Thermoelectric Combined Heat and Power (CHP) Technology Development

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Hi-Z Technology

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Why Thermoelectric CHPs?

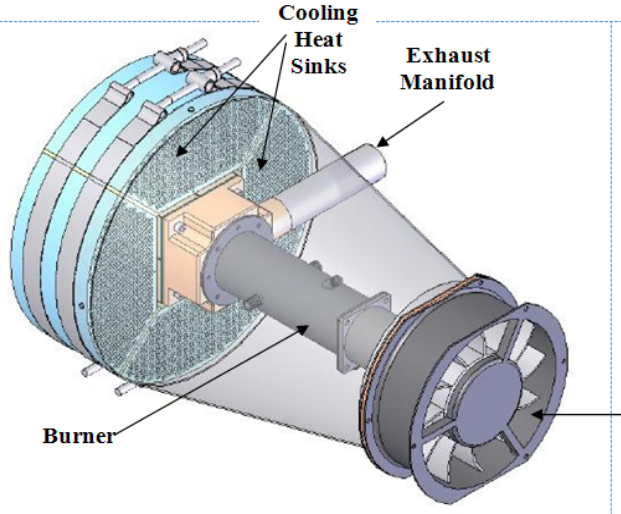
- Current TE modules exhibit low heat to electricity conversion efficiency (Bi_2Te_3 $\eta \sim 5\%$)
- For each W_e produced by TEG 20 W thermal energy is wasted
- How can we use heat rejected from TEG?
  - Heat air – space heaters
  - Heat water – water heaters
  - Supply electrical and thermal energy to thermally activated devices (chillers, heat pumps, etc.)

Thermoelectric CHPs (T-CHP) Development at Hi-Z

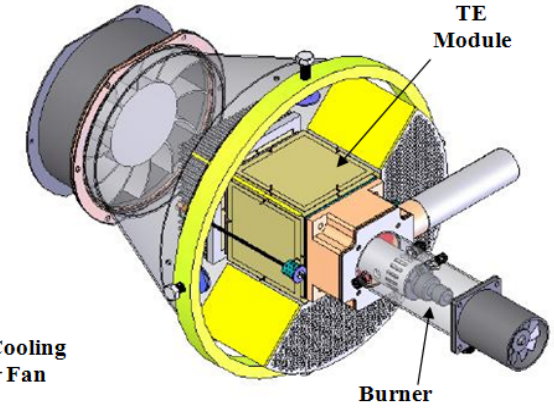
Hi-Z fabricated and demonstrated several thermoelectric CHPs (T-CHP):

- Self-powered space heater prototype, surplus power ~ 2-3 W_e (modified Espar heater)
- 40 W_e space heater/ APU for military applications (employs Espar burner)
- 50 W_e space heater/APU, equipped with Hi-Z's burner
- 500 W_e water heater/APU, with Hi-Z's burner
- Self-Powered Army food Heater with DC burner

50 W_e Space Heater/APU Designs



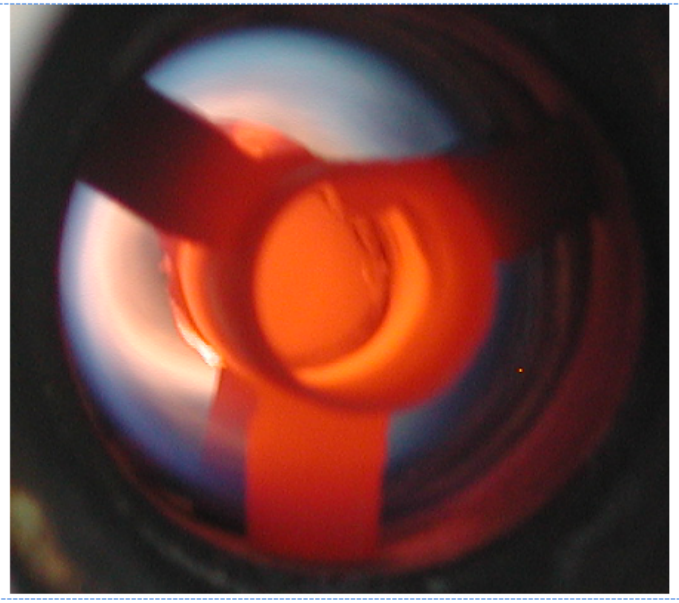
- Compact design
- Cooling fan assists combustion blower



