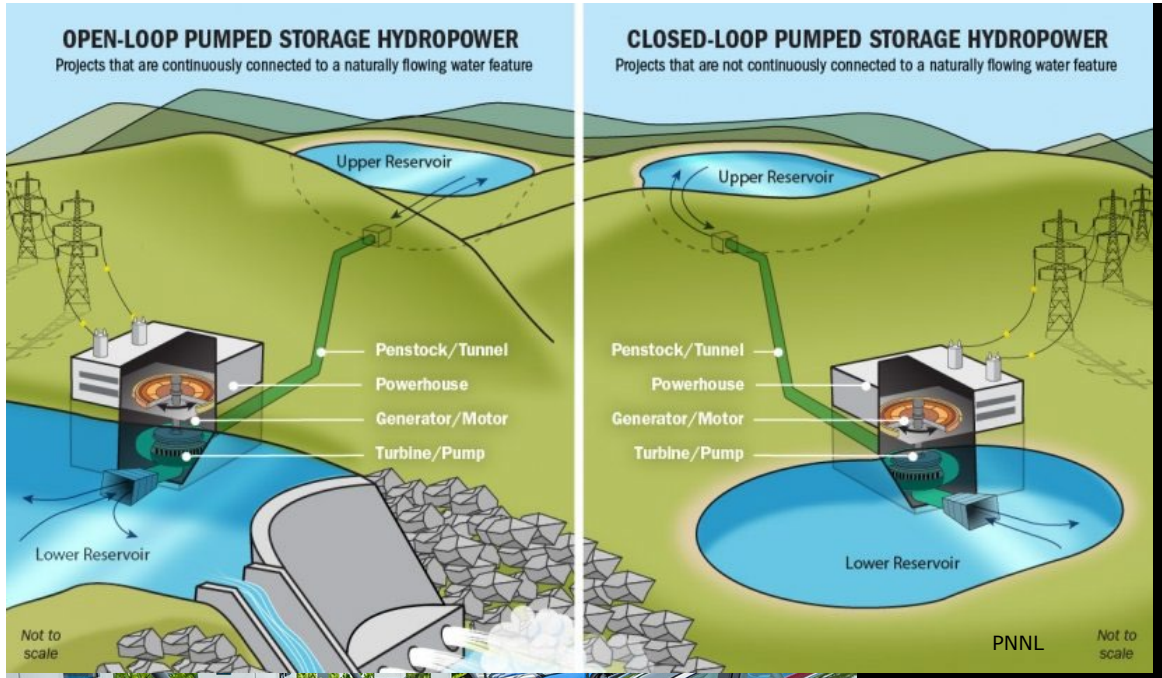

1


OPEN-LOOP PUMPED STORAGE HYDROPOWER
Projects that are continuously connected to a naturally flowing water feature
Upper Reservoir
Penstock/Tunnel
Powerhouse
Generator/Motor
Turbine/Pump
Lower Reservoir
Not to scale
CLOSED-LOOP PUMPED STORAGE HYDROPOWER
Projects that are not continuously connected to a naturally flowing water feature
Upper Reservoir
Penstock/Tunnel
Powerhouse
Generator/Motor
Turbine/Pump
Lower Reservoir
PNNL
Not to scale


