Compact Power

S&T Campaign: Materials Research
Energy & Power
Power Generation & Energy Harvesting

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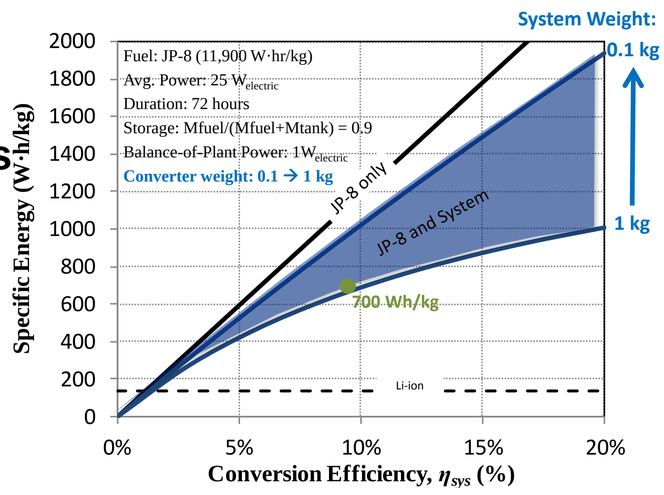
Research Objective

- **Investigate energy conversion and energy harvesting to enable extended duration, expeditionary-type missions with minimal physical burden and without the need for resupply**
- **New materials, models, and concepts for:**
  - ***Multi-fuel*** **(gaseous and liquid hydrocarbons)** ***microcombustion*** **for wearable power sources**
  - **Increased energy conversion using** ***thermophotovoltaics (TPV)***, ***thermoelectric***, **and** ***pyroelectrics*** **for power sources and thermal energy harvesting applications**



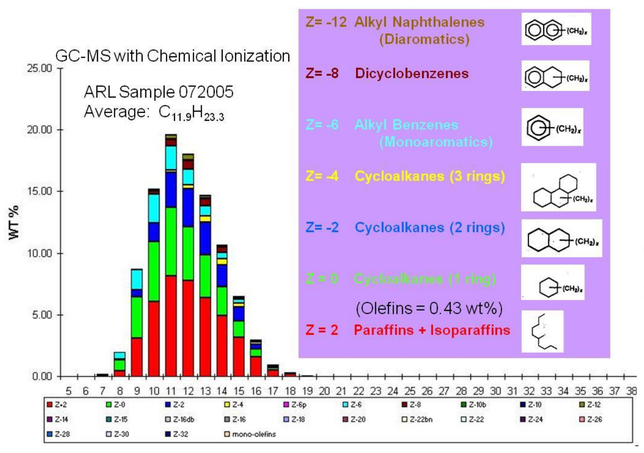
10% efficient conversion of JP-8 with a 1kg (dry) system can provide 700 Wh/kg compared to 145-160 Wh/kg for a rechargeable battery

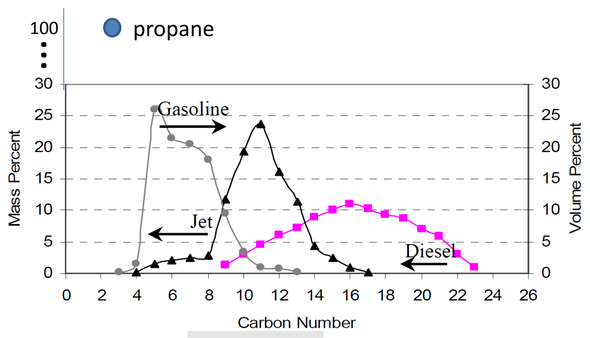
ARL Facilities and Capabilities Available to Support Collaborative Research

- **Thermal, surface, and chemical characterization of compact reactors operating in air or vacuum**
- **Numerical and CAD software available locally and on ARL supercomputer**
- **Thin-film pyroelectric materials growth, synthesis, and processing for test structures and devices**
- **Isothermal ferroelectric/pyroelectric materials characterization from 70K-600K**
- **Evaluation of pyroelectric energy conversion cycles over a range of temperatures, electric fields, and frequencies**
- **State of the art III-V MBE system for PV, PEC materials and IV-VI MBE system for TE materials.**
- **Ultrahigh vacuum variable temperature STM for tunneling spectroscopy and atomic imaging.**
- **Device processing and characterization.**

Challenges

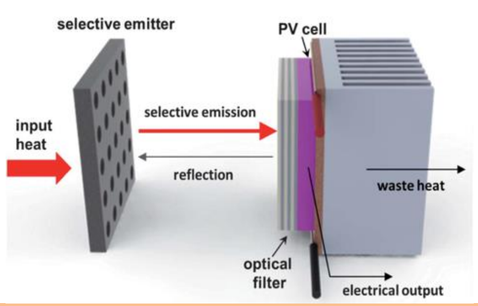
- **Limited detailed modeling for specific fuel/catalyst combinations and design tools for micro-reactors with both surface and gas-phase oxidation reactions**
- **Spectral matching between the radiating heat source and the TPV converter limit the conversion efficiency**
- **Limited knowledge on critical pyroelectric energy harvesting material properties and the coupling between the thermodynamics associated with the energy harvesting cycle and the desired pyroelectric properties at different cycle frequencies has restricted the conversion efficiency**



