Development of a Novel, High Efficiency, Low Cost Hybrid SOFC–IC Engine Power Generator

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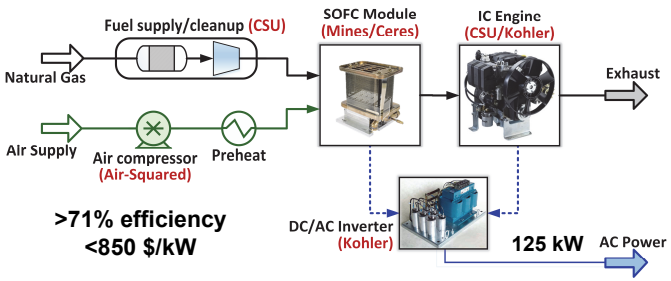
Project Vision and Innovation

PROGRAM: ARPA-E INTEGRATE

Goal: Demonstrate a hybrid fuel cell system that can drive both radically lower cost (<850 $/kW) and ultra-high efficiency (>71%) for 125 kW class distributed power generation applications.

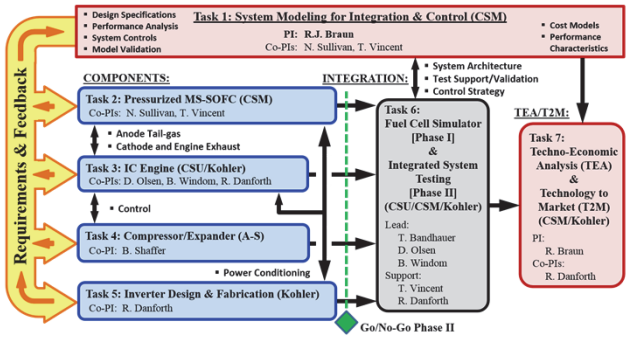
Features:
- Low cell temp, thermal management → reduce air preheater duty by >60%
- Pressurization → increase power density, lower both cost and BOP duty
- Gasified diesel engine converts residual fuel gas to drive auxiliaries (BOP)
- Simple after-treatment enables low engine emissions (NOx, CO)

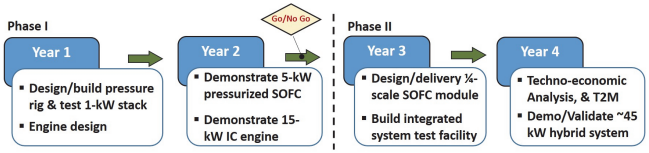
System Schematic



>71% efficiency
<850 $/kW

Tasks and Project Objectives

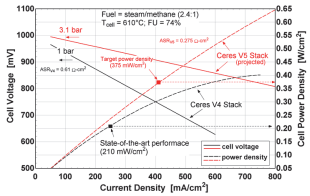




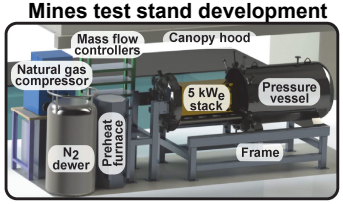
Pressurized Solid Oxide Fuel Cell Stack

- Target performance: 375 mW/cm² at 3-5 bar
- Durability evaluation: degradation, X-MEA Δp's, coking
- Challenges: power density, cost trajectory with pressure vessel

SOFC performance estimate



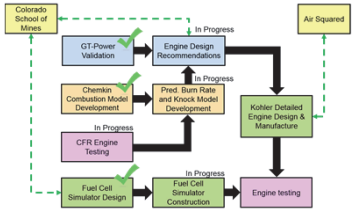
Mines test stand development



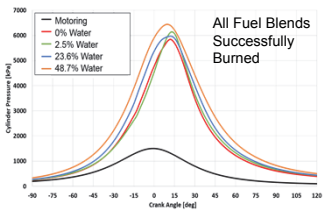
High Efficiency Tail-gas Engine Development

- Efficiency target: 35%-LHV from dilute SOFC tail-gas
- Durability/service intervals for target life (20,000-h)
- Focus: combustion control with low-Btu/high moisture fuel

Engine Development Pathway

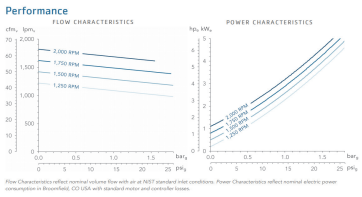


CFR Engine Testing



Scroll Compressor/Expander Development

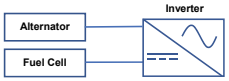
- Efficiency targets: 78% compressor / 76% expander
- Challenges: scaling, expander inlet temperature, efficiency



Approach: Scale-up P34 unit
- Orbiting Idler shaft design
- Suction = 933 cc
- Volume Ratio = 1.2

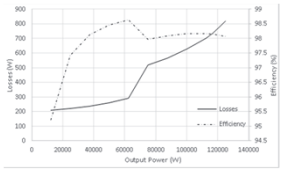
- No motor losses (90%)
- No controller (95%)
- ↑ compression η (~85%)

High Efficiency DC/AC Inverter Development



- 480V_{AC}, 3-Ph, 98% effic. @ 120kW (150 A)
- Power Factor correction up to 0.8pf
- 20-yr design life
- Grid-tied with int. protection, Island operation

Performance estimate



SiC wide-bandgap switches
- Lower conduction & switching losses
- Higher speed switching, smaller output filter; transformer-less operation

Amorphous Iron Cores
- Lower cores losses, High saturation levels allow compact design
- Compactness reduces winding losses

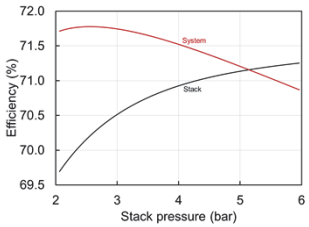
System Integration & Control

SYSTEM-LEVEL TRADE STUDIES FOR INTEGRATION

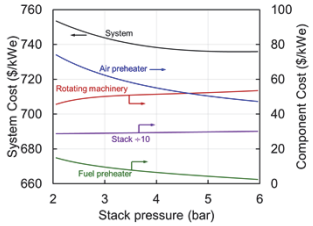
Control
- Over dynamic operating range
- Through mode transitions

BOP and Operation
- Water/thermal management
- Engine/SOFC interactions

Optimizing system pressure



System cost vs. pressure



Tech-to-Market (T2M) Objectives

KEY ELEMENTS FOR PRODUCT DEVELOPMENT & SUCCESS:
- Kohler's ability to scale, systems integrator, and existing customer base to help define requirements
- System design amenable to multiple SOFC stack developers

Anticipated First Markets
- Critical loads
- Commercial
- Industrial CHP (eventually)

Data Centers

Commercial Buildings