







sCO₂ ... Research to Reality

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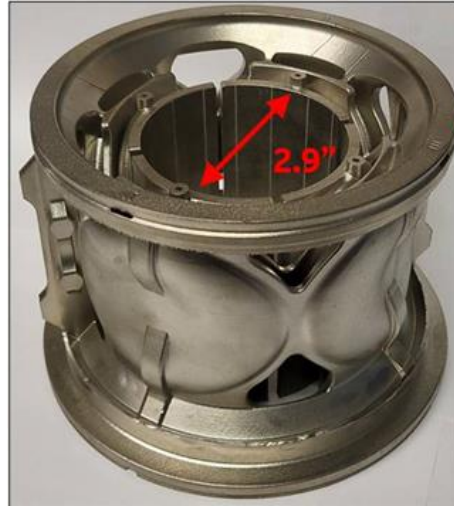
sCO2 Power Cycle Walk

Technology	Current Programs <i>percent-3 yrs</i>	TRL	Where are the GAP <i>3-5+ yrs</i>	Connection to GE Roadmap
Fossil Gen Oxy-Fuel 	<ul style="list-style-type: none"> ✓ ARPA-e (\$700K) ✓ DOE FE: SwRI (primes) (\$1M) 	<ul style="list-style-type: none"> ● Expander ● Heat source ● Compressor ● Heat Exchangers 	<ul style="list-style-type: none"> • Scale-up • Expander inlet temperature • Limited retrofit opportunity 	<ul style="list-style-type: none"> ✓ 19% gap requires NG powered resources ✓ Decarbonized by process ✓ H2 Economy
Waste Heat Recovery 	<ul style="list-style-type: none"> ✓ DOE FE Bearings (\$3M) ✓ DOE FE/SETO STEP (\$12M ... \$140M) 	<ul style="list-style-type: none"> ● Expander ● Heat source ● Compressor ● Heat Exchangers 	<ul style="list-style-type: none"> • Efficiency Challenge vs Recip Engines • Variety of Markets limits standardization 	<ul style="list-style-type: none"> ✓ 19% gap requires NG powered resources ✓ Carbon intensity reduction ✓ Fast starting / flexibility
REN Gen Concentrated Solar Power 	<ul style="list-style-type: none"> ✓ DOE SETO <ul style="list-style-type: none"> ✓ Bearing (\$3M) ✓ Near Net Shape HIP (\$2M) 	<ul style="list-style-type: none"> ● Expander ● Heat source ● Compressor ● Heat Exchangers 	<ul style="list-style-type: none"> • GE content low fraction of CAPEX • Overall CSP system needs to meet LCoE targets 	<ul style="list-style-type: none"> ✓ Large growth in renewables ✓ 24/7 solar capability with TES
Nuclear 	<ul style="list-style-type: none"> ✓ Several commercial interests 	<ul style="list-style-type: none"> ● Expander ● Heat source ● Compressor ● Heat Exchangers 	<ul style="list-style-type: none"> • Paced by advanced reactor timeline 	<ul style="list-style-type: none"> ✓ Small modular reactors support higher temperatures ✓ sCO2 higher efficiency at higher temperatures

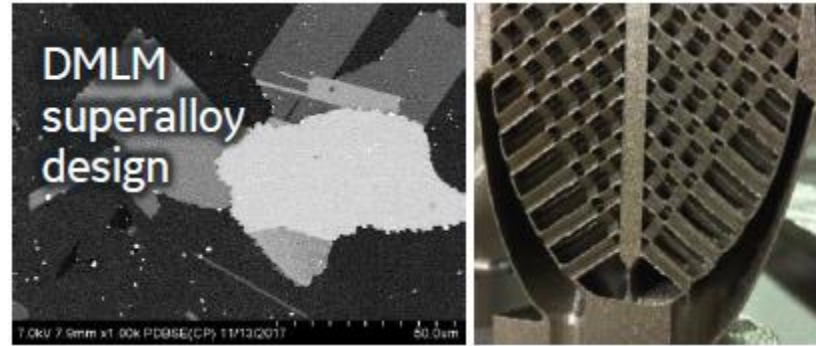
Commercial Roadmaps Still Challenged

GE Research Strategy

Key to address commercial challenge: incorporate technologies that increase performance, lower cost, and/or enhance ancillary benefits.