- Burner easy accessible
- Cooling system not obstructed
- More TE modules employed

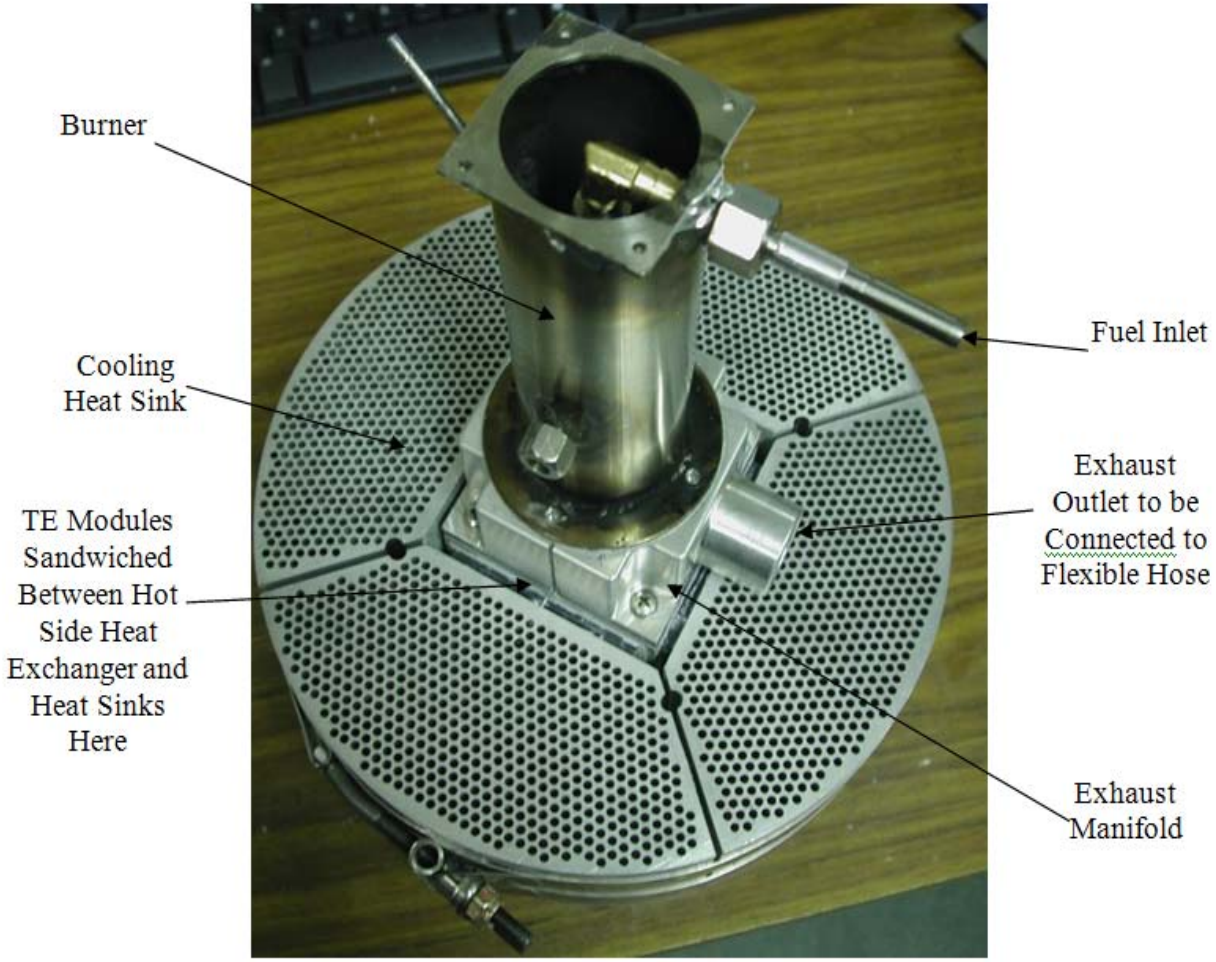
50 W_e Space Heater/APU
Novel Low Power Consumption Burner

