NZE Summer House Retrofit

Concept Design – Wolfeboro, NH

Final Project Report

CEE 176A: Energy Efficient Buildings

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Submitted on:

12/09/22

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Project Overview

The motivation behind this project is to efficiently re-design an existing summer home located at Springfield Point Rd, Wolfeboro, NH to make it a net-zero energy building that can be used all year long. The existing house was built on this plot in the 1960s and was designed and built as a summer home, effectively shut down during the winter months (see Figure 1 below for a recent picture of the home).

Figure 1. Existing structure of the home of interest on the banks of Lake Winnipesaukee. This image shows the Northern Elevation.

As with older construction, the thermal resistances of the assemblies are not that high, and there is a high rate of infiltration, making it difficult from an energy standpoint to weatherize this home for the winters. The goal of this project is to propose a concept design for a building that would fit this footprint, stick to the similar style of the home, and make use of the latest energy efficiency techniques and technologies to achieve net zero energy status while being operated all year long.

Located at a latitude of 43.57° and a longitude of -71.2° (pinpointed in the map below) on the edge of Lake Winnipesaukee, it experiences very harsh winters and requires significant considerable weatherproofing for the winter.

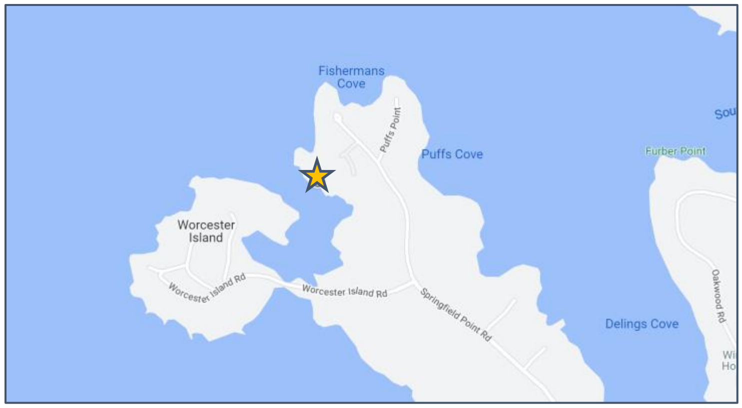

Figure 2. Location of site on Lake Winnipesaukee in Wolfeboro, NH.

Our house incorporates all the passive solar design strategies (a direct gain-Trombe wall hybrid and a sunspace) and makes use of a geothermal heat pump given the low efficiency of conventional heat pumps in extremely cold climates. Given the proximity of the house to the lake, from a technical standpoint, the coils of the geothermal system could be placed underwater, thus making use of the high thermal capacitance of water. However, this may not be straightforward from a practical standpoint given the tedious permit processes involved.

From a financial standpoint, the goal of the project was to maximize the Net Present Value (NPV) of savings in our Zero-Energy Home (ZEH) while also ensuring that we remained positive in terms of savings in year 1. We found that to achieve this, it was essential to maximize the SSF to reduce the heating costs.

Given the harshness of the winters, we wanted to maximize the Solar Savings Fraction (SSF) and hence oriented the axis of the house along the E-W direction to maximize southern exposure. The main passive design strategies that have been used are as follows: direct gain, sunspace, and Trombe wall. Each is described below, and depictions are included in Figures 3 and 4.

Sunspace

A sunspace was inserted between the two wings of the home to be the solar aperture for the space. This semi-enclosed sunspace features a common masonry wall and an insulated slab (mirroring the SSE2 designation). To ensure that the heat stays in during winter after sunset, night insulation (in the form of manual honeycomb structure window shades) are used to achieve the SSF desired. Additionally, during the winter, there are internal openings (doors and windows) from this sunspace leading to adjacent rooms that, when needed, can be opened to allow the heat absorbed from the slab to travel into these spaces, reducing the overall heating load in the rest of the house.

During the summer months when increased ventilation is desired (and to take advantage of the breeze off the lake), fully operable doors allow the South façade of the sunspace to completely open and let fresh, cool lake breezes into the space to passively ventilate.

Trombe Wall

The Trombe wall system used within this design is technically a half wall. This means that instead of a full height Trombe wall, the system lies below that of the direct gain system. This allows for occupants to still view the beautiful lake view out of this south facing window while also benefiting from the increased thermal efficiencies that the Trombe wall provides. This system matches the TWI4 designation, is unvented, and consists of double-glazed windows and a 12" thick mass wall.

Direct Gain

To achieve maximum efficiency, night insulation was used on these windows to provide an additional R-5 of thermal resistance.' To have some mass to soak up this solar gain, a marble countertop is added that sits atop the Trombe wall.

