Reversible Counter-Rotating Turbomachine to Enable Brayton-Laughlin Cycle

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Project Vision: *Develop the practical reversible gas turbine engine for a pumped thermal energy storage cycle.*

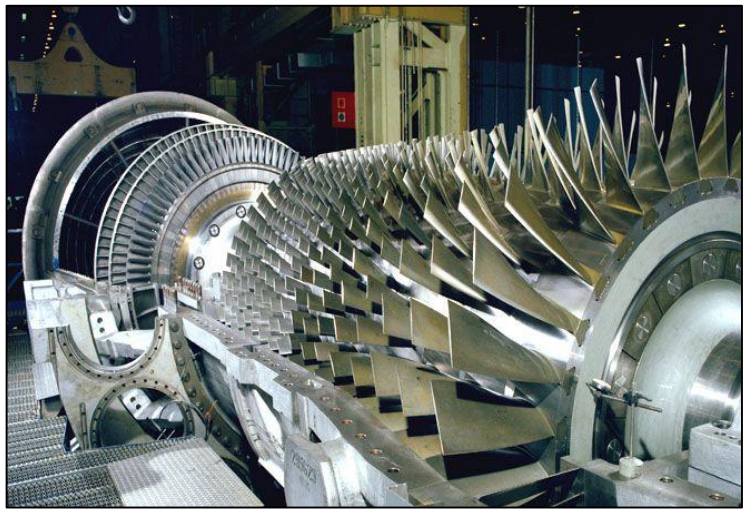
The Team

BraytonEnergy

- 50 person technical staff
- Turbomachinery for Advanced Energy Systems
- Performed pioneering R&D w/ Prof. Laughlin (2011-2015)
- Detailed design work for Google-X (2015-2018)
- 5 Acre campus, 38,000 SF; Testing & fab

