The Pursuit of Affordable Zero Energy Homes

Jeff Christian

Oak Ridge National Laboratory

Southeastern Solar Summit

October 25, 2007

Focus on Zero Energy House 5

- ZEH5 results
- Zero energy peak potential
- Commercial house plans and detailed specifications now available

First four occupied houses to sell solar power to TVA the largest public electric utility in U.S.

- Solar credits $1.00/day
- Net off site total energy cost $1.00 to $0.42/day
- Construction cost $100,000

ZEH1 built in 2002

TVA Electric Rate Structure

- Residential rate flat; $0.07/kWh
- National average; ~$0.10/kWh
- Grid-tied Solar buyback on dual metered houses; $0.15/kWh
- Ontario, CA; $0.42/kWh
- Wisconsin Electric; $0.22/kWh

ZEH2 August total monthly energy bill $16.70 2004, $26.54, 2007

ZEH 3 entire heating season cost <$40

ZEH5 an unoccupied test house for two year period

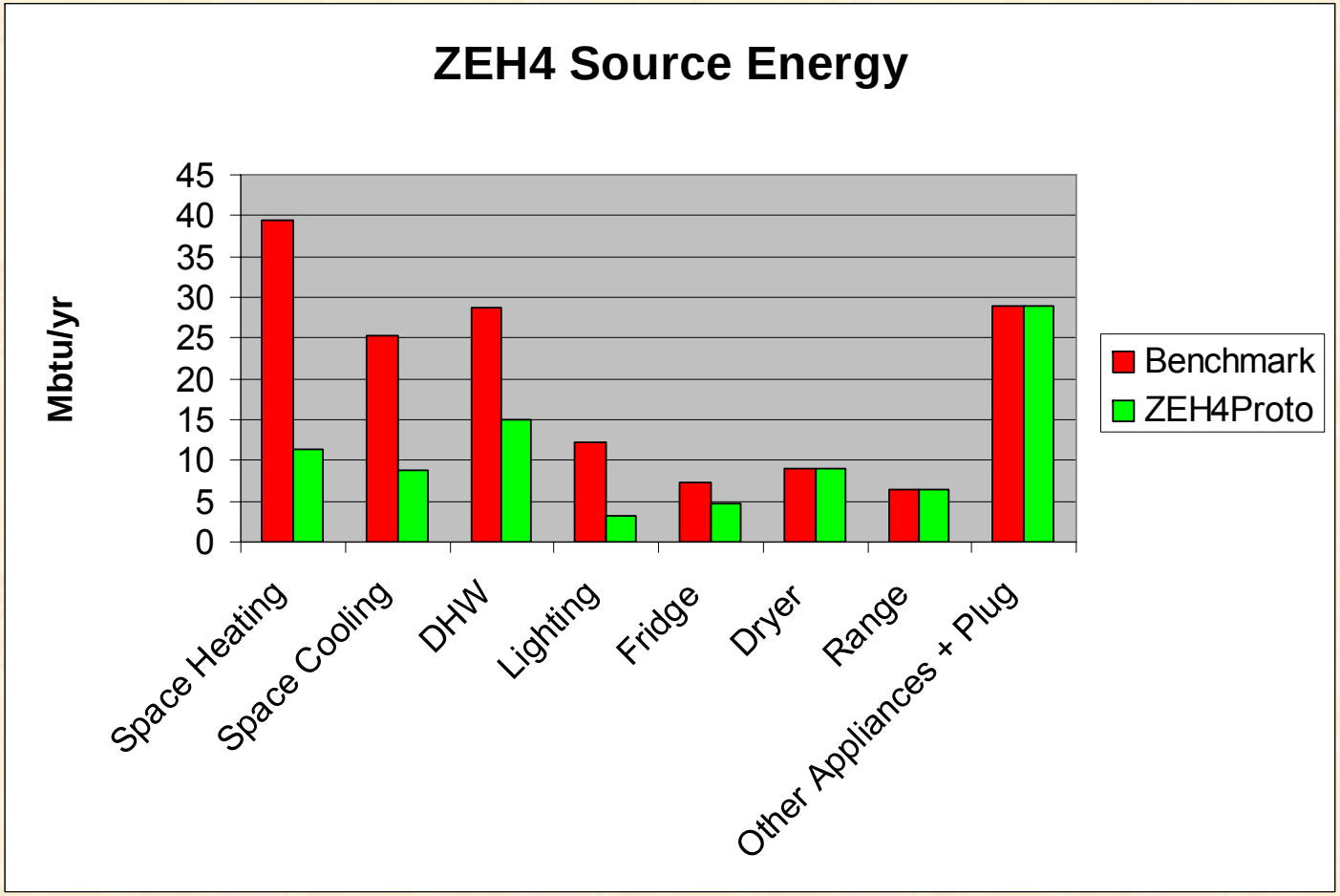
- Tested as a one-story conditioning 1232 ft^2 in 2006
- Testing two ton heat pump conditioning 2600 ft^2 in 2007
- Geothermal horizontal water loop in existing excavations (Foundation geothermal system)
- Air-tight, mechanical ventilation, ducts inside
- R-21 walls, R-36 roof
- Exterior insulated block walkout basement

ZEH4; measured $0.42/day in 2006 for all off-site energy

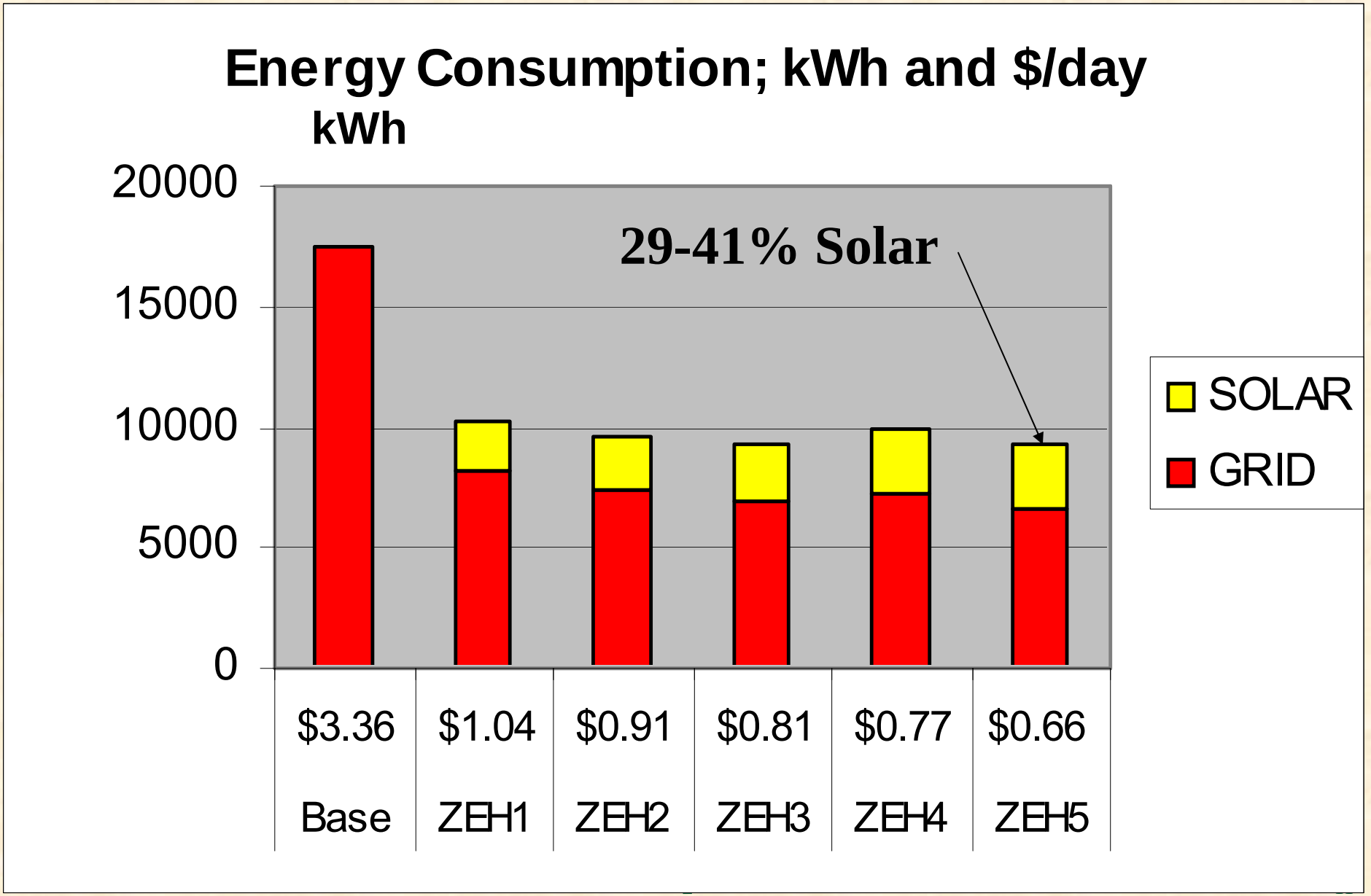
ZEH4

- $15.41, August 2006 including hook up charge of $6/month
- $17.43, August 2007, the hottest month out of 113 years of recorded history.
- Features
  - 2.2 kWp Solar PV
  - Structural Insulated Panels
  - SEER 17 Heat Pump
  - Air-tight, mechanical ventilation
  - Exterior insulated thermal mass in the walkout basement

