FLORIDA SOLAR ENERGY CENTER

A Research Institute of the University of Central Florida

Let the Sunshine In: Rating Solar Water Heating and Photovoltaic Systems

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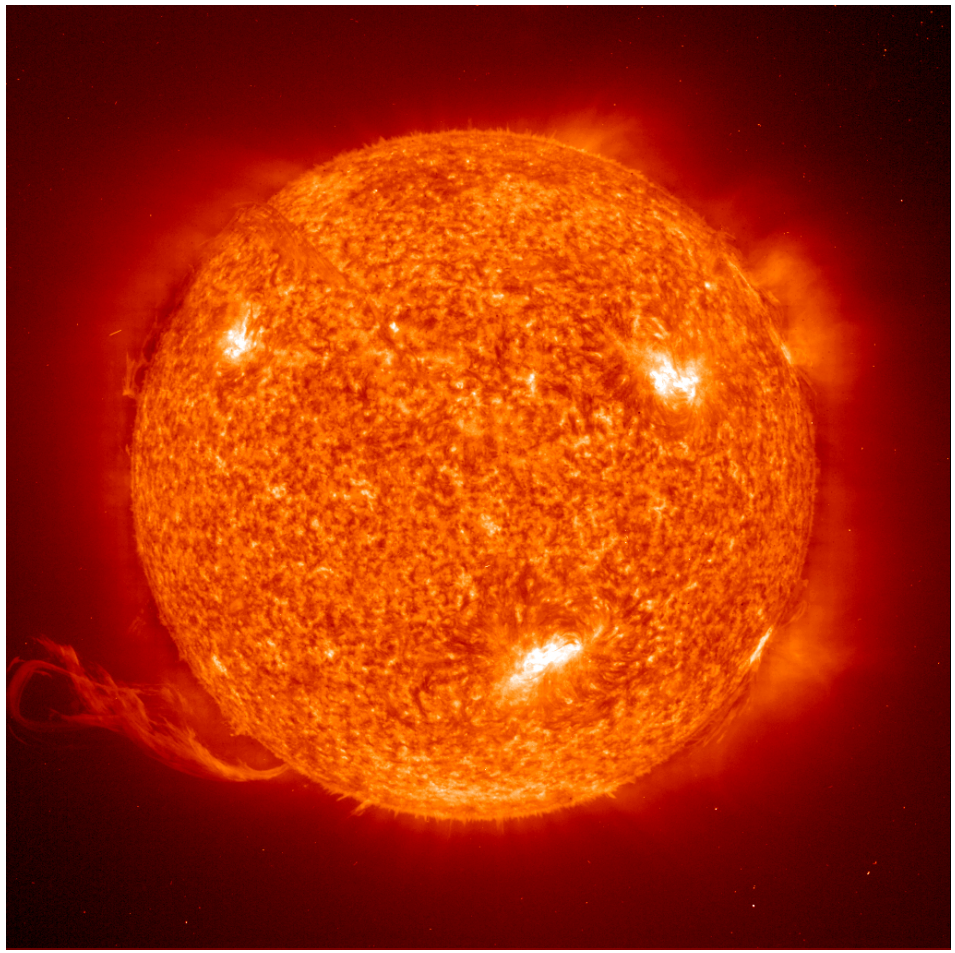
RESNET, March 2004

How to get a hold of the sun?

For ratings . . .

Why rate the sun?

- Solar water heating is effective around the U.S.
- Solar electricity (photovoltaics or PV) is more common
- Both have large potential with very efficient homes



Solar Water Heating

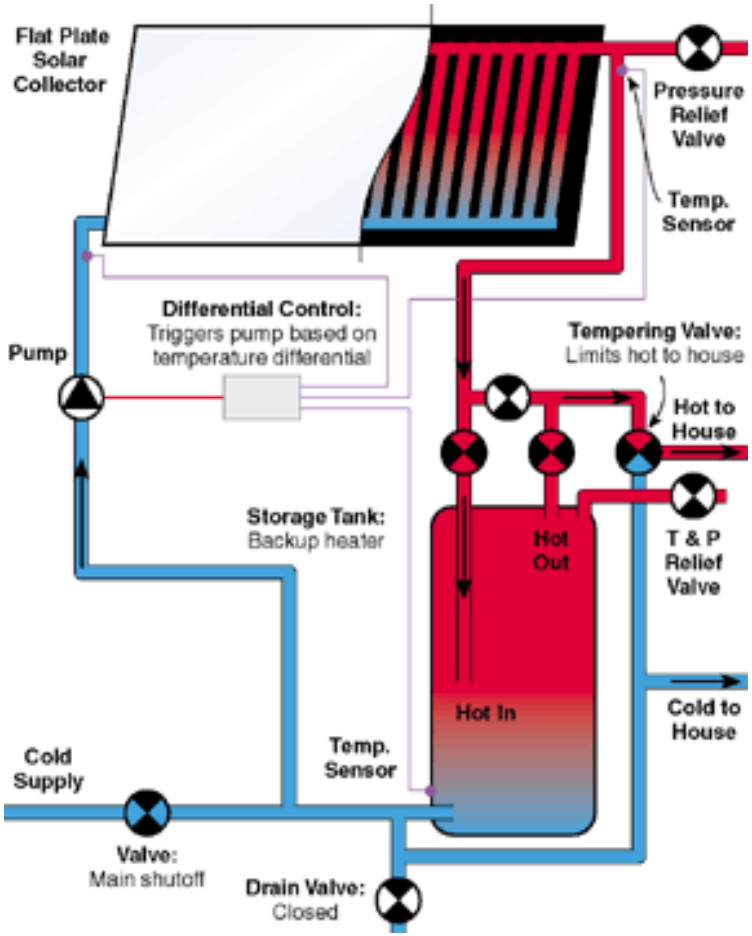
Popular Myth:

Solar hot water systems are non-cost effective dinosaurs.

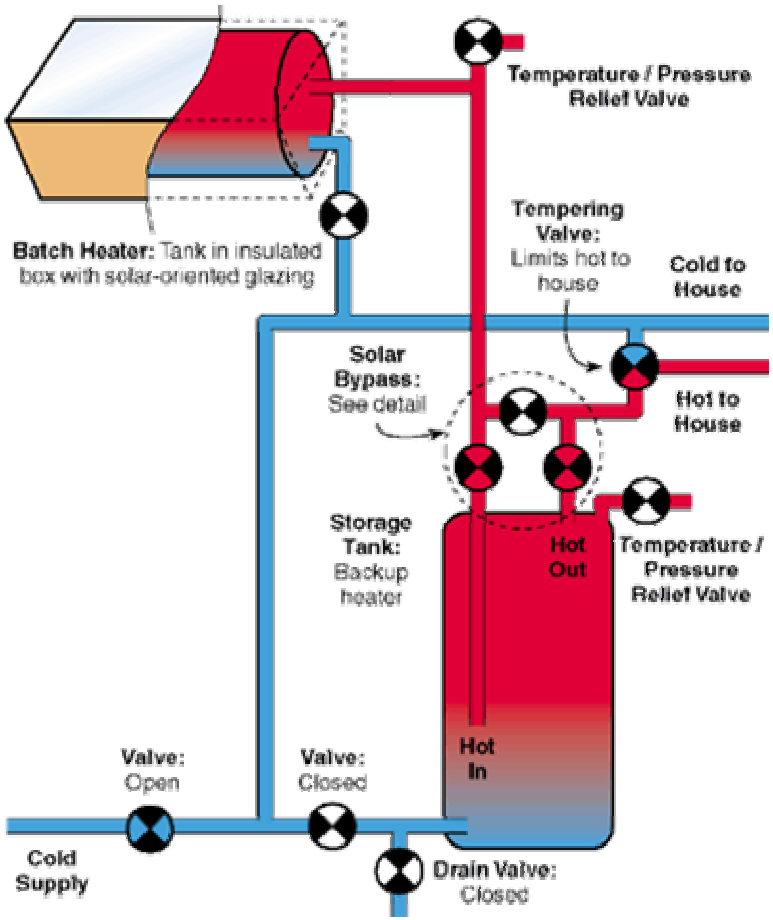
Truth:

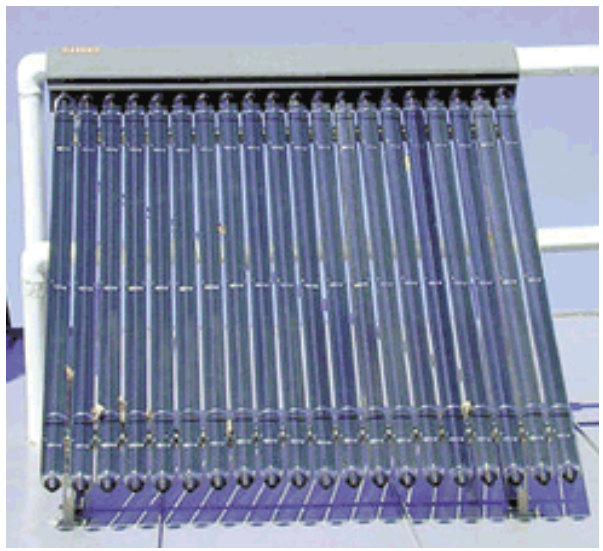
Solar water heating systems remain very cost effective for larger households with electric resistance water heating.

