UT-BATTELLE

Building America Near Zero Energy Habitats

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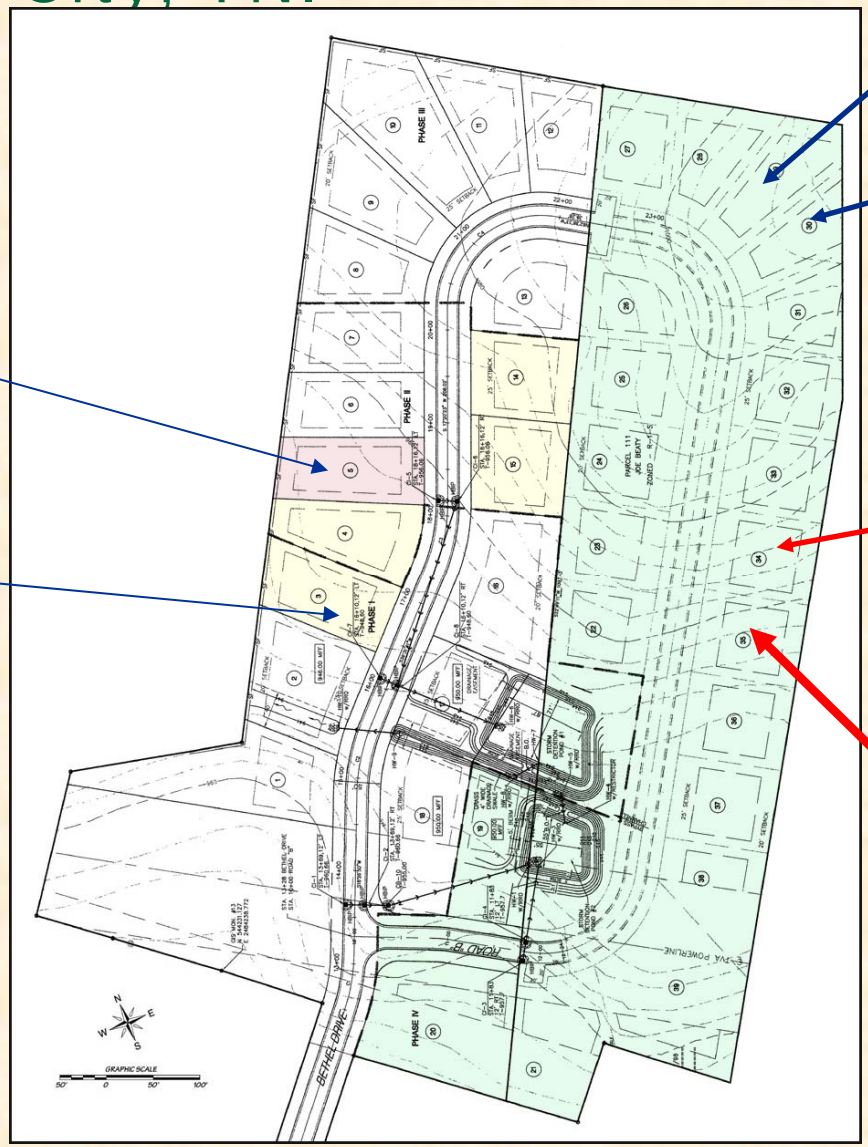
Building AMERICA
U.S. Department of Energy

OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Building America near Zero Energy House Test Site; Lenoir City, TN.



✓ZEH2
IBACOS

✓ZEH3
IBACOS

✓ZEH1
BSC

✓Base House

✓ZEH4
CARB

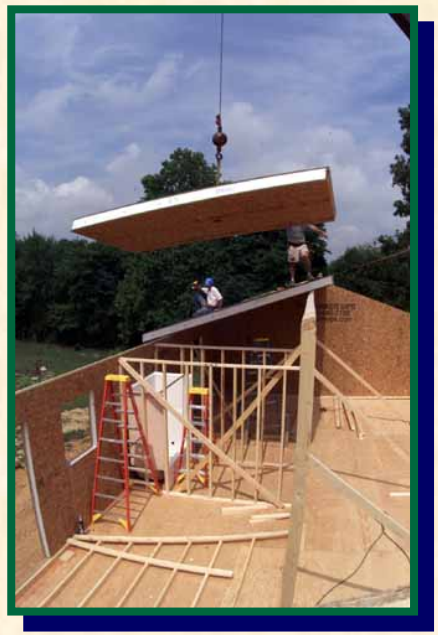
ZEH5

CONSOL

South

ZEH1 first house to sell solar power to TVA

- **Annual measured heating cost - $98,**
- **Cooling - $79,**
- **Domestic hot water $96,**
- **Space heating and cooling energy $0.48 / day**
- **Solar credits $0.82 / day**
- **Net off site total energy $0.93 / day**
- **Construction cost - $100K**