ZEH4 DOE Building America modeling validation



$0.50/day for 1200 ft^2


Energy Consumption; kWh and $/day
kWh
20000
15000
10000
5000
0
29-41% Solar
SOLAR
GRID
$3.36
$1.04
$0.91
$0.81
$0.77
$0.66
Base
ZEH1
ZEH2
ZEH3
ZEH4
ZEH5

ZEH5 a 2-story 2600 ft^2 walkout

6-pipe Geothermal Heat exchanger installed in ZEH5 overcut

3 pipes pinned to the clay soil wall and 3 spread about a foot apart at base of the overcut

Geothermal loop utilized water trench dug out another 4 foot deeper

Water trench

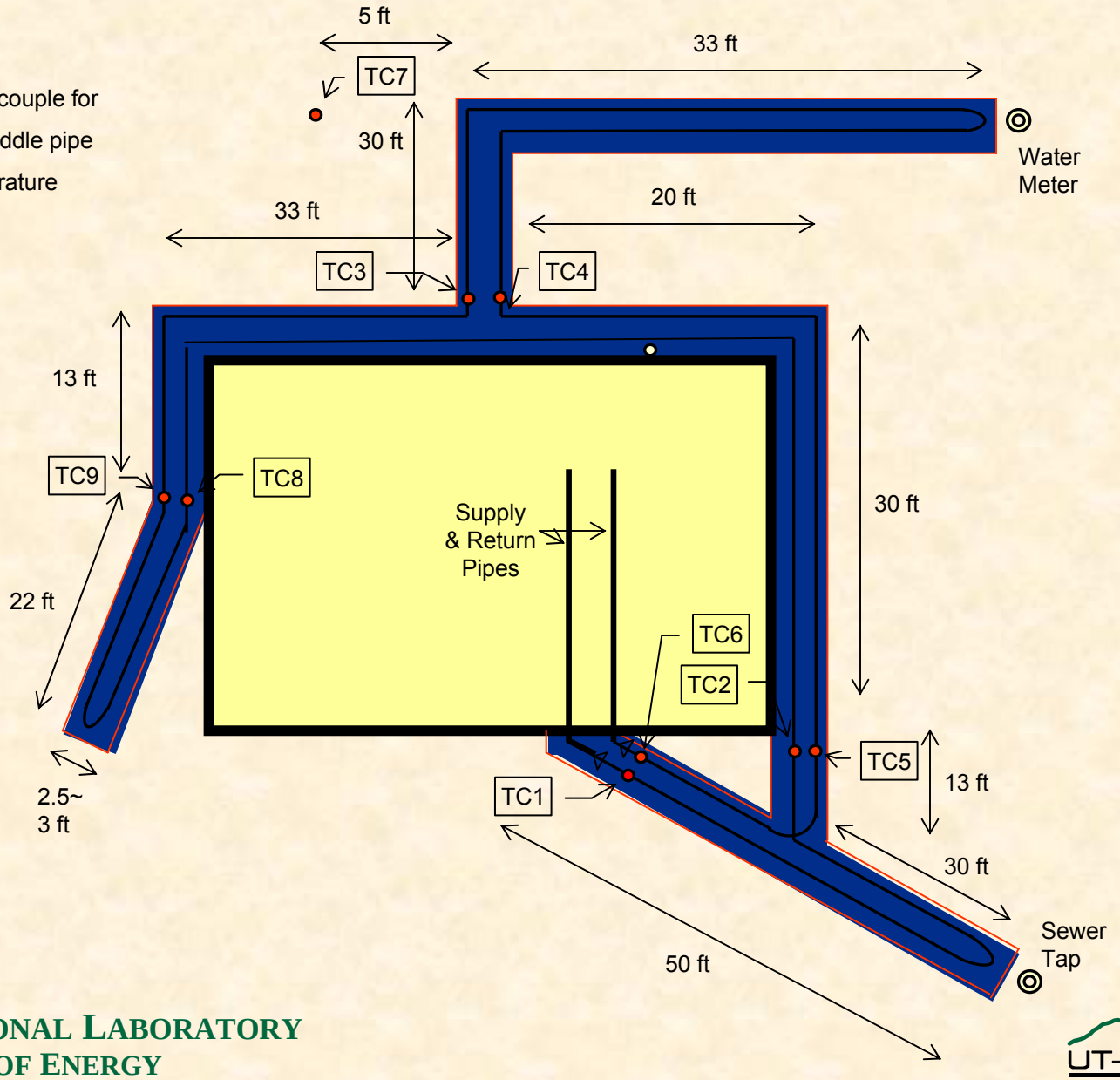
Heat exchangers also run in trenching for sewer tap

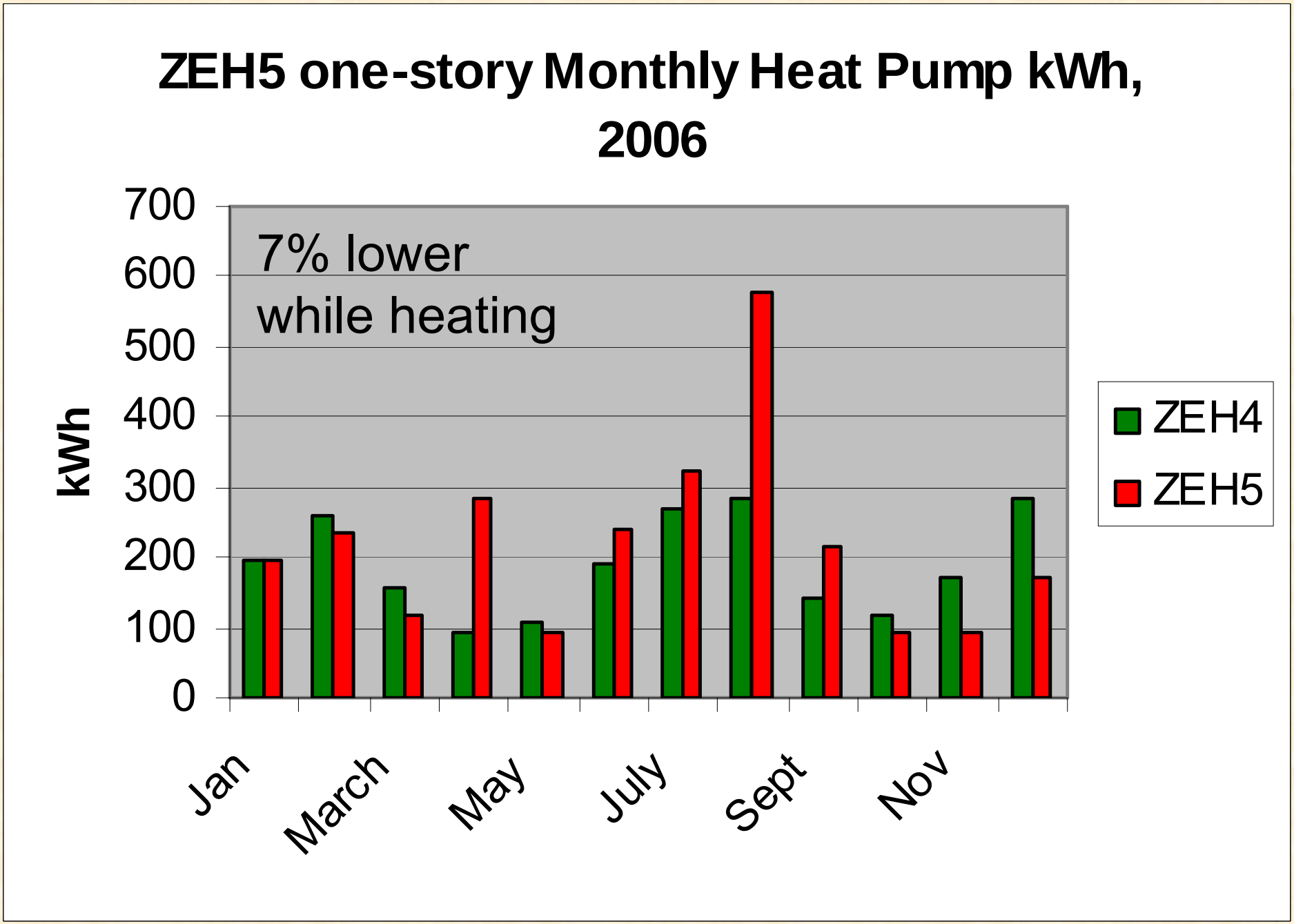
Ground Pipe Installation and Sensors (ZEH5)

