BUILDINGENERGY BOSTON

In the Last Analysis: An Electrified Town Garage for the 21st Century

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Curated by Fred Davis

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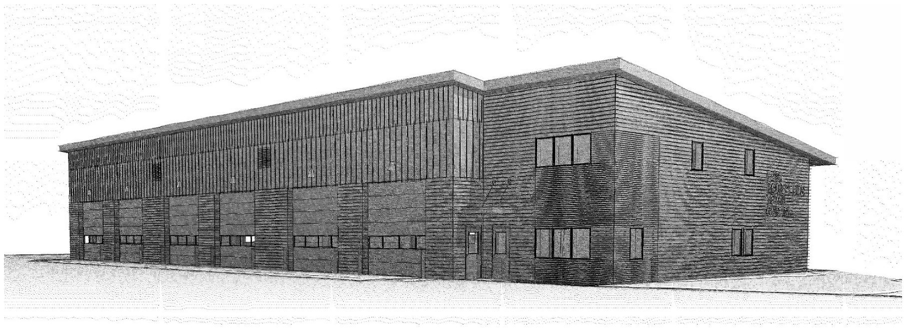
What we will do today

- The building
- Options studied
- Energy analysis – embodied and operational
- Construction costs
- Life cycle cost analysis
- Selected systems
- Design phase commissioning
- Lessons learned

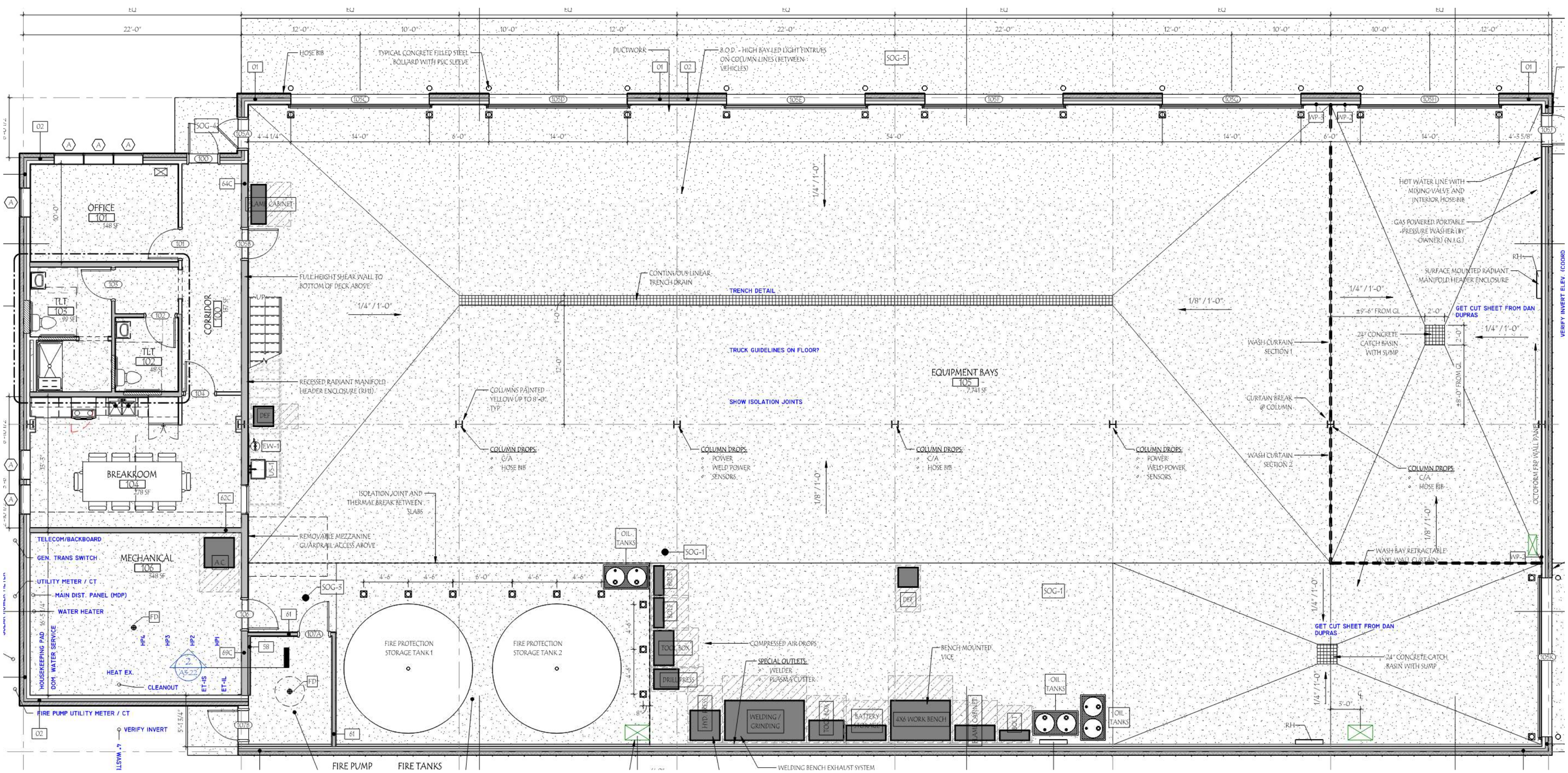
Learning objectives

- Compare heating COP of
  - ground source open loop
  - ground source closed loop
  - air-to-water heat pumps
- Understand a simplified method to estimate closed loop ground source heat pump heating system over the course of a winter
- Understand the role of peak electrical demand in an all-electric building on system design and on operating cost
- Understand the multiple roles that radiant heat can play in a road maintenance garage



North elevation

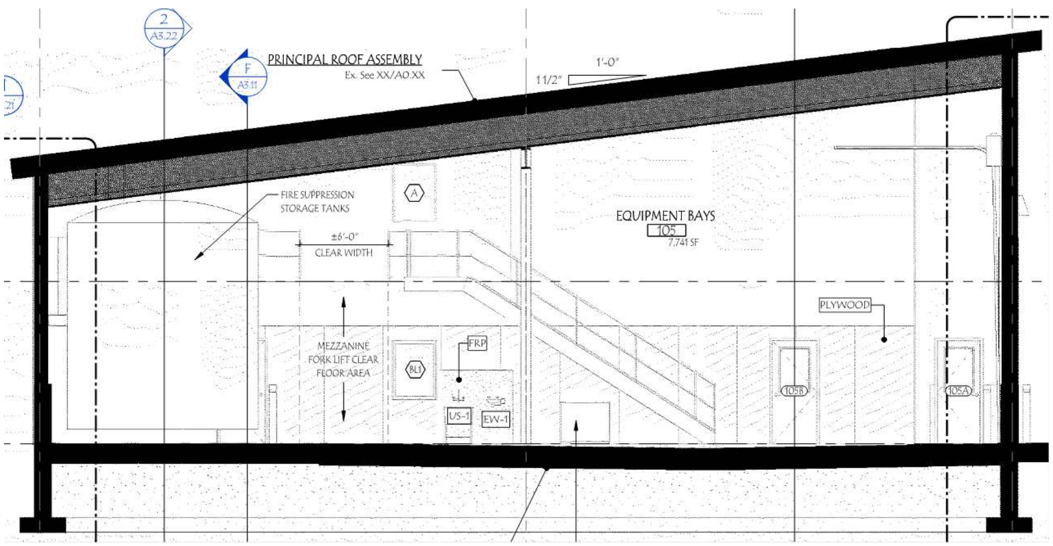
Floorplan

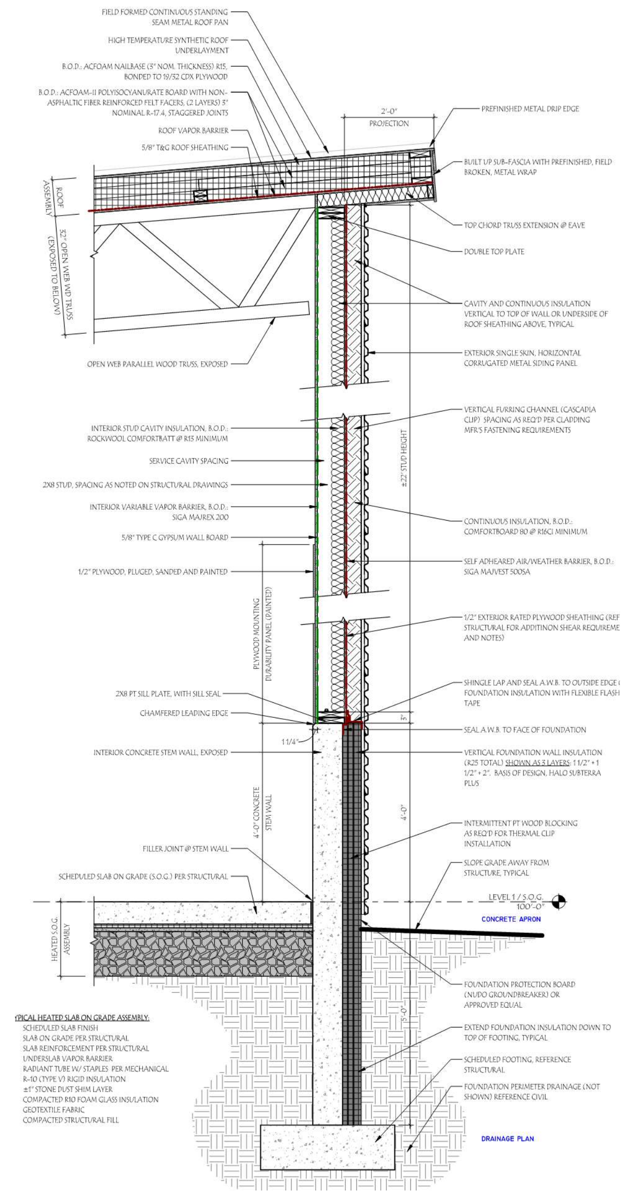


OFFICE
101
CORRIDOR
100
TLT
105
TLT
102
BREAKROOM
104
MECHANICAL
106
EQUIPMENT BAYS
105
TRENCH DETAIL
TRUCK GUIDELINES ON FLOOR?
SHOW ISOLATION JOINTS
FIRE PROTECTION STORAGE TANK 1
FIRE PROTECTION STORAGE TANK 2
FIRE PUMP
FIRE TANKS
WELDING / GRINDING
4X6 WORK BENCH
TELECOM/BACKBOARD
GEN. TRANS SWITCH
UTILITY METER / CT
MAIN DIST. PANEL (MDP)
WATER HEATER
HEAT EX.
CLEANOUT
FIRE PUMP UTILITY METER / CT
VERIFY INVERT
GET CUT SHEET FROM DAN DUPRAS

