We can design "Zero Energy Homes" but when these are tested after occupancy sometimes the energy use is not what was expected. More houses can be Net-Zero Capable, but they need the occupant to make them so. We will look at how to compare house designs when the occupant in near-zero energy homes matters so much

NESEA 2011

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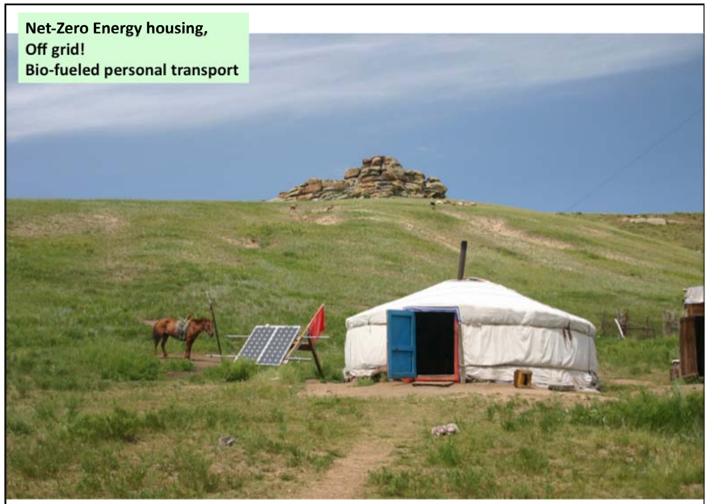
Learning Objectives

- At the end of this program, participants will be able to:
  - Understand different components of housing energy use
  - The relative impact of heating
  - The importance of occupant behavior
  - The role of misc electrical loads

Net Zero Occupants

Dr John Straube P.Eng
Building Science Corporation
University of Waterloo
www.BuildingScience.com



Presentation Outline

- What is the influence of occupant behavior / needs and "other" energy consumers

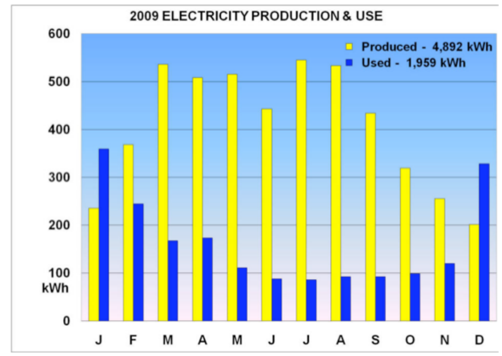
Zero Energy Powerhouse Montague

Attractive, small, sensible, **astounding** performance
1152 Square feet
R40 walls, R100 roof, triple glazing, R30 slab (no basement!)

- Sundanzer **8-cubic foot chest refrigerator** has an estimated use of only 33 kWh per year
- Energy Star laptop computers, clothes washer, back-up heating/cooling Fujitsu heat pump, lights, fridge and TV. **No clothes dryer or dish washer**.
- Solar DHW reduces this component to near zero

- Boston Herald March 9, 2010
  - "The 1,152-square-foot, cedar-shingled house has a metal roof covered with photovoltaic solar panels that last year generated 4,892 kilowatt hours of electricity. The house itself only used 1,959 kilowatts for the entire year – making its annual energy bill for heating, cooling, hot water, cooking, appliances and lighting an astoundingly low $392."
- This is not due to technology: most is the people!

Monthly Energy use 2009



Energy and Buildings, 1 (1977/78) 313 - 324

Movers and Stayers: The Resident's Contribution to Variation across Houses in Energy Consumption for Space Heating*

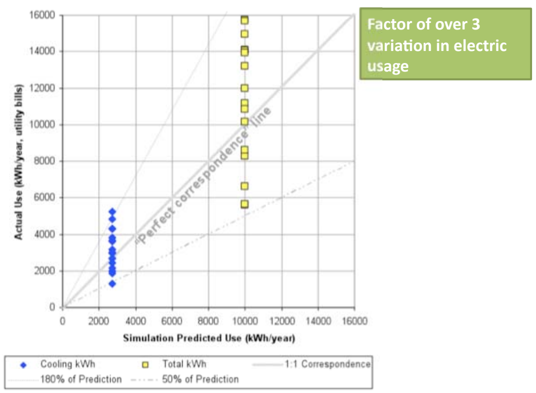
ROBERT C. SONDEREGGER

We have proved experimentally that (so far) unpredictable behavior patterns of the occupants introduce a large source of uncertainty in the computation of residential space heating energy requirements. The lesson to be learned is two-fold: (i) there is little practical usefulness in pushing too far the detail of any deterministic model for the prediction of heating load requirements; (ii) the effect of retrofits, weather or other factors physically influencing the heat load of a house should be tested on many houses occupied by real people. These conclusions may be the strongest *a posteriori* justification

