Novel Energy Systems for Distributed and Mobile Power Generation

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Outline

- Semi-closed cycle description
  - Use in distributed generation
  - System benefits and challenges
  - Analytical and experimental results
  - Discussion and Conclusions
- DMFC introduction and system description
  - Advanced architecture
  - Application focus
  - Status and challenges

What Do We Want from a Power System?

- Efficiency, compactness, low cost…

- We really want a "best friend"
  - Helps you be comfortable
  - Doesn't intrude on your space
  - Anticipates your needs
  - Is there when the chips are down
  - Doesn't ask for money

How Does Current System Do?

- Comfort from major appliances
  - Need electricity from grid, gas from pipe, water from pipe
  - Disruptions unless all distribution systems work - vulnerable
- Intrudes on our space a little
  - Emissions
  - Transmission lines
  - Geopolitics (non-renewable fuels)
  - Local maintenance
- Anticipates needs well - except transmission lines
- Displays character flaws when chips are down
  - Hurricanes
  - Homeland security
- Sneaky expensive

Disaster Infrastructure?

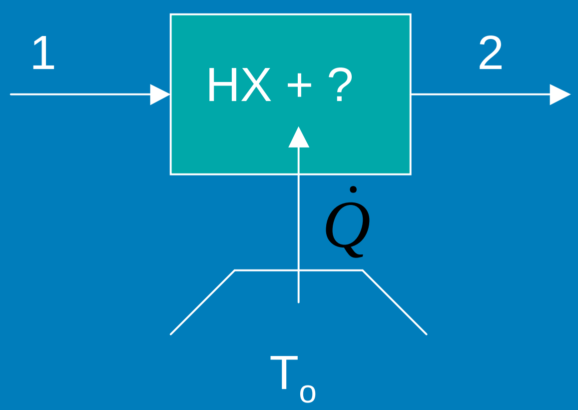

FEMA
EMERGENCY
RELIEF
TRANSTAR
KYU 016301

Distributed Energy

- Smaller engines installed near loads
- CCHP - local cooling, heating, power
- Efficiency not bad
  - Include cooling (how?)
- Local transmission, robustness, process heat/cooling
- Disadvantages: Cost, space, noise (esp. Diesel), maintenance…don't run continuously

Waste Heat Cooling Potential

- How cold can State 2 be?
- Ideal gas, reversible process, isobaric, zero work
- 1st & 2nd Laws, Gibbs eqn:



$$\dot{Q} = \dot{m}(h_2 - h_1)$$

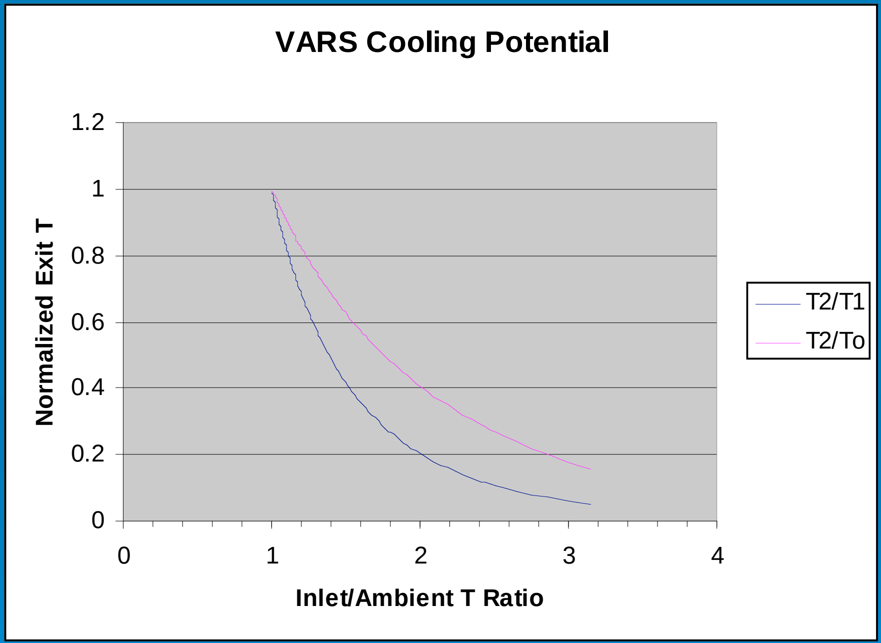
$$\frac{\dot{Q}}{T_o} \le \dot{m}(s_2 - s_1)$$