Aspirating Wick Atomizer Test.
Fine Diesel Fuel Atomization

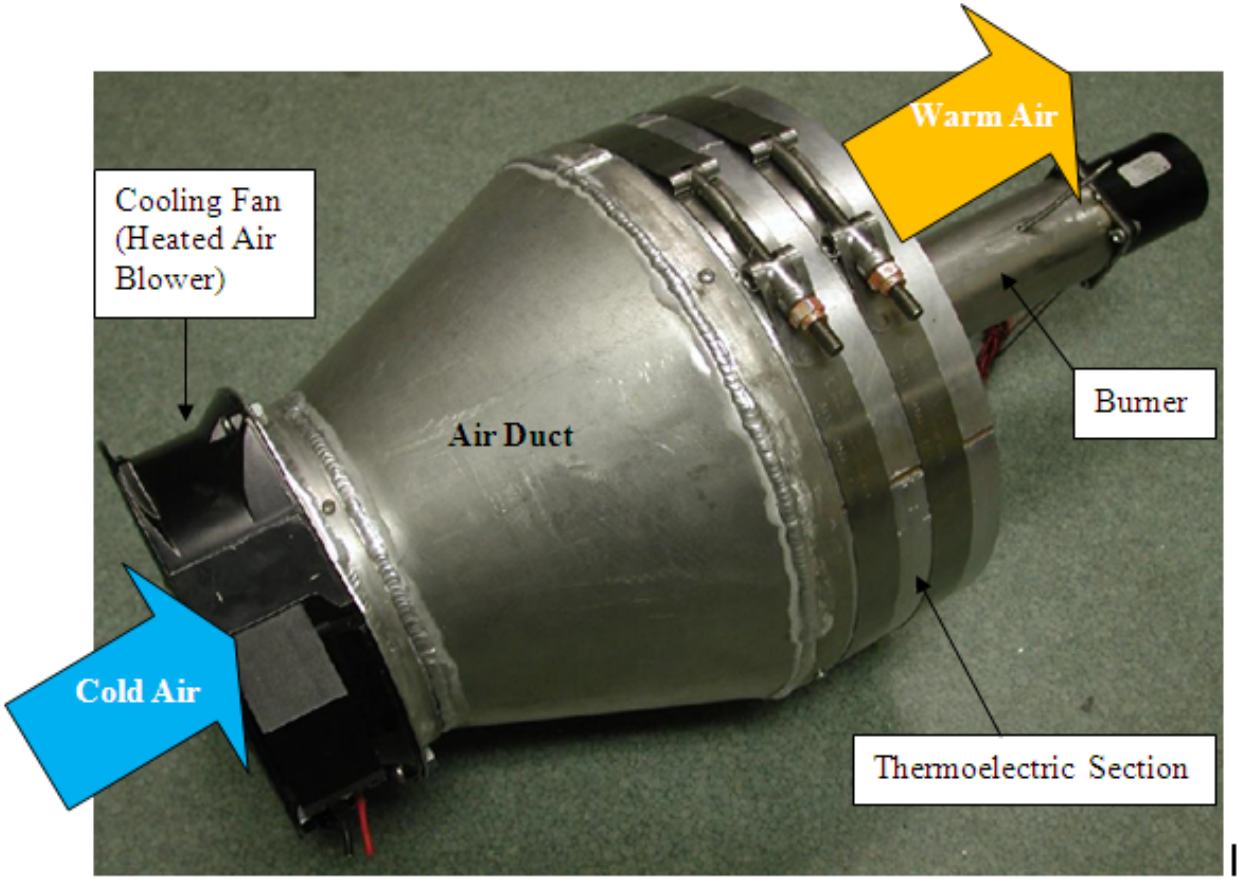


Diesel Fuel Burns in Blue Flame Mode

50 W_e Space Heater/APU Assembly



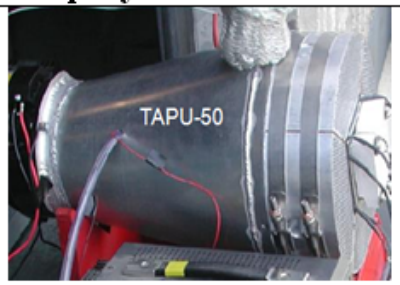
50 W_e Space Heater/APU



50 W_e T-CHP Performance in Comparison with Airtronic-2 (Espar)

Parameters	Airtronic-2	50 W_e T-CHP
Fuel Input, l/hr (gal/hr)	0.3 (007)	0.3 (007)
Heat output, W (Btu/hr)	2200 (7,500)	2200 (7,500)
Electric Power Consumed, W	**34**	**24**
Electric Power Produced, W	0	75.4
Net Electric Power Produced	**NA**	**51.4**