1977 townhomes

- Variation between lowest 10% and highest 10% energy users (eg 80% of population) was about two times

17 identical OK homes



Parker 1996 Ten homes

MONITORED ENERGY USE PATTERNS IN LOW-INCOME HOUSING IN A HOT AND HUMID CLIMATE

Danny S. Parker, Maria D. Mazzara,
and John R. Sherwin

Florida Solar Energy Center
1679 Clearlake Road
Cocoa, Florida 32922

ABSTRACT

The Florida Solar Energy Center (FSEC) is metering energy use in two Habitat for Humanity developments. The objective is to understand how energy is used in low income housing and how it can be effectively reduced.

The ten "control homes" come from a conventional housing project built by in 1993 Habitat for Humanity in Homestead, Florida. Another ten "experimental homes" have been recruited from the 190 home Jordan Commons development in the same vicinity. These houses, which are soon to be metered, feet); the four bedroom models total 111 m² (1190 ft²). The construction is conventional for South Florida: concrete block on an uninsulated monolithic slab with an exterior light colored stucco finish. The homes generally face north or south with a small porch over the entrance. The roofs are of standard A-frame construction with plywood decking covered by asphalt shingles. The concrete block walls are insulated with RSI-0.5 $m^2 \cdot K/W$ (R-3 $ft^2 \cdot hr \cdot °F/Btu$) insulation on the interior; the attic has RSI-3.3 (R-19) fiberglass batts over the sheetrock ceiling. The windows are single glazed units with aluminum frames and are single-hung so that about 30% of their gross area can be opened for

3:1 variation in total energy

Average Daily Energy-End Use at Habitat Sites: August 31, 1994 - September 1, 1995†
kWh/Day

Site	Bed-rooms	Occu-pants	Total kWh/Day	AC kWh	Air Hndlr	Heat kWh	Int. Temp (°C)	DHW kWh	Dryer kWh	DHW Gals	Range kWh	Refrig. kWh	Freez. kWh	Miscel. kWh
H01	4	8*	53.7	17.6	2.7	2.0	24.2	9.9	5.1	81.7	1.9	2.4	0.9	11.0
H02	3	4	55.6	17.4	2.4	0.0	24.4	13.0	1.9	113.0	4.7	2.4	1.0	12.8
H03	3	3	36.5	12.3	1.6	2.0	25.1	6.2	3.7	38.5	1.4	2.3	N/A	6.6
H04	4	8	53.7	10.0	2.8	0.5	25.7	12.4	9.2	110.3	5.1	3.4	N/A	10.3
H05	4	3	38.7	11.1	1.8	2.8	25.3	5.6	5.3	55.9	1.2	2.3	N/A	8.2
H06	3	5*	45.9	17.2	2.4	0.8	23.2	9.9	3.5	82.4	1.4	1.9	2.1	6.5
H07	3	4*	35.8	13.0	2.2	1.2	25.9	6.1	2.9	48.3	0.9	2.2	N/A	7.1
H08	3	5*	59.0	24.4	4.3	0.5	22.7	10.4	4.4	59.8	1.6	2.5	3.9	7.1
H09	3	3*	21.1	4.7	0.6	5.3	26.7	2.7	0.5	18.1	0.1	2.4	N/A	4.7
H10	3	3	27.7	8.5	1.2	0.6	25.4	4.0	0.7	27.9	0.9	2.0	N/A	9.7
Avg.†	3.3	4.6	42.8	13.6	3.8	1.6	24.9	8.0	3.7	63.6	1.9	2.4	2.0	8.4

MELS: Annual 1700 – 4672 kWh/year

22 German Townhouses DHW

Figure 67: Average hot water consumption per day in litres per person from 1. October 1999 to 30. September 2000 in the 22 permanently occupied houses.

