP 80 Diff. control	118.2	116.4
ICS+ 50 gal. WH *	121.7	119.3
FP 80 gal. PV Pump	122.4	122.1
NG 40 gal.	123.7	122.2
Tankless NG	116.6	117.0
HPWH	118.1	116.9

* Hard to achieve on a Std. electric 50 gal. w/single upper element. Seasonal thermostat adjustment was required

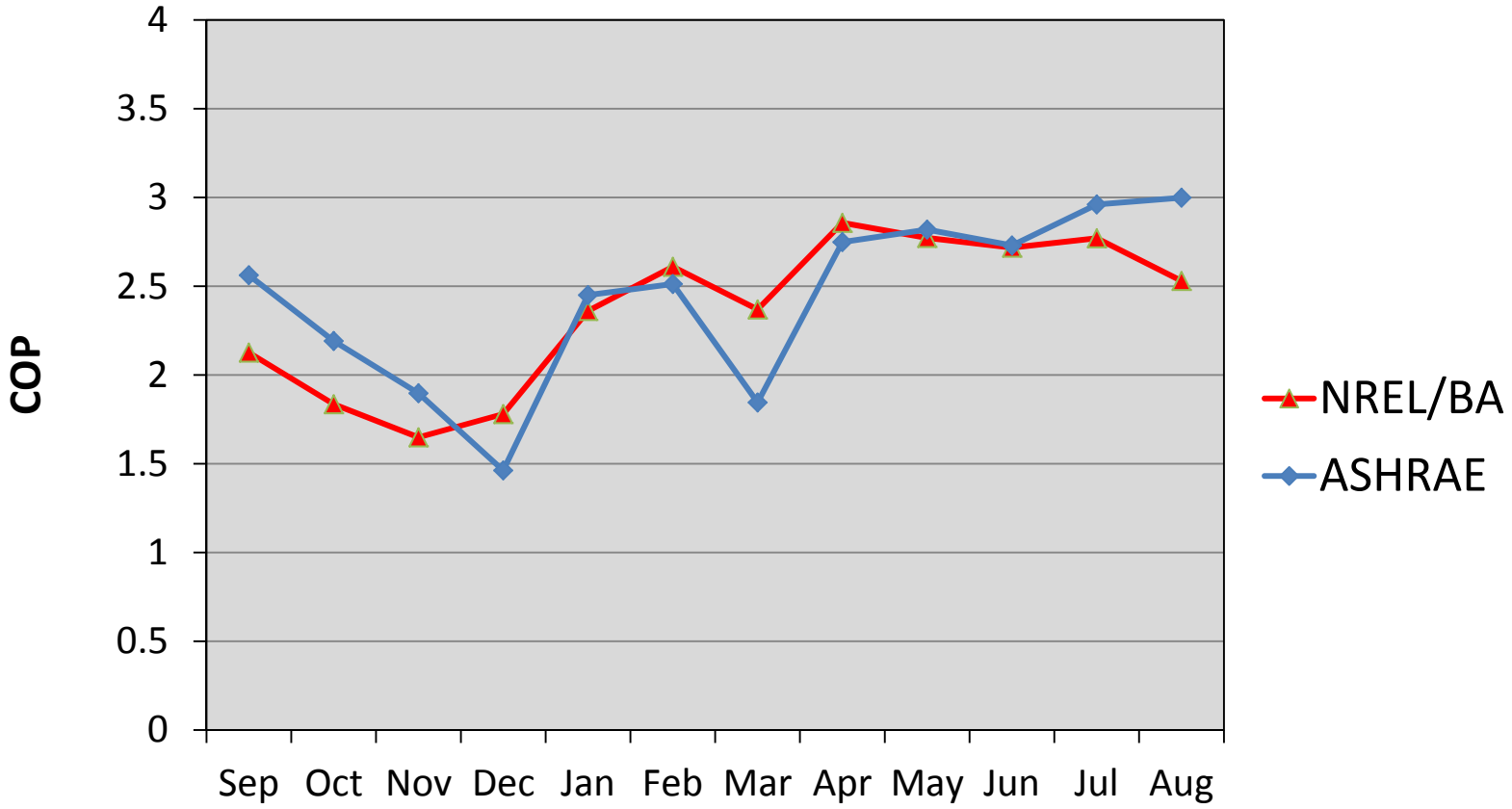
Standard Electric vs HPWH
Outlet temperatures compared