Active Solar Hot water



Passive Solar Hot Water





Ratings for SDHW

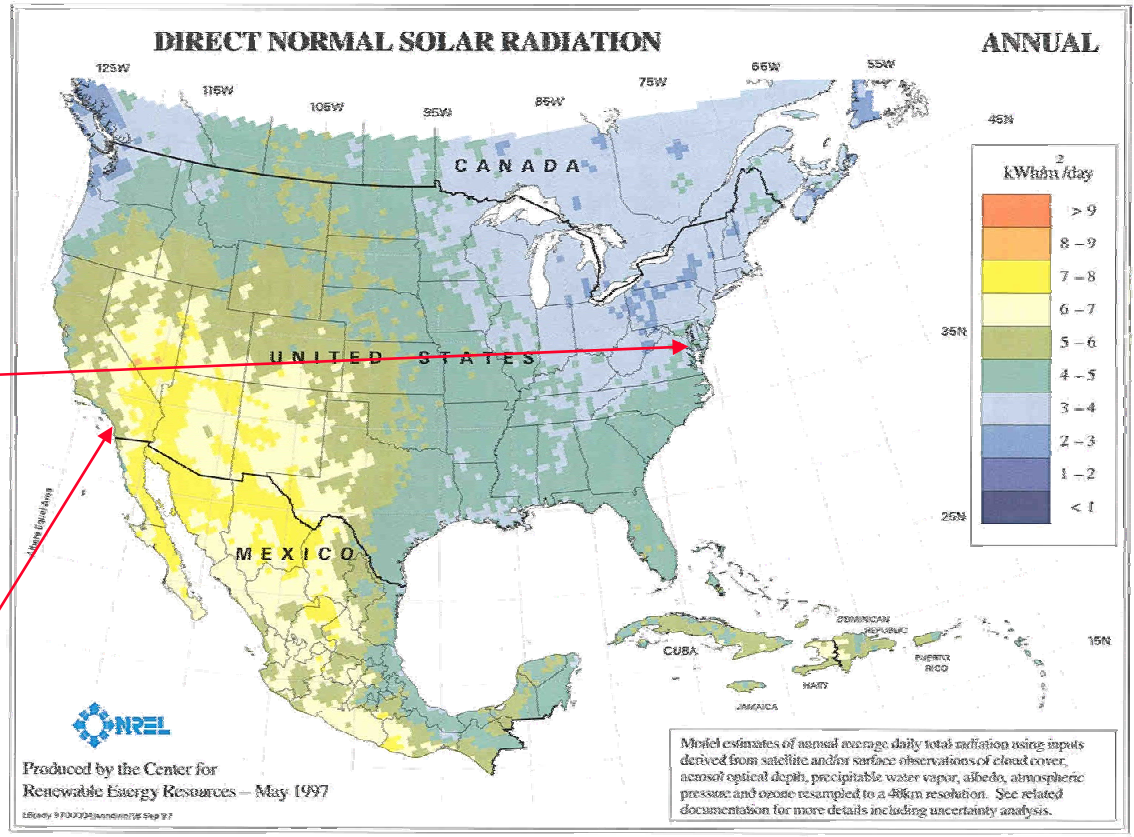
- Already there…
- Lower kWh or fuel use impacts rating
- Varies with system size, load and location
- Load varies with house size in climate (inlet water temperature)

Generic Solar System

- 4 x 8 ‘ collector
- Standard type
  - F_rU_L = 4.17 W/m^2
  - F_rTauA= 0.75
- Glycol loop with heat exchanger
- 80 gallon storage
- PV pumped
- Simulated in differing locations in the U.S.

How many HERS points?

- Baltimore: Base= 80.5
  - 3420 kWh DHW
  - 1790 kWh saved
  - 53% solar fraction
  - *Rating goes to 82.1*
- San Diego: Base= 82.1
  - 3040 kWh
  - 2170 kWh savings
  - 71% solar fraction
  - *Rating goes to 86.2*



Solar Water Heating

Non-cost effective Dinosaurs?

Solar water heating systems can be very cost effective for larger households. The SWAP program showed an annual 1,570 kWh savings in households with 4 or more persons at a cost $1,500. Though a long payback, that's a 8.4% after tax real rate of return– superior to conventional investments.

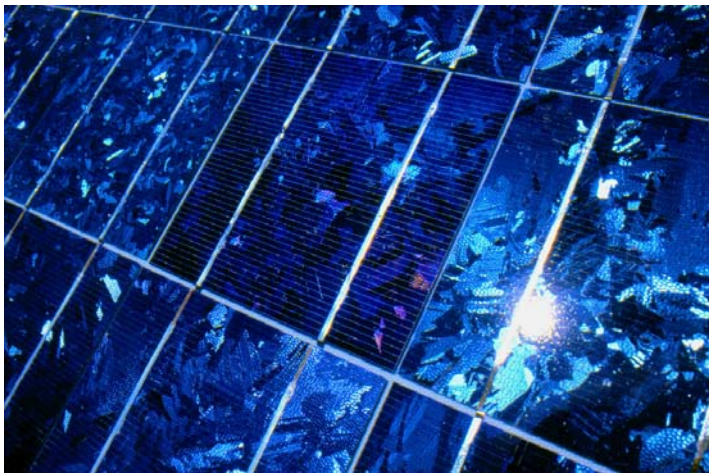
Considerations:

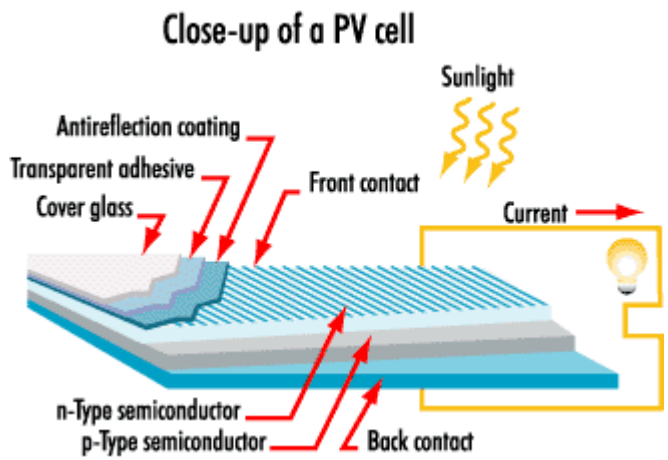
Consider solar water heating if you have a larger household. It's a natural solution in sunny climates.

Reference:

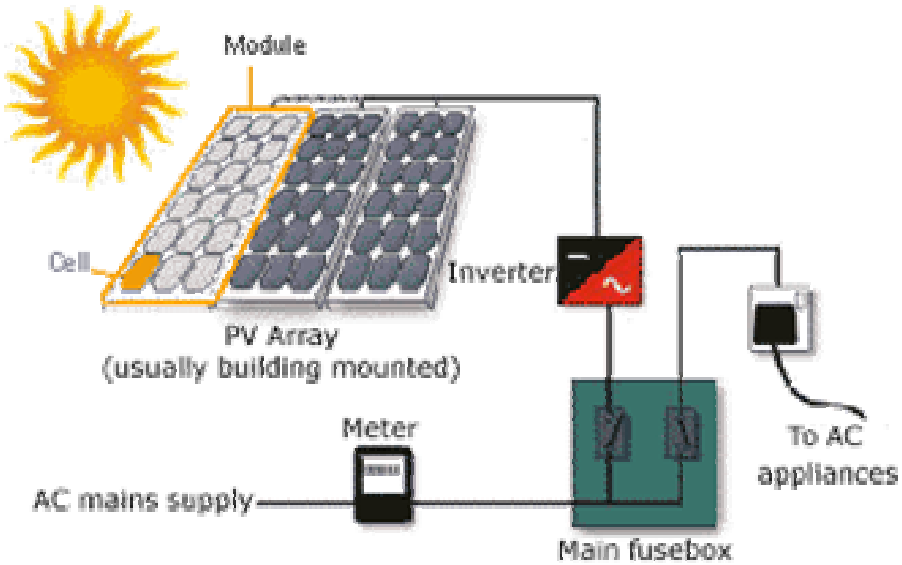
J. Harrison and Steven Long, 1998. "Solar Weatherization Assistance Program," FSEC-CR1028-98, Florida Solar Energy Center, Cocoa, FL.