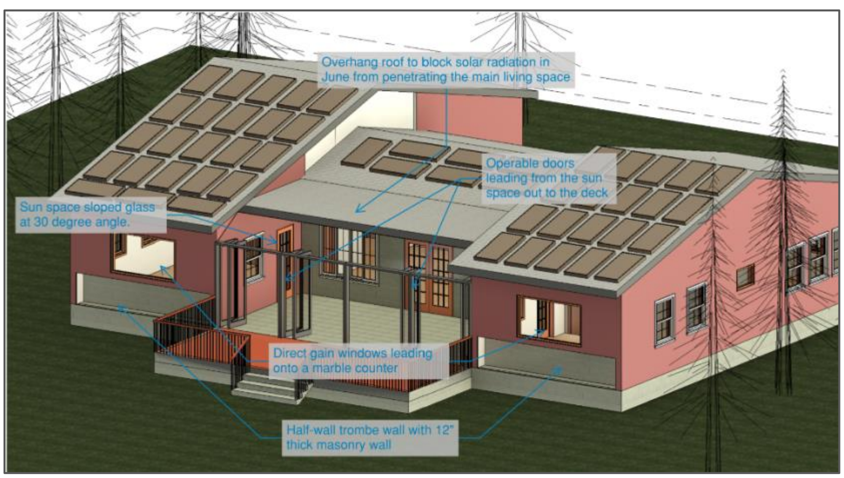

Figure 3. Isometric view showing select passive solar design techniques applied to this project.

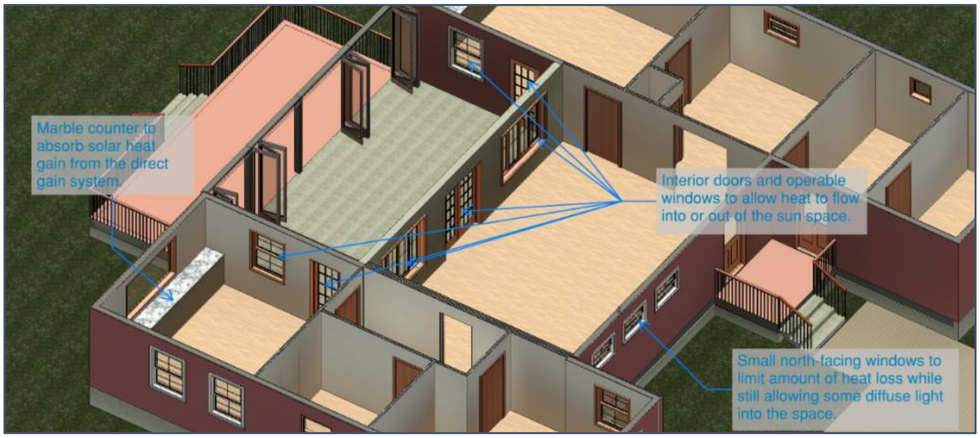

Figure 4. Floor section view showing select passive solar design techniques applied to this project.

Design Strategy

We considered the data for Portland, Maine from the passive solar handbook given the unavailability of data for New Hampshire. Portland is at the same latitude as Wolfeboro and experiences a very similar climate.

We realized that the roof, which is usually designed to be at an angle equal to the latitude of the house, would be very steep at an angle of 43.57°. Hence, it was decided to keep the angle of the roof at 14.04°, and the solar panels would therefore be tilted at an angle of 29.53° to the roof to achieve a net angle of 43.57° with the local horizontal. We also designed the roof such that it would have sufficient space for the solar array.

Our goal was to minimize infiltration losses (as the house, located on the lakeside, receives icy, gusty winds in the winter), based on a target $n_{infiltration}$ of 0.1 ach. To calculate the $n_{ventilation}$, we calculated a total air change per hour value of 0.15 ach using the guideline of 15 CFM/person from which we subtracted the $n_{infiltration}$ of 0.1 ach to arrive at a $n_{ventilation} = 0.15 - 0.1 = 0.05$ ach.

Table 1.Cost Comparison between the ZEH and Reference House.

	Reference	**ZEH**
Capital Cost	$547,800	$629,874
Fuel or Rev $/yr	$5,938	$507

Table 2. NPV results for the ZEH.

NPV of savings of ZEH (over 20 years)	$30,654
Year 1 savings of ZEH	$1,635

Although our ZEH has a capital cost higher than the reference house by $82,074, we achieve a savings of $1,635 starting from year 1 itself, which is a very compelling incentive in the long run to build a ZEH instead of a conventional home.

We went through an iterative process to arrive at our final design, while trying to maximize NPV and having a net positive savings in year 1. These were the parameters that we kept tweaking to achieve our final design:

- The areas and R-values of various parts of the building envelope.
- The type and area of the passive solar system to maximize SSF.
- The number of glazings used for exterior windows (it was ultimately decided to use double pane, low emissivity windows with a gap filled with krypton gas to achieve a sufficient R-value.
- Strategy for shading the East/West windows. Ultimately, the intent is to keep the trees already planted on those facades there to assist with blocking any solar gain in the morning and evening.

We went through several iterations of varying the above-mentioned parameters to arrive at a final holistic design where we not only tried to maximize NPV of savings but design a comfortable home that takes advantage of the lake views.

