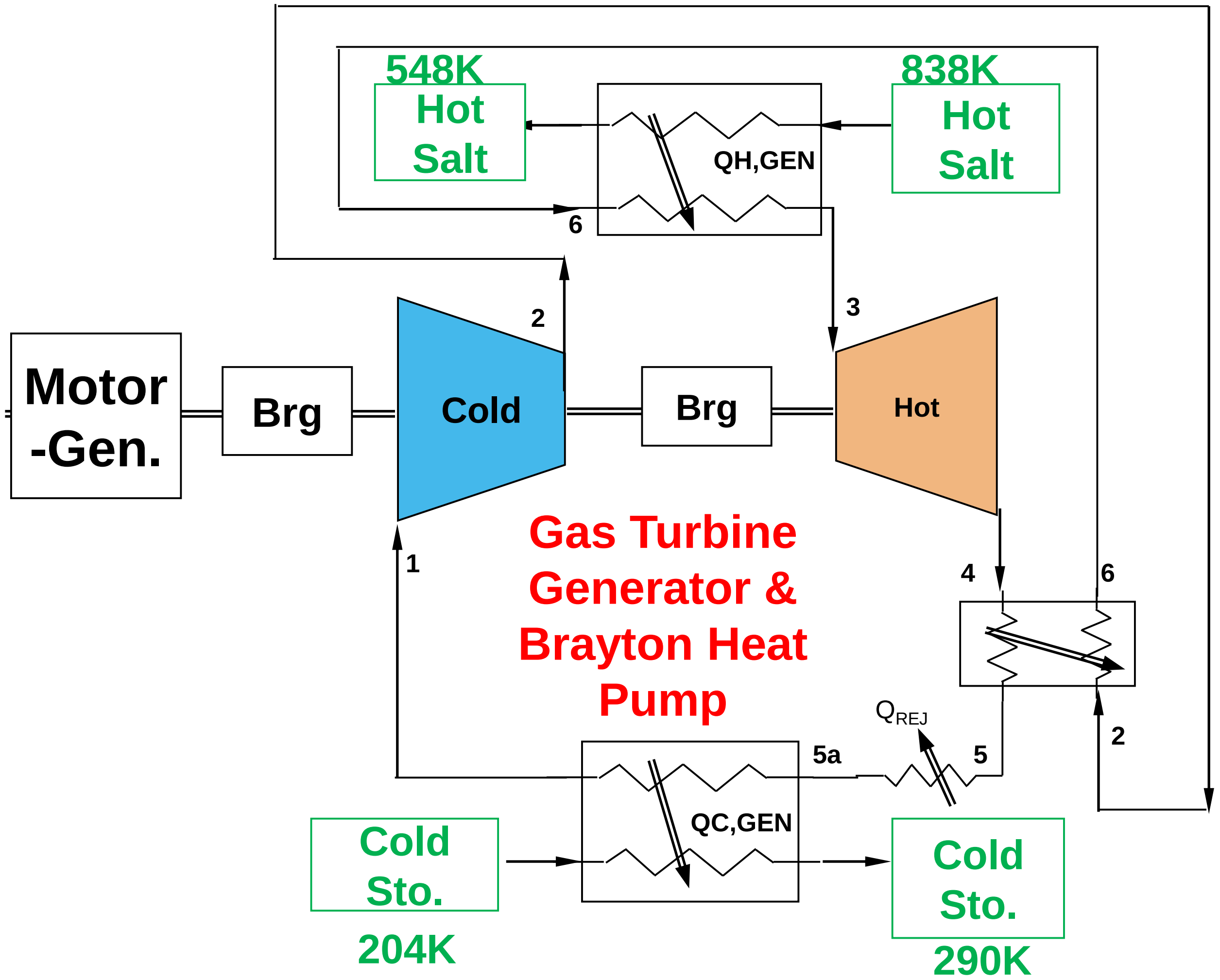
# Reversing Turbomachine to Enable Laughlin-Brayton Cycle *for Thermally-Pumped Electrical Energy Storage*