What are Photovoltaics?





Grid-Tied PV Systems



How do PV systems look?

Stand-off/Roof Mounted … or… Building Integrated (BIPV)

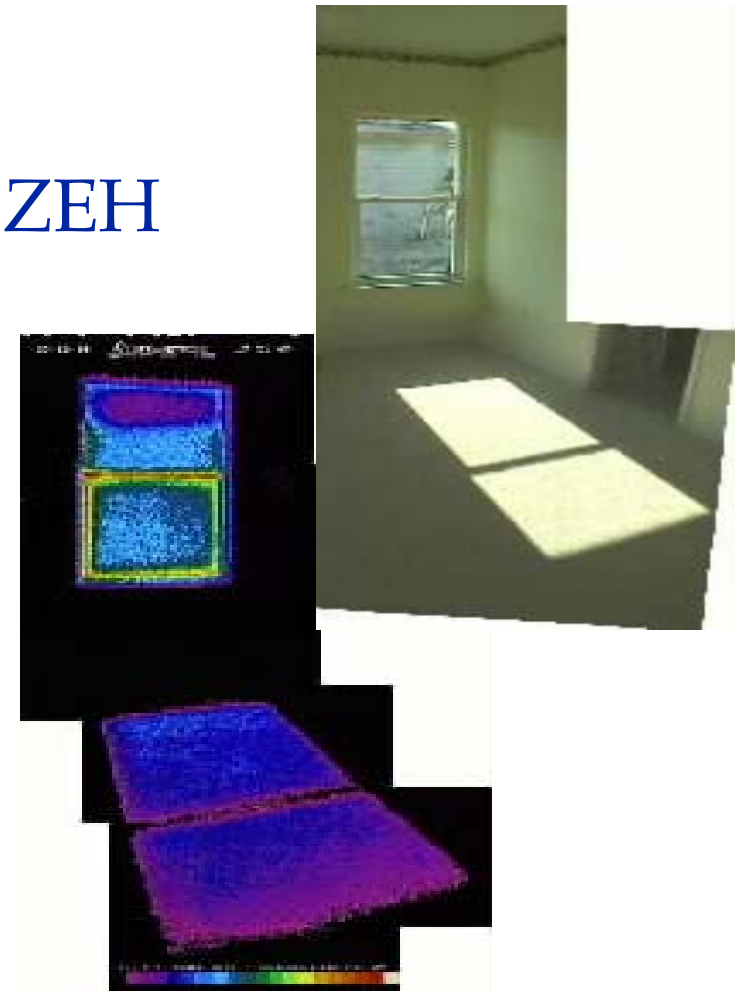
Efficiency and Solar

- Good partners
- Old saw is still true:
- "*First* efficiency, *then* solar"
- Together, they can really make a difference
- First house in Florida to nearly eliminate site energy use.
- *Super-efficient* +solar= Wow!

Could windows be important?

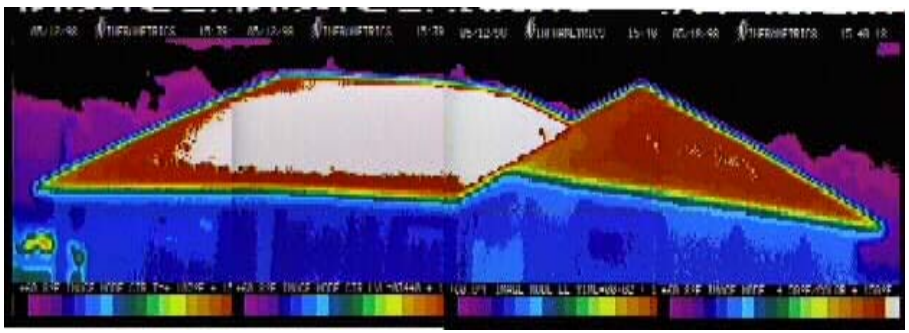
Control House

ZEH

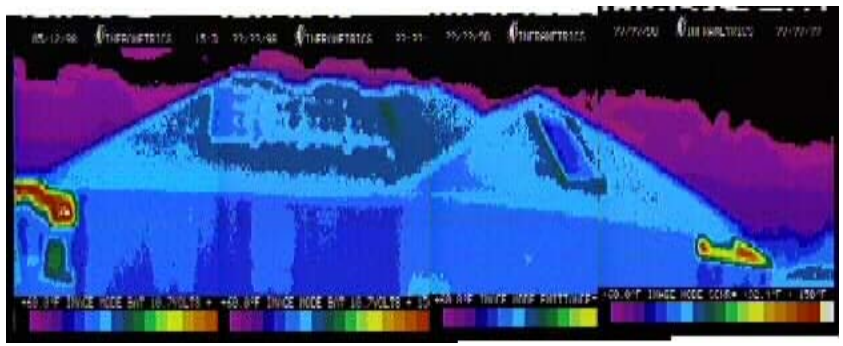


Are roofs important?

