SAGE GEOSYSTEMS
Geothermal everywhere.

November 14, 2023

Sage Geosystems

Innovations in Mid-Enthalpy Geothermal using Supercritical CO_2

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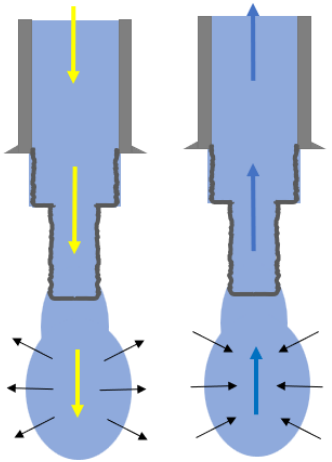
CONFIDENTIAL

Sage is advancing two material business lines

1. Energy Storage
2. Power generation

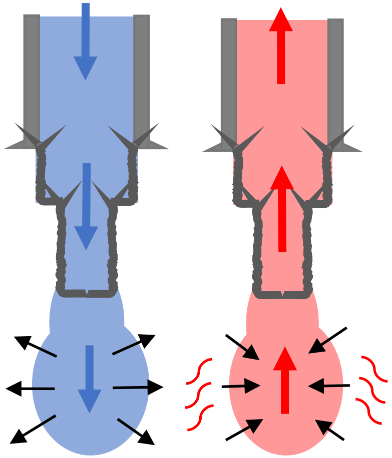
Solutions from Our Technologies

Mechanical Storage
< 150°C



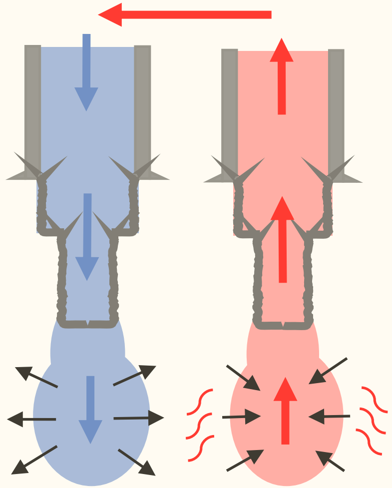
Storage Energy = Pressure

Geothermal Storage
> 150°C



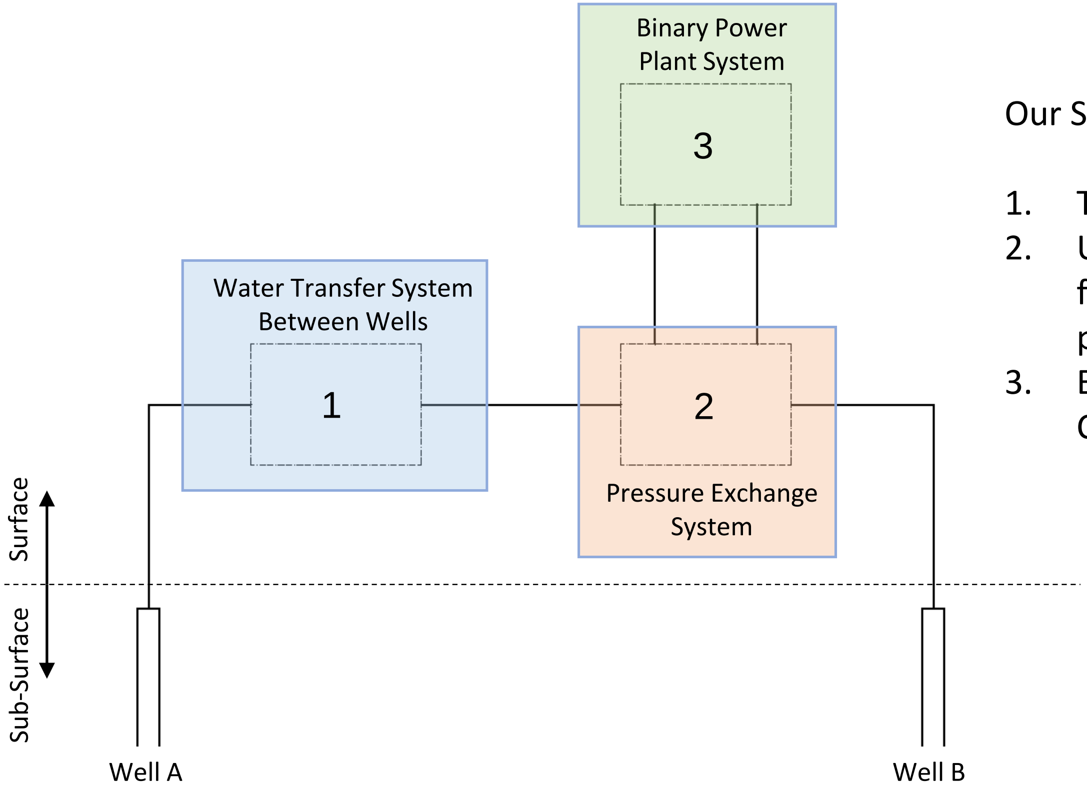
Storage Energy = Heat
(+ Pressure)