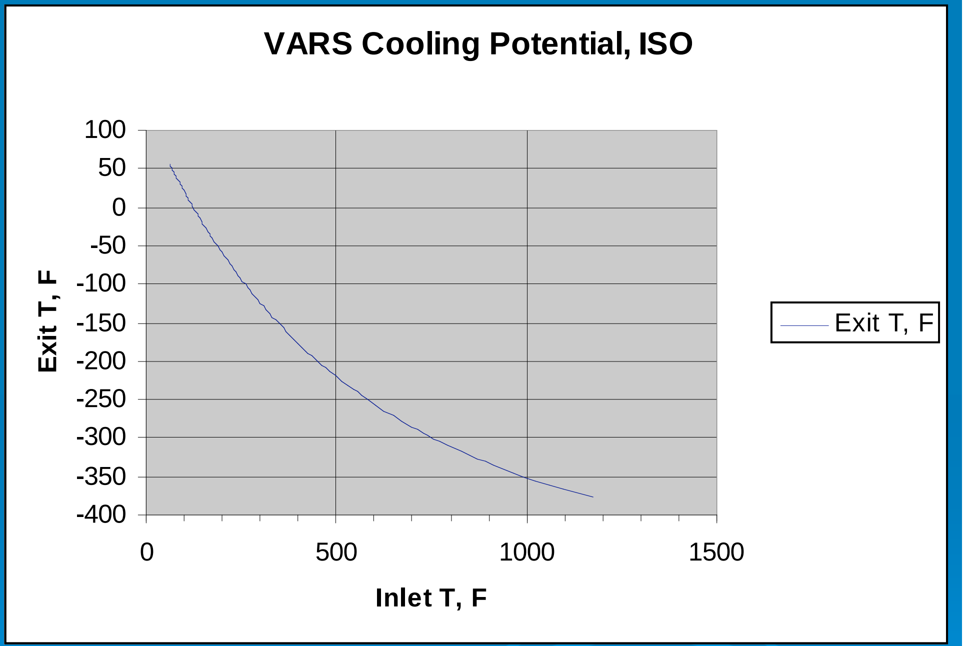
$$s_2 - s_1 = C_p \ln\left(\frac{T_2}{T_1}\right)$$

- Result:

$$\frac{T_1}{T_o} = \frac{\ln\left(\frac{T_2}{T_1}\right)}{\frac{T_2}{T_1} - 1}$$