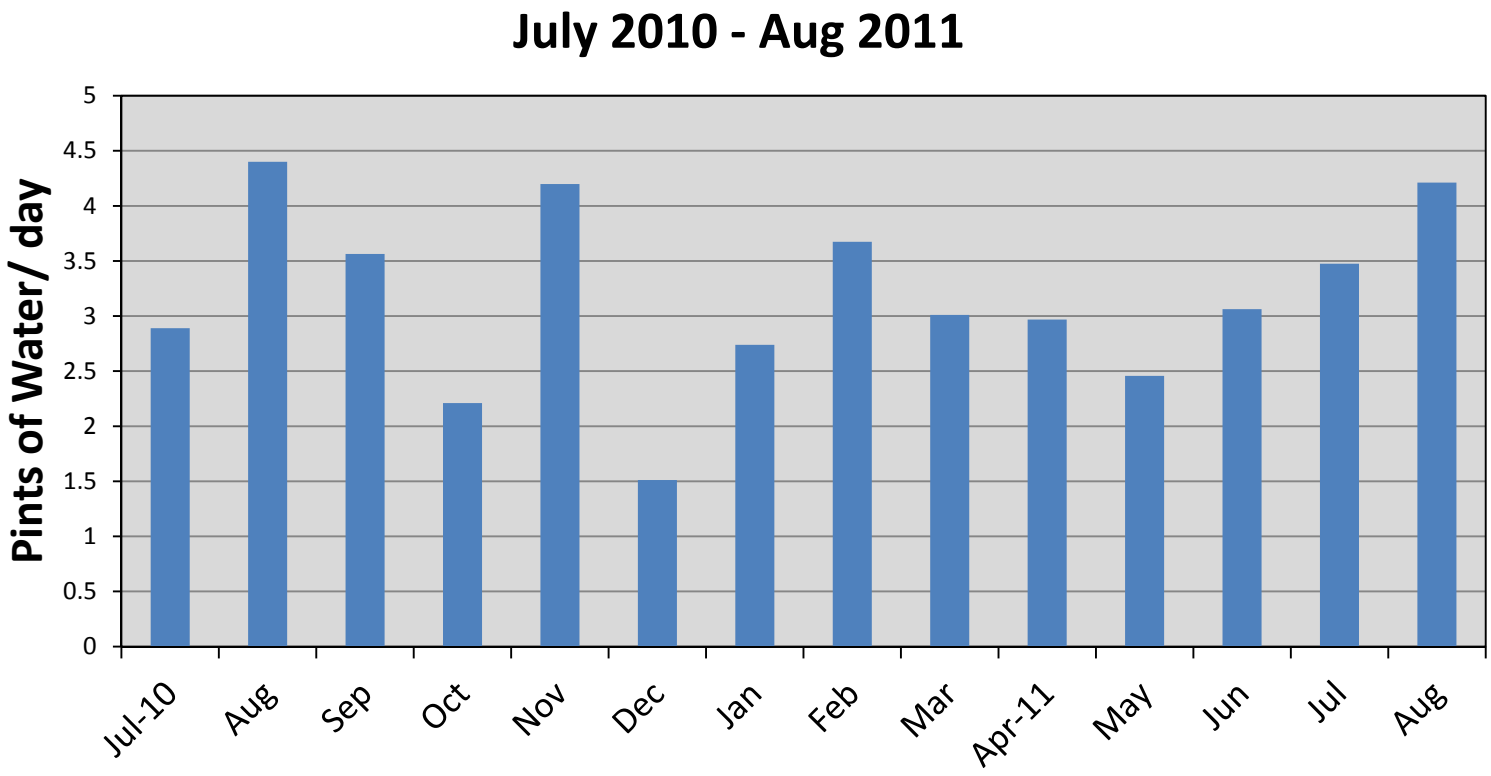
Std. Electric 50- Gallon Water Heater Efficiency