Some of our biggest learnings/takeaways from the designing process include the following:

- The more extreme the climate, the more important it is to invest higher initially to keep operating costs low and save significantly in the long-run.
- Air-source heat pumps have a very low efficiency in cold climates, which we felt was a good business case for installing a geothermal heat pump. We learnt of Dandelion, a geothermal heating installation company based in the Northeast US, which gave us confidence on the technical feasibility of our proposal.

We did realize the limitations and the highly simplifying assumptions that went into doing the energy analysis of the house such as:

- Assumptions of steady state all the time, which may not be the case when there are solar gains.
- The HDD and CDD numbers are just an average for the entire year, even though there are more granular approaches to calculate them.
- System losses for the solar array were assumed, although they could vary based on real-time site conditions.
- A fixed $/kWh is assumed to be paid by the utility during TOU, while it is highly variable.

However, as was mentioned in class, we tried to maximize the NPV while bearing in mind the uncertainty baked into the results. Given the experiments that both of us did in the lab, we also understand that many of the assumptions are good tools to simplify the analysis.

The intent of this concept design, as noted above, is to inform the owners of the current home that there may be a viable option to invest in this house to transition to net zero energy and that there is a both an environmental and economic incentive to do so.

Floor Plan

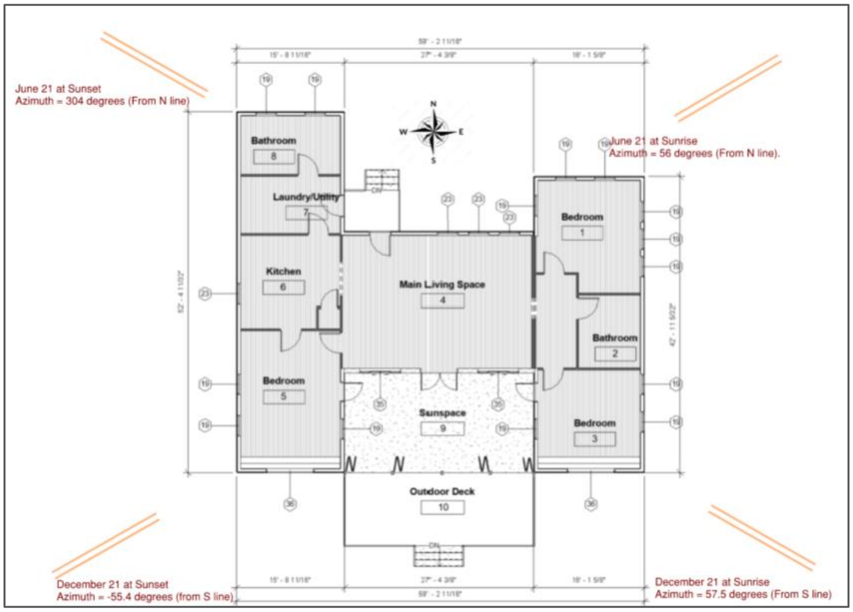

Figure 5. Floor Plan of the home (with a 1/8" = 1' scale). All windows are tagged (number corresponds to different architectural window types). Azimuth angles at solstices at sunrise and sunset are included in the above image (obtained from TimeandDate.com).

Please note that the area of the deck (just off the sunspace) which equals 292 ft^2 is only included to account for the cost of construction and is excluded from the areas related to the energy analysis.

Revit Model

See below for various screenshots of the modeled design including at various times of year at noon to exemplify shading effects and effectiveness of the southern overhangs.

Figure 6. Isometric view of Northern side of home, depicting the electric car and driveway.

December 21 – Shading

Figure 7. Revit model shown with shadows on December 21. Note that the sun can penetrate through the direct gain windows as well as the sunspace and Trombe wall.

June 21 - Shading

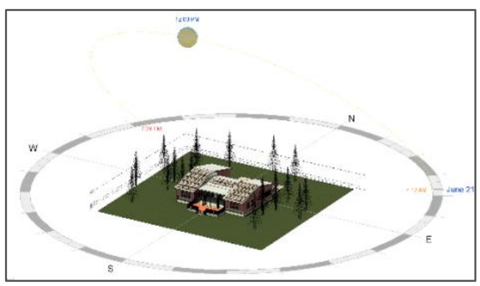

Figure 8. Revit model shown with shadows on June 21. Note that the overhangs prevent the solar gain from penetrating through the direct gain windows as well as the sunspace and Trombe wall.