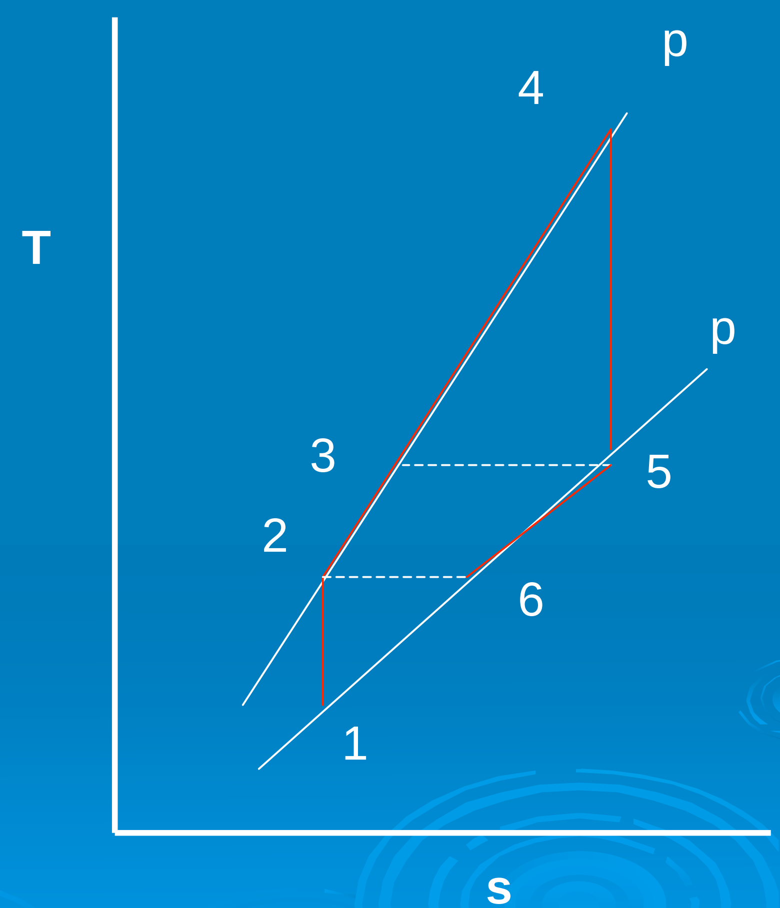
Cooling Potential - Results



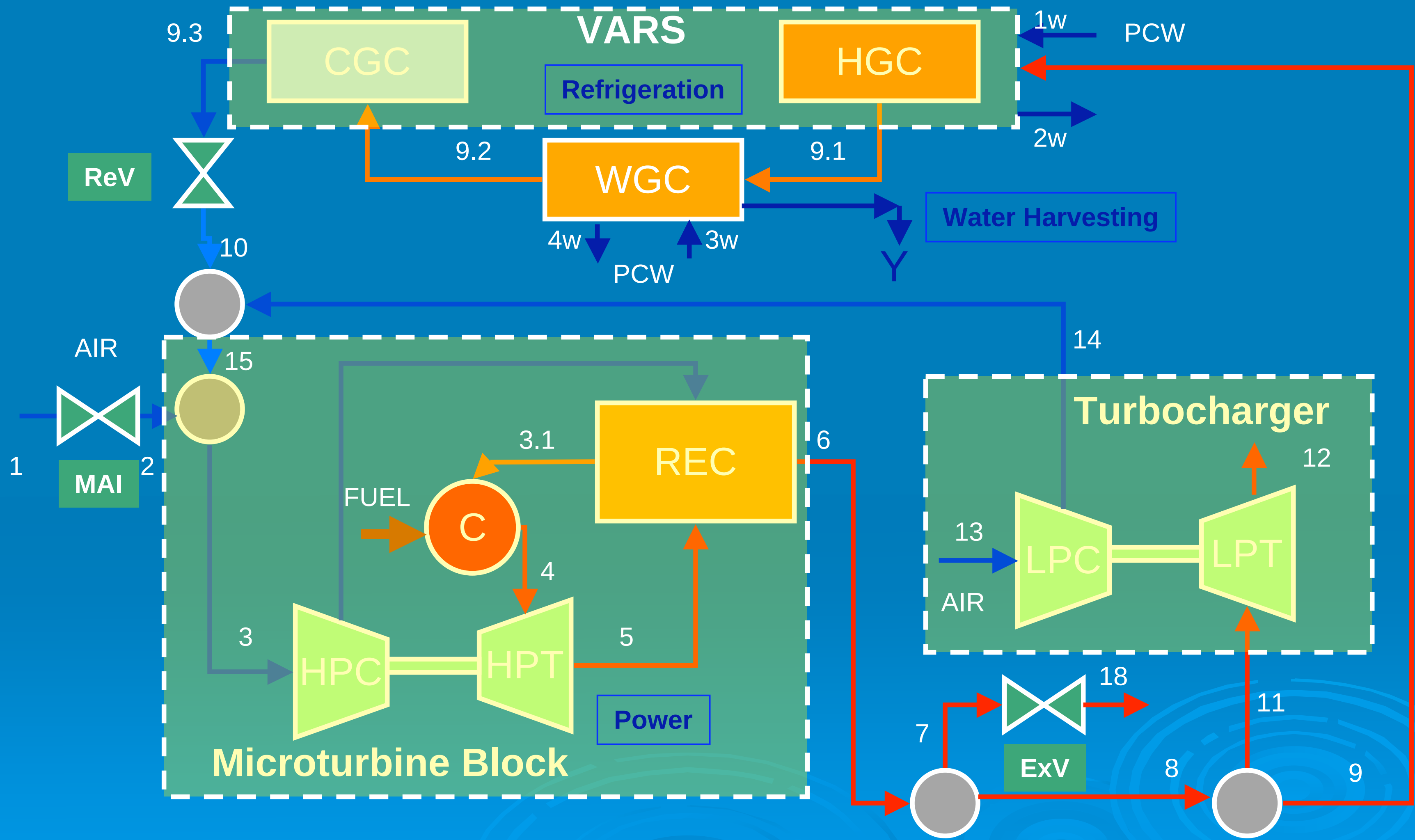


Gas Turbine Recuperation

- Low pressure ratio
  - Typically small engines
  - Centrifugal compressor, but not necessarily
- Flat efficiency curve
- Desire high combustor inlet T
  - $T\,ds = \delta Q$
  - High T gives small ds
  - High p ratio unnecessary



