



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



TVA/DOE Retrofit Research Houses with Transforming Impacts

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Residential Summit

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Target

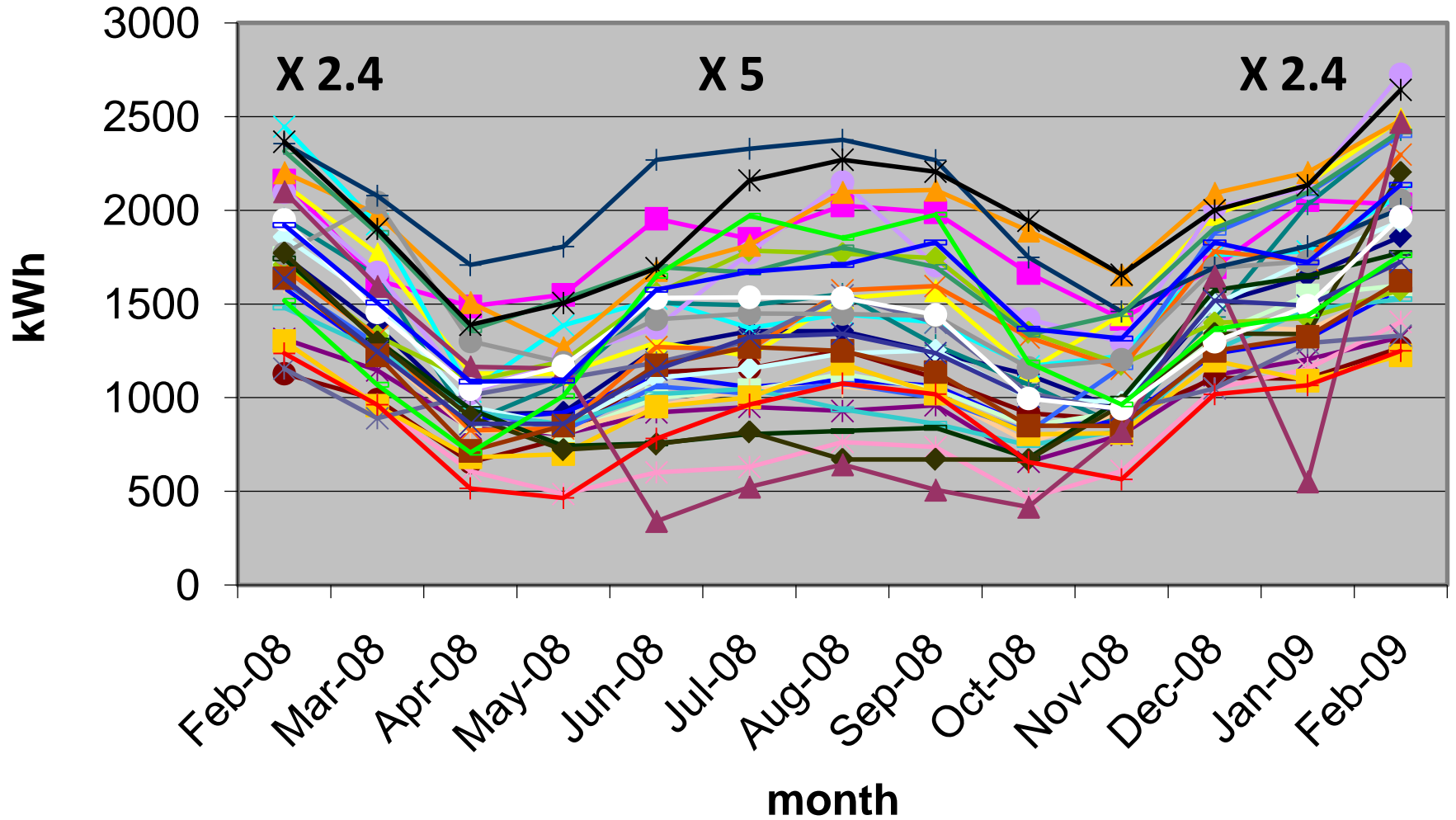
1. Inform TVA's residential retrofit incentive program to help attain 1400 MW of peak power savings by 2012
2. Local government electronic retrofit tool box
3. TVA In-home evaluation participants



Path towards maximum affordable retrofit homes journeys through research houses

- Past: 10 Habitat for Humanity research homes
 - 3 months to 1 year unoccupied
 - 1-3 years occupied
- Present:
 - Three TVA simulated occupancy Campbell Creek research homes
 - Four Schaad Wolf Creek simulated occupancy research houses
- Future:
 - FY10 ten 40% occupied retrofits
 - FY11 ten 50% occupied retrofits
 - FY12 Urban multifamily simulated occupancy retrofits
 - FY 13 Affordable new and retrofit kits
 - FY14 Nursing Home retrofits

Monthly kWh demand of Conventional Habitat occupied houses



Campbell Creek Builder and Retrofit Research Houses





TVA Campbell Creek Research Houses

- Builder house, 2400 ft², HERS 101
- Retrofit house, 2400 ft², HERS 68
- Maximum affordable, 2500 ft², HERS 34
- TVA pays
 - Rent
 - All utilities
 - Monthly house cleaning
 - Grounds keeping
 - For identical furnishings in all three (internal thermal Mass)