March 21 - Shading

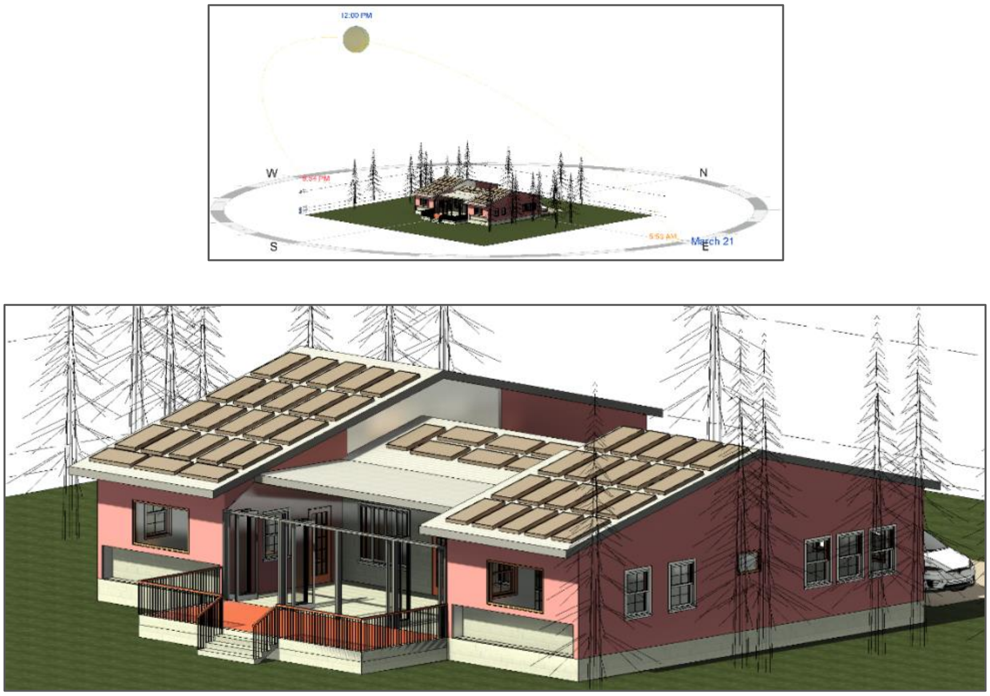

Figure 9. Revit model shown with shadows on March 21.

Analysis Spreadsheets

HEATING ANALYSIS FOR YOUR HOUSE, CEE 176A

Location:	Springfield Point, Wolfeboro, NH	
Floor area of house, Af	2739	ft2 (total area including conditioned basement)
Base Cost of Construction	$ 547,800	Af x $200/ft2
Avg Ceiling height (H)	10	ft (your estimate)
Gross wall area estimate (GW)	2617	simplify using GW = 5 x H x (Af^0.5)

Blank squares	= calculated values or definitions
(blue)	= Given quantities
(yellow)	= data entry (your choices)

NPV	$ 30,654
Year 1	$ 1,635

BUILDING ENVELOPE:

Component	Area (ft^2)	R-effective	U=1/R	UA (Btu/hr^{o}F)	Extra Cost	
Direct Gain (Maximum R-3)	56	3	0.333	18.7	$ 358	$ = $5/ft2*(R minus 1.72)*A
Trombe Wall	90	5	0.200	18.0		Mass cost below
Water wall	0	5	0.200	0.0		Mass cost below
Sunspace	280	5	0.200	56.0		Mass cost below
Non-S Windows (up to R-7)	178	4.3	0.233	41.4	$ 2,296	$ = $5/ft2x(R-1.72)xA
Doors	40	5	0.200	8.0	$ 600	$ = $5/ft2x(R-2)xA
Bermed & conditioned bsmnt walls (R includes R20)	0	40	0.025	0.0	$ -	$ = $0.20x(R-20)xA
Net wall (GW-solar -windows - door - berm)	1973	30	0.033	65.8	$ 7,497	$ = $0.20x(R-11)xA
Ceiling	2050	40	0.025	51.3	$ 1,025	$ = $0.05/ft2x(R-30)xA
Floors: crawl space or uncond basemt (R includes R6)	2050	30	0.033	68.3	$ 677	$ = $0.03/ft2x[R-19] xA
Conditioned basement floor (R includes R20)	0	41	0.024	0.0	$ -	$ = $0.20x(R-11)xA
	P (ft)	**F2(Btu/h^{o}Ff**	**Min F2**	**P x F2**		
Slab-on-grade floor (unheated) P (ft), F2	0	0.50	0.200	0.0	$ -	$ = $20/ftx(0.6-F2)*Perim
Slab-on-grade heated (radiant) P (ft), F2	397	0.60	0.600	238.2	$ 5,558	$ = $20/ftx(1.3-F2)*Perim
	ACH	**Volume (ft^3)**	**Efficiency**			
Infiltration	0.1	24,470	0	44.0	$ 2,739	$ = Af x(1.20 - 2xach)
Ventilation	0.05	24,470	70%	6.2	$ 3,500	$ =5000*eff if ach>0
			(UA)Tot =	**615.9**	**$ 24,250**	

SOLAR LOAD RATIO ANALYSIS:

BUILDING LOAD COEFFICIENT (BLC):	12,557.04	BLC=24[(UA)tot-(UA)solar]	Btu/oF-day
APERTURE AREA (Ap):	**426**	Ap=Adg + Atw + Aww + Ass	ft2
LOAD-COLLECTOR RATIO (LCR):	**29.48**	LCR = BLC/Ap	Btu/ft2oFd
Direct Gain Night Insulation? (YES/NO)	YES	ADDED cost of Direct Gain Night Insulation @ $10/ft2 =	**$ 560.00**