TC 1,2,3,4,5,6,8,9: Thermal couple for
Temperature on the middle pipe

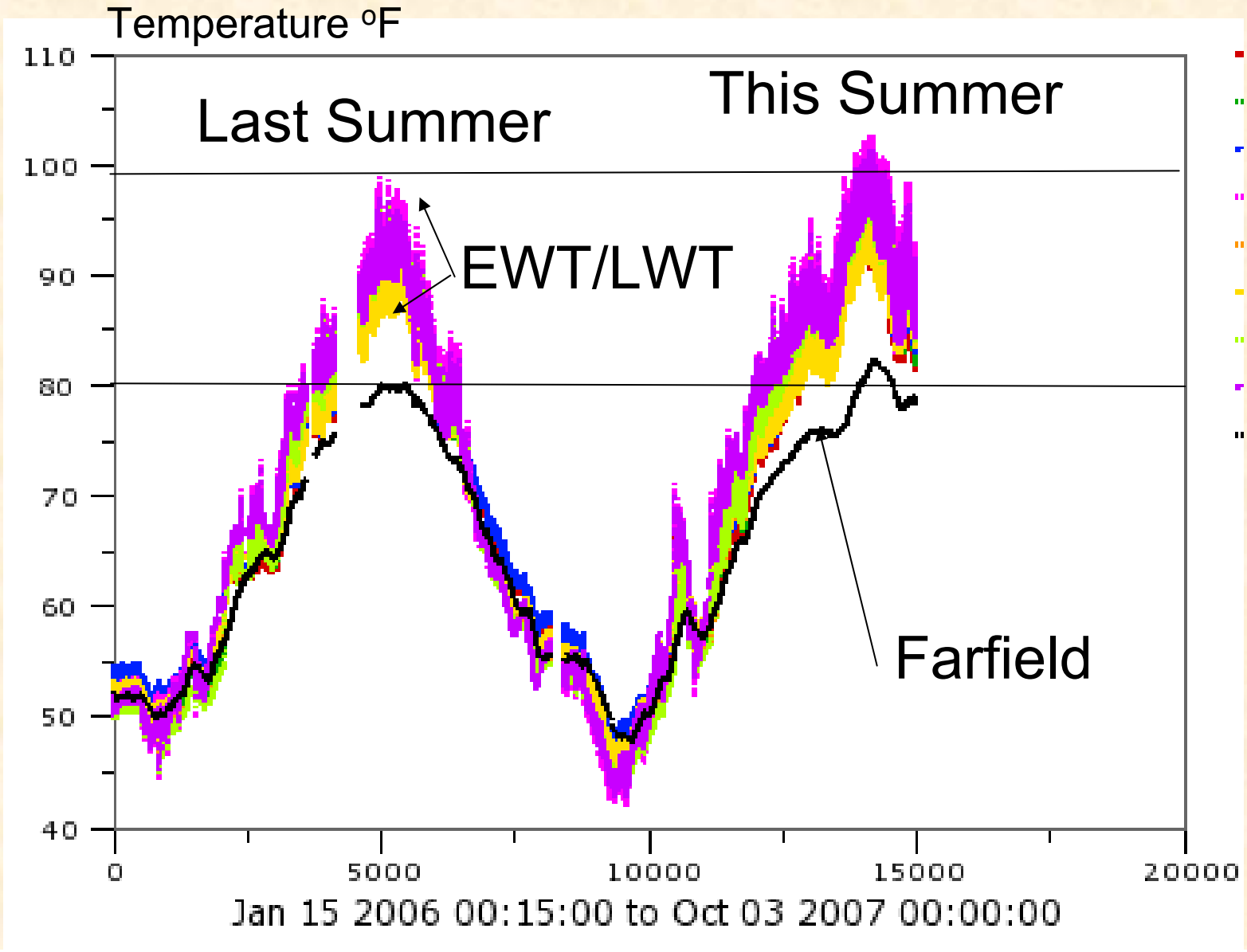
TC7: Far field ground temperature

Δ : Ground pipe header



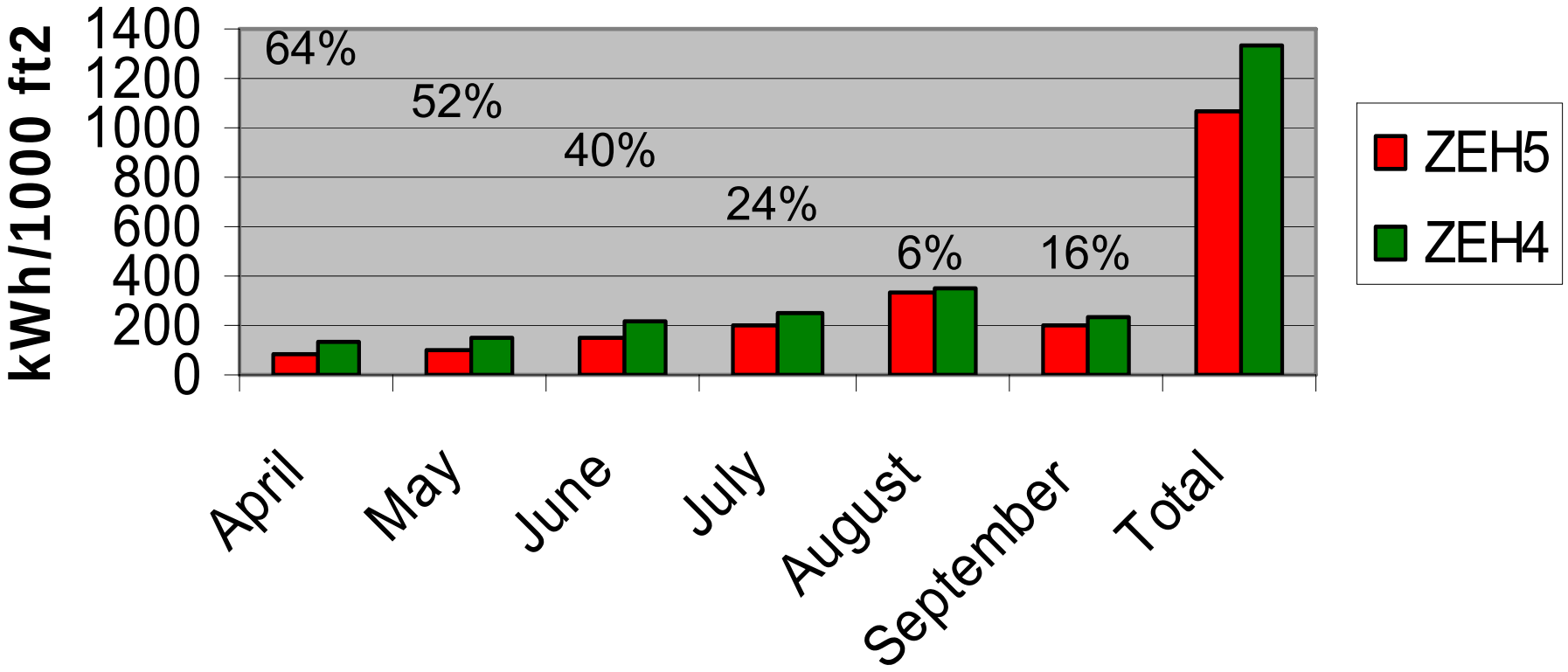

ZEH5 one-story Monthly Heat Pump kWh, 2006
7% lower while heating
kWh
700
600
500
400
300
200
100
0
Jan
March
May
July
Sept
Nov
ZEH4
ZEH5