Sections

- R-50 PI roof
- R-35 -- 4” rigid foil faced PI continuous +5.5” wood fiber batts
- R-20+ Glavel + foam under slab
- R-10 Thermal break at edges of slab
- R-5 Tripane FG windows
- R-15   3” foam overhead doors
- 0.05 cfm50/sq.f.t shell

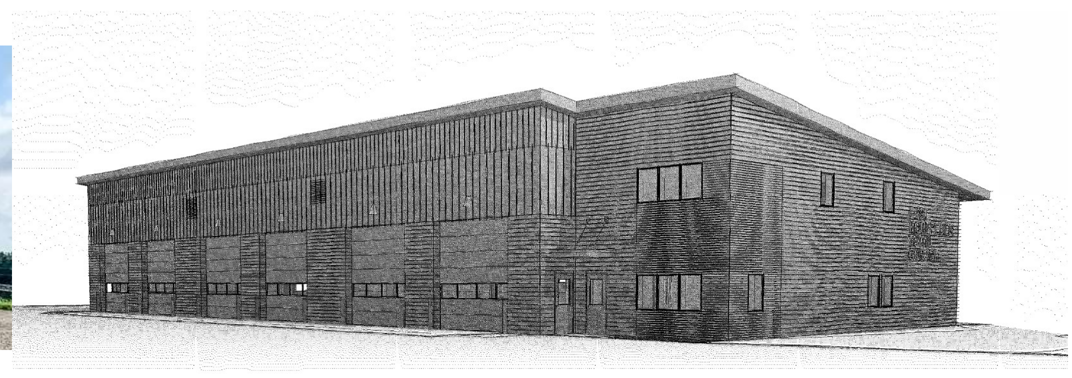




Options studied

Building enclosure

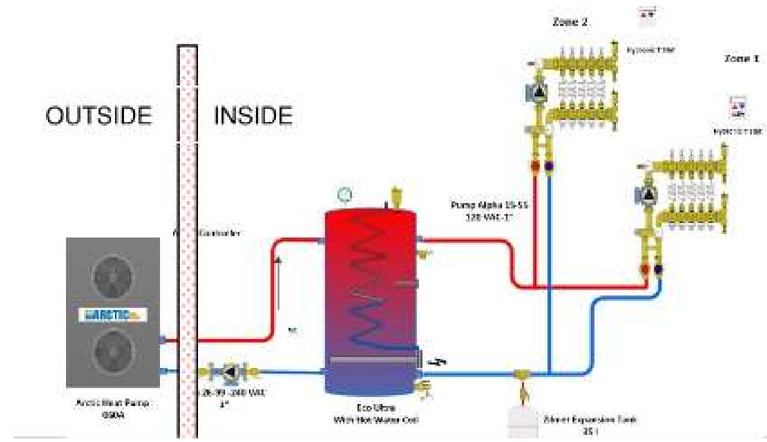
- Code metal
- high efficiency wood enclosure

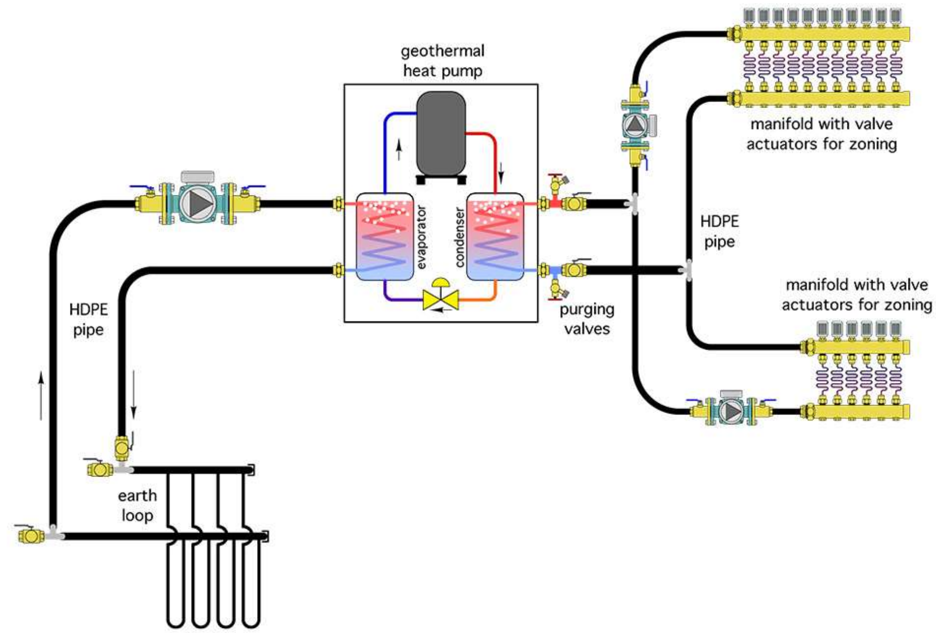


Options studied

Mechanical systems

- Propane boiler
- Wood pellet boiler
- Air to water heat pump (A2WHP)
- Ground source heat pump (GSHP)





Options studied

All options with radiant floor

- Better melting/warming of trucks
- Heats incoming fresh air
- Large thermal flywheel

Baseline wood pellets
Baseline, Propane
High Performance, Wood pellets
High Performance, Propane
High Performance, Air to Water Heat Pump
High Performance, Ground Source Heat Pump
High Performance, Air to Water Heat Pump with PV
High Performance, Ground Source Heat Pump with PV

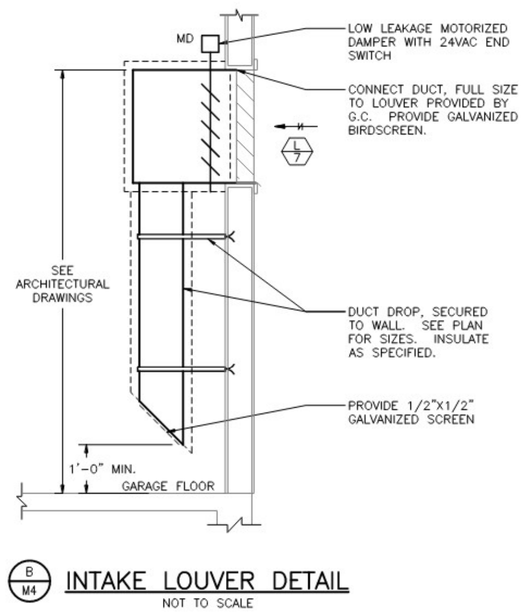
Baseline = metal building; High Performance = efficient wood building

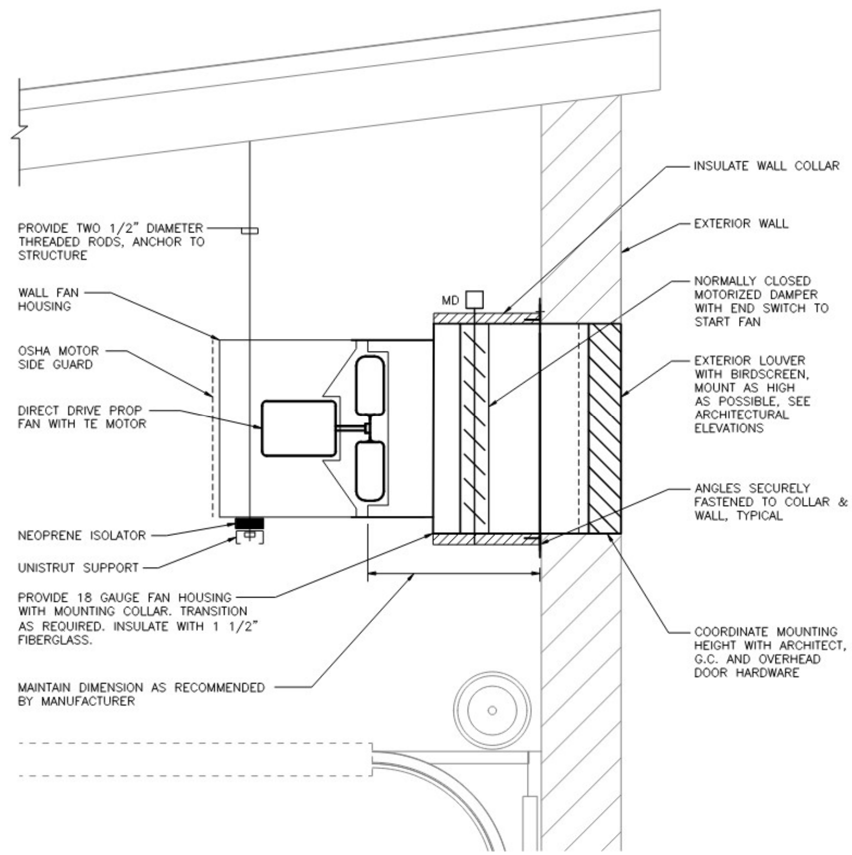
Also looked at demand control for heat pump systems

Demand controlled ventilation

- RH
- CO
- NO_2
- Manual

Air heated by passing over radiant floor!





Peak electrical demand reduction – the dirty secret of electrification!