Power, Water Extraction and Refrigeration (PoWER) System



HPRTE Advantages

- Increased efficiency/high part-load efficiency
  - “Inlet” temperature low
- Increased specific power and compactness
- Ultra-low emissions
- Low intake filtration, exhaust handling
- Small lapse rate with temperature
- Water extraction (mostly with VARS)
  - Load leveling
  - Emergency drinking water
  - Ice
  - Couple to steam gasification

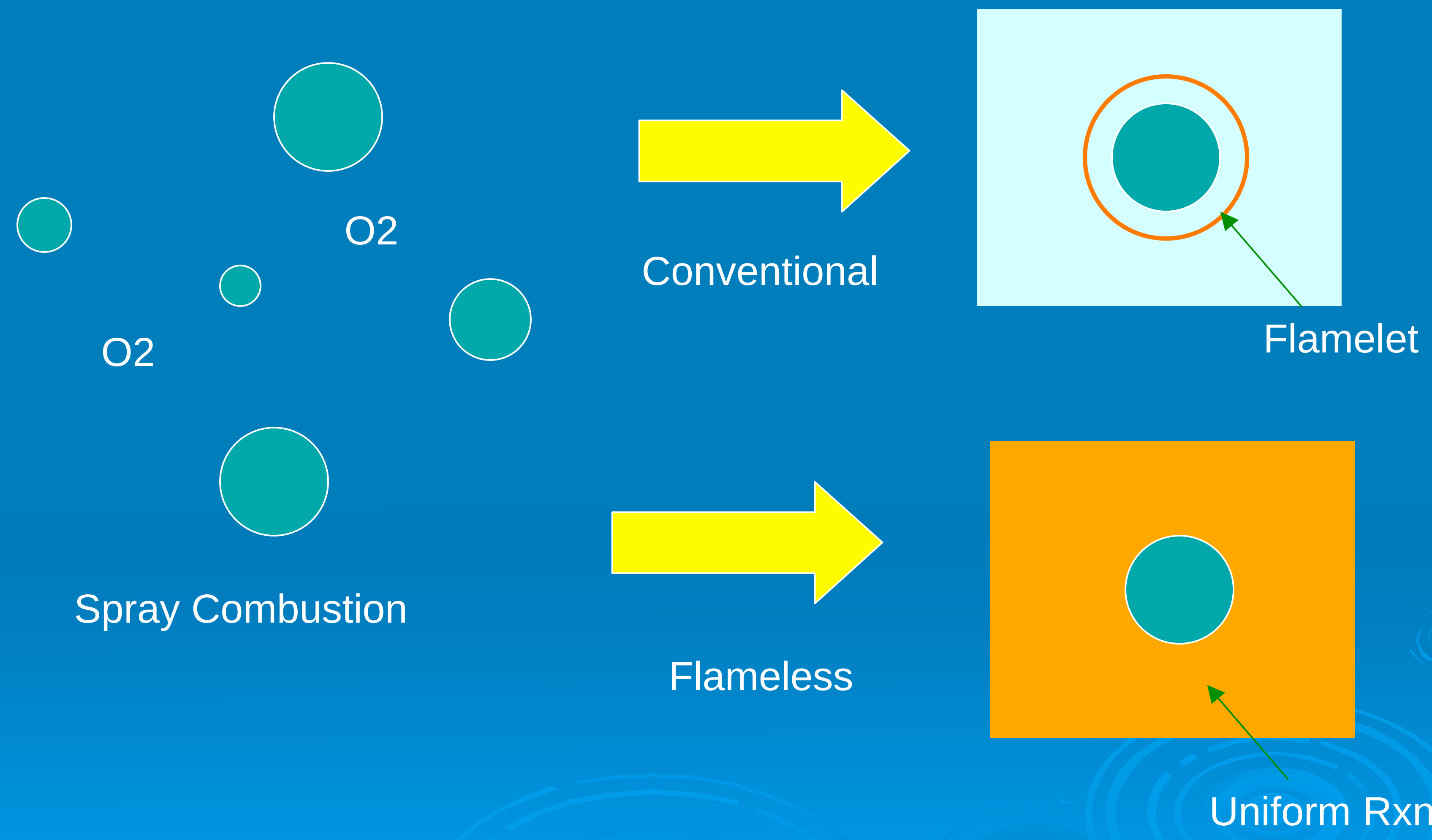
System Benefits of PoWER Distributed Energy