50-Gallon Heat Pump Water Heater Efficiency

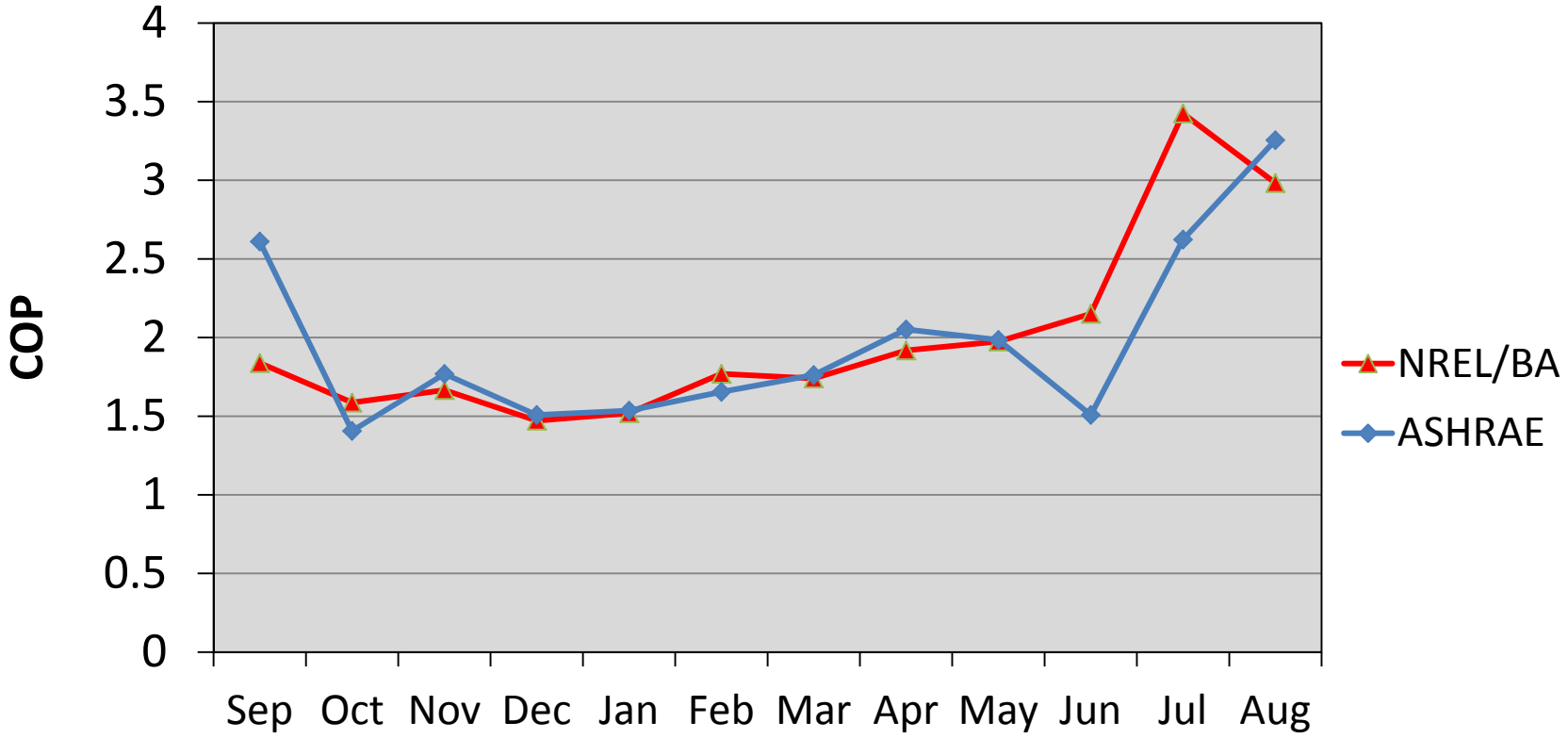


50-Gallon Heat Pump Water Condensate

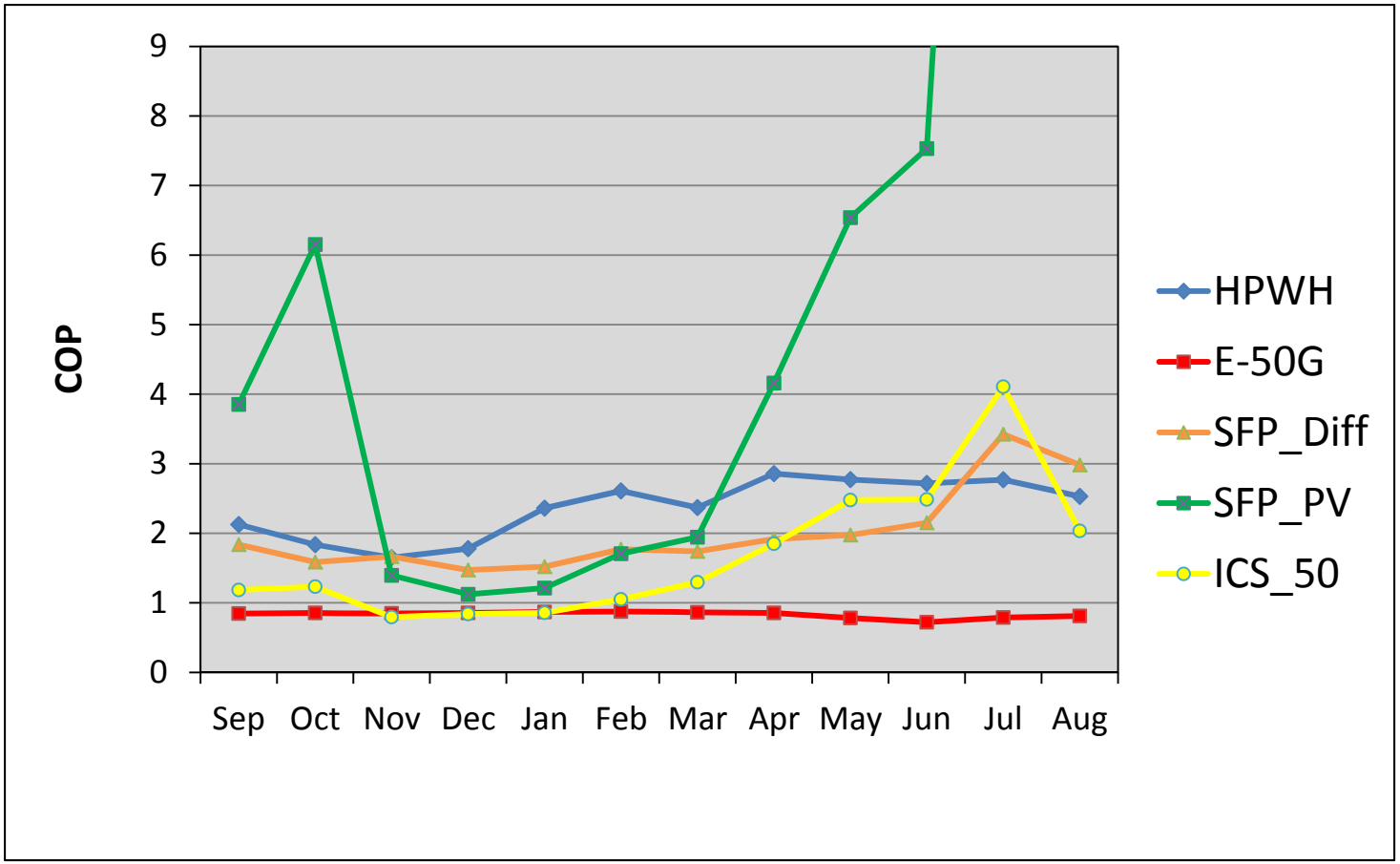


Average = 3.2 pints/day

Solar Flat Plate 40/80 gal (Diff.-controlled AC Pump) Efficiency

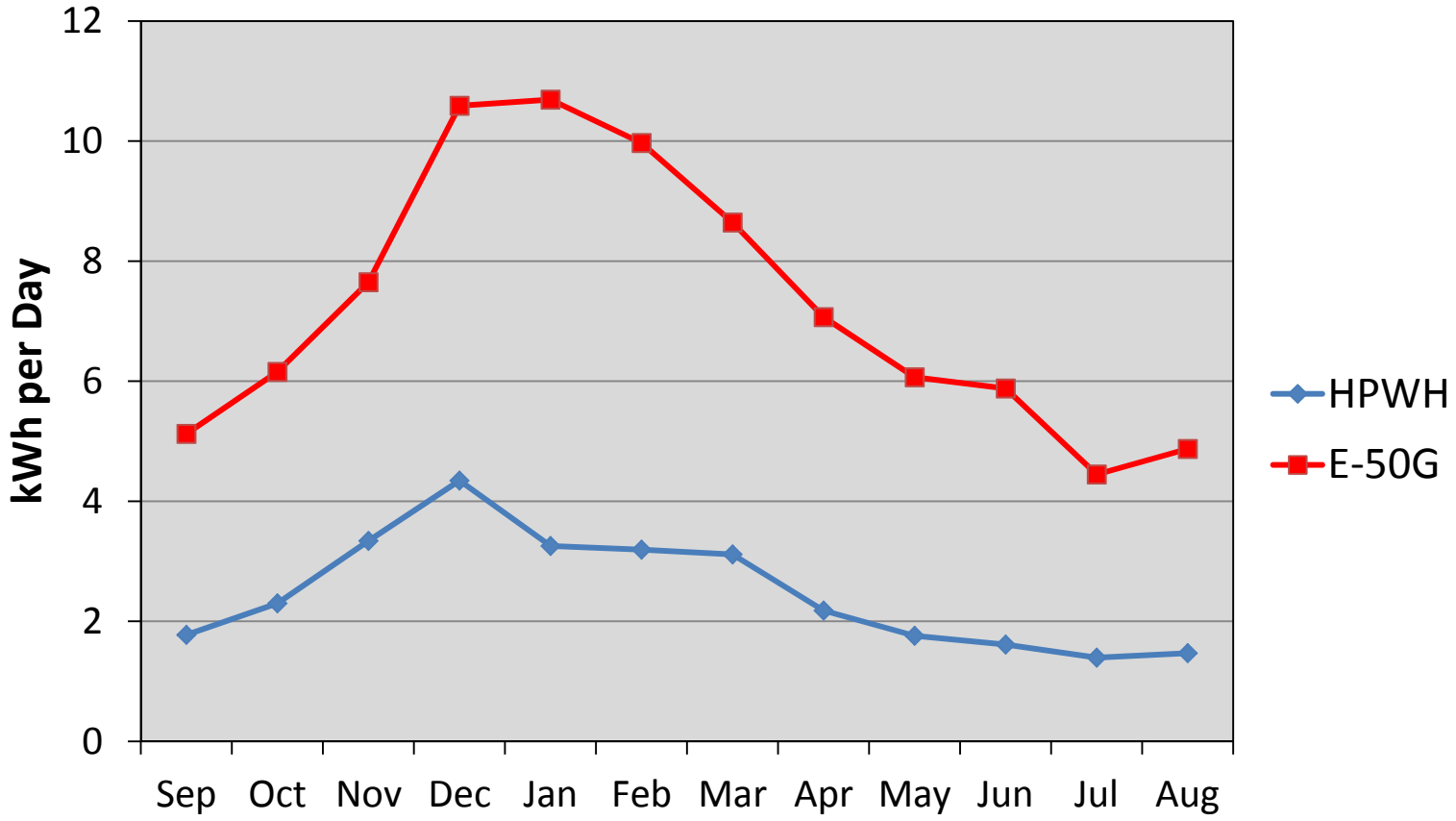


Efficiencies Compared under NREL/BA Draw Schedule



Average Month Electric Consumption under NREL/BA Draw Profile

Std. Electric vs HPWH 50 Gallon



Breaking the Recommended Rules on Appliance Installation

Current Case Scenario:

700+ units - HPWH
Confined in >100 ft^3
Quasi-vent Closet

Laboratory Test Results:

14.3% Electric increase

12.8 % COP reduction

0.93 ^oF Hot Water outlet temperature reduction

Energy Savings Electric Systems

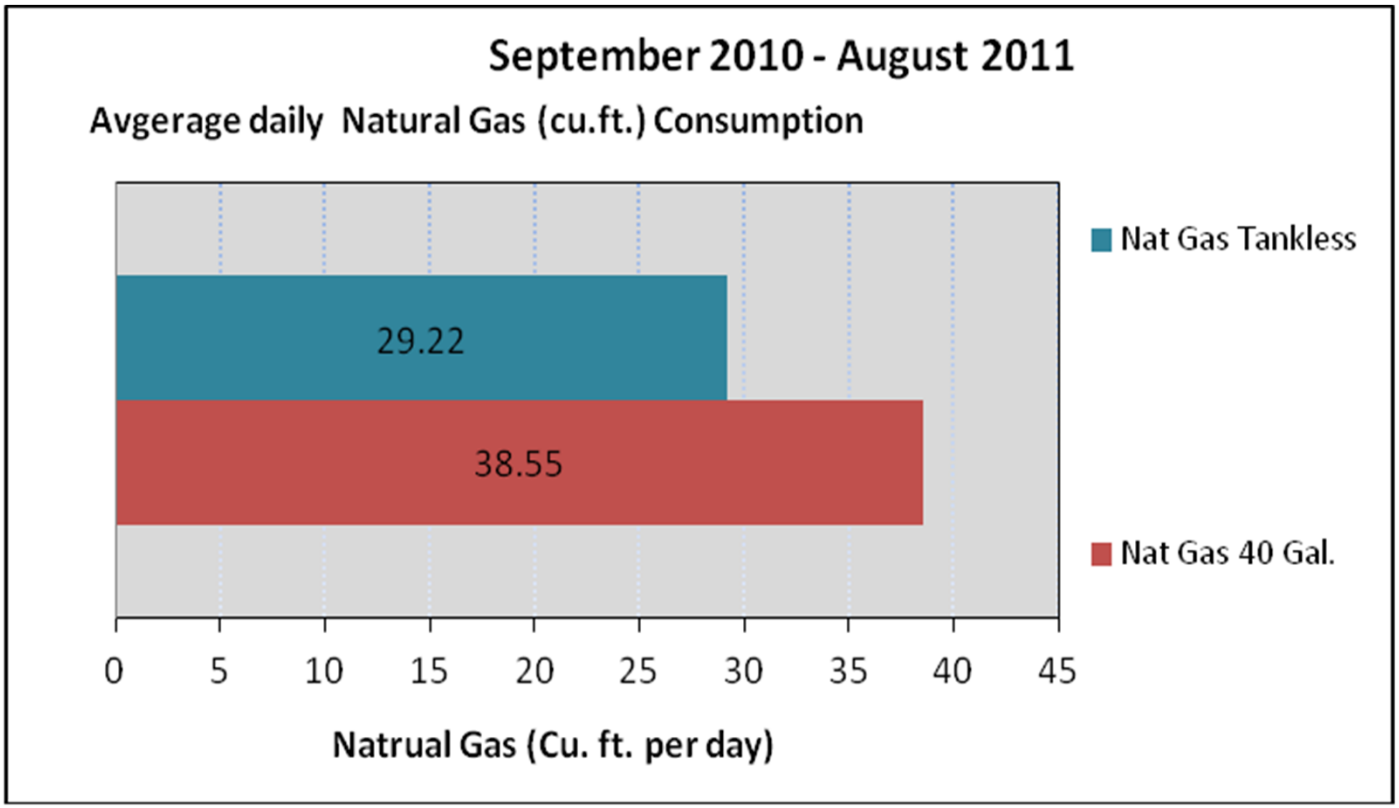
2009-2010 Testing Rotation

	ASHRAE 90.2	NREL/BA
Solar Flat Plate Differential w/80 gal. tank	62.7%	61.2%
ICS w /50 gal. tank	39.2%	26.3%