Forbes

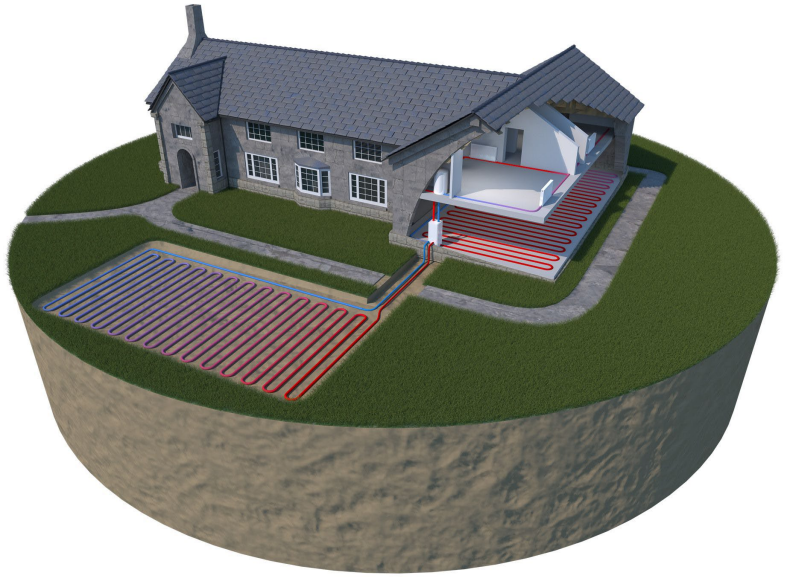

2
TESLA





3



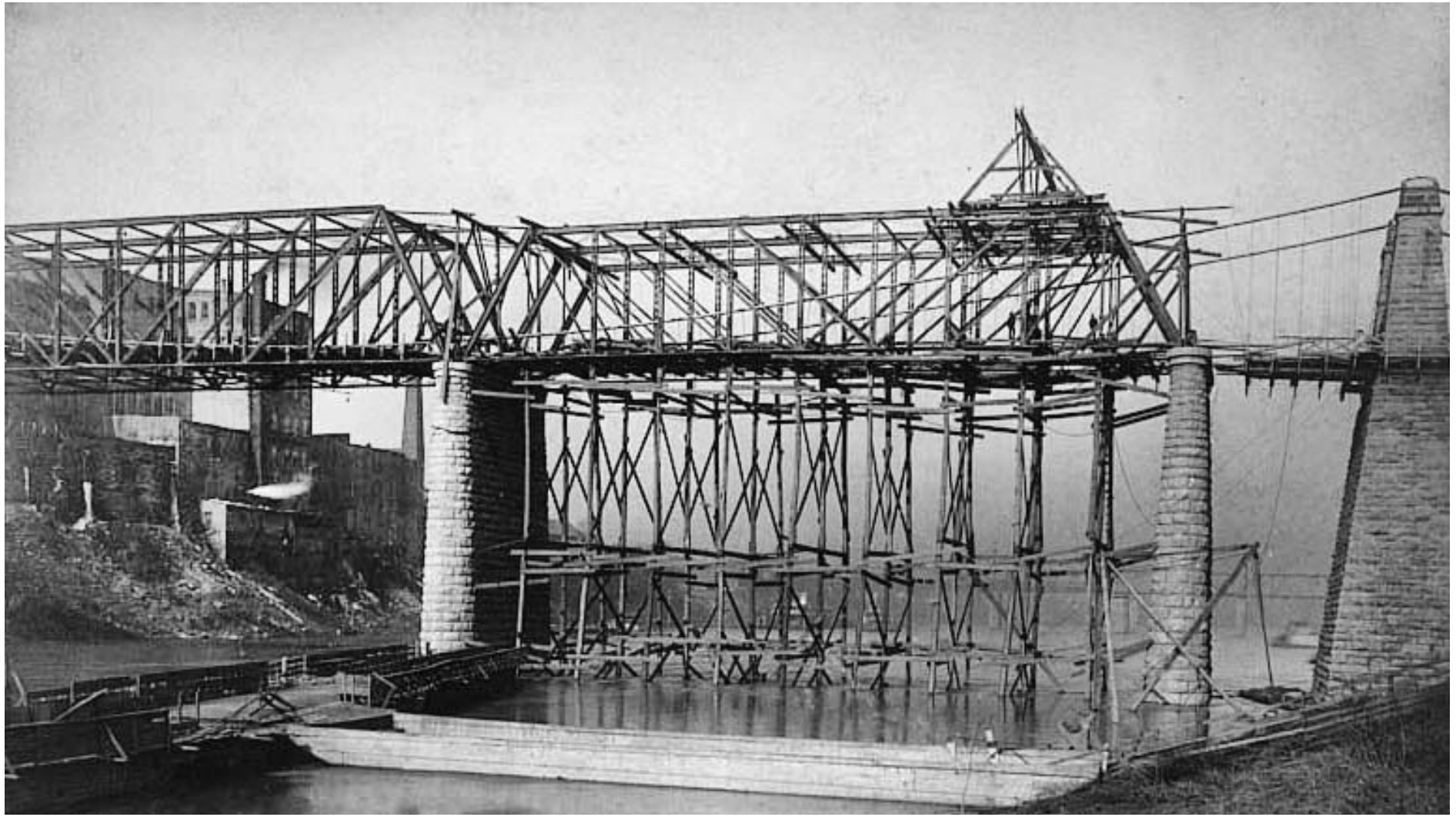




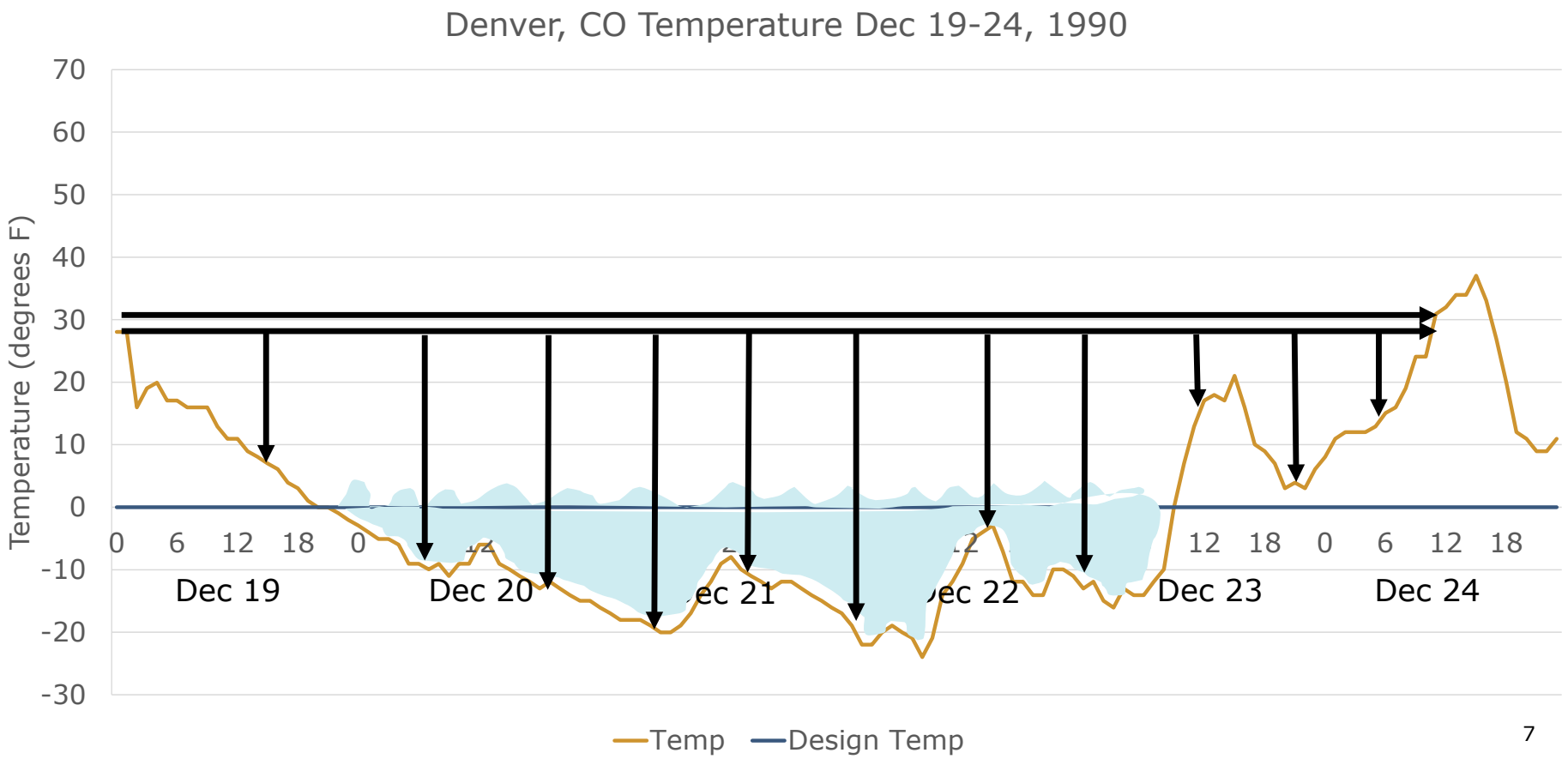

MITSUBISHI
ELECTRIC


SNICE


Heat pumps are almost as awesome as trains – I love 'em!



What does a river of cold look like? In Denver?



Extreme conditions matter –what does your system failure look like?



HOUSTON CHRONICLE

Texas officials add 36 more deaths to February 2021 winter storm, bringing total to 246

Fall of 2014… At ~switch at eTown Hall

APEX ANALYTICS



If Electricity Emissions are 0, Electric Heating Emissions are 0

APEX ANALYTICS

$$E_h = E_e \times (F\,\eta_{hp} + (1 - F)\,\eta_{er})$$

$$E_h = 0 \times (F\,\eta_{hp} + (1 - F)\,\eta_{er})$$

$$E_h = 0$$

Secrets of future decarbonized grid: We will still burn gas to make electricity.