Massachusetts Institute of Technology

- MIT Gas Turbine Lab
- Blade geometry aerodynamic optimization



Dr. Choon Tan

Prof. Ed Greitzer

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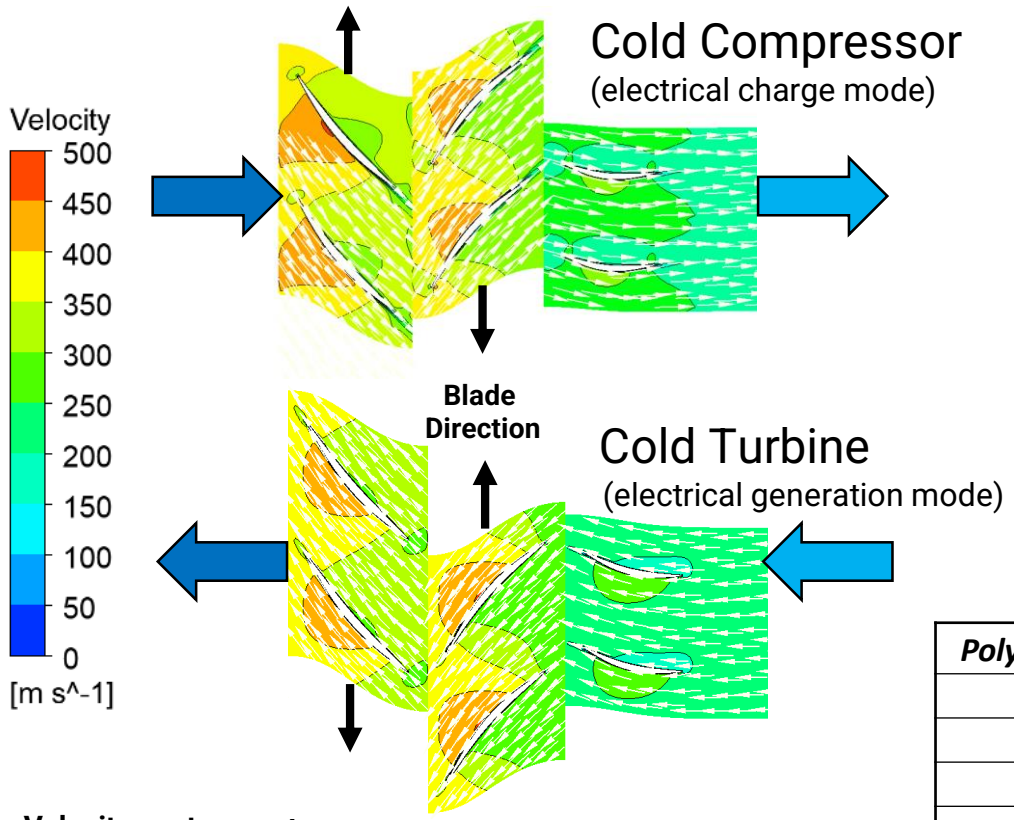
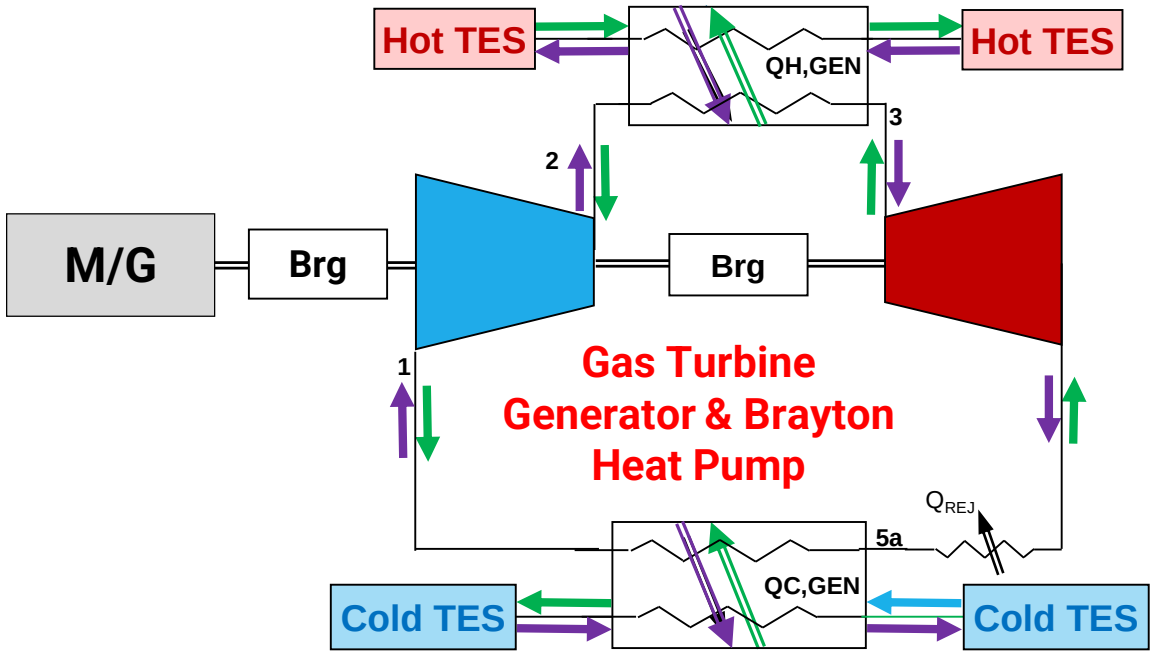
The Concept: Pumped Thermal Electric Energy Storage

Counter-Rotating Reversing Turbomachine*: *Nearly* Symmetrical Thermodynamics and Aerodynamics

Thin leading and training edges – incidence angles in both directions optimized for minimal deviation



Velocity contour and vectors at 50% span



Polytropic efficiencies	TT	TS
Cold compressor	0.945	0.927
Cold turbine	0.915	0.894
Hot compressor	0.920	0.901
Hot turbine	0.935	0.914
Average	**0.929**	**0.909**

