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Emerging Energy Technologies to Support the Canadian Armed Forces of Tomorrow

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Overview

- Big challenge: operational energy costs, logistic tail
- Examples of future energy technologies
- Some energy technologies enabled by nanotechnologies
- Improved conductance and potential energy system impact
- Examples of possible sustainable future energy systems
- EmDrive versus classical Photon RocketPower
- New nuclear technology devices
- Some POCs

Big challenge: operational energy costs, logistic tail

- One aspect is the fully burdened cost of energy (FBCE) in a theatre of operations where opposing forces disrupt fuel supply chain or in a difficult to access location such as CFS Alert.
- A recent energy audit of CFS Alert reveals that the cost of fuel is about five times as much as the bulk price negotiated across Canada for the CAF. The fuel at CFS Alert needs to be airlifted out of the US Base Thule in Greenland.
- For operations in the Middle East, fuel delivered by convoys is often disrupted by opposing forces. Here are some DoD examples of FBCE costs: "The Defense Logistics Agency buys military fuel for $2.82 per gallon. But that same fuel can cost $13 if it's shipped by ground to a forward-deployed location, during peacetime. If it's transferred in-flight from a refueling airplane to another aircraft, the gas is $42. If troops are in hostile areas, prices can range from $100 to $600 for "in theater" delivery. The Army estimated fuel can cost up to $400 a gallon if the only way to ship it is via helicopters."

Can we avoid having to transport and store fuel for months?

- High energy density sources
- Indigenous (local) renewable energy
- In situ fuel production
- Reduce energy demand
- Increase system efficiency
- Recycle resources
- Recuperate energy wastes

Examples of energy systems enabling technologies

- In situ hydrogen production:
  - Direct solar to H_2 or via electricity (PVs)
  - Using radiation-free nuclear technologies, e.g., SHT and E-Cat

SHT: Solar Hydrogen Trends, Inc.

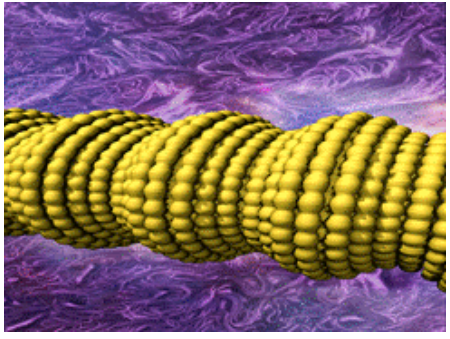
- Producing electricity with radiation-free nuclear sources, fuel cells…
- Increase efficiency of powered amenities and capabilities
- Condensing water vapor to recuperate heat and water
- Using heat pumps for cooling and heating
- Increase conductance using nanotechnology
- Reduce loss in wiring and devices
- Others?

For more examples see "Evidence base for the development of an enduring DND/CAF Operational Energy Strategy (DOES): Expressing Canadian values through defence operational energy stewardship here and abroad":

http://cradpdf.drdc-rddc.gc.ca/PDFS/unc189/p800726_A1b.pdf

Increase conductance and flexibility using nanotechnologies

- Electrically conducting fibers that can be reversibly stretched to over 14 times their initial length and whose electrical conductivity increases 200-fold when stretched. Fibers and cables derived from the invention might one day be used as interconnects for super-elastic electronic circuits; robots and exoskeletons having great reach; morphing aircraft; giant-range strain sensors; failure-free pacemaker leads; and super-stretchy charger cords for electronic devices.
- Wearable energy-dense and power-dense supercapacitor yarns enabled by scalable graphene–metallic textile composite electrodes: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4490556/
- Printable elastic conductors with a high conductivity for electronic textile applications (using nanoparticle-based inks): http://www.nature.com/ncomms/2015/150625/ncomms8461/full/ncomms8461.html
- In theory, metallic nanotubes can carry an electric current density of 4 × 10^9 A/cm^2, which is more than 1,000 times greater than those of metals such as copper, where for copper interconnects current densities are limited by electromigration. Hong, Seunghun; Myung, S (2007). "Nanotube Electronics: A flexible approach to mobility". Ref.: Nature Nanotechnology 2 (4): 207–208. https://en.wikipedia.org/wiki/Carbon_nanotube



