Unmanned Undersea Vehicle (UUV) Energy
ONR Industry Day

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TODAY'S DISSCUSION

Objective:

- Examine Feasibility of Existing Power/Energy Systems to Meet UUV Requirements
- Describe Desirable System Features

Conclusions:

- Current obvious energy sources don't satisfy Navy UUV requirements.
- New Storage/Conversion systems and concepts are needed.

Outline:

- Mission Definition and System Requirements
- Options Considered
- Performance Comparisons

2004 UUV MASTER PLAN
Sea Power 21 Sub-Pillar Capabilities

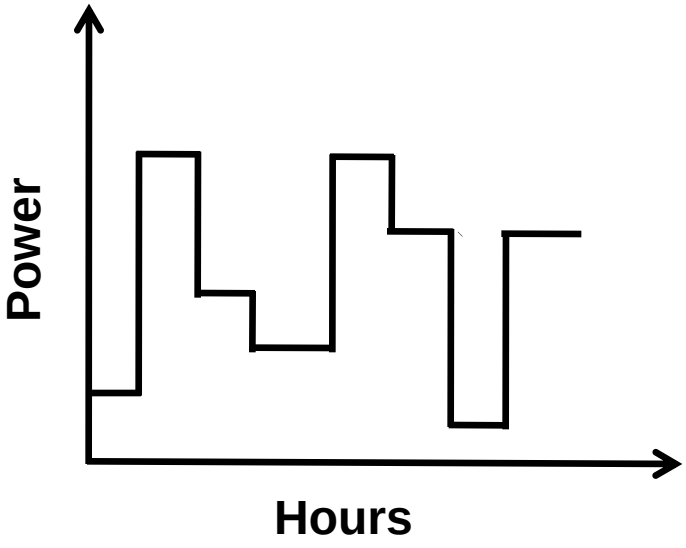
The Navy Unmanned Undersea Vehicle (UUV) Master Plan

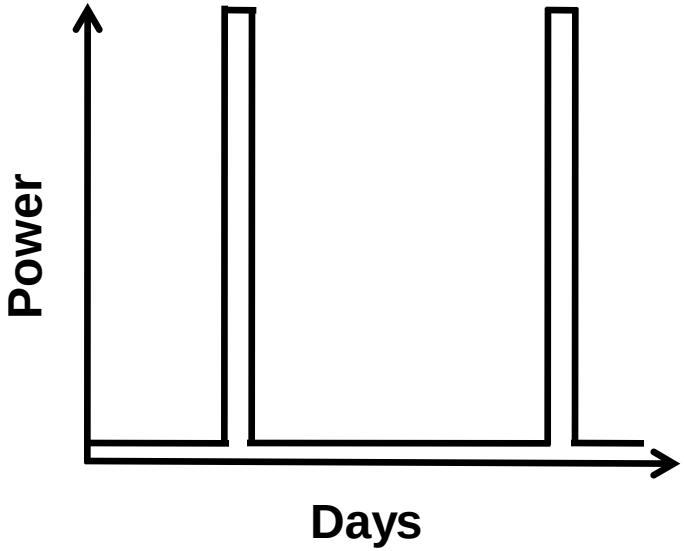
November 9, 2004

1. Intelligence, Surveillance, Reconnaissance
2. Mine Countermeasures
3. Anti-Submarine Warfare
4. Inspection / Identification
5. Oceanography
6. Communication / Navigation Network Node
7. Payload Delivery
8. Information Operations
9. Time Critical Strike