ELECTRICAL CHARGE MODE
A heat pump

ELECTRICAL GENERATION MODE
A gas turbine genset

* patent pending

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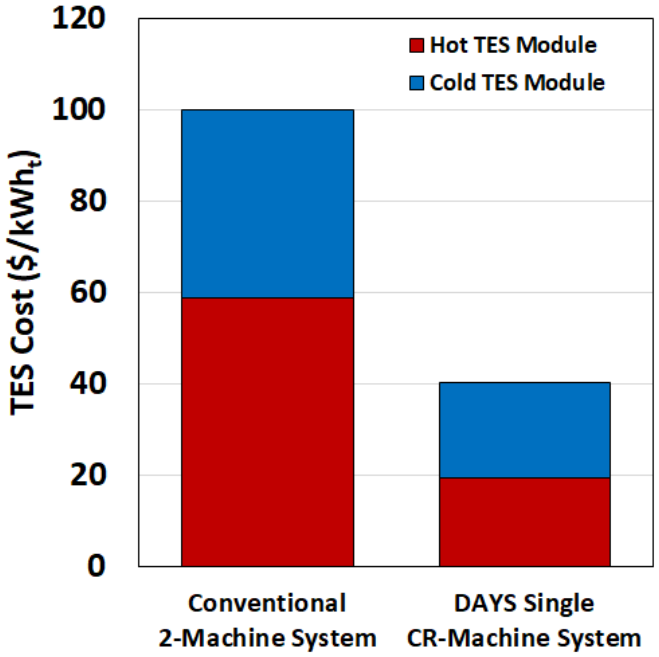
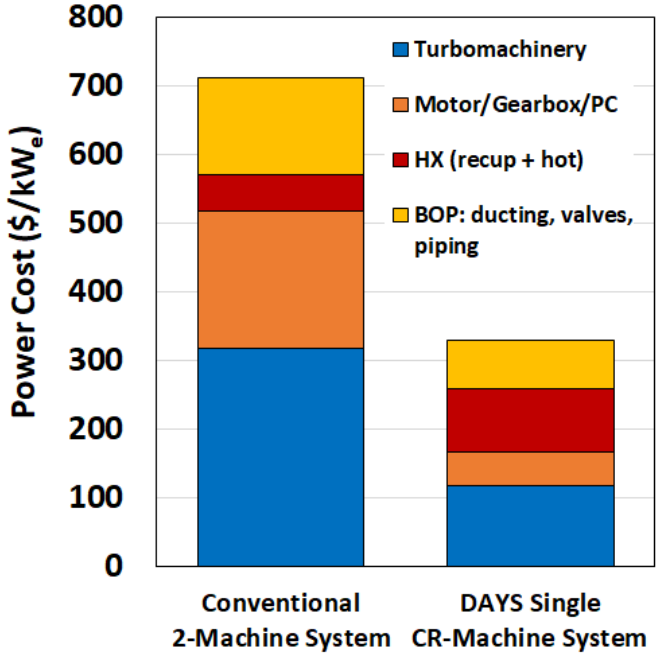
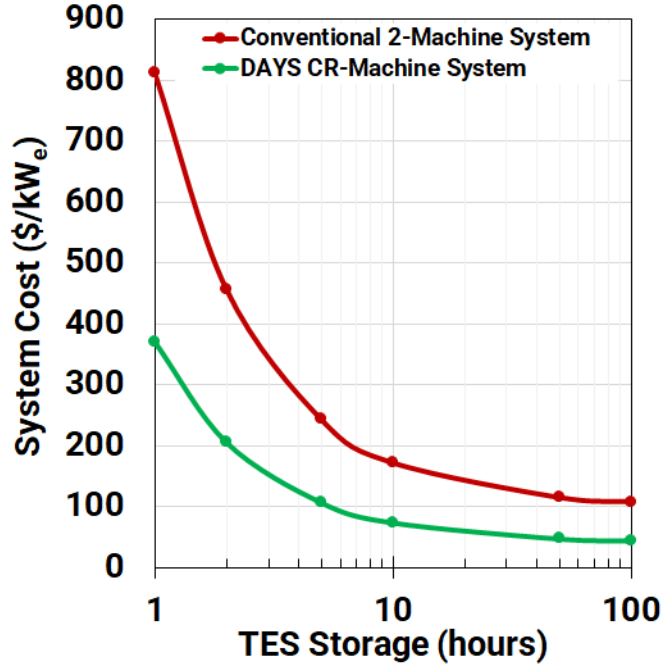
The Economic Advantage