- Control EV chargers!
- Control heat pumps (?)
- 25,000 gallons of fire protection tanks for thermal storage

30F drop in tank temperature = 24 hrs of heat at -20F outside

Analysis

- Embodied emissions
- Operational energy
- operational emissions
- construction costs
- operating expense
- 30 yr life cycle cost analysis

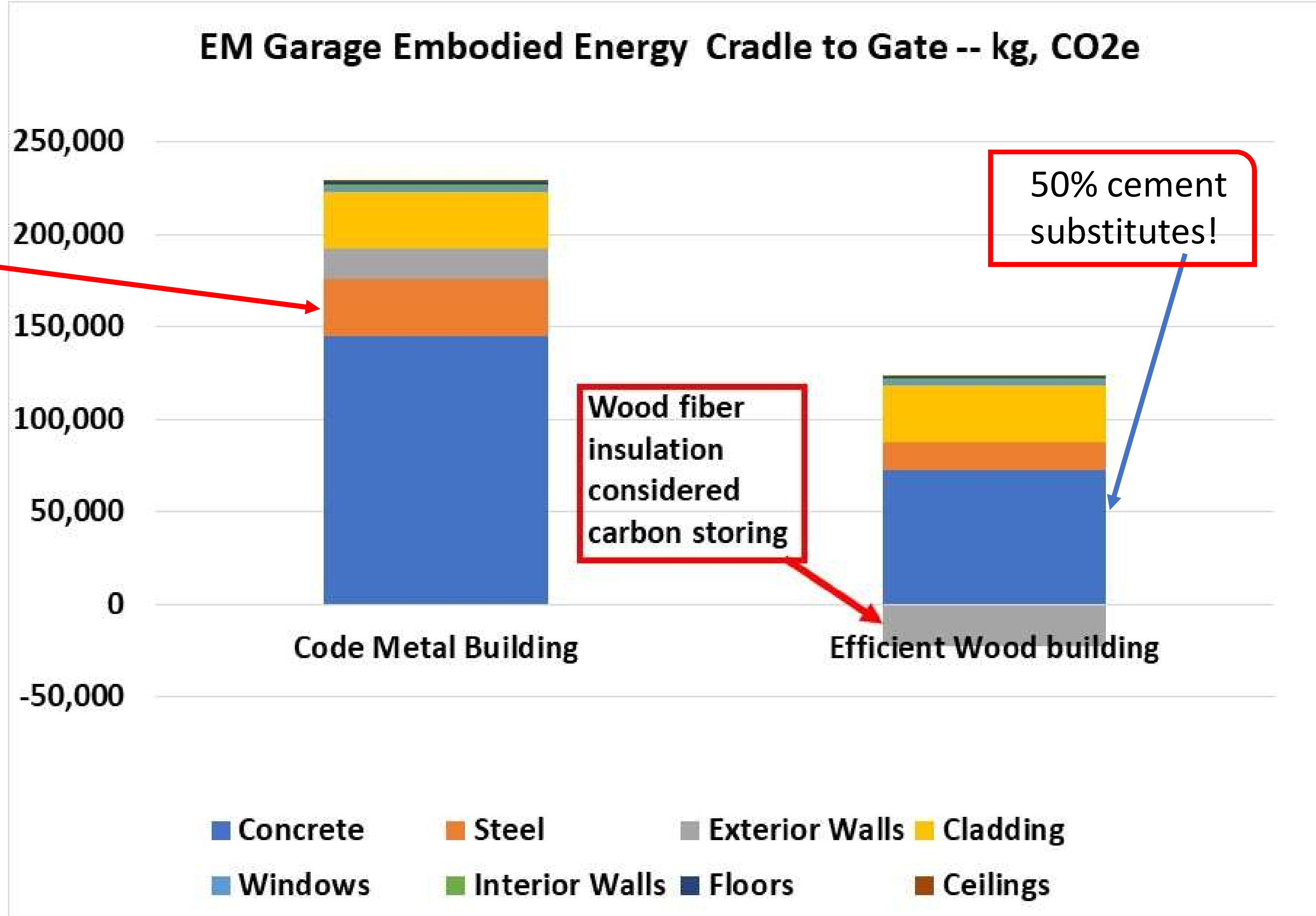
EM Town Garage	Assumptions for Energy Modeling	240624

	Building	Metal Building, per 2024 CBECS code	Efficient Wood Building
Envelope	Windows	R-3.5	R-3.5
	Skylights	none w/ 0.5 wsf lights	none w/ 0.5 wsf lights
	Doors	R-2.7	R-2.7
	Air/Vapor Barrier	Inner VB is inner skin of metal building panels	Full VB interior of walls, full VB on roof top, wall VB fully connected to roof VB
	Insulation Roof	R-42, 6" foam insulated steel panels	R-60 / U=.0167
	Insulation Walls	R-25 , 4" foam insulated steel panels	R-30
	Stem Wall	R-10 continuous rigid exterior	R-20 continuous rigid exterior insulation
	Slab under	f-0.434 by code, but modeled at 0.71 for 2" under 48"	4" EPS under whole slab, R-18; f-0.2
	Slab edge	none	4" exterior of stem wall, up 4 ft and down 4'
	Overhead doors	R-6 -- no requirement	R-18
	Air Leakage rate	0.25 cfm75/sf. Shell 6 sides, equivalent to 0.19 cfm50/sq.ft. shell 6 sides	0.06 cfm50/sq.ft. shell 6 sides
	Envelope Commissioning	yes	yes

	EM Town Garage		
		Metal Building, per 2024 CBECS code	Efficient Wood Building
Mech	Ventilation	Two exhaust fans, controlled on CO, NO2, RH and	Two exhaust fans, controlled on CO, NO2, RH and
	Domestic Hot	Tank off boiler, full recirc	HPWH, EF =3.0, controlled circulation
	Controls	programmable thermostat	programmable thermostat
	Heating	Propane or wood pellet boiler boiler, eff = 0.80, AFUE = 0.82	A2WHP COP 2.3; or GSHP COP 4.0; or propane or wood pellet boiler Eff=0.80 (HP COPs modeled dynamically)
	Cooling	office only, ASHP	office only, ASHP
	Lighting	LED	LED
	Plug Loads	Low	Low

Embodied emissions

24 tons of steel in steel prefab building



BEAM Estimator Software

Embodied emissions

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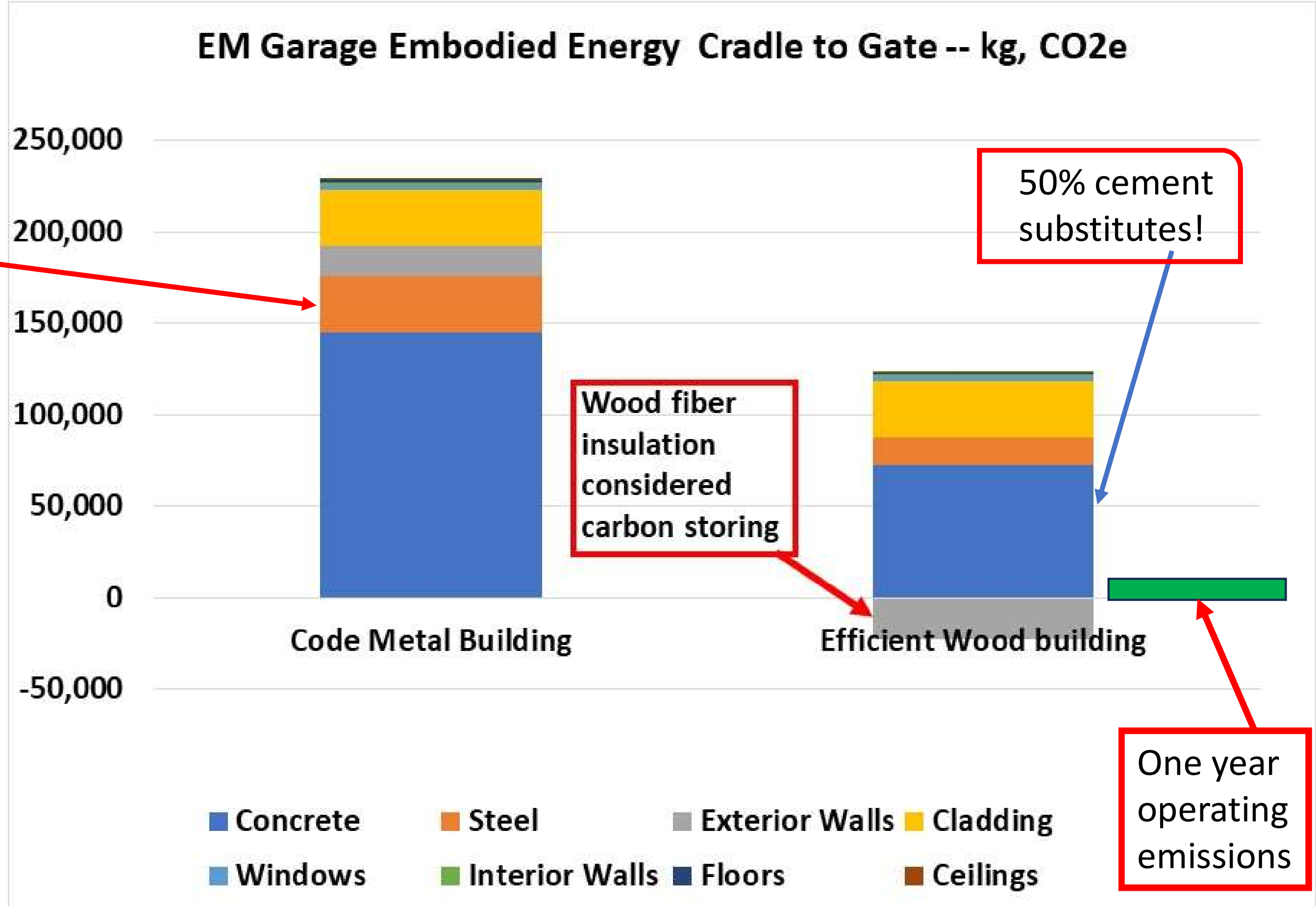
BEAM Estimator Software

BUILDERS FOR CLIMATE ACTION



Operating Energy and Cost Analysis Process

1. Takeoffs from building design
2. Inputs into Energy 10 to generate hourly loads (hourly simulation model)
3. Run model to output hourly loads for heat, hot water, lights, and other (no cooling in garage) and hourly outside temperature
4. Develop efficiency curve/equation for air to water heat pump (A2WHP) and for ground source heat pump (GSHP)
5. Apply heating efficiency equation to each hour’s heating load

Wait – there’s more!

