



**BRACKETING RESIDENTIAL
“NET-ZERONESS” DURING
DESIGN STAGE**

July 31st 2008, SimBuild

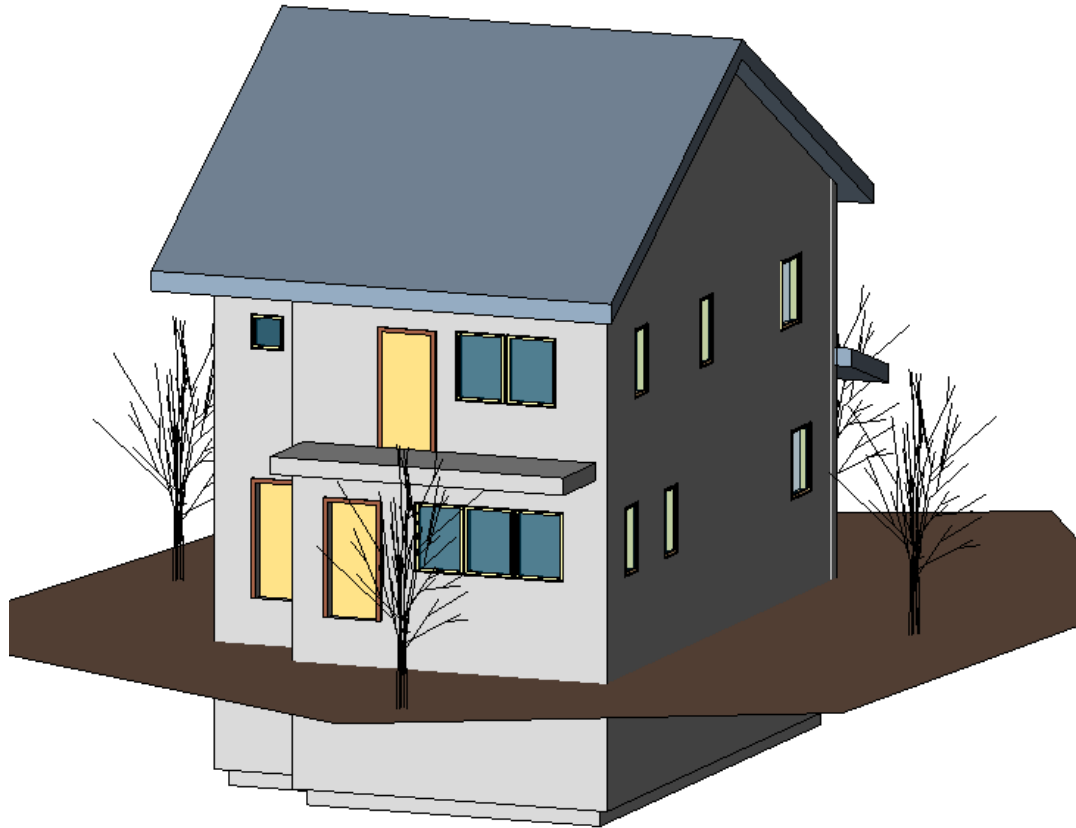
SAND Project

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- Community of affordable, highly energy efficient, possibly net-zero single and two-family homes
- a net-zero energy residence produces at the site, at least as much energy as it consumes over the year.

SAND Residence

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- 1576 ft² (146 m²)
- Two-storied single family residence in Hartford
- Unconditioned basement
- Three bedrooms
- Occupancy of four people