www.navy.mil/navydata/technology/uuvmp.pdf

MISSION PROFILE EXAMPLES





Case 1: ~80 kWh,
130 liters, 615 Wh/L

Case 2: ~1800 kWh,
2000 liters, 900 Wh/L

- **Total Mission Energy**
- **Average, Peak, Hotel Power**

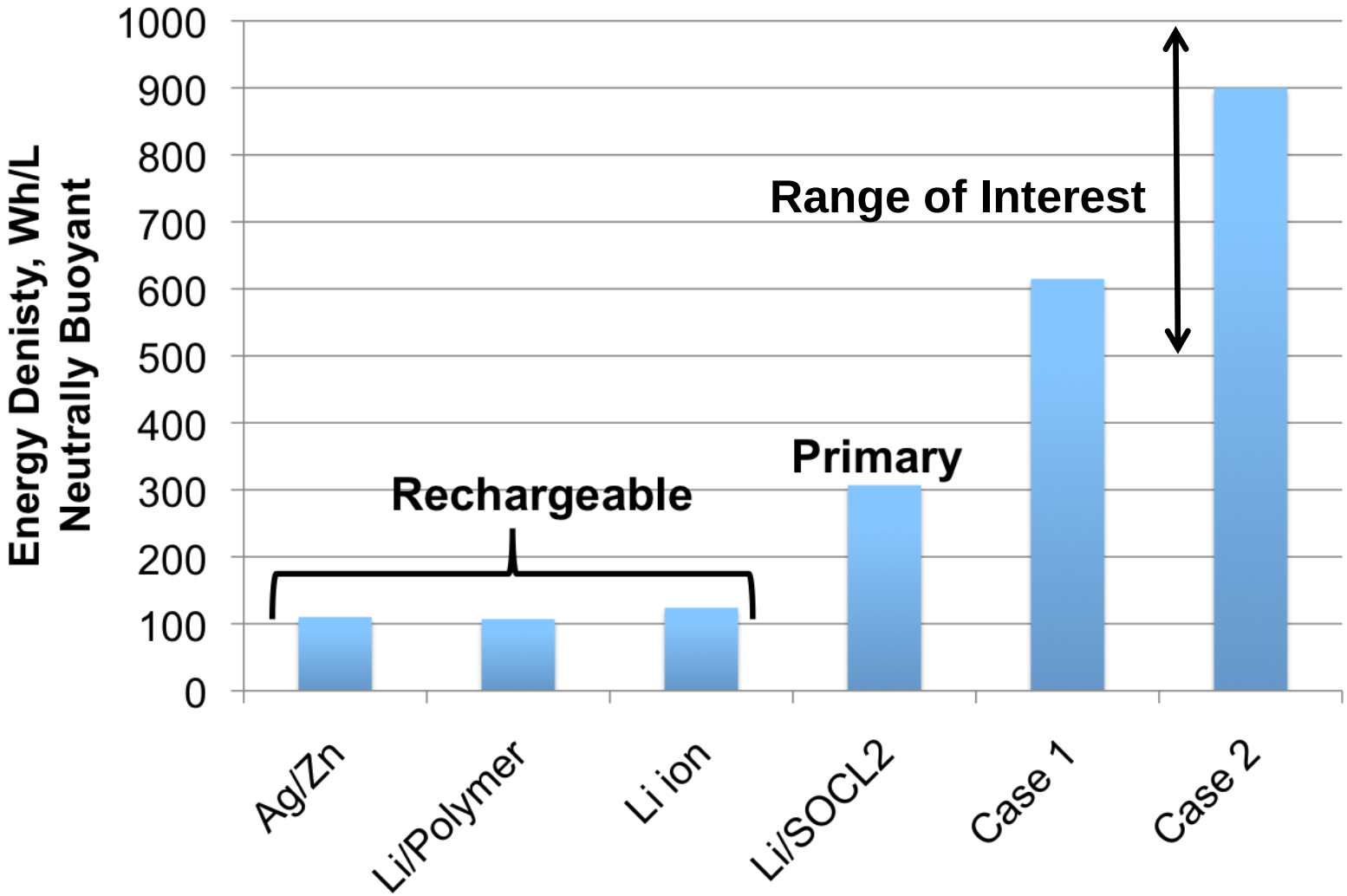
DESIRED POWER/ENERGY SYSTEM FEATURES

- Safety
- Air Independent
- Reliable
- Rapid Start-Up, Shut-Down, Load Follow
- Neutrally Buoyant
- Low/No Observables (noise, discharges)
- Easy/Rapid/Safe Refueling
- No Hull Penetrations
- Orientation (operation & storage)

DESIRED POWER/ENERGY SYSTEM FEATURES, continued

- Cost Effective (Acquisition and Recurring)
- Hibernation Capability
- Long Shelf Life
- Efficient Over a Wide Power Range; Hybrid?
- Scalable (Power Plant, Fuel, Oxidant)

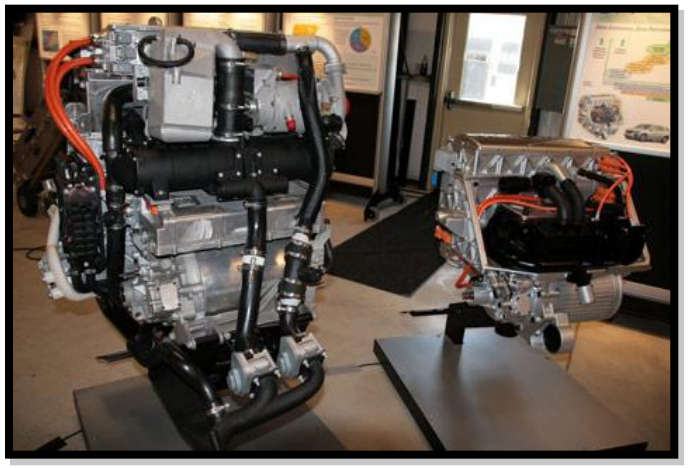
BATTERIES CANNOT MEET FUTURE ENERGY GOALS