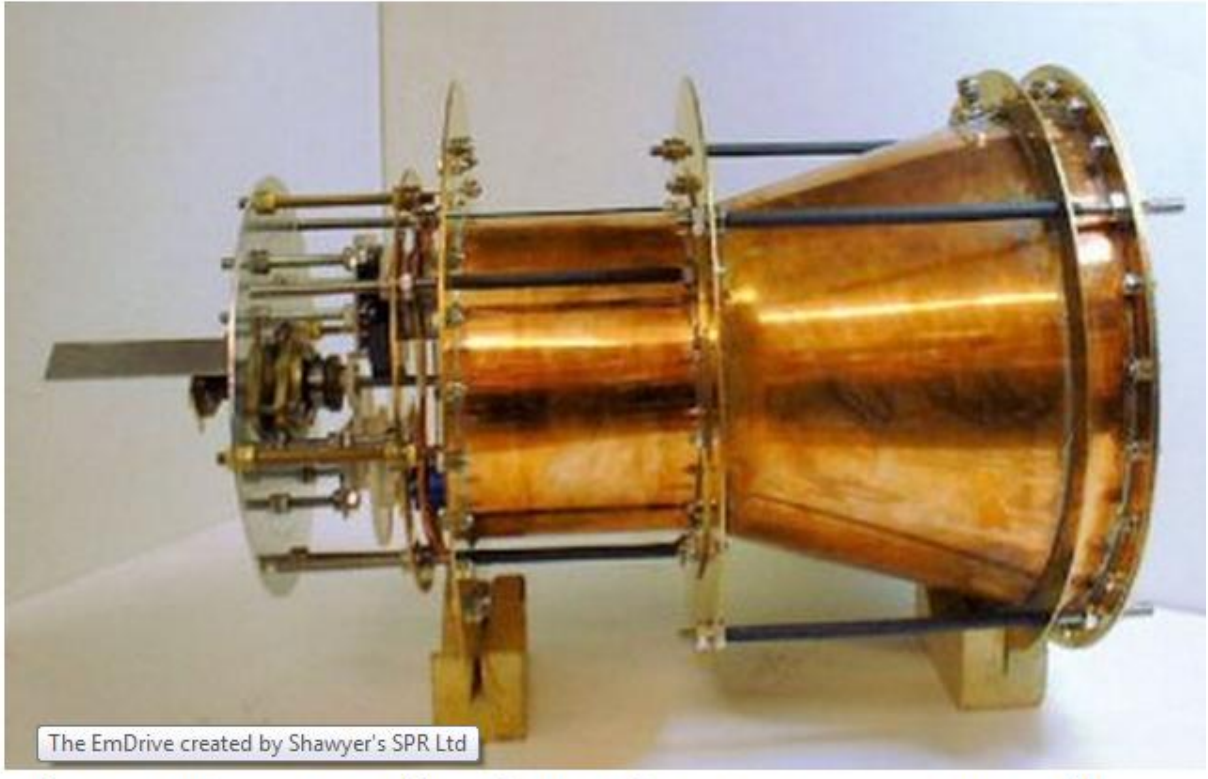
http://www.utdallas.edu/news/2015/7/23-31627_Scientists-Stretch-Electrically-Conducting-Fibers-_story-wide.html?WT.mc_id=NewsHomePageCenterColumn

Having the wiring, electronics and energy storage integrated in a uniform provides a net advantage for the dismounted soldier of the future.

Example of a technology that does not disperse matters

(no fuel behind, no contrails)

- For space travel: EmDrive
- The only difference between EmDrive and a classical Photon Rocket, is that no particles get out.
- EmDrive is said to be a thousand times more efficient than a Photon Rocket.