Measured temperatures, Jan. 2006- Oct. 3, 2007, 1:00 am



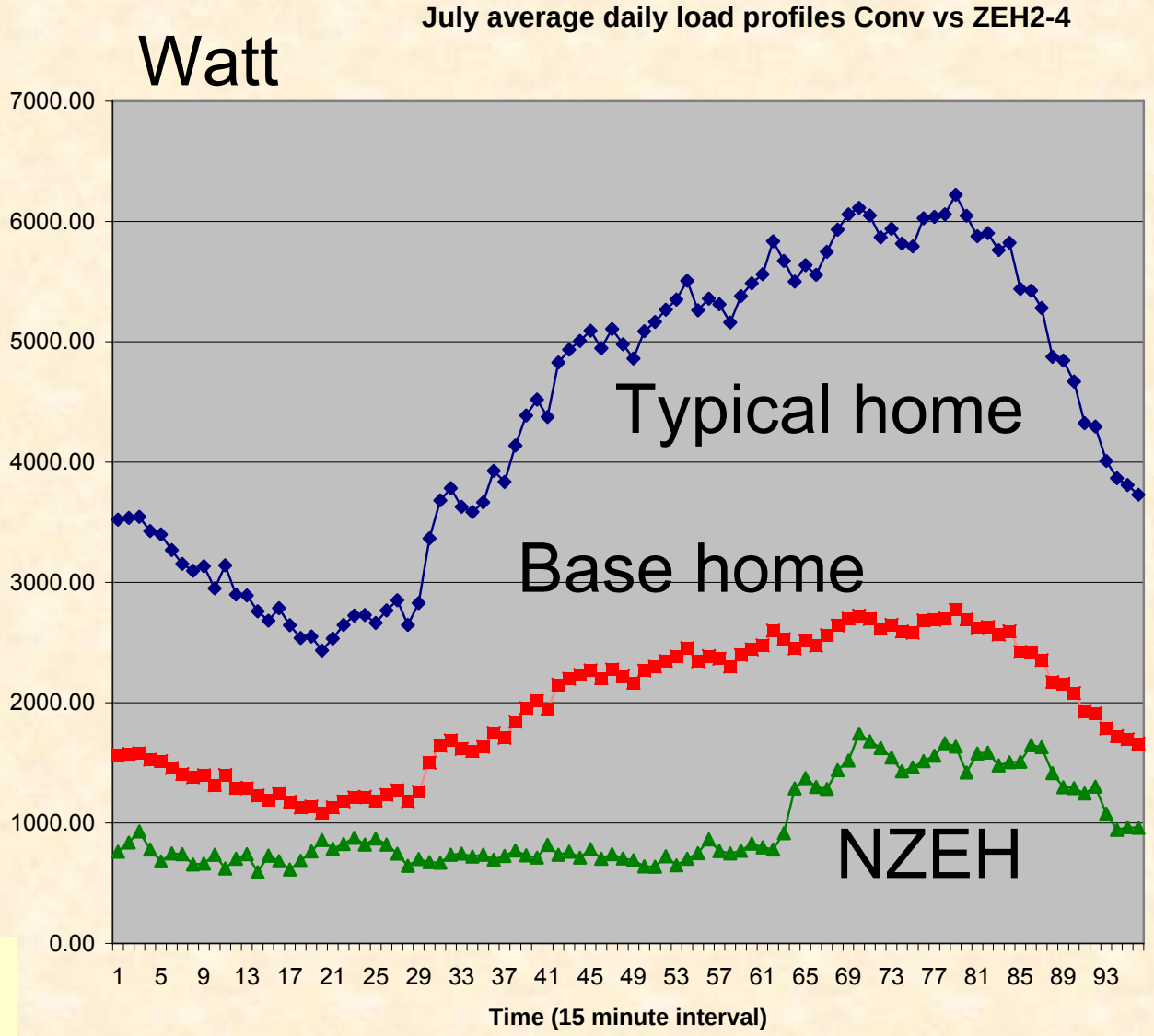
ZEH5 vs ZEH4 Heat Pump Energy; 24% less cooling energy per 1000 ft^2