ENERGY CONVERSION TECHNOLOGIES

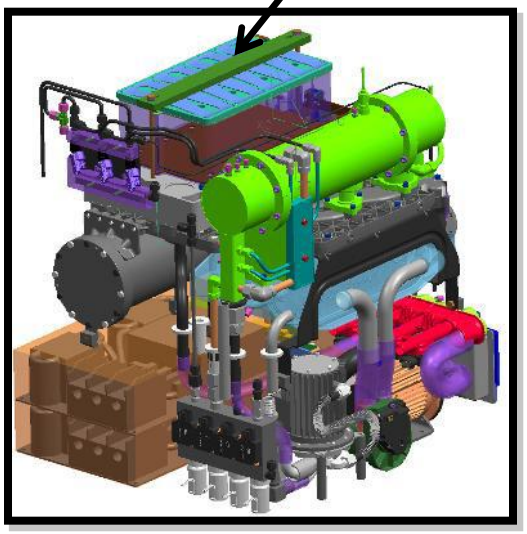
- **FUEL CELLS**

Equinox Gen 5



GENERAL MOTORS 93 kW PEM

Fuel cell stack



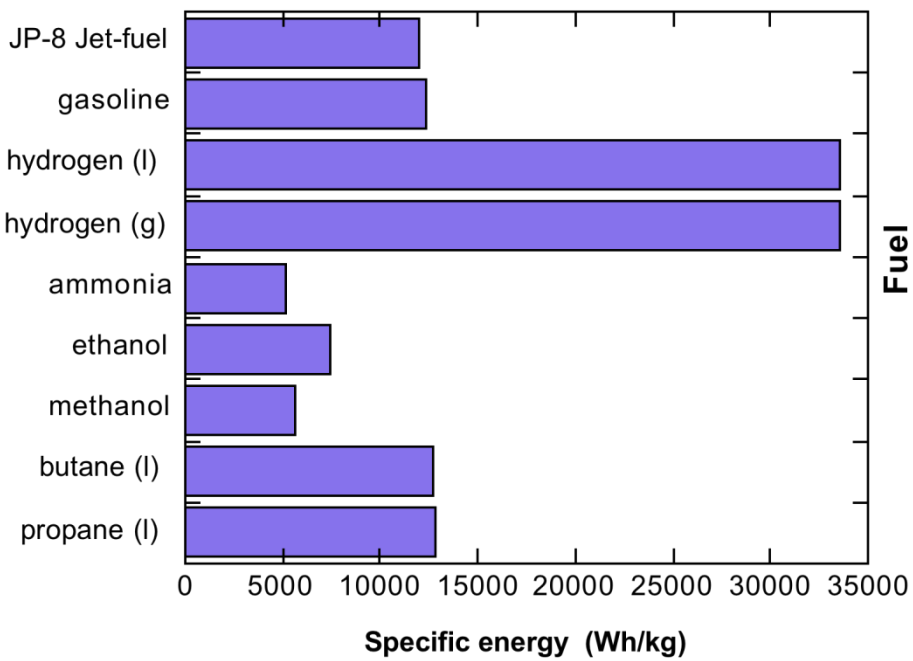
DELPHI 3 kW SOFC

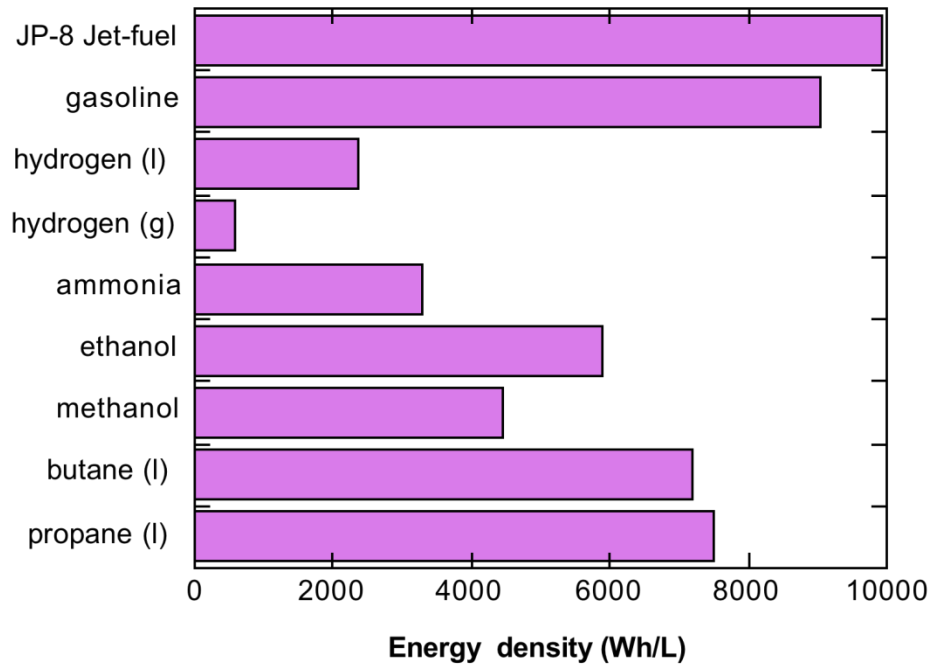
- **SEMI CELLS**
- **HYBRID SYSTEMS**
- **HEAT ENGINES**
- **THERMOELECTRICS**

FUEL OPTIONS

- **Hydrogen**
  - **Gaseous, 5 kpsi and 10+kpsi**
  - **Liquid (1 Atm, 20 K)**
  - **Supercritical**
- **Reversible Metal Hydrides**
- **Chemical Hydrides**
  - **Dry Hydrides (thermally or water activated)**
  - **Slurry/Dissolved Hydrides**
- **Reformed Hydrocarbons**
  - **Methanol**
  - **JP8/Kerosene**
  - **Butane/Propane**
- **Ammonia**

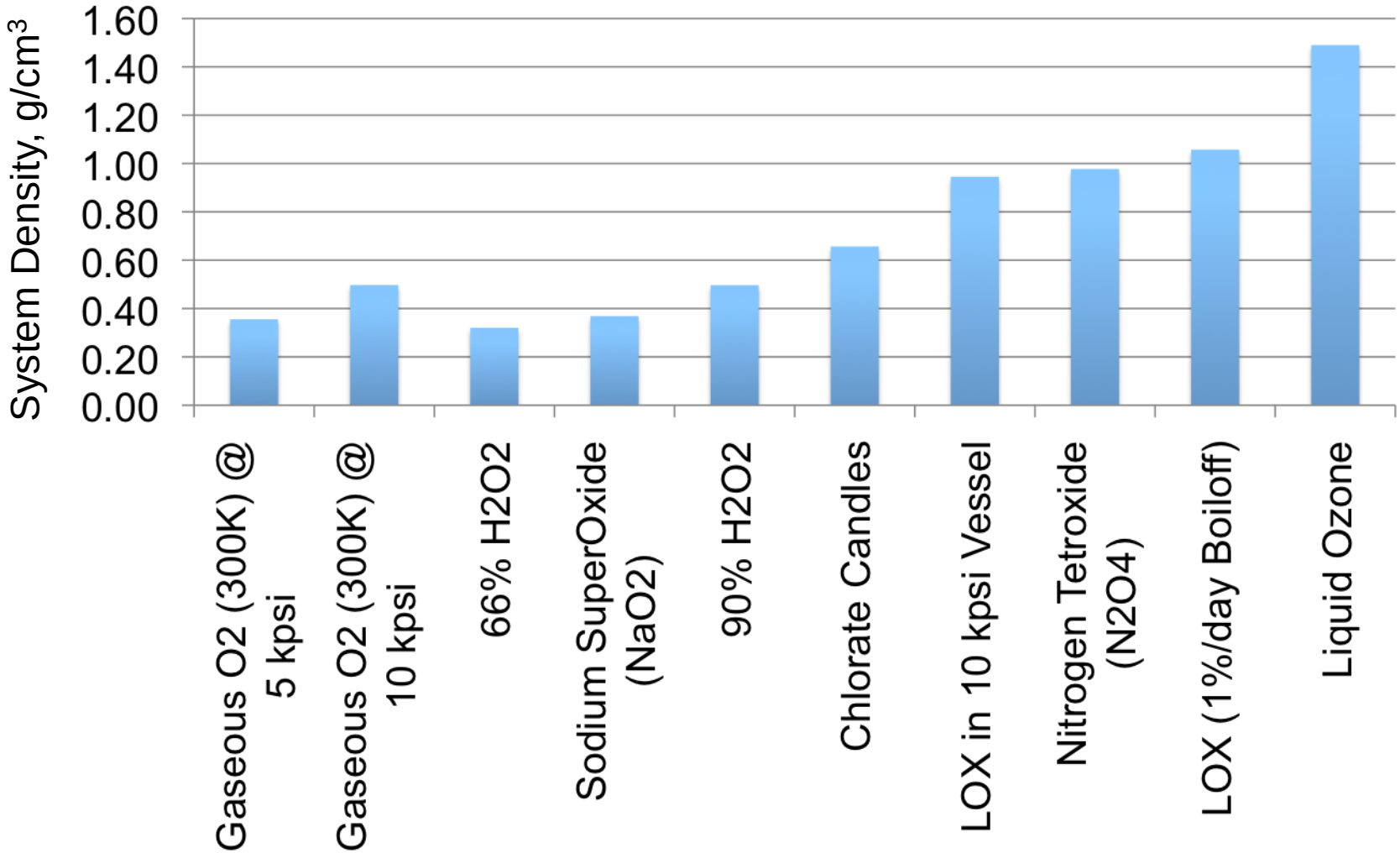
ENERGY CONTENT OF VARIOUS FUELS
Lower Heating Values (LHVs)