Control House

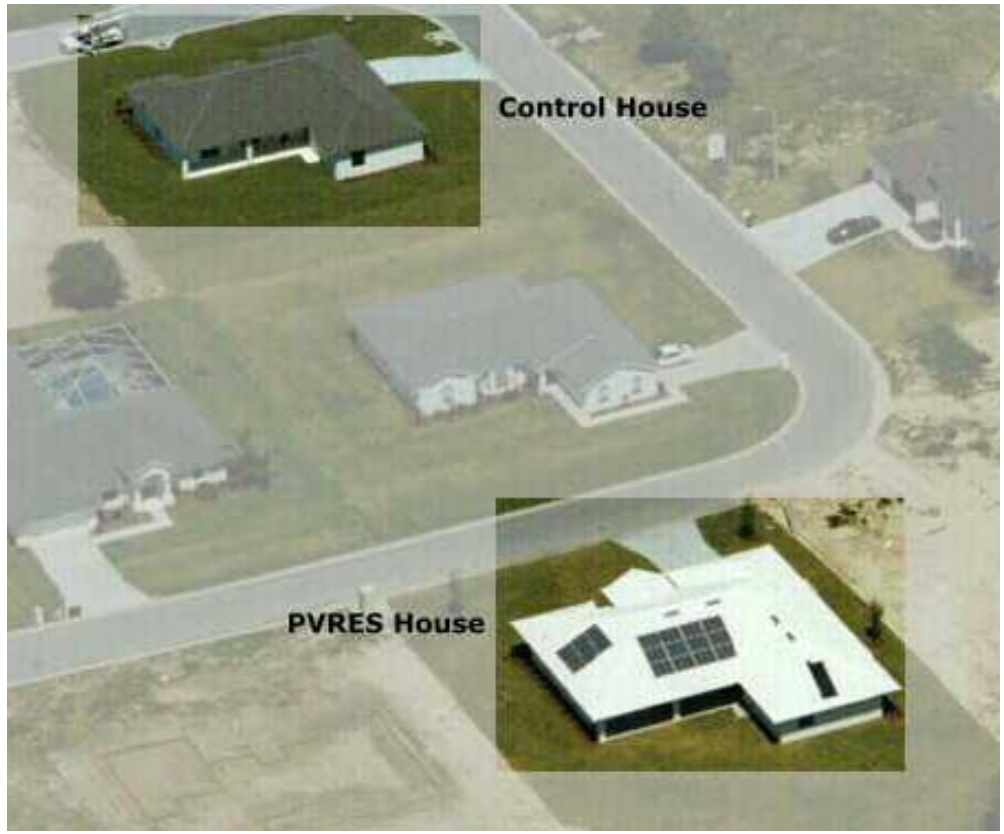


ZEH



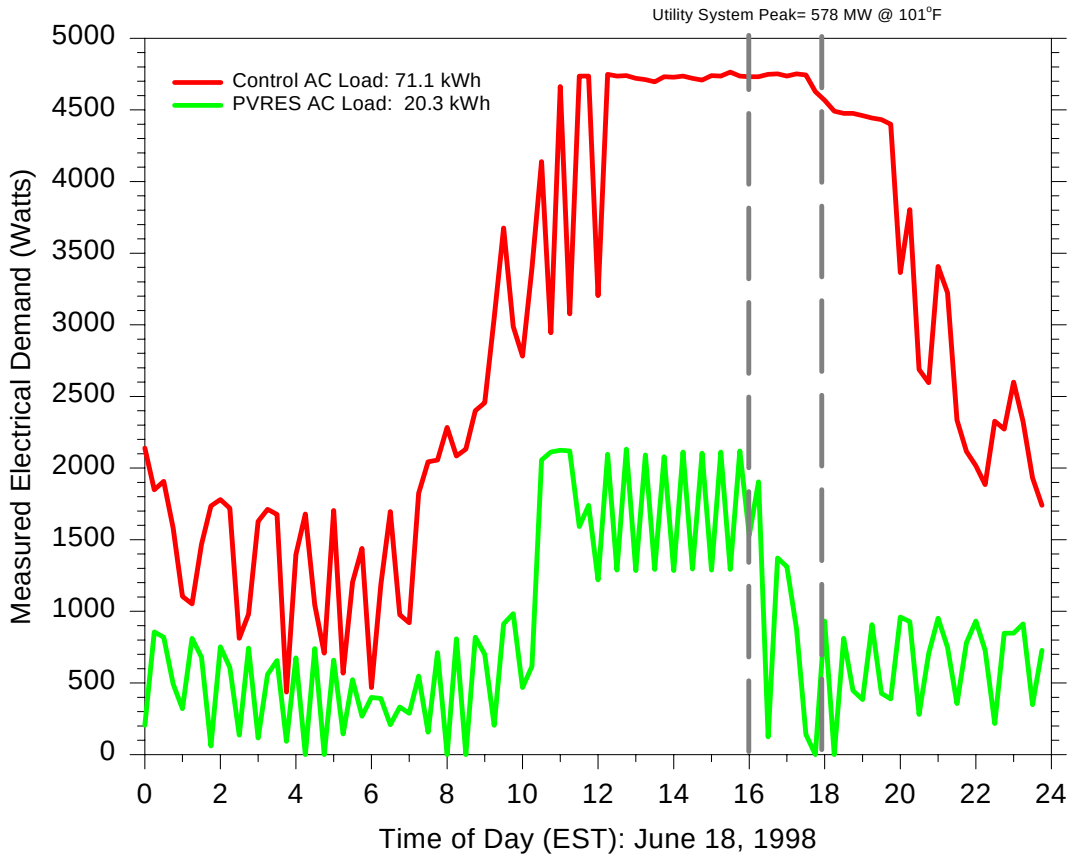
Zero Energy Homes

- Seeing is believing!
- Side-by-side test
- ZEH used 80% less measured cooling!
- 90% of energy use generated
- No peak demand when solar included
- First FL ZEH home still active in Lakeland, FL



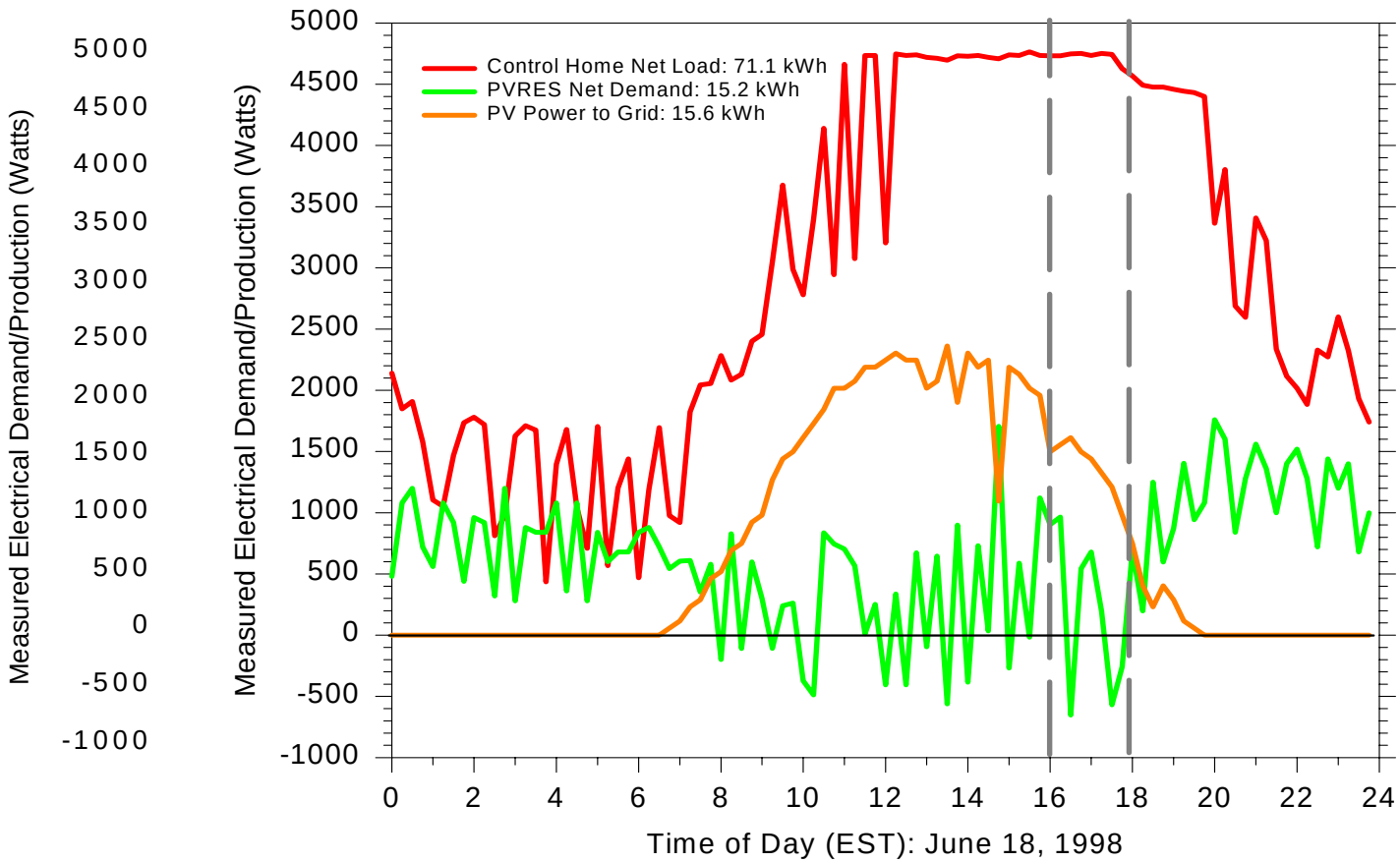
YES! Important!

Control and PV House AC Load on the Electric Grid, Summer Peak Day: June 18, 1998