Sealed and insulated attic with single stage two zoned heat pump system

- Major retrofit expense
Spray foam
- Major gap is optimum
Lowest cost insulation
combination that
controls moisture for each
climate



TVA three research houses; 1.5 yrs of detailed measurements collected

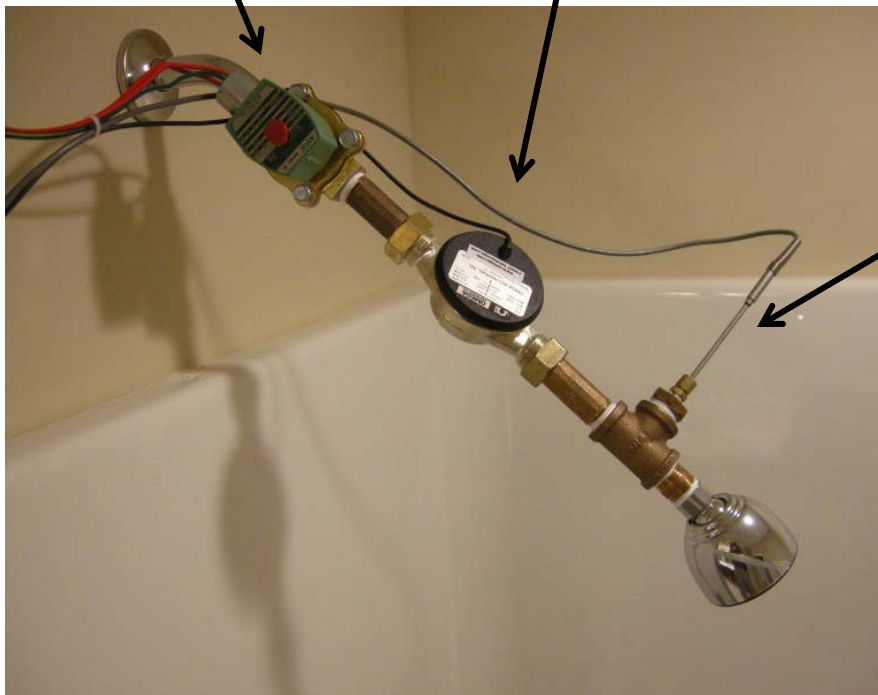
- Builder house
 - Standard framing package R-13 walls, R-30 Ceiling
 - 2 Heat Pumps, SEER 13, HSPF 7.7, totaling 4.5 tons
- Retrofit house
 - Sealed insulated attic
 - One 3 ton two stage heat pump, HSPF= 9.5, SEER 16, zone control
 - Multi-splits to be retrofitted September 2010 (pipes left exposed in unoccupied research house)
 - 100% CFL
 - Energy star appliances, demanded enabled appliances 09/10
 - Single-hung LowE, gas filled windows
 - Heat pump water heater in the garage
 - Measured 42% whole house savings compared to the Builder house, positive cash flow using 10 year, 6% loan, ACEEE 2010 summer study paper



Shower Control

RedHat Solenoid

Omega 4605 Flowmeter



Omega OL-703
Thermister Probe



Refrigerators



Laundry Control



Dryer Mister

Minimize dryer duct run in these very air tight Structures (dryer performance as function of house air tightness)



Relay Rack



Example of appliance
control board interface.

Dishwashers run daily



“Builder House”

- One HVAC unit per floor
- Ducts and the indoor coil not in conditioned space
- 4.5 tons for 2400 ft²
- TVA selected after housing market study





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Retrofit Research House



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Only retrofit change to the walls and windows; LowE-gas filled windows



Vents carefully blocked before sealing and insulating the attic





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Foam being installed in attic





Insulated to R-value of 30





Single Heat Pump serving the whole house; SEER 16, HSPF= 9.5 with supply ventilation