Solar Flat Plate PV pumped w/80 gal. tank	60.7%	59.4%
Tankless Electric	6.9%	5.1%

2010 -2011 Testing Rotation

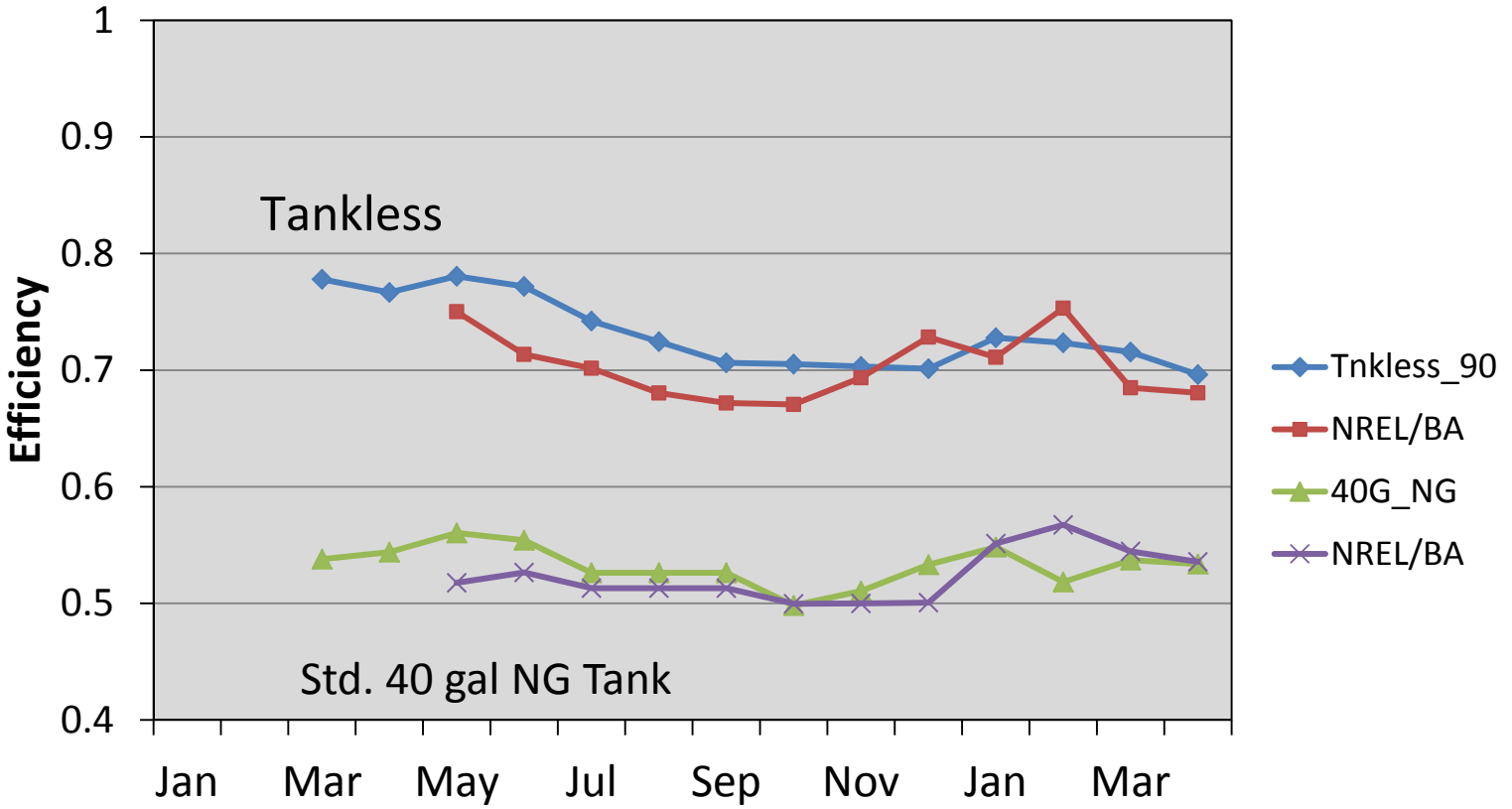
	ASHRAE 90.2	NREL/BA
Solar Flat Plate Differential w/80 gal. tank	55.0%	54.4%
ICS w /50 gal. tank	34.6%	36.6%
Solar Flat Plate PV pumped w/80 gal. tank	60.4%	59.4%
HPWH	61.4%	66.8%