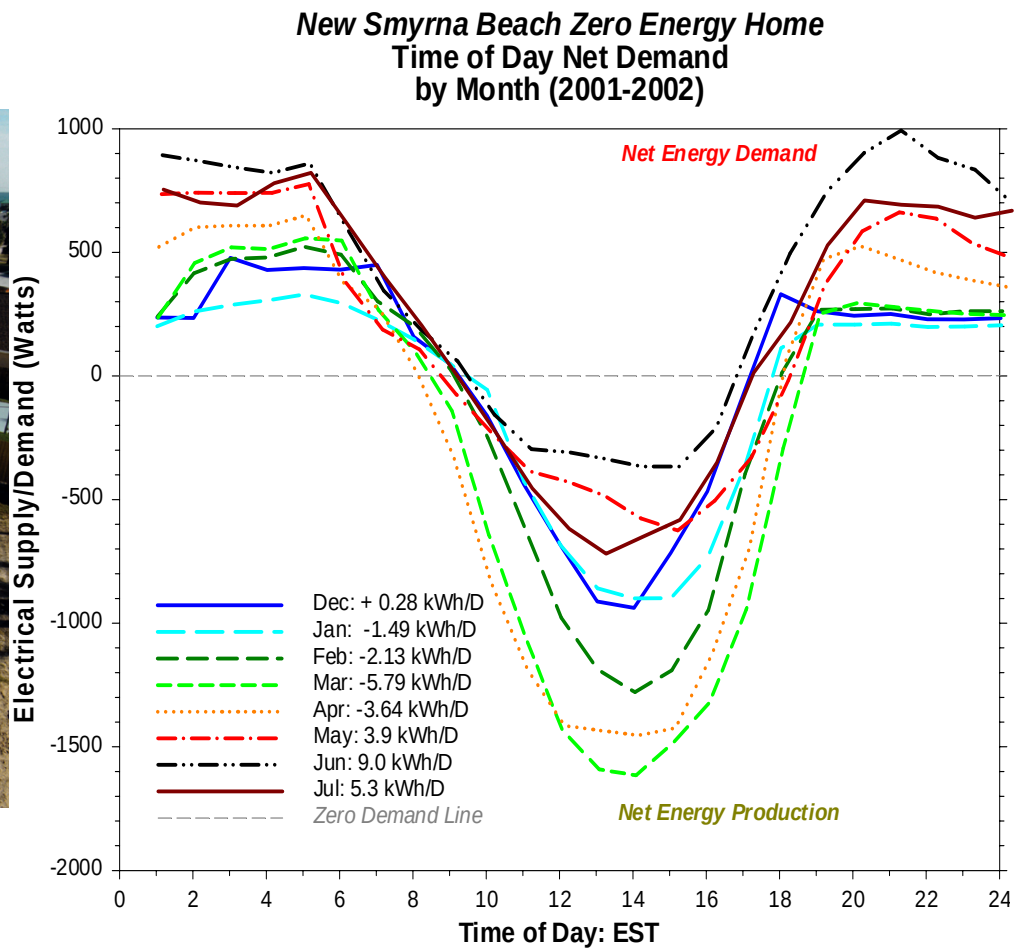


Utility Peak Day Performance

Control and PV House Net Load on the Electric Grid, Summer Peak Day: June 18, 1998



New Smyrna Beach, FL



CA ZEH #1: Livermore, CA

- 3,079 sqft conditioned
- High efficiency
  - Insulation package/RBS
  - Trellis shading
  - High effic. windows
- *NightBreeze* smart economizer/ ventilation system
- SDHW with instantaneous gas auxiliary

Nice Web Site… on-line data

fsec | Davis Energy Group | CENTEX

California Zero Energy Home 1
Livermore

Home > Homes & Buildings > Activities > ZEH > Livermore > PerformanceData

- Location
- Construction
- Building Envelope
- HVAC
- Photovoltaics
- Solar Thermal
- **Performance Data**
- Contacts

News
- Solar Energy Clips
- Sacramento Business Journal
- East Bay Business Times

NREL | energy.gov

Performance Data Plots

PV System and House Net Power
Total Power, PV Power, Net Power
Yesterday | 3-Day Trend | 7-Day Trend | 30-Day Trend

Power Use
Total Power, AC Condenser, AC Fan, Refrigerator, Miscellaneous
Yesterday | 3-Day Trend | 7-Day Trend | 30-Day Trend

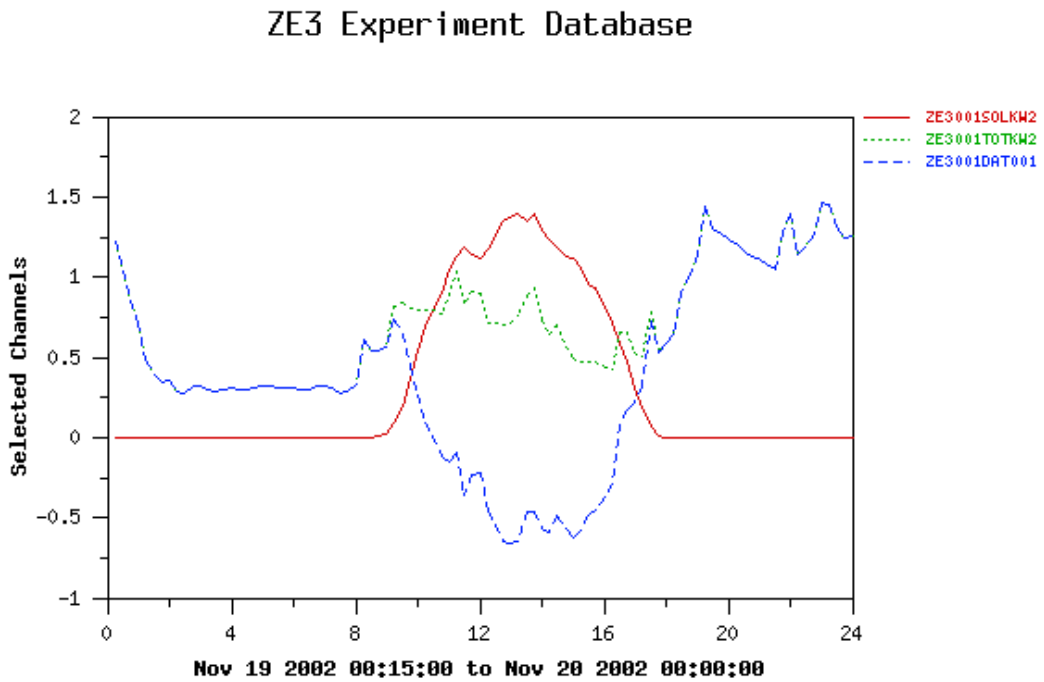
Solar Water Heating System
Temp. To Tank, Temp. To Collector, Pump Flow Rate
Yesterday | 3-Day Trend | 7-Day Trend | 30-Day Trend

NightBreeze Cooling System
Ambient Temp., Interior Temp., Q Vent 1, Q Vent 2
Yesterday | 3-Day Trend | 7-Day Trend | 30-Day Trend

AC Fans and Condensers
AC Condenser 1, AC Condenser 2, AC Fan 1, AC Fan 2
Yesterday | 3-Day Trend | 7-Day Trend | 30-Day Trend

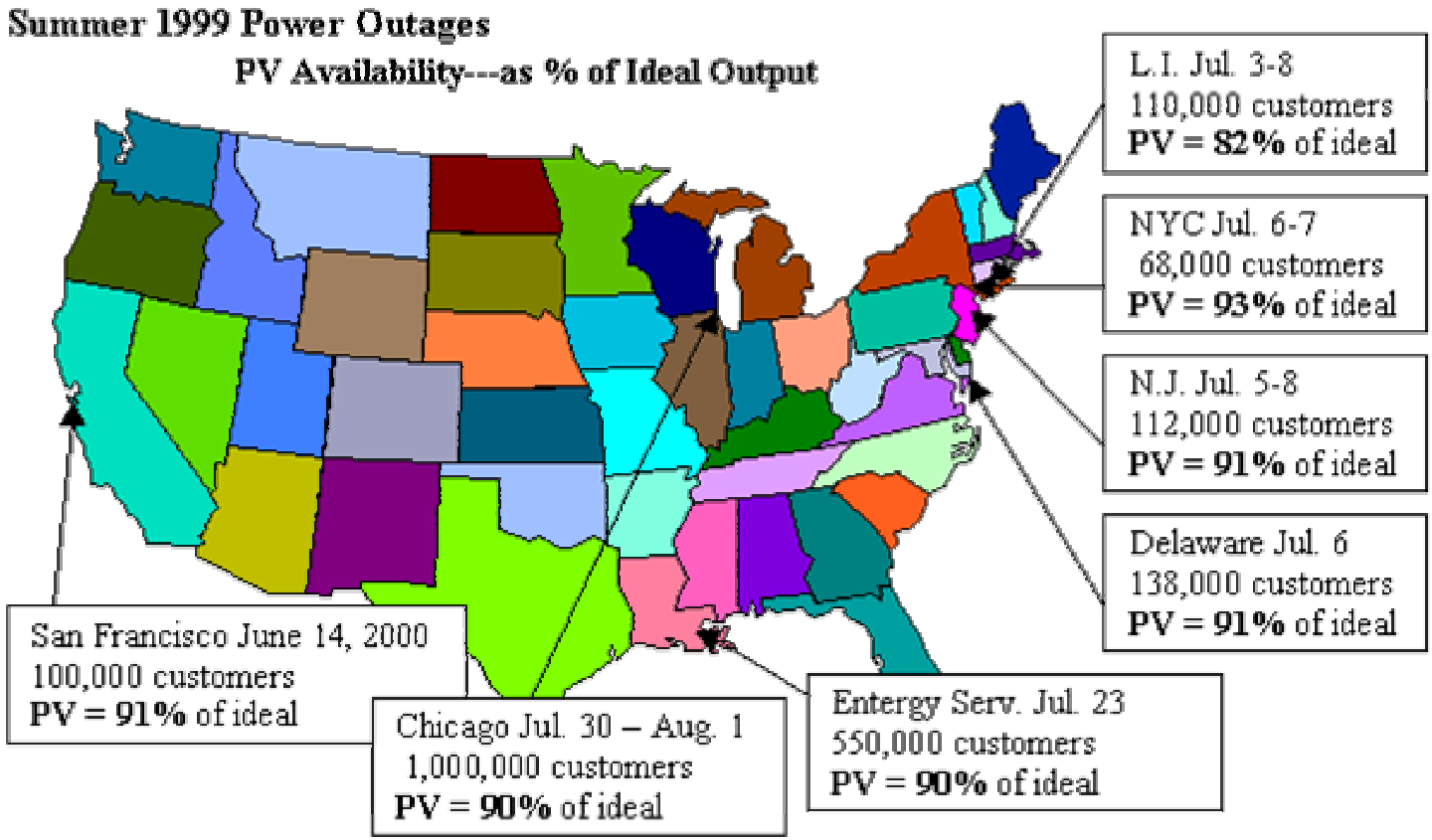
End-Uses
AC Condensers, AC Fans, Refrigerator, Miscellaneous
Yesterday | 3-Day Trend | 7-Day Trend | 30-Day Trend

