State of the Art in Supercritical Carbon Dioxide Power Systems

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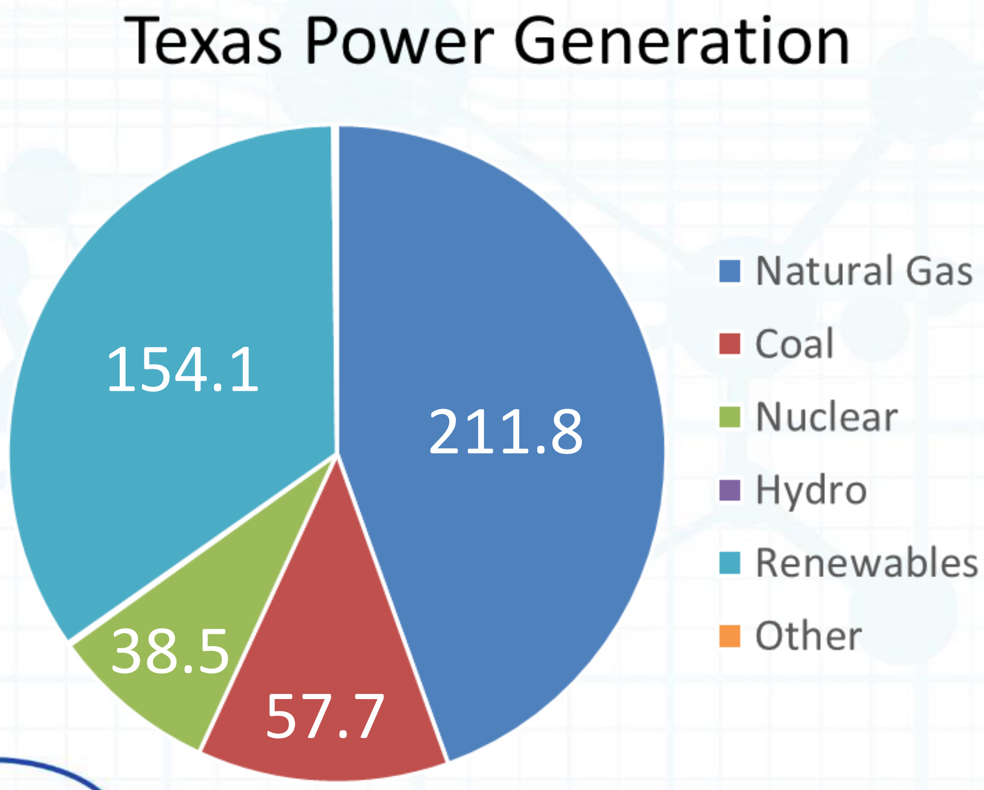
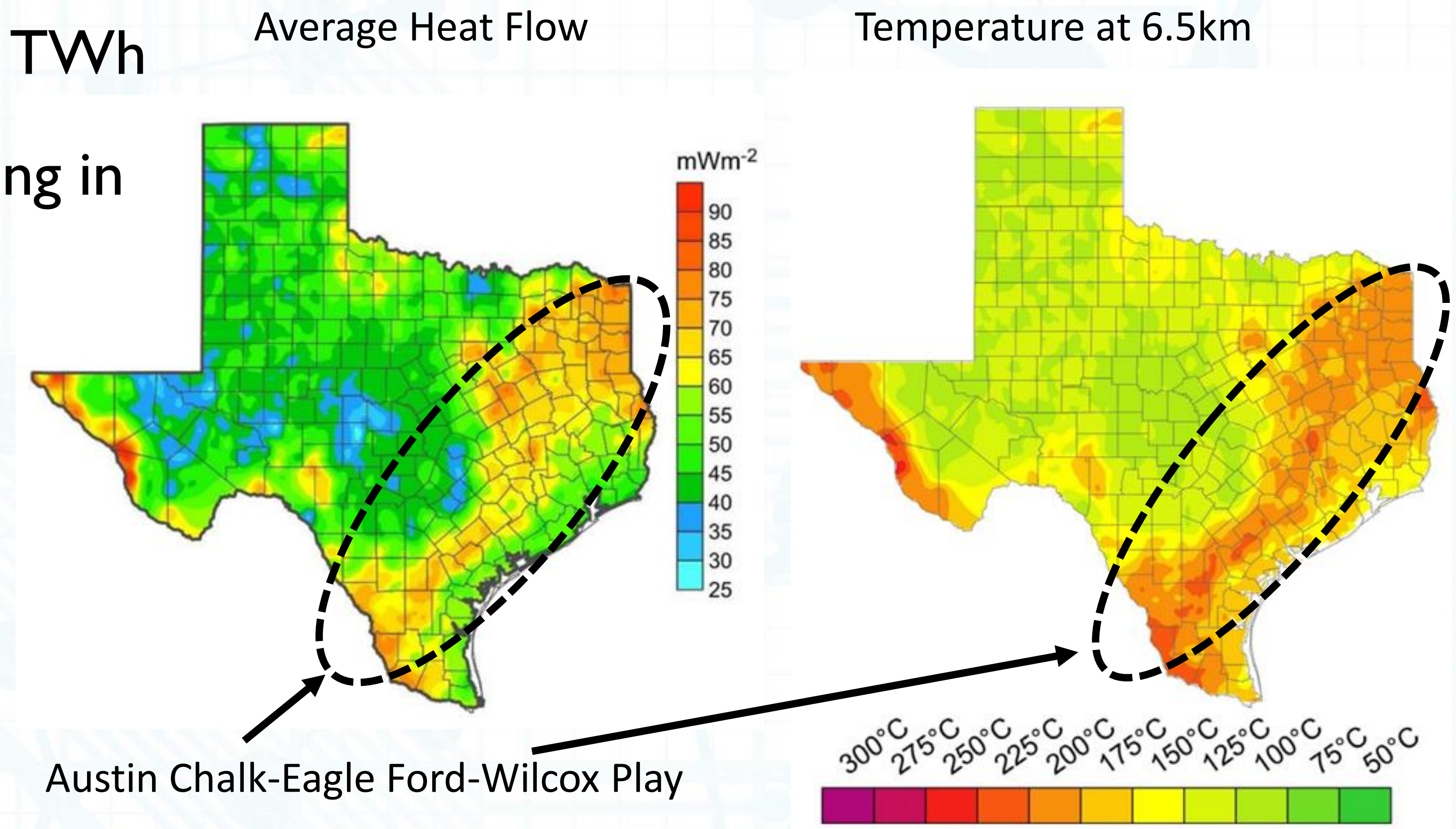
Texas has potential for geothermal power

- Texas is a leader in renewable power generation in the United States with 464 TWh
- No geothermal power plants are operating in Texas





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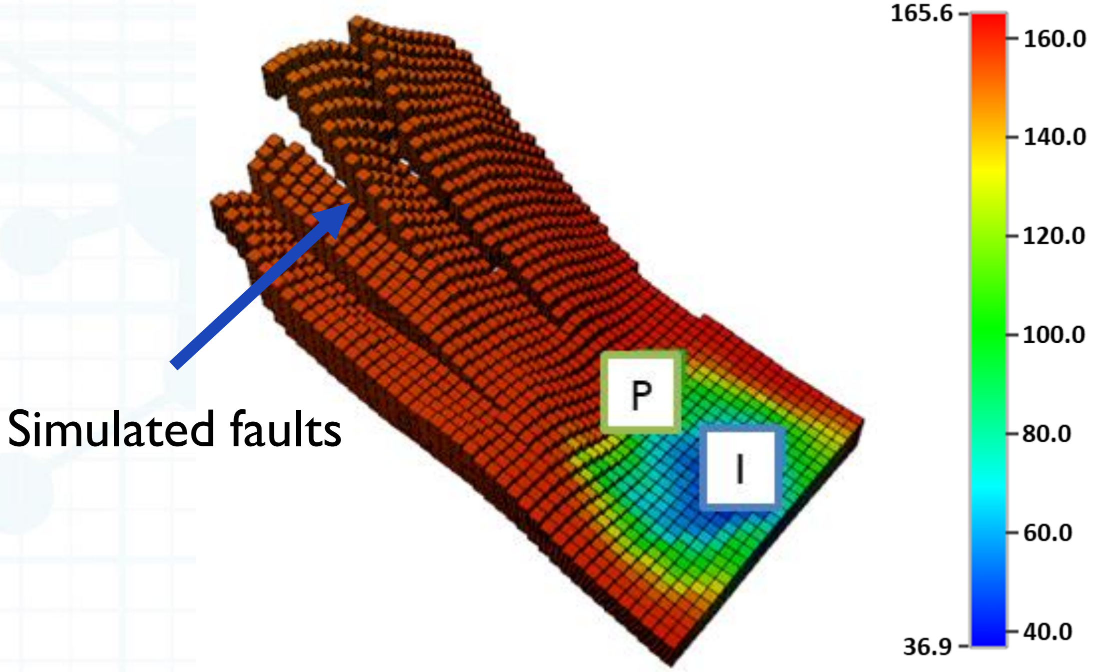
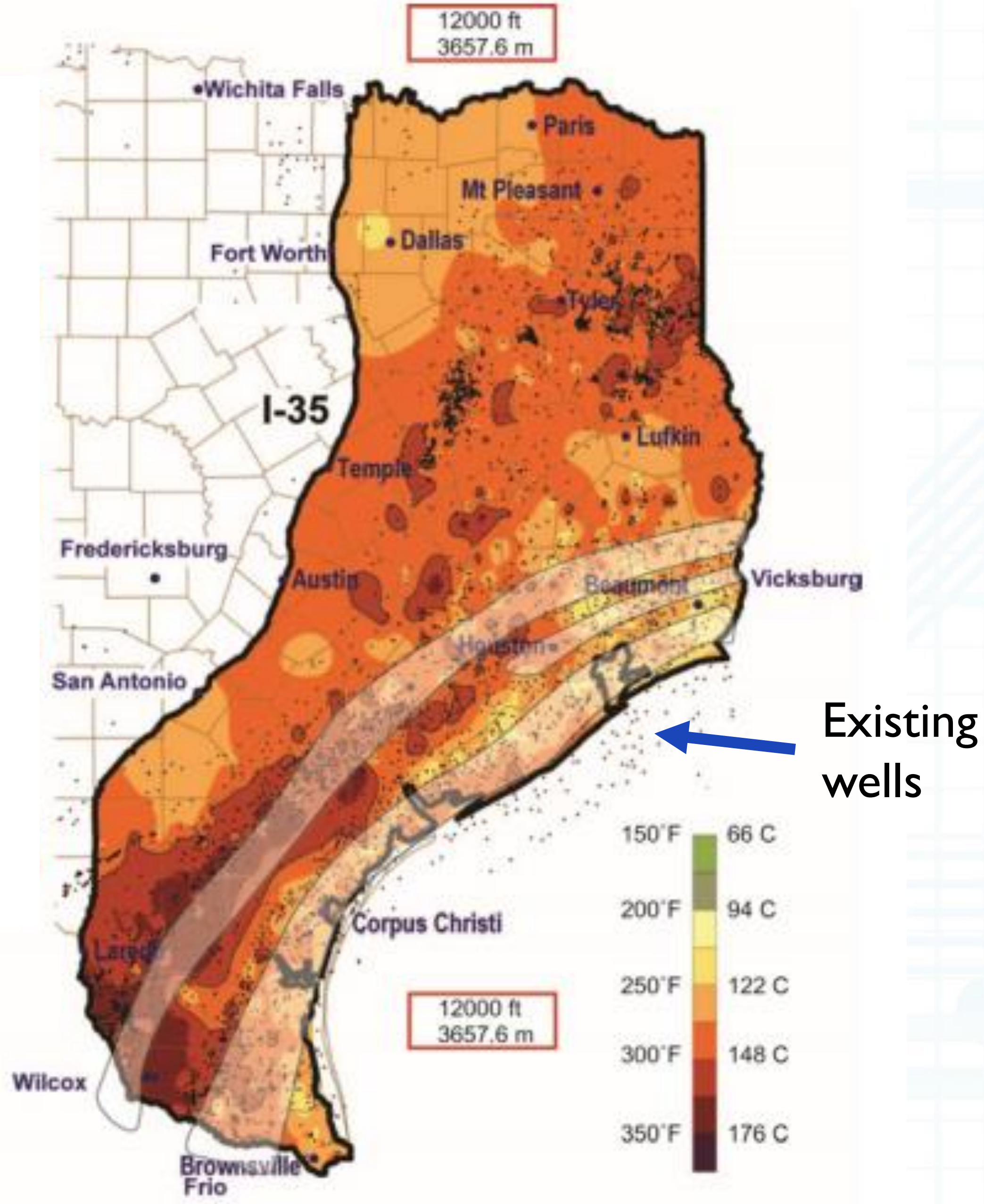
Texas's oil wells overlap with the geothermal resources