- Complete local service
  - Power, refrigeration, fresh water, heat
  - Normal mode:
    - AC load, use water for peaking
    - Design for max efficiency or AC/power blend
    - Controlled by utility to follow loads
    - Efficiency & emissions warrant high usage
  - Emergency mode:
    - Local loads met, decreasing widespread impact
    - Switch to icemaking
- Compactness, decreased siting requirements
- Life-cycle costs competitive

Flameless Combustion

- Multiple Definitions in literature
  - Absence of broadband luminosity
  - Reaction zone uniformity
- Implementation
  - Low heating value fuel
  - Dilute fuel with products (cooled)
  - Dilute oxidizer stream
- Advantages
  - Low emissions
  - Fuel flexibility

Flameless Combustion



Fuel Flexibility/Emissions

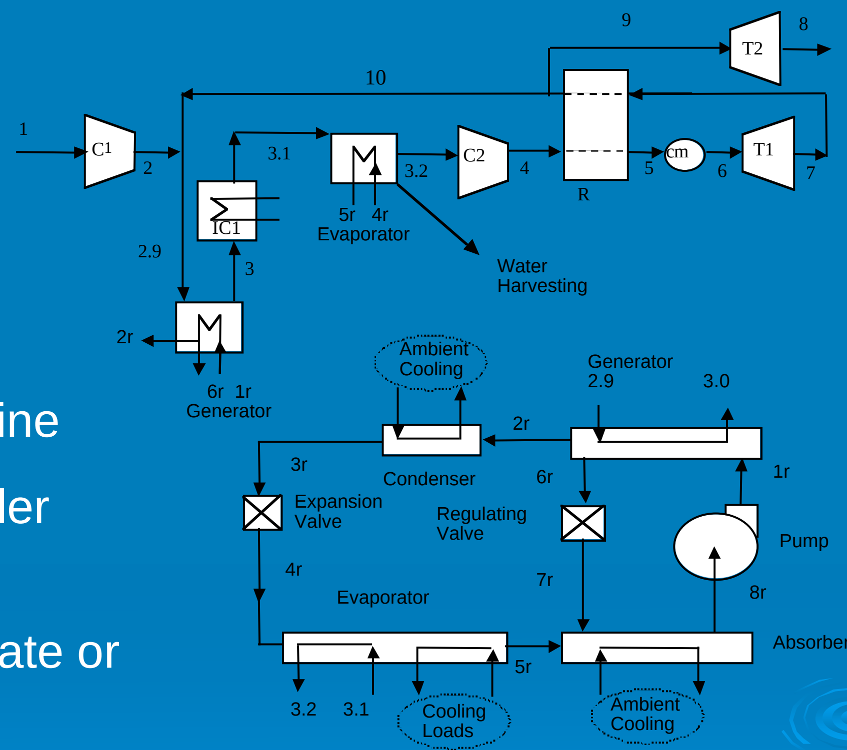
- Flameless combustion regime
  - Low luminosity (neglegible soot)
  - Flame uniformity
- Flame chemistry
  - Damkohler number order unity
  - Oxidation reaction distributed
  - Limited pyrolysis due to oxidation radicals

High Recirculation Combustion Facility

PoWER System (…Continued)

- Semi-Closed Cycle Engines and Flameless Combustion
  - More Uniform Combustor Conditions
  - Flatter Efficiency Profiles
  - Fuel Flexibility
  - Lower Flame Temperatures
  - Lower NOx Emissions
  - Lower Flame Luminosities
- Suitable for distributed energy systems

