Analysis of Winter Greenhouse Heating Methods in VT

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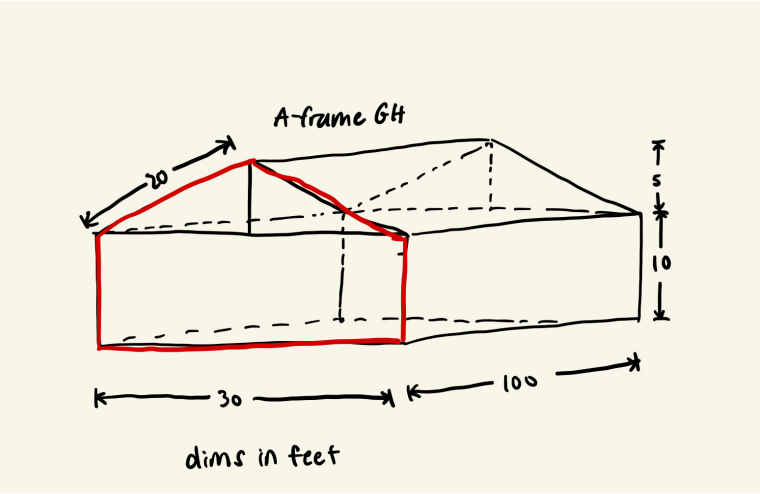
context

- greenhouses used to extend growing season
- heating fuels used by VT growers:
  - electricity, propane, biomass (corn, wood, grass, fryolator oil, biodiesel)



model a-frame greenhouse used in following analysis

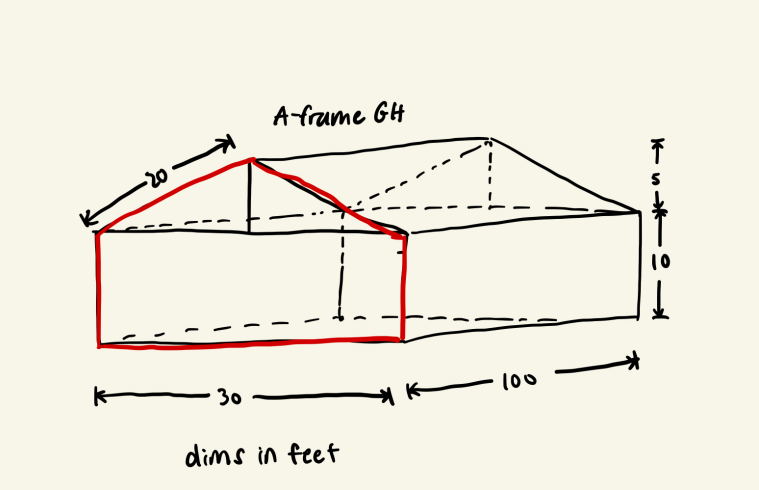

growing kale in winter. Source: Vermont Public

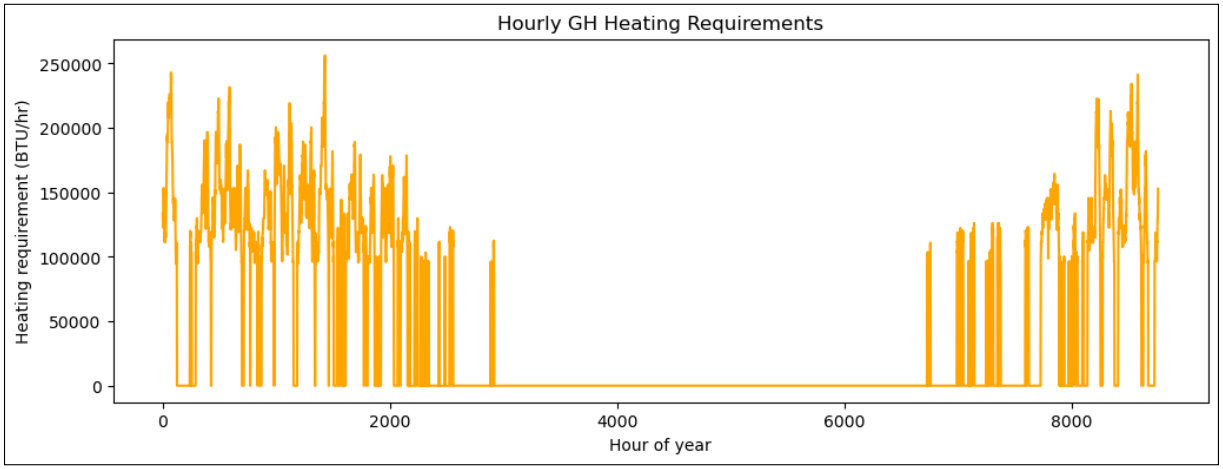
problem statement

- heating in winter months required to maintain minimum temp inside (60F for greens)
- simplified heat-on condition: turn on heat when outside temp is below threshold, neglect daytime solar gain
- goal: to compare energy demands and costs of electric, LP, biomass