Simulated Conditions

- Reservoir size – 2000m x 1000m x 200m
- Average depth – 3km (~10,000 ft)
- Average temperature of reservoir – 160°C
- Reservoir Pressure – 60,000 kPa
- Wellbore inner diameter – 0.13m (5 in)
- Porosity – 22%
- Permeability – 25 mD
- Salinity – 60,000 ppm





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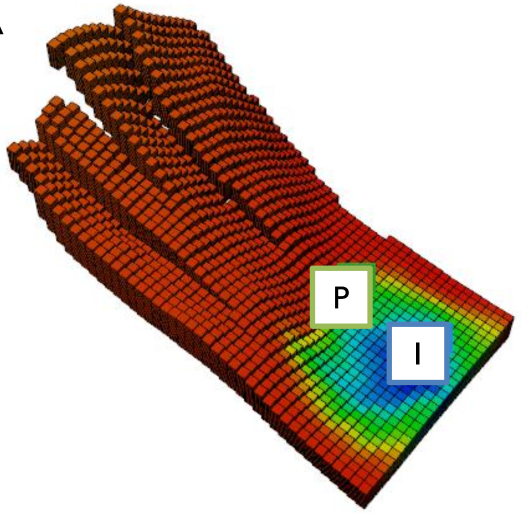
Four Configurations Investigated

Case A

Both wells near peak temperatures

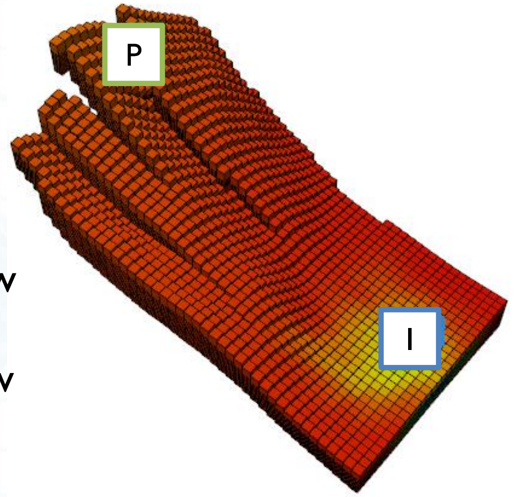
- High initial temperature
- High initial flow rates
- Quickly declines over time



Case B

Producer at top and injector at bottom of reservoir

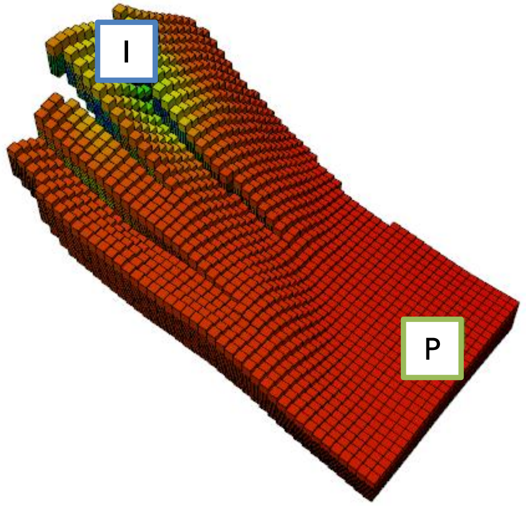
- Lower temperatures with steady output over time
- Wells farther away reduces flow rate
- Slight decline over time for flow rate



Case C

Producer at bottom and injector at top of reservoir

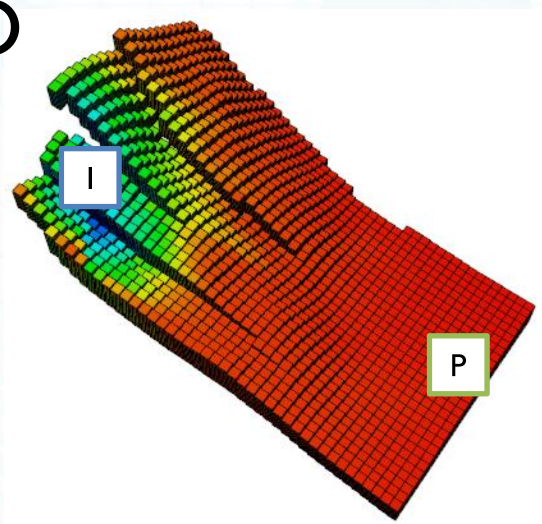
- High temperatures
- Low flow rates
- Slight decline over time both flow rate and temperature

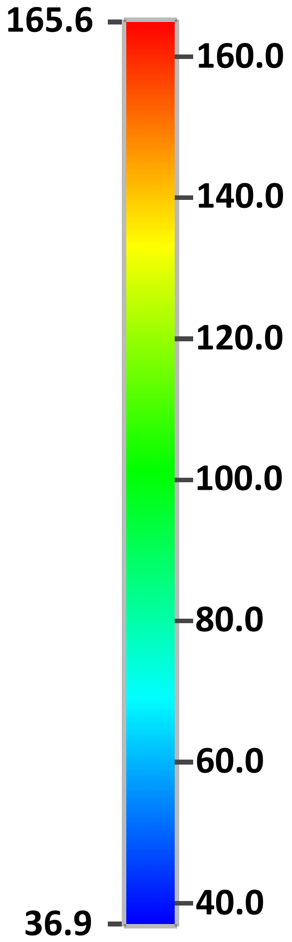


Case D

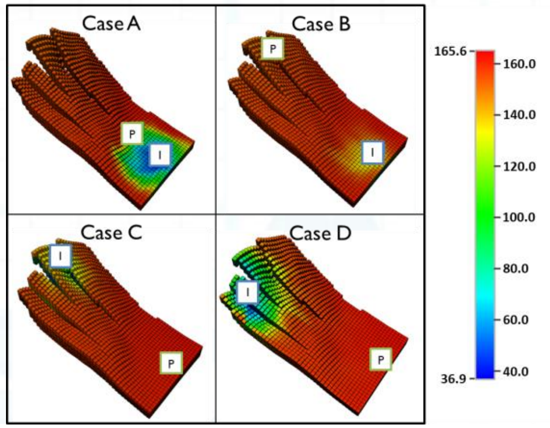
Injector moved to lower fault line

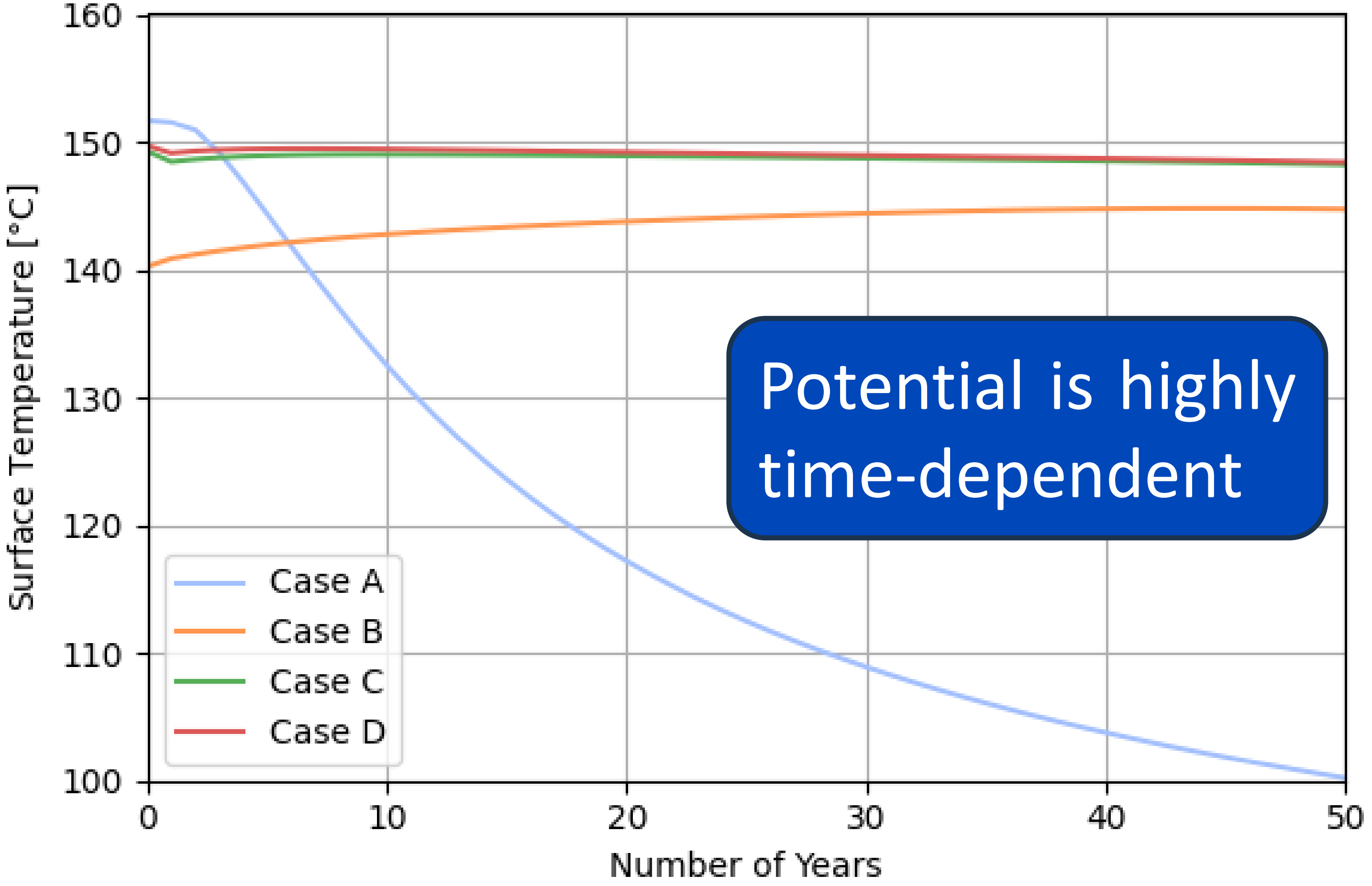
- High temperatures
- Low flow rates
- Slight decline over time both flow rate and temperature