	Area (ft2)	LCR2 at SSF=0.2	LCR5 at SSF=0.5	SSF* if all Ap is that type	Mass Btu/ft^{2o}F	Capacitance Btu/^{o}F	Mass Cost $0.40/Btu^{o}F
Direct Gain (DGC3)	56	55	16	0.332	60	3360	$ 1,344
Trombe Wall (TWI4)	90	44	14	0.285	30	2700	$ 1,080
Water Wall (WW)	0					0	$ -
Sunspace (SSE2)	280	62	15	0.337	30	8400	$ 3,360
*SSF=0.18+0.3*log(LCR2/LCR)/log(LCR2/LCR5)			**Wt. AVG SSF =	**0.325**		Total Mass $=	**$ 5,784**

**Wt. Avg SSF=DGx%DG+TWx%TW+WWx%WW+SSx%SS

HEAT PUMP ANALYSIS

Distribution Efficiency % (e.g. enter 90 if 90%)	100	100 if radiant or Ductless Heat Pump (DHP); otherwise enter %
Extra distribution cost =	$ -	= $0 if radiant floor or DHP; otherwise = $150x(eff-85)
Indoor set point, Ti	68	oF (70 normal, 68 radiant)
HDD 65 (oFday/yr)	7180	oFd/yr Reader Aii 7.1 - 7.5
Design Temperature (Coldest Temp expected)	-11.8	Can use [Tdes= 60 - 0.01 HDD65] to estimate, but best to look up online
Heating pick-up factor	1.4	(given)
Heat pump output (Btu/hr)	68,806	=(UA)totx(Tset-Tdes)xp.u./dist eff
Air Source HSPF (RATED)	13.00	Air Source 8 - 13 Btu/Wh
Cost Air Source Heat Pump + Xtra dist eff cost	$ 7,156	= $8/kBtu x kBtu/h(B50) x HSPF (rated) + xtra distrib cost (B45)
Air Source HSPF (adjusted)	5.80	=HSPFx[0.8959+0.008862Tdes+0.000153xTdes^2-0.02817HSPF]
Geothermal Heat Pump (YES/NO)?	Yes	
FINAL HSPF	19.00	If GHP = YES, then HSPF = HSPF(rated)+6, if NO then HSPF(Adjusted)
FINAL Heat Pump Cost (above ref house furnace)	**$ 17,156**	If GHP = YES, then add $10,000 to heat pump cost

Summary of Costs

Base Cost	$ 547,800	
Envelope	$ 24,250	
Night Insul	$ 560	
Mass	$ 5,784	
Heat Pump	$ 17,156	page 2
Water Heater	$ 800	page 2
Battery cost	$ 6,750	page 2
PV cost	$ 26,775	page 2
Total 1st cost	**$ 629,874**	
NPV (pg 4)	$ 30,654	page 4
Year 1 Savings	$ 1,635	page 4

ANNUAL HEATING LOAD:

Internal Gains, qint (Btu/hr)	2363	Can use: [(20,000 + 15*Af)/24] to estimate, or add up loads/people inside
Balance Point Temp (oF)	64.2	= Ti - qint/(UA)tot
HDD @ Tbal (oFd/yr)	6959	=HDD65-(0.021*HDD65+114)(65-Tbal)
HEAT Qdel (Btu/yr)	58,945,030	=BLC*(1-SSF)*HDDTbal
Heat Pump output (Btu/yr)	58,945,030	= Qdel /(dist efficiency)
Heat Pump electric for space heating (kWh/yr)	**3,102**	= (Btu/yr)/HSPF(adjus. Btu/Wh) / 1000 W/kW

YOUR HOUSE ELECTRICAL CALCULATIONS — PAGE 2

Calculated values
Data Entry
Givens

HEAT PUMP WATER HEATER:		
No. people in household	4	your choice
Gallons per day /person	15	given
Efficiency Factor	2.1	given
Annual hot water (Btu/yr)	10,958,760	= N x 15 g/d-p x 8.34 x(120-60)x365
Electrical Input (kWh/yr)	1529	= Btu/yr / 3412Btu/kWh / E.F.
Extra water heater Cost	$ 800	given (compared to Ref house gas heater)

ANNUAL COOLING LOAD:		
HDD65	7,180	from your house heating sheet
Avg annual amb temp TA (oF)	46	Reader pgs VII 7.1 - 7.4
CDD65	245	Can estimate with [HDD65-365 x (65-TA)], but best to look up online
Distribution efficiency	100	% (from your house heating sheet)
(UA)tot	616	Btu/hroF (from your heating sheet)
Envelope cooling load Btu/yr	3,621,355	Btu/yr=24(UA)totxCDD65/dist eff
Latent Heat Factor LHF	4.90	from U.S. Map of Latent Heat Factors
Extra latent cooling (Btu/yr)	1,448,443	24(UA Vent + UA Infil)*LHF*CDD65/Dist Eff
Total Cooling Load (Btu/yr)	5,069,797	Envelope + extra latent
SEER(rated) Btu/Whr	26.00	= 2 x HSPF(rated), from Heat Page
Estimated Tamb max (^{o}F)	60	If GSHP = "yes" then 60^o; otherwise 100^{o}F
SEER (adjusted) Btu/Wh	27.51	= SEER x (1.5864-0.005668*Tamb-0.01029*SEER)
Heat Pump Cooling kWh/yr	184	= Cooling Btu/yr / SEER(adj Btu/Wh) /1000Wh/kWh