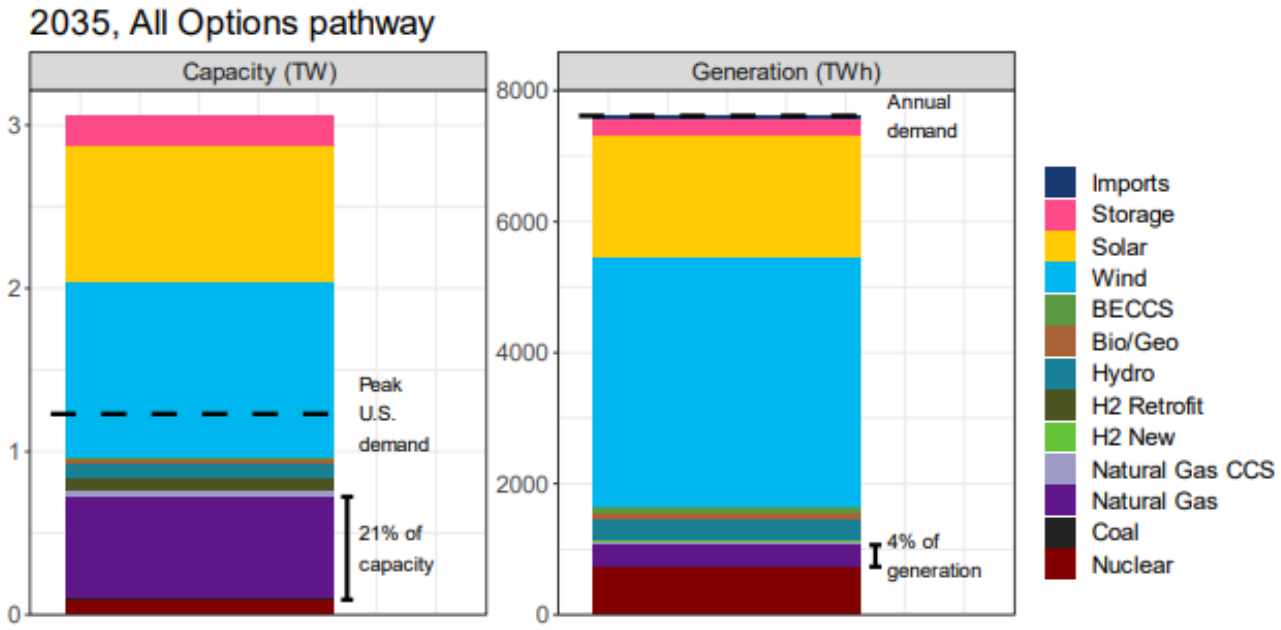
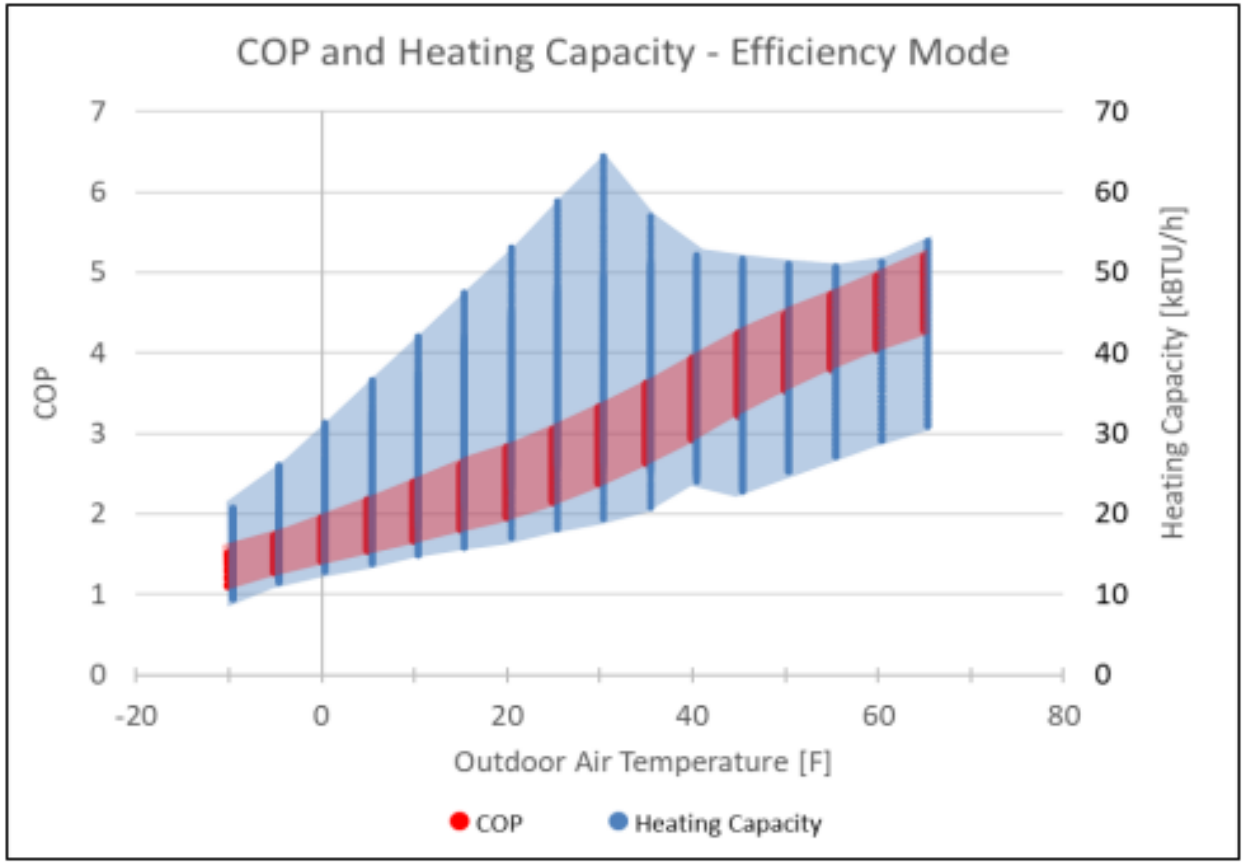


Figure 19. Energy and capacity in the 2035 All Options scenario (ADE demand case) show the significant dependence on remaining fossil-fueled capacity to provide peaking capacity and ensure resource adequacy during the clean energy transition.

Recent NREL study (Denholm et al, 2022) forecasts that the decarbonized grid is likely to still burn natural for the last ~5% of loads.