Part-Power Efficiency

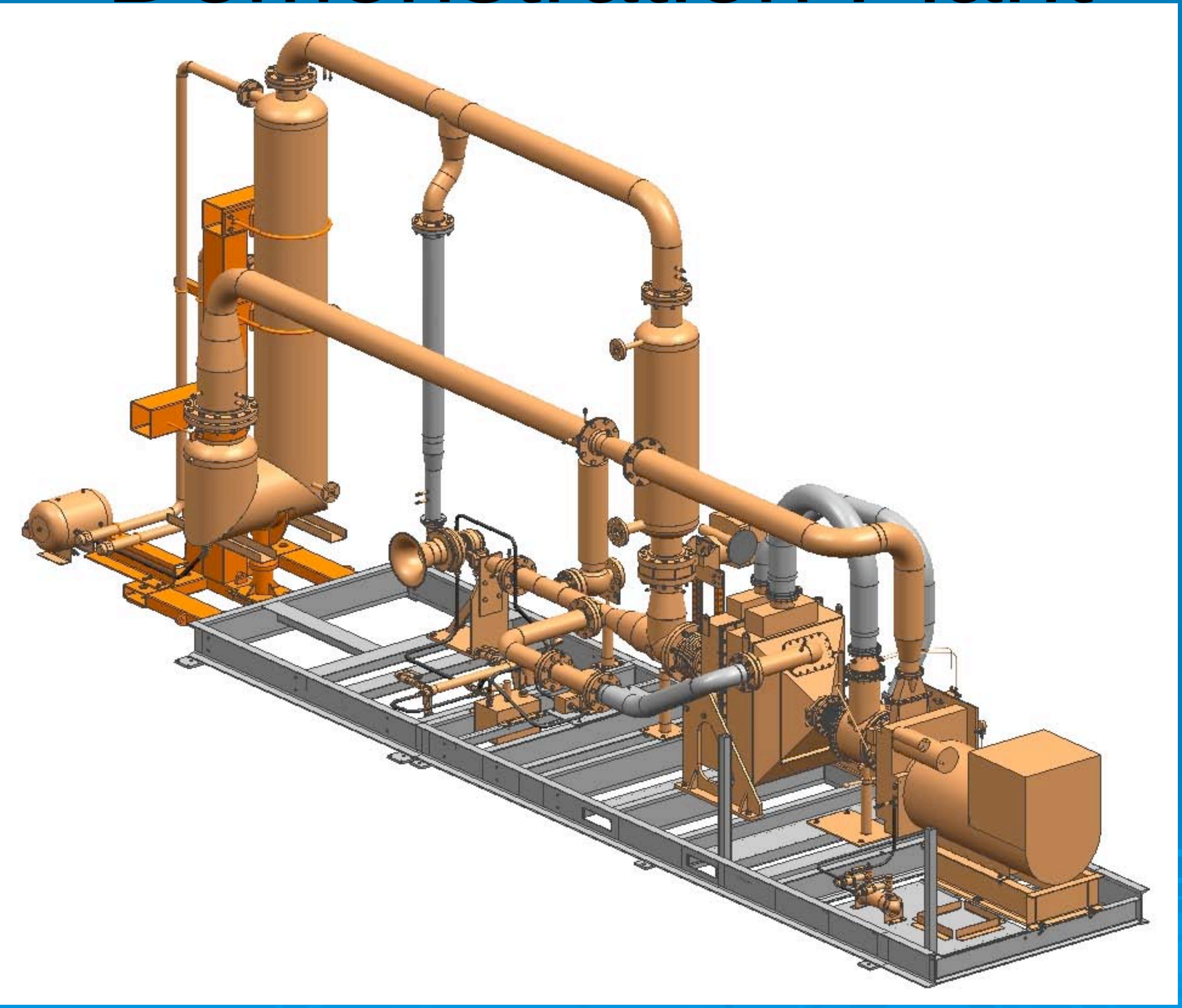


- Design-point efficiency comparable to or better than conventional recuperated engine
  - Issues include sensitivity to intercooler effectiveness and pressure drop
- Throttling to part-power via turbo wastegate or variable geometry
- Leaves core engine at design point over most of power band