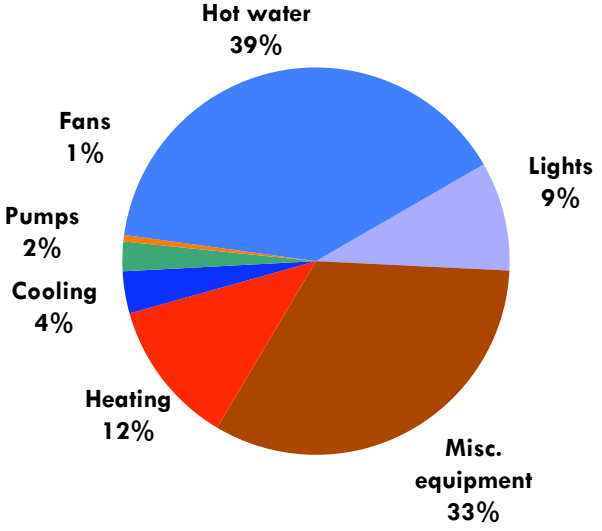
Design Parameters

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- Air tight envelope with high levels of insulation and efficient window
- Internal loads: CFL's and energy star appliances
- HVAC system: Geothermal heat pump with ERV; Natural ventilation through opening windows
- Hot water system: Solar hot water with electric backup heaters
- 5 kW Photovoltaic system

Energy Consumption

Values in kWh/yr	Base
Cooling	311
Heating	1073
Lighting	807
Plug load	2903
Fan/pumps	266
Hot water	3500
PV production	0
Total	8860
% Reduction	-



Energy Consumption


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<small>Values in kWh/yr</small>	Base	New England Avg (2001)
Cooling	311	
Heating	1073	
Lighting	807	
Plug load	2903	
Fan/pumps	266	
Hot water	3500	
PV production	0	
Total	8860	33,690
% Reduction	-	

Energy consumption reduced to **almost quarter** of a average New England house

Energy Consumption



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Values in kWh/yr	Base	New England Avg (2001)	
Cooling	311		207
Heating	1073		1073
Lighting	807		807
Plug load	2903		2903
Fan/pumps	266		262
Hot water	3500		3500
PV production	0		0
Total	8860	33,690	8752
% Reduction	-		1%

Natural ventilation for cooling – open windows take care of **1/3rd of cooling**

Energy Consumption




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Values in kWh/yr	Base	New England Avg (2001)		
Cooling	311	207	207	207
Heating	1073	1073	1073	1073
Lighting	807	807	807	807
Plug load	2903	2903	2903	2903
Fan/pumps	266	262	262	262
Hot water	3500	3500	3500	500
PV production	0	0	0	0
Total	8860	33,690	8752	5752
% Reduction	-	1%	35%	

Solar hot water –
 120 gallons tank,
 80 sq ft of
 collector size
Takes care of
85% of the hot
water needs

Energy Consumption

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Values in kWh/yr	Base	New England Avg (2001)			
Cooling	311	207	207	207	
Heating	1073	1073	1073	1073	
Lighting	807	807	807	807	
Plug load	2903	2903	2903	2903	
Fan/pumps	266	262	262	262	
Hot water	3500	3500	500	500	
PV production	0	0	0	-5937	
Total	8860	33,690	8752	5752	-185
% Reduction	-	1%	35%	102%	