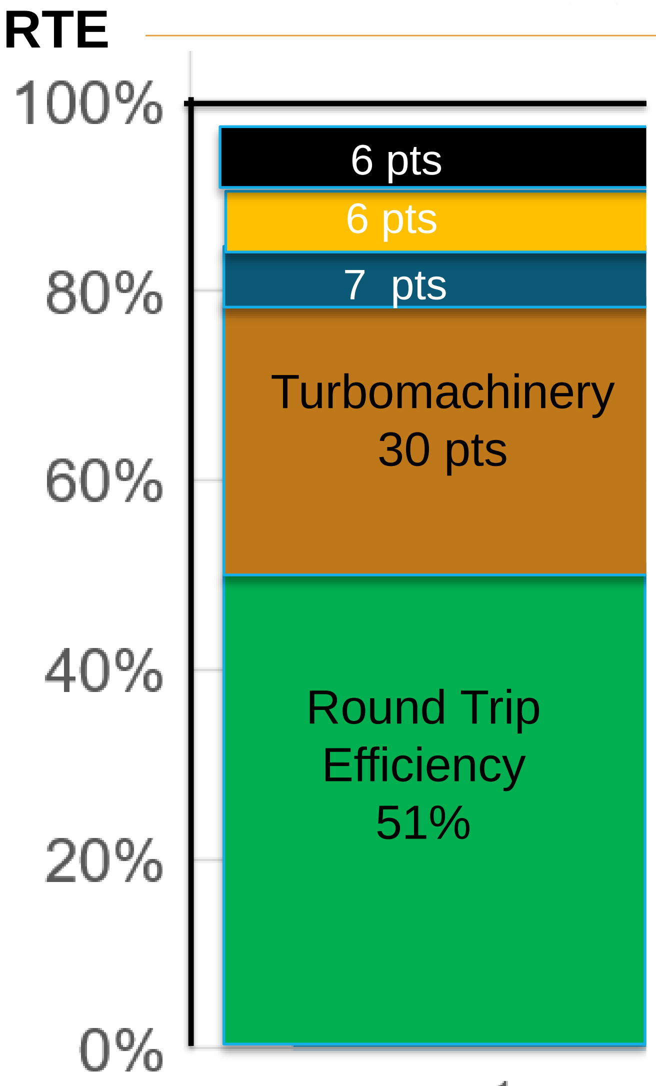
**Brayton Energy, LLC**
**Massachusetts Institute of Technology, Gas Turbine Lab**

## Project Vision

***Exploring new aero-mechanical regimes toward turbomachinery efficiency improvement for a novel Brayton cycle energy storage***

# *Pumped Thermal-Electric Storage: Very Sensitive to Imperfections*




$\eta_{gen}$=95% (gen + mech)

$\Delta T$=5 K (HX approach)

$\Delta P/P$=2%/HX (12% total)

Typical industrial gas turbine component efficiencies (90% polytropic)

Not counting:

- Leakage,
- Heat loss,
- Ambient temp control,
- Mechanical losses,
- Electrical parasitics