HOUSE ELECTRICAL LOAD		
Your floor area Af (ft2)	2447	from your house heat sheet
Annual Misc Load kWh/yr	4894	=2 kWh/ft2/yr x floor area (ft2)
Air Conditioning Load kWh/yr	184	(above)
Heating Load kWh/yr	3102	(from your house heating sheet)
Hot Water Load kWh/yr	1529	(above)
Total House Load	9710	kWh/yr (Plug+A/C+Heat+DHW)

HOUSE BATTERY SYSTEM		
Storage capacity (kWh)	13.5	delivered per charge cycle; default Powerwall 13.5 kWh
System cost ($/kWh)	$ 500	Given
System cost ($)	**$ 6,750**	= Cap (kWh) x $/kWh
Hours/day for TOU rate	4	Given (4 pm - 8 pm)
Avg house kW during TOU	0.559	= Annual Miscellaneous Load / 8760
kWh to house during TOU	2.23	= TOU Hrs/day x House kW during TOU
kWh/day to utility during TOU	11.27	= Battery kWh - House kWh during TOU
Days/yr for TOU rate	180	Given (half-year for Duck curve impact)
kWh/yr to Utility during TOU	2028	= kWh/day during TOU x days/yr of TOU
TOU $/kWh paid by utility	$ 0.25	Given
Revenue from utility ($/yr)	$ 506.94	= kWh/yr to utility x $/kWh
Round-trip Battery efficiency	90%	Given
Battery losses (kWh/yr)	270	= [kWh delivered/% eff - kWh cap] x days/yr

ELECTRIC VEHICLE		
Electric Vehicle miles/yr	15,000	Your choice
EV miles/kWh	4	Given, but if your HDD>5000, use 3
Electric Vehicle Load	3,750	kWh/yr =(miles/yr) / (miles/kWh)

PV SIZING		
Total electrical load kWh/yr	13730.09197	House + EV + battery losses
PV Tilt	43.57	degrees (default at your latitude)
PV Azimuth (180o = South)	180	South = 180o; West = 270o
PVWatts yield per kWp	1282	kWh/yr per kWp from http://pvwatts.nrel.gov
PV sizing kWp dc, stc	10.71	kW (total load kWh/yr) / (kWh/yr/kWp)
PV efficiency	0.18	Given
Area (ft2)	640	A=P(kW)/(PV eff)*10.76ft2/m2
Cost $/W	$ 2.50	$/W dc (given)
PV cost	**$ 26,775**	$= ($/W)*P(kw)*1000

REFERENCE HOUSE PROJECT SPREADSHEET:	PAGE 3	
	GIVENS	= given quantities
	Data Entry	(none for this page)

LOCATION DATA:		
Heating degree days base 65 (HDD65):	7180	from your house heating sheet
Average annual temperature TA:	46	From Electrical Page
Design temperature, Tdes:	-11.8	From your house heating sheet
Natural gas cost at t = 0 yr	$ 1.20	$/therm (given)
Electricity cost at t = 0 yr	$ 0.15	$/kWh (given)

SPACE HEATING:		
Floor space area, Af	2447	ft2 (from "your house" sheet)
Normalized efficiency factor (E.F.):	8	Normalized Btu/ft2-HDD (given)
Furnace efficiency %:	90	given
Duct efficiency %:	85	given
Annual heating energy (Qfuel):	183,732,915	Btu/yr, Qf = 8 * Ahouse * HDD65 / (0.90eff*0.85 eff)
Heating fuel cost:	**$ 2,205**	$/yr (natural gas) $ = Qf*unit fuel price
Thermostat set point:	70	F (given)
Pick up factor:	1.4	(given)
Furnace size:	109,894	Btu/hr = E.F.*Af*(Tset-Tdes)*Pickup/(24*duct eff)
WATER HEATING:		
Number of residents	4	from your house electrical page
Hot Water heating demand (Btu/yr)	21,808,478	N x 20g/dp x 8.34lb/g x(120-60)*365/ 0.67 Btu/yr
Hot Water cost	**$ 262**	$/yr natural gas $ = Btu x n. gas price

COOLING LOAD:		
Cooling degree days base 65 (CDD65)	245	CDD65 = HDD65 - 365*(65-TA)
Cooling deltaT bldg envelope	4,796,120	Btu/yr, Qc, env=E.F. *Af * CDD65
Cooling hot roof (assume 1-story)	6,965,793	Btu/yr Qc roof = (1/R30)*Af*(140-70)*10h/d*122d/y
E,W window area	196	ft^2 (8% of the floor area)
SHGC (solar through window)	0.35	(given) assumes curtains
Solar gains	9,194,847	Btu/yr, Qc sg = Awindow e,w * 1100 Btu/ft2d x 122d/yr x SHGC
Latent heat	6,345,267	24 h/d x 0.018 x V x (n=0.5) x CDD65 x LHF
Total cooling load	32,120,032	Btu/yr = (Qenv + Qroof+Qsgain)/dist.eff
SEER	13	Btu/Wh (given)
Electricity for A/C	2,471	kWh/yr = (tot cooling load Btu/yr)/(SEER Btu/Wh x 1000 W/kW)