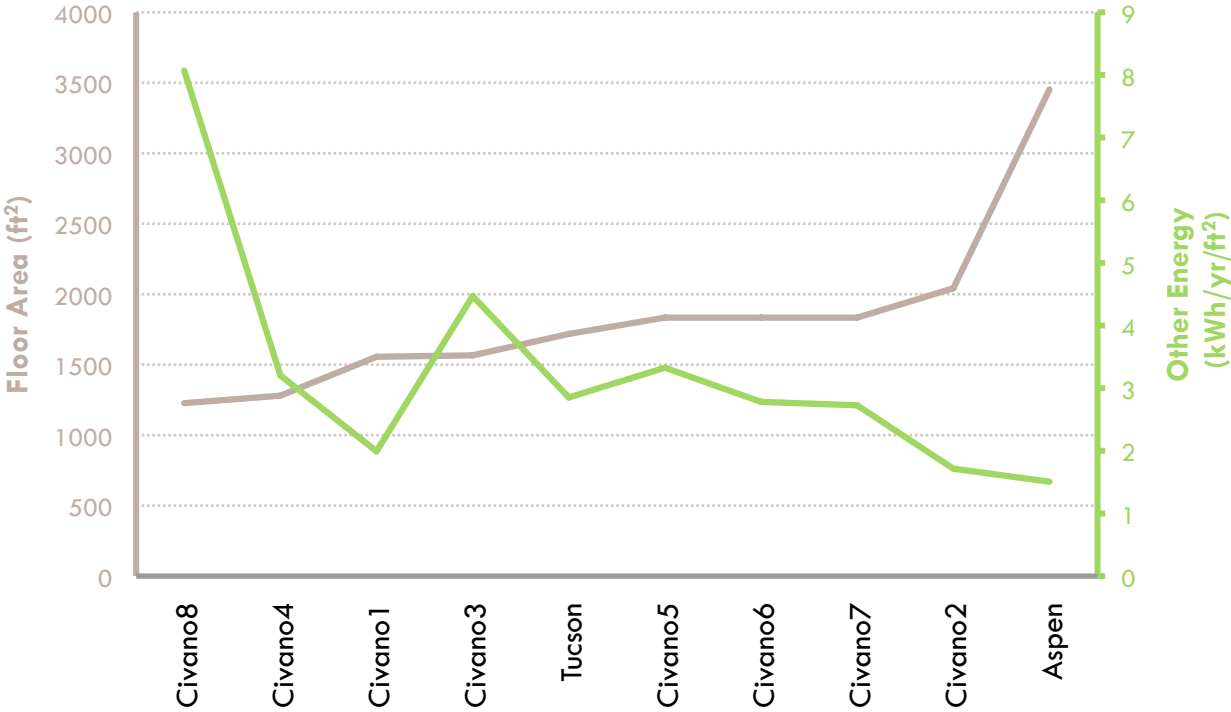
**5 kW Photovoltaic panels –
Net zero residence**

Behavior considerations

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Ranges		Design case
Internal load	(kWh/yr)	3710
Infiltration	(ACH)	0.1
Thermostat-heating	(°F) (°C)	68/60 (20/16)
Thermostat-cooling	(°F) (°C)	78/85 (26/29)
Avg. daily hot water use	(gallons/day) (L/day)	56 (212)
Hot Water Consumption	(kWh/yr)	3500
Natural ventilation for cooling		1/3 of cooling load
PV system efficiency		75%
Solar thermal system losses		12%

Other loads (plug, appliances)



Brown, R., Rittleman, W., Parker, D., and Homan, G.; 2007; Environmental Energy Technologies Division, LBNL, California 94720; LBNL-62440;

Behavior – internal loads

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Ranges		Best case	Design case	Worst case
Internal load	(kWh/yr)	2685	3710	7430
Infiltration	(ACH)		0.1	
Thermostat-heating	(°F) (°C)		68/60 (20/16)	
Thermostat-cooling	(°F) (°C)		78/85 (26/29)	
Avg. daily hot water use	(gallons/day) (L/day)		56 (212)	
Hot Water Consumption	(kWh/yr)		3500	
Natural ventilation for cooling			1/3 of cooling load	
PV system efficiency			75%	
Solar thermal system losses			12%	

Construction - infiltration

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Ranges		Best case	Design case	Worst case
Internal load	(kWh/yr)	2685	3710	7430
Infiltration	(ACH)	0.1	0.1	0.2
Thermostat-heating	(°F) (°C)		68/60 (20/16)	
Thermostat-cooling	(°F) (°C)		78/85 (26/29)	
Avg. daily hot water use	(gallons/day) (L/day)		56 (212)	
Hot Water Consumption	(kWh/yr)		3500	
Natural ventilation for cooling			1/3 of cooling load	
PV system efficiency			75%	
Solar thermal system losses			12%	