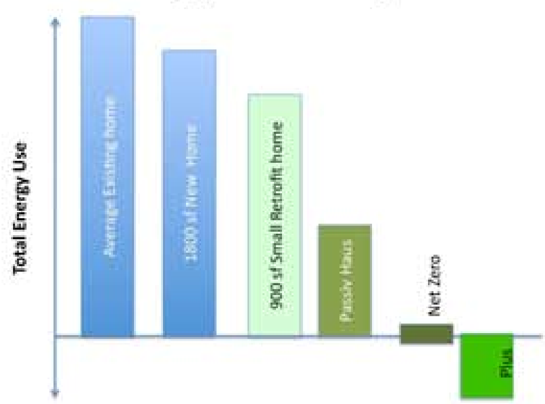
Why do we care

- If we want
- 1. to reduce society's consumption, we need to know what work
- 2. to promise delivery of a building of a certain performance
- 3. to compare building techniques/ technologies

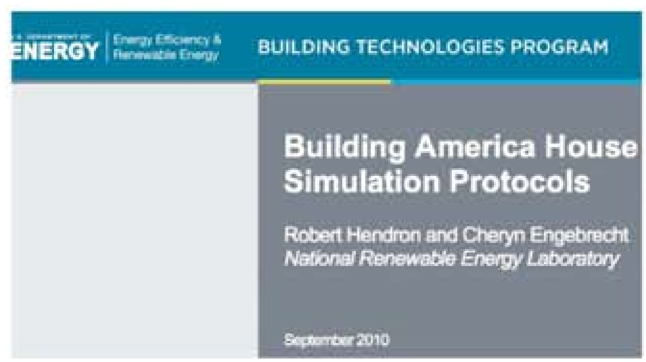
Net Zero Energy

- **Generate** as much **energy** in a **year** as you consume
  - Generation: on site, usually solar, sometime wind
    - 1.0 kWh = 3.6 MegaJoule = 3412 BTU =0.12 m^3 NG
  - Energy can be electricity, natural gas, oil, LPG
  - Annual: Make up for low winter solar gain
    - Wind can be more in winter than summer
    - Uses the grid as a big 100% efficient battery
- PlusHouses *produce* more than they consume

Energy Use Comparison



Predicting "Standard" Energy use


ENERGY | Energy Efficiency & Renewable Energy
BUILDING TECHNOLOGIES PROGRAM

Building America House Simulation Protocols

Robert Hendron and Cheryn Engebrecht
National Renewable Energy Laboratory

September 2010

MELs & LAMES

Appliance	Electricity (kWh/yr)
Refrigerator	434
Clothes washer (3.2 ft^3 drum)	$38.8 + 12.9 \times N_{br}$
Clothes dryer (electric)	$538.2 + 179.4 \times N_{br}$
Clothes dryer (gas)	$43 + 14.3 \times N_{br}$
Dishwasher (8 place settings)	$87.6 + 29.2 \times N_{br}$
Range (electric)***	$250 + 83 \times N_{br}$
Range (gas)****	$40 + 13.3 \times N_{br}$
Miscellaneous loads (gas/electric house)	$1595 + 248 \times N_{br} + 0.426 \times FFA$
Miscellaneous loads (all-electric house)	$1703 + 266 \times N_{br} + 0.454 \times FFA$

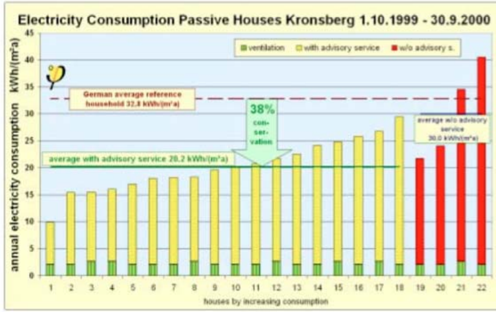
MEL	Average Units/ Household	Energy/Unit (kWh/yr)	Energy/Household (kWh/yr)
Bottled water	0.010	300.0	3.0
Trash compactor	0.010	50.0	0.5
Slow cooker/crock pot	0.581	16.0	9.3
Home Office			
Laptop PC (Plugged In)	0.287	72.1	20.7
Desktop PC w/Speakers	0.906	234.0	212.1
PC monitor	0.906	85.1	77.1
Printer (laser)	0.049	92.5	4.5
Printer (inkjet)	0.660	15.5	10.2
Dot matrix printer	0.030	115.0	3.5
DSL/cable modem	0.359	52.6	18.9
Scanner	0.050	49.0	2.4
Copy machine	0.086	25.0	2.1
Fax machine	0.115	326.3	37.6
Multifunction device	0.217	58.8	
Bathroom			
Hair dryer	0.861	41.1	35.4
Curling iron	0.532	1.0	0.5
Electric shaver	0.243	1.0	0.2
Electric toothbrush charger	0.078	11.5	0.9
Beard trimmer	0.067	1.0	0.1
Garage and Workshop			
Auto block heater	0.007	250.0	1.8
Lawn mower (electric)	0.059	42.9	2.5
Heat tape	0.030	100.0	3.0
Kiln	0.020	50.0	1.0
Pipe and gutter heaters	0.010	53.0	0.5
Shop tools	0.130	26.4	3.4
Cordless power tool chargers	0.443	16.0	7.1