Volume, L (Ft^3)	4.3 (0.15)	10 (0.36)
Weight kg, (lb.)	2.7 (5.9)	9.3 (20.5)

T-CHP EVOLUTION AT HI-Z

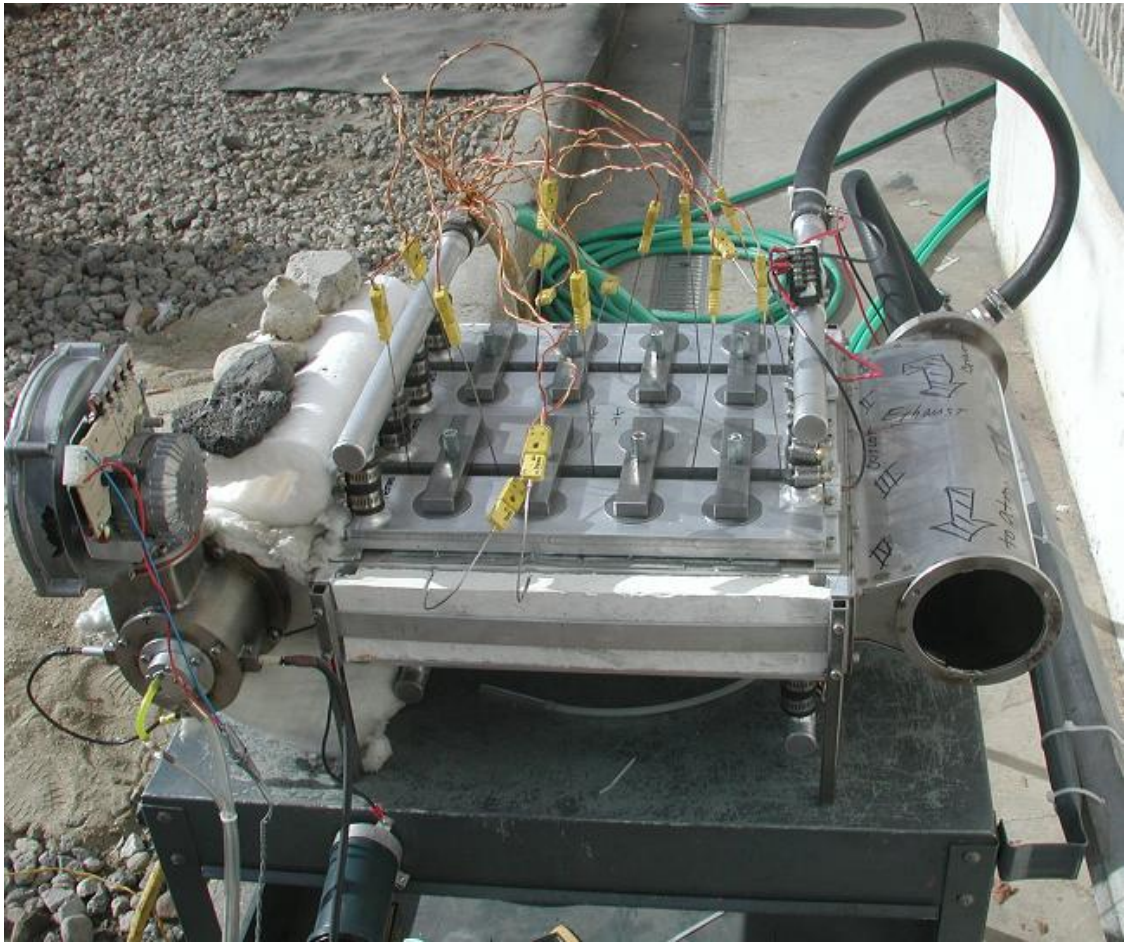
Parameters	Picatinny TEG employs Espar burner	TAPU 50-1 (Burner inside cooling duct) employs Hi-Z burner	TAPU 50-2 (Hi-Z burner against cooling duct)	QW TAPU
				To be Made in Future
TAPU weight, kg (lb.)	45.4 (100)	9.1 (20)	9.3 (20.5)	9.0 (19.8)
TAPU volume, l (ft^3)	130 (4.6)	13.9 (0.49)	10.2 (0.36)	10 (0.28)
Net power production, W	40	35	51	279
Power density, W /kg (W/l)	**0.9 (0.3)**	**3.9 (2,5)**	**5.5 (5.0)**	**31.0 (27.9)**