The EmDrive created by Shawyer's space company Satellite Propulsion Research Ltd (Roger Shawyer, Satellite Propulsion Research Ltd)

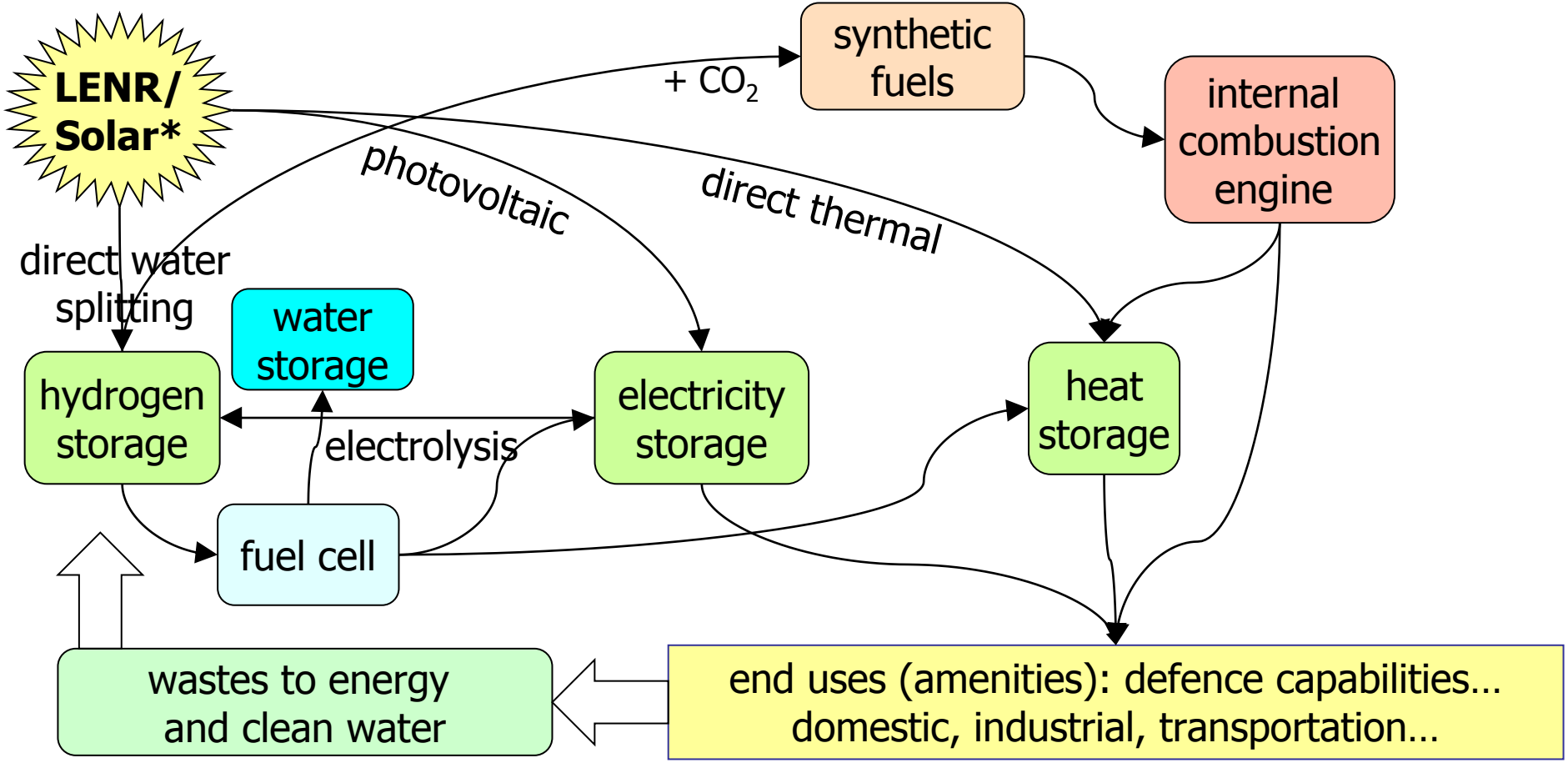
EmDrive by Shawyer's Satellite Propulsion Research Ltd.