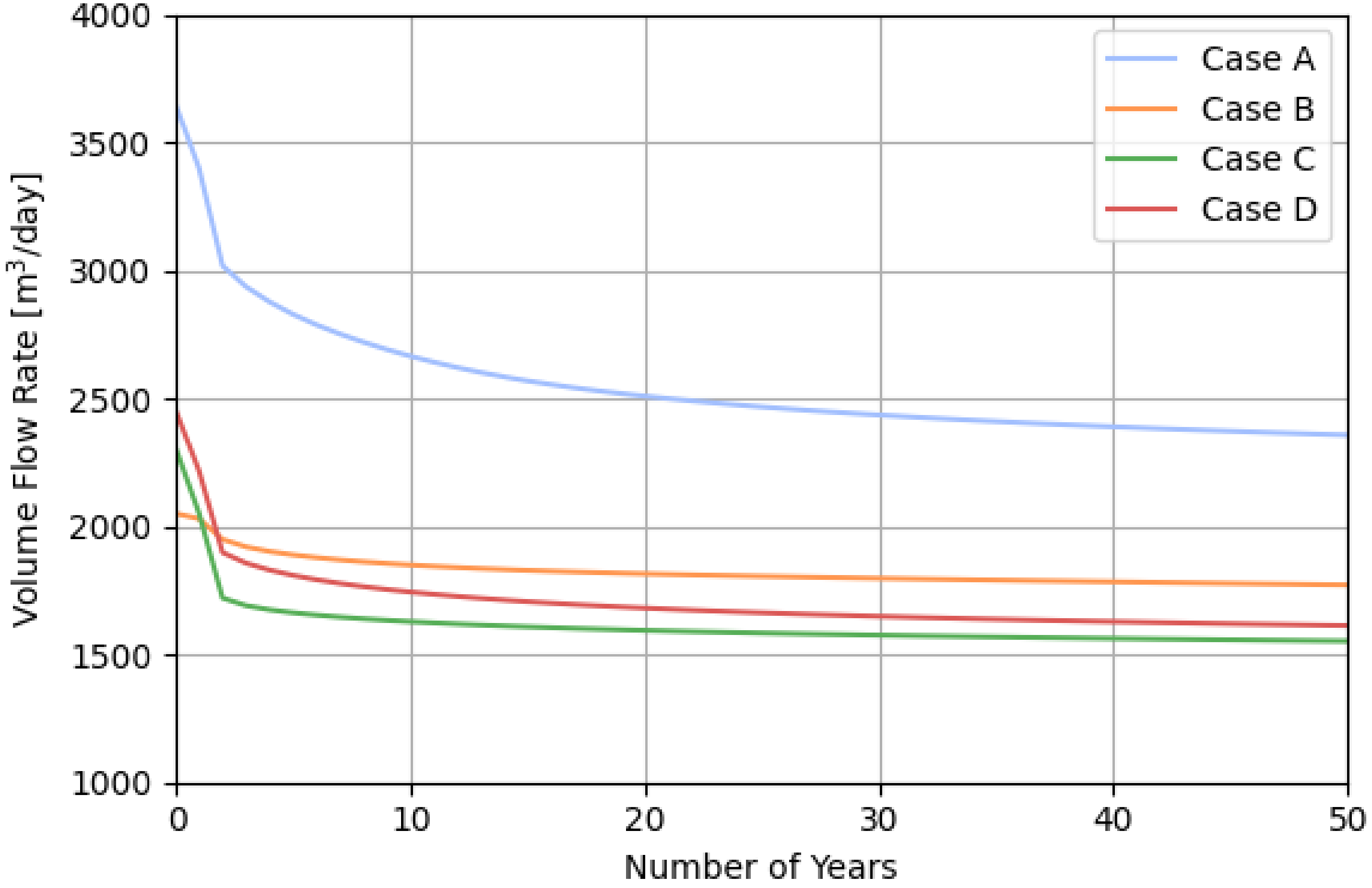




Case A has highest initial potential but falls off extremely fast in temperature and flow



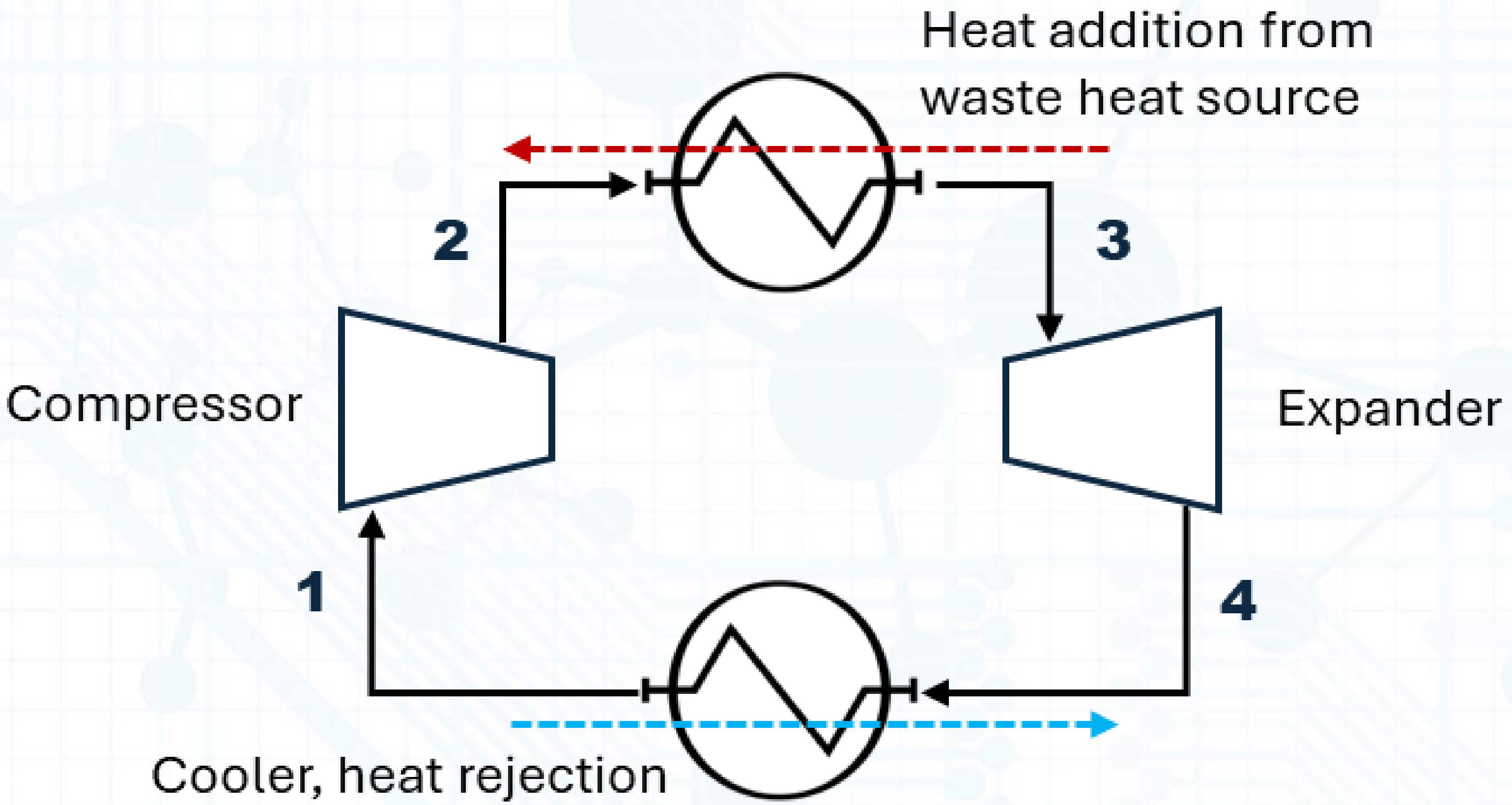




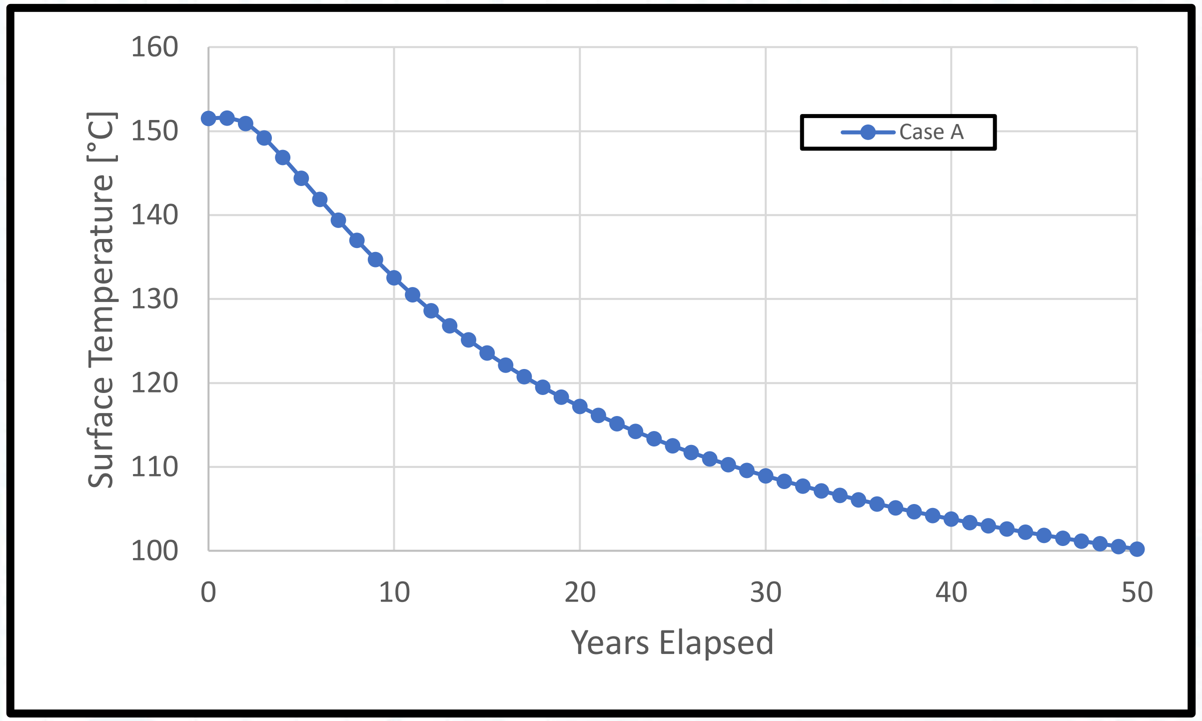
A simple cycle configuration for the low turbine inlet temperatures