2007

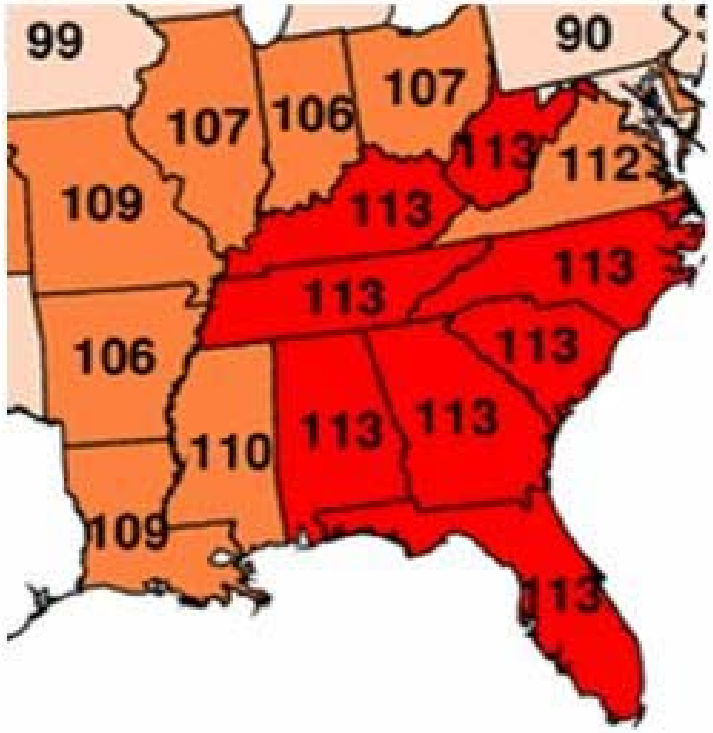


Zero Peak Energy

ZEH reduces summer peak loads by 40% with no Demand side Management

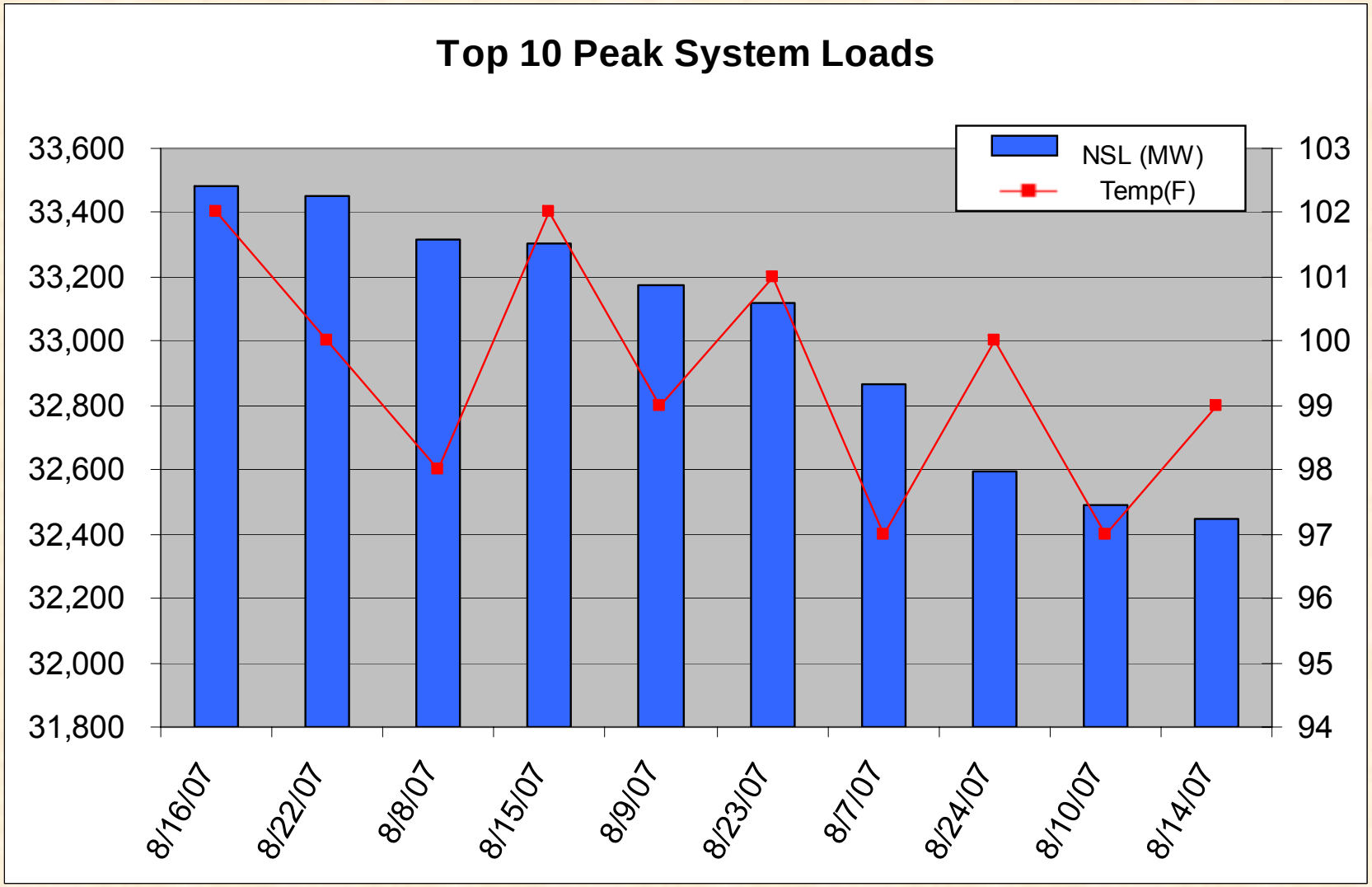


August 2007 The Hottest on Record

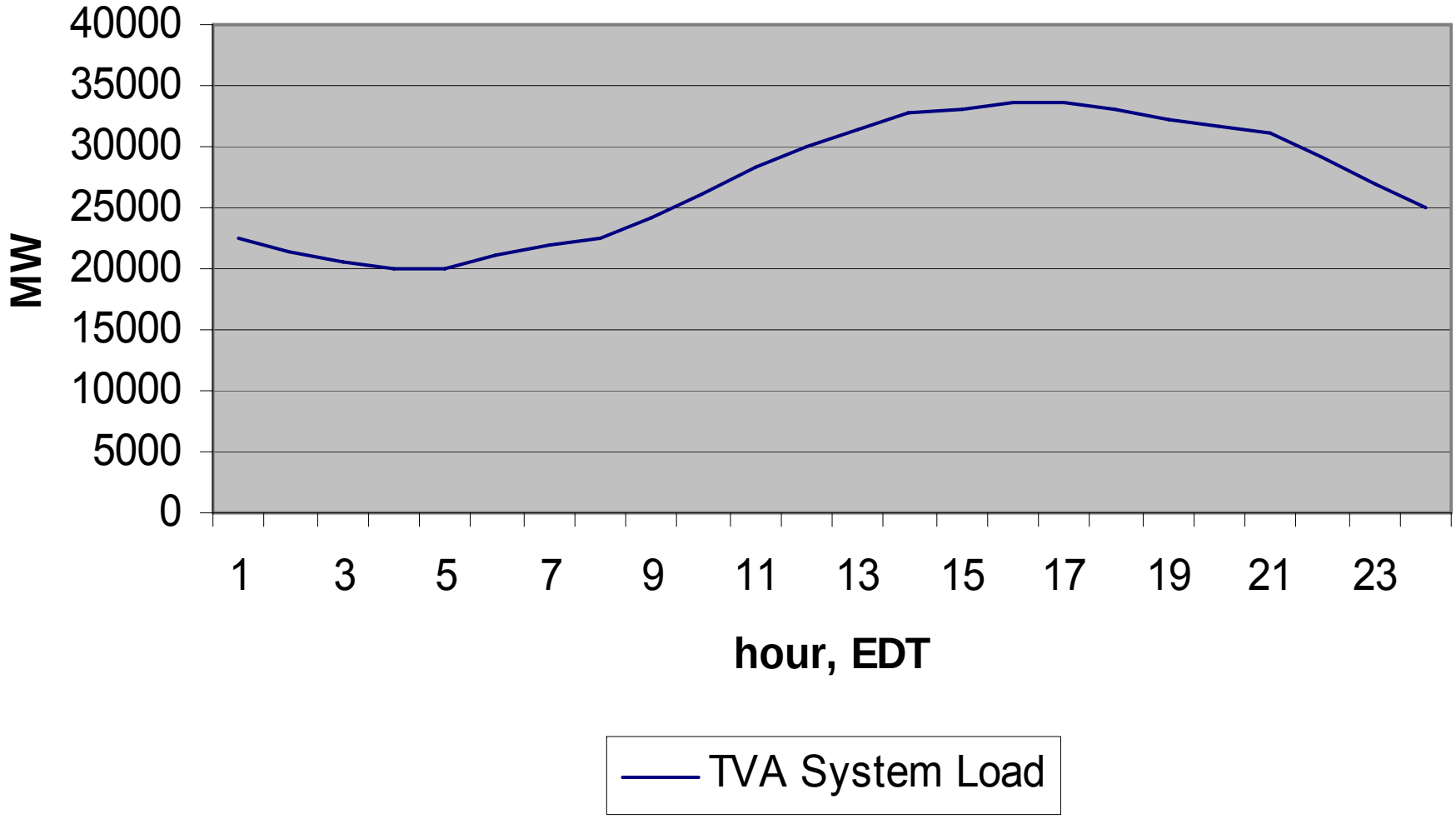


August 2007 Statewide Ranks over 113 years, i.e., 113 indicates record high.
Source: National Climatic Data Center, NESDIS/NOAA