Select Findings

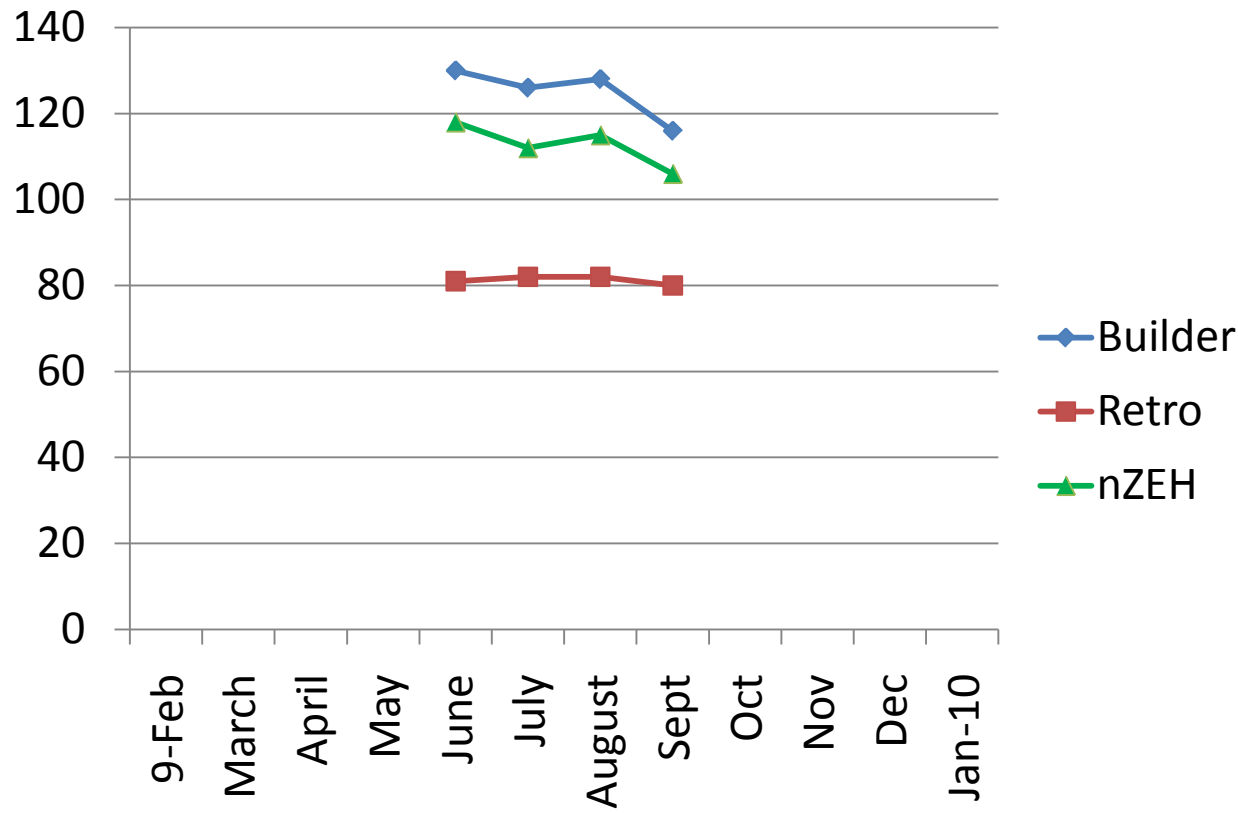
- House uses 42% less energy than the builder, ORNL 34 page report and ACEEE 2010 Summer Study paper available
- Costs \$3.76/day compared to the builder house at \$6.46 day.
- \$10K incremental cost meets neutral cash flow criteria assuming 10yr@6% home equity loan
- In the cooling season the upstairs heat pump in the builders' house, uses 70% of the cooling energy for the whole house. This is the unit that is located in the hot attic, which results in much poorer performance than the unit located in the garage with most of the supply ducts in between floors within the conditioned space. (tstat set at 76 F in summer)
- The GE HPWH (~\$1.5K) and lower hot water demand from the energy star cloths and dish washers saves 71% compared to the standard electric water heater in the builder house with standard appliances.



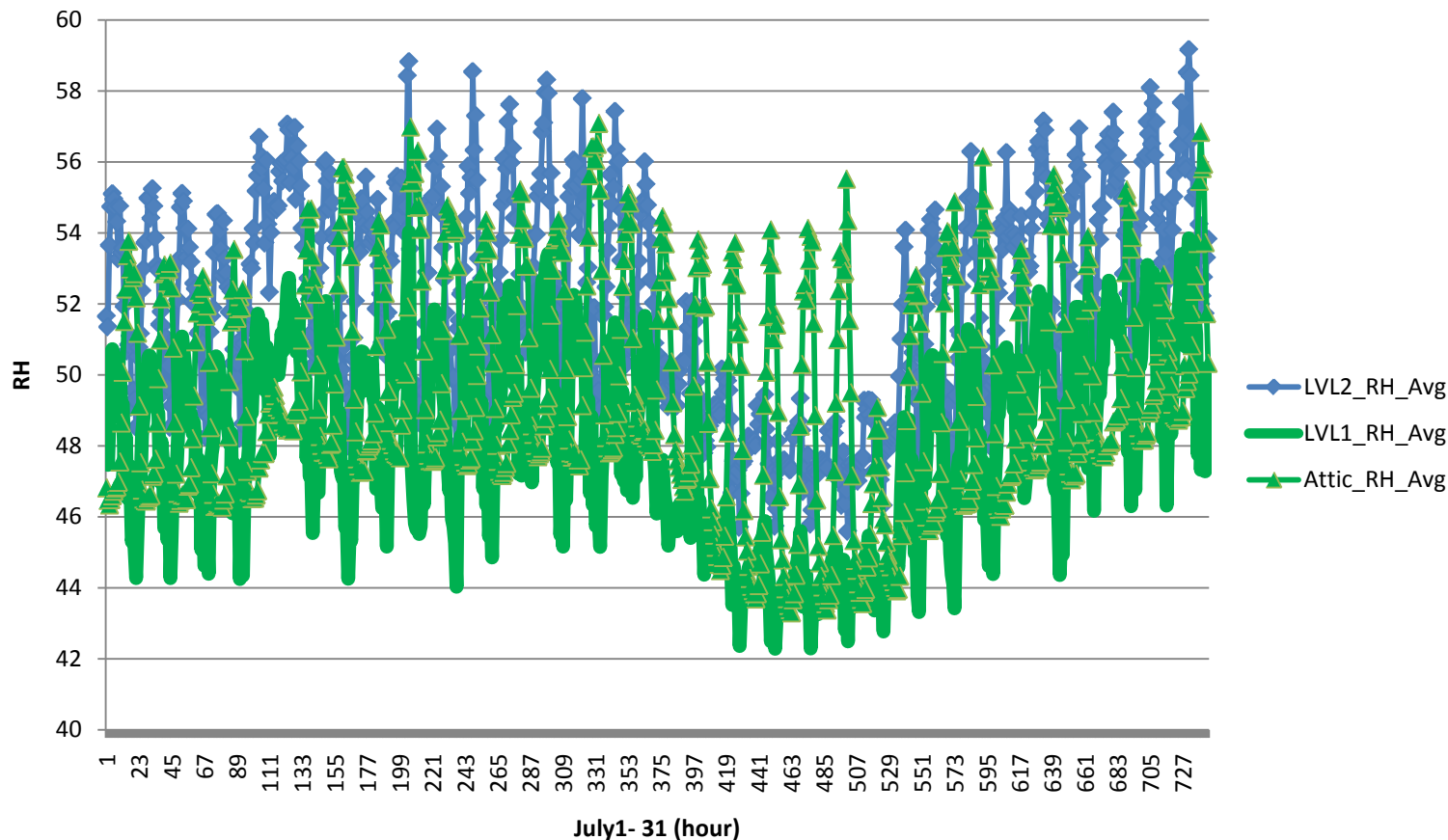
Lessons on Retrofit Research House to inform 10 house retrofits