Operating Energy and Cost Analysis Process

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4. Develop efficiency curve/equation for air to water heat pump (A2WHP) and for ground source heat pump (GSHP)
5. Apply heating efficiency equation to each hour’s heating load
6. Tally annual energy use by end use
7. Tally peak demand by month for whole building
8. For boilers, much simpler: apply efficiency of equipment (85%) to annual heating and hot water usage
9. Apply utility rate structure to monthly energy and peak demands
10. Apply emissions per unit energy to annual energy use

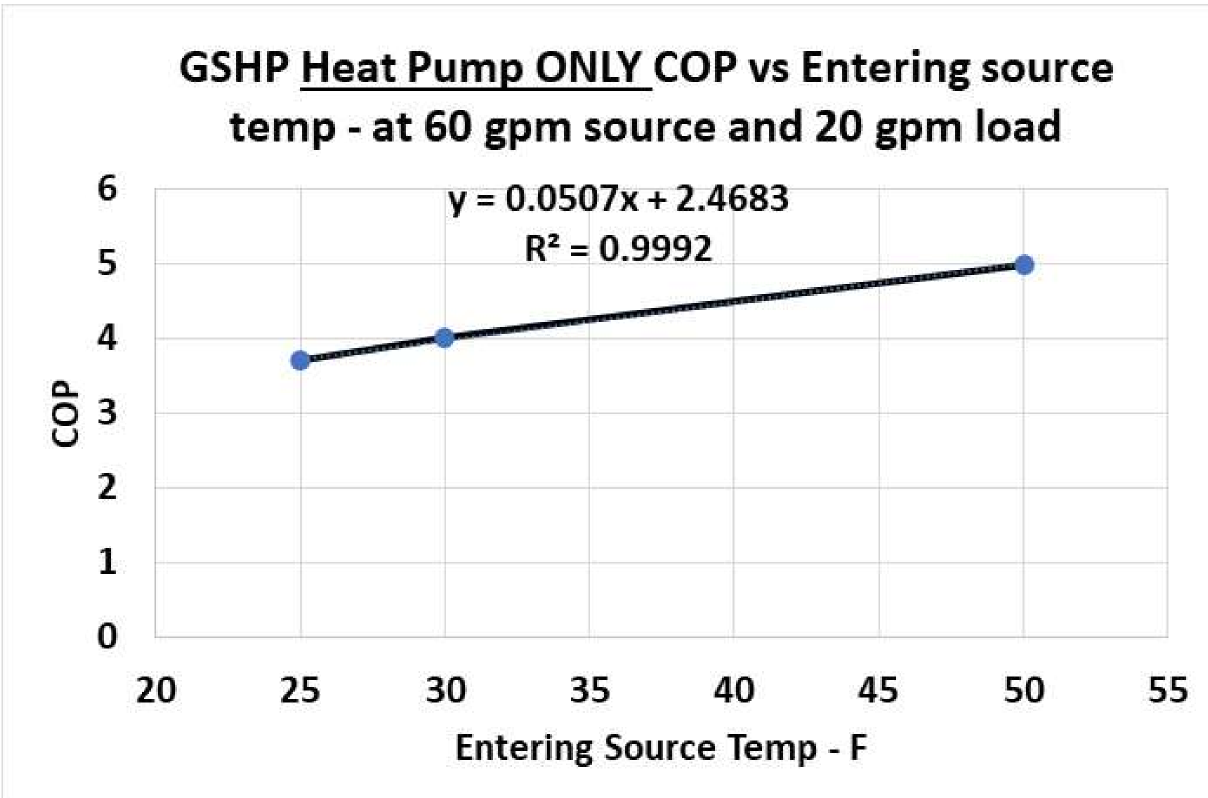
Hourly energy/load model output (8760 hours)

*Heating "**load**" is how much energy is required to keep building warm*
*Heating "**energy**" is how much electricity or fuel is required to supply that energy*

For a heating load of 600 MMBtu/yr, with a heat pump with COP of 3, the energy required *would be 200 MMBtu/yr of electricity. With a boiler with 80% efficiency, the energy* required *would be 750 MMBtu/year of propane*

Outside temp, F dry bulb	**Hour of the Year**		**Bldg** kWh	**DHW** kWh	**Lighting** kWh	**Plug** kWh	**Heating Load** kWh
	High performance			at COP=2			
	Total kWh		168,914	5,116	3,154	5,620	149,898
	Max	Max>>	68	1.0	0.6	1.0	64
34	1		32.8	0.29	0.09	0.38	32
33	2		30.3	0.29	0.09	0.38	29
35	3		29.3	0.29	0.09	0.38	28
34	4		28.9	0.29	0.09	0.38	28
29	5		31.2	0.29	0.09	0.38	30
27	6		33.5	0.29	0.09	0.38	32
26	7		34.7	0.29	0.08	0.38	34
26	8		35.1	0.29	0.08	0.48	34
25	9		34.8	0.38	0.08	0.48	33
25	10		33.4	0.38	0.08	0.48	32
25	11		33.3	0.38	0.08	0.48	32
27	12		31.5	0.38	0.08	0.48	30
26	13		30.4	0.38	0.08	0.48	29
25	14		31.6	0.38	0.08	0.48	30

Efficiency curves/equations Ground Source Heat Pump



Looking at this, why is an open loop system more efficient than closed loop?

THIS TABLE IS NOT TO BE READ!

060 - Performance Data cont.

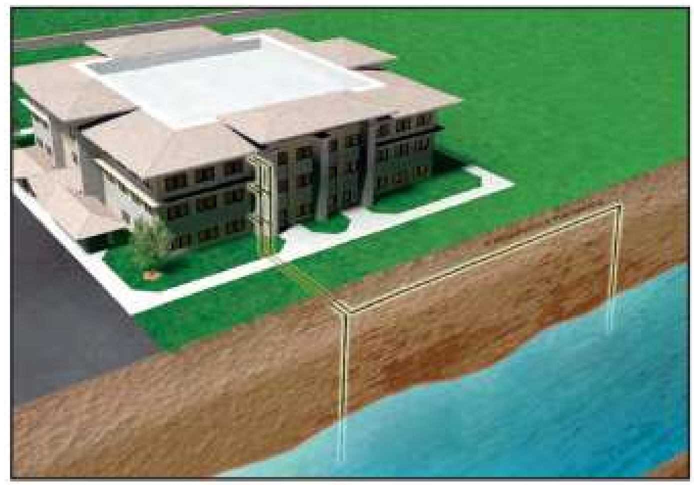
Heating Capacity

Source		Load Flow-9 GPM							Load Flow-13.5 GPM						Load Flow-18 GPM					
EST °F	Flow GPM	ELT °F	LLT °F	HC MBTUH	Power kW	HE MBTUH	COP	LST °F	LLT °F	HC MBTUH	Power kW	HE MBTUH	COP	LST °F	LLT °F	HC MBTUH	Power kW	HE MBTUH	COP	LST °F
25	13.5	60	Operation not recommended																	
		80																		
		100																		
		120																		
	18	60	71.1	48.3	2.93	38.3	4.83	20.6	67.4	48.6	2.86	38.8	4.98	20.6	65.6	48.9	2.79	39.4	5.14	20.5
		80	90.8	47.3	3.93	33.9	3.53	21.1	87.3	47.6	3.85	34.4	3.62	21.1	85.5	47.8	3.76	35.0	3.72	21.0
		100	110.6	46.3	4.93	29.5	2.75	21.6	107.1	46.5	4.83	30.0	2.82	21.6	105.4	46.8	4.74	30.6	2.89	21.5
		120	130.4	45.3	5.93	25.1	2.24	22.1	126.9	45.5	5.82	25.6	2.29	22.1	125.2	45.7	5.71	26.2	2.35	22.0
30	9	60	71.5	50.1	2.94	40.1	4.99	20.8	68.7	50.5	2.87	40.7	5.17	20.7	65.8	50.9	2.79	41.4	5.35	20.5
		80	91.3	49.3	3.95	35.9	3.66	21.8	88.5	49.7	3.86	36.5	3.77	21.6	85.7	50.0	3.77	37.1	3.89	21.5
		100	111.1	48.6	4.95	31.7	2.87	22.7	108.4	48.8	4.85	32.3	2.95	22.6	105.6	49.0	4.74	32.8	3.03	22.5
		120	131.0	47.8	5.96	27.5	2.35	23.7	128.2	48.0	5.84	28.0	2.41	23.6	125.5	48.1	5.72	28.6	2.46	23.5
	13.5	60	71.9	52.1	3.0	42.0	5.17	22.9	68.9	51.8	2.87	42.0	5.29	22.9	65.9	51.6	2.8	42.0	5.41	22.8
		80	91.7	50.9	4.0	37.4	3.77	23.7	88.7	50.8	3.86	37.6	3.86	23.6	85.8	50.7	3.8	37.8	3.95	23.5
		100	111.4	49.7	5.0	32.8	2.94	24.4	108.6	49.8	4.84	33.2	3.01	24.3	105.7	49.8	4.7	33.7	3.08	24.3
		120	131.1	48.6	6.0	28.2	2.39	25.2	128.4	48.8	5.83	29.0	2.45	25.1	125.6	49.0	5.7	29.5	2.51	25.0
	18	60	72.4	54.1	2.97	44.0	5.34	25.0	69.2	53.2	2.88	43.3	5.41	25.0	66.0	52.2	2.79	42.7	5.48	25.1
		80	92.0	52.5	3.96	39.0	3.88	25.5	89.0	52.0	3.86	38.8	3.95	25.6	85.9	51.4	3.76	38.6	[illegible]	25.6
		100	111.7	50.9	4.96	34.0	3.01	26.1	108.7	50.8	4.84	34.2	3.07	26.1	105.8	50.6	4.72	34.5	3.14	26.1
		120	131.5	49.3	5.95	29.0	2.43	26.7	128.5	49.6	5.82	29.7	2.50	26.6	125.7	49.8	5.69	30.4	2.56	26.5
50	9	60	75.1	66.0	3.0	55.7	6.34	37.2	71.4	66.2	2.92	56.2	6.62	37.1	67.6	66.3	2.8	56.7	6.90	37.0
		80	94.6	63.9	4.0	50.2	4.66	38.5	91.0	64.1	3.89	50.8	4.83	38.4	87.4	64.3	3.8	51.4	4.99	38.2
		100	114.1	61.7	5.0	44.7	3.63	39.8	110.6	62.0	4.86	45.4	3.74	39.6	107.1	62.3	4.7	46.1	3.86	39.4
		120	133.7	59.6	6.0	39.3	2.93	41.0	130.3	60.0	5.83	40.1	3.02	40.8	126.9	60.3	5.7	40.9	3.11	40.6
	13.5	60	75.8	68.8	3.1	58.4	6.61	40.1	71.8	68.5	2.93	58.5	6.84	40.1	67.8	68.2	2.8	58.5	7.09	40.0
		80	95.2	66.2	4.0	52.5	4.81	41.1	91.4	66.1	3.90	52.8	4.96	41.0	87.6	66.1	3.8	53.2	5.13	41.0
		100	114.6	63.7	5.0	46.6	3.72	42.1	111.0	63.8	4.87	47.2	3.84	42.0	107.3	64.0	4.7	47.8	3.96	41.9
		120	134.0	61.1	6.0	40.6	2.98	43.1	130.5	61.5	5.85	41.5	3.08	42.9	127.1	61.9	5.7	42.4	3.18	42.8
	18	60	76.4	71.6	3.1	61.1	6.79	43.0	72.2	70.8	2.95	60.7	7.01	43.0	68.0	70.0	2.8	60.4	7.24	43.1
		80	95.7	68.6	4.1	54.7	4.93	43.7	91.7	68.2	3.92	54.8	5.09	43.7	87.8	67.8	3.8	54.9	5.25	43.7
		100	115.0	65.6	5.1	48.4	3.79	44.5	111.3	65.6	4.89	48.9	3.92	44.4	107.5	65.6	4.7	49.4	4.06	44.3
		120	134.3	62.6	6.0	42.0	3.03	45.2	130.8	63.0	5.87	43.0	3.15	45.1	127.3	63.4	5.7	44.0	3.26	45.0
	9	60	78.8	81.9	3.12	71.3	7.69	53.7	74.1	81.8	2.98	71.6	8.07	53.6	69.4	81.7	2.83	72.0	8.46	53.5
		80	98.0	78.4	4.06	64.5	5.65	55.2	93.5	78.5	3.92	65.1	5.88	55.1	89.0	78.6	3.78	65.7	6.10	54.9
		100	117.2	74.9	5.01	57.8	4.38	56.8	112.9	75.2	4.87	58.6	4.54	56.6	108.7	75.6	4.72	59.4	4.69	56.4
		120	136.4	71.4	5.95	51.1	3.52	58.3	132.3	72.0	5.81	52.1	3.63	58.1	128.3	72.5	5.67	53.1	3.75	57.8