**Arrows shown for Generation cycle, all reverse direction for the charge (heat pump) cycle**

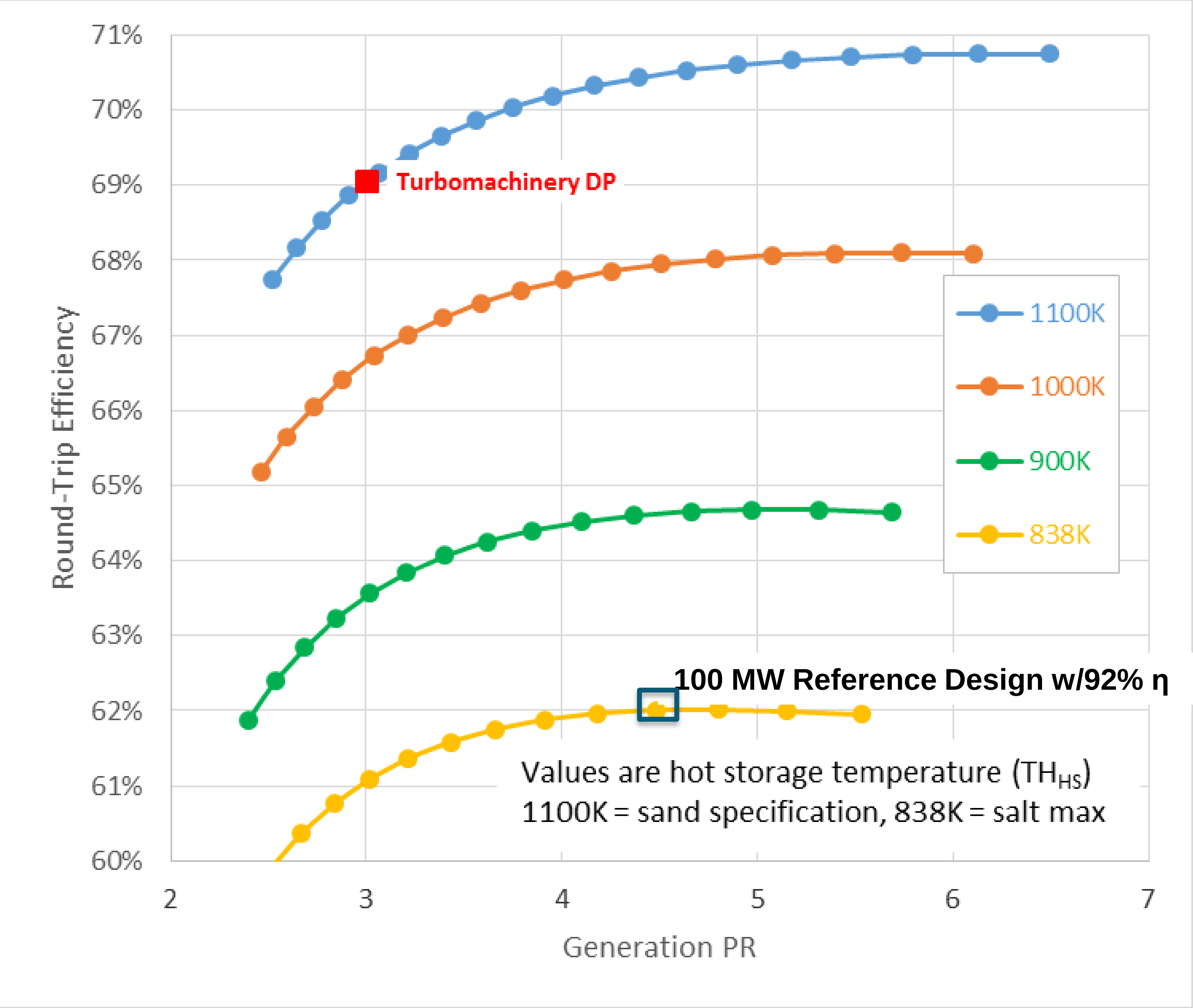
# Sensitivity parameters

| Quantity | Symbol | Baseline | Δ Applied | Δ Effy (pts) |
|---|---|---|---|---|
| Gen Compressor Polytropic Effy | $\eta_{comp}$ | 92.0% | -1.0% | 0.84% |
| Chg Compressor Polytropic Effy | $\eta_{comp}$ | 92.0% | -1.0% | 0.51% |
| Gen Turbine Polytropic Effy | $\eta_{turb}$ | 93.0% | -1.0% | 0.82% |
| Chg Turbine Polytropic Effy | $\eta_{turb}$ | 93.0% | -1.0% | 0.48% |
| Gas-to-Salt HX Pressure Loss | $\Delta p/p_{6,3}$ | 1.1% | +1.0% | 0.70% |
| Gas-to-Hexane HX Pressure Loss | $\Delta p/p_{5a,1}$ | 1.1% | +1.0% | 0.64% |
| Recuperator HP Pressure Loss | $\Delta p/p_{2,6}$ | 1.7% | +1.0% | 0.70% |
| Recuperator LP Pressure Loss | $\Delta p/p_{4,5}$ | 1.7% | +1.0% | 0.64% |