- The energy star range when using the large oven consume 60% more energy than the lower cost builder model. Muffin oven saves about 5%
- The retrofit package saved 30% in the cooling months of August – September 2009 compared to the builder house.
- The insulated and sealed attic maximum temperature in the retrofit house this summer was found to be only 82F that is 6 F higher than the Tstat set point serving the upstairs level. This is compared to the conventional attic in Builder which had a maximum attic temperature of 131F.
- Sealing the attic reduces the whole house on a slab air leakage by 40%.
- The single unit 2- zoned HP distribution systems in Retro maintains uniform temperature in this two story house.
- The peak loads in these houses in the summer have been dominated by the dryer.
- The energy star cloths washer uses 70% more energy than the conventional washer. This does not account for water usage.
- The Retro mechanical ventilation CFM is a function of the amount of time the HP is providing heating or cooling. The more load the larger the ventilation air coming into the Retro. May call for seasonal manual damper adjustments to hit the target ventilation flow.
- The dashboards created for this project in a glance have proven to be very insightful.

Maximum hourly Attic air temp. 09

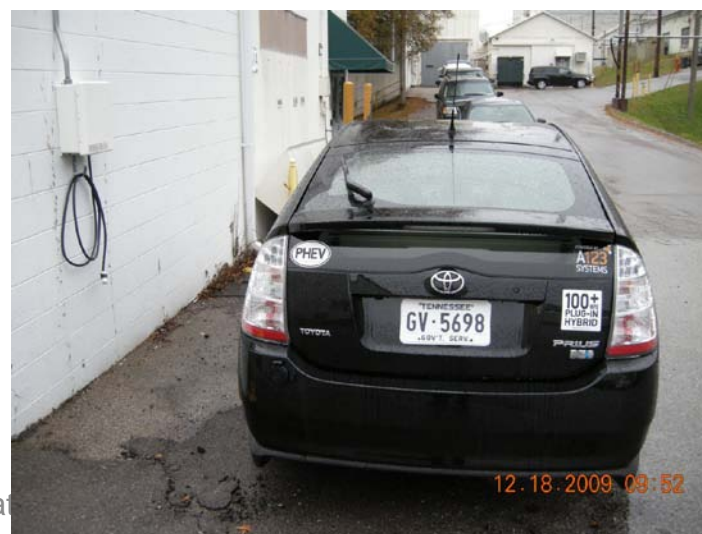


July hourly average RH in the retrofit house

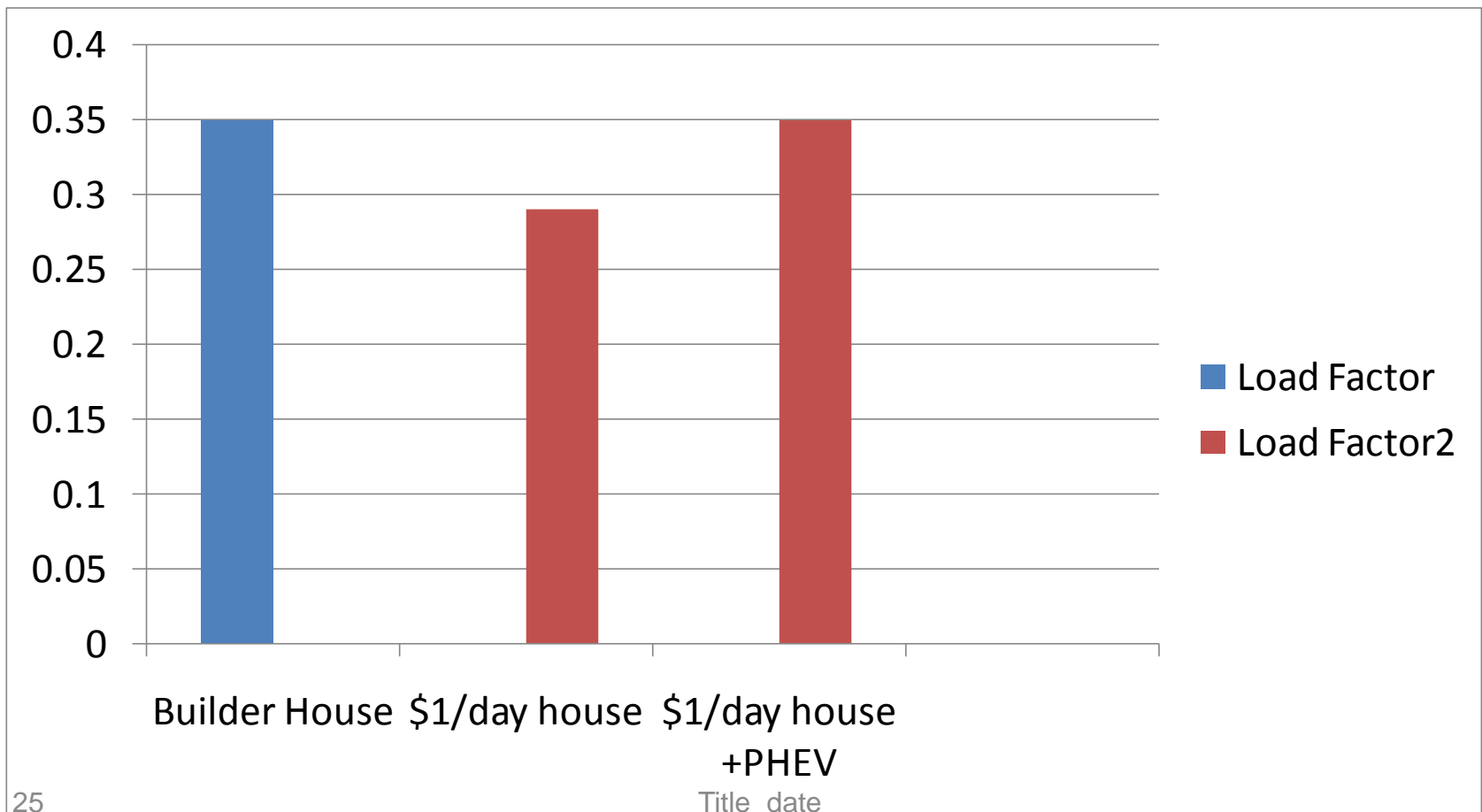


Electric Utilities pay very close attention to load factor

- In January and-March 2010
- Commuting 5-days/wk, 16 miles one way between \$1/day Campbell Creek Research House and ORNL Building 2518 with 50 kW Solar inverter
- 102 MPG
- 1000 Miles on One Tank of Gas
- Smart charging only between 11:00 PM- 4:00 AM next morning.
- Makes high performance homes load factor very attractive to electric utilities



High performance home plus PHEV has very attractive load factor from Electric Utility Perspective, March 2010





Next Step in the pursuit of maximum residential energy savings

- DOE/TVA 40% whole house retrofits
- Targeting Knoxville area surrounding research houses