National Average is ….

MEL	Average Units/ Household	Energy/Unit (kWh/yr)	Energy/Household (kWh/yr)
Air cleaner	0.217	65.7	14.2
Vacuum cleaner (cordless)	0.183	41.0	7.5
Heating pads	0.670	3.0	2.0
Surge protector/power strip	0.360	3.9	1.4
Timer (lighting)	0.280	20.1	5.6
Timer (irrigation)	0.050	45.2	2.3
Iron	0.922	52.7	48.6
Baby monitor	0.100	22.8	2.3
Large Uncommon MELs and MGLs			
Pool heater (electric)	0.004	2300.0	8.3
Pool pump (electric)	0.075	1102.0	82.3
Hot tub/spa (electric heating and pump)	0.048	2040.7	97.4
Hot tub/spa pump (electric for gas spa)	0.038	460.0	17.5
Well pump (electric)	0.127	400.0	50.8
Gas fireplace	0.032	1760.0	57.0
Gas grill	0.029	879.0	25.5
Gas lighting	0.012	1671.0	19.6
Pool heater (gas)	0.014	6506.0	87.8
Hot tub/spa heater (gas)	0.011	2374.0	25.6
Other	1.000	9.4	9.4
Total MEL Load			**3373**

That is about 2.5 kW of PV to run the MEL's of a normal house!

22 German Townhomes, electric



Variation from low to high more than 3 times

112 m^2 1120 to over 4000 kWh/yr
German average 3600 kWh/yr

Occupant Factors

- Indoor temperature
- Number and age of occupants
- Appliance use
  - Showers
- Technology intensity
  - Game consoles, computers, PVR
- Open windows/doors

What uses energy in normal houses?

- Space heating: Big deal in cold climates! (50-65%)
  - 10 000 to 30 000 kWh and up for newish house
- Domestic hotwater DHW
  - Assuming system efficiency is 100% 2000 - 4000
- Other (in kWh)
  - Refrigeration (500 kWh)+ Range (500 kWh) = 1000
  - Washer (75 kWh), Dryer (925 kWh) = 1000
  - Lighting 500- 3000
  - Plug and misc 1000-4000

Typical Household:Heating	**10 000- 30 000 kWh**	16 – 43 000 kWh
DHW	**2 000- 4 000 kWh**	
Electric	**3 500- 9 000 kWh**	

Summary of uses

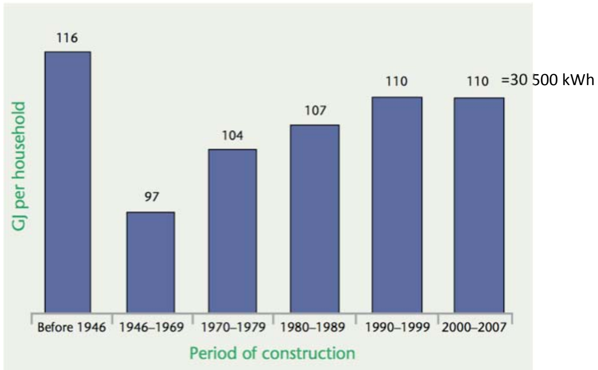
End use	Site (kWh)	Source (MBtu/yr)
Space heating	11,225	115
Space cooling	2,732	28
DHW	4,837	50
Lighting	3,110	32
Appliances and MELs	7,646	78
OA ventilation	400	4
Total usage	29,950	307