Geothermal Baseload



Baseload Energy from
Heat + Pressure

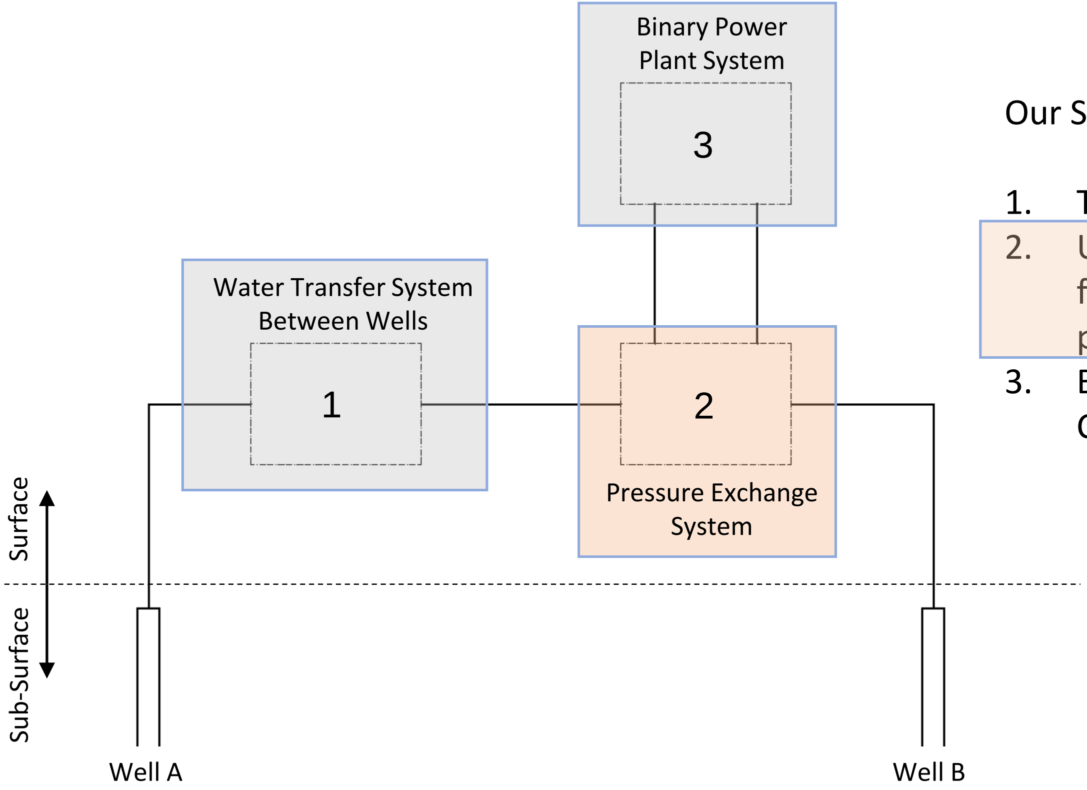
Sage Surface Design – 3 Key Systems



Our Surface Design comprises 3 key areas:

1. Transferring water between two wells
2. Utilizing a pressure exchanger (PX) to move water from the high pressure Well-side system to the low pressure Power Plant system and back
3. Binary power plant design to optimize Levelized Cost of Electricity (LCOE)