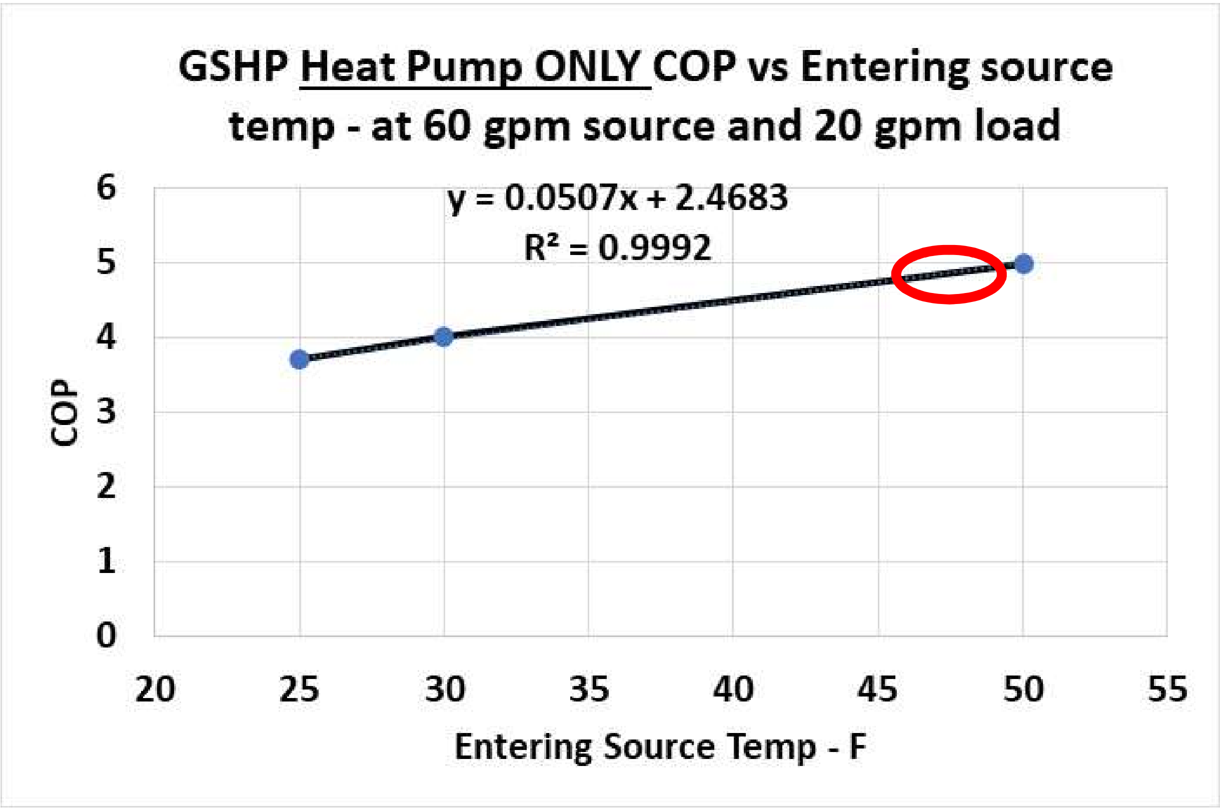
Selected system:
Ground Source Heat Pump System

Closed loop, boreholes

Open loop, "pump and dump"

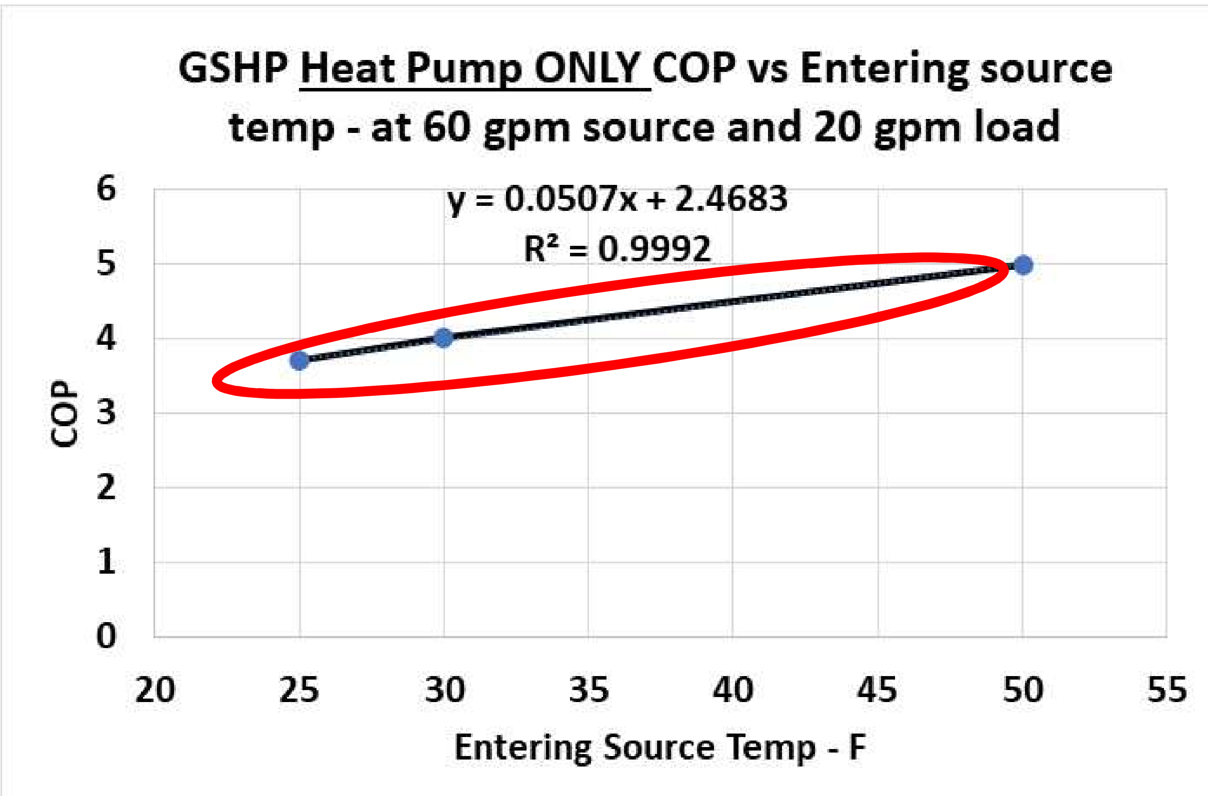


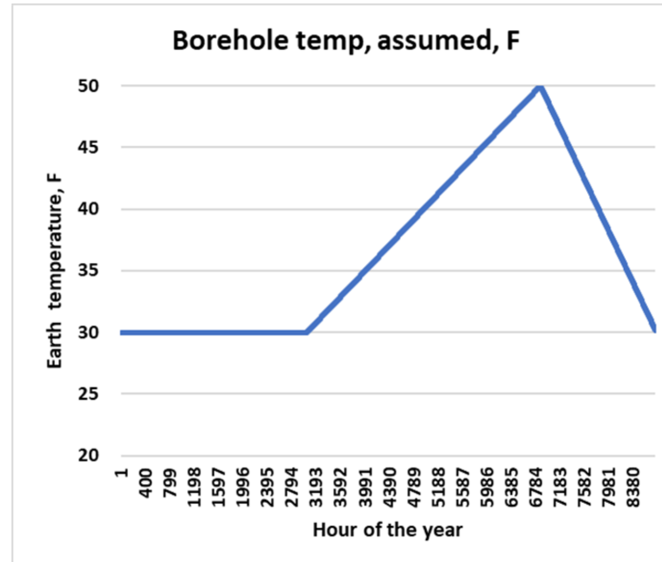
Efficiency curves/equations Ground Source Heat Pump



Looking at this, why is an open loop system more efficient than closed loop?

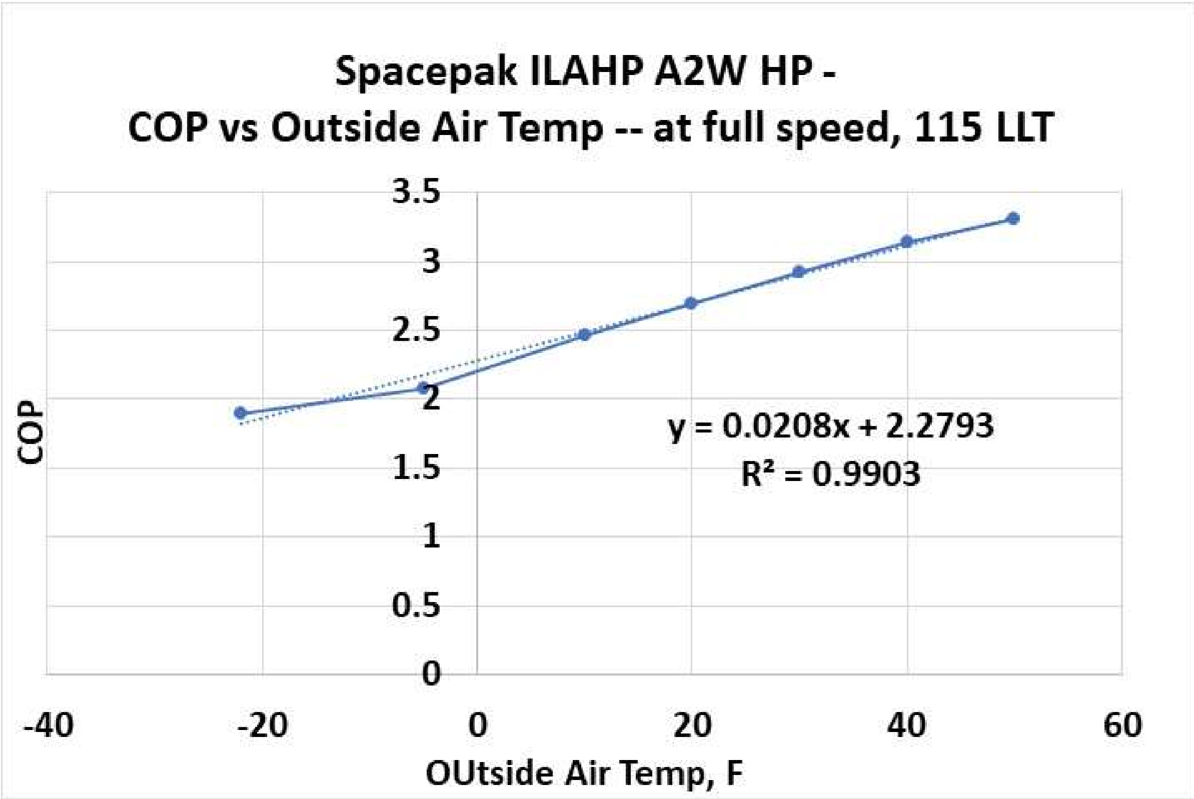
Efficiency curves/equations Ground Source Heat Pump