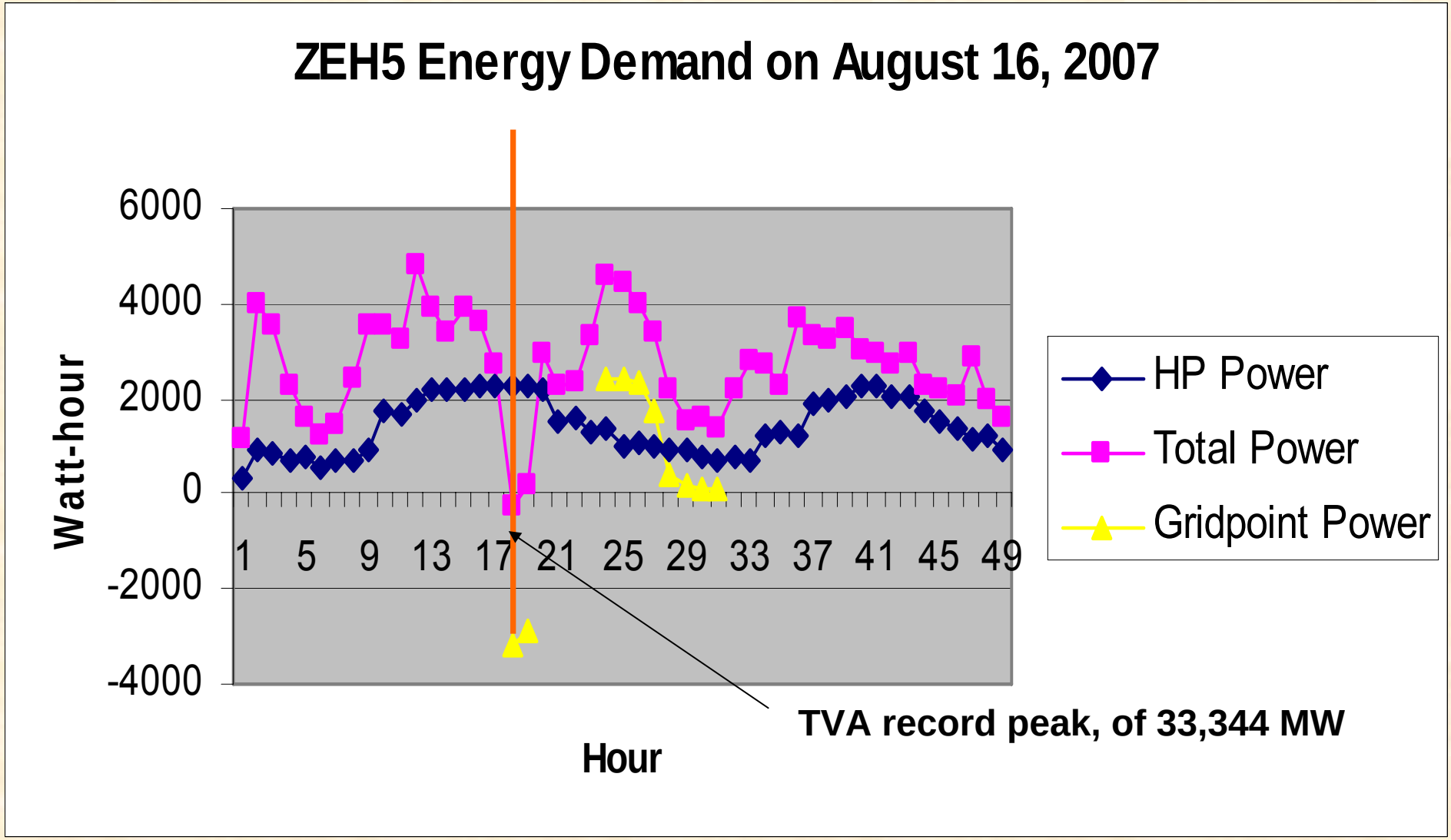
TVA all time Top 10 System Peaks



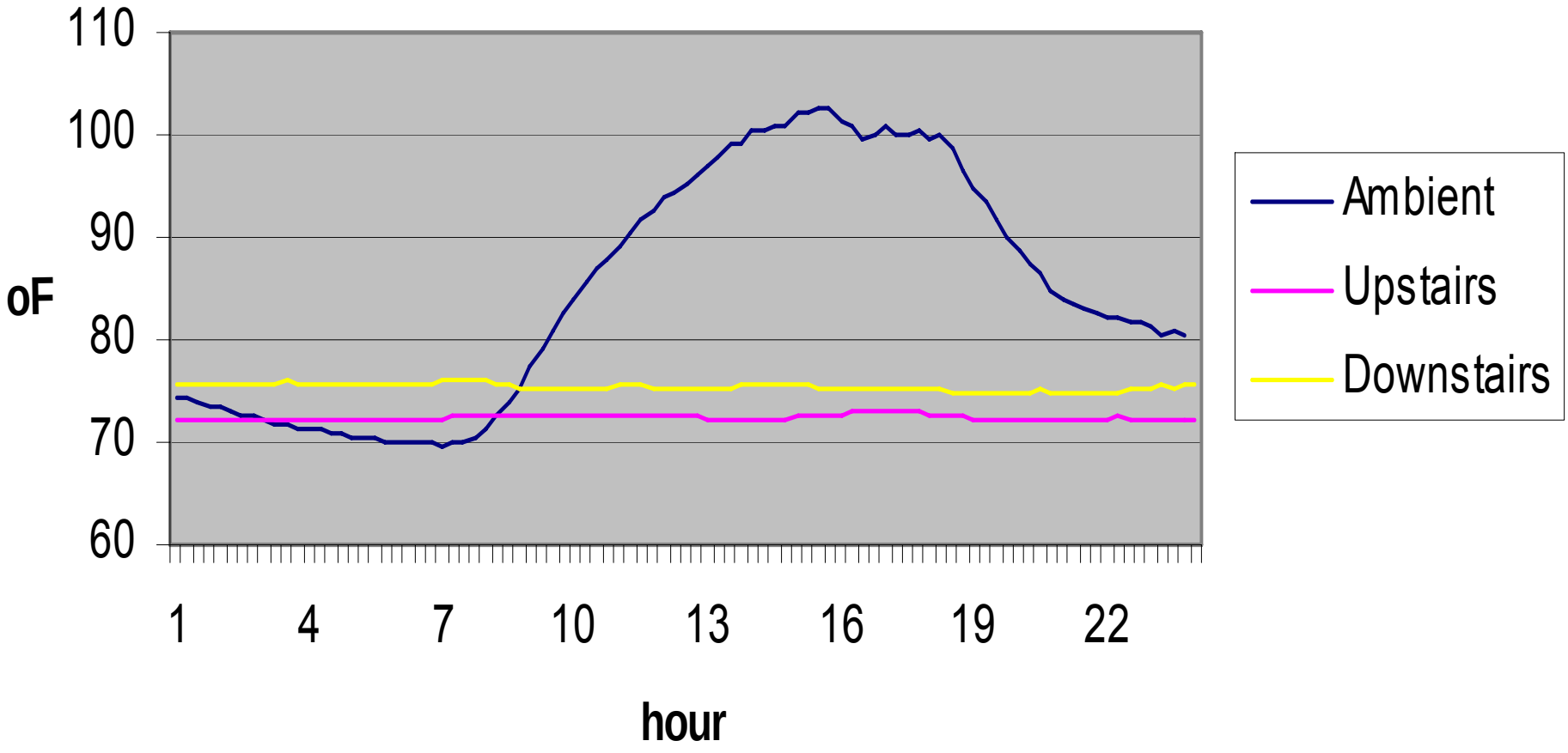
TVA System Load August 16, 2007



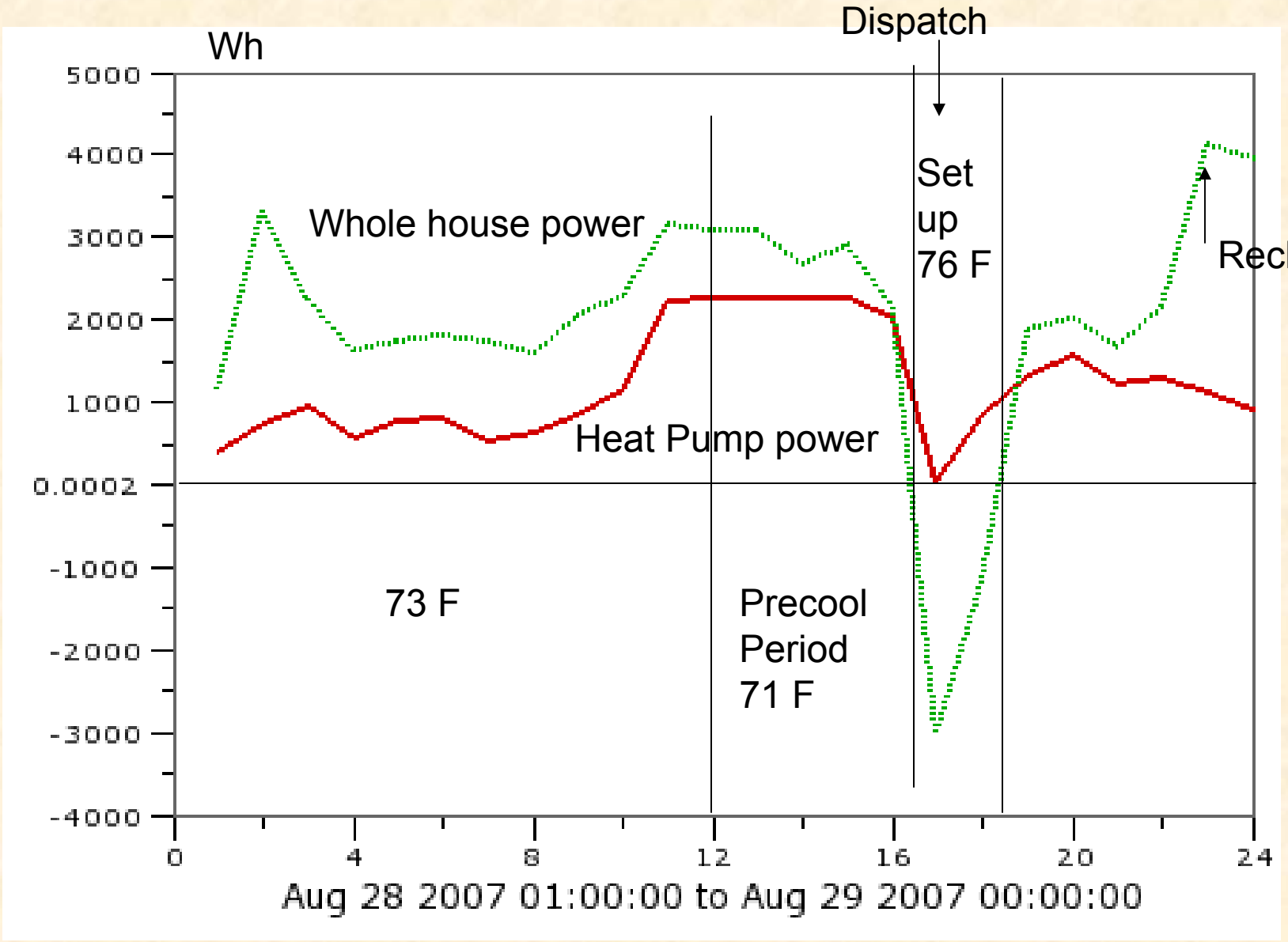
With DSM these houses can reach zero peak; ZEH5 Hourly energy on TVA peak day, August 16, 2007