Sage Surface Design – 3 Key Systems



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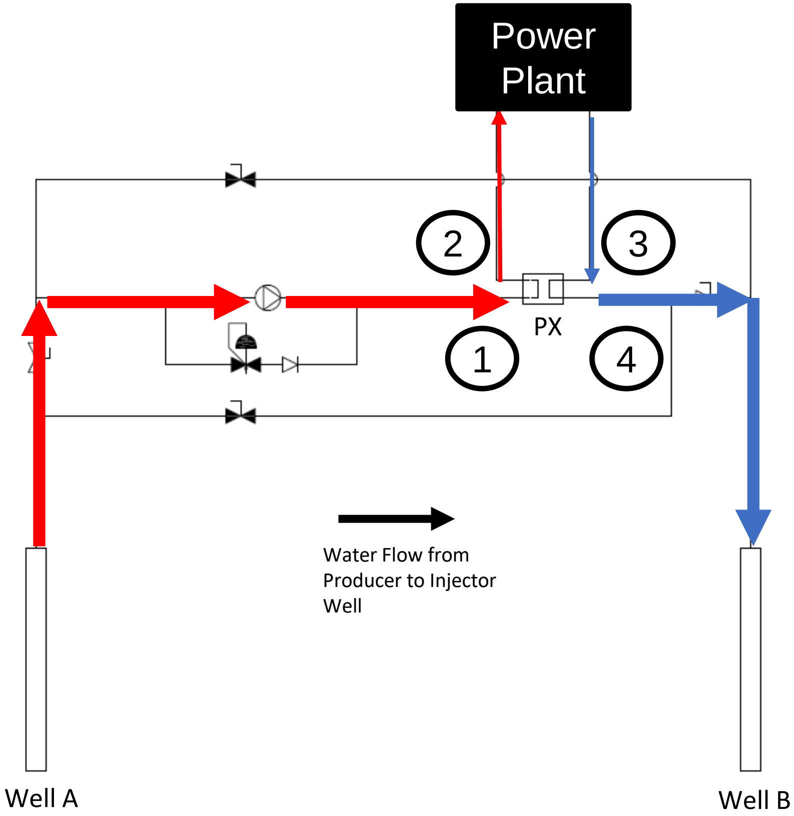
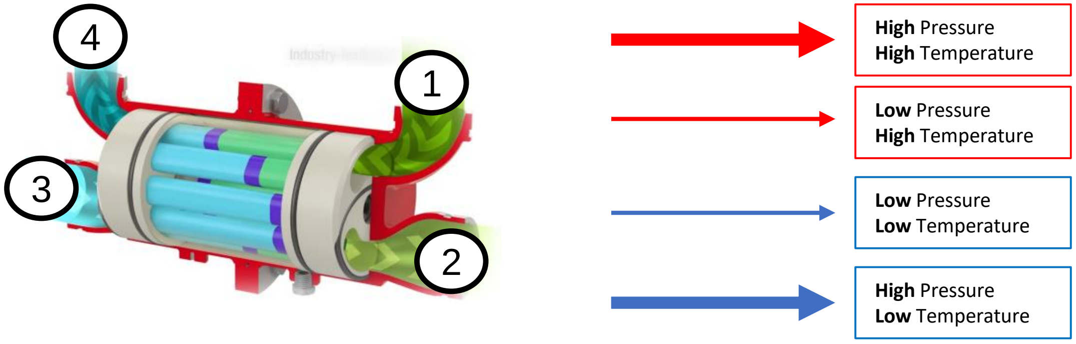
Pressure Exchanger (PX) Technology