Process lubricated gas bearings
Hermetically sealed turbomachinery



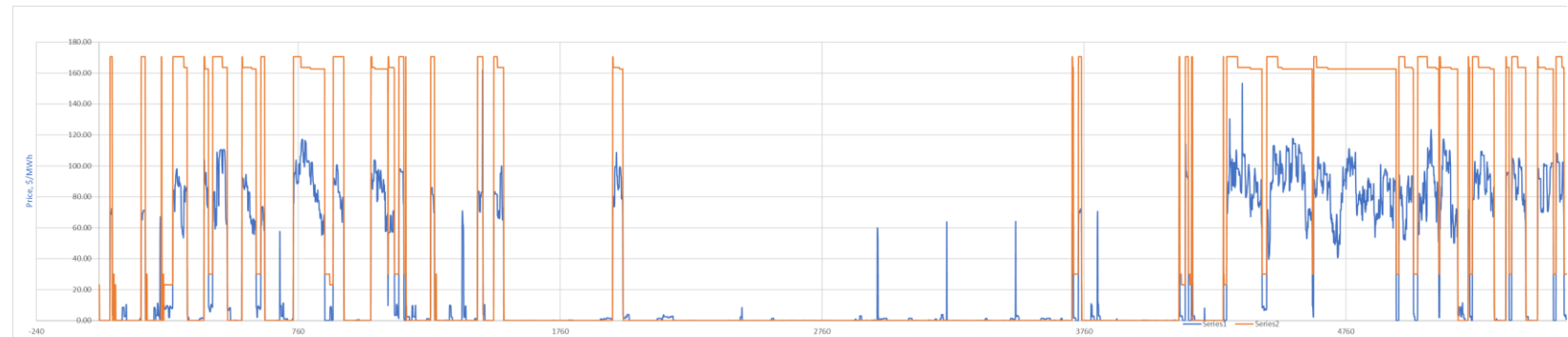
Additive heat exchangers:
Up to 900C capability; over 50%
reduction in size and cost