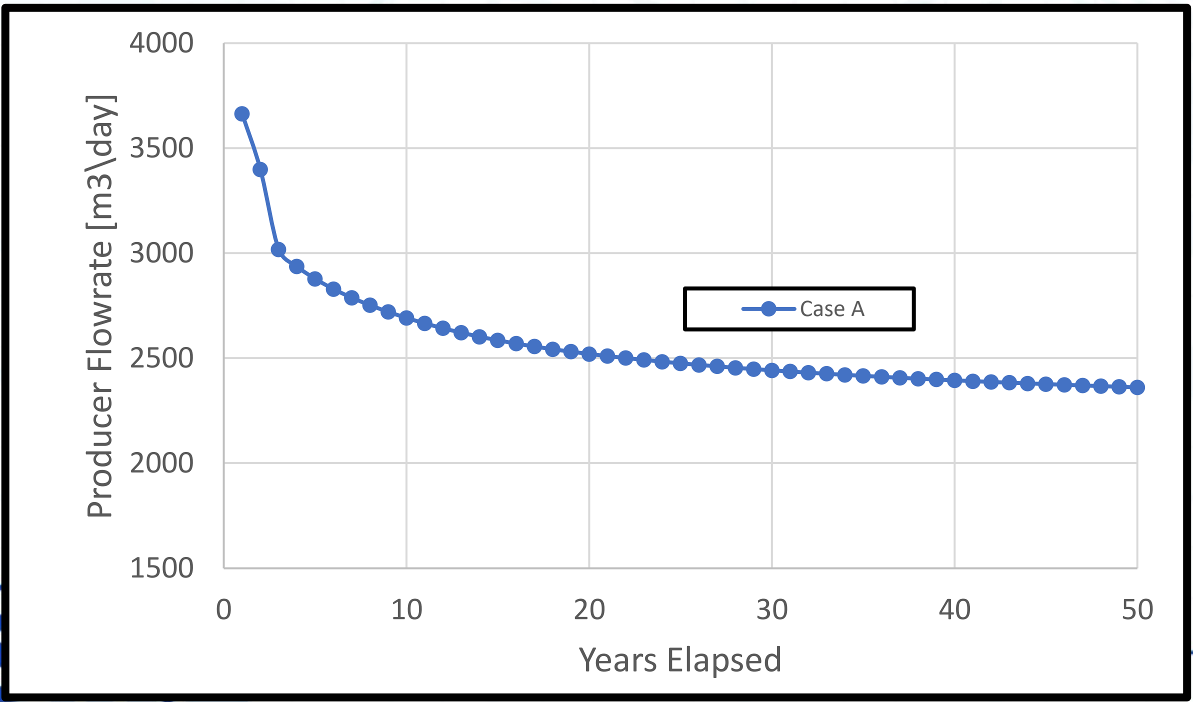
Parameter	Value
Pump/Compressor Isentropic Efficiency	85%
Heat Exchanger Approach Temperature	10°C
Pump / Compressor Inlet Temperature	35°C
Capacity Factor	90%

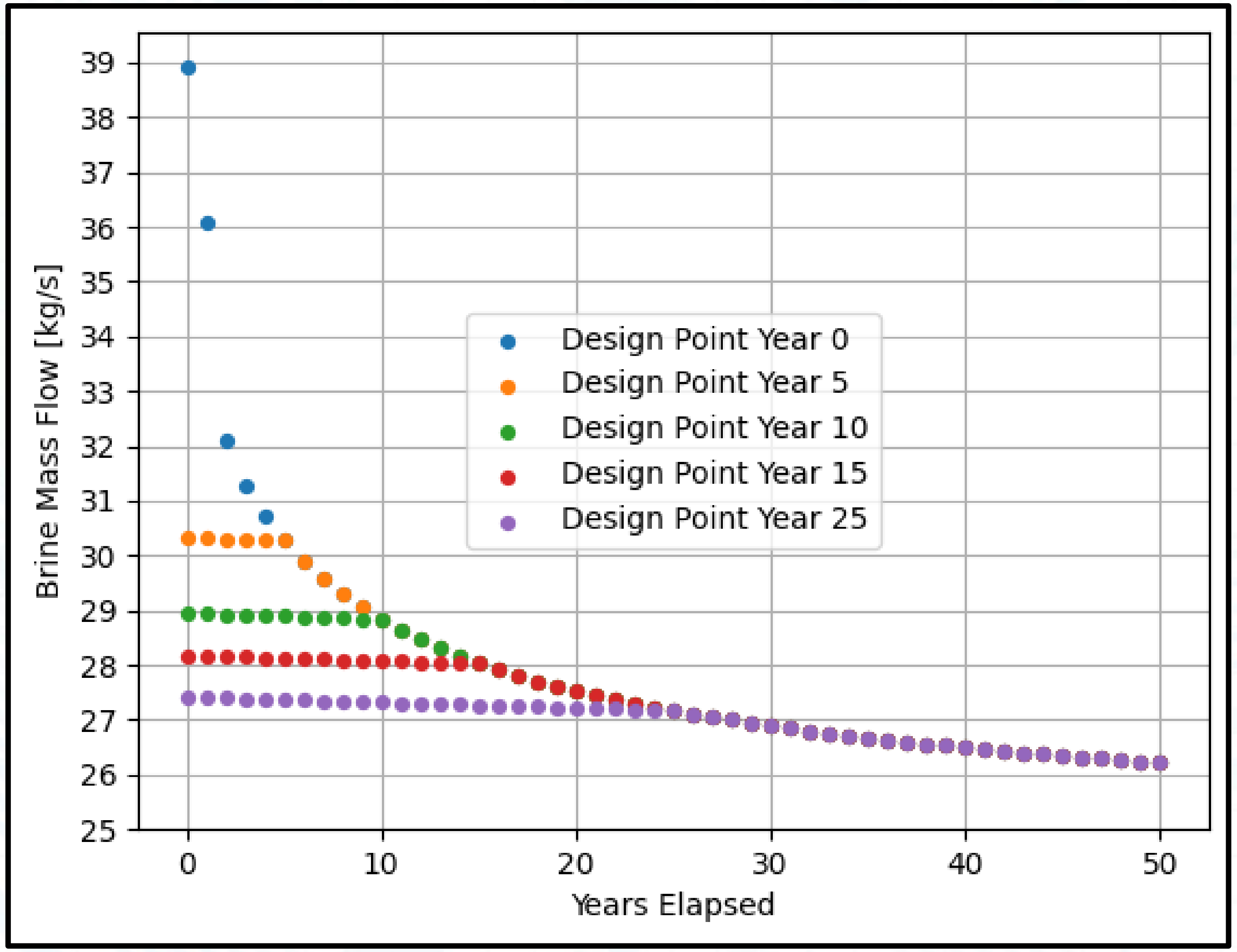
Turbine inlet temperatures are expected to be around 100-140°C