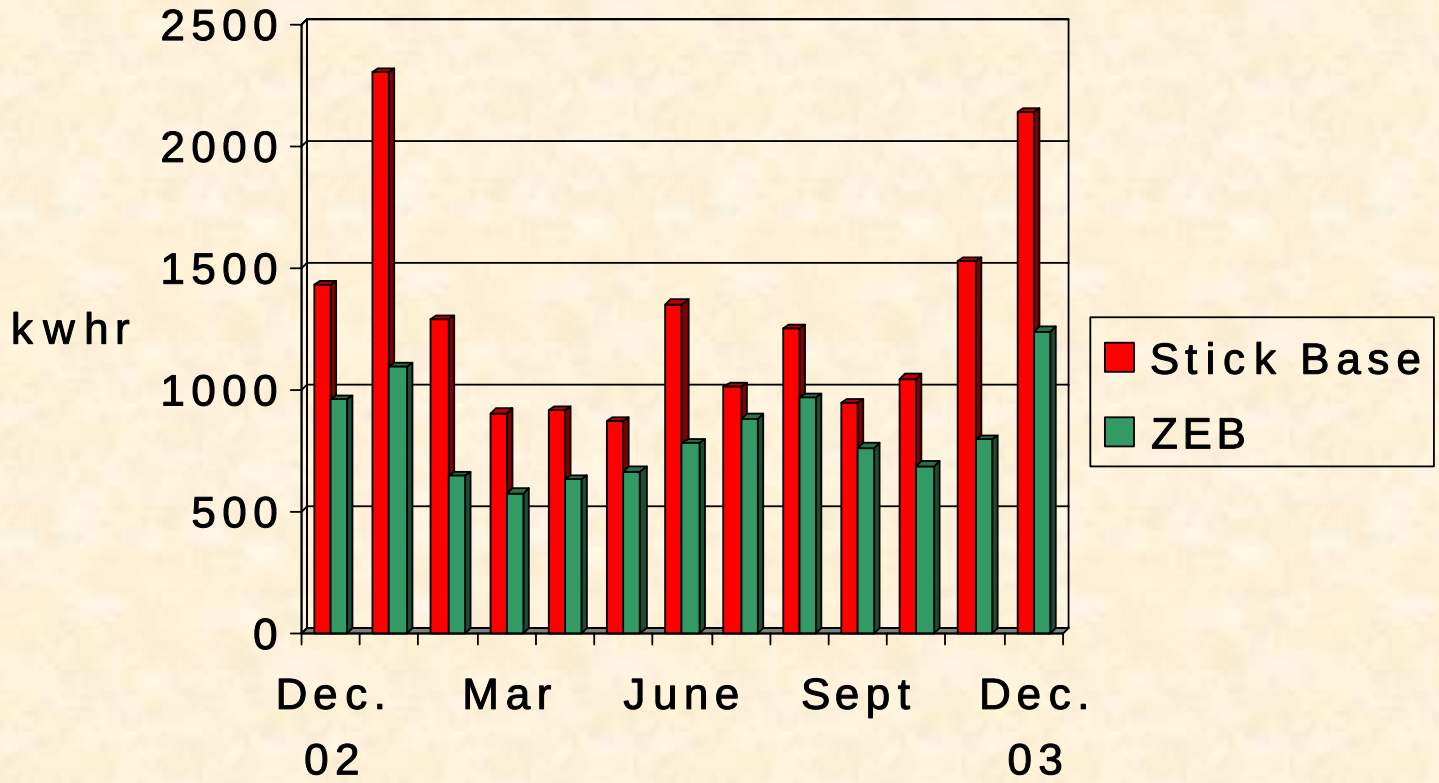
TVA Green Power Switch Generation Partner Program

- **Residential retail rate ~$0.067/kWh**
- **Sells green power for~$0.094/kWh**
- **Buys solar AC for**
  - **$0.15/kWh**
  - **10 years**
- **Going up to $0.20/kWh?**
  - **Retroactive**
  - **-$0.27 / day**
  - **New net cost of $0.66/ day**