OXYGEN STORAGE

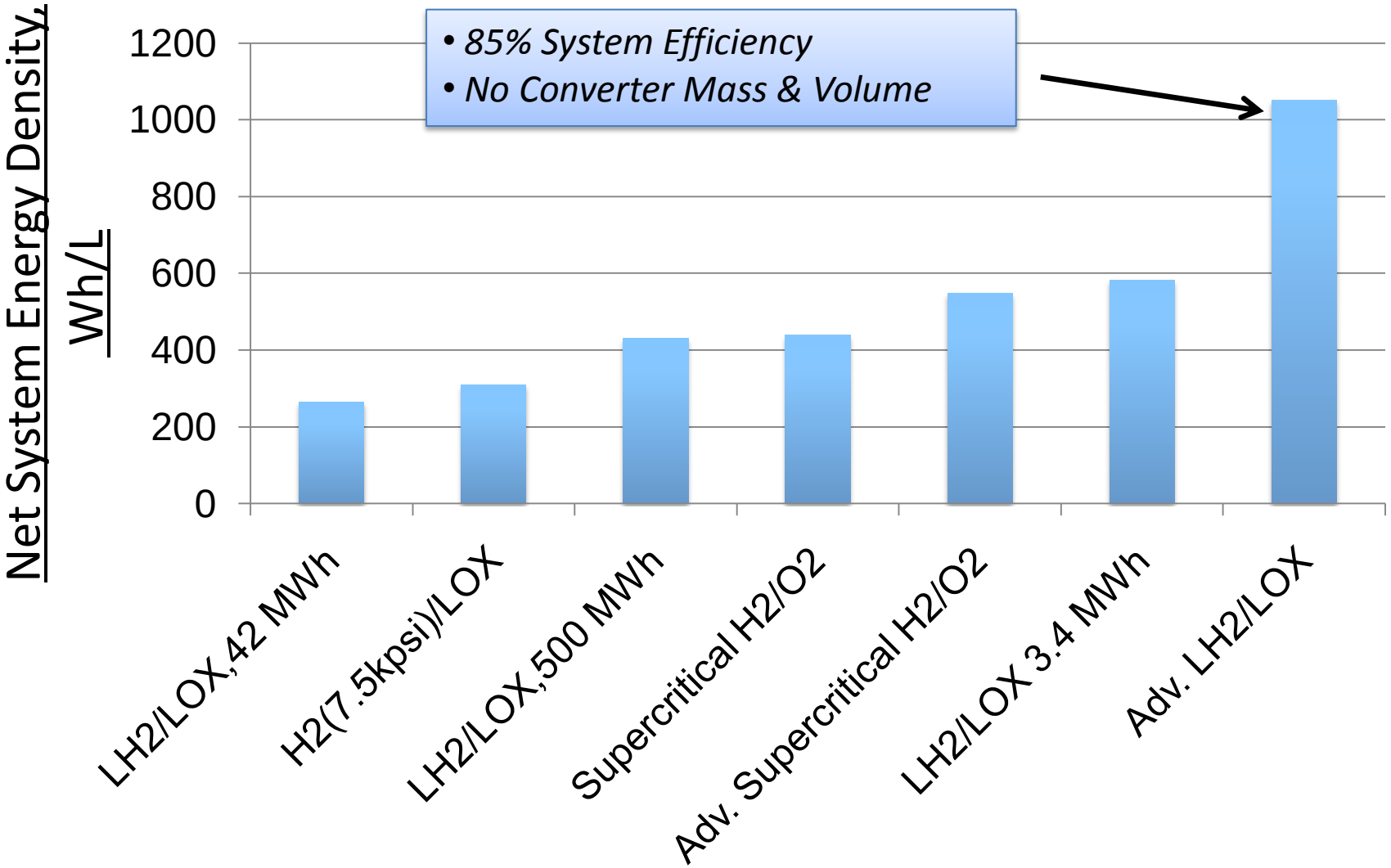
effective O2 density, g/cm^3 of system



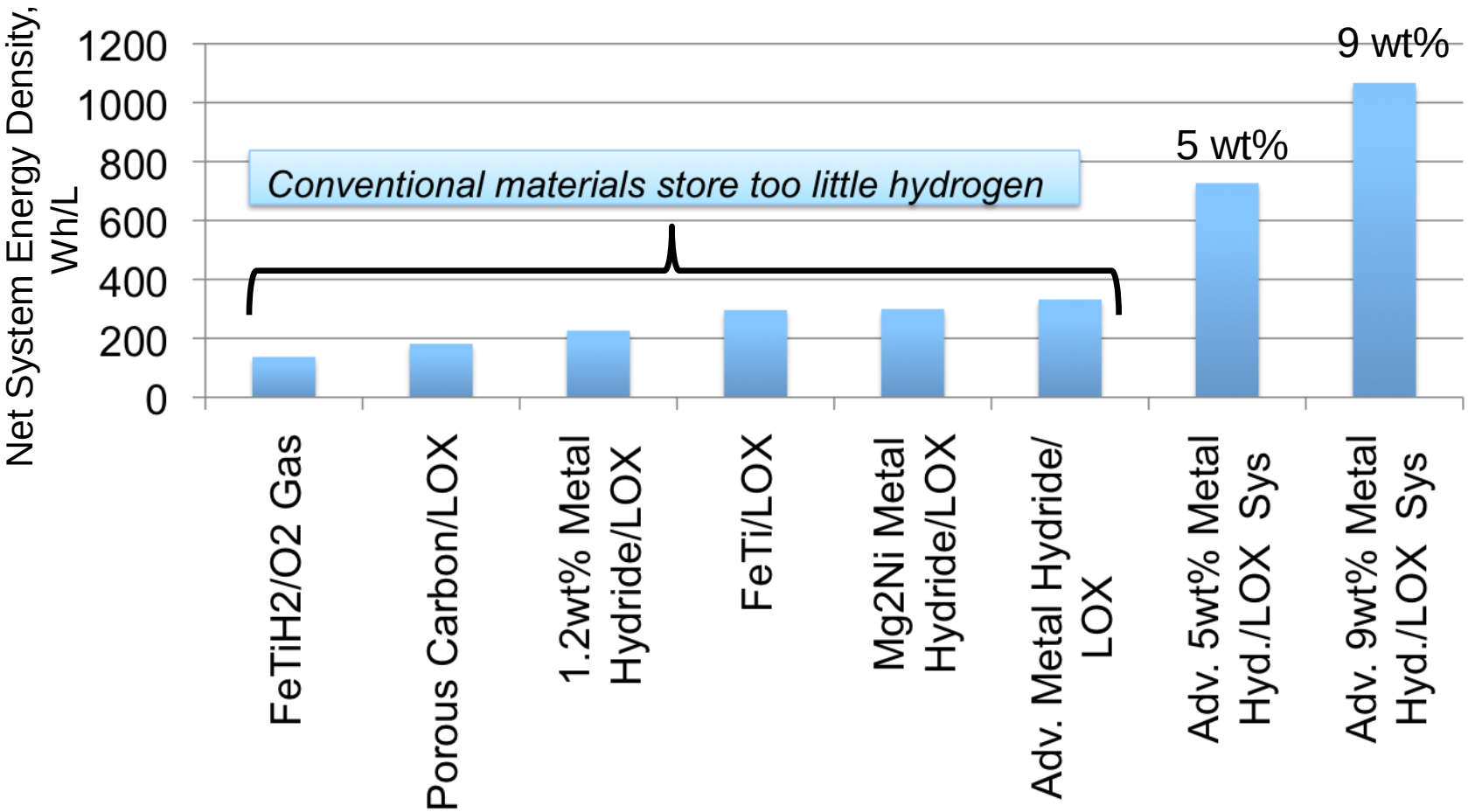
SYSTEM STUDIES

- Multiple fuel/oxidant systems considered
- Each is ~5,000 liters total volume
- All neutrally buoyant
- Not rigorous designs but approximate