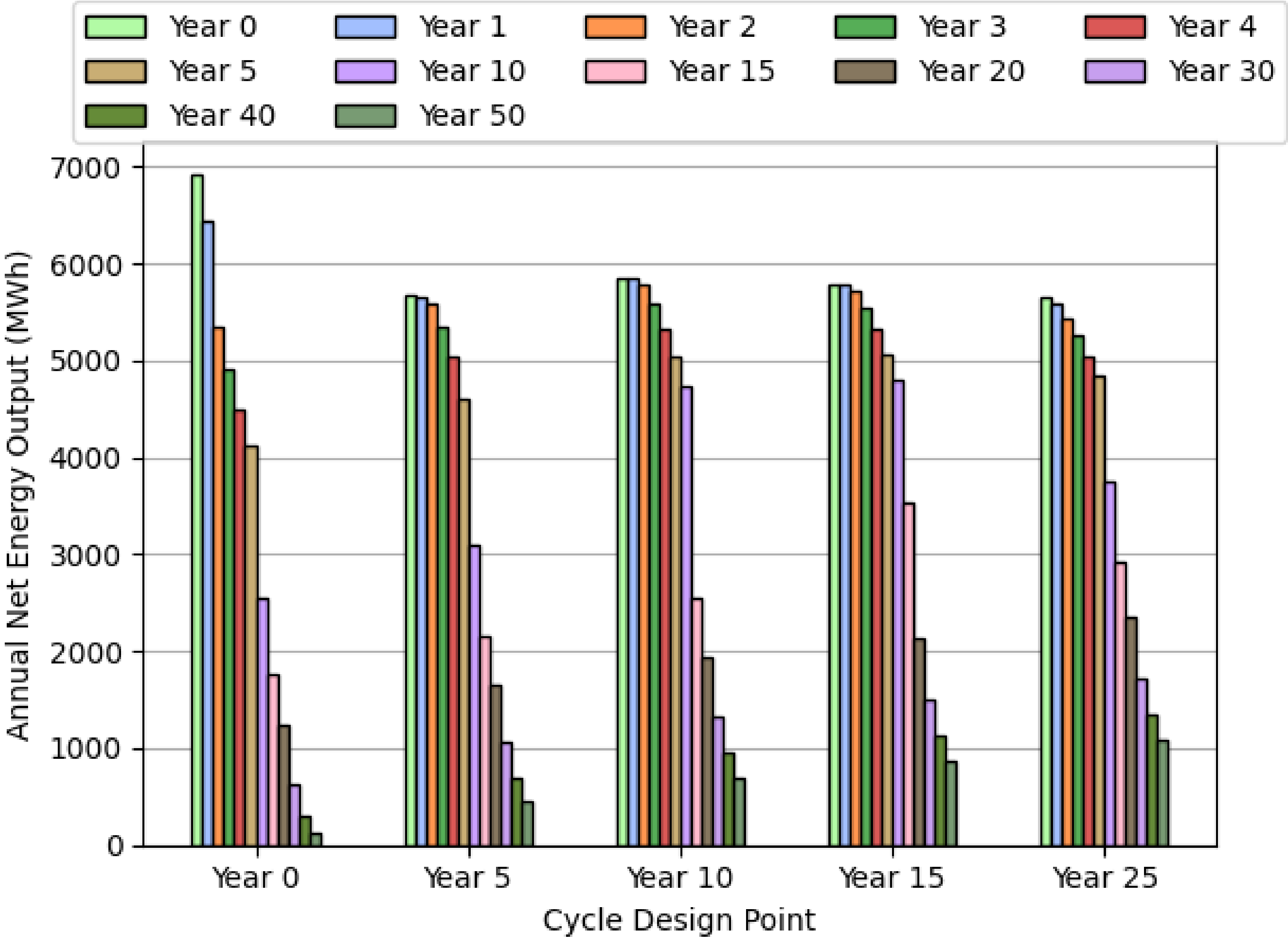
Case A has highest producer flow





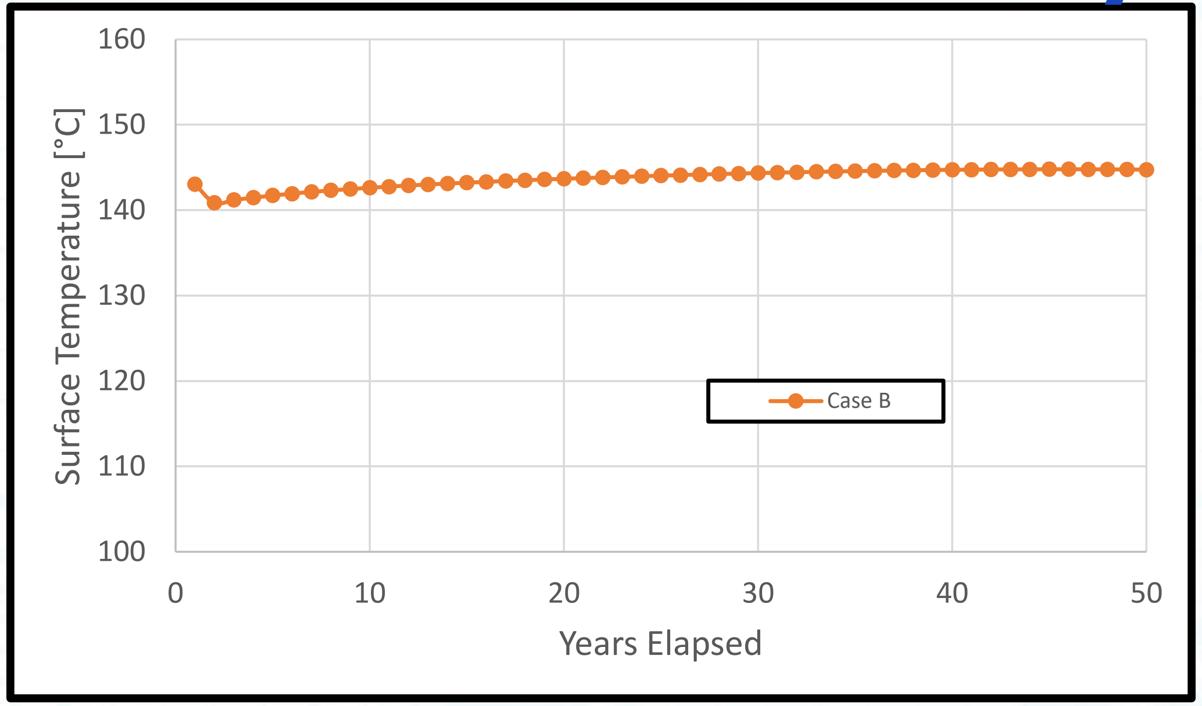


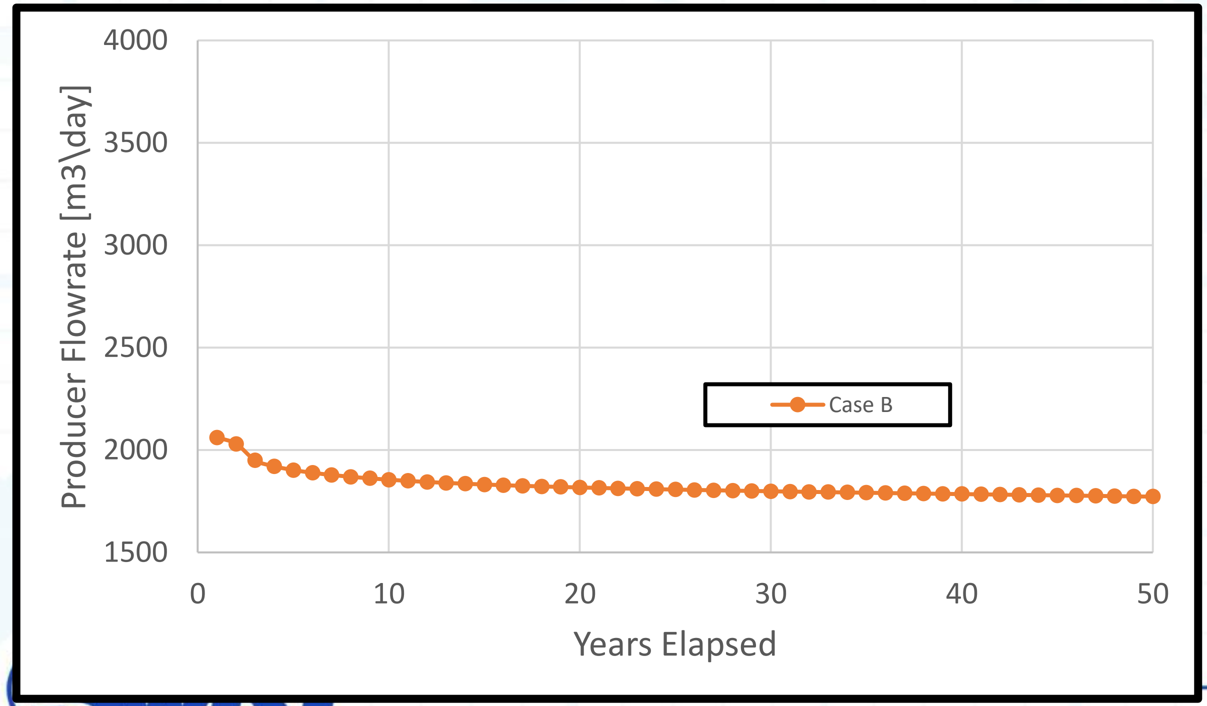
Case A experiences significant drop off past year 10

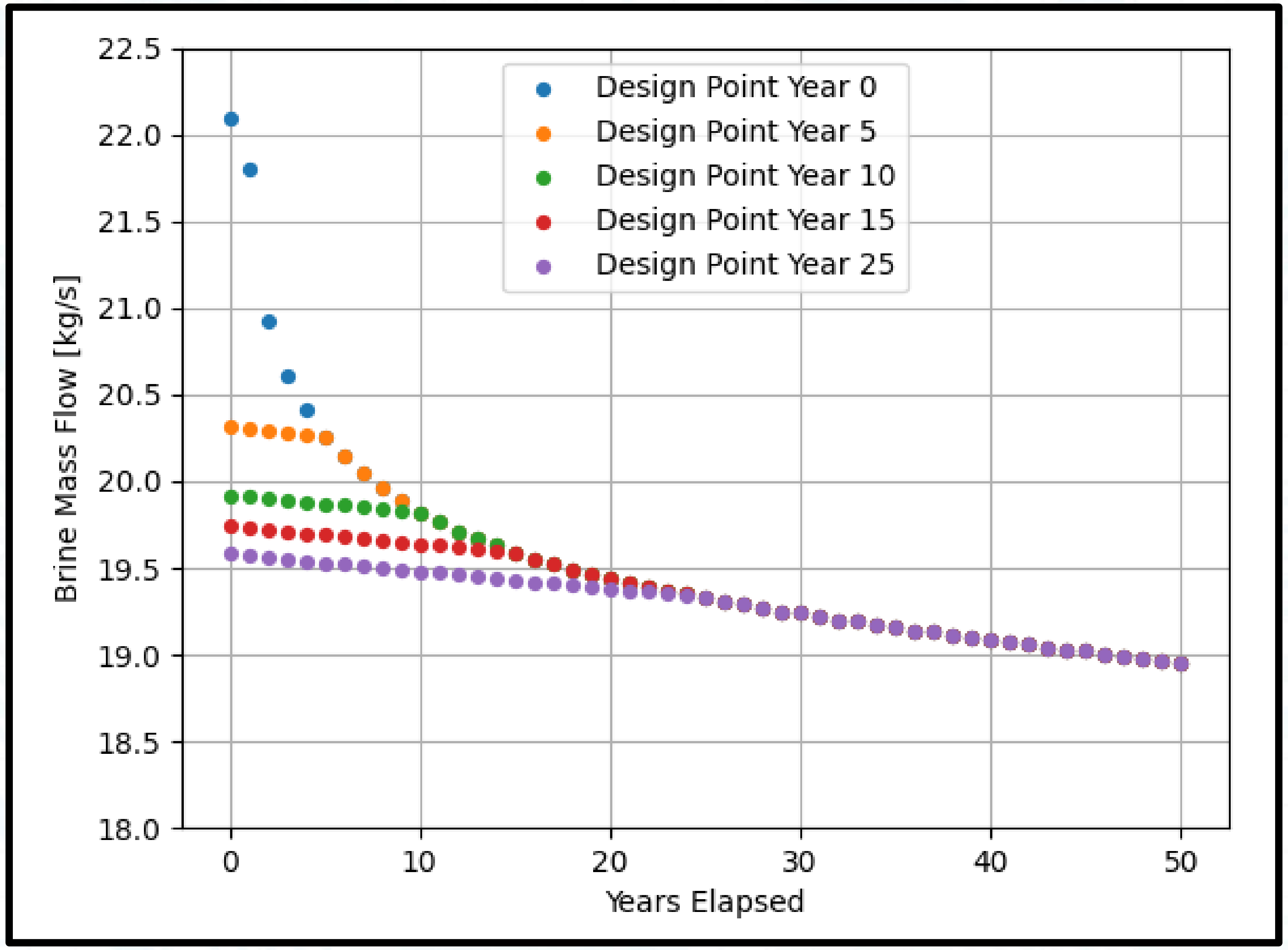


- Large flow rate decreases surface temperature significantly in later years
- Higher energy production in years near design point
- Energy production decreases with deviation from design point

