Portable Power for Tomorrow's Soldier

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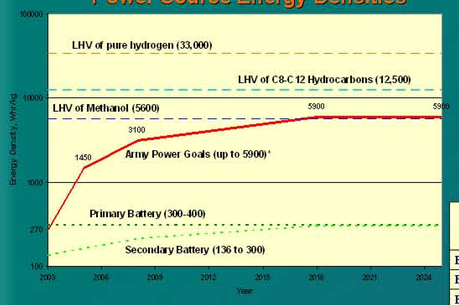
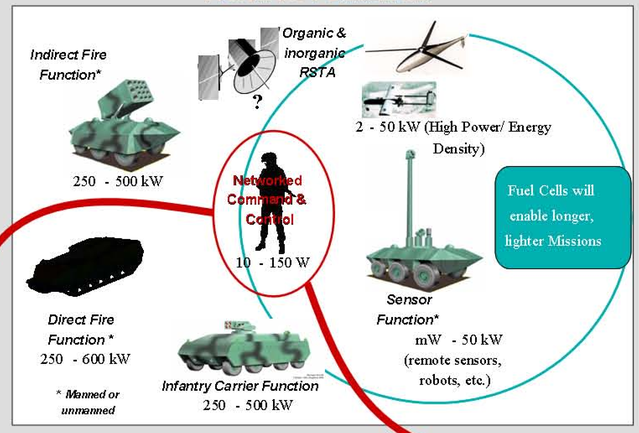
Army Goals Relative to Power Source Energy Densities



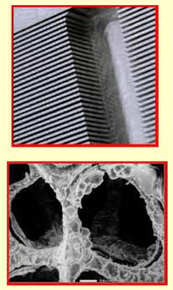
Power Source Energy Densities

Source	Energy Density (Whr/kg)	Comments
BB-2590	81	Secondary
BA-5590	150	Primary
BA-5390	235	Primary
BA-8180	345	Primary Zn-Air battery, large unit
Compressed Hydrogen	500-1000	5000 psig, value includes container weight
Sodium Borohydride	3600	[$NaBH_4$ + 2 H_2O] weight only
Methanol	5500	Based on lower heating value of fuel
Most Liquid Hydrocarbons	~12,400	Based on lower heating value of fuel
Hydrogen Gas	33,200	Unpackaged
Nuclear Material	2,800,000	Raw power

Tomorrow's Battlefield



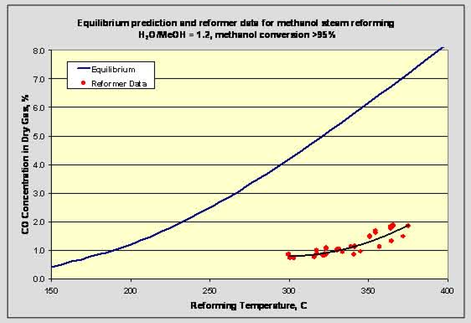
Microchannels and Advanced Catalysts



- Micron-scale dimensions
- **Rapid heat & mass transfer**
- Laminate fabrication
- Integrated monolith supports
- Porous substrates
- **Highly active catalysts**
- Low pressure drop

- **Process intesification**

Excellent Selectivity: Microchannels and Advanced Catalysts



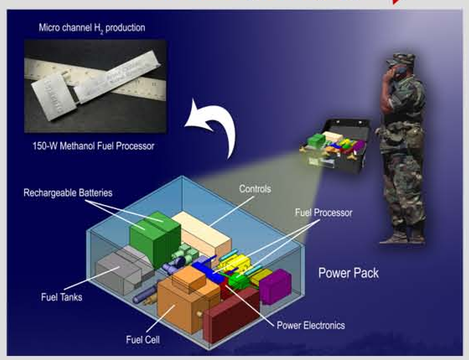
Applications: Battery Charging, Silent Watch
Fuel: Methanol
Goals: Output = 150-250 W
Mass = 5-7 kg
Volume = 15-20 L

System consists of battery charging equipment powered by a PEM fuel cell coupled to a methanol reformer.

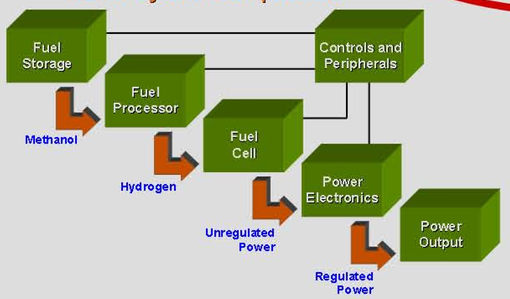
Power system fits in a case similar in size to current military battery chargers and offers increased portability and versatility.

System enables battery charging in the field, making practical the use of rechargeable batteries.