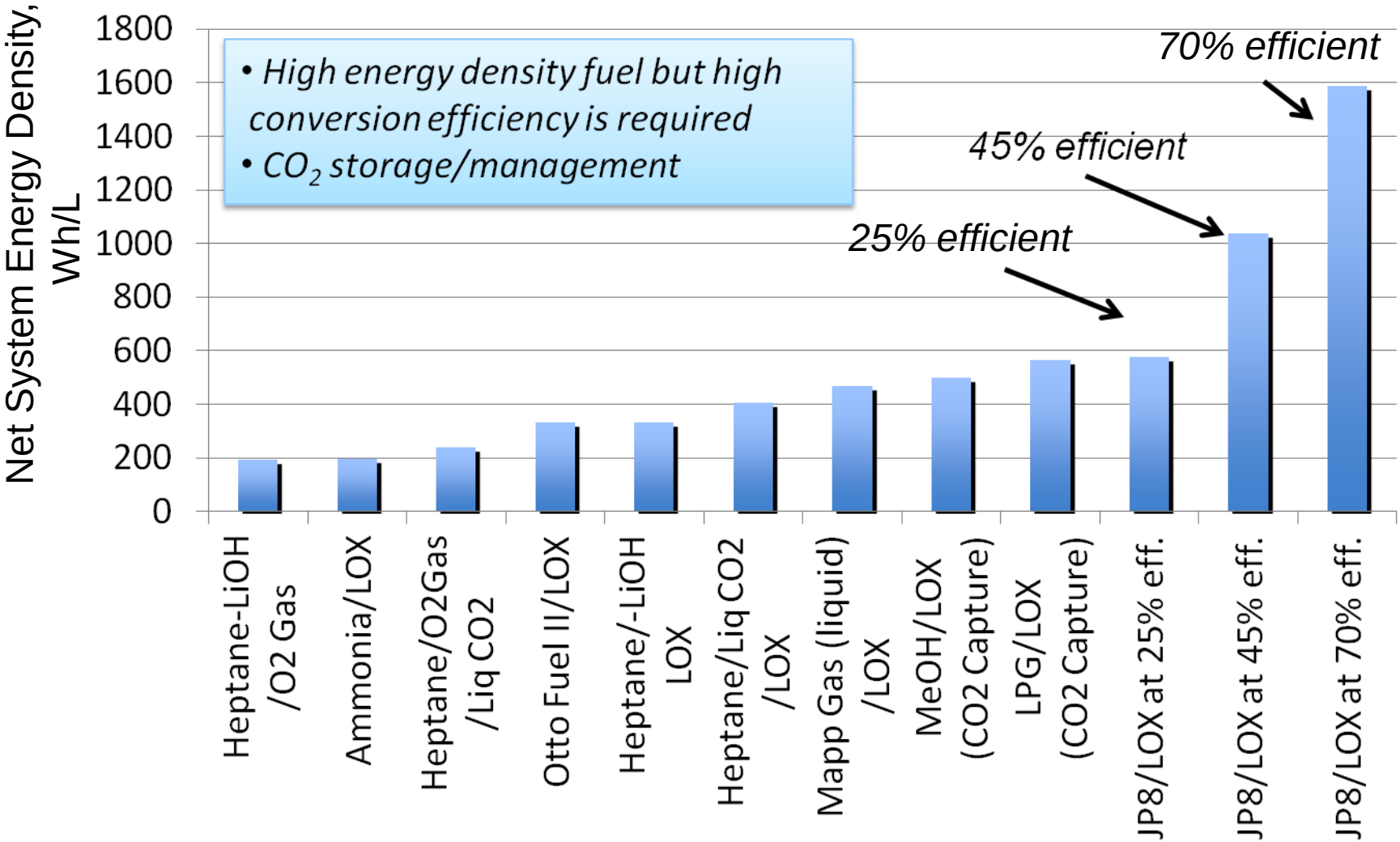
PURE HYDROGEN/OXYGEN FUEL CELL



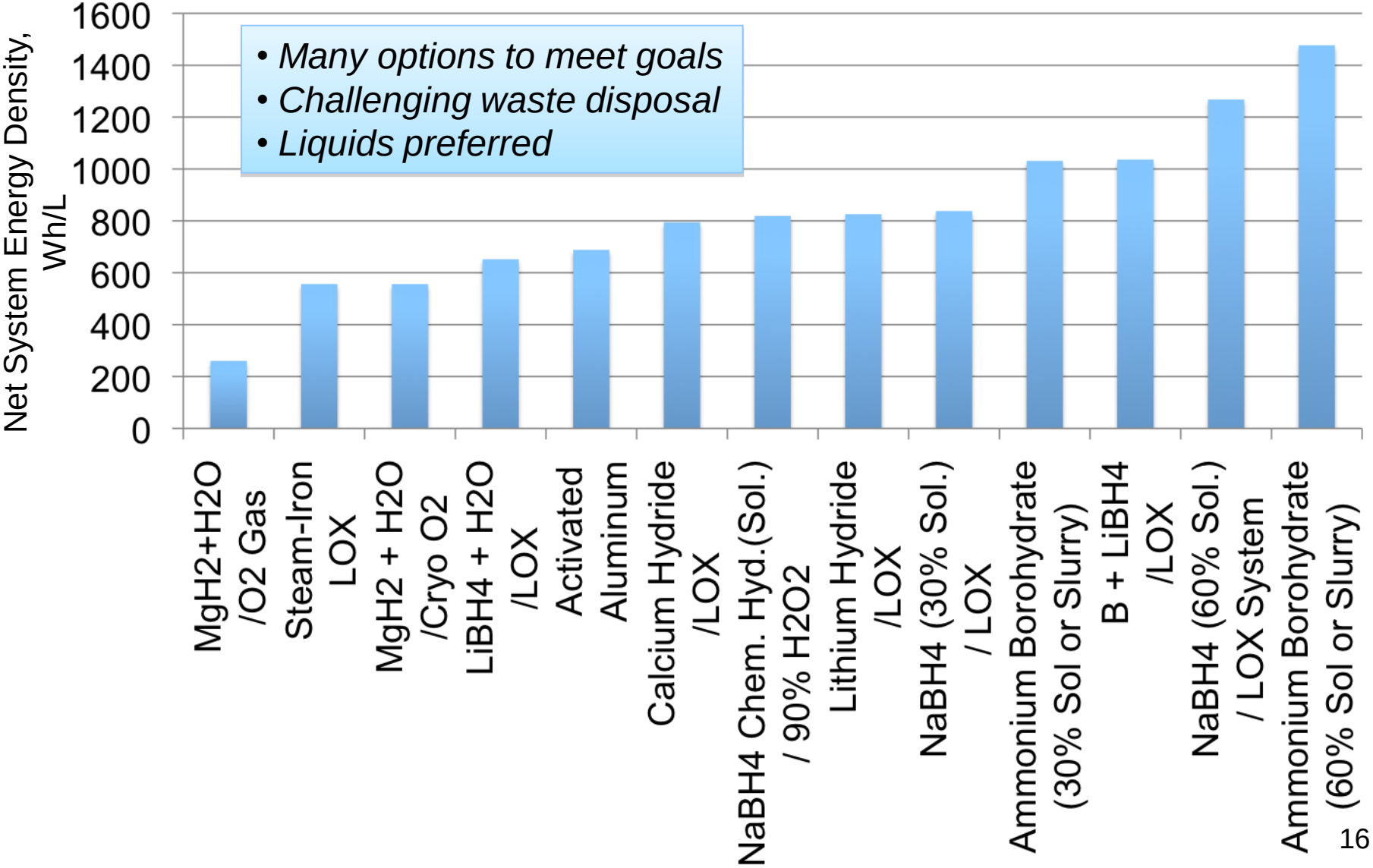
FUEL CELL w/ REVERSIBLE METAL HYDRIDES



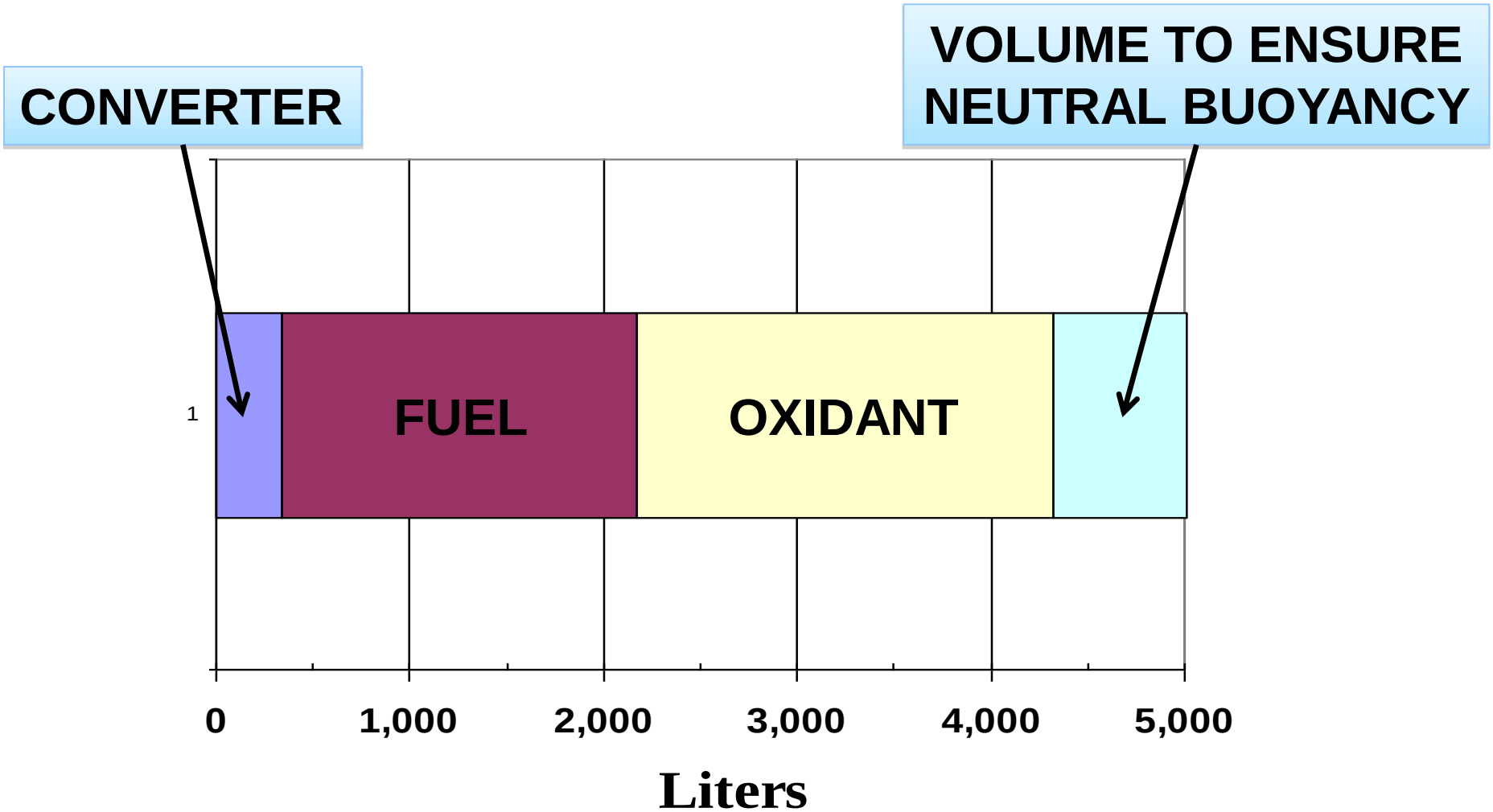
FUEL CELL w/ HYDROCARBON REFORMATE