NREL Typical 2250 Sq ft 3 BDR new home

"Typical" Electrical use

Size of House	2250	sf		
No of Bedrooms	**1**	**2**	**3**	**4**
Refrigerator	434	434	434	434
Clothes washer	52	65	78	90
Clothes Dryer (elec)	717	896	1075	1254
Range elec	333	416	499	582
Dishwasher	117	146	175	204
MEL elec	2991	3257	3523	3789
Total (all elec)	**4643**	**5213**	**5783**	**6354**
Lighting (inside)	1554	1554	1554	1554
Exterior lighting	326	326	326	326
Total	**6523**	**7093**	**7663**	**8233**

Chart 9. Energy consumption by year of construction, 2007 (GJ per household)



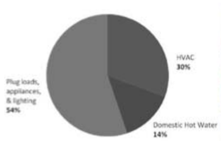
Natural Resources Canada, OEE, 2007 Survey

Heating Load Reduction

- Easy to cut heating/cooling in half
- DHW can be reduced
- Lights

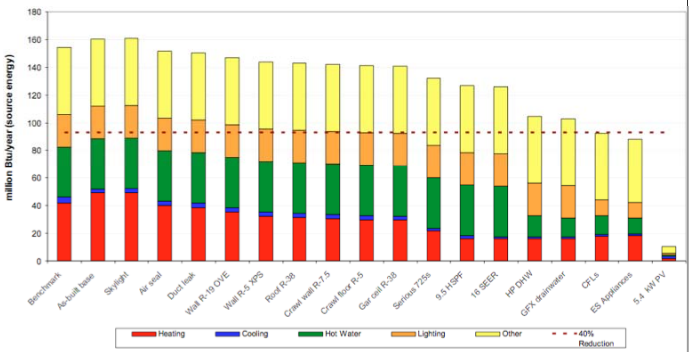
Pill House, Vermont, 2800 ft^2

- 10 kW wind turbine on 120 ft tower=6500 kWh
- R56 ceiling, R40 walls, R5+ triple-glazed window
- R20 basement, 2 ACH50, 8500 kWh/yr heating load
- About 3500 kWh/yr for all other loads
- **GSHP COP=2.5**



Zeta Homes

Energy Use Parametric



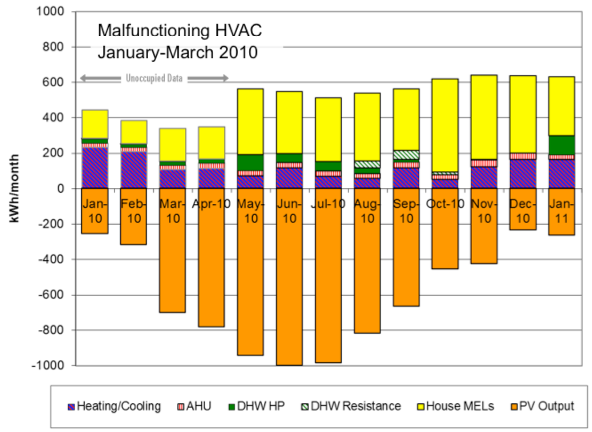
Zeta Lancaster

Table 1.4: Summary of End-Use Site-Energy

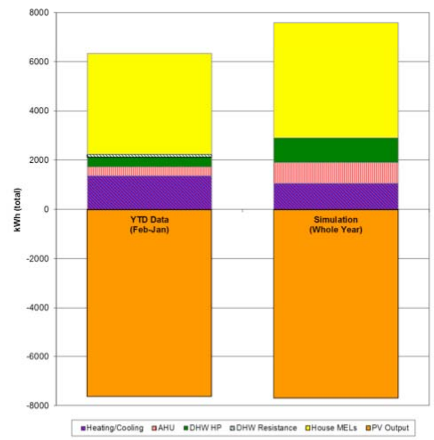
	Annual Site Energy			
	BA Benchmark		Prototype	
End-Use	kWh	therms	kWh	therms
Space Heating	3990	0	1806	0
Space Cooling	365		144	
DHW	3174	0	999	0
Lighting*	2054		819	
Appliances + Plug	4223	0	3866	0
OA Ventilation**	0		0	
Total Usage	13805	0	7634	0
Site Generation	0	0	6918	0
Net Energy Use	13805	0	716	0