- 10 deep retrofitted occupied homes 17-72 years old have been selected and detailed preretrofit site evaluations completed
- Energy savings with neutral cash flow
- Inform TVA's in-house energy retrofit program
- Local government electronic tool box to encourage citizen retrofits



DOE funding American Economic Recovery Residential Retrofit Research at ORNL started March 2010 runs until September 2011

- Out growth of the 3-TVA Campbell Creek research homes
- House 2 is the “retrofit house” proposed to engage the surrounding community in the research
- TVA statisticians selected the house size, type, features to be representative of what people want in a Tennessee home and representative of a dominate fraction of similar “middle class” housing
- Build upon TVA’s new residential retrofit program to identify “deep retrofits” (save 40-50% whole house energy savings)



The perfect Candidate for “extreme retrofit” project

- Two story > 15 yr
- Two HVAC units at least 10 yrs old, one for each floor
 - Upstairs in the attic
 - Main level either in the garage or side of house with ducts in crawl space
- Windows in need of replacement, i.e. seals broken
- Space for a vertical chase from attic to at least ceiling of main level or at most all the way to the crawl space or basement (2 ft X 3 ft closet space, old chimney, laundry shoot)
- Needing new energy star appliances including water heater
- Financial position to replace windows, HVAC, appliances
- Bonus –
 - need or desire to install a new wall exterior facing (old stucco, vinyl or wood siding)
 - Room for a horizontal geothermal loop
- Double bonus – would consider adding solar electric and solar water heating systems to roof and have good solar access



Interest in Extreme Retrofit

- DOE/ORNL/TVA press release in March 2010
- Would consider an extreme retrofit in the next 3 months,
- Requested complete energy records for 3 years
- Prepared for estimated cost of \$10/ft² – floor area
- Must first complete TVA In-home energy audit
- Would permit 12 months of detailed energy monitoring of home after completion of retrofit, aggregated use of results and publication of pictures.