| Heat-Rejection HX Pressure Loss | $\Delta p/p_{5,5a}$ | 0.5% | +1.0% | 0.46% |
| Gas-to-Salt HX Approach Temp | $\lvert T_G - T_S \rvert_{HS}$ | 5.0K | +1.0K | 0.19% |
| Gas-to-Hexane HX Approach Temp | $\lvert T_G - T_{HX} \rvert_{CS}$ | 2.5K | +1.0K | 0.38% |
| Recuperator Hot-Side Approach Temp | $T_4 - T_6$ | 10.0K | +1.0K | 0.27% |
| Heat-Rejection HX Approach Temp | $T_{5a} - T_{amb}$ | 4.0K | +1.0K | 0.11% |

**Δ~ polytropic efficiency point equates to 2.7 RTE pts**

**ΔP/P increase of 4 % is 3 RTE pts**

**Δ~ 2pct RTE for 10K**




# Sensitivity to hot source temperature

(From solar salt to *GEN3*)

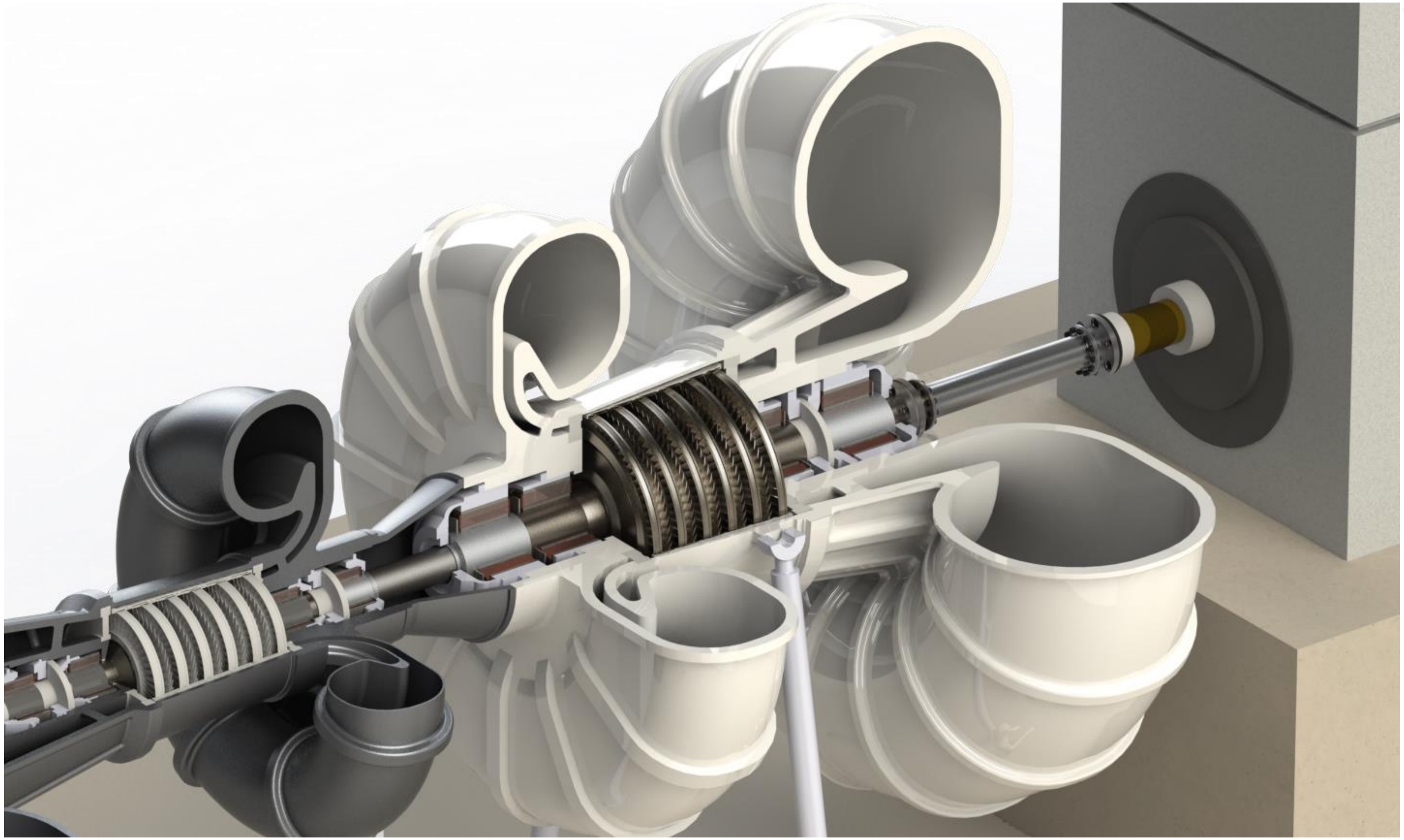
- Parametric study, varying only high-side temp and pressure ratio.
- Component performance nominal figures on next slides.