ECONOMICS:		
Unit cost of construction:	200	$/ft2 (given)
Base cost of construction:	$ 547,800	$200/ft2* floor area Af
Plug/lighting Load electrical	7,341	kWh/yr = Af x 3 kWh/ft2
A/C load electrical	2,471	from above AC kWh/yr
Total electrical use	9,812	kWh/yr = sum of plug + A/C
Cost of electric loads	**$ 1,472**	$/yr = total electric load x price of electricity
1st yr fuel $(heat, plug +A/C+hot water)	**$ 3,938**	$/yr (Heating$ + Cooling $ + Electric $)

ADDING FUEL FOR A GASOLINE POWERED CAR TO THE COST:		
Miles driven in their gasoline powered car	15000	From Page 2 EV miles
Fuel efficiency	30	mpg (given)
Gasoline cost	$ 4.00	$/gal (given as average, but feel free to lookup for your location)
Fuel cost	**$ 2,000**	$/yr (miles / mpg) x $/gal
TOTAL FUEL COST (HOUSE + VEHICLE)	**$ 5,938**	$/yr (1st year fuel for house + fuel for car)

ECONOMICS FOR COST-EFFECTIVE HOUSE PROJECTS	Page 4

	Reference	ZEH	
Capital Cost	$ 547,800	$ 629,874	
Fuel or Rev $/yr	$ 5,938	$ 507	TOU revenue pg 2

NPV of ZEH =	$ 30,654	below
Year 1 Savings	$ 1,635	below

Loan term (yrs)	20	given	
Loan interest	0.04	given	
CRF(i,n)	0.0736	CRF = I(1+I)^n/((1+I)^n-1)	**calculate this !!**
Marginal Tax Bracket	32%	given	
Fuel escalation rate	3%	given	
Discount rate	7%	given	

REFERENCE HOUSE

End of year	Loan Pmt	Interest	Tax Savs	Delta Bal	Loan Balance	Fuel Cost	Total Cost
0					$ 547,800.00		
1	$ 40,308.08	$ 21,912.00	$ 7,011.84	$ 18,396.08	$ 529,403.92	$ 6,116.41	$ 39,412.65
2	$ 40,308.08	$ 21,176.16	$ 6,776.37	$ 19,131.93	$ 510,271.99	$ 6,299.90	$ 39,831.62
3	$ 40,308.08	$ 20,410.88	$ 6,531.48	$ 19,897.20	$ 490,374.79	$ 6,488.90	$ 40,265.50
4	$ 40,308.08	$ 19,614.99	$ 6,276.80	$ 20,693.09	$ 469,681.70	$ 6,683.57	$ 40,714.85
5	$ 40,308.08	$ 18,787.27	$ 6,011.93	$ 21,520.81	$ 448,160.88	$ 6,884.07	$ 41,180.23
6	$ 40,308.08	$ 17,926.44	$ 5,736.46	$ 22,381.65	$ 425,779.23	$ 7,090.60	$ 41,662.22
7	$ 40,308.08	$ 17,031.17	$ 5,449.97	$ 23,276.91	$ 402,502.32	$ 7,303.31	$ 42,161.42
8	$ 40,308.08	$ 16,100.09	$ 5,152.03	$ 24,207.99	$ 378,294.33	$ 7,522.41	$ 42,678.47
9	$ 40,308.08	$ 15,131.77	$ 4,842.17	$ 25,176.31	$ 353,118.02	$ 7,748.09	$ 43,214.00
10	$ 40,308.08	$ 14,124.72	$ 4,519.91	$ 26,183.36	$ 326,934.66	$ 7,980.53	$ 43,768.70
11	$ 40,308.08	$ 13,077.39	$ 4,184.76	$ 27,230.70	$ 299,703.96	$ 8,219.94	$ 44,343.26
12	$ 40,308.08	$ 11,988.16	$ 3,836.21	$ 28,319.92	$ 271,384.04	$ 8,466.54	$ 44,938.41
13	$ 40,308.08	$ 10,855.36	$ 3,473.72	$ 29,452.72	$ 241,931.32	$ 8,720.54	$ 45,554.91
14	$ 40,308.08	$ 9,677.25	$ 3,096.72	$ 30,630.83	$ 211,300.49	$ 8,982.15	$ 46,193.52
15	$ 40,308.08	$ 8,452.02	$ 2,704.65	$ 31,856.06	$ 179,444.42	$ 9,251.62	$ 46,855.06
16	$ 40,308.08	$ 7,177.78	$ 2,296.89	$ 33,130.31	$ 146,314.12	$ 9,529.17	$ 47,540.36
17	$ 40,308.08	$ 5,852.56	$ 1,872.82	$ 34,455.52	$ 111,858.60	$ 9,815.04	$ 48,250.31
18	$ 40,308.08	$ 4,474.34	$ 1,431.79	$ 35,833.74	$ 76,024.86	$ 10,109.49	$ 48,985.79
19	$ 40,308.08	$ 3,040.99	$ 973.12	$ 37,267.09	$ 38,757.77	$ 10,412.78	$ 49,747.74
20	$ 40,308.08	$ 1,550.31	$ 496.10	$ 38,757.77	$ 0.00	$ 10,725.16	$ 50,537.15