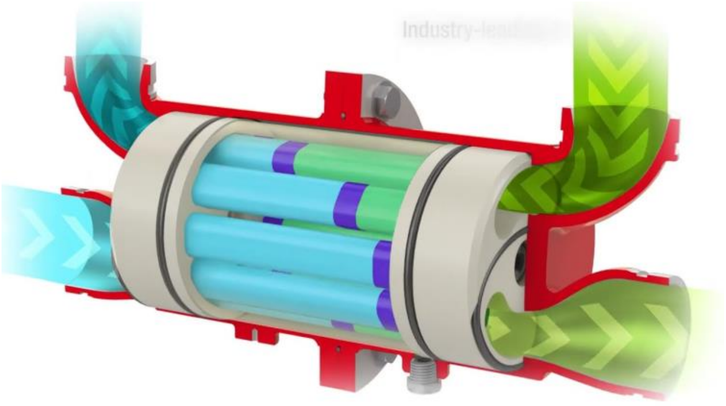




Pressure Exchange Process

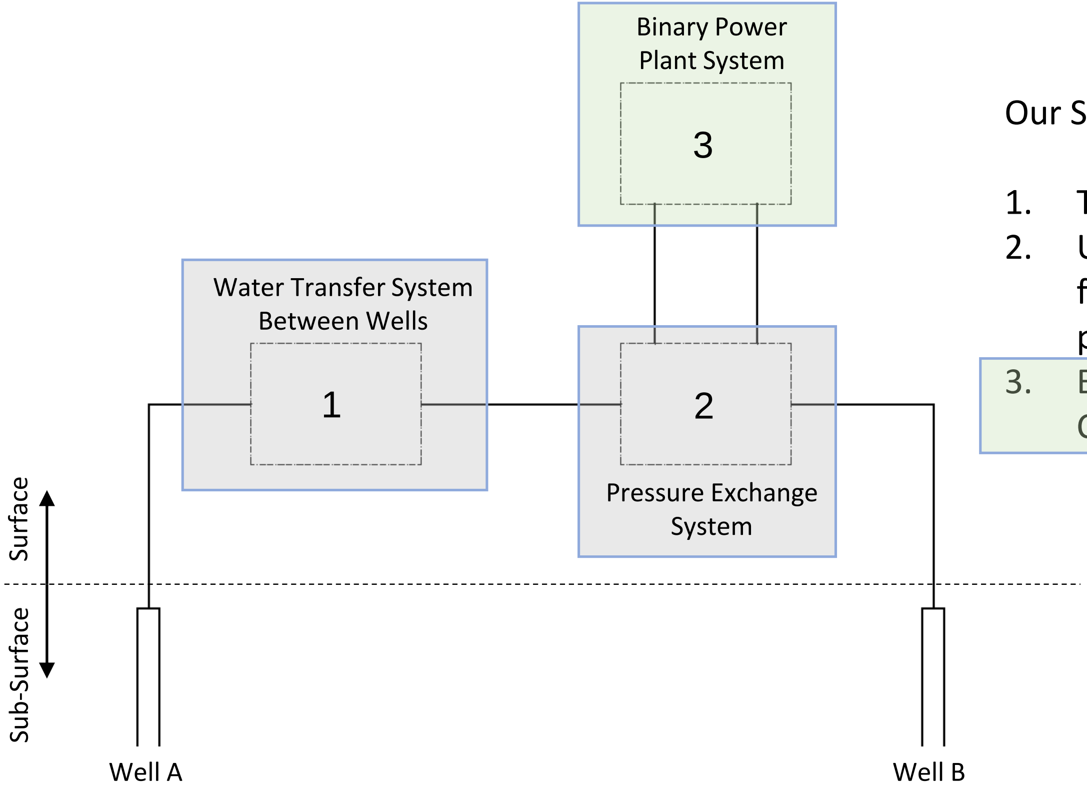
1. The Hot water from the Producer well enters the Pressure Exchanger (PX)
2. The PX moves the Hot water from the High Pressure Well-side system to the Low Pressure Power Plant system
3. Simultaneously, Cold water from the Power Plant System enters the PX
4. The PX moves the Cold water from the Low Pressure Power Plant System to the High Pressure Well-side System

Benefits of PX Technology in Geothermal



1. PX allows to transfer pressure from high pressure, high temperature side to low pressure, high temperature stream
2. This low pressure, high temperature stream can then be converted to electricity using an efficient low pressure heat exchanger + binary plant
3. Mechanical energy is recovered on high-pressure, low temperature side (for reduced parasitic load on injection pump)

Sage Surface Design – 3 Key Systems



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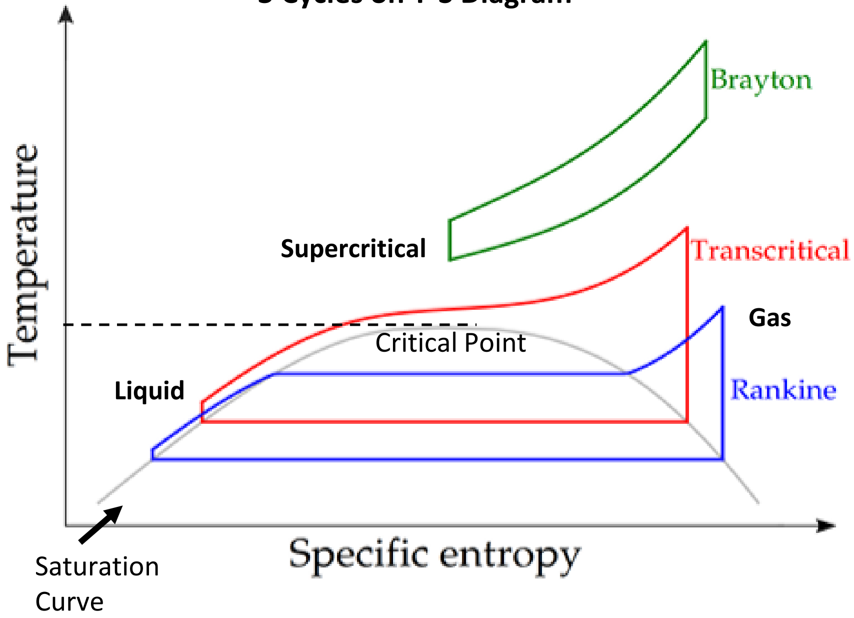
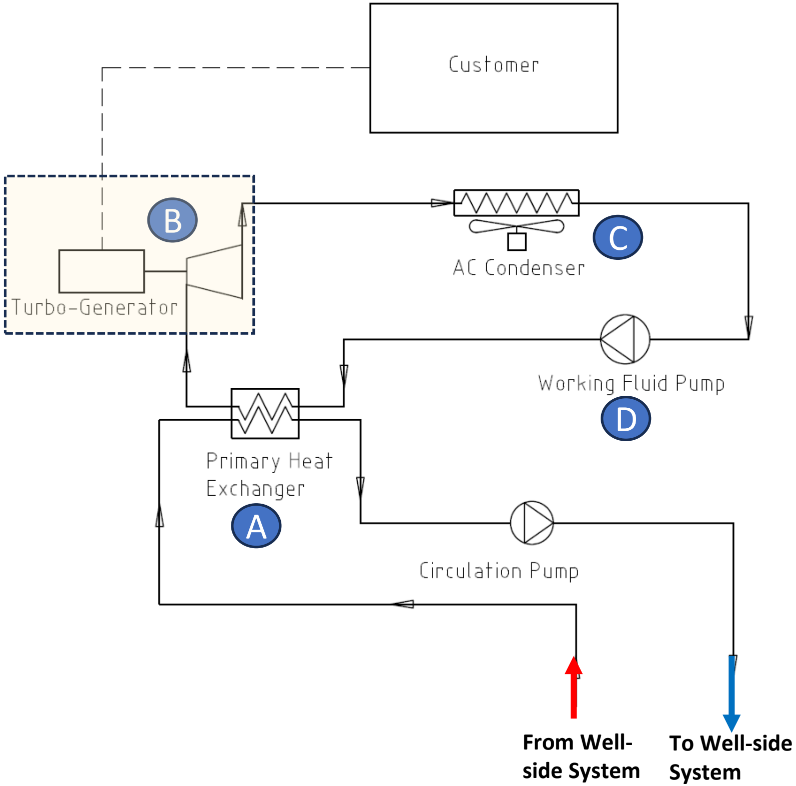
Thermodynamic Cycle Design Considerations