Temperatures
Ambient Temp., Attic Temp., Interior Temp. 1, Interior Temp. 2
Yesterday | 3-Day Trend | 7-Day Trend | 30-Day Trend



http://www.fsec.ucf.edu/bldg/active/zeh/livermore/index.htm

PV vs. Power Outages



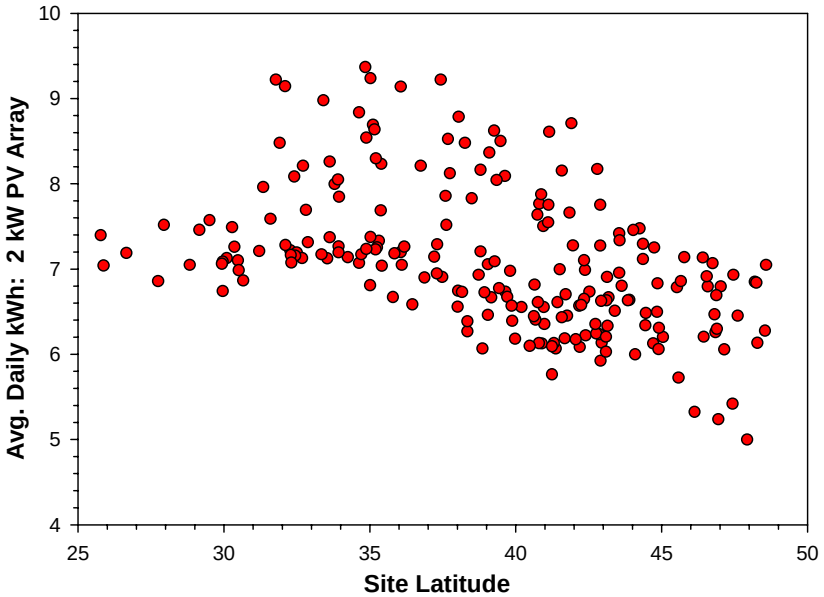
Source: "Residential Customer-Sited Photovoltaics Niche Markets 1999," Herig et al., and "Mapping the Value of Commercial PV Applications in the US—Accounting for Externalities," Perez et al., American Solar Energy Society Conference Proceedings, Portland, Maine, June 1999.

PV Performance: How different?

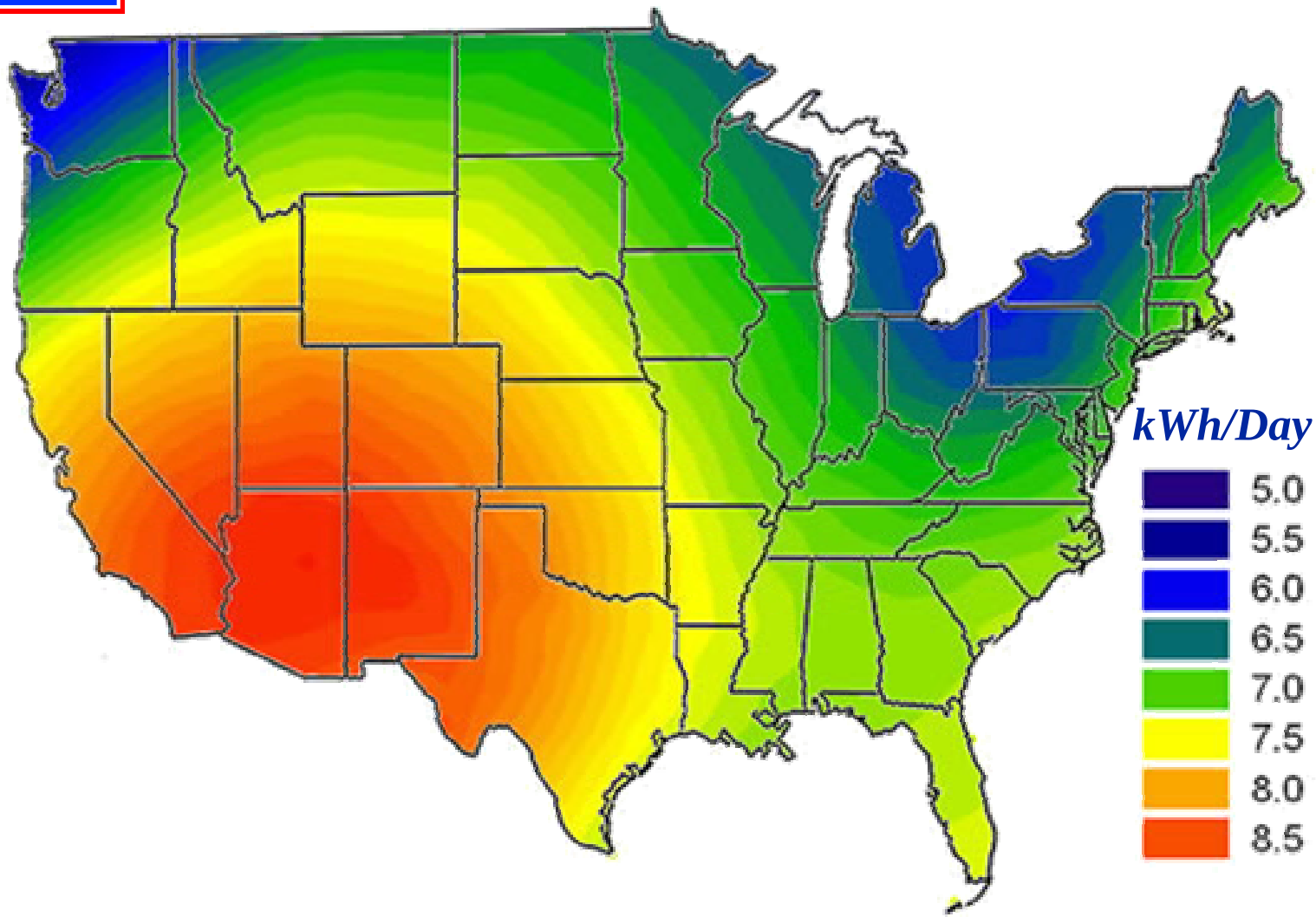
- Simulated generic 2 kW PV system
- Grid-tied with an 2 kW inverter
- 239 TMY2 locations around the U.S.
- Annual solar electric power production

PV kWh/Day vs. Latitude

Rooftop Photovoltaic System Performance vs. Latitude
for the Continental United States
(215 TMY2 Sites)