Behavior – Thermostat settings

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Ranges		Best case	Design case	Worst case
Internal load	(kWh/yr)	2685	3710	7430
Infiltration	(ACH)	0.1	0.1	0.2
Thermostat-heating	(°F) (°C)	68/60 (20/16)	68/60 (20/16)	70 (21)
Thermostat-cooling	(°F) (°C)	78/85 (26/29)	78/85 (26/29)	72 (22)
Avg. daily hot water use	(gallons/day) (L/day)		56 (212)	
Hot Water Consumption	(kWh/yr)		3500	
Natural ventilation for cooling			1/3 of cooling load	
PV system efficiency			75%	
Solar thermal system losses			12%	

Behavior – Hot water usage

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Ranges		Best case	Design case	Worst case
Internal load	(kWh/yr)	2685	3710	7430
Infiltration	(ACH)	0.1	0.1	0.2
Thermostat-heating	(°F) (°C)	68/60 (20/16)	68/60 (20/16)	70 (21)
Thermostat-cooling	(°F) (°C)	78/85 (26/29)	78/85 (26/29)	72 (22)
Avg. daily hot water use	(gallons/day) (L/day)	45 (170)	56 (212)	67 (254)
Hot Water Consumption	(kWh/yr)	2800	3500	4100
Natural ventilation for cooling			1/3 of cooling load	
PV system efficiency			75%	
Solar thermal system losses			12%	

Behavior – Natural cooling

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Ranges		Best case	Design case	Worst case
Internal load	(kWh/yr)	2685	3710	7430
Infiltration	(ACH)	0.1	0.1	0.2
Thermostat-heating	(°F) (°C)	68/60 (20/16)	68/60 (20/16)	70 (21)
Thermostat-cooling	(°F) (°C)	78/85 (26/29)	78/85 (26/29)	72 (22)
Avg. daily hot water use	(gallons/day) (L/day)	45 (170)	56 (212)	67 (254)
Hot Water Consumption	(kWh/yr)	2800	3500	4100
Natural ventilation for cooling		1/2 of cooling load	1/3 of cooling load	None
PV system efficiency			75%	
Solar thermal system losses			12%	