- **Nasa says it works when tested in a vacuum**
- The researchers explain that the reason why Shawyer's EmDrive models and EmDrive experiments carried out by Chinese researchers had been criticised in the past was because none of the tests had been carried out in a vacuum.
- Physics says particles in the quantum vacuum cannot be ionised, so therefore you cannot push against it, but Nasa says Shawyer's theory does indeed work.
- "Nasa has successfully tested their EmDrive in a hard vacuum – the first time any organisation has reported such a successful test. To this end, Nasa Eagleworks has now nullified the prevailing hypothesis that thrust measurements were due to thermal convection," the researchers wrote.
- Nasa says its researchers joined forces with a large community of enthusiasts, engineers, and scientists on several continents to discuss EmDrive theories on the NasaSpaceflight.com EmDrive forum, and "despite considerable effort within the NasaSpaceflight.com forum to dismiss the reported thrust as an artefact, the EmDrive results have yet to be falsified".
- At least now Shawyer's work is being validated and he continues to work on a souped-up second generation version of the EmDrive that uses super conductors and an asymmetrical cavity to increase the thrust by up to five orders of magnitude.
- "The space industry doesn't want to know about it as it's very disruptive. If the customer will spend hundreds of millions of dollars on launching a satellite, why would you want to make something that could do it cheaper?
- "This technology is a quantum leap – it would enable vertical take-off and landing for airplanes, it's quiet and it uses liquid hydrogen as a fuel, so it's green too."

So we can avoid having to transport and store fuel for months!

- For space use a radiation-free nuclear energy source to power the EmDrive (it does not directly use a fuel or pushes particles behind)!
- For applications in our atmosphere with oxygen, what about using nuclear energy to produce fuel/hydrogen to a fuel cell that generates electricity to power electrical motors to propel a platform (main drive for ship, truck or airplane). Here the initial water is recycled.
- Challenges include:
  - Producing nuclear energy with minimal radiation
  - No high risk waste
  - No atomic and radioactive material proliferation

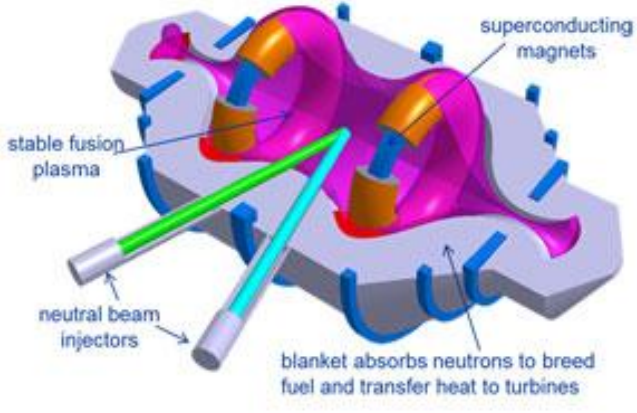
Hydrogen power plant for off-grid applications



*** The LENR/solar energy source could be combined with (or replaced by) small hydro, wind and geothermal or new emerging energy technologies where available and suitable.**

Lockheed Martin claims sustainable fusion is within its grasp

- Lockheed Martin's Skunk Works claims the ability to generate cheap energy from nuclear fusion with little waste or global warming is within its grasp.
- Imagine a source of electrical power that uses water for fuel, produces by products that are totally safe and releases no air pollution.
- Then imagine that once it's up and running, it'll be so portable that an entire power plant could fit into the cargo hold of an airplane. Now, imagine that it'll be running in