hot water distrubution manifold for a hydronic heating system
source: UVM Extension

the case





- double polycarbonate sheet cover (u = .55 Btu/hr sqft °F)
- surface area of poly cover = 6750 sqft
- estimated heating requirement Q = 374 million BTU in a year
  - assume: min temp 60F inside, threshold temp 35F outside

- heat demand modeled using 2022 Burlington temperature data

greenhouses in winter
Source: Vine Ripe Greenhouse Construction

analysis

Reznor UEZ gas-fired heater
Source: Rimol Greenhouses

modeled for year 2022:
- output 374 million BTU
- capital cost: $7803
- fuel cost ($3.60/gal LP): $16165
- heater on for 2768 hours at full cap.

LB White Volt 9 electric forced air heater
Source: LB White

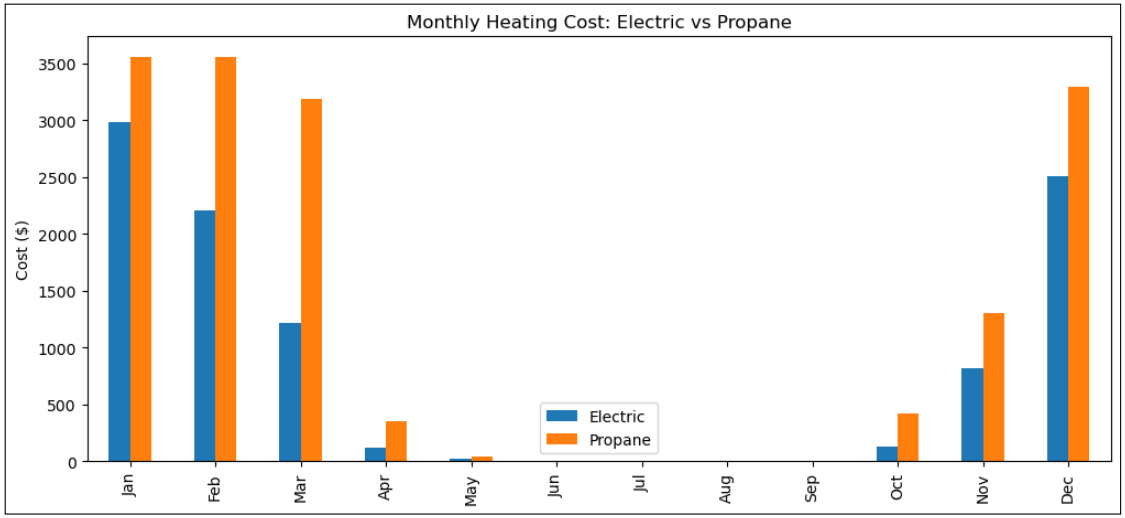
modeled for year 2022:
- output 374 million BTU
- capital cost:
  - ~$3,800 (for 4 units)
- electricity cost:
  - $10,008.12
  - for 93450.1 kWh
- heaters on for
  - 1530 hrs at full cap.
  - 1195 hrs at partial cap.
  - total: 2725 hours

Source: VVBGA
LDJ A-Maize-Ing Heat Biomass Furnace at ICF in Burlington

results based on actual usage in year 2010:
- input 57 million BTU* to heat 2,880 sqft area
- capital cost:
  - $6502 in 2010 dollars
  - $8,725.684 in 2022 dollars
- 1-year fuel cost (wood pellets and corn):
  - $3000 in 2010 dollars
  - $4,026.32 in 2022 dollars

conclusions

- considerations:
  - cost
    - fluctuating fuel costs
  - reliability
  - geography
  - resource availability



using 2022 VT electricity price data and average $3.60/gal LP price in VT 2022

manure/bedding biomass bricks
Source: SARE / Finger Lakes Dexter Creamery

waste vegetable oil biomass, Cate Farm East Montpelier
Source: UVM Extension