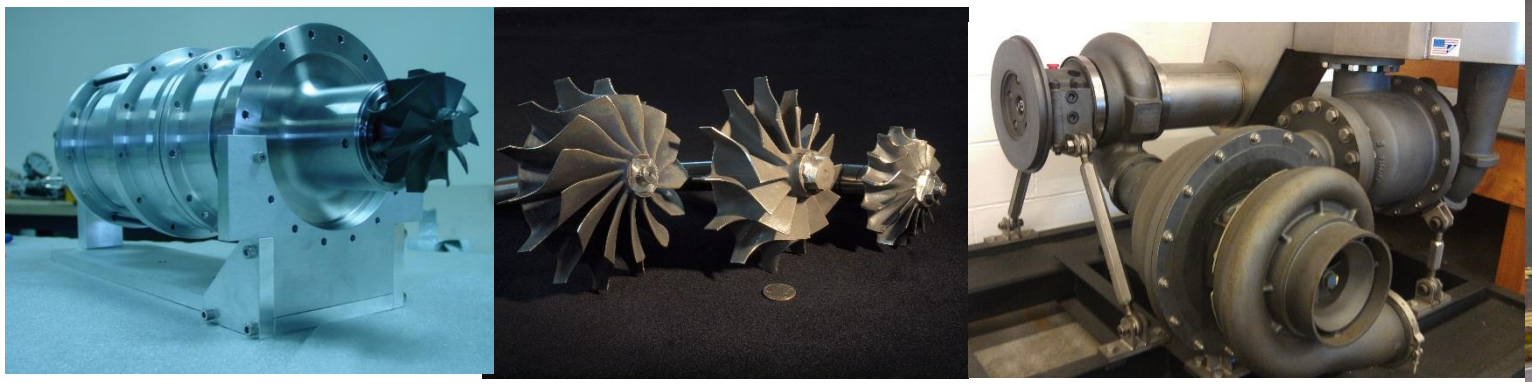
Brayton Energy LLC

ARPA-e 1kW GenSET

Established 2004
Located in Seacoast of New Hampshire
35 Engineers, Designers and Technicians

Research and Development of:
- Micro gas turbines
- Heat exchangers & combustors
- Solar receivers & energy storage

Facilities: 28,000 square-ft facility, including:
- CNC machining center for metals & ceramics, weld & assembly shop
- Turbomachinery test stands: aerodynamics, combustion, emission testing
- Recuperator pilot manufacturing plant: vacuum braze oven, auto-core welders



Core competency hardware design & manufacturing of Brayton Energy

Brayton Energy 28,000 sq./ft. Campus, Hampton NH

Brayton Energy LLC

ARPA-e 1kW Technologies

arpa·e CHANGING WHAT'S POSSIBLE

Main Concept of Project:

- 1kW Recuperated Brayton-Cycle Engine Using Positive-Displacement Components.
- Demanding life and reliability factor
- Combined heat & power (CHP) with delivery high temperature (>80C)

Why its unique:

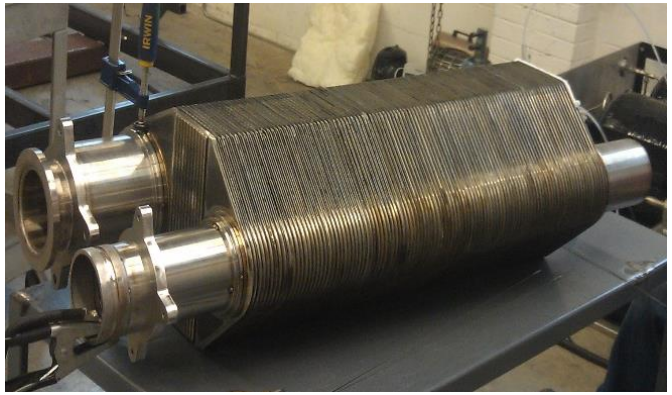
- Tiny power and ultra high efficiency make traditional turbomachinery targets *intractable*: bound fundamentally by Reynolds Numbers, trailing edge thickness, and other practical design features.
- Screw compressor & expanders dominate the small air compressor market (below centrifugals). Minimal Reynolds Number effects, and larger scale.