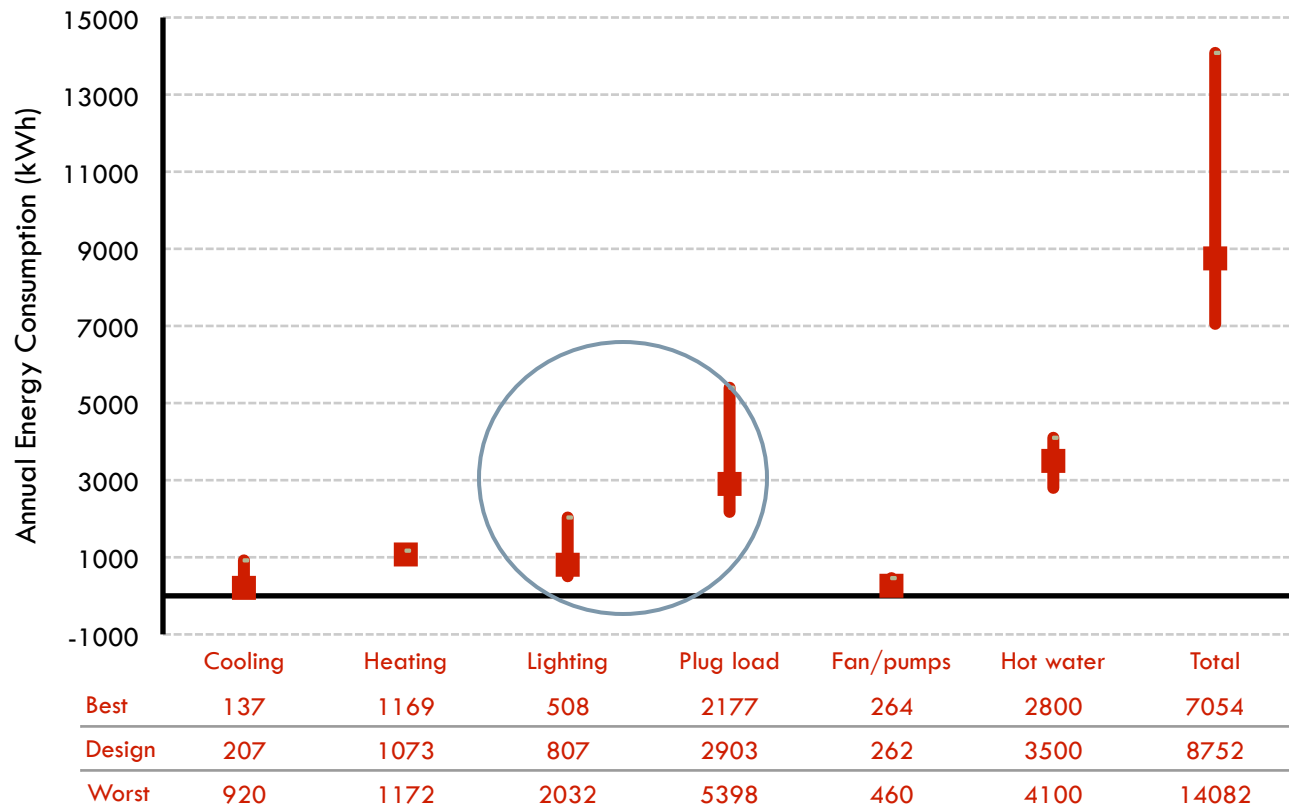
Behavior - efficiencies

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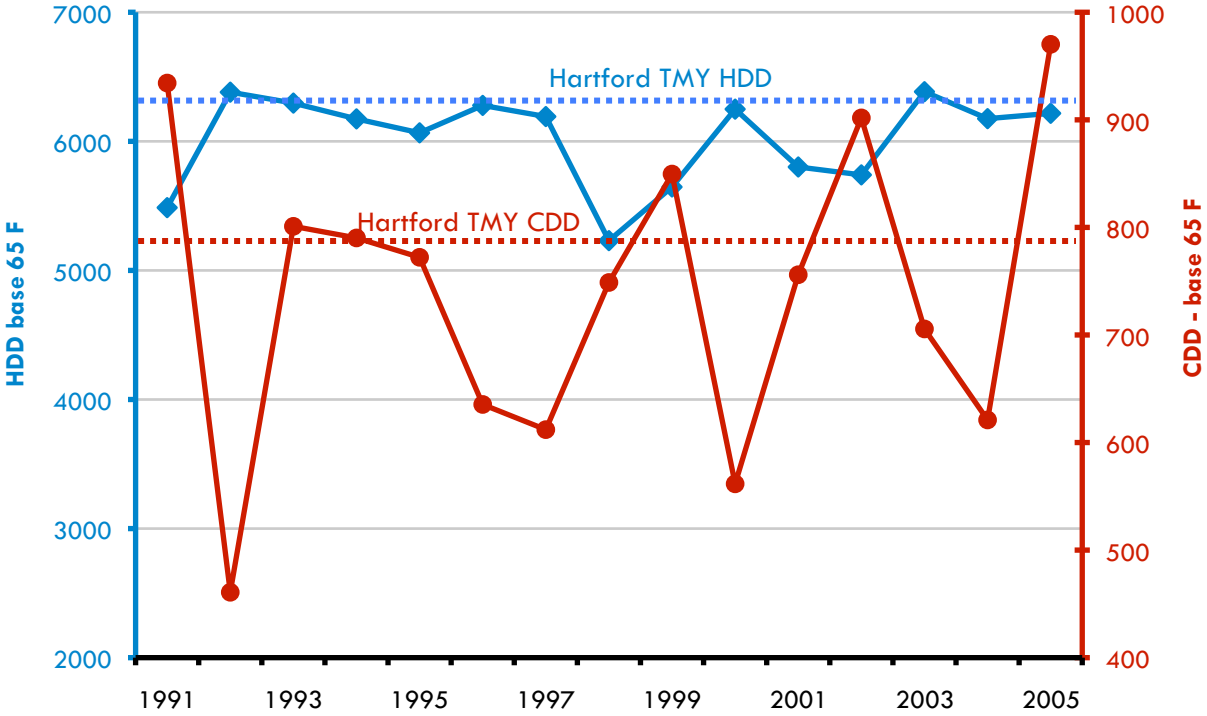
Ranges		Best case	Design case	Worst case
Internal load	(kWh/yr)	2685	3710	7430
Infiltration	(ACH)	0.1	0.1	0.2
Thermostat-heating	(°F) (°C)	68/60 (20/16)	68/60 (20/16)	70 (21)
Thermostat-cooling	(°F) (°C)	78/85 (26/29)	78/85 (26/29)	72 (22)
Avg. daily hot water use	(gallons/day) (L/day)	45 (170)	56 (212)	67 (254)
Hot Water Consumption	(kWh/yr)	2800	3500	4100
Natural ventilation for cooling		1/2 of cooling load	1/3 of cooling load	None
PV system efficiency		80%	75%	70%
Solar thermal system losses		7%	12%	20%