U.S. Avg. Daily PV kWh

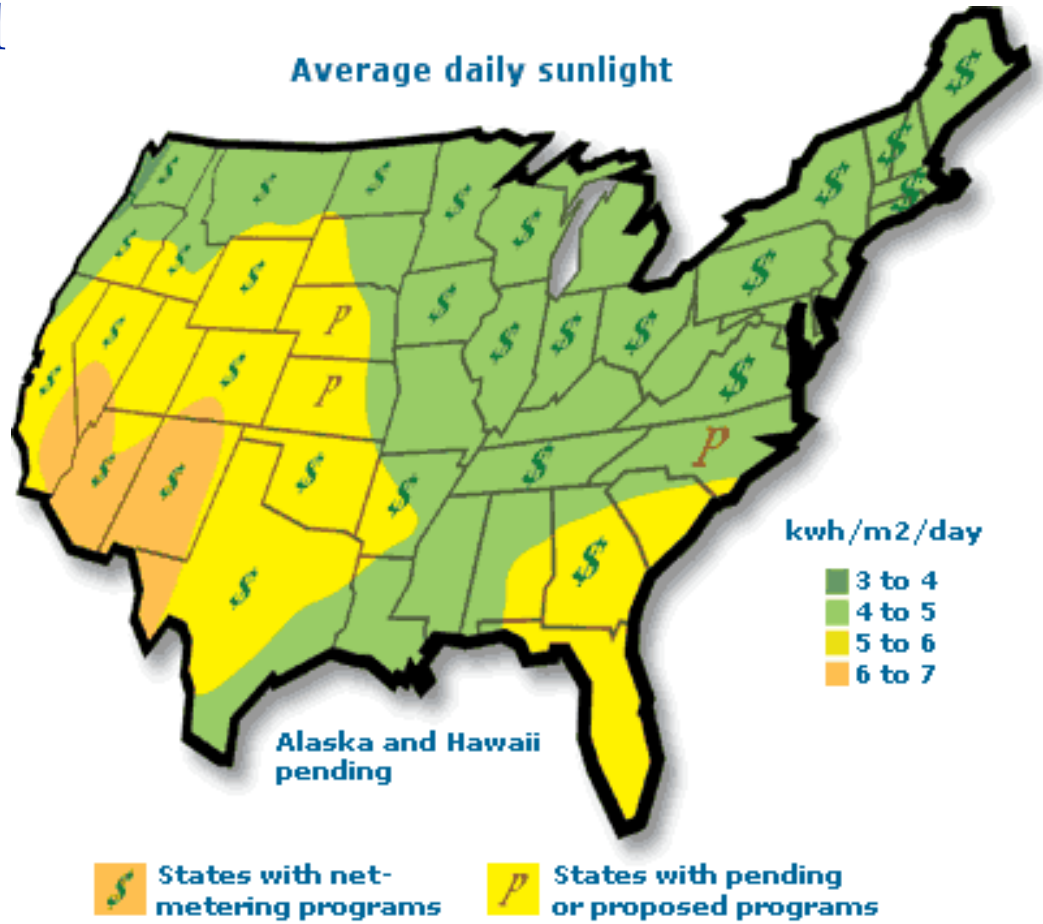


HERS Guidelines for PV

- No consideration for on site PV power (for now)
- Implementation Issues:
  - Apportion to end-uses?
  - How to treat houses with gas/oil heating and water heating?
  - How to treat "sell-back"?
  - Peak same value as other periods?
- Important to address with HERS

Some working assumptions…

- All power whether used or sent to utility grid is credited to Rated home's energy use.
- ***Net metering*** assumed
- Credit against oil/gas converted to electric equivalent representative of modern power plants



Two Proposed Methods…

- Method #1: Apply PV power to total home energy, including non-rated equipment
- Method #2: Apply PV power only to rated part of use (35-65% of total)
- Second method would result in higher scores, but misleading

Proposed Rating Method

- Normalize fossil fuel end-uses
- Apportion PV to all end uses
- Calculate percent of purchased energy:

PE = (Total-PV)/Total

*Score= 100 – (PE * TnML/TRL)*20)*

Where:

TnML= Total of all normalized Loads

TRL= Total Reference Home Loads

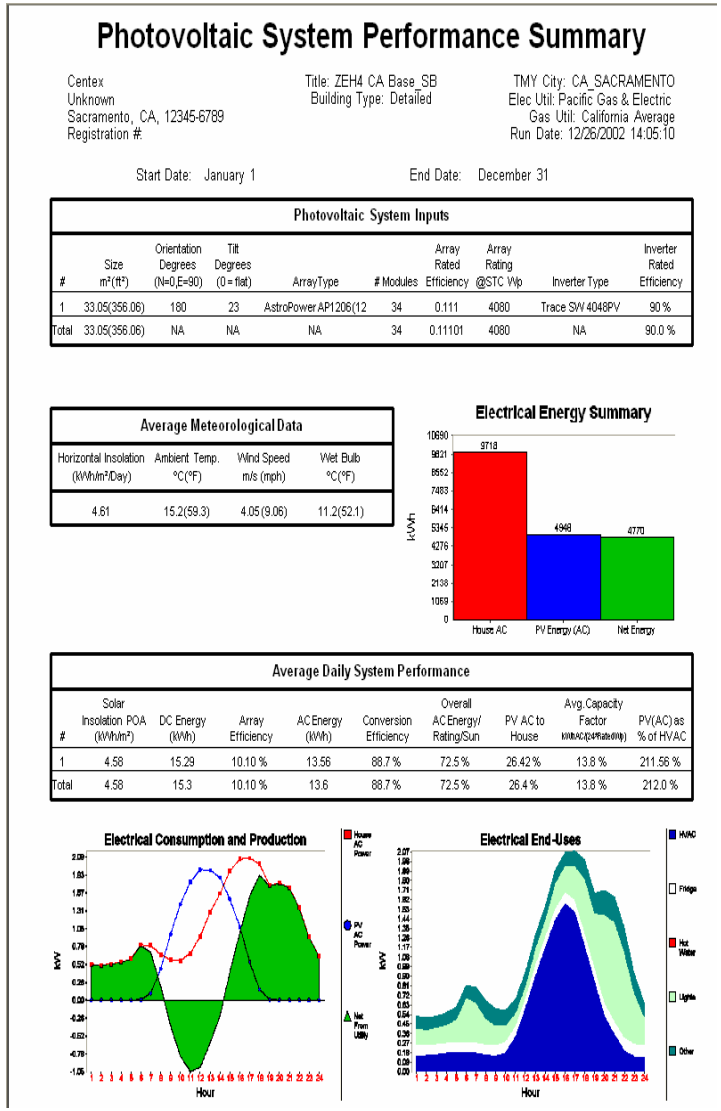
Advantage: Easy to estimate impact on HERS Scores

PV Impact: Example

- HERS Reference Building
  - Score = 80.0
- San Diego
  - Total Energy Use = 9,580 kWh/yr (32.7 MBtu)
  - Heat, Cool, Hot Water= 3,135 kWh (10.7 MBtu)
  - 2 kW PV array producing 2,500 kWh/yr (8.5 MBtu)
  - PE_{frac} = *(Total-PV)/Total*
  - *Score= 80 + (1-PE)/0.05*
- *Score = 85.2*

EnergyGauge USA V. 2.3

- Version 2.3 is released…
- Faster, more powerful
- Improved rendering of building geometry, heat pumps, cool roofing.
- Simulation of photovoltaic systems
- Solar water heating systems (active & batch)
- Hourly output of energy-end use, thermal and humidity data



Photovoltaic System Performance Summary

Centex
Unknown
Sacramento, CA, 12345-6789
Registration #:

Title: ZEH4 CA Base_SB
Building Type: Detailed

TMY City: CA_SACRAMENTO
Elec Util: Pacific Gas & Electric
Gas Util: California Average
Run Date: 12/26/2002 14:05:10

Start Date: January 1 End Date: December 31

Photovoltaic System Inputs

#	Size m²(ft²)	Orientation Degrees (N=0,E=90)	Tilt Degrees (0 = flat)	ArrayType	# Modules	Array Rated Efficiency	Array Rating @STC Wp	Inverter Type	Inverter Rated Efficiency
1	33.05(356.06)	180	23	AstroPower AP1206(12	34	0.111	4080	Trace SW 4048PV	90 %
Total	33.05(356.06)	NA	NA	NA	34	0.11101	4080	NA	90.0 %

Average Meteorological Data

Horizontal Insolation (kWh/m²/Day)	Ambient Temp. °C(°F)	Wind Speed m/s (mph)	Wet Bulb °C(°F)
4.61	15.2(59.3)	4.05(9.06)	11.2(52.1)

Electrical Energy Summary

Average Daily System Performance

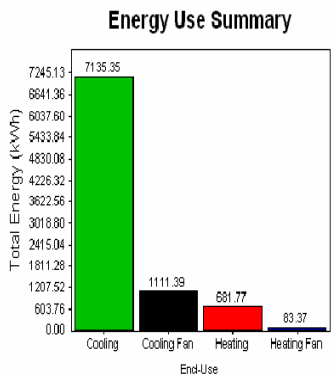
#	Solar Insolation POA (kWh/m²)	DC Energy (kWh)	Array Efficiency	AC Energy (kWh)	Conversion Efficiency	Overall AC Energy/ Rating/Sun	PV AC to House	Avg. Capacity Factor	PV(AC) as % of HVAC
1	4.58	15.29	10.10 %	13.56	88.7 %	72.5 %	26.42 %	13.8 %	211.56 %
Total	4.58	15.3	10.10 %	13.6	88.7 %	72.5 %	26.4 %	13.8 %	212.0 %