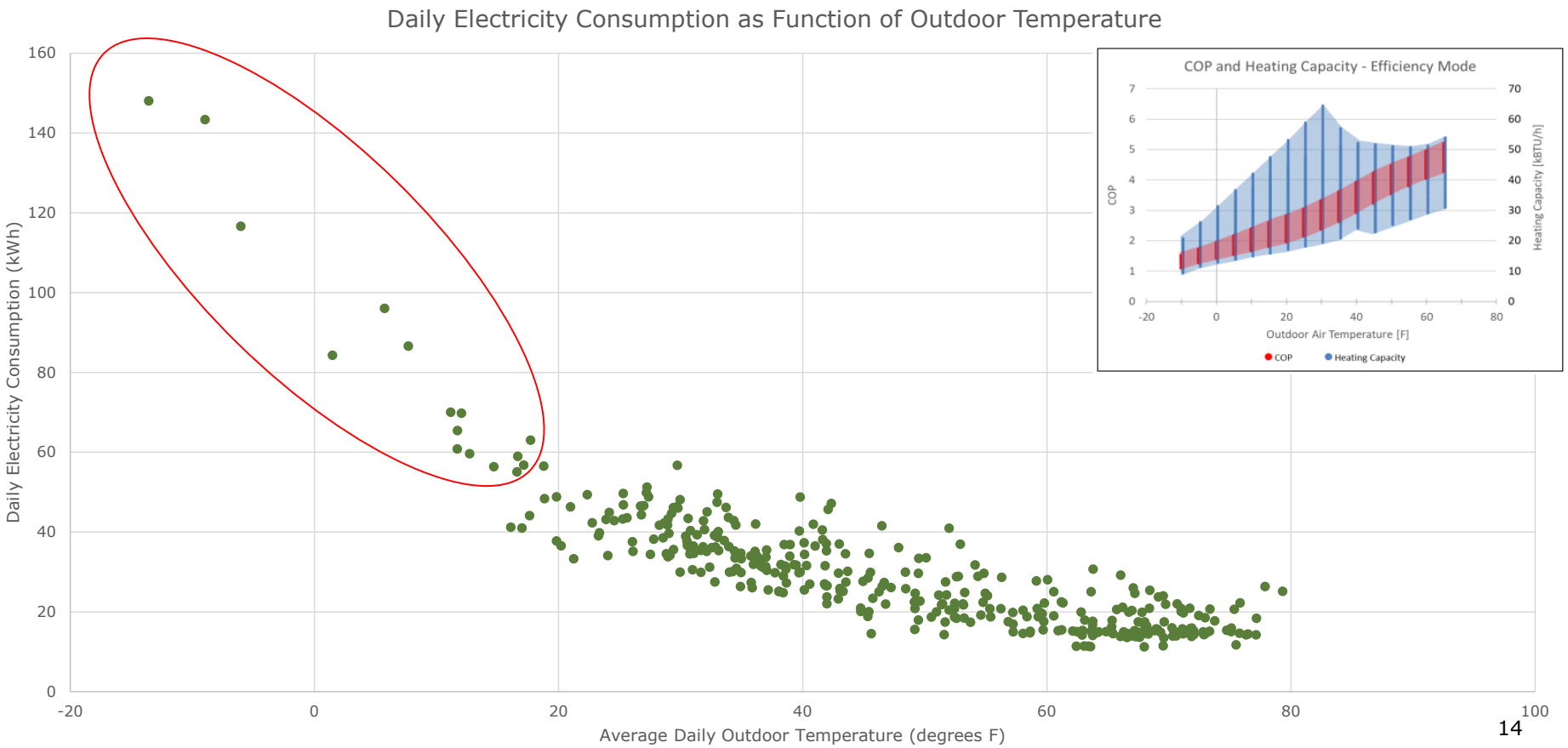

DANGER!
PELIGRO!
NO TRESPASSING
PROHIBIDO ENTRAR

Heat pump efficiency and capacity drops at cold temperatures.