3 Cycles on T-S Diagram

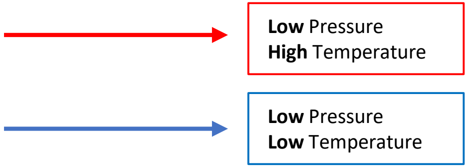


Cycle	Rankine (Baseline Cycle)	Transcritical Rankine	Brayton (Supercritical Rankine)
Turbine expansion	Below Critical Point	Above Critical Point	Above Critical Point
Cooling	Below Critical Point	Below Critical Point	Above Critical Point
Operating Pressure	Low	Medium	High
Complexity	Low	Medium	High
Plant Cost/ MWe	Low - Medium	Medium - High	Medium - High

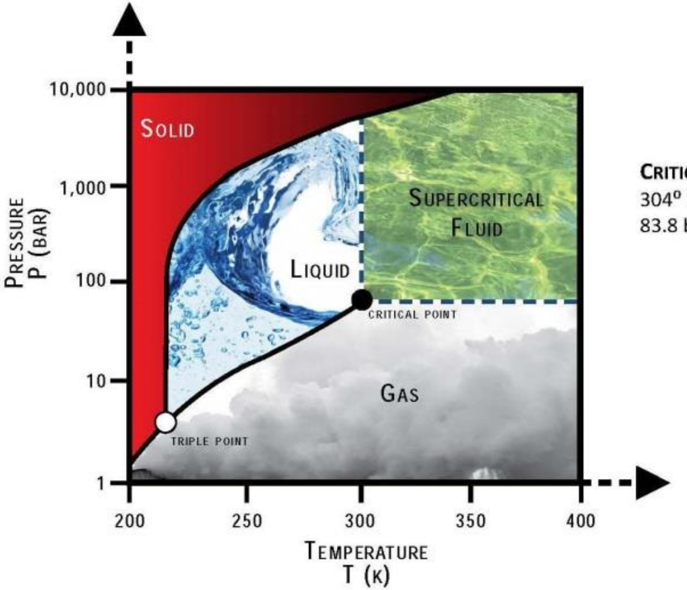
How to optimize Levelized Cost of Electricity (LCOE)?
Initial Focus to Increase Power Generated, Reduce CAPEX



Letter	Description	Purpose
A	Primary Heat Exchanger	Transfers heat from the water to the working fluid
B	Turbo-Generator	Expansion of the working fluid through the turbine generates electrical power
C	AC Condenser	Converts the working fluid from vapor to liquid
D	Working Fluid Pump	Pressurizes the working fluid