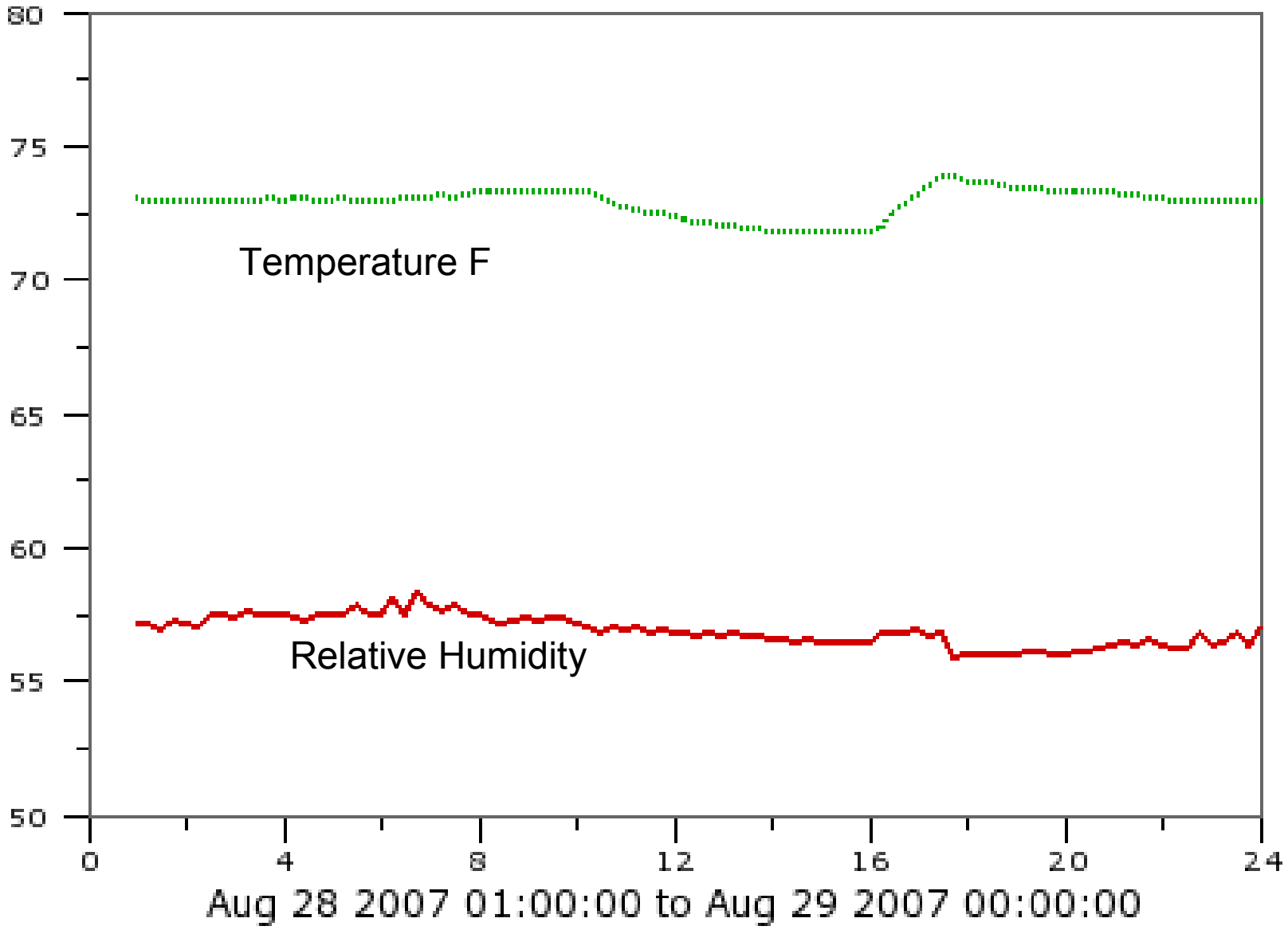
Temperatures on August 16

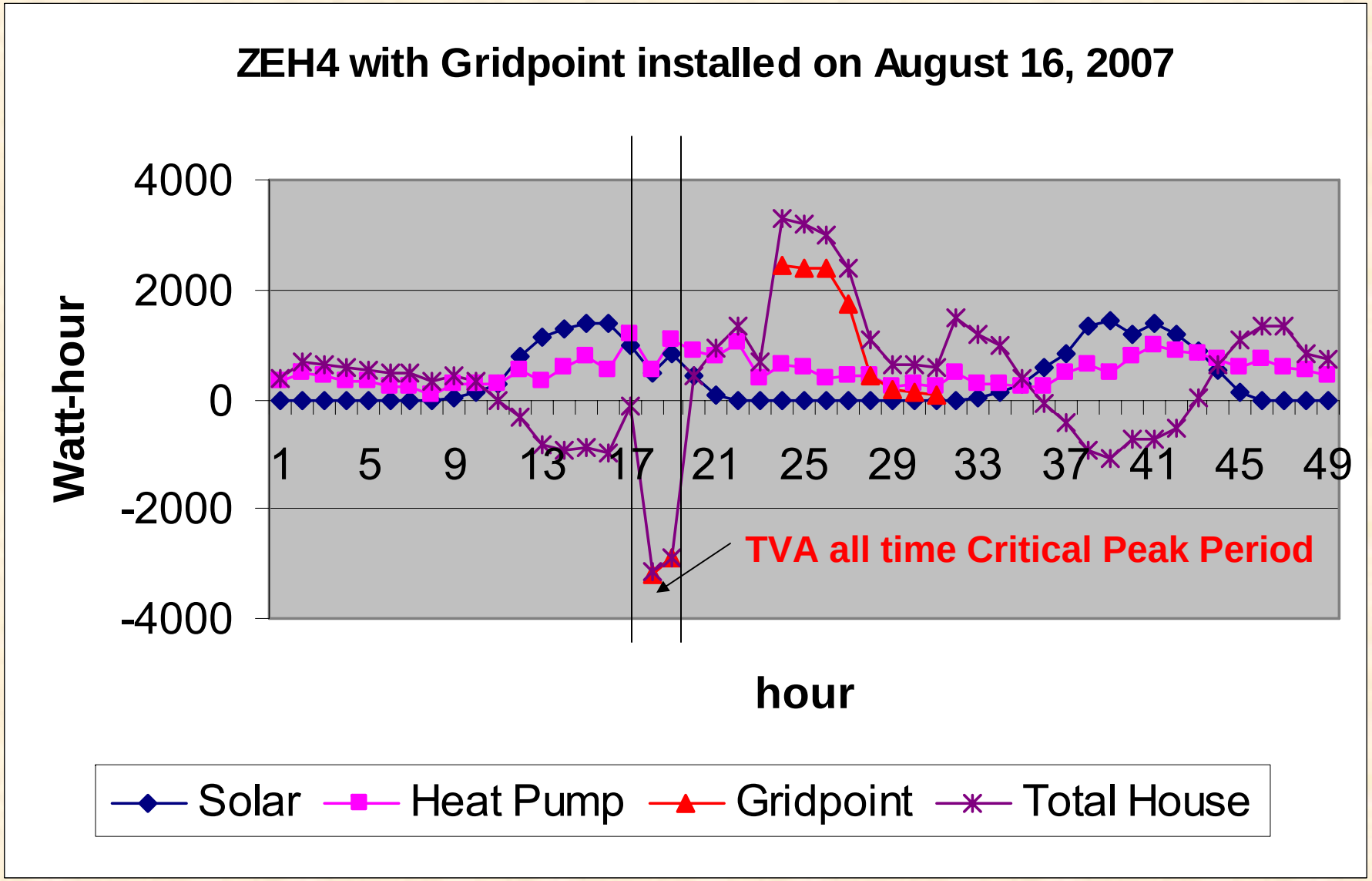


Precooling helps reduce peak cooling



Thermal comfort maintained; precool starts before critical peak



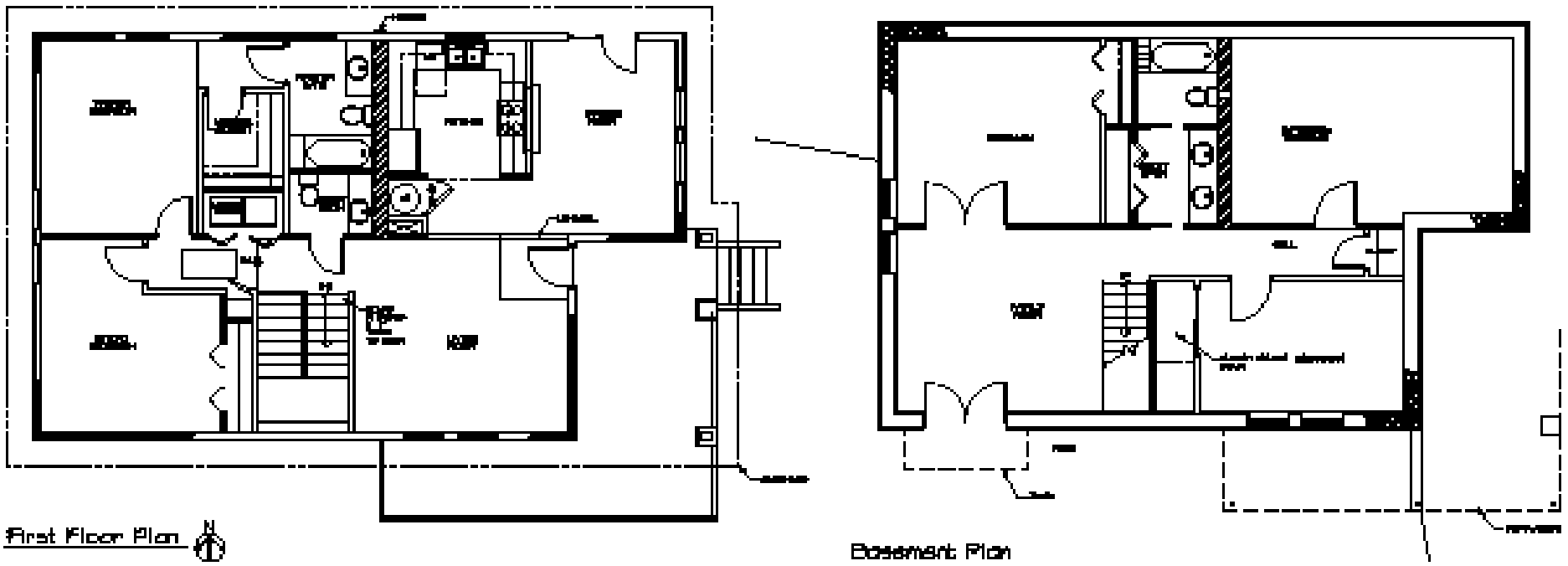

ZEH4 with Gridpoint installed on August 16, 2007
Watt-hour
4000
2000
0
-2000
-4000
1
5
9
13
17
21
25
29
33
37
41
45
49
TVA all time Critical Peak Period
hour
Solar
Heat Pump
Gridpoint
Total House

Summary of peak load savings from near zero annual energy homes in East Tennessee

Component	Low estimate of Peak load savings kW	Average Peak load savings kW	High estimate of Peak load savings kW
ZEH Energy efficiency	0.55	0.75	4
2.2 Solar PV	0.55	0.75	1
Battery dispatch	2.9	3	3.1
Pre-cooling strategy	1.5	2.5	3
TOTAL	5.5	7.0	11.1

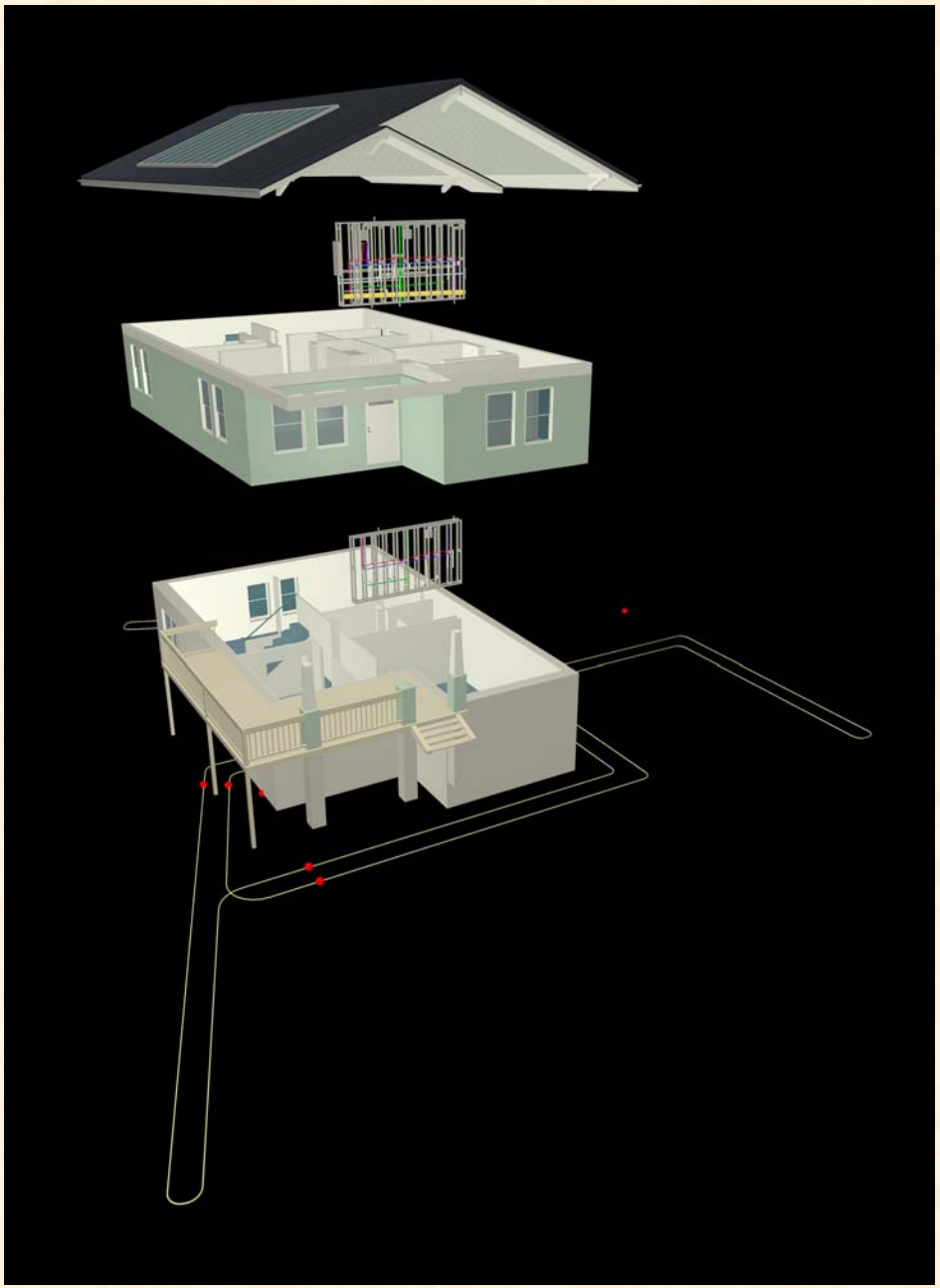
ZEH7; 2.5 kW PV, Solar HW, SIP walls and roof, less than $1/day, Solar 37%, enough roof area to be “ZEH ready”

2640 ft^2



This SIP house is designed with a family of 4 in mind. It is equipped with a high efficiency geothermal heat pump, a solar water heater, and a 2.5 Kw photovoltaic system. In the TVA service territory the PV connected to the TVA green power generation program reduces your electric bill by allowing you to sell the solar power back to your service provider*. With the PV system in place the house, with typical internal energy loads, costs just $0.80 a day. The same house without the PV system cost is estimated at $2.12. The HERS index with the PV is 37 and without it is 53.

The cost per day with PV was determined using a $0.15/Kw buyback rate.



Upscale version with same energy performance

- **8/12 pitch roof**
- **Cedar shakes**
- **Crab Orchard Stone**
- **Stair Punch out**
- **400 ft^2 Loft option**
- **Cost estimate $310K**


METAL ROOF
HORIZONTAL SIDING
STONE
P.V.

Thank you!

Jeff Christian

ChristianJE@ORNL.gov