YOUR ZEH HOUSE COST including CAR, Battery and PV Systems

End of year	Loan Pmt	Interest	Tax Savs	Delta Bal	Loan Balance	TOU Sales	Total Cost	YOUR SAVS	PresVal SAVS
0					$ 629,874.18				
1	$ 46,347.24	$ 25,194.97	$ 8,062.39	$ 21,152.28	$ 608,721.91	$ 506.94	$ 37,777.92	$ 1,634.74	$ 1,527.79
2	$ 46,347.24	$ 24,348.88	$ 7,791.64	$ 21,998.37	$ 586,723.54	$ 506.94	$ 38,048.67	$ 1,782.95	$ 1,557.30
3	$ 46,347.24	$ 23,468.94	$ 7,510.06	$ 22,878.30	$ 563,845.23	$ 506.94	$ 38,330.25	$ 1,935.26	$ 1,579.75
4	$ 46,347.24	$ 22,553.81	$ 7,217.22	$ 23,793.44	$ 540,051.80	$ 506.94	$ 38,623.09	$ 2,091.76	$ 1,595.80
5	$ 46,347.24	$ 21,602.07	$ 6,912.66	$ 24,745.17	$ 515,306.63	$ 506.94	$ 38,927.64	$ 2,252.59	$ 1,606.06
6	$ 46,347.24	$ 20,612.27	$ 6,595.92	$ 25,734.98	$ 489,571.65	$ 506.94	$ 39,244.38	$ 2,417.84	$ 1,611.11
7	$ 46,347.24	$ 19,582.87	$ 6,266.52	$ 26,764.38	$ 462,807.27	$ 506.94	$ 39,573.79	$ 2,587.63	$ 1,611.45
8	$ 46,347.24	$ 18,512.29	$ 5,923.93	$ 27,834.95	$ 434,972.31	$ 506.94	$ 39,916.37	$ 2,762.09	$ 1,607.56
9	$ 46,347.24	$ 17,398.89	$ 5,567.65	$ 28,948.35	$ 406,023.96	$ 506.94	$ 40,272.66	$ 2,941.34	$ 1,599.89
10	$ 46,347.24	$ 16,240.96	$ 5,197.11	$ 30,106.29	$ 375,917.67	$ 506.94	$ 40,643.20	$ 3,125.50	$ 1,588.85
11	$ 46,347.24	$ 15,036.71	$ 4,811.75	$ 31,310.54	$ 344,607.14	$ 506.94	$ 41,028.56	$ 3,314.70	$ 1,574.79
12	$ 46,347.24	$ 13,784.29	$ 4,410.97	$ 32,562.96	$ 312,044.18	$ 506.94	$ 41,429.34	$ 3,509.08	$ 1,558.07
13	$ 46,347.24	$ 12,481.77	$ 3,994.17	$ 33,865.48	$ 278,178.70	$ 506.94	$ 41,846.14	$ 3,708.76	$ 1,539.01
14	$ 46,347.24	$ 11,127.15	$ 3,560.69	$ 35,220.10	$ 242,958.60	$ 506.94	$ 42,279.62	$ 3,913.90	$ 1,517.88
15	$ 46,347.24	$ 9,718.34	$ 3,109.87	$ 36,628.90	$ 206,329.70	$ 506.94	$ 42,730.44	$ 4,124.62	$ 1,494.95
16	$ 46,347.24	$ 8,253.19	$ 2,641.02	$ 38,094.06	$ 168,235.64	$ 506.94	$ 43,199.29	$ 4,341.08	$ 1,470.47
17	$ 46,347.24	$ 6,729.43	$ 2,153.42	$ 39,617.82	$ 128,617.82	$ 506.94	$ 43,686.89	$ 4,563.41	$ 1,444.66
18	$ 46,347.24	$ 5,144.71	$ 1,646.31	$ 41,202.53	$ 87,415.29	$ 506.94	$ 44,194.00	$ 4,791.79	$ 1,417.72
19	$ 46,347.24	$ 3,496.61	$ 1,118.92	$ 42,850.63	$ 44,564.66	$ 506.94	$ 44,721.39	$ 5,026.35	$ 1,389.83
20	$ 46,347.24	$ 1,782.59	$ 570.43	$ 44,564.66	$ 0.00	$ 506.94	$ 45,269.88	$ 5,267.27	$ 1,361.16
						TOTAL NPV OF SAVS=			**30,654**