- Conventional design practice suggests separate machine for the Brayton cycle heat pump and the Brayton cycle turbine generator.
- The ducting and valves to use two separate turbomachines sharing common recuperator, hot heat source, cold storage, and heat rejection HX results in high losses and costs.



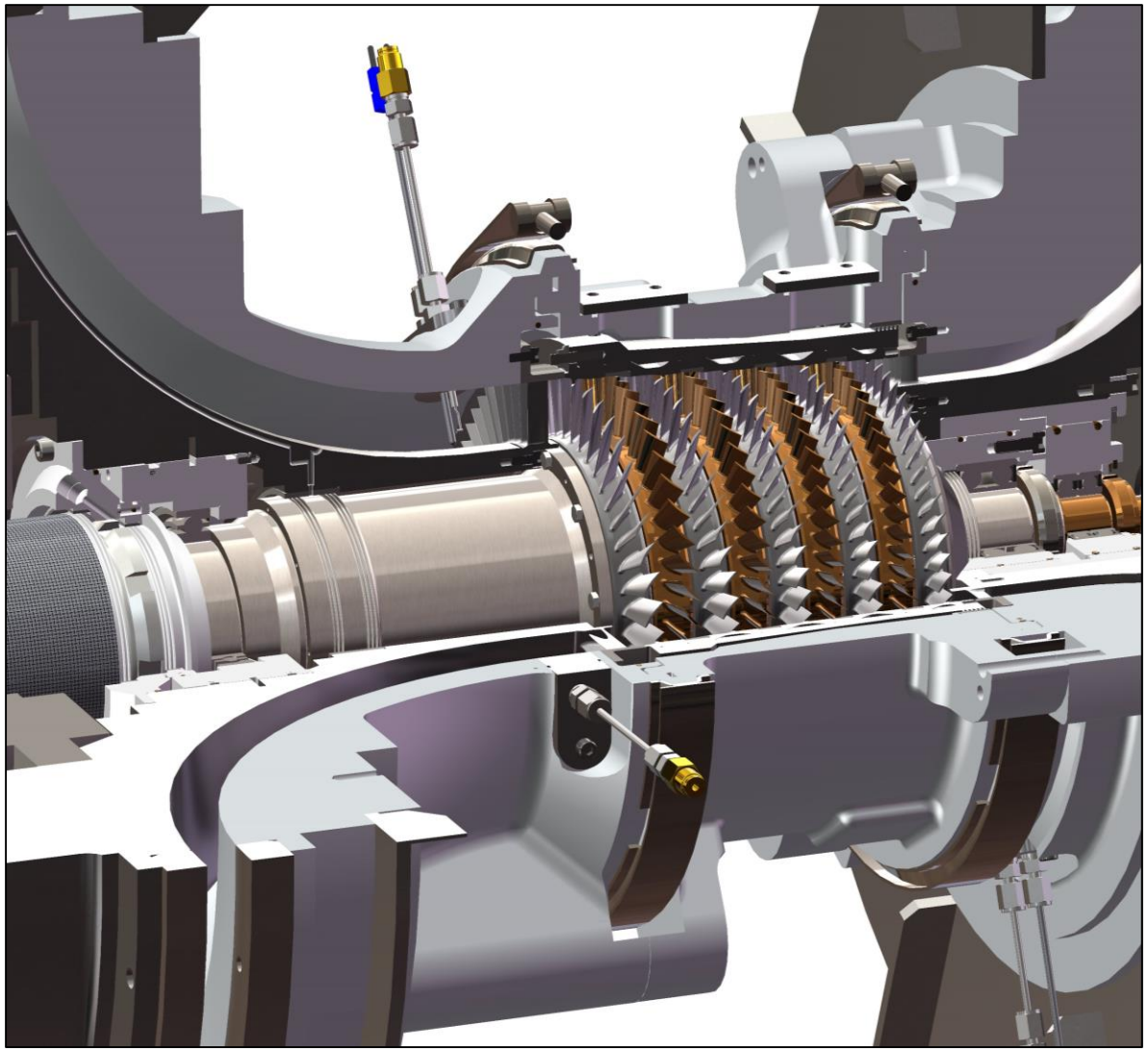


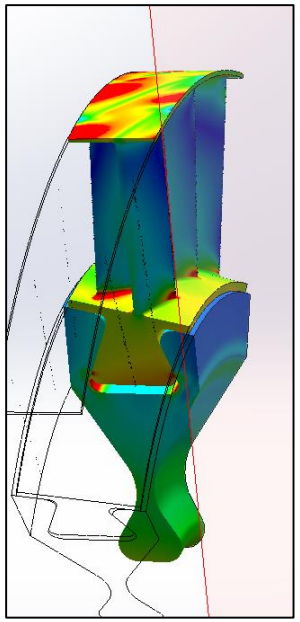


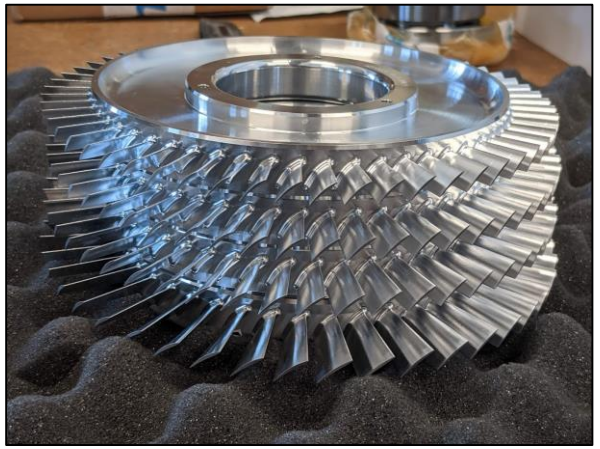
  - Consolidation into one machine can be achieved via a full set of interstage variable position stators, or with the simpler counter-rotating turbomachine; either design represents a major economic breakthrough for the energy storage cycle.
    - DAYS TES may eliminate the recuperator, which is required conventionally to match operating temperature range to molten salt constraints

** Conventional system based on prior work: separate charge and generating turbomachines w/ switching valves, interconnecting piping, and molten salt TES DAYS system employs solid particle hot TES system, leveraging Brayton and Sandia Gen3 learnings*