FUEL CELL w/ CHEMICAL HYDRIDES

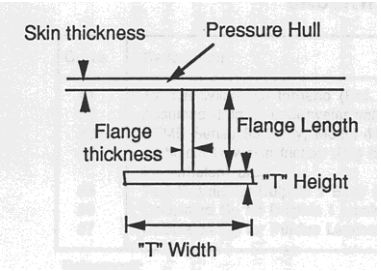


Typical Volume Distribution within Power/Energy Hull Section



DESIGN ELEMENTS TO CONSIDER

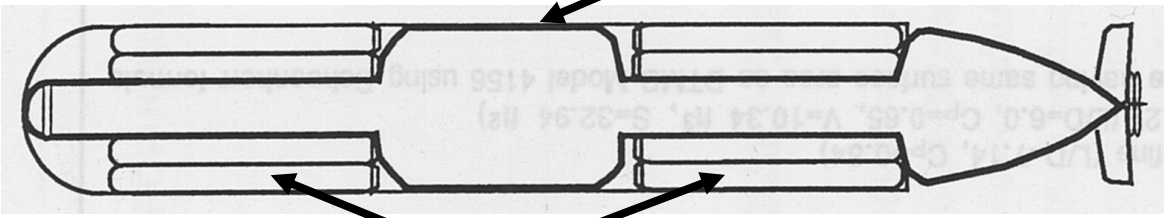
Use of Inner Rib Volume