Advanced sealing capabilities without
limit to temperature and/or size



Advanced manufacturing modalities
~50% cost reductions



Complex economic modeling – dispatch strip charts

Traditional GE products



GE Strategy – traditional turbomachinery

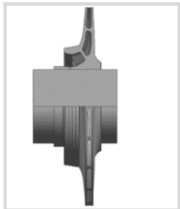
Components



Advanced manufacturing



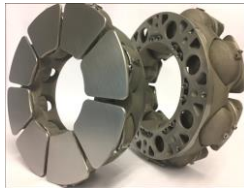
NNS HIP



Real gas aerodynamics

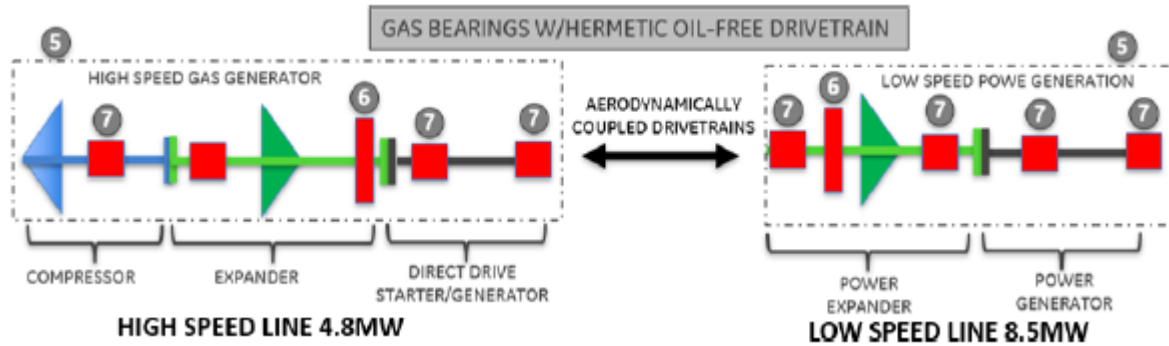
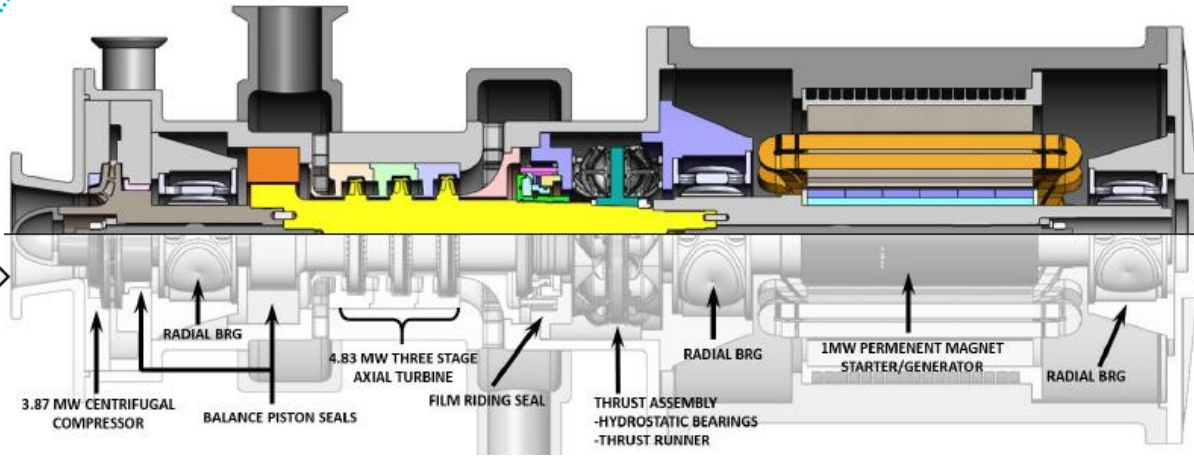