Heat pump

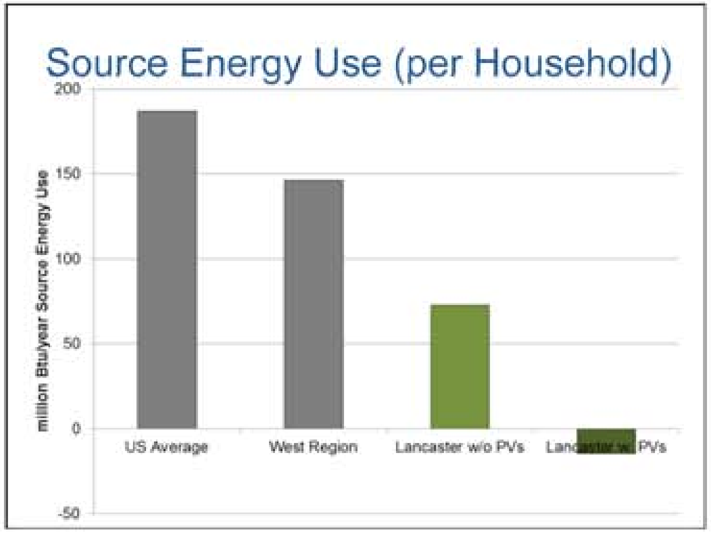
Actual Measurements

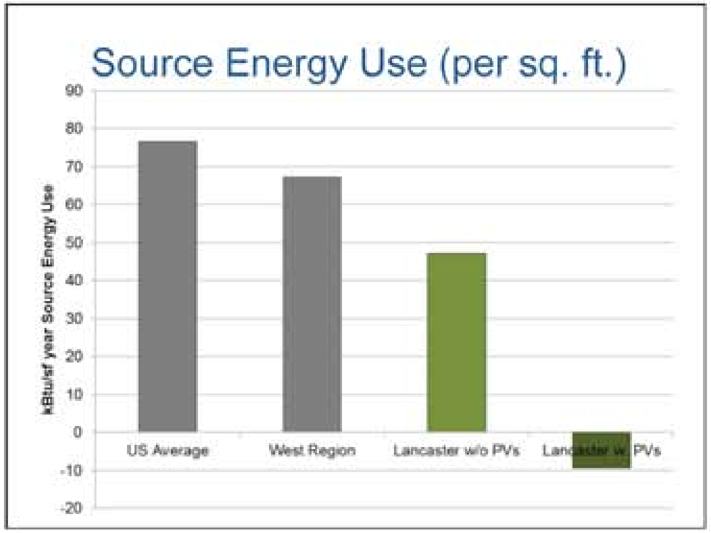


Simulation vs. Actual



- 1 year recent data (Feb 2010-Jan 2011) vs. simulation
- PV output matches simulations
- DHW use significantly lower than predicted (homeowner behavior)
- Miscellaneous end use loads (MELs) lower than predicted



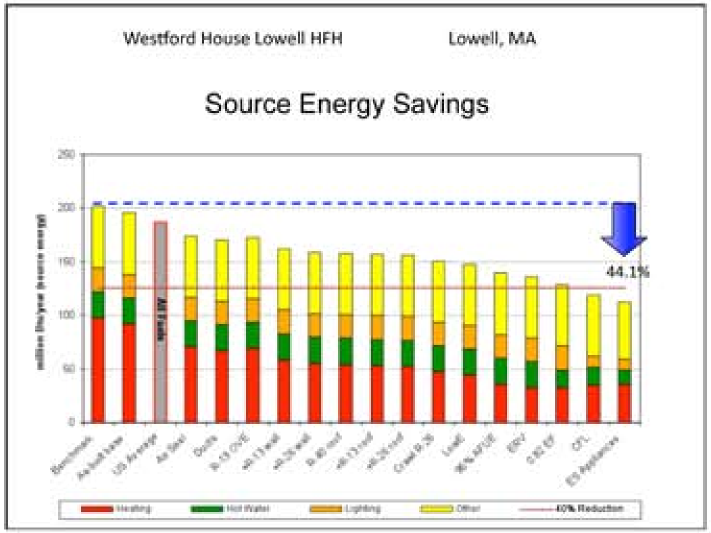


Lowell Habitat for Humanity Westford, MA

2,156 sq. ft. @ $92/sq. ft. HERS 49

Gas (400 therms) = $50/month @ $1.50 /therm
Electric (4200 kWh) = $50/month @ $.15/kWh
= $3.30 per day