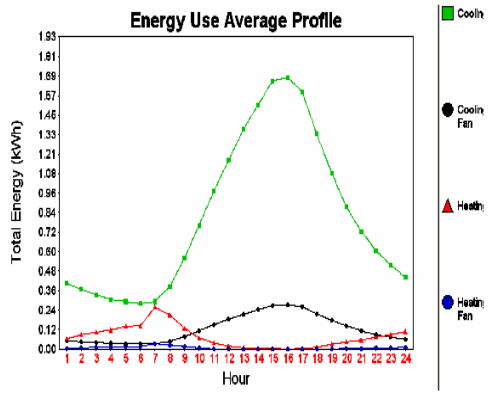
Electrical Consumption and Production

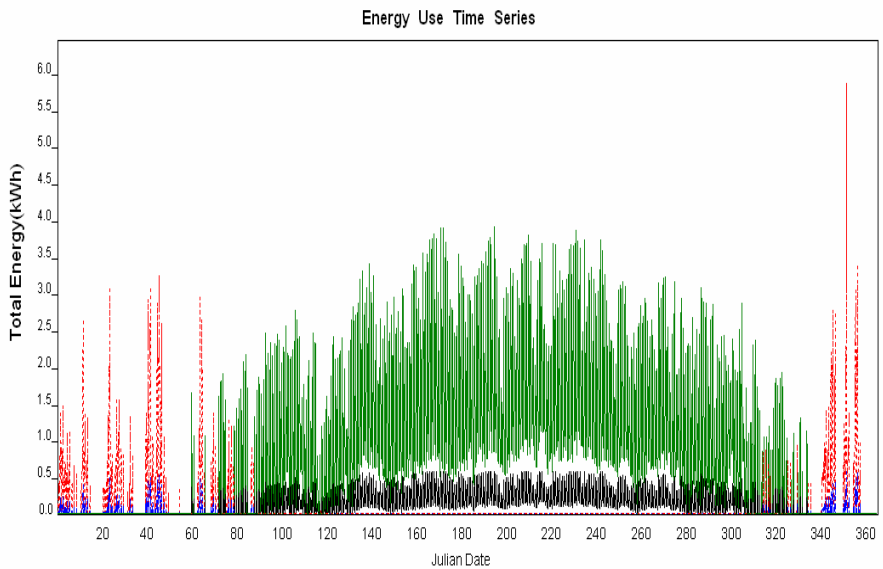
Electrical End-Uses

Power of Hourly Reports…

- Energy end-uses, temperature, RH
- Time-series and averages
- Visual data: intuitive understanding of how to reduce loads
- Example new home in Tampa, FL →

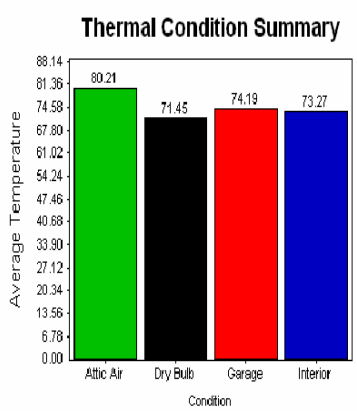


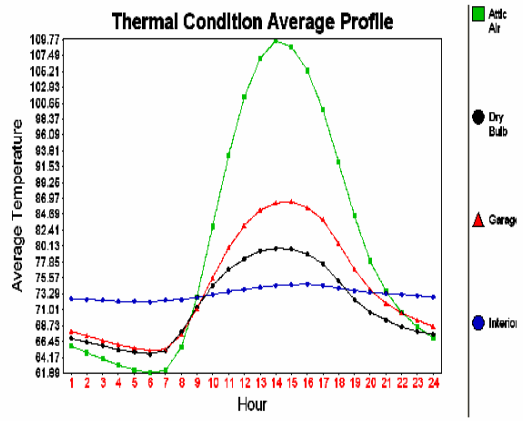


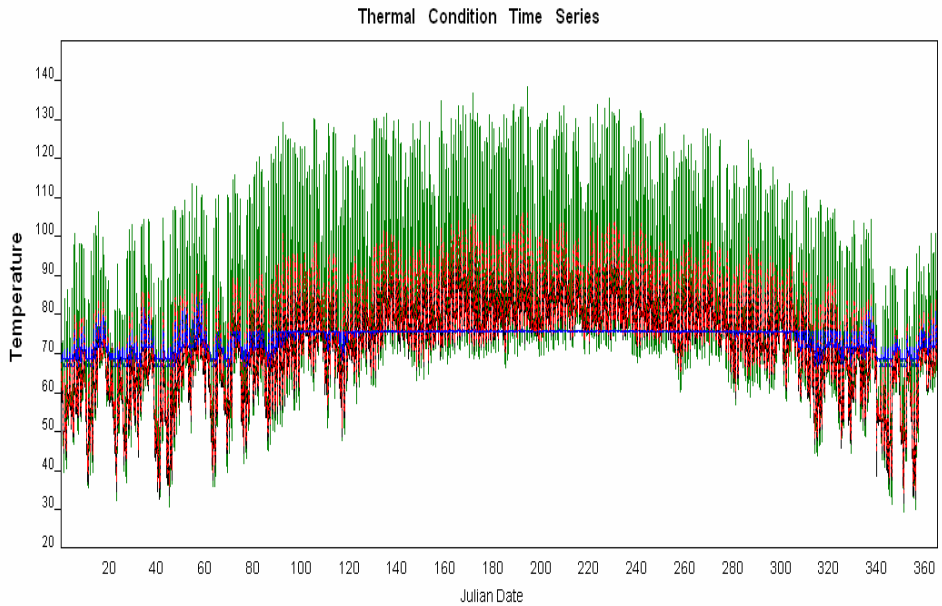


Hourly Reports: Thermal Conditions

- Same building in Tampa, FL
- Temperatures in time-series and averages
- Attic extremes: large portion of cooling load….







Evaluation of ZEH Designs

- Same home in Tampa…
- Add 2 kW PV array facing south
- PV System #2 is identical, but faces west
- Which better?
- West better matches load shape, but building is far too inefficient for PV!
- *Make it more efficient!*

HOURLY SUMMARY REPORT

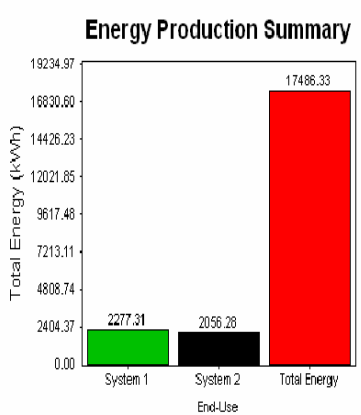
FPC Customer

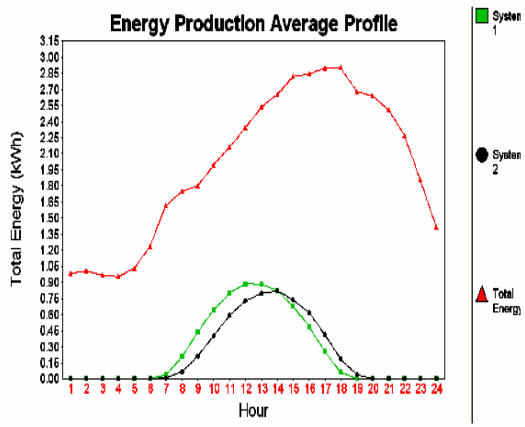
Project Title:
FPC_New
Building Type: Detailed

TMY City: FL_TAMPA
Elec Util: Florida Power Corp
Gas Util: Florida Average
Run Date: 12/26/2002 14:56:06

Start Date: January 1 — End Date: December 31

End-Use	Units	Average	Minimum	Maximum	Total
System 1	kWh	0.26	0.00	1.47	2277.3
System 2	kWh	0.23	0.00	2.50	2056.3
Total Energy	kWh	2.00	0.43	7.32	17486.3





Our Oil Energy Future?

Economics

- **Which do *you* want?**
- **How cost effective?**

"What's the cost effectiveness of kitchen cabinets?" – Steve Loken

Economics: Big Picture

- *"Economists would conclude from an lifecycle perspective, that the earth is not worth saving"*
  – *Don Osborne, SMUD*
- Perspective from space:
  - Dead Mars once had an atmosphere and water…
  - Earth: High stakes atmospheric experiment
  - Taking care of our home is our responsibility

Thank you!