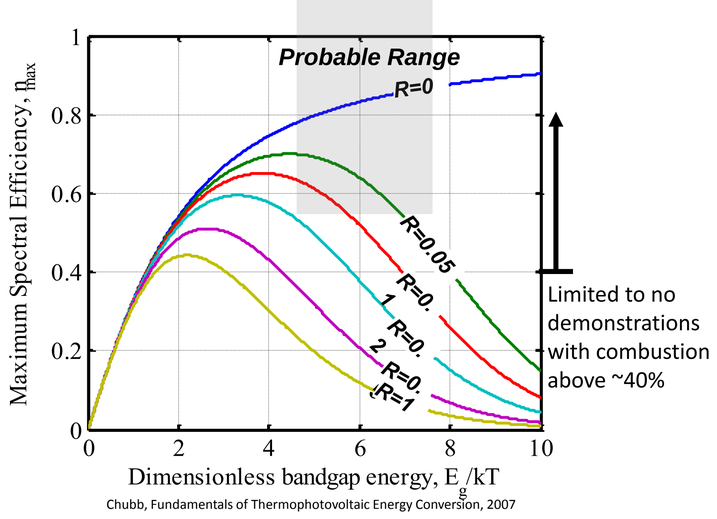


Altin and Eser, *Prepr. Pap.-Am. Chem. Soc., Div. Fuel Chem.* **2004**, *49(2)*, 765

The varying thermodynamic properties and reaction pathways, mechanisms, and rates pose a challenge to modeling, simulating, and designing multi-fuel capable reactors for power sources.



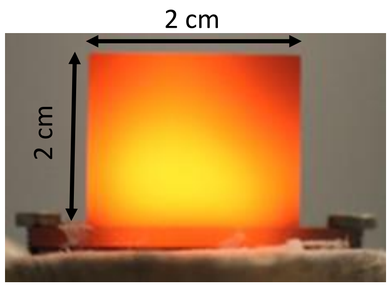
Each component, heat source, selective emitter and low bandgap (0.5 eV – 0.72 eV) photovoltaic cells must be matched thermally and spectrally to conversion efficiency required for Army applications.



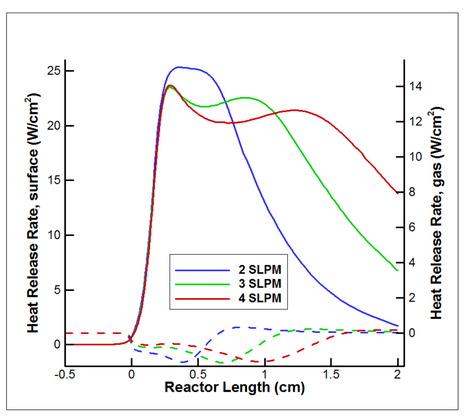
Limited to no demonstrations with combustion above ~40%

Chubb, Fundamentals of Thermophotovoltaic Energy Conversion, 2007

Tolmachoff *et al., Combustion and Flame.* 162 (2015) 3674-3680



Inconel micro reactor with 2 LPM total flow rate (air + dodecane). The flow passage height is 0.5 mm and is coated with Pt.

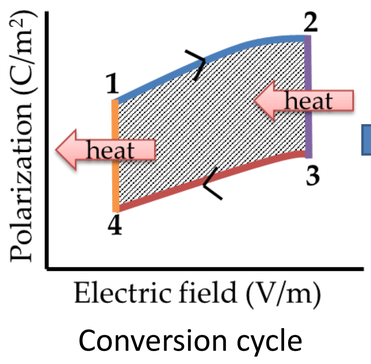


Heat release simulation from surface (solid lines) and gas phase (dashed lines) reactions

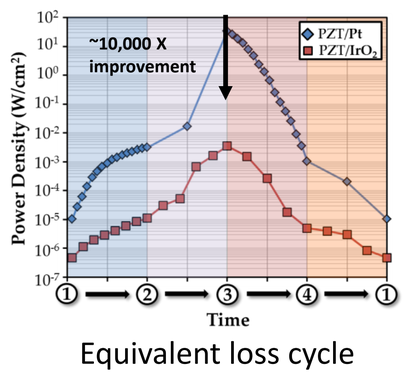
Hybrid heterogeneous/ homogeneous micro-reactor device characterization and dodecane surface (Pt) and gas-phase reaction models coupled to flow models enable reactor design optimization.

Hanrahan *et al., Smart Mater. Struct.* 25 (2016) 015025

O_2-permeable electrodes allowed for reintroduction of oxygen to the PZT lattice enabling a 10-10,000X reduction in leakage current for temperature changes of 200°C to 300°C and electric field changes of 2 MV/m to 10 MV/m.



Conversion cycle



Equivalent loss cycle

Complementary Expertise / Facilities / Capabilities Sought in Collaboration

- **Multi-fuel or JP-8 fueled meso-scale and micro-combustion modeling and device development**
- **Thermal-to-electric materials and devices development partners for high temperature operation**
- **New thin film materials are needed with optimized energy conversion properties are needed to enable pyroelectric energy harvesting for unique Army applications.**