TVAs “In-home Evaluation “pilot”

- Initiated February 2009
 - \$150 reimbursable audit fee
 - \$500 after spending \$1000 of retrofits
- Two models
 - CSG direct (working better)
 - TVA distributor
- 75 distributors signed up for the pilot
- CSG has more auditors, 20 (total in TN 70)
- Cue per auditor 6 weeks
- Positive action taken on 40-50%
- All 156 on program October 1, 2010 (this project has helped accelerate bring two distributors on board)



TVA's pilot



- Goals different than California or New York, (more focus on peak load reduction)
- Maintains “quality contractor list”
- Auditor inspects work before distributing the incentive and can have contractor culled from the list if quality installation not met
- No Blower door, duct blaster or IR survey only pre and post walk through inspection.
- Evaluators required to take one week BPI like course and heat pump installation inspection class (taught by CSG in-house instructor), shadow inspector for three weeks and pass test



CSG in TN

- In 2009, 1200 “walk through” evaluations
- Completed as of May 2010; 6000
- TVA not disclosing long term goal but are now ‘fully staffed and see no obstacles’
- Future direction is more towards low interest loans with monthly payments on electricity bill
- Focus is currently attic, crawlspace and duct air tightness along with attic insulation to R-38.



TVA/DOE/ARRA retrofit initiative

- TVA cost sharing \$500K with ARRA funds
- Received ~70 emails expressing homeowner interest in being selected as one of the 10 extreme retrofits.
- Incremental retrofit model goes from fruit on the ground, to low hanging but very little elevated harvesting
- FY10 goal is 40% energy savings from current state as measured with 3 years of monthly pre energy bills.
- FY11 goal 50% whole house energy savings

Deliverables

- Hold series of town hall meetings; focus on case study results in your community, electronic handbook, energy performance label, financial arrangement with local bank
 - Farragut
 - Knoxville
 - Kingston
 - Oak Ridge
 - Memphis
 - Nashville
 - Johnson City
- 10 heavily instrumented houses
 - With proposal partners; TVA, City of Knoxville, City of Farragut, East TN Quality Growth Council, GE, Diekin, Lennox, Owens Corning, Contractors (Schaad, John Kerr), Weatherization and HVAC contractors (Triangle, Biobased, Beyer, Icynene, Spray Foam Manufacturers Association, develop selection criteria
 - Selected 13 houses for site evaluations, Completed June 2010
 - Oversee incremental Retrofit, 1. Weatherization, 2. test, 3. HVAC
- Monitor for one year post retrofit (75-100 sensors)
- Place monthly dashboards on Website compared to TVA/DOE research houses with simulated occupancy
- Create TVA in home evaluation customer focused “case study fact sheet” at close out meeting between the auditor and homeowner, Local Government Electronic Tool Box

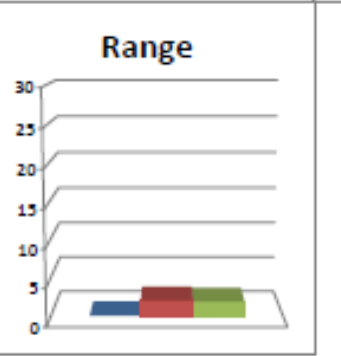
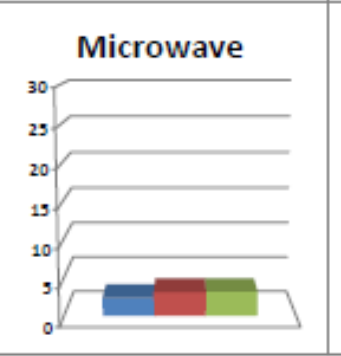
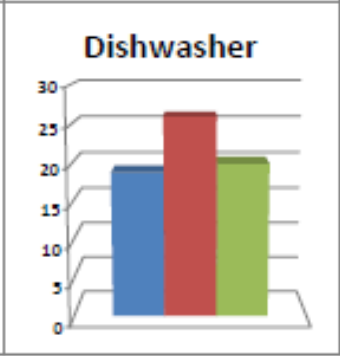
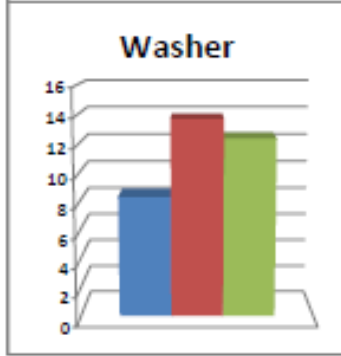
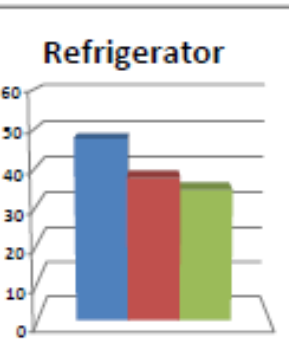
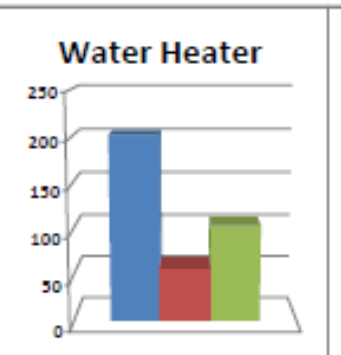
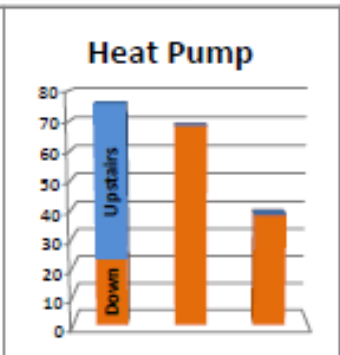
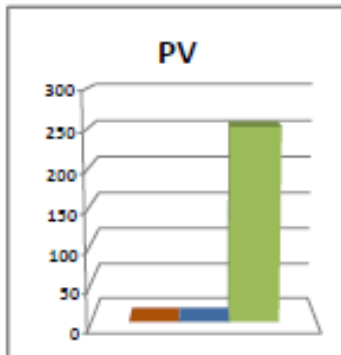
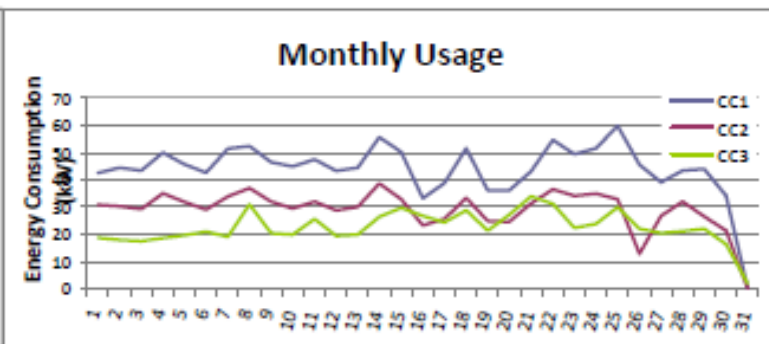
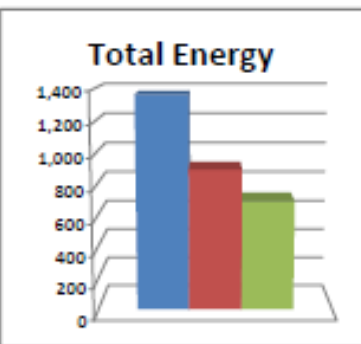