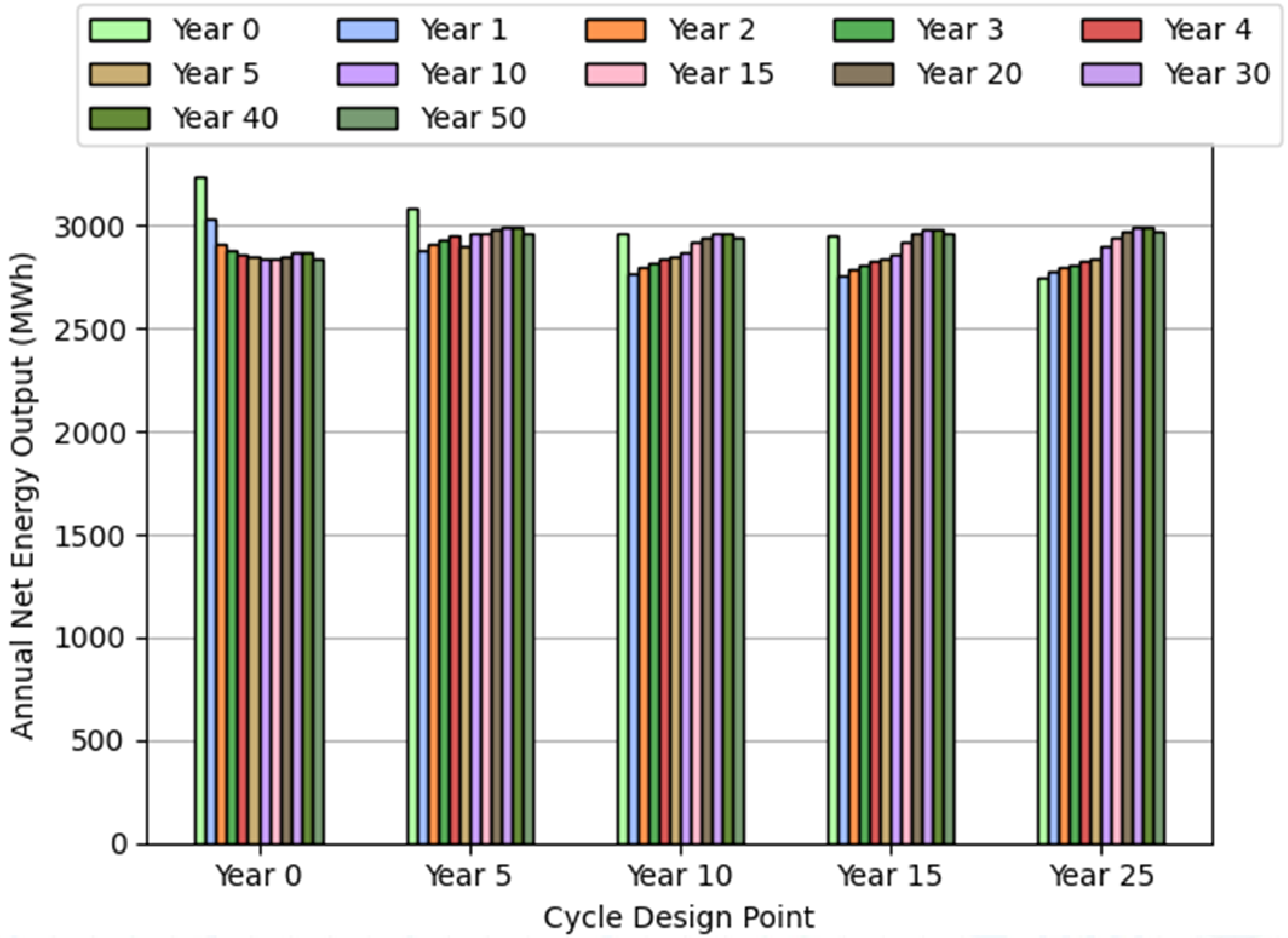
Case B is most thermodynamically stable





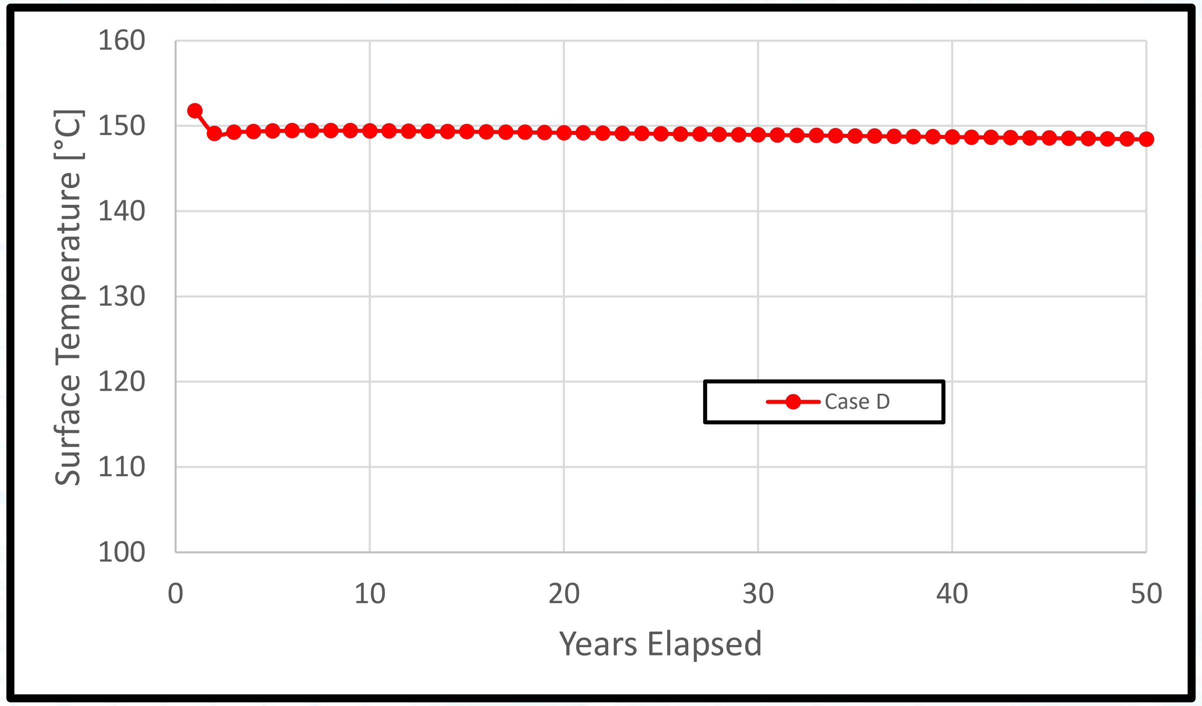


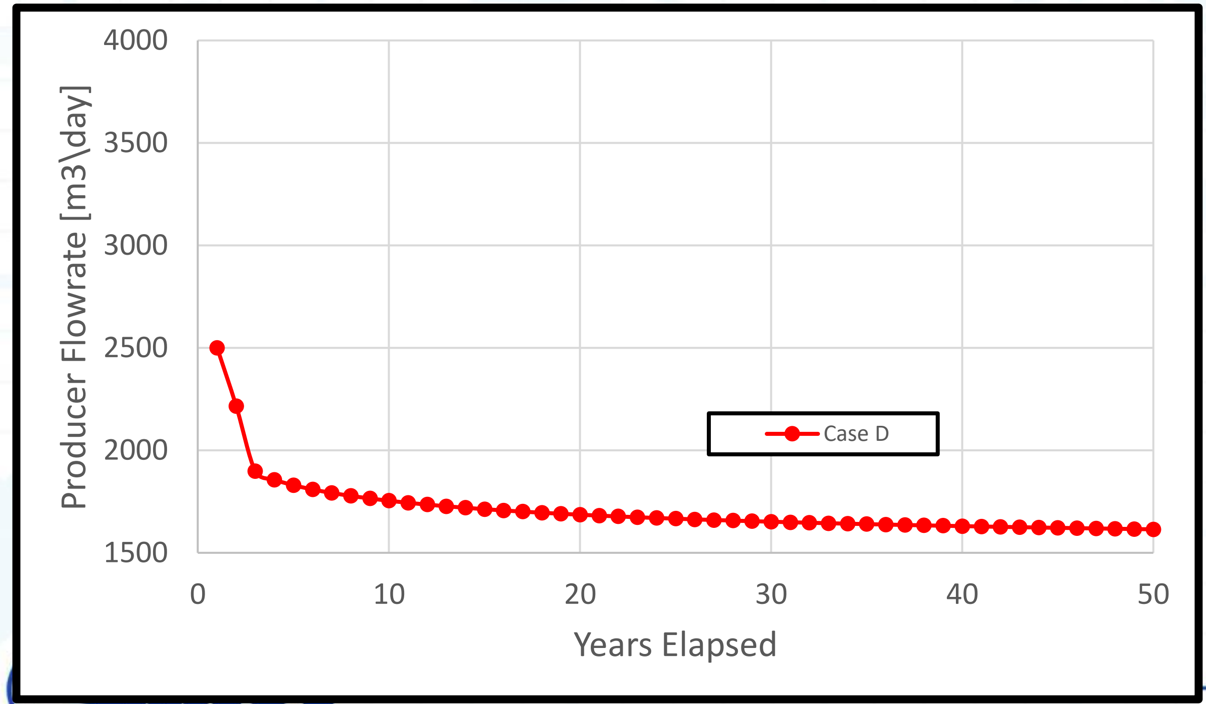
Case B relatively agnostic to chosen design point

