

# Getting to *Zero*

In which the Author did a bunch of modeling of heating energy use and made some SWAGs to draw some mealy-mouthed conclusions that might be all wrong

# What I did:

- Using Sunrel V1.14, I modeled a house that is a two story 24' x 32' with a one story 16' x 16' ell. Total gross square feet is 1792.
- I used Boston climate data from a TMY2 file.
- The house has a full basement that is unheated.
- Gross window area is 270 sf (~15% of floor area) and 2/3 of that (180 sf) is on the south.
- I modeled nine cases total, beginning at a typical construction type and progressively getting more efficient

# The cases:

Case #	Title	Walls	Ceiling	B'ment ceiling	B'ment walls	Windows	Glass	NI, R-4	ELA	ERV	Mass
1	Base	R-14	R-38	R-19	None	R-3	Double Low-e2	None	106 (2.5)	None	2 BTU/F/sf
2	Upgrade	R-24	R-50	R-19	R-10	R-3	Double Low-e2	None	42.4 (1.0)	50 cfm 65%	2 BTU/F/sf
3	Super	R-40	R-60	R-30	R-15	R-5	Triple 2 EA	None	21.2 (0.5)	50 cfm 65%	2 BTU/F/sf
4	Super, Mass	R-40	R-60	R-30	R-15	R-5	Triple 2 EA	None	21.2 (0.5)	50 cfm 65%	4 BTU/F/sf
5	Super, xtight, 85%	R-40	R-60	R-30	R-15	R-5	Triple 2 EA	None	8.5 (0.2)	50 cfm 85%	2 BTU/F/sf
6	Super (5) NI on south	R-40	R-60	R-30	R-15	R-5	Triple 2 EA	Yes	8.5 (0.2)	50 cfm 85%	2 BTU/F/sf
7	Super (5), 45 sf S gl, Mass	R-40	R-60	R-30	R-15	R-5	Triple 2 EA	None	8.5 (0.2)	50 cfm 85%	4 BTU/F/sf
8	Ultra	R-56	R-70	R-40	R-15	R-5	Triple 2 EA	None	8.5 (0.2)	50 cfm 85%	2 BTU/F/sf
9	Ultra, Mass, NI	R-56	R-70	R-40	R-15	R-5	Triple 2 EA	Yes	8.5 (0.2)	50 cfm 85%	4 BTU/F/sf

# Windows and glass

Window Type	U window	Uc.o.g	SHGC	Frame
Double SolarBan 60 (on outer lite), Wood	0.33	0.24	0.39	Wood
Triple with two EnergyAdvantage (on two inner lites), Fiberglass	0.33	0.15	0.61	Fiberglass (hollow with insulation in sash and frame)

# The results:

Case #	Title	Annual heating energy, MMBTU	Annual heating energy, kWh	Annual heating energy, kWh, COP=3	Peak heating, BTU/hour
1	Base	48.2	14,122	4,707	36,550
2	Upgrade	21.3	6,241	2,080	21,250
3	Super	5.2	1,527		13,450
4	Super, Mass	3.8	1,106		16,650
5	Super, xtight, 85%	3.2	937		11,000
6	Super (5) NI on south	2.4	697		10,700
7	Super (5), 45 sf S gl, Mass	1.8	533		13,800
8	Ultra	2.0	576		9,650
9	Ultra, Mass, NI	0.6	189		11,300

# Mechanical systems and cost

Case #	Title	System	Cost, K\$	Components and cost, K\$
1	Base	GSHP	26	GSHP – 7K; Ground loop – 10K; Distribution – 9K
2	Upgrade	GSHP	23	GSHP – 6K; Ground loop – 7K; Distribution – 8K; ERV – 2K
3	Super	Electric	5	ERV, distribution, electric heater – 5K
4	Super, Mass	Electric	5	ERV, distribution, electric heater – 5K
5	Super, xtight, 85%	Electric	5	ERV, distribution, electric heater – 5K
6	Super (5) NI on south	Electric	5	ERV, distribution, electric heater – 5K
7	Super (5), 45 sf S gl, Mass	Electric	5	ERV, distribution, electric heater – 5K
8	Ultra	Electric	5	ERV, distribution, electric heater – 5K
9	Ultra, Mass, NI	Electric	5	ERV, distribution, electric heater – 5K

# Solar electric system size and cost

Case #	Title	Heat, kWh	kW of PV, @1.1 kWh/Wp/year	PV cost, @ \$9,000/kWp
1	Base	4,707	4.3	38.7
2	Upgrade	2,080	1.9	17.1
3	Super	1,527	1.4	12.6
4	Super, Mass	1,106	1.0	9.0
5	Super, xtight, 85%	937	0.9	8.1
6	Super (5) NI on south	697	0.6	5.4
7	Super (5), 45 sf S gl, Mass	533	0.5	4.5
8	Ultra	576	0.5	4.5
9	Ultra, Mass, NI	189	0.2	1.8

# Construction cost of upgrades

Upgrade	Cost/sf of upgrade, \$/sf	Cost, K\$
Strapped wall (7 inch cavity)	2.5	4.7
12 inch wall	6	11.3
12 inch wall + 4 inches foam	8.5	16.0
R-50 blown-in ceiling	0.3	0.3
R-60 blown-in ceiling	0.5	0.5
R-70 blown-in ceiling	0.7	0.7
R-10 basement wall	2.5	2.7
R-15 basement wall	2.8	3.0
R-30 basement ceiling	0.25	.25
R-40 basement ceiling	0.35	.35
R-5 window	10	2.7



# Construction cost of upgrades

Upgrade	Cost/sf of upgrade, \$/sf	Cost, K\$
Airsealing package 1	LS	0.6
Airsealing package 2	LS	0.8
Airsealing package 3	LS	1.2
R-4 night insulation	7	1.3
Thermal mass	5	2.4
45 sf added south window	50	2.3
65%>85% ERV, earth tube	LS	1.0

# Total cost

Case #	Title	Heat, kWh	HVAC Cost, K\$	PV Cost, K\$	Upgrade Construction Cost, K\$	Upgrade Construction Cost/sf, \$	Total Cost, K\$
1	Base	4,707	26	38.7			64.7
2	Upgrade	2,080	23	17.1	9.3	5.19	49.6
3	Super	1,527	5	12.6	18.6	10.38	37.2
4	Super, Mass	1,106	5	9.0	21.0	11.72	35.0
5	Super, xtight, 85%	937	5	8.1	20.0	11.16	33.1
6	Super (5) NI on south	697	5	5.4	21.2	11.83	31.6
8	Ultra	533	5	4.5	25.0	13.95	34.5
7	Super (5), 45 sf S gl, Mass	576	5	4.5	24.6	13.73	34.1
9	Ultra, Mass, NI	189	5	1.8	28.6	15.96	35.4