With 3.5 kWp PV (350+- kWh/month)
Electric = $0



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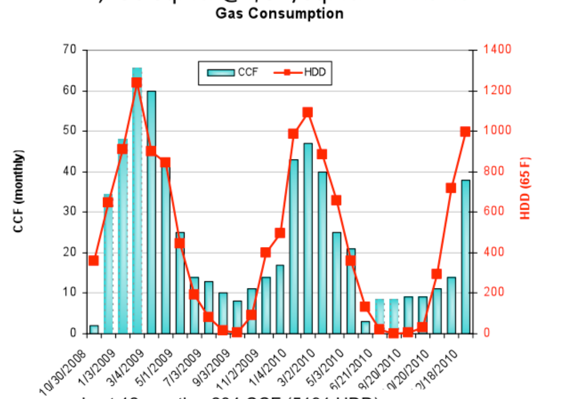
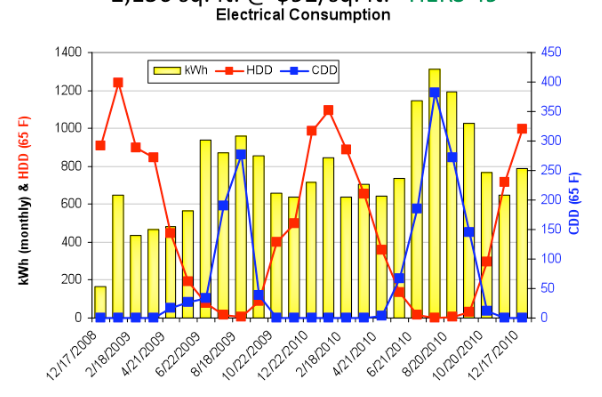


Last 12 months: 234 CCF (5191 HDD)

Summertime gas use ~9 therms/month—DHW for family of 4

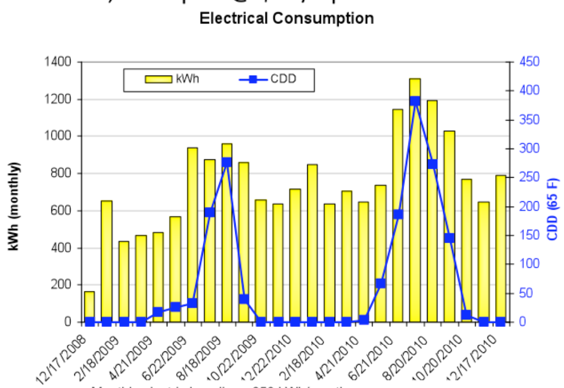
Lowell Habitat for Humanity Westford, MA
2,156 sq. ft. @ $92/sq. ft. HERS 49



Monthly electric baseline ~650 kWh/month

Simulation baseline ~500 kWh/month (Benchmark assumptions)

Lowell Habitat for Humanity Westford, MA
2,156 sq. ft. @ $92/sq. ft. HERS 49

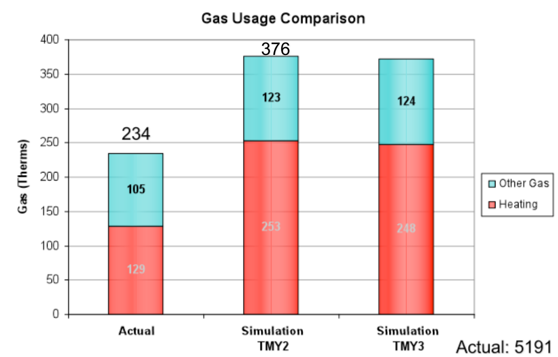


Monthly electric baseline ~650 kWh/month

Simulation baseline ~500 kWh/month (Benchmark assumptions)