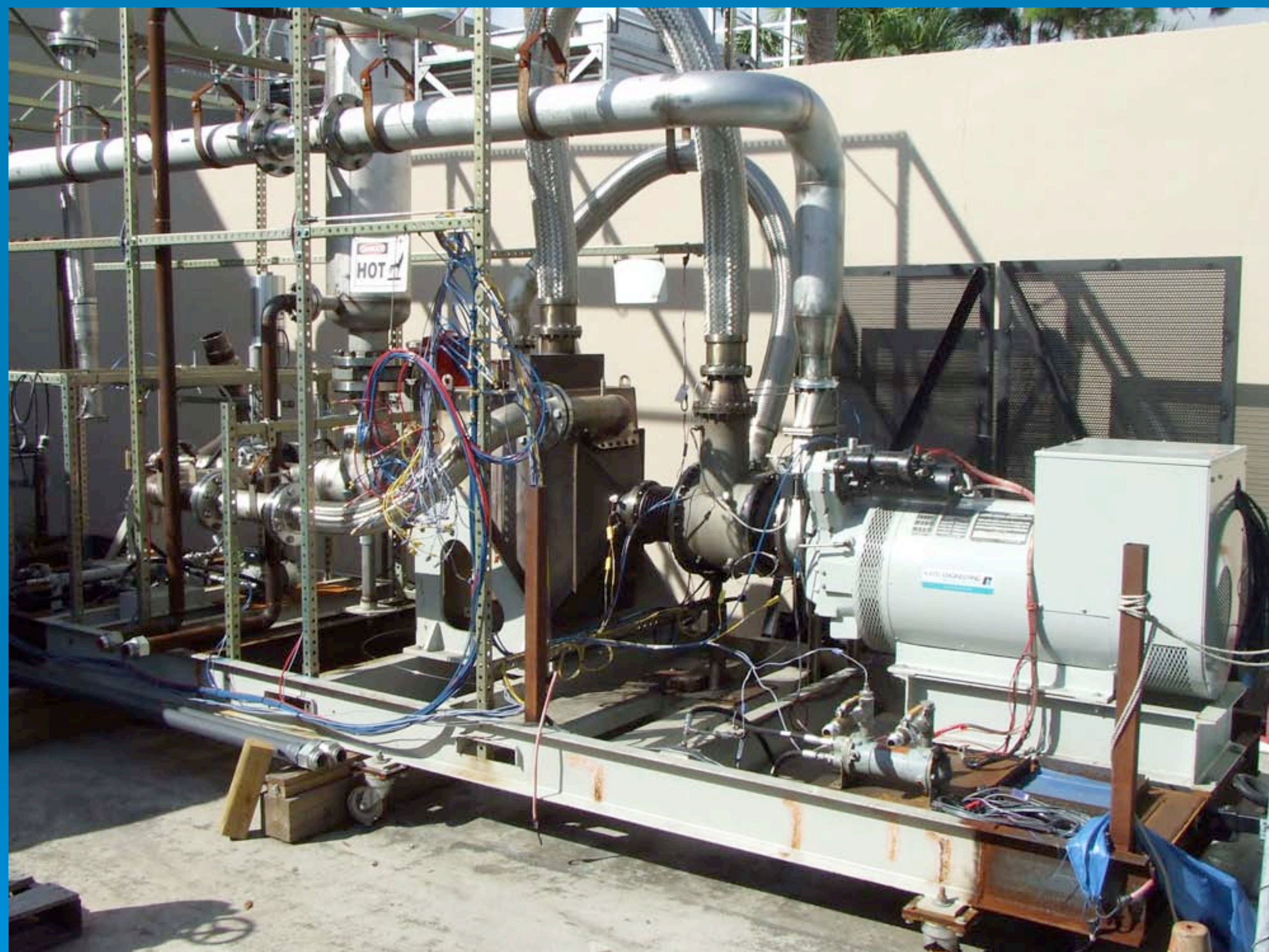
Life-Cycle Costs

- Our studies (MS thesis) show cost advantage over conventional microturbine for distributed generation
- Boost of 4:1 increases power density of high temperature components by an order of magnitude
- Additional components (turbo, HX) relatively inexpensive
- Part-load efficiency advantage reduces fuel costs
- Result: Several percent cost savings typical

Demonstration Plant



PoWER Demonstrator



Potential Applications

- Stationary vs Transportation
- Military vs Civilian
- Combined Cycle vs Simple Cycle

- Focus: stationary, small, distributed generation, multi-fuel, dual-use