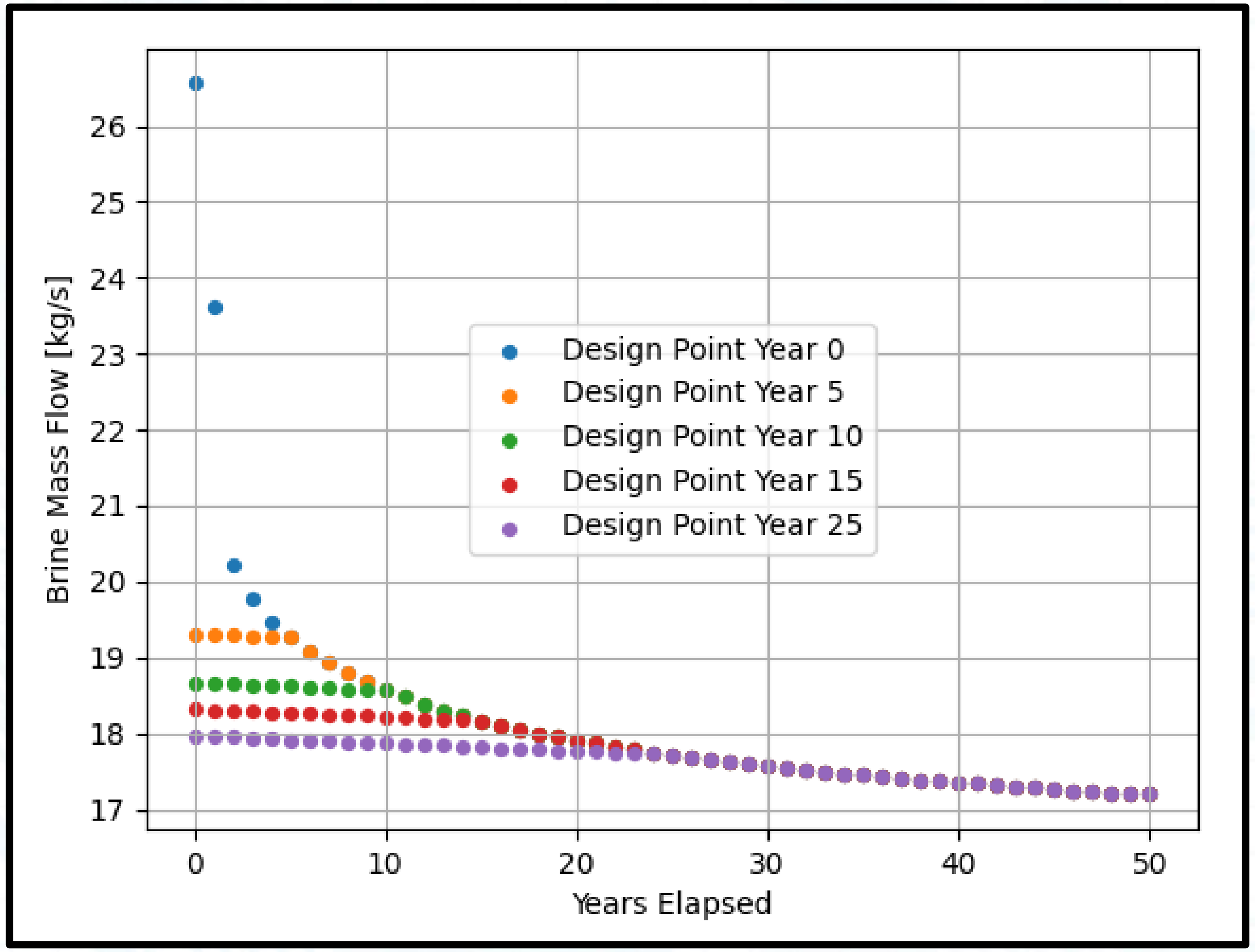


- Smaller flow rate keeps surface temperatures constant
- Variations in energy output over time less pronounced
- Later years produce nearly 3x more energy per year than Case A

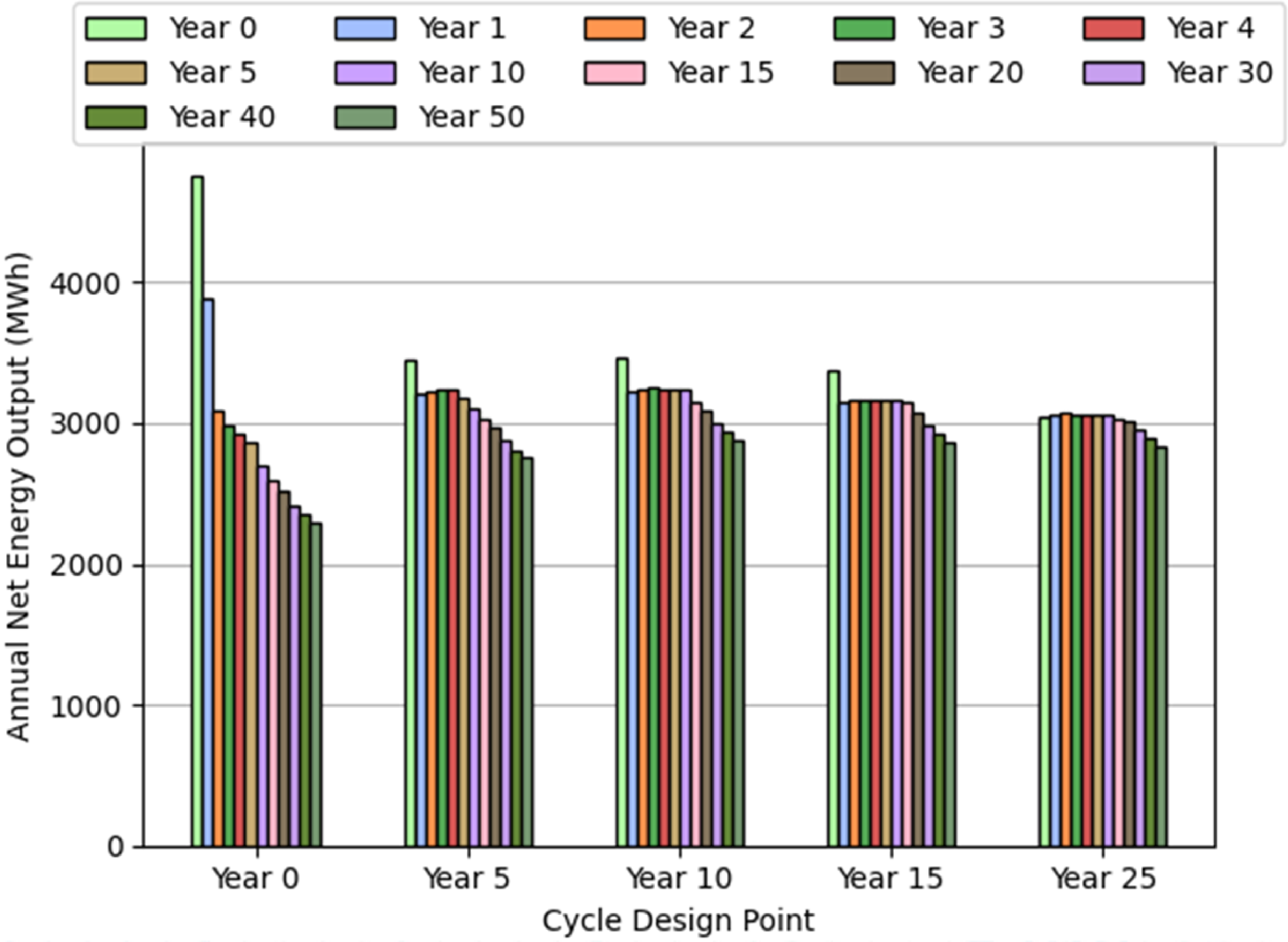
Case D "middle man" between Case A & B





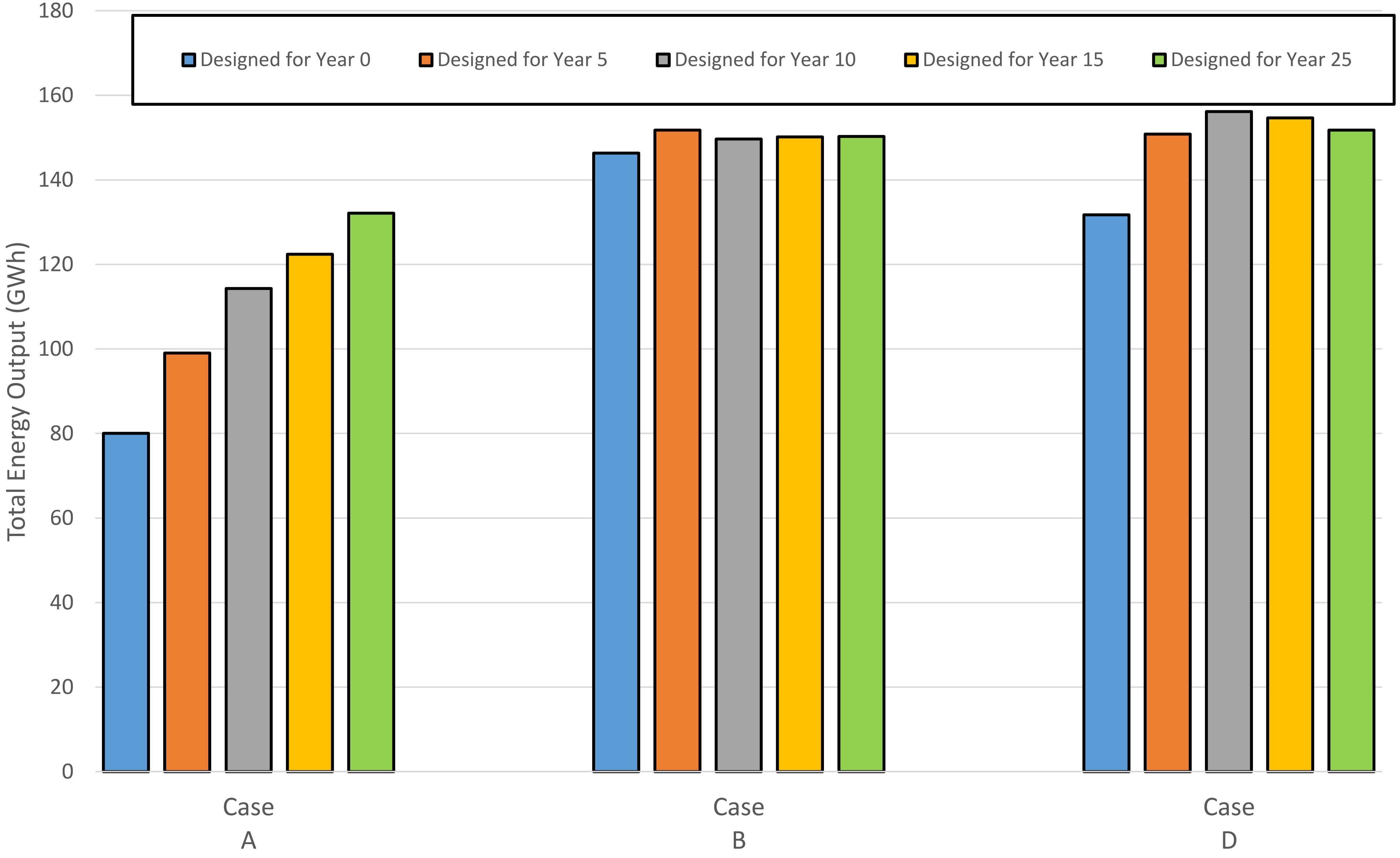


Case D experiences gradual decline for all design points



- Higher energy output in first 5 years
- Beyond 5 years, Case D generally follows Case B