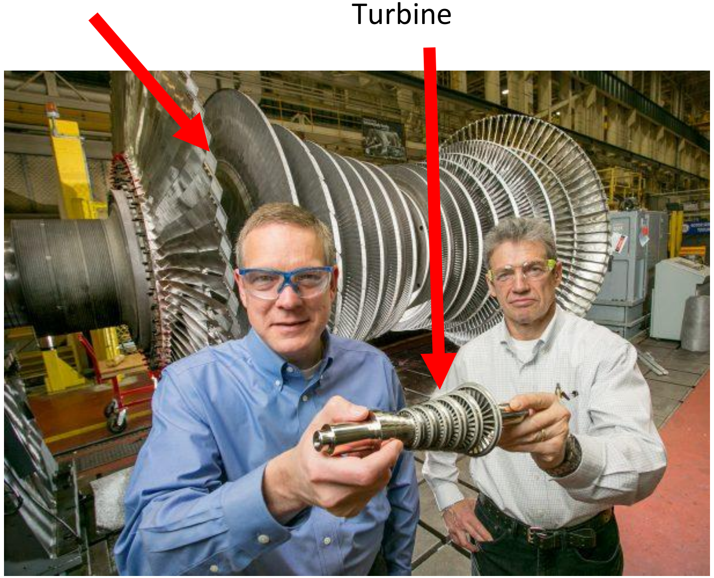
Innovations in Supercritical CO_2 (sCO_2)



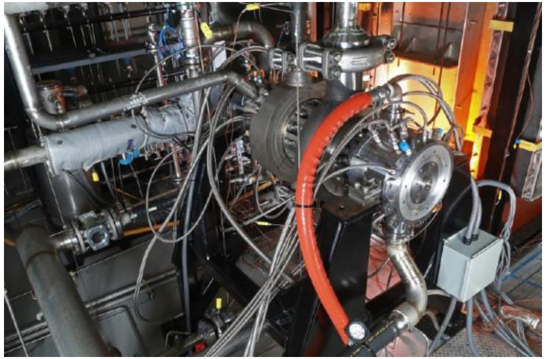
Critical Point
304° K = 31° C = 88° F
83.8 bar = 8.38 Mpa
= 1,070 psi

300 MWe Steam Turbine

10 MWe Brayton Cycle Turbine



Partnering with SwRI on sCO_2 Turbine Development



sCO_2 10 MW turbine for concentrated solar

Inlet Temperature	550 - 715 C
Inlet Pressure	250 bar
Mass Flow Rate $C0_2$	8.410 kg/s
Power Output Tested	1 MWe

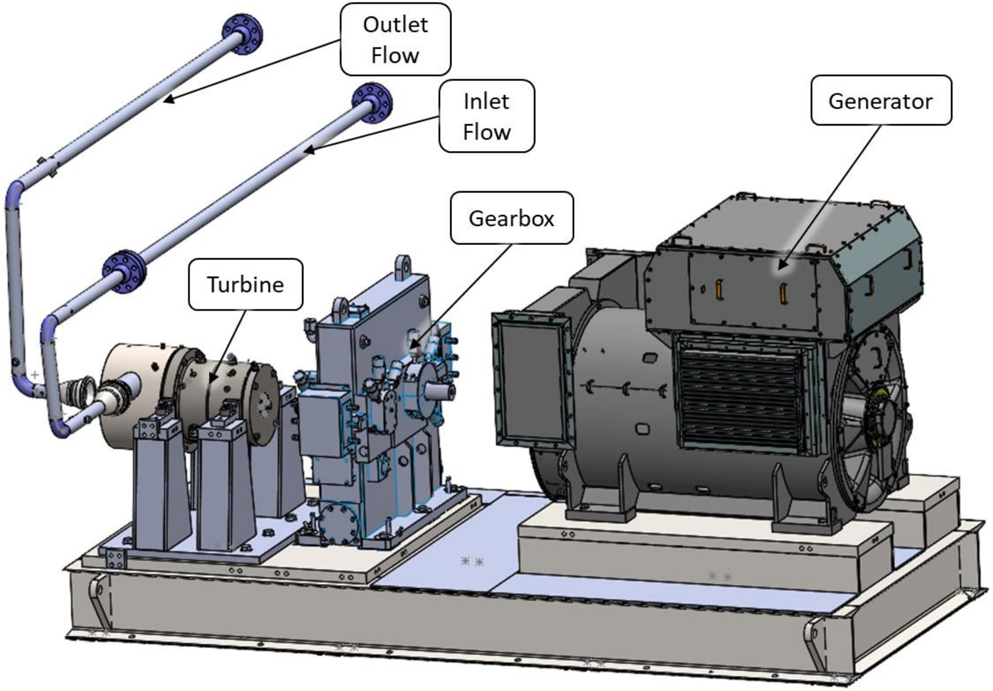
Back to the drawing board

sCO_2 3 MW turbine for geothermal

Inlet Temperature	150 - 180 C
Inlet Pressure	225 bar
Mass Flow Rate $C0_2$	15 kg/s
Power Output Tested	0.750 MWe