Low leakage seals



Gas bearings

System Architectures

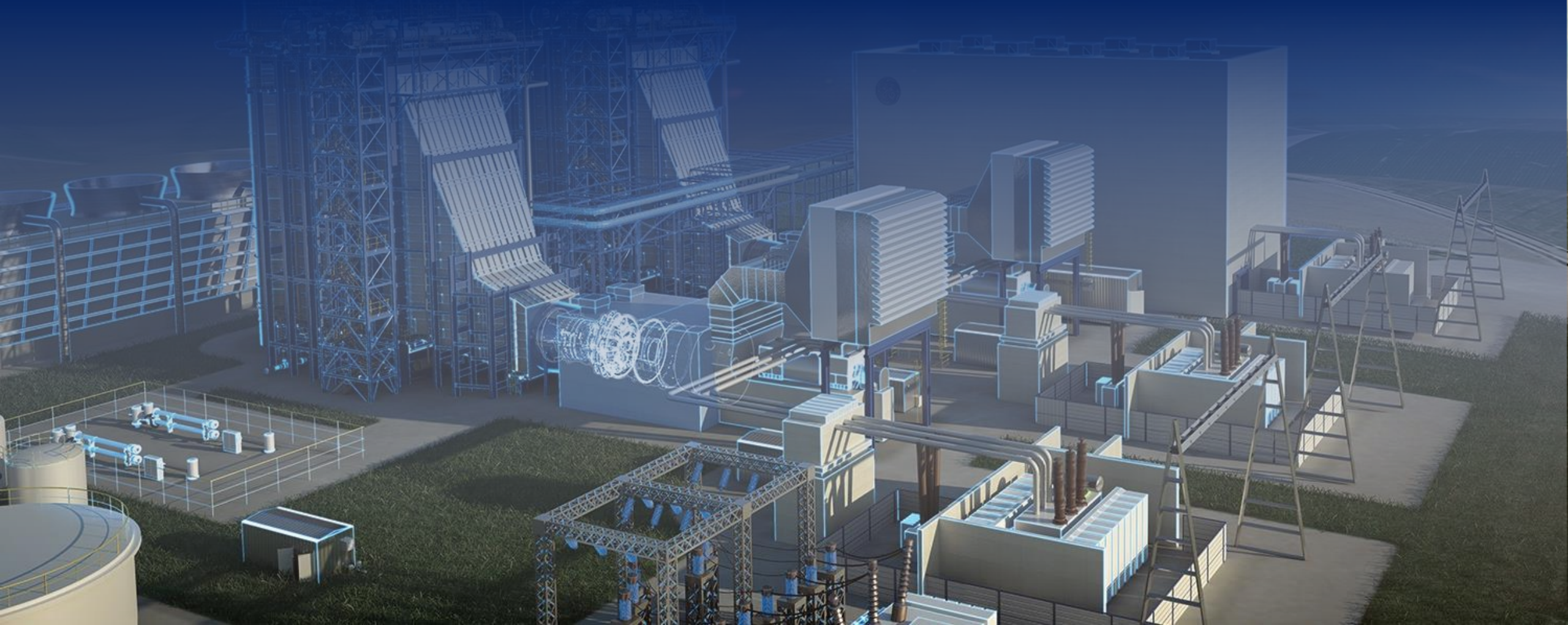


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Driving component technologies in parallel with system architectures advancements



Non-traditional products



Additively-enabled trifurcating heat exchangers



Technology Description

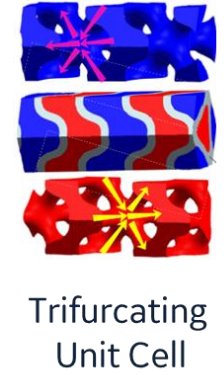
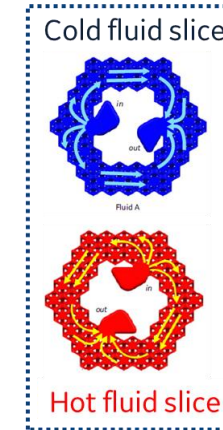
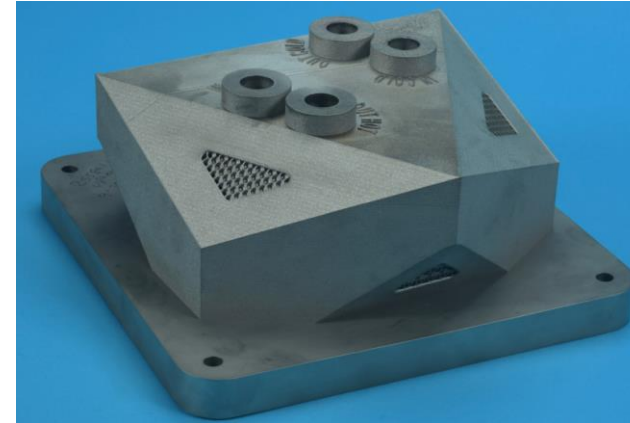
- Compact, low-pressure loss, counterflow HX
- Direct Metal Laser Melting (DMLM)
- Up to **2X power density** of conventional HXs
- GE tri-furcating design enables **$\Delta P/P$ of $<0.5\%$**
- GE superalloy enables max **$900^{\circ}\text{C} / 250 \text{ bar}$**
- TRL4 / MRL4 / CRL4

Markets

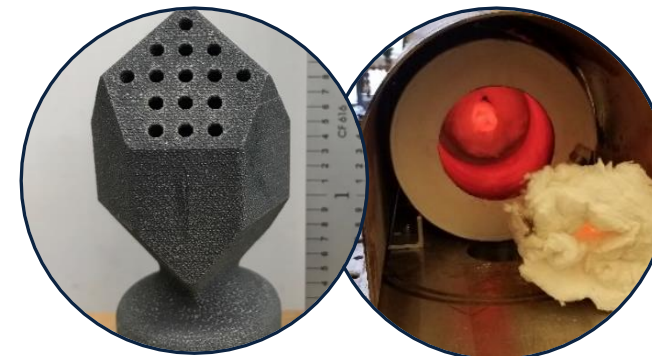
- Aviation: A/C propulsion, environmental cooling
- Power: sCO₂ cycles, nuclear
- Chemical processing

Opportunities

- **Seeking partners** for government-funded tech maturation opportunities towards commercial **scale-up** and technology **licensing**