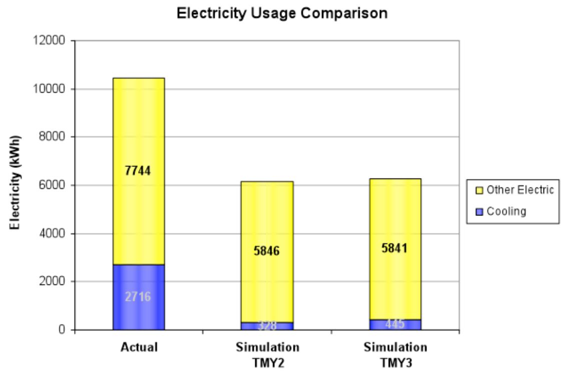
This is a simpler version with only CDD, instead of both HDD and CDD

Comparison w. Simulation: Gas



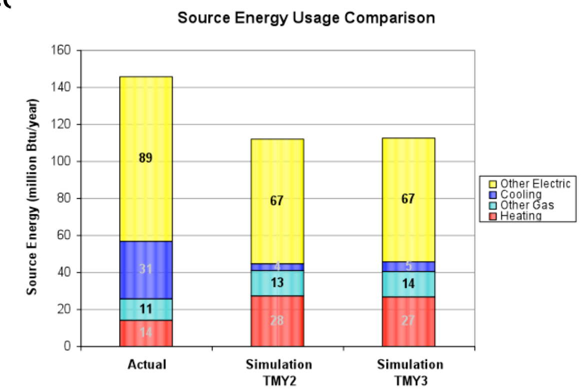
Actual: 5191 HDD
TMY2: 5621 HDD
TMY3: 5793 HDD

Comparison w. Simulation: Electric



"Cooling" (blue) not actually submetered; estimated by subtraction of baseline from summertime peaking behavior

Comparison w. Simulation: Source Energy



Foulds House MA

Foulds House 2800 sf

End-Use	Annual Site Energy: BA Benchmark kWh	BA Benchmark therms	Prototype kWh	Prototype therms	
Space Heating	1003	1290	475	380	11 611
Space Cooling	2814		975		
DHW	0	275	0	106	3 100
Lighting*	4281		1376		
Appliances + Plug	5853	116	5207	80	7 552
OA Ventilation**	0		0		
Total Usage	13951	1681	8033	566	24 620

End-Use	Estimated Annual Source Energy: BA Benchmark 10^6 BTU/yr	Prototype 10^6 BTU/yr
Space Heating	152	47
Space Cooling	32	11
DHW	30	12
Lighting*	49	16
Appliances + Plug	80	69
OA Ventilation**	0	0
Total Usage	344	153

How to deal with this?

- Do our best with what we control
  - Improve skin, mechanical efficiencies
- Make it easy for occupants to save energy
  - Energy monitoring and display
  - Local heat sources in bathrooms
- Beware Nintendo engineering
  - The model is not reality

Summary

- We know how to get heating/cooling loads down
- Lighting can be significantly reduced
  - Daylighting? Or occ sensors
- How do we manage DHW
  - Better appliances, more efficient appliances
- How do we manage MEL?
  - Better appliances

Summary

- Comparing houses without "standard" occupants and appliance usage is apples to oranges
- Major savings possible by modifying usage patterns
  - But we cant force people and we cant build national policy on the assumption

Comparison of CMHC Equilibrium

- NZE Possible: Super-insulated, Super-tight, large PV arrays, large SHW systems

	Now	**Avalon**	**Riverdale**	**ecohome**
Location	**Toronto**	**Red Deer AB**	**Edmonton**	**Ottawa**
HDD (18C)	4000	5500	5600	4600
Floor Area (heated m2)	139	240	234	310
Total Site Energy (ekWh)	13475	13094	14391	20646
Heat Energy (kWh/m2)	23.1	23.9	33.7	40.2
Roof (R)	36	87	100	60
Wall	40	70	56	44
Window	5.7	5	7.3/10	5.7
Basement walls	25	none	54	40
Slab	25	60	24	15
ACH@50	2.6	0.5	0.5	0.65
PV Installed (kWp)	2.7	8.6	5.6	6.2
SHW produced (kWh)	1824	3886	1907	6665
PV produced (kWh/yr)	2800	9569	6224	8184
Notes	Not NZE		Duplex	

Strategy

- Should we build NetZero Houses?
  - On site renewables are not very cost or resource effective
  - Who will pay for the grid when we get a lot of NZE?
- But, Fun to try!
- Reduce heating loads ***first and foremost***
- Reduce DHW, appliance, lighting loads