Counter-Rotating Layout and Hardware







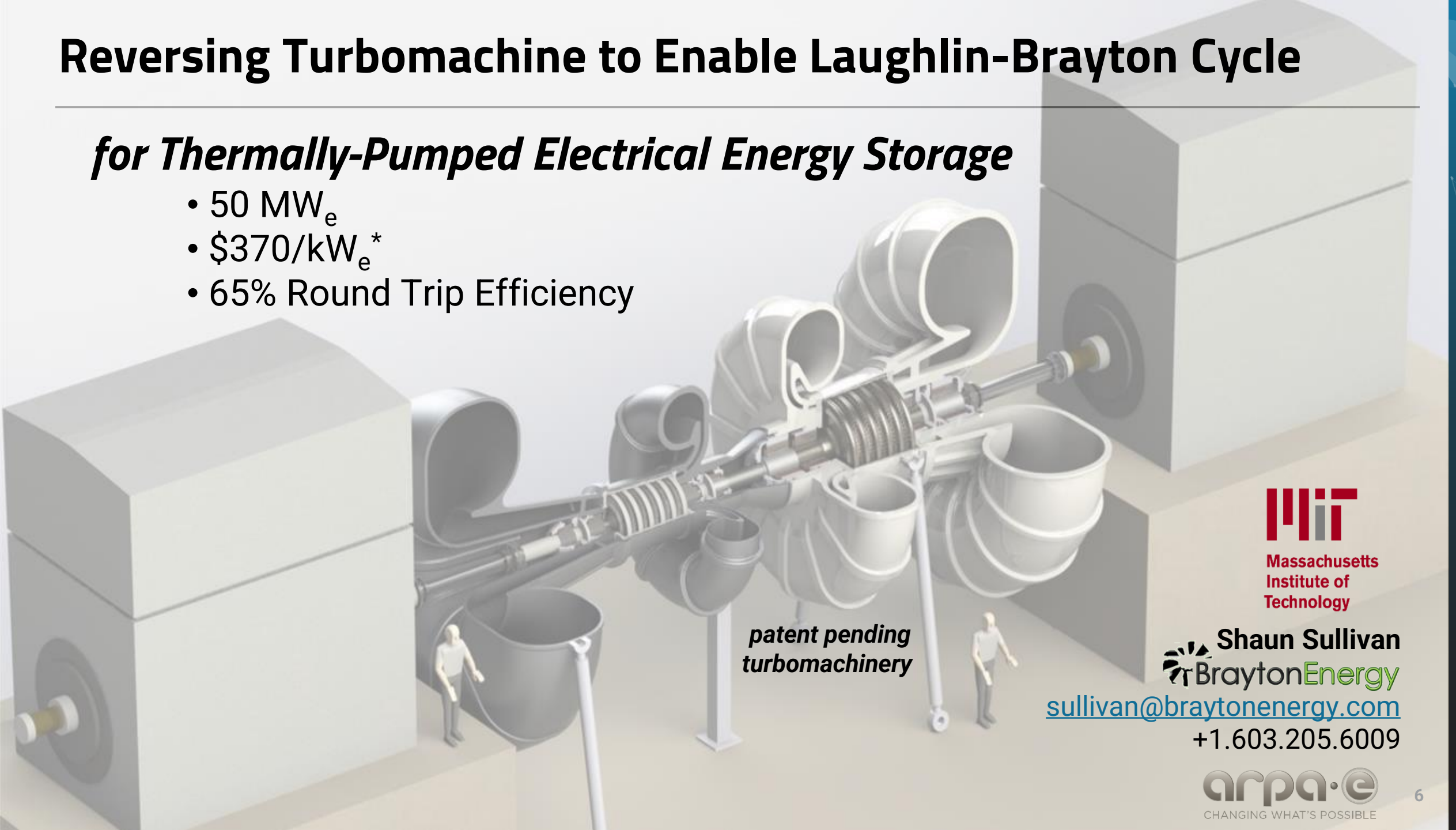
Next Steps at Brayton

- Fabricating 1/5th scale turbomachine – to test in both modes
- Evaluating salts, sand particles, and other appropriate thermal storage systems
- Controls and transient modeling, with rigorous attention to physical parameters of this turbomachine, the interconnecting ducting, heat exchangers, and a practical system layout
- Seeking strategic partners to build full scale system
  - Dual-function turbomachine
  - Hermetic magnetic bearings
  - No gearbox, frequency conversion (inverter)
  - Turbine-compressor polytropic efficiencies averaging over 93%

Reversing Turbomachine to Enable Laughlin-Brayton Cycle

for Thermally-Pumped Electrical Energy Storage

- 50 MW_e
- \$370/kW_e*
- 65% Round Trip Efficiency



patent pending turbomachinery

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