Behavior considerations

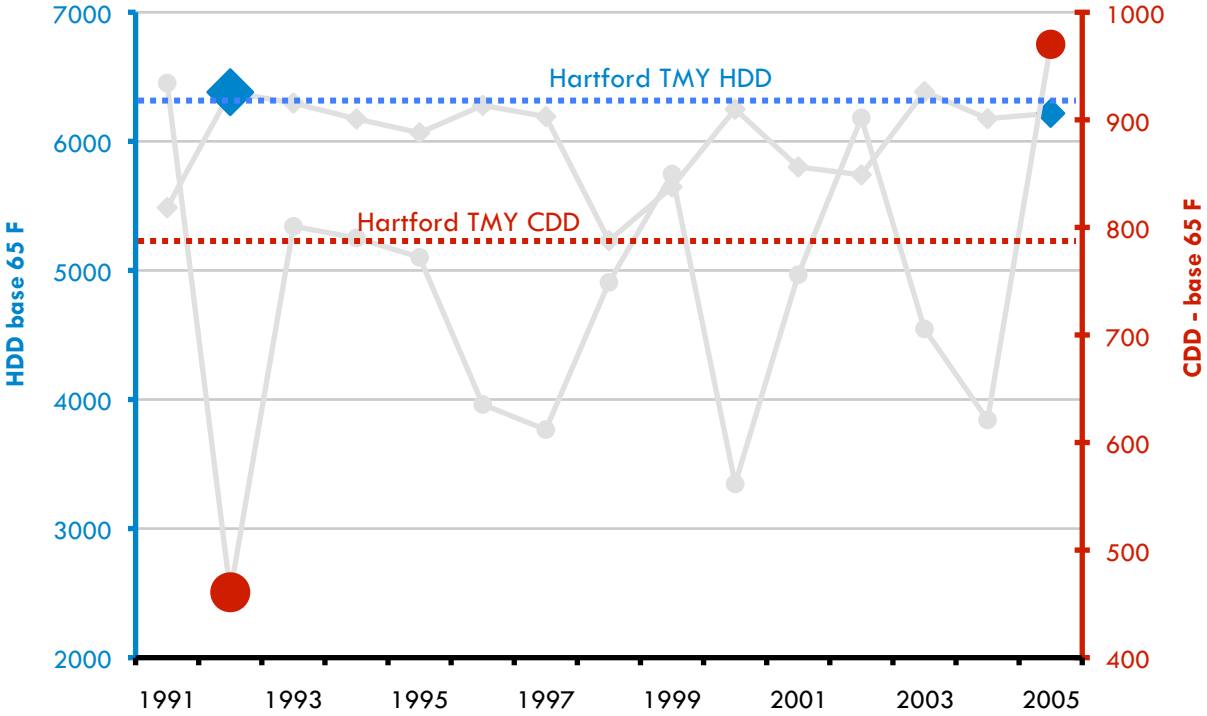
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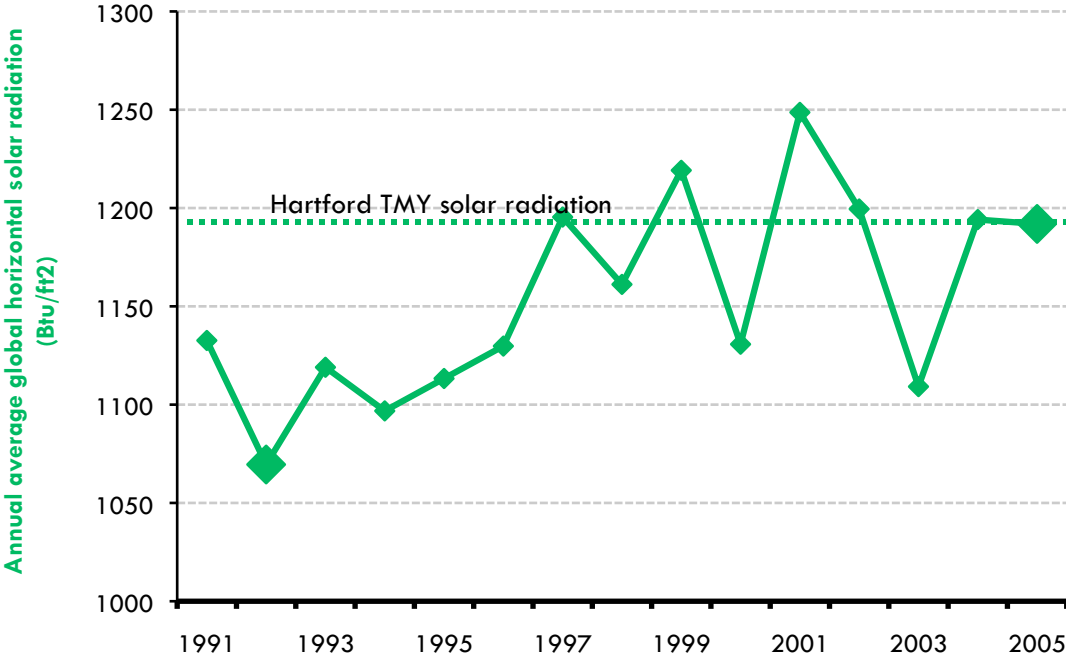
Weather – Degree days