Brayton Energy LLC

Gas Turbine / Microturbine Technology Development Program

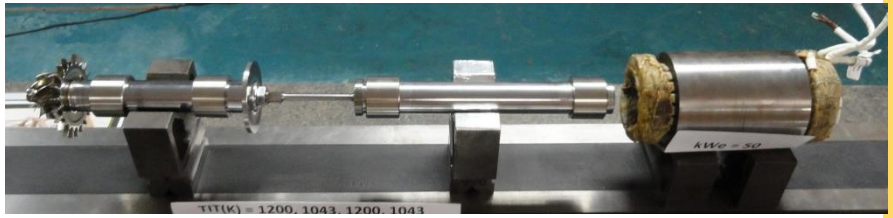
arpa·e CHANGING WHAT'S POSSIBLE

TECHNOLOGY



Strain-tolerant gas turbine recuperators

Air bearings up to 180,000 RPM

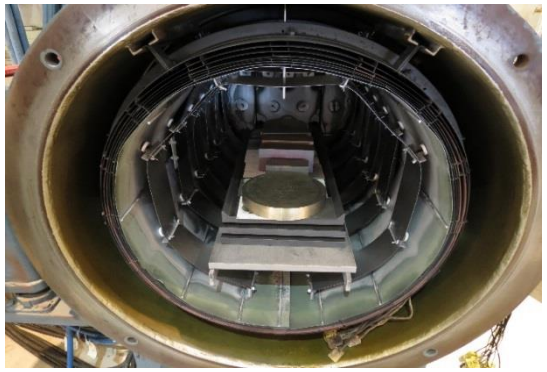


Small Turbomachinery Design/Mfg/Test

Microturbine & Gas turbines systems from:

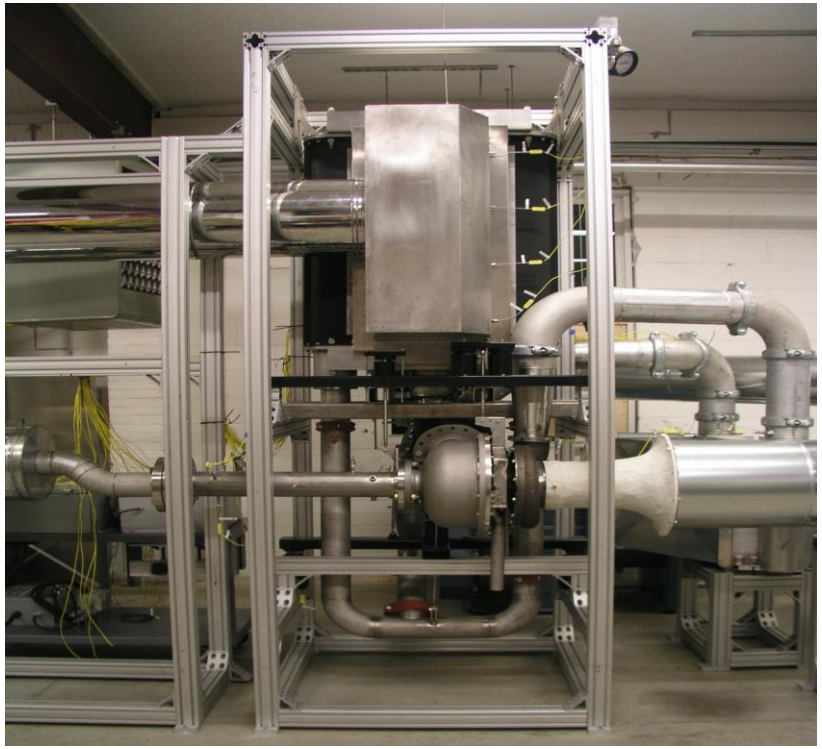
- **250 W (space power), 1.5 kWe Air Force, 12 kWe commercial**
- **50, 60, 80 & 350 kWe: vehicular**
- **1.2 & 2MW gas turbine engines**
- **20 to 300 MW recuperators**

In-house MANUFACTURING



Combustor Technology

Gas Turbine Hot Testing



Emissions	Stationary	Distributed Generation	Class-8 Trucks	ICR350 (Test*)	
	EPA Tier 4 g/bhp-hr	CARB g/kWh	CARB/ EPA g/bhp-hr	g/kW_eh	g/bhp-hr
NO_x	0.3	0.032	0.2	0.015	0.010
CO	2.6	0.045	15.5	0.031	0.021

**Brayton MT measurements with no after-treatment*

- Operate to TIT of 1100°C
- Testing 3 to 40 inch combustors
- Fuels: natural gas, propane, diesel & bio-oil
- Highly instrumented performance, emissions, thermal imaging, acoustics
- Proven formula for meeting CARB

GenSET Challenges & Impact

Technical Challenges:

- 40% net electrical efficiency with high (80C) availability.
- Expander and compressor efficiency and manufacturing with ceramics.
- Heat Exchanger; pressure losses, premature oxidation & Thermo-mechanical fatigue.
- Alternator and bearing losses.

Industry Challenges:

- Integration with utility services
  - Net metered, surcharges & utility rate structure
- Competitive, utility-friendly solar PV power systems
  - Effective power producing during peak demands.

Expected Impact if Successful:

- Reduction of electrical grid use/ dependency.
- Deployment of field units.
- Further technical development of 3kW or 5kW units.

Resources Needed:

- None

Brayton-developed in-house green-machining process