Natural Gas (NG) Tank vs Tankless



Tankless vs Std. 40 Gallon Natural Gas

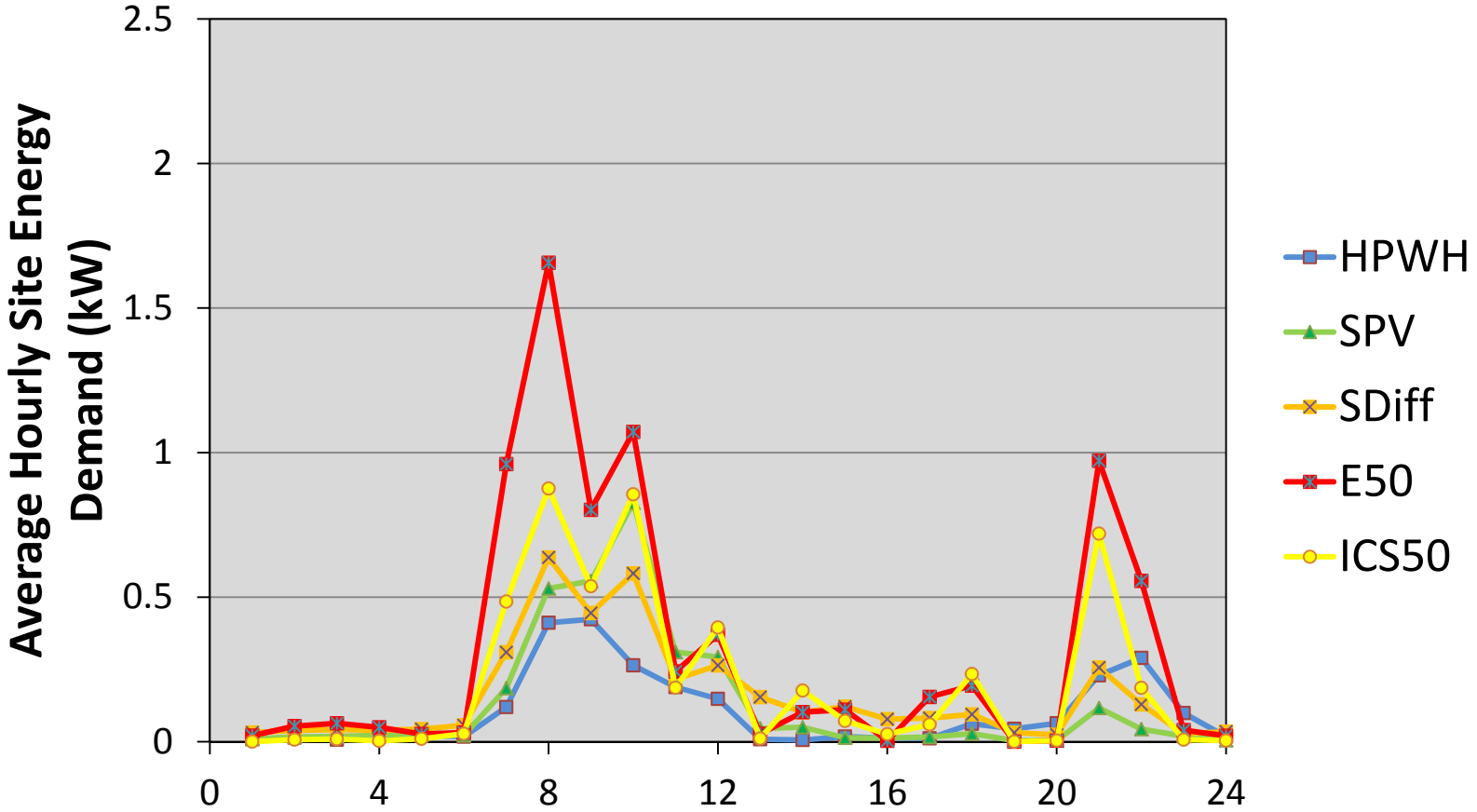
2009 -2010



Energy Savings of Tankless Natural Gas Water Heater

	ASHRAE 90.2	NREL/BA
Tankless Natural Gas	23.5%	26.9%

Time of Day Demand under NREL/BA Draw Schedule

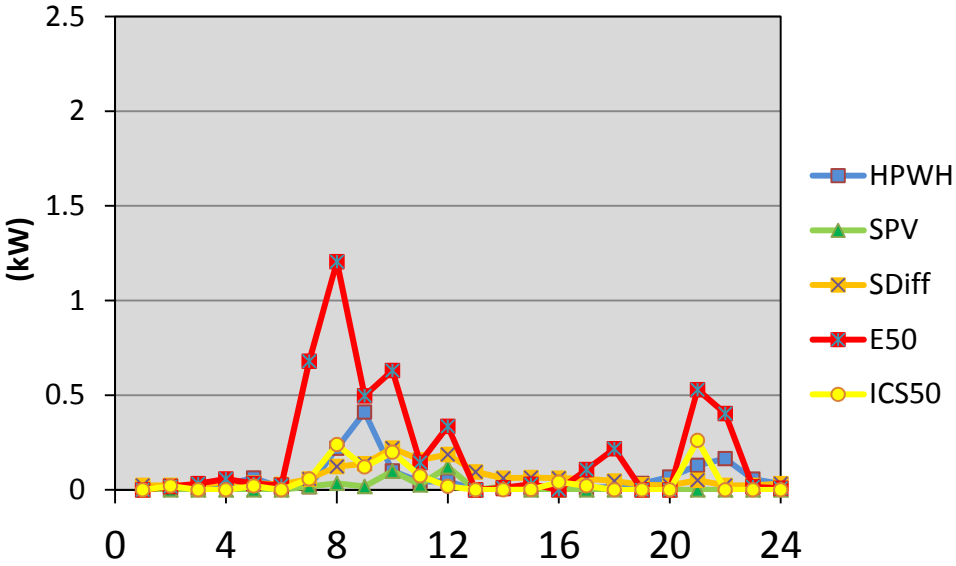


Peak Demand Reduction

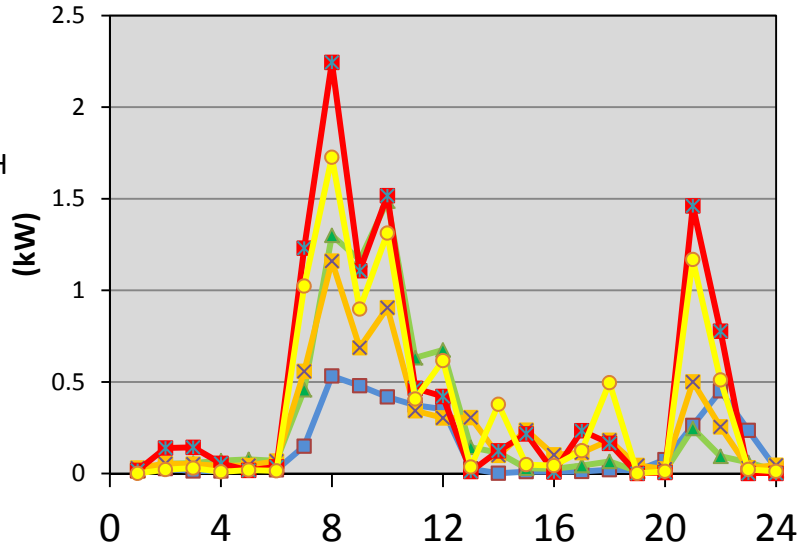
	NREL/BA schedule (Sep. 2010- Aug 2011)		Winter Season (Dec. 2010 – Feb 2011)		Summer Season (June – Aug. 2011)	
	Morning 8:00 AM	Night 9:00 PM	Morning 8:00 AM	Night 9:00 PM	Morning 8:00 AM	Night 9:00 PM
Diff. Solar	61.5%	73.6%	48.3%	65.8%	89.8%	90.4%
ICS/50 gal	47.1%	25.9%	23.0%	20.0%	80.1%	50.7%
Diff. PV	68.0%	**88.0%**	42.1%	**83.2%**	**97.1%**	**100%**
HPWH	**75.1%**	76.3%	**76.3%**	82.0%	81.8%	75.6%