ZEH1 Features

- **Air-tight floor, wall and ceiling SIPS**
- **All ducts inside conditioned space**
- **Mechanical supply ventilation- Air-cycler**
- **14 SEER - 1.5 ton HP**
- **CFL and Energy Star Appliances**
- **Windows .34 U-value, .36 SHGF**
- **Reflective hidden metal seam roof (light grey)**
- **Grid-connected 2 kWp PV**
- **Integrated HPWH**

1st ZEH used 40% less total energy than HERS rated 84 stick base house (already 20% better than IECC)



ZEH1 Performance

- **This all electric house used 28 kWhr/day**
- **Other loads averaged 17 kwhr/day**
- **Solar AC generation 5.5 kWhr/day**
- **On site power 20% of total energy**
- **41% of solar goes to the grid.**
- **Solar system**
  - **Current first cost $13.6K**
  - **Simple payback**
    - **@$0.20/kWh – 34 years**
    - **@$0.30/kWh – 23 years**
  - **First cost must drop to $8K for 20 payback @$0.20/kWh**

Lessons learned from ZEH1

- **Downsize and near zero energy is affordable**
- **Potential for creating a whole new product**
  - **Small affordable near zero energy houses**
  - **Grouping premium components**
    - **SIPs**
    - **High performance windows**
    - **Metal roof**
    - **Solar PV**
    - **High SEER Heat Pump**
    - **Heat Pump Water Heater**
  - **Construction cost less than $100K**
  - **Use less than a dollar a day, for energy**
- **National Scale zero energy housing is a stretch goal**
- **Creates a buildings technology R&D focus**

ZEH 2 Features

- **R-15.5 walls, R-23 ceiling, SIPs 1.8 lb/ft^3 EPS R-4/in and R-23 floor**
- **2 ton HP two speed compressor, variable speed ECM indoor fan**
- **HPWH hard duct linked with crawl and fridge on outside wall, wall, COPs of 2.0, pulling from the crawl space.**
- **Occupancy sensor for energy control**
- **6/12 pitch, grid-tie 2kWp Sharp 165W Solar PV, 15% efficiency**
- **Insulated-unvented crawlspace**
- **Airtight taped joints with supply supply mechanical ventilation, preconditioned fresh air.**

Sept. 03, 2003

August 04 total energy bill $14.52

ZEH 2 Integrated Heat Pump Water Heater

- **Located on outside wall**
- **Ducts**
  - **Much shorter**
  - **No flex**
- **HPWH using 2.7 kWh/day(36gal/day)**
- **Fridge using 1.23 kWh/day**

After 10 months of detailed monitoring

- **ZEH 2 using $0.92/day**
- **$0.12 less than ZEH1 during this same period**
- **Using $0.20/kWhr for solar credit currently at $0.59/day**
- **Looks like about a $0.05 day improvement over ZEH1**
  - **No CFL**
  - **No dishwasher**
  - **Found low space heat pump charge beginning of summer**
  - **Accidental high setting of heat pump water heater 155 F first four months**

Lessons learned from ZEH2

- **HPWH integration with fridge works well**
- **SIPS / metal roof / solar module connections need some work**
- **Elevated RH in crawl mystery solved homeowner opened vents, cold pipes must be insulated or installed in floor system above floor insulation**
- **Commissioning important part of install; solar, HPWH, HPWH, HP**
- **ZEH friendly homeowner is critical to attaining long term goal.**
- **Homeowner is delighted**