- For purposes of limiting stage count, below-optimum pressure ratio ($PR_{gen}$ = 3) chosen for design of reversible counter-rotating turbomachinery.

# *Exploring new directions in Turbomachinery aerodynamics.*

## Design of a high efficiency, economical solution for the Laughlin-Brayton Battery

- Combine the Brayton cycle heat pump and the gas turbine generator into a single turbomachine – reducing cost and improving efficiency.



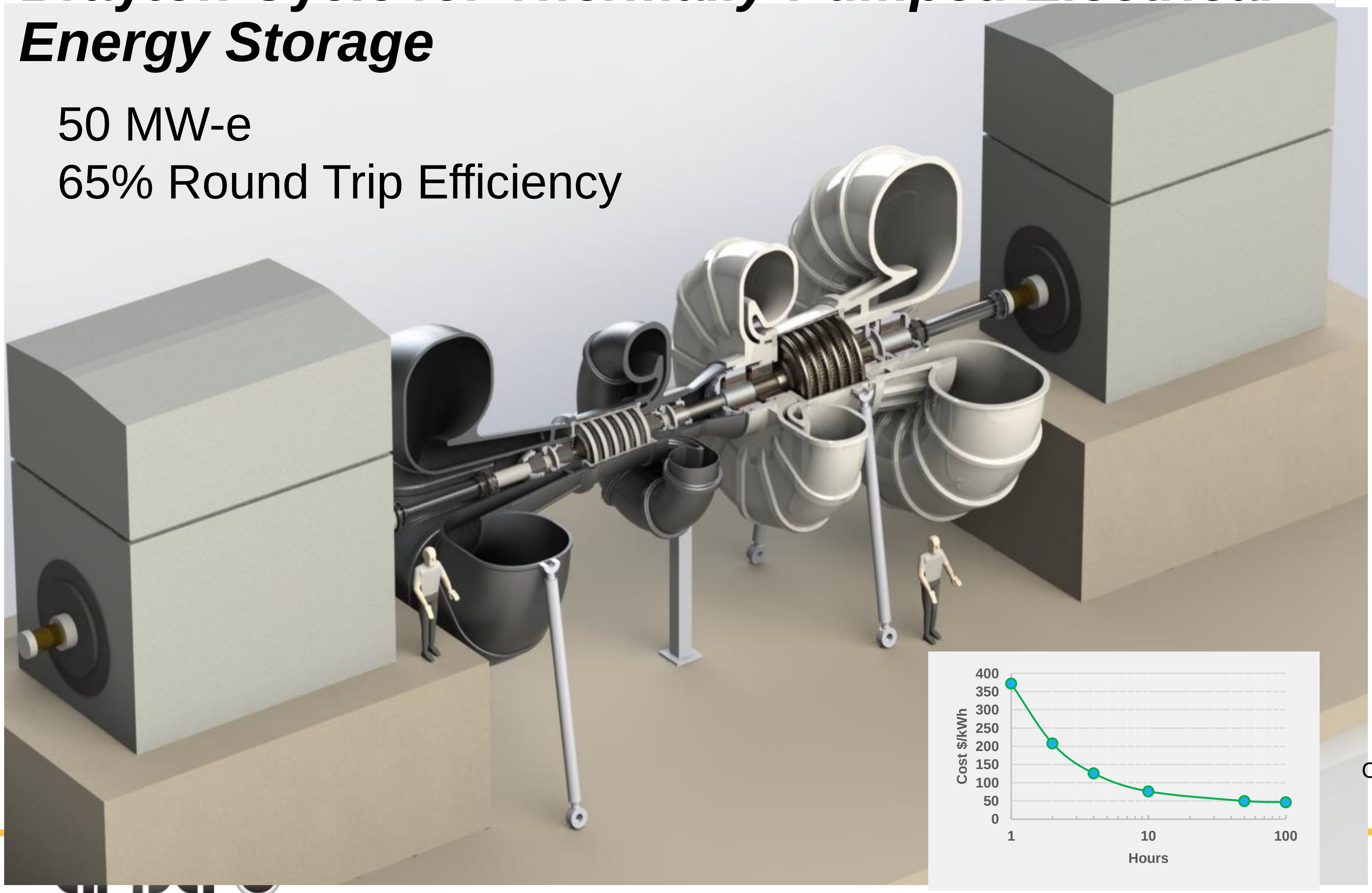
## Approach:

- Counter-rotating axial compressor and turbine.
- Elimination of conventional stators and associated losses.
- Optimized blade shapes to minimize compromises associated with reversing flow.

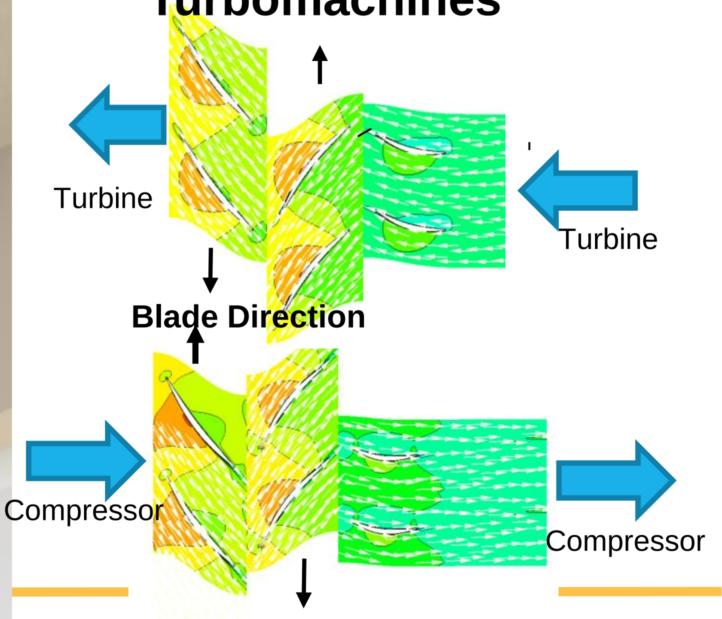
# Reversing Turbomachine to Enable Laughlin-Brayton Cycle *for Thermally-Pumped Electrical Energy Storage*