Time of Day Demand under NREL/BA schedule

Summer Electric Demand

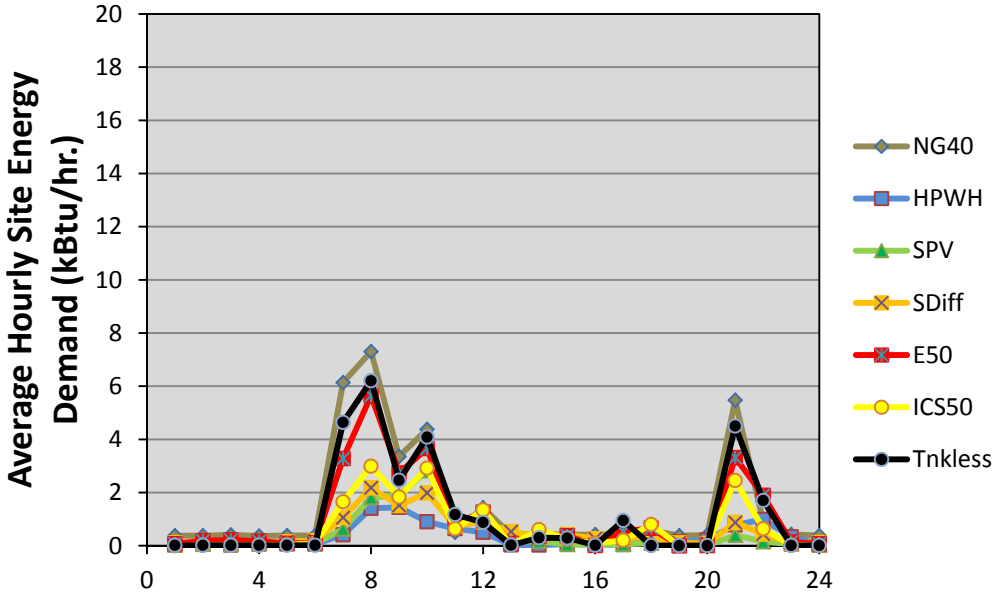


Winter Electric Demand

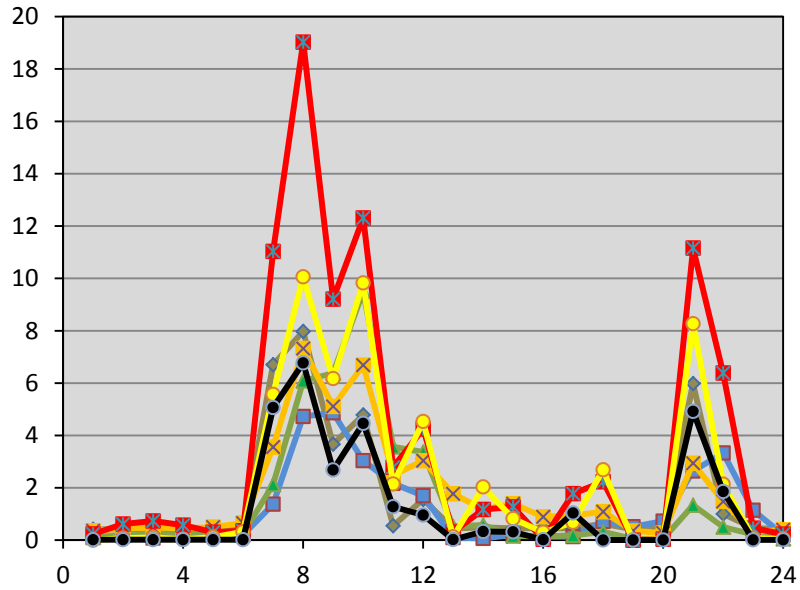


Site and Source Demand

Site Energy Demand



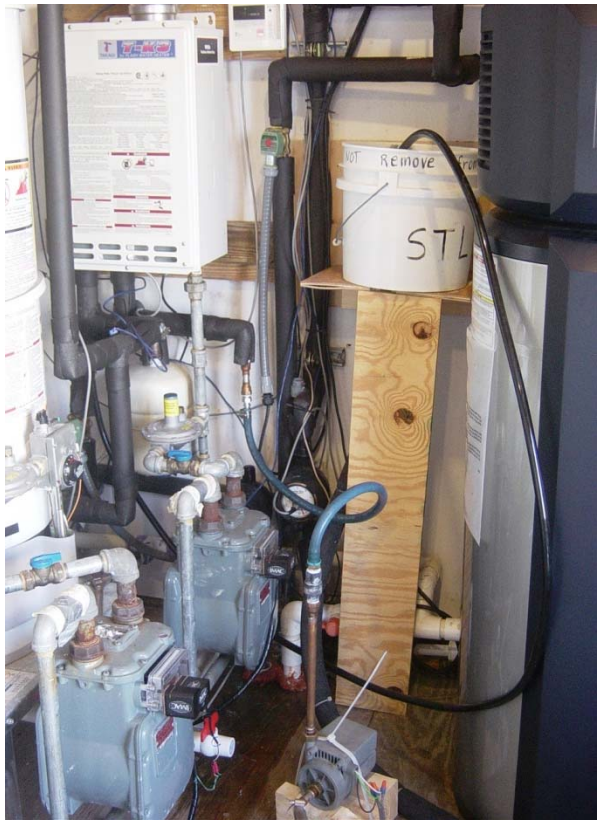
Source Energy Demand



Multiplier Factors: Me = 3.365 , Mg = 1.092

Gaps and Barriers in Residential Water Heating Appliances

- This presentation addresses the difference between ratings (EF) and operating efficiencies (FL region) for Residential water heating systems
- Storage vs Tankless difference on immediate delivery of hot water at draw events.
- Data reveals lower than expected operating efficiency of natural gas tankless at 1.5 gpm draw.
- Higher efficiency comes at a premium ($)cost
- Comfort: HPWH recovery might be an issue on high dynamic draws (Winter)



Tankless Vinegar Flush

Flush Debris:
No efficiency Improvement detected

Anode rod replaced on solar thermal 3 Years

Gaps and Barriers in Residential Water Heating Appliances

- Results of testing/evaluation brings up the subject of residential energy modeling
  - Is EF best metric to use as input parameter ?
- Maintenance & Reliability
- Solar Acceptance &Installation Cost
- With improvement and availability of HPWH (EF>1.5)
  - Gradual phase out of resistance element ?
- New Energy Factors for 2015 – How will they fare under field and testing evaluations?

Moving Forward to Investigate and Demonstrate Higher Efficiencies

www.infomonitors.com/HWS

Nat. Gas Tankless Condensate

Hybrid Solar Thermal/Nat. Gas

Hybrid Heat Pump/Solar

Innovative Low Cost Solutions

FSEC

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The End

We hope you have enjoyed the highlights/results of our work

Thank You!

Questions / Discussion

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Partnership for Improved Residential Construction

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