In-Field Battery Charging



Power System Components



Soldier-Portable Power

Application: Fuel Cell/Battery Hybrid System
Fuel: Methanol
Goals: Output = 10-20 W
Mass = 1.1 kg
Volume = 0.9 L

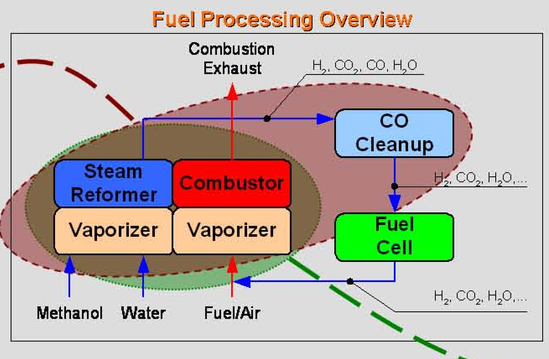
System consists of a small fuel cell system based on methanol reforming.

Fuel cell power unit is the same size as one military battery (BA-5590).

Fuel cell system is hybridized with rechargeable military battery.

Complete hybrid system is same size as two military batteries.

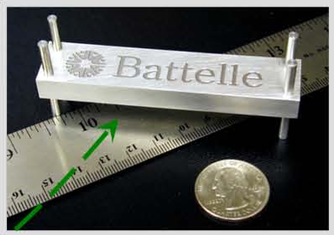
Fuel Processing Overview



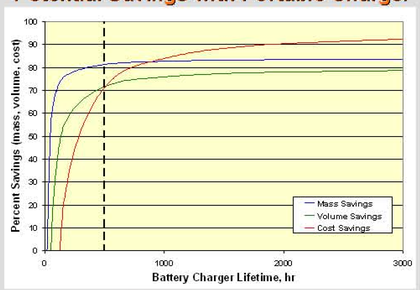
Complete 150-W Methanol Fuel Processor

Power Output	60-180 W_e
Volume	160 cm^3
Mass	480 g
H_2 Concentration	~70%
CO Concentration	30-100 ppm
Thermal Efficiency	56-70+ %

Integrated 20-W Methanol Steam Reformer



Potential Savings with Portable Charger



	Total Mass (kg)	Total Volume (L)	Batteries Used	Total Cost ($)	Energy Cost ($/Whr)
Primary Batteries	1633	1425	1600	160,000	0.67
Secondary Batteries with Portable Charger	272	313	21	15,400	0.064
Percent Decrease	83%	78%	98%	90%	90%

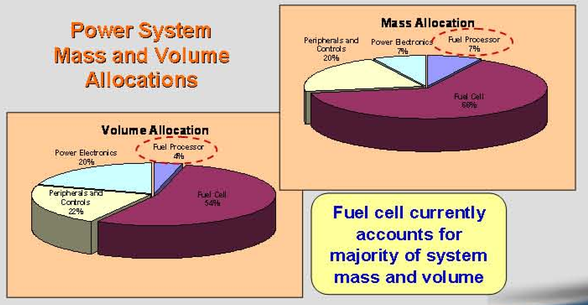
Calculations based on the following assumptions:
- Battery charger hardware: 120 W, 2000-hr. life, 10 kg, 30 L, $10,000 ea.
- Battery charger fuel (methanol/water): $0.62/gal., 130 mL/battery charge
- Primary battery BA-5590: 0.89 L, 1.02 kg, $100 ea., 150 Whr.
- Secondary battery BB-390: 0.89 L, 1.7 kg, $254 ea., 118 Whr.

Proof-of-Concept Demonstration System

Microchannel Steam Reformer Properties

Material	316 stainless steel
Fabrication Method	Diffusion bonding and welding
Unit operations	Catalytic steam reforming, catalytic combustion, vaporization (2), heat recuperation (2)
Combustor feed stream	Methanol and air
Reformer feed stream	Methanol/water premix (60 wt% methanol, 1.2:1 steam to carbon ratio)
Operating temperature	300-350 °C
Reformate composition	~71% H_2, ~24% CO_2, ~4.8% H_2O, ~0.8% CO
Methanol conversion	95-100%

Power System Mass and Volume Allocations



Fuel cell currently accounts for majority of system mass and volume

Integrated Methanol Reformer Properties and Performance

Design Power, W_e [α]	20	50	100	150
Demonstrated Power, W_e [β]	6-34	26-54	45-150	60-300
Demonstrated Thermal Efficiency, % [γ]	38-63	62-84	78-85	71-78
Estimated System Electrical Efficiency, % [α]	18-30	30-40	37-41	34-37
Estimated Fuel Specific Energy, Whr/kg [δ]	1000-1680	1680-2240	2070-2300	1900-2070
Mass, g	65	105	155	245
Volume, cm^3	11	19	28	67
Power Density at Design Power, W/L [ε]	1750	2680	3650	2240
Specific Power at Design Power, W/kg [ε]	300	470	650	470

[α] Based on fuel cell having 60% conversion efficiency and 80% hydrogen utilization
[β] Performance values are reported for methanol conversion >95%
[γ] Based on lower heating values of methanol and hydrogen
[δ] Specific energy based on fuel weight; system specific energy will depend on complete system size and weight
[ε] Power density and specific power numbers are for reactor hardware only

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