50 MW-e

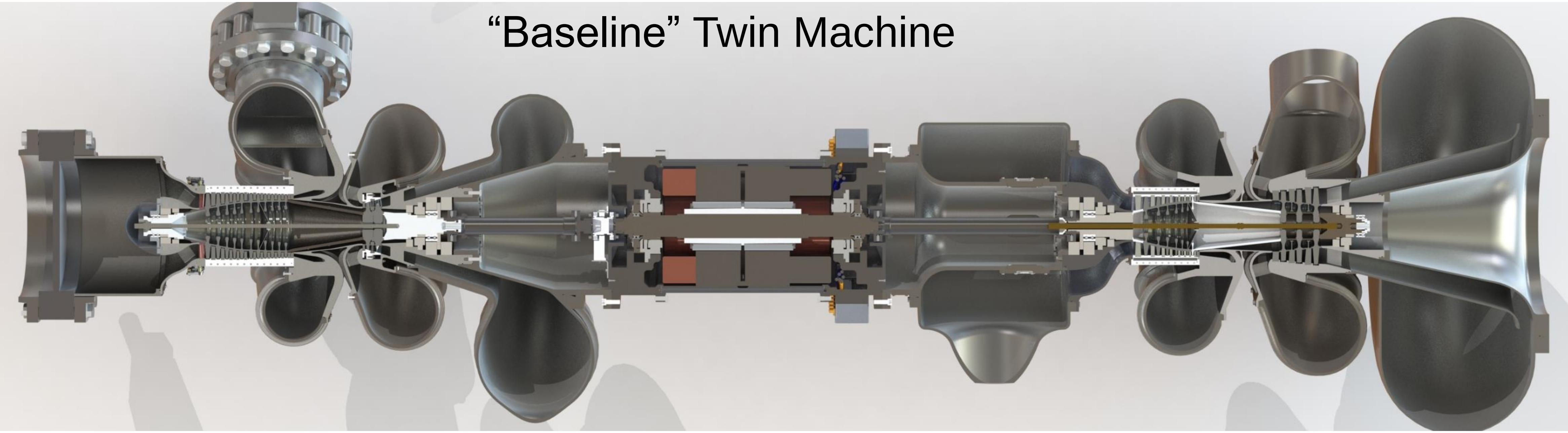
65% Round Trip Efficiency




**Advances in Aerodynamic Efficiency for Turbomachines**



# “Baseline” Twin Machine



- Aero reviewed by four prominent teams: Final Detailed Design
  - PCA
  - Turbo Solutions
  - Brayton & ConceptNREC
  - MIT  Gas Turbine Lab
- Thermal-structural
- Rotor system
  - Full rotor dynamic and structural design
  - Mag bearings complications

Alternator – a second generation product

- with our sponsored structural design by OEM
- Housing and Cooling – thru PDR
- Brayton purchases only magnet sleeve and wound stator.  Add shaft & housing

Power electronics- a second gen product

- highly customized – needs re-quote

# DAYS Progress on Cost vs Baseline

| DAYS 50 MW-e Summary | | Baseline 8.5MW | DAYS-50MW |
|---|---|---|---|
| Hot thermal storage | $/kWh | 59.0 | 19.4 |
| Cold thermal storage | $/kWh | 41.0 | 21.0 |
| **TOTAL Energy** | **$/kWh** | **100.0** | **40.4** |
| | | | |
| Turbomachinery | $/kW | 317.4 | 117.7 |
| M/G/ power control | $/kW | 200.0 | 50.0 |
| HX (recup + hot) | $/kW | 53.0 | 91.0 |
| HX cold and heat rejection | | not estimated | |
| BOP Mechanical Systems: ducting, piping, valves | $/kW | 141.6 | 70.8 |
| **TOTAL Power** | **$/kW** | **712.0** | **329.4** |

**Baseline**

- Separate custom gen and charge turbomachines
- Molten salt & hexane

**Brayton DAYS**

- Single duel purpose (reversible) turbomachine
- Particle thermal storage + water-alcohol or glycol

# Technology needs for successful PTES

- Custom turbomachinery: it's a very low pressure ratio machine with atypical operating temperatures
- A dual purpose turbomachine: two separate units are too expensive
- Ultra-high aerodynamic efficiency; punishing impact of irreversibility
- High temp thermal storage media: for safety and efficiency 700 to 800 ℃ (with no phase change at room temp)