T-CHP PROTOTYPES ENERGY DESITY WAS IMPROVED BY FACTOR OF 6 (weight wise) and BY FACTOR OF 17 (volume wise) with CURRENT BI_2Te_3 MODULES!

500 We Water Heater/APU T-CHP
Dual Mode Operation: Exhaust/Auxiliary Burner
General Specification

Parameters	Unit	Value
Capacity (nominal) • Net power production • Parasitic losses (Burner, water pump) • Gross power production	 W W W	 500 108 608
Type of TE modules	-	HZ-20
HZ-20 nominal power production	W	19
Number of modules	ea.	32
Burner nominal capacity	kW_{th}	50
Fuel	-	JP-8, Diesel

500 W TEG TEST



500 W_e Water Heater/APU T-CHP Performance Estimation

Unit	TEG weight, kg	TEG Power production, W	Power Density W/kg
TAPU-500-1 (currently measured)	48.5	500	10.3
TAPU500-2 (expected with light weight alloy)	38.5	500	13.0
TAPU – QW (estimated)	38.5	2,300	59.7

Self-Powered Army Food Heater
Goal: to eliminate logistically fueled generators from military field kitchens

Current Equipment

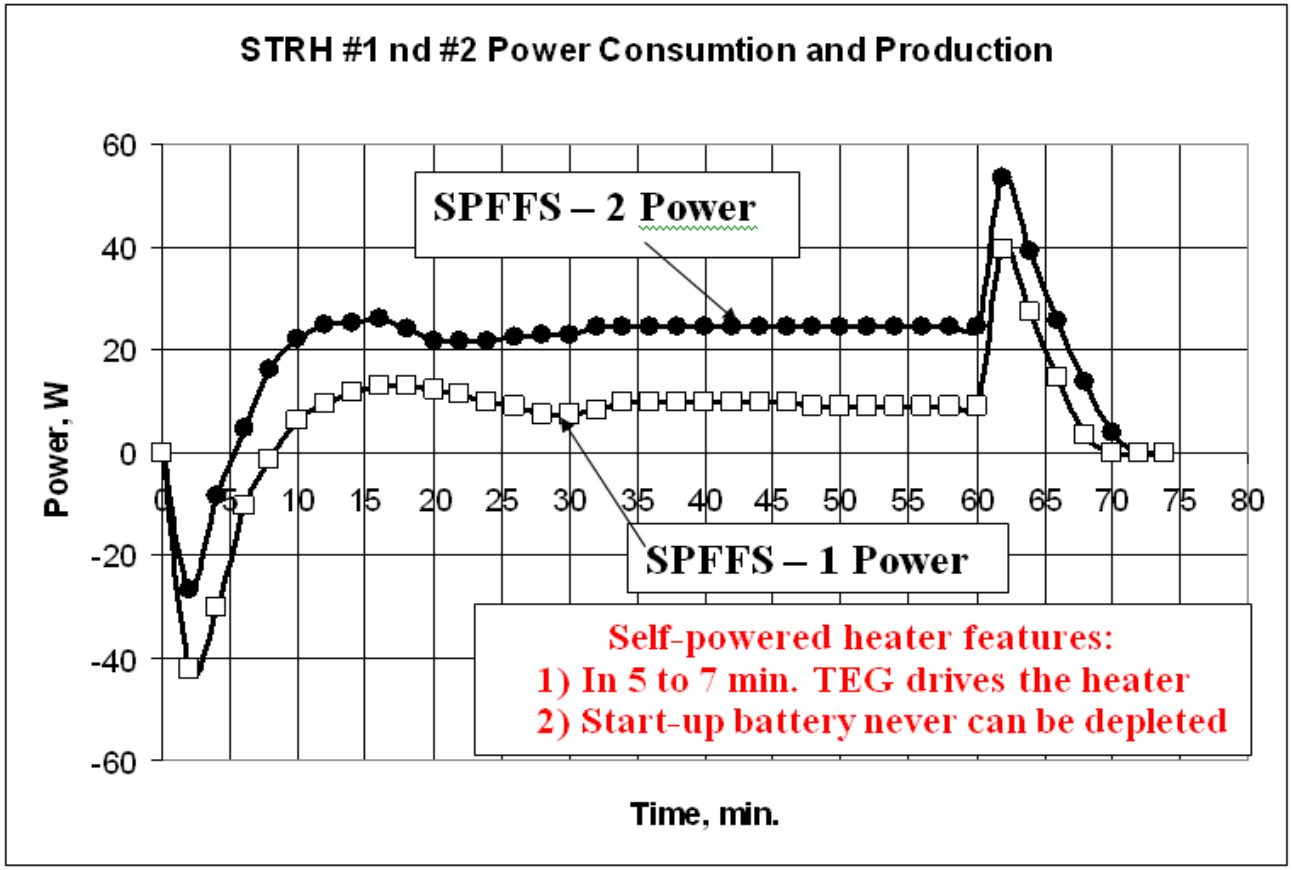
Device	Dimensions inch	Volume ft^3 (%)	Weight (dry) lb (%)	Fuel Consumption GPH	Cost $$ (%)
MRH	42 x 24 x 27	16 (73)	275 (64)	0.75	17,500 (75)
MTG (2 kW)	**30 x 16 x 22**	**6 (27)**	**158 (36)**	**0.33**	**5,750 (35)**
Total	--	22 (100)	433 (100)	1.08	23,250 (100)

50 W TEG REPLACES MTG THAN COSTS $5,750, SAVES EXPENSIVE (up to $400/gal) FUEL, ELIMINATES MAINTENANCE and NOISE, REDUCES WEIGHT and VOLUME of DEPLOYED EQUIPEMENT, IMPROVES FIELD KITCHEN RELIABILITY

Self-Powered Army Food Heater

Self-Powered Army Food Heater Test

(TEG converts only 0.2% of fuel energy to make the heater self-powered, overall fuel efficiency > 80%)



Conclusions

- There are military and commercial markets for CHPs
- T-CHPs can be designed and fabricated today with current thermoelectric modules performance
- When properly designed, current T-CHP can be cost-effective
- New, high efficiency TE materials will significantly improve T-CHP performance and cost