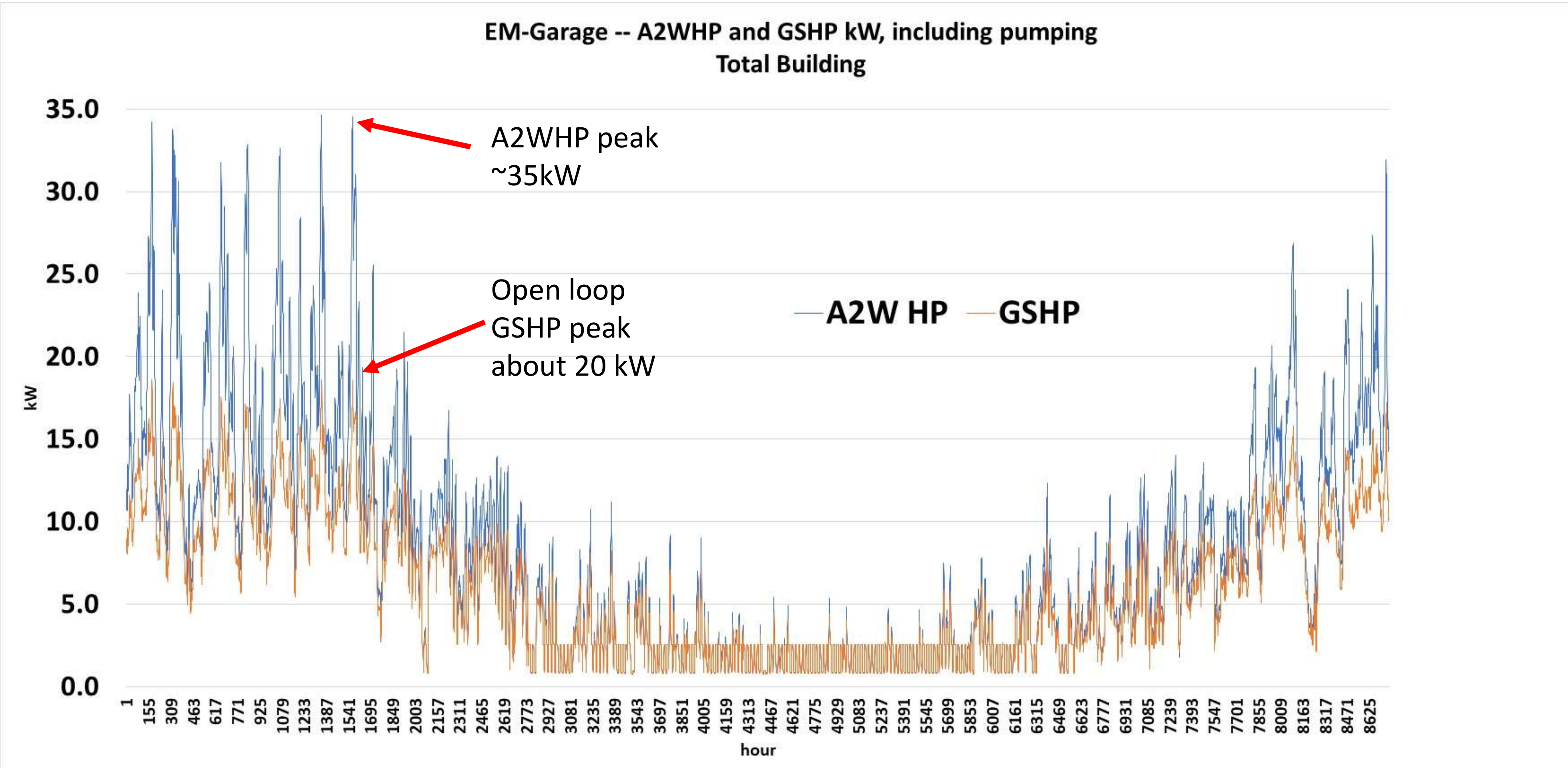


Looking at this, why is an open loop system (more efficient than closed loop borehole)?

Efficiency curves/equations Air-to-Water Heat Pump



Apply heating efficiency equation to each hour's heating load And graph total building energy usage by hour

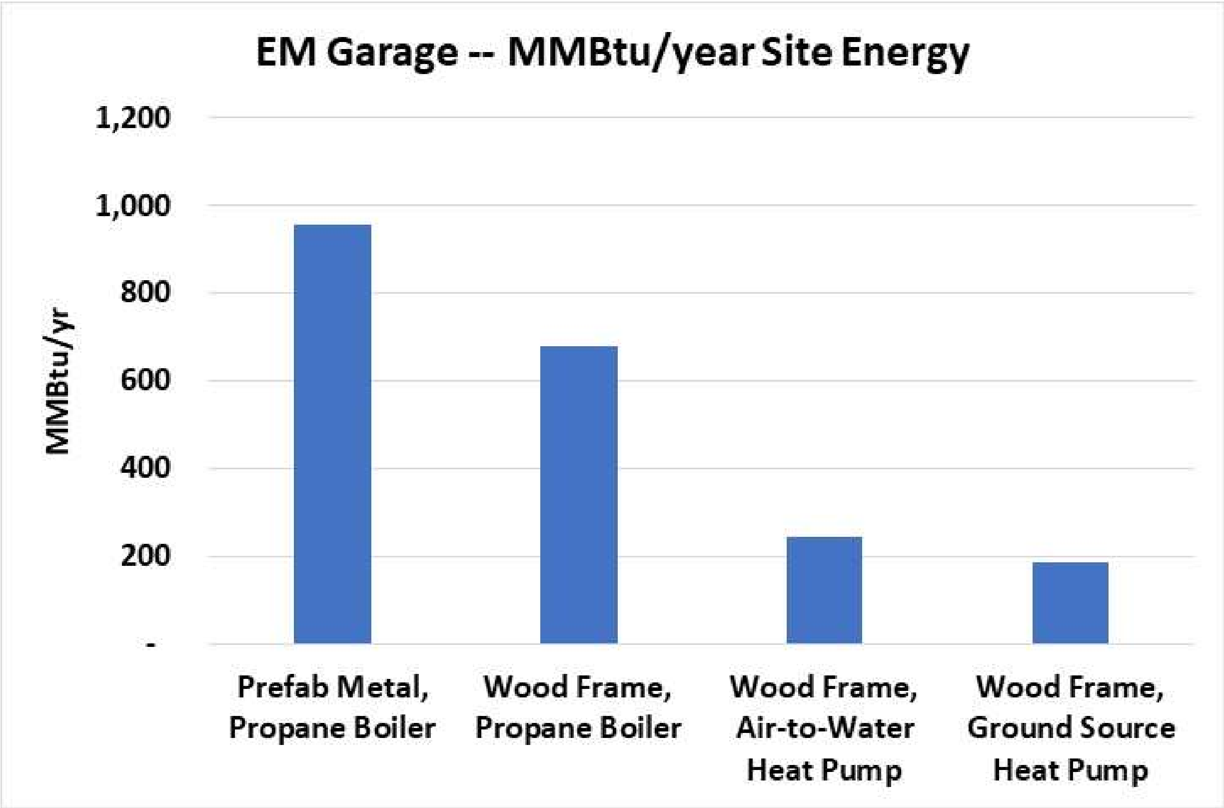


Energy and peak demand by month for whole building

Month	A2W HP	GSHP	A2W HP	GSHP
	Building kWh/month		kW peak/month	
1	13,000	8,000	35	19
2	13,000	8,000	35	19
3	10,000	7,000	35	19
4	5,000	4,000	17	11
5	2,000	2,000	11	8
6	2,000	2,000	9	7
7	1,000	1,000	6	4
8	1,000	1,000	8	6
9	2,000	2,000	13	9
10	4,000	3,000	14	10
11	8,000	6,000	21	13
12	11,000	8,000	32	17
	72,000	52,000		

Operational energy 1st year

Option		Energy Use [4]	
#	Name [2]	Electricity	Propane
		kWh/year	Gal/year
1	Prefab Metal, Propane Boiler	12,000	10,000
2	Wood Frame, Propane Boiler	11,000	7,000
3	Wood Frame, Air-to-Water Heat Pump	71,000	-
4	Wood Frame, Ground Source Heat Pump	54,000	-



Operational energy -- Uncertainty in Modeling

- EV chargers (not included in building analysis)
- Future equipment chargers
- Open 10X14 overhead doors
- Cold, iced trucks
- Infiltration rate over time

Energy cost by month for whole building

					No Demand Limit, no resistance heating		Demand limited, no resistance heating, at	
Month	A2W HP	GSHP	A2W HP	GSHP	A2W HP	GSHP	A2W HP	GSHP
	Building kWh/month		kW peak/month		Cost/month		Cost/month	
1	13,000	8,000	35	19	$ 2,600	$ 1,500	$ 2,600	$ 1,500
2	13,000	8,000	35	19	$ 2,600	$ 1,500	$ 2,600	$ 1,500
3	10,000	7,000	35	19	$ 2,200	$ 1,400	$ 2,200	$ 1,400
4	5,000	4,000	17	11	$ 1,500	$ 1,000	$ 1,100	$ 800
5	2,000	2,000	11	8	$ 1,100	$ 700	$ 700	$ 500
6	2,000	2,000	9	7	$ 1,100	$ 700	$ 700	$ 500
7	1,000	1,000	6	4	$ 900	$ 600	$ 500	$ 400
8	1,000	1,000	8	6	$ 900	$ 600	$ 500	$ 400
9	2,000	2,000	13	9	$ 1,100	$ 700	$ 700	$ 500
10	4,000	3,000	14	10	$ 1,300	$ 800	$ 1,000	$ 700
11	8,000	6,000	21	13	$ 1,900	$ 1,300	$ 1,600	$ 1,100
12	11,000	8,000	32	17	$ 2,300	$ 1,500	$ 2,300	$ 1,500
	72,000	52,000			**$ 19,500**	**$ 12,300**	**$ 16,500**	**$ 10,800**