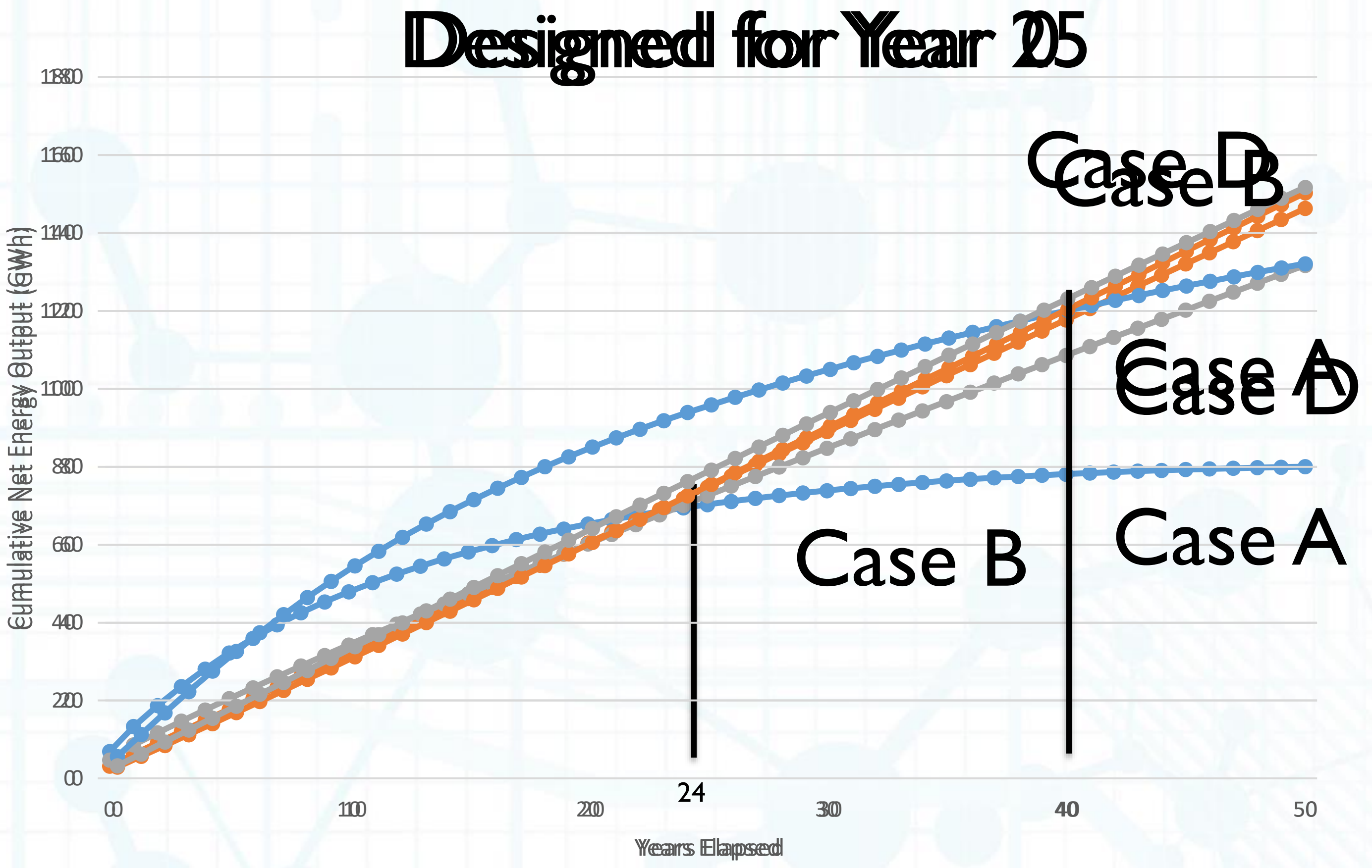
System needs to be designed for both the subsurface characteristics and desired project lifespan

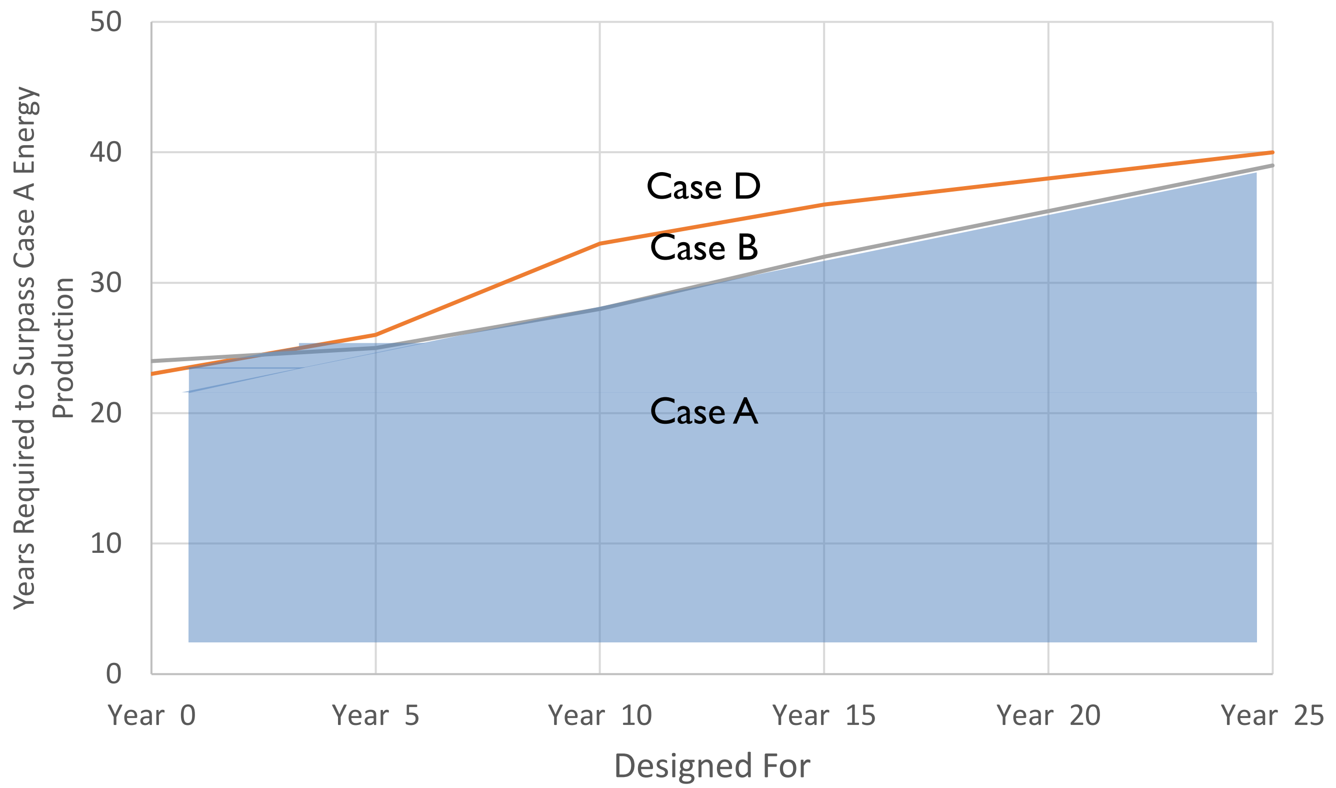


Design Point	Case A	Case B	Case D
	Average Power [kW]	Average Power [kW]	Average Power [kW]
Year 0	199	364	328
Year 5	246	377	375
Year 10	284	372	388
Year 15	304	373	385
Year 25	329	374	377

- Case B and Case D produce 36% more energy on average through their 50-year lifetime
- This energy production gap decreases as lifetime

Shorter well distances is favorable for most cases

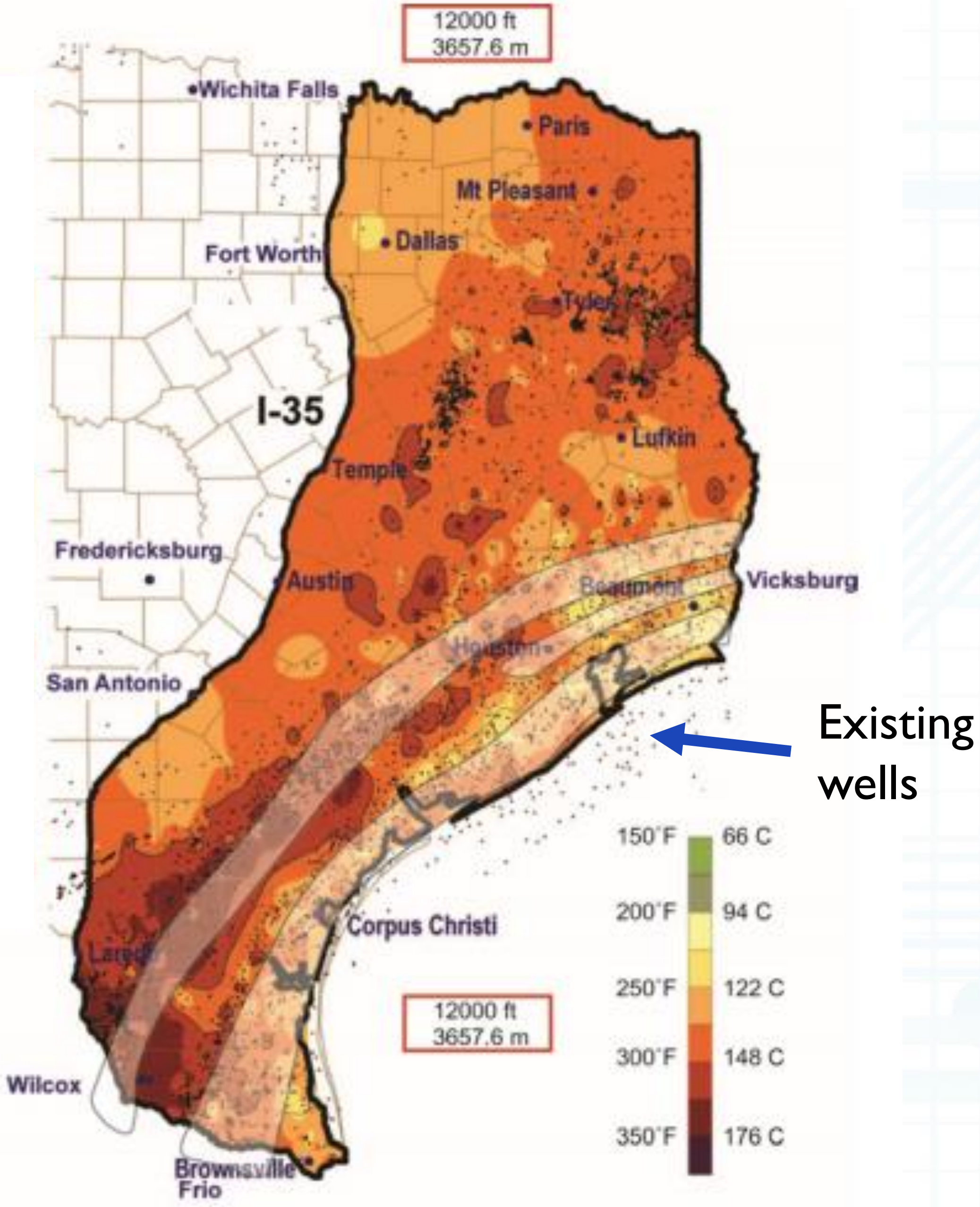




- Shorter time scale favors commercial interests
- Case A produces larger rates of power in early years
- Possible trade space between machinery & well lifetime

Conclusions

- Texas has significant potential with geothermal
  - Potential to re-use existing infrastructure
- Current infrastructure favors binary cycles
  - Temperatures around 150°C
  - Small well-bores
- Need to account for entire life cycle of reservoir



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