Volume between pressure vessels ribs can be used for storage

Hull Fairing Liquid Storage

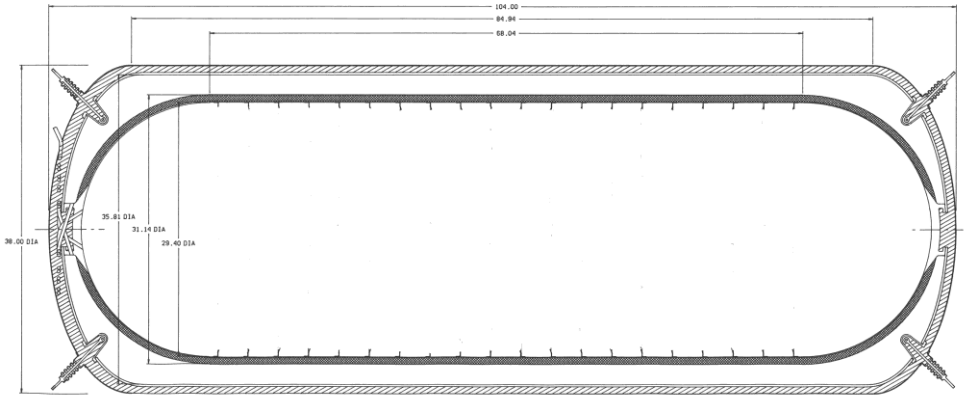
Darker Line Denotes Hull



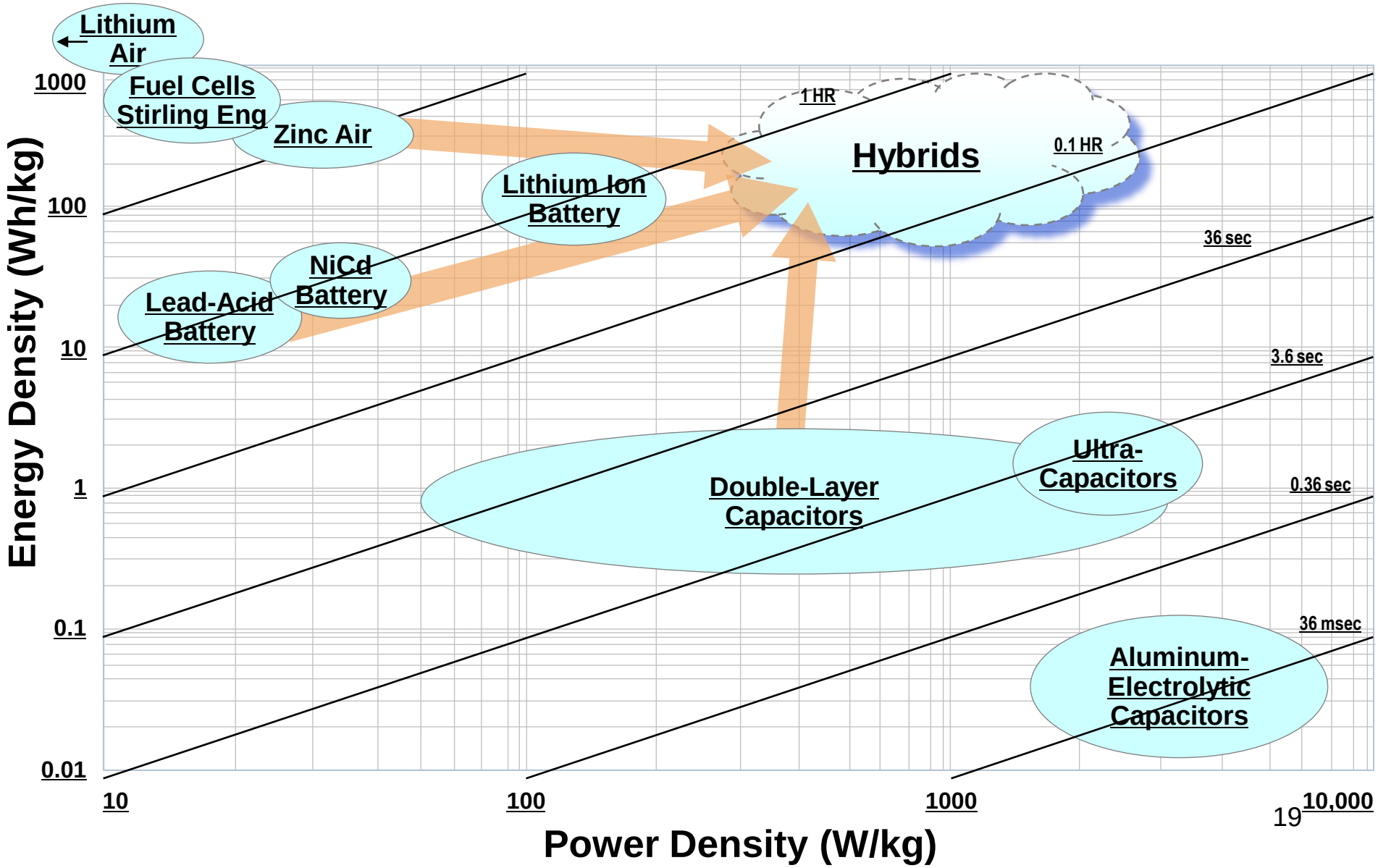
Wetted Fuel/Oxidant Volume External to Hull