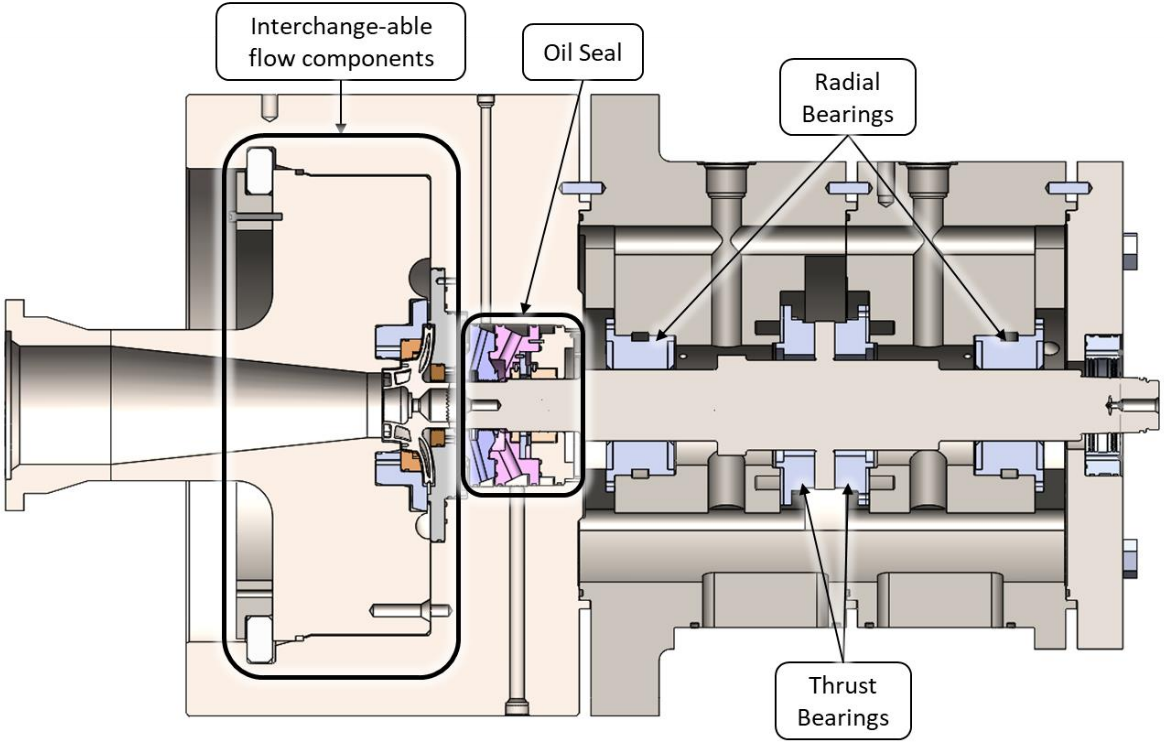
Critical Design Factor – Modularity

- 3 MWe frame design
  - Good middle point for most wells
  - Can run multiple in series or parallel depending on well conditions
- Skid can be unbolted and shipped easily
- Gearbox with fixed speed ratio can be swapped for changing speeds



Interchangeable Aero Design

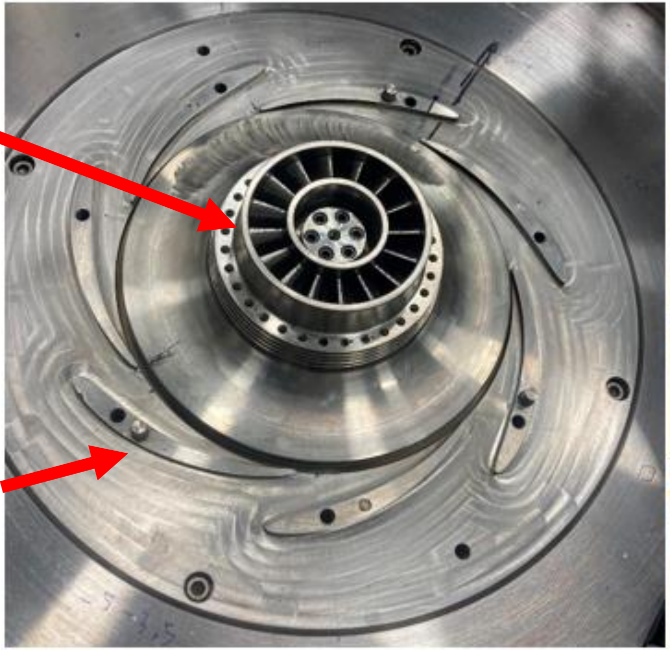
- Impeller is coupled to shaft through a hirth coupling and a tie-bolt.
- All flow components can be interchanged to maximize well power output
- Overhung design
  - Rotordynamics
  - Oil seal