Energy cost by month for whole building

					No Demand Limit, no resistance heating		Demand limited, no resistance heating, at			
Month	A2W HP	GSHP	A2W HP	GSHP	A2W HP	GSHP	A2W HP	GSHP	A2W HP	GSHP
	Building kWh/month		kW peak/month		Cost/month		Cost/month		Demand charges *only*	
1	13,000	8,000	35	19	$ 2,600	$ 1,500	$ 2,600	$ 1,500	$ 731	$ 391
2	13,000	8,000	35	19	$ 2,600	$ 1,500	$ 2,600	$ 1,500	$ 739	$ 391
3	10,000	7,000	35	19	$ 2,200	$ 1,400	$ 2,200	$ 1,400	$ 738	$ 391
4	5,000	4,000	17	11	$ 1,500	$ 1,000	$ 1,100	$ 800	$ 370	$ 235
5	2,000	2,000	11	8	$ 1,100	$ 700	$ 700	$ 500	$ 370	$ 196
6	2,000	2,000	9	7	$ 1,100	$ 700	$ 700	$ 500	$ 370	$ 196
7	1,000	1,000	6	4	$ 900	$ 600	$ 500	$ 400	$ 370	$ 196
8	1,000	1,000	8	6	$ 900	$ 600	$ 500	$ 400	$ 370	$ 196
9	2,000	2,000	13	9	$ 1,100	$ 700	$ 700	$ 500	$ 370	$ 196
10	4,000	3,000	14	10	$ 1,300	$ 800	$ 1,000	$ 700	$ 370	$ 209
11	8,000	6,000	21	13	$ 1,900	$ 1,300	$ 1,600	$ 1,100	$ 443	$ 271
12	11,000	8,000	32	17	$ 2,300	$ 1,500	$ 2,300	$ 1,500	$ 682	$ 362
	72,000	52,000			**$ 19,500**	**$ 12,300**	**$ 16,500**	**$ 10,800**	**$ 5,900**	**$ 3,200**

Match complexity of systems to owner's ability to manage it!

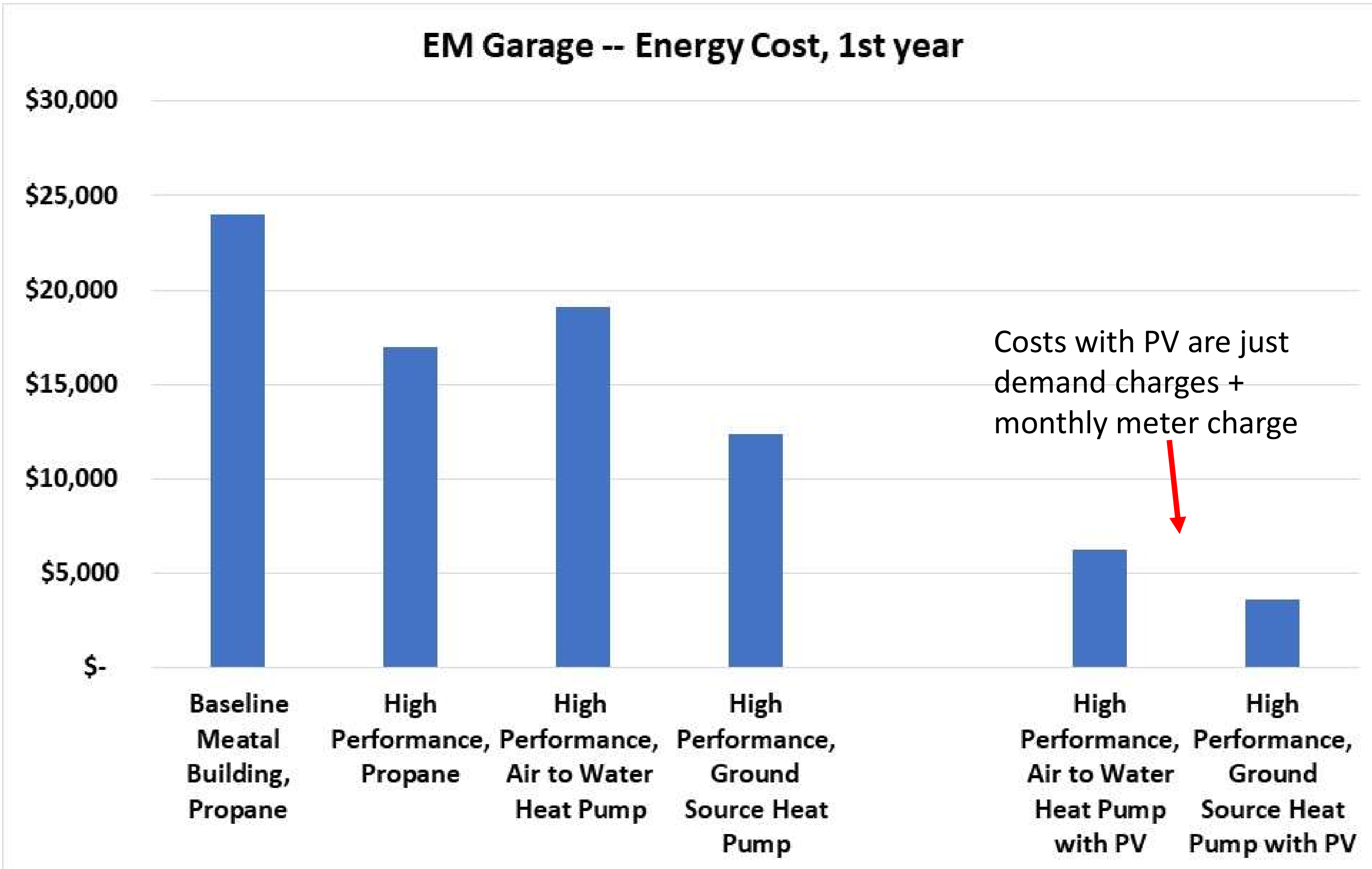
Gory details of WEC electricity rates

WEC Large Power Rate		
$	21.00	Demand Charge per kW/month
$	0.14	Per kWh
$	35.87	monthly charge
WEC Small Commercial Rate		
$	0.23	Per kWh
$	29.89	monthly charge
$	0.14	payment/kWh exported
$	0.12	lifetime cost/kWh for PV electricity [5]
Fuel Costs		
$	400	$/ton pellets
$	2.00	$/gallon propane

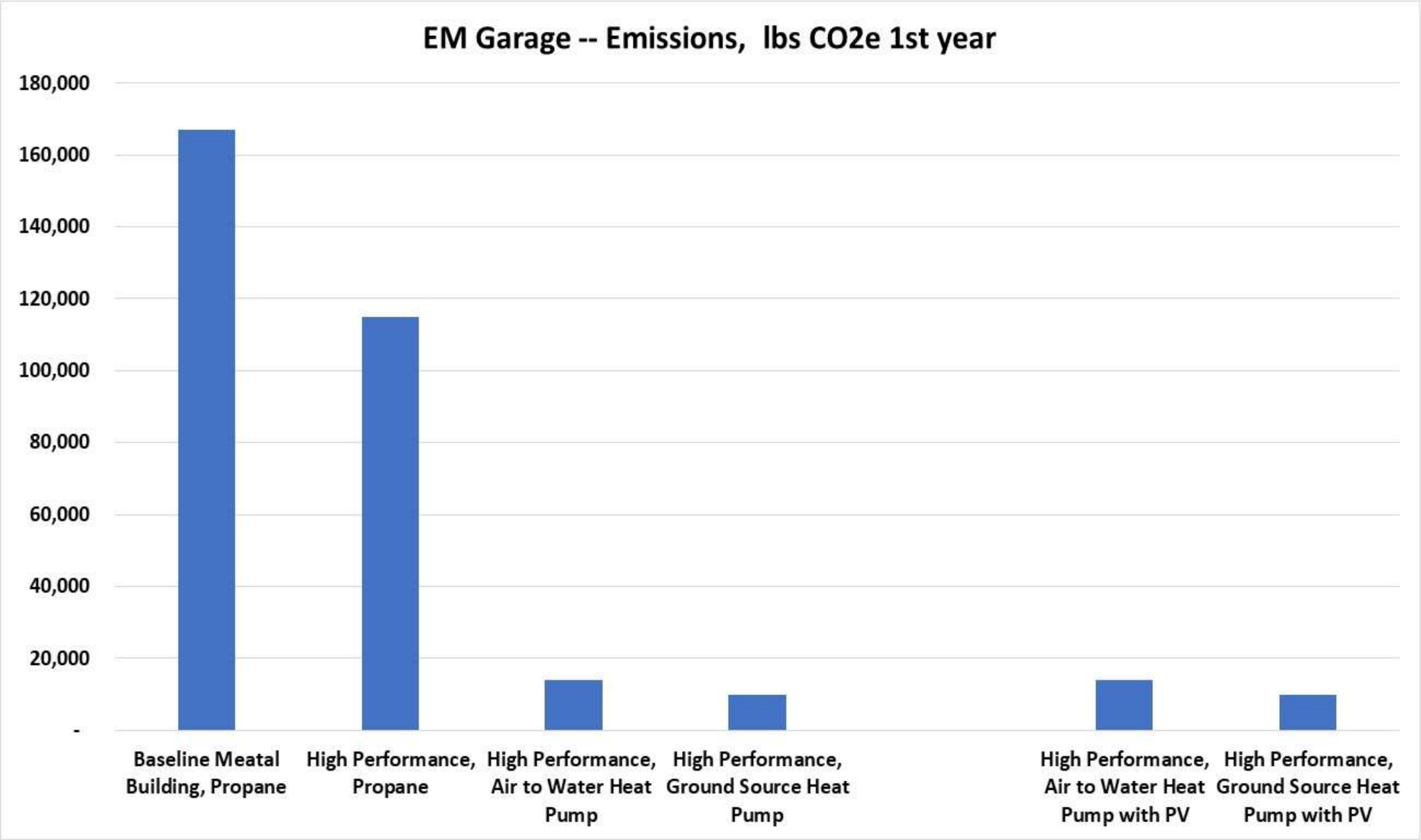
Note that demand charges are ratcheted at 50%