Air / sCO ₂ HX		Conventional	GE Trifurcating
Material		Stainless steel, commercial high temperature alloys	GE AM303
Max Temperature	C	750	900
Power Density	kW/kg	2	4



Successful 2021 sub-scale tech demo

- ✓ $>200 \text{ bar}$
- ✓ $>900^{\circ}\text{C}$

Binderjet Additive Trifurcating Heat Exchangers



Technology Description

- Compact, modular, high temp. HX enables lower cost relative to conventional HXs (PCHEs etc.)
- Binderjet additive - **10x faster** than DMLM
- **Trifurcating** geometry → **>2X power density**
→ **>50% less material**, $\Delta P/P$ of ~2%
- SS316L prototype designed for **590°C / 260 bar** (higher temp alloys possible)
- TRL4 / MRL4 / CRL4

Markets

- Aviation: A/C propulsion, environmental cooling
- Power: sCO₂ cycles, nuclear, waste heat rec. etc
- Chemical processing

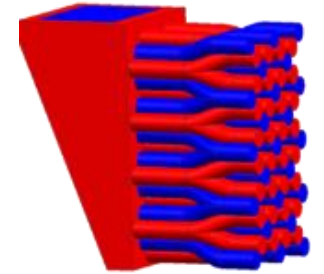
Opportunities

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Printed, de-powdered, & sintered SS316L HX cores



Trifurcating geometry



Representation of fluid flow

sCO ₂ HX	Unit	Leading HX Vendor	GE Technology
Style	-	Diff. Bonded μ -channel	Trifurcating Unit Cell
Material	-	Stainless Steel	SS316L
UA	W/C	1379	2.5e6
Specific Power	kW/kg	2.0	4.3
Power Density	MW/m ³	14	50

Modular assembly of overall HX



Near-Net-Shape Hot Isostatic Press Manufacturing Modality



Technology Description

- Reduced 2~3X volume of material vs wrought
- Reduced machining costs
- Reduce welds & weld repair
- Chemical & structural homogeneity
- Ultrasound inspectability
- TRL5 / MRL5 / CRL3

Markets

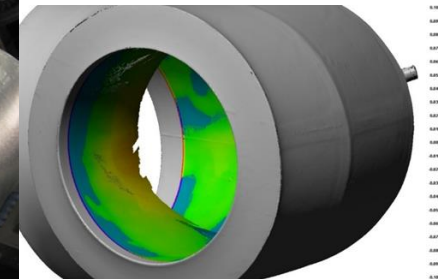
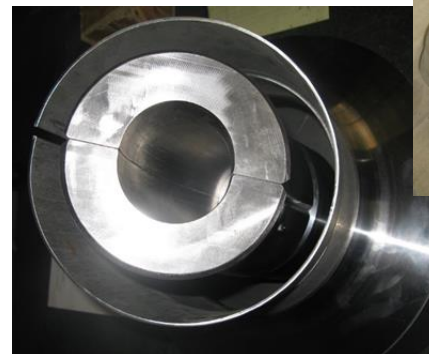
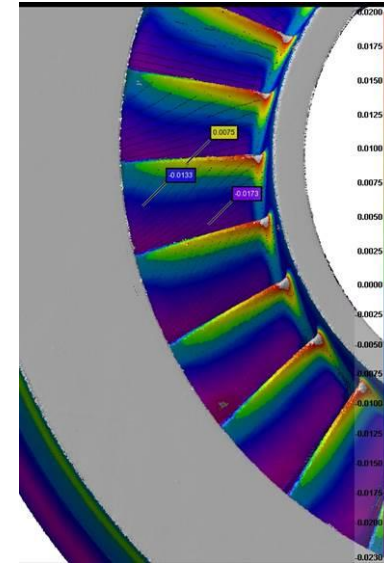
- High temperature piping components
- Valve bodies

Opportunities

- **Seeking partners** for tech maturation opportunities towards commercial **scale-up** and technology **licensing**



**Net-shape airfoil
> 60% \$/kW cost
reduction than
machining from
forging**



**Net-shape pipe components
> 50% \$/kW cost reduction than
machining from forging**