Interchangeable Aero Design

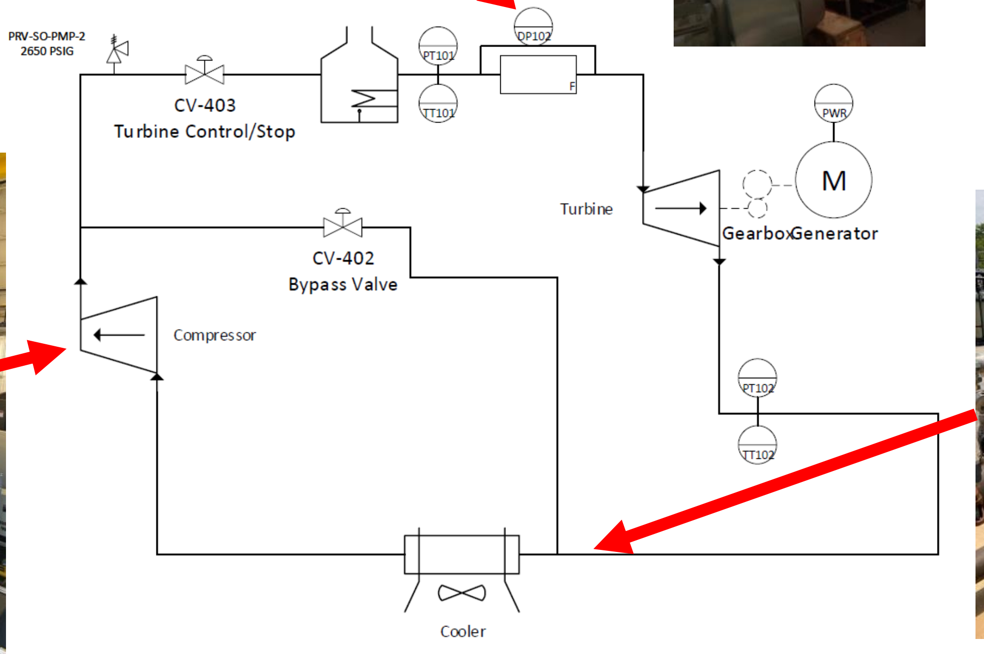
3D Printed Titanium Impeller

Guide vanes



Pressure-Side End Cap

SwRI sCO_2 Test Loop



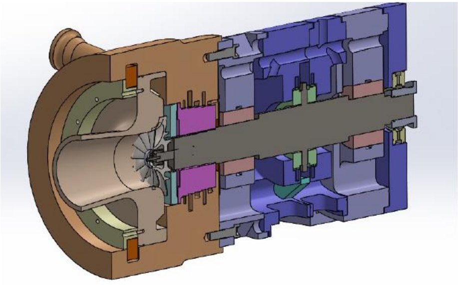
Build Time Lapse

Conclusions & Next Steps

R&D Roadmap – Incremental Milestones

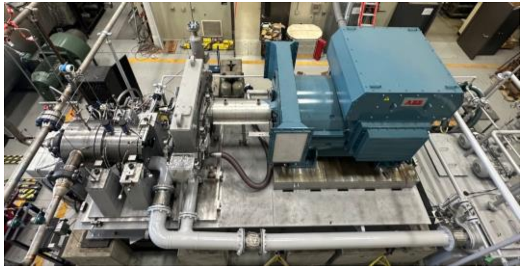
2022

- ✓ Conceptual Design
- ✓ Detailed Design
- ✓ Procurement & Assembly



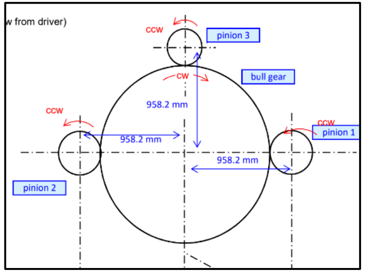
2023

- ✓ Uncoupled Air Test
- ✓ Finalize Commissioning for Load Test
- Complete Load Test



2024+

- Optimize Design with OEM
- Investigate options to further reduce parasitic load in pumping/condensing



Thank You