Weather – Degree days



Weather – Solar radiation



Is it net zero?

Input parameter	Best			Design			Worst		
	Mild	TMY	Max	Mild	TMY	Max	Mild	TMY	Max
Weather effect									
Energy consumption (electric)	7024	7054	7087	8693	8752	8806	13753	14082	14352
Energy production	-11%	0%	0%	-11%	0%	0%	-11%	0%	0%
Solar hot water	2225	2500	2500	2670	3000	3000	2848	3200	3200
PV - electricity	5595	6286	6286	5284	5937	5937	4972	5587	5587
Net energy consumption	-796	-1732	-1700	739	-185	-131	5933	5295	5565

Discussion

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- Data collection
- Simulation tools
- Owner education
- Marketing, policy

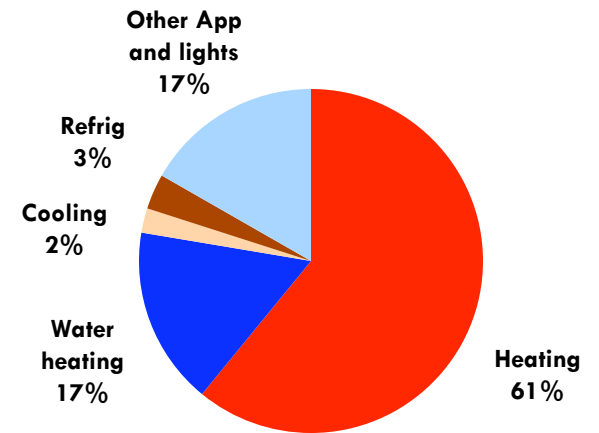
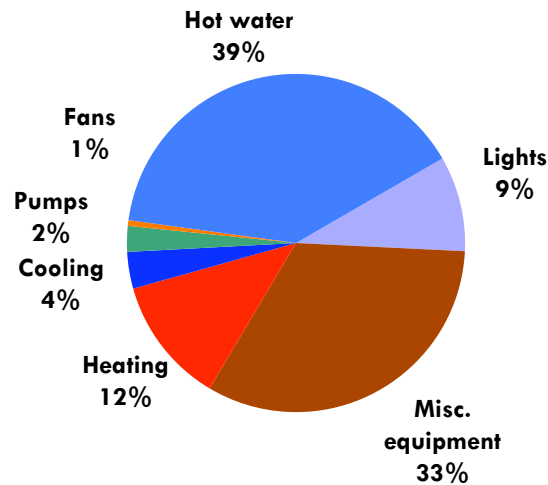
Backup

CATEGORY	COMPONENT	VALUE
Envelope	Wall	R-40 h.ft ² .F/Btu (7 m ² .K/W)
	Attic floor	R-60 h.ft ² .F/Btu (11 m ² .K/W)
	Basement wall	R-10 h.ft ² .F/Btu (2 m ² .K/W)
	Basement ceiling	R-30 h.ft ² .F/Btu (5 m ² .K/W)
	Window	U-0.31 Btu /h.ft ² .F (1.8 W/ m ² .K) SC-0.34
	Infiltration	0.10 ACH
Internal loads	Lighting	0.15 W/ft ² (1.6 W/m ²)
	Plug loads/ appliances	0.5 W/ft ² (5.3 W/m ²)
HVAC system	Geothermal water source heat pump with energy recovery ventilator	Cooling COP of 5.6, Heating COP of 4; The well is 300 ft (91 m) deep with 6 in (0.4 m) diameter
	Fresh air	60 cfm (28.32 L/s)
	Natural ventilation	Provides 1/3 rd of the required cooling
Domestic hot water system	Solar hot water heater with point of use electric backup heaters	120 gallon (454 L) storage tank with 80 ft ² (7 m ²) of collector area
Power generation	Photovoltaic system	PV eff. 16.2%, 5 kW peak

Energy Consumption

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Values in kWh/ yr	Base	New England Avg Avg (2001)
Cooling	311	
Heating	1073	
Lighting	807	
Plug load	2903	
Fan/pumps	266	
Hot water	3500	
PV production	0	
Total	8860	33,690
% Reduction	-	



Other (plug, appliances) loads

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Case	Floor Area ft² (m²)	Other Energy kWh/yr	Other Energy kWh/yr/ft² (kWh/yr/m²)
Civano1	1556 (145)	3100	1.99 (21)
Civano2	2042 (190)	3500	1.71 (18)
Civano3	1566 (145)	7000	4.47 (48)
Civano4	1280 (119)	4100	3.20 (34)
Civano5	1834 (170)	6100	3.33 (36)
Civano6	1834 (170)	5100	2.78 (30)
Civano7	1834 (170)	5000	2.73 (29)
Civano8	1227 (114)	9900	8.07 (87)
Aspen	3453 (321)	5200	1.51 (16)
Tucson	1718 (160)	4900	2.85 (31)

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What does it mean

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Ranges	Number of input options
Internal load	3
Infiltration	2
Thermostat-heating	2
Thermostat-cooling	2
Avg daily hot water use	2
Hot Water Consumption	3
Natural ventilation for cooling	3
PV system efficiency	3
Solar thermal system losses	3
Weather	2
Number of combinations	7776