[5] At $2.50/Wp-DC installed cost, 30 yr life, 0.5% degradation in output peryear

Energy cost


EM Garage -- Energy Cost, 1st year
$30,000
$25,000
$20,000
$15,000
$10,000
$5,000
$-
Costs with PV are just demand charges + monthly meter charge
Baseline Meatal Building, Propane
High Performance, Propane
High Performance, Air to Water Heat Pump
High Performance, Ground Source Heat Pump
High Performance, Air to Water Heat Pump with PV
High Performance, Ground Source Heat Pump with PV

Energy emissions*



** combustion emissions * site/source factor + precombustion emissions + combustion emission*

Basis of energy emissions

CO2e emissions per unit of fuel			
	total lbs CO2e/unit [2]		
Propane	16	lbs/gallon	
Electricity	0.9	ISO NE	*Includes methane leakage*
Electricity	0.2	WEC [4]	
Electricity, PV	0.11	from PV [3]	

[2] combustion emissions * site/source factor + precombustion emissions + combustion emission -- Note that this is at the building meter. This value does not include combustion or heat pump efficiencies or distribution efficiency within the building

[3] includes energy to produce and install PV system

[4] estimated value based on WEC selling class 1 RECs and buying RECs frome existing old hydro, and landfill embodied emissions

Construction costs

Option		Construction Cost [3]	
#	Name [2]	Without Soft Costs	**With soft costs**
1	Prefab Metal, Propane Boiler	$ 3,910,000	**$ 4,720,000**
2	Wood Frame, Propane Boiler	$ 4,050,000	**$ 4,860,000**
3	Wood Frame, Air-to-Water Heat Pump	$ 4,040,000	**$ 4,850,000**
4	Wood Frame, Ground Source Heat Pump	$ 4,350,000	**$ 5,160,000**

$4,654,000
as of 37/25

30 yr life cycle cost analysis

BLCC 5.3-24 -- Building Life-Cycle Cost software from
Applied Economics Office, Engineering Laboratory, National Institute of Standards and Technology

- Discount (3%) and Escalation Rates (2.3%) are NOMINAL (inclusive of general inflation)
- Replacement costs included for HPs (20 years), circulators (15 years) boilers (20 years), controls (20 years), HP compressor repair and boiler repair (10 years)
- Annual repair and maintenance costs, based on similar systems
- Run for 30 years -- 50 year life for wells and piping, etc., so residual value at end
- Residual building value at 30 years is estimated at 75% of initial construction cost.

Run by Dan Dupras, PE, Engineering Services of Vermont

30 yr life cycle cost analysis

Option		Life Cycle
		Operating Cost [5]
		$$$
1	Prefab Metal, Propane Boiler	$ 2,955,000
2	Wood Frame, Propane Boiler	$ 2,916,000
3	Wood Frame, Air-to-Water Heat Pump	$ 2,953,000
4	Wood Frame, Ground Source Heat Pump	$ 2,923,000

[5] Not including incentives, not including enclosure maintenance

Note that these costs are all very close to the same -- within the margins of error!

Probably gone Federal Incentives:

- $244,000 for ground source system
- $48,000 for Air-to-water HP
- $37,500 for smaller 50 kW array
- Feds make direct payment to Town.

Efficiency VT incentives not included

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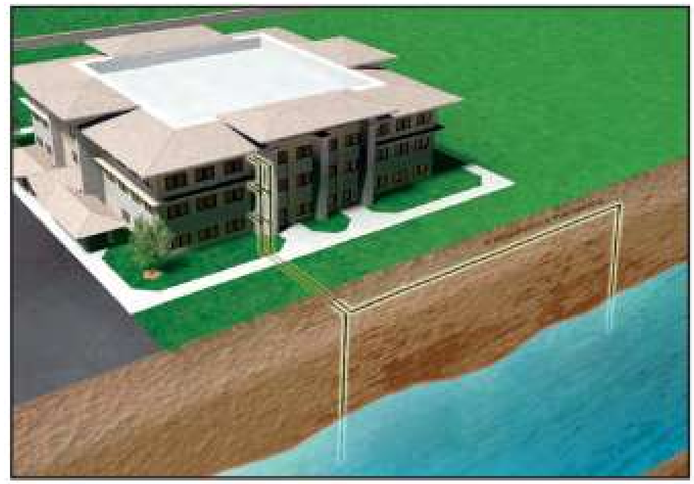
Efficiency VT incentives not included

Selected system:
Ground Source Heat Pump System

Closed loop, boreholes

Open loop, "pump and dump"



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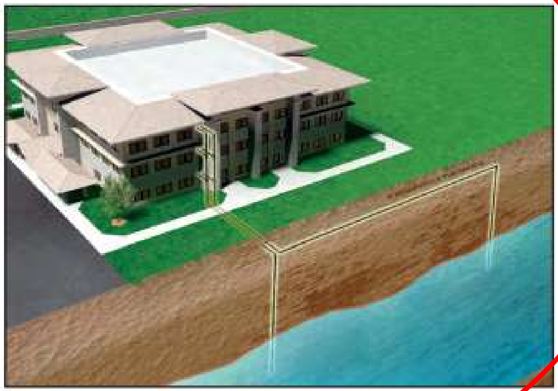
Ground Source Heat Pump System

Closed loop, boreholes

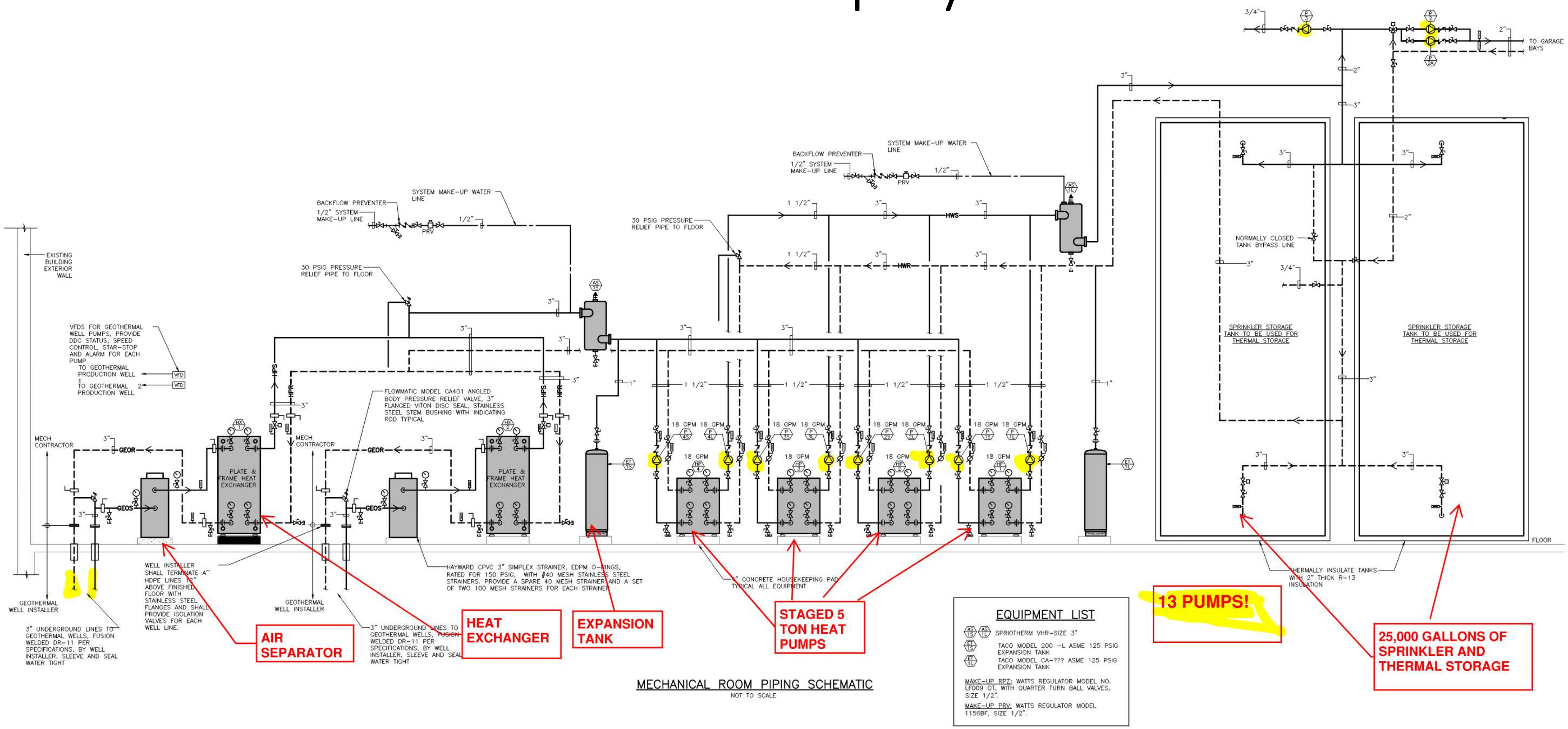
Open loop, "pump and dump"



Drilled test well with hydro-geologist advice and found 90 gallons per minute. Open loop!

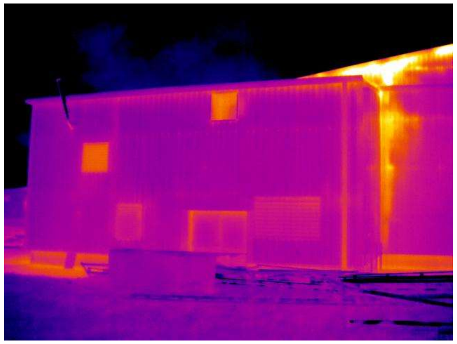
	HP only COP	Total COP	
GSHP, open loop	4.9	3.9	Constant over years
GSHP closed loop	4.2	3.6	COP decreases as earth cools with unbalanced heat/cool loads
A2WHP	2.7	2.6	Constant over years

Ground Source Heat Pump System



Commissioning

Cx Associates and A. Shapiro detailed review of MEP and Enclosure



Two formal reviews:

- Design Development
- Construction Document stage

Cx Associates on-site inspection and testing

- MEP systems
- Enclosure – inspection, “first instance” testing with fog, IR and blower door; final compliance testing (0.05 cfm50/sq.f.t. shell 6 sides)

Lessons learned

- Prepare for peak demand early!
  - Don’t forget EV chargers
- Bang down pumping loads!
- Handle big wild card loads -- frozen trucks and big open doors – without increasing peak demand
- Value of commissioning

Thank you!