Tank-in-a-Tank

- **Better volumetric storage**
- **Reduces wall thickness for highly pressurized systems**
- **Reduces insulation/boil-off for cryogenic systems**



HYBRID POWER SOURCES OFFER HIGH SPECIFIC ENERGY AND POWER



CONCLUSIONS

- Discussion was to highlight issues, not advocate a specific approach or technology
- Traditional approaches will not meet future Navy goals
- Rankings may change with vehicle size/requirements/missions/materials breakthroughs
- Energy conversion efficiency is critical: reactants dwarf converter mass and volume
- Thermal management, neutral buoyancy, product removal, safety, vehicle turn-around time, and cost must be addressed
- Hybrid systems may offer higher system efficiencies and better performance

KEEP IT SIMPLE, GET THE JOB DONE, INNOVATE

Vaccine Fridge CFS49IS System

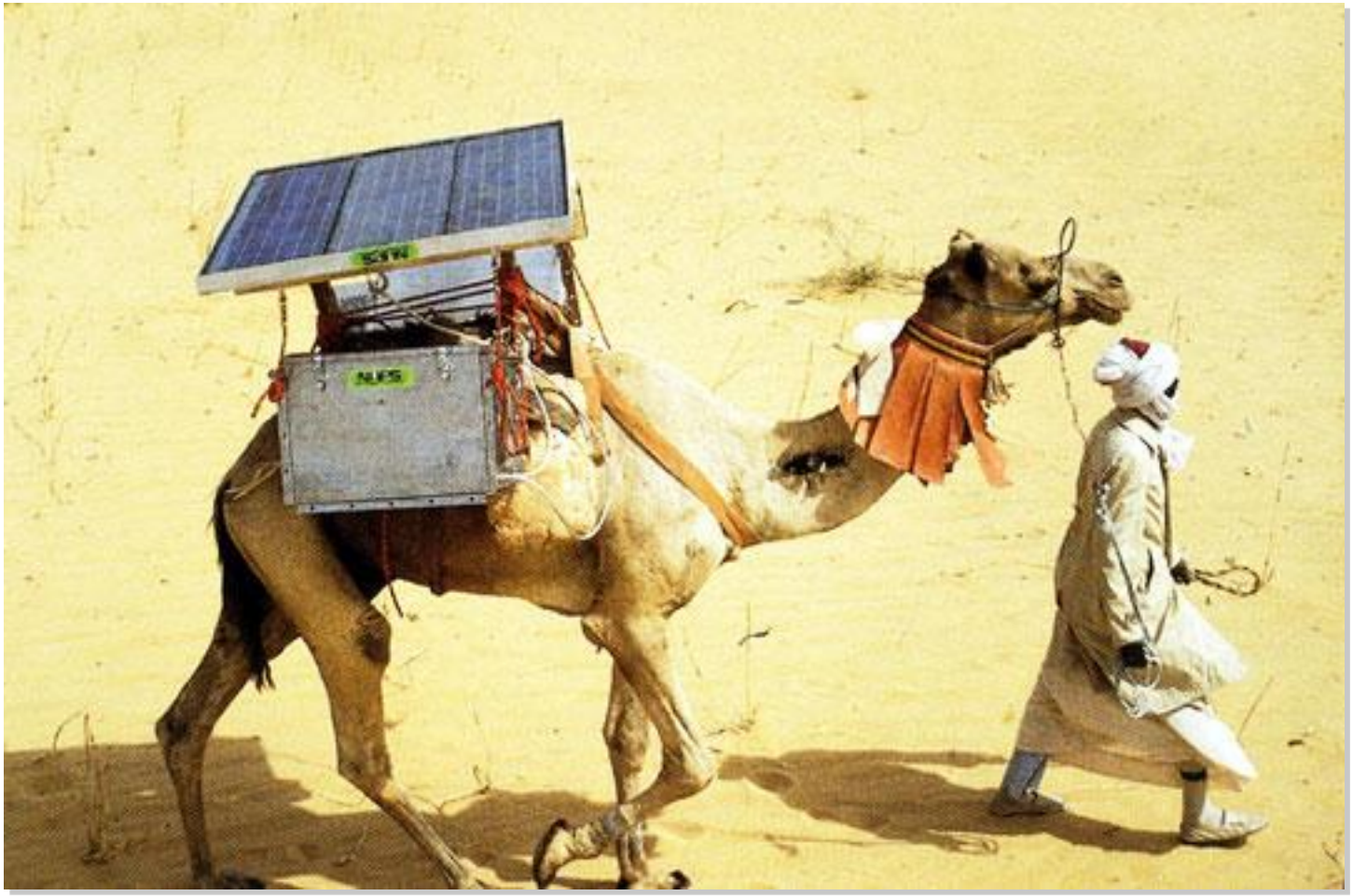


Photo courtesy of Naps Systems

ACKNOWLEDGEMENT

Brian James (Directed Technologies) provided data, the system configuration modeling and analysis, and many of these charts.

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