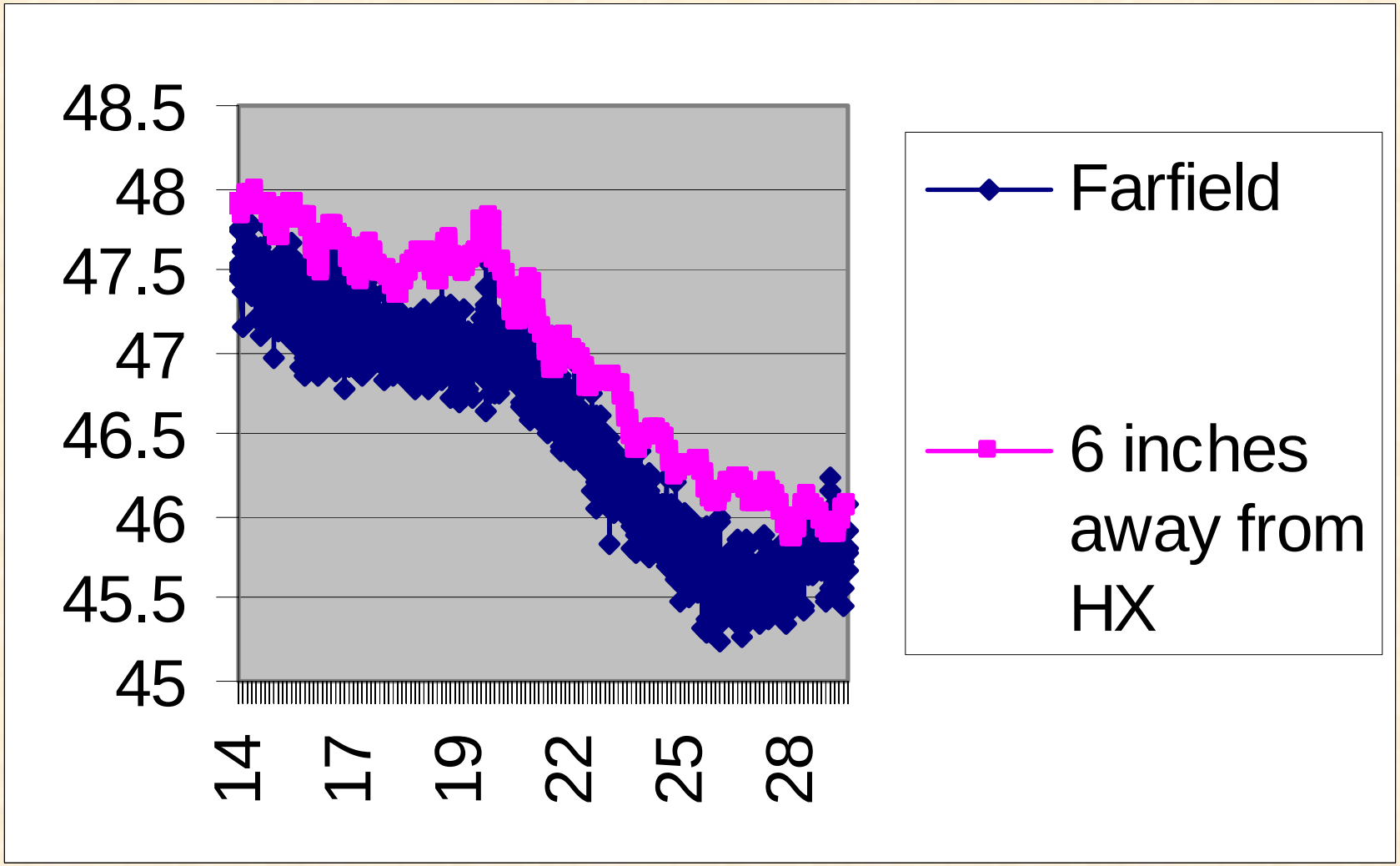
ZEH test house 3

- **less than $100k and $0.68/day for off site site energy**
- **50% savings from BA benchmark**
- **6 inch SIP wall, 10 in. roof**
- **Cool pigmented roof(0.23 instead of 0.17) 0.17)**
- **2 ton direct exchange geothermal heat pump with SEER of 16.**
- **Whole house 0.06 ACH.**

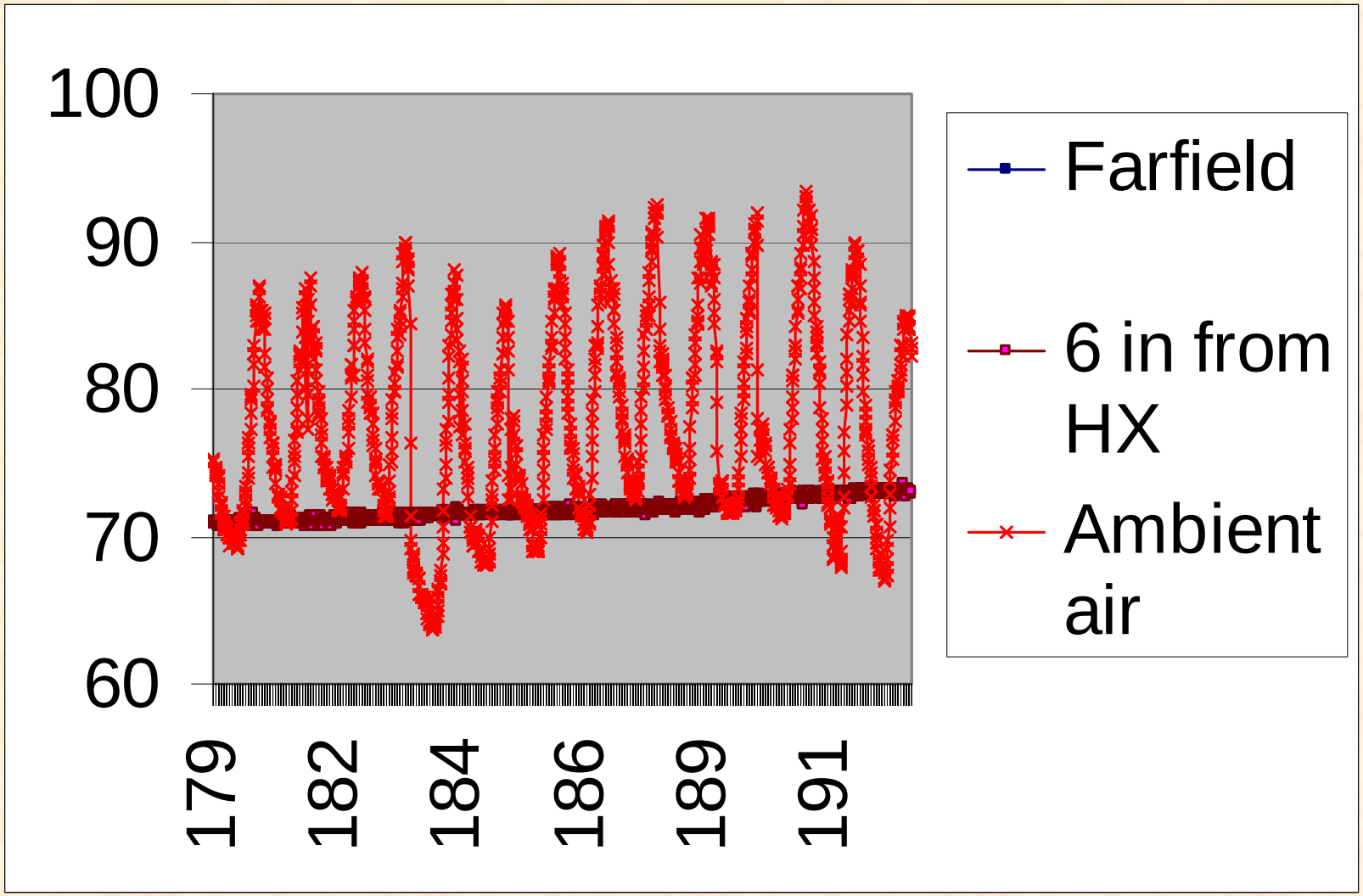
ZEH 3 using geothermal

No HVAC noise, compressor unit located in crawl

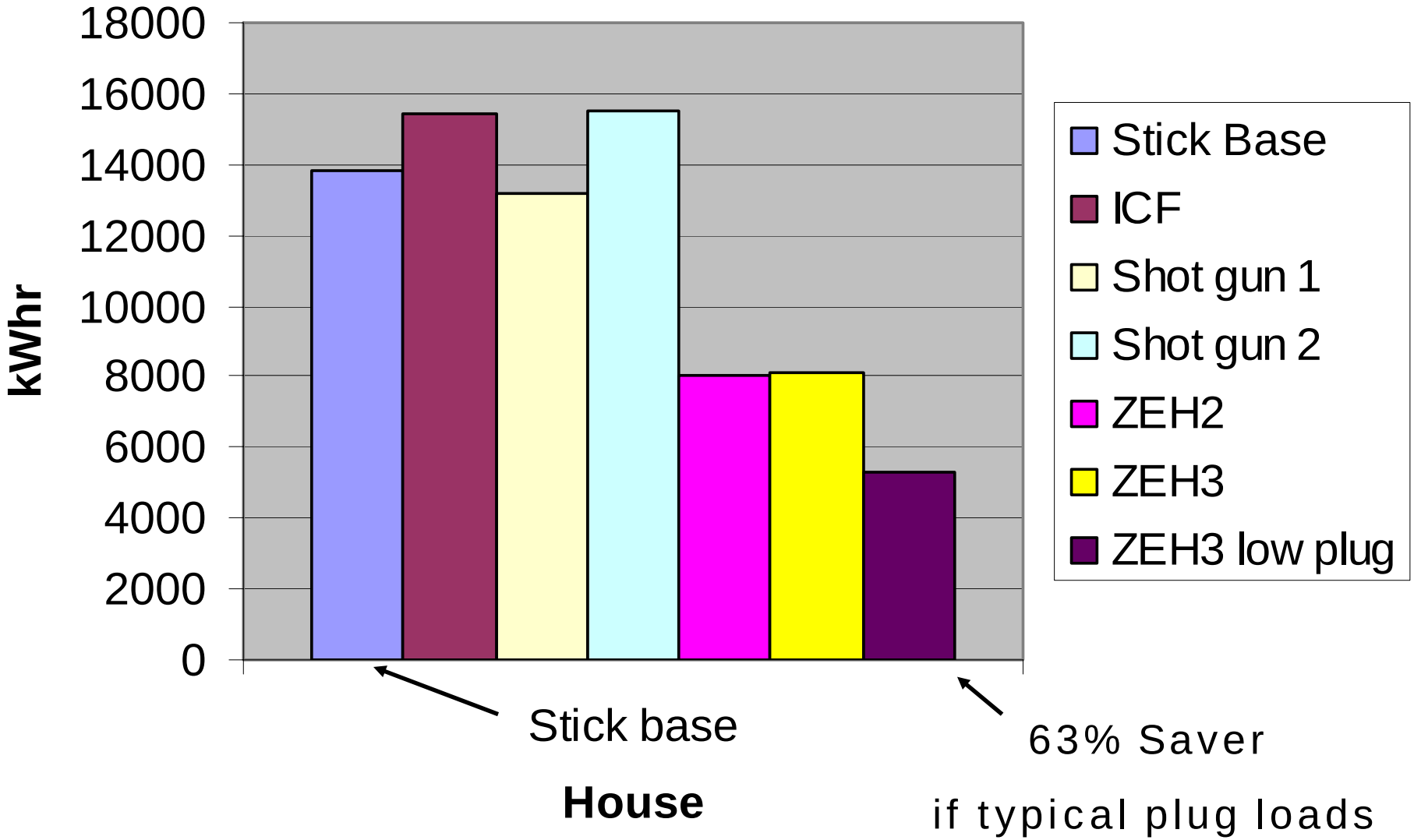
Ground Temperature ^{0}F in January



Ground Temperature ^{0}F in July



ZEH2 & 3 performing 44% better than base houses in same development 9(mo)



Lessons learned from ZEH3

- **Bigger the panels the easier the assembly**
- **Geothermal HP terrific energy savings**
- **Sufficient roof area to reach net zero energy**
- **If TVA were to offer $0.31/kWhr zero energy bill attainable**
- **Dehumidification would help in June-August**
- **Thermal mass would offer improvement in energy performance and enhance comfort**
- **Add dishwasher**
- **Add CFL package**
- **Go beyond energy star appliances**

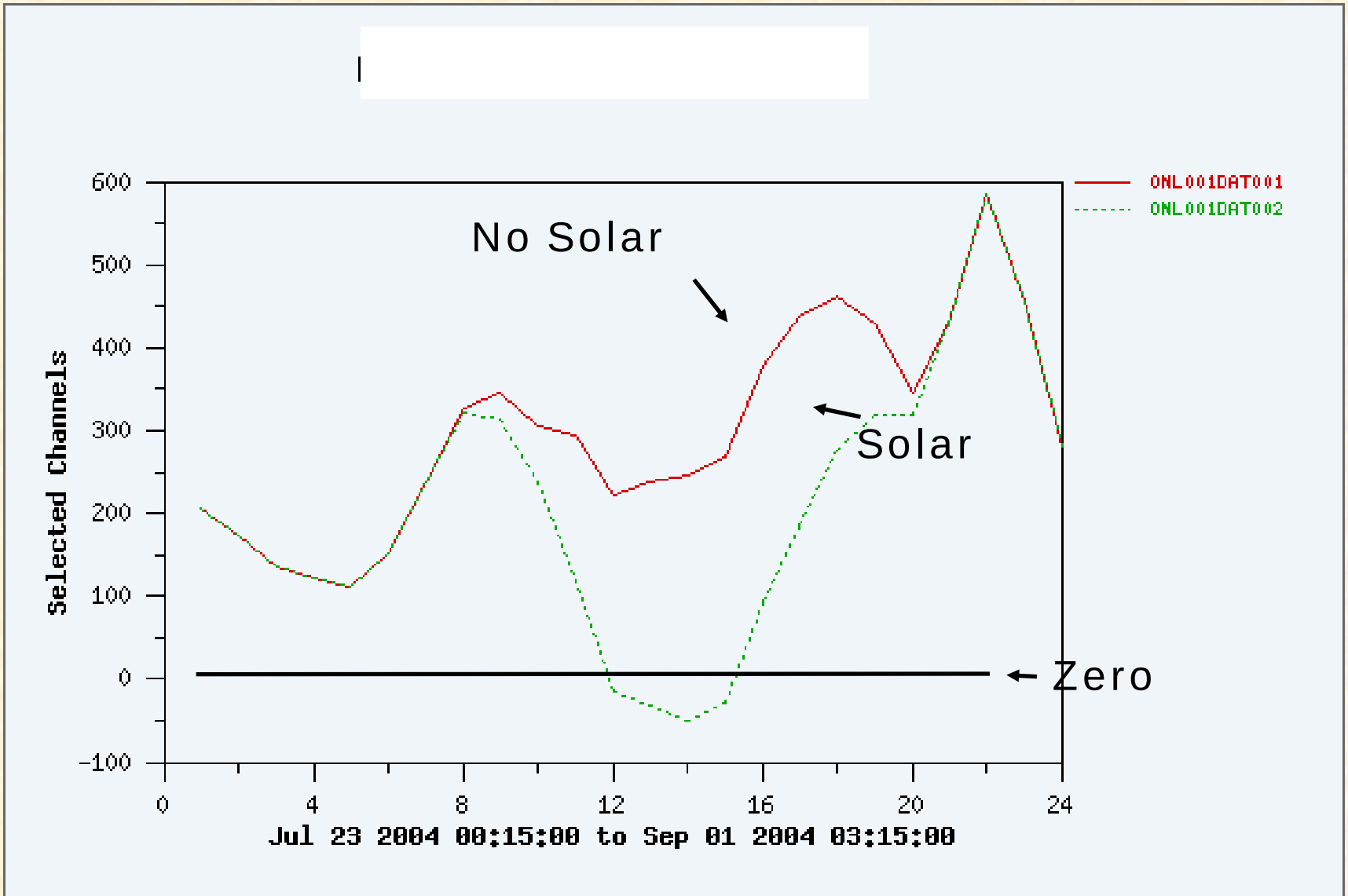
ZEH4 Combination of Polyiso-pentane blown SIPS and T-Mass most promising

ZEH4 features

- 2.2 kWp Evergreen cedar
  - 110 V output
  - 20 modules
- Sunny Boy 2500 inverter
- Lennox 2 stage HP
  - 17 SEER
  - Programmable thermostat
- Air cycler controlled
  - Supply ventilation
  - Upstairs ½ bath fan
- Tmass foundation
- Polyiso- pentane blown SIPS, 4 in walls, 8 in 4X12 cathedral roof
- ATAS highly reflective metal tile roof, engineered solar connection to SIP

Meter watching the next hot eco-tourism activity

ZEH4 PV on average helps meet summer early PM peaks from July 23-august 31, 2004



Industry Partners

- **TVA**
- **SIPA / Insulspan / FischerSIPs) / Winter Panel**
- **Andersen Windows**
- **Habitat for Humanity**
- **Dow**
- **Lennox**
- **American Geothermal**
- **Metal Roofing Alliance/ATAS**
- **Dupont**
- **EMI heat pump water heater**
- **BASF**
- **Design Basics**
- **Sharp**
- **NOVA Chemicals**
- **Nextech Power/EPRI (DC power)**

Opportunities

- **Market for affordable healthy near zero energy houses with capability for integration of on-site power**
- **Assembling partners for ZEH Kit to enable**
  - **a mass purchase**
  - **Conduct critical path integration**
- **Community scale demonstrations**
- **Learning Module for University graduate level Architecture and AIA Continuing Education**