Shoukas et al, 2022

All-electric homes use 7X electricity on coldest days



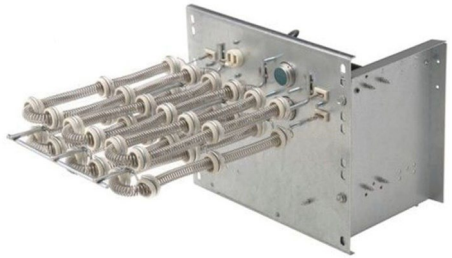


1

VS



TEMPSTAR





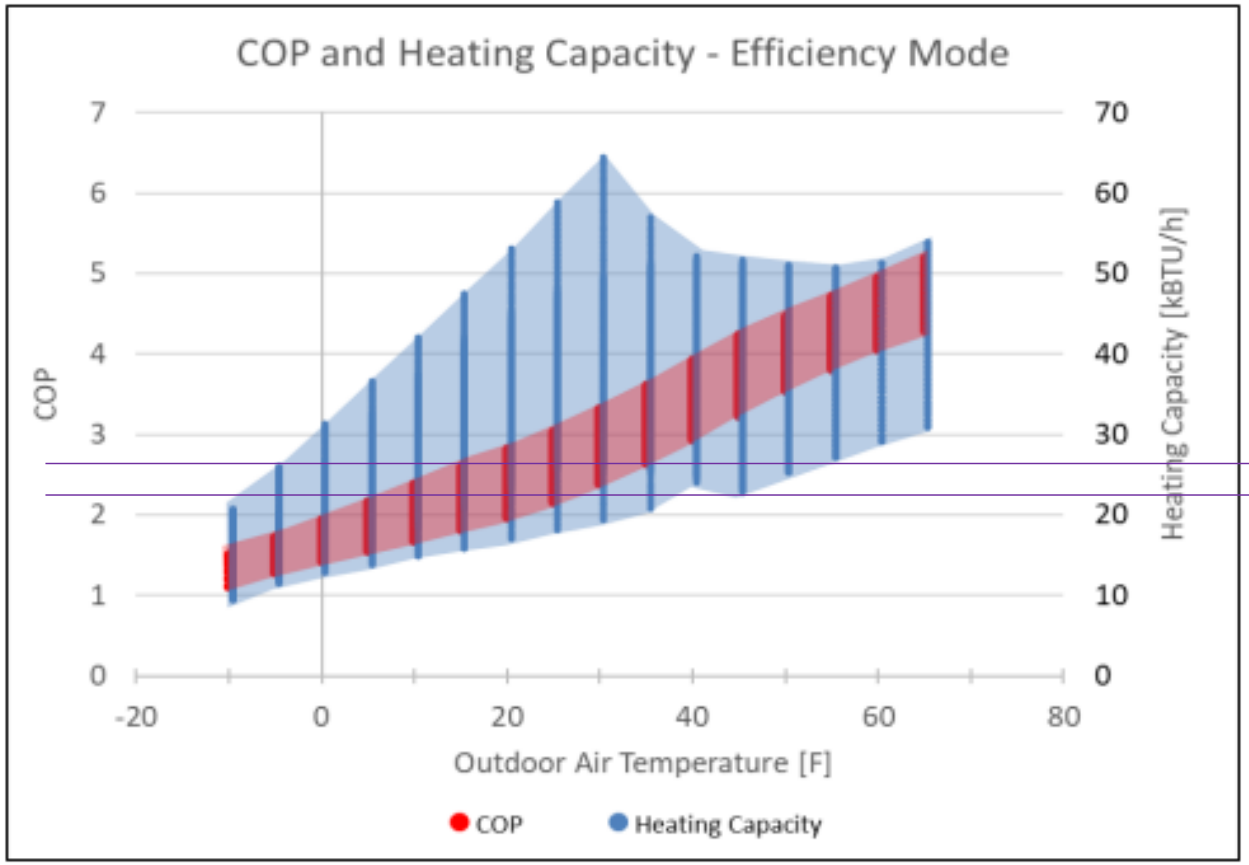
2

VS





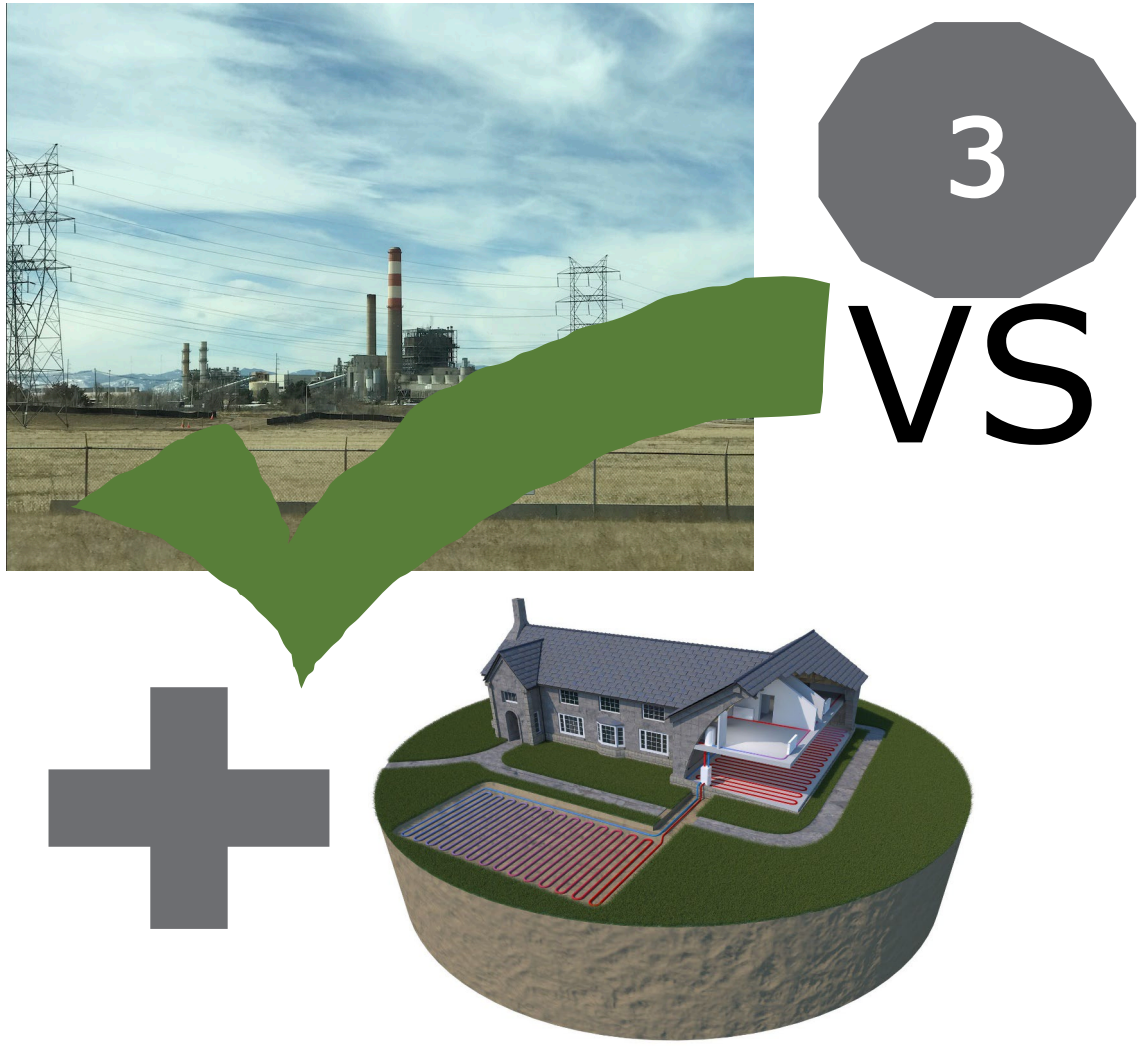
HP Needs 2.25 COP to match standard furnace, 2.67 COP to match HE furnace



HE Furnace

Std Furnace

Shoukas et al, 2022


3
VS





4

VS




MITSUBISHI
ELECTRIC
XV20i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