Campbell Creek Research Houses Dashboard; 09/09

Monthly Dashboard Report
September-09

House Name	Energy	Peak kW	Peak Day	Peak Time
CC1	1,365	9.02	9/25	21:15
CC2	901	7.08	9/14	12:30
CC3	697	7.37	9/21	15:30

House Name	Energy	Peak kW
CC1	100.00%	100.00%
CC2	66.00%	78.49%
CC3	51.09%	81.73%



- Presentations
 - Farragut town hall, 75
 - Kingston Town Hall, 30
 - Tennessee NAHB, 125
 - USGBC, 80
 - ORNL Sustainable Campus, 250
- Press releases
 - Lisa Brass column Knoxville News Sentinel
 - ORNL Press Release
- 13 detailed preretrofit site evaluations completed
 - ACH@50 PA varied from 6.5 to 28
 - Some ducts could only be pressurized to 3 PA
 - Several return ducts open to attic, crawl space and at least one to both
 - Laundry shoot open completely to the attic
- DOE permission to conduct research on humans applied for in July 2010
- Recommendations with pre and post modeling results sent to 4/13 homeowners



First ORNL Sustainable Campus Seminar attracts 250 and produces a web video educating and motivating homeowners to take charge



Compare TVA research houses to extreme retrofits



House 5; 18 year old occupied TVA retrofit simulated occupancy retrofit, 2438 ft²

research house, 2400 ft²

House 1, Oak Ridge

- First House Tested and Measured for HERS Rating
- Blower Door; 28 ACH@50 Pa
- Duct Blaster; Leakage from ducts, 3 PA is maximum pressure
- Results indicate a higher than average envelope leakage, recommendations include extensive envelope air tightening particularly the rim joists, 2nd blower door study, replace the HP unit and install a GE HPWH



Methods of Evaluation



Software using the measurements we make at each house

- REM Rate
- Energy Gauge
- Owens Corning Energy Bill Analyser
- HESPro
- HERS =135, to use MMBtu/yr/#bedrooms
- Recommendations in post retrofit model suggest 40% whole house savings

Preliminary prediction after retrofit; HERS = 80, ~40% energy savings



Laundry looks like
it is in the garage



- But it is really in the house

Knoxville 1982 Worlds Fair House retrofit





Insulated and sealed the attic

- Knox Heritage design team did not want spray foam in walls
- Design called for
 - house wrapped walls
 - foamed rim joist between basement and main and main and upper level
 - R-38 open cell foamed attic
 - Closed soffits and gable rakes filled with foam, encasing top edge of wall house wrap, needed follow up spot sealing with help of blower door



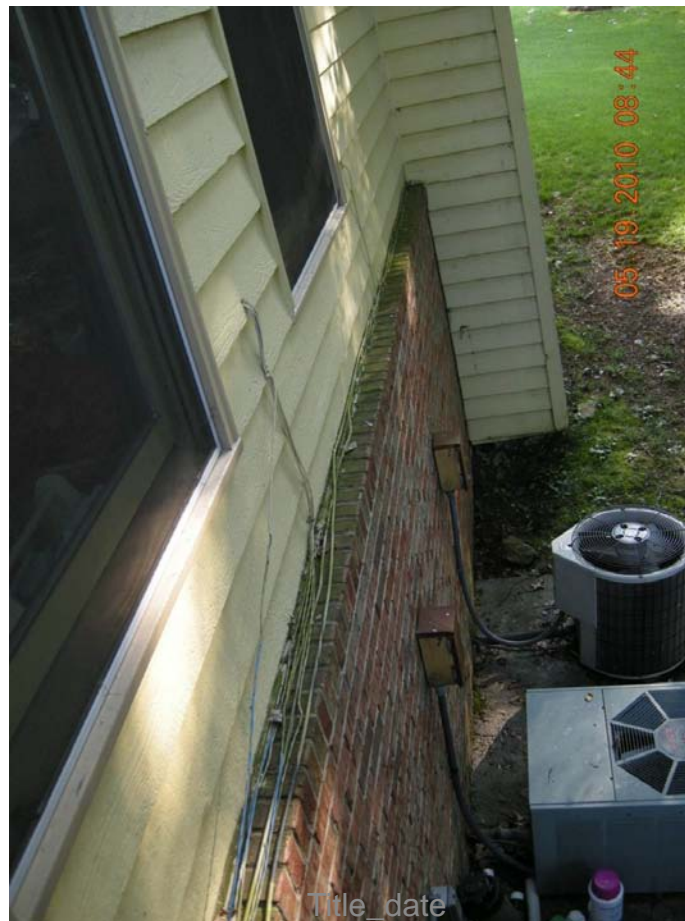
Compare Carrier SEER 18 Air Source Heat Pump to SEER 18 Multi Split



Remove siding possibility



Need to extend above grade wall over brick ledge or at least flash



Title_date



Below grade space has not one but two dehumidifiers



72 year old gut rehab in downtown Knoxville



04.29.2010 20:16

Title_date

No insulation in the walls or in walkout basement



Smoky Mountain National Park “Mission 66” Oasis House



<http://www.youtube.com/watch?v=VWqkTKoJel>

Bath Fan moisture dumped directly into the attic



Attic/Crawl-by pass



title_date

A place to not install the water heater





Each Retrofit House to have a major research element

1. Spray foam rim joist between two finished floors
2. Solar integrated heat pump case study to expand TVA's generation partner hook up criteria
3. Horizontal Geothermal HP retrofit
4. Window and siding replacement cut heat pump capacity in half, preretrofit has 2-2.5 ton HP, after retrofit need only one
5. Perfect comparison to TVA retrofit research house
6. Historic preservation mixed with 40% retrofit on 72 yr old
7. Insulated sealed crawl space on moisture troubled site
8. Cost effective R-5 window retrofit, huge national education opportunity



Each retrofit house to have major research element

9. Gut rehab, low cost attic, wall and basement spray foam, cost effective R-5 windows
10. Pull all HVAC into the conditioned envelope, horizontal coil geothermal HP, single pane window replacement, insulated and sealed crawl space, two to one zoned HP
11. SIP addition and SIP nail base, double floor area with no increase in HP capacity
12. Siding replacement/wall sheathing addition to solve moisture problem on good average energy performing 24 yr old house
13. Run at 2010 zero energy house retrofit of 1982 Worlds Fair “Energy House”, enormous educational and historic preservation opportunity.

DOE helps ABC TV Extreme Makeover provide an extreme retrofit for Washington DC Community Center, 5700 ft²



Potential DC
Research House

Extreme
MAKEOVER
HOME EDITION



Secretary Chu told me “we will demonstrate to US homeowners that Energy Efficiency residential retrofit is a good investment”



The U.S can save more energy, better educate our children and produce a more skilled green labor force



Secretary Chu, Duncan, and Solis



Arne Duncan, Secretary of Education told; “technology installed in these two projects will teach children how the weather impacts the amount of energy used and produced by our schools and homes



S1,Ty P, Secretary Solis and Secretary Duncan



Close look at GE's hybrid water heater





Features

- Triple layer windows, Serious Materials
- 4 kW PV, Aurora Energy
- SEER 17 Lennox solar integrated Heat Pumps
- 2X6 OVF, with closed cell spray foam
- GE Hybrid Water Heaters
- Weather Station with Fat Spaniel Data Logger
- If a house HERS of 40
- Owners would welcome with open arms DOE Research House designation

Potential occupied research house, 2700 ft² in Hyattsville, MD



Features

- Geothermal Heat Pump
- Manual J sized HVAC, Manual D sized HVAC
- ICF foundation
- Winter Panel SIP walls and roof
- Triple Layer Windows
- Raised metal seam roof, S5 clips
- 4 kW PV
- Hybrid Water Heater
- 100% CFL
- Supply ventilation, Aircycler
- Fat Spaniel DAS
- HERS= 27 (developed 2009)

ABC gave me 400 ft² of south facing roof area to work with



PEPCO interconnection requires only DC cutoffs



SIPs provide high cathedral ceiling easy rough opening for round window



R-6 windows





This ABC episode of Extreme Makeover Home Edition was a 2 hour Special aired during the SWEEPS, February 14, 2010, 8:00 – 10:00 PM

Secretary Chu spent about 3 hours on the set

Homeowners and PEPCO would love to make this a DOE Research House



Gaps and Barriers

- “need to clearly demonstrate to US homeowners that Energy Efficiency residential retrofit is a good investment” Secretary Chu
- Variable Refrigerant Flow Heat Pumps vs central forced air
- Lower cost methods to insulate and seal
 - Attics
 - Crawlspace
 - Basements
 - and ducts
- Guidelines for home and homeowner life stage retrofit optimization
- High performance home interface with smart grid must team with electric utilities with a heart or guts, preferably both
 - Inverters
 - Heat pumps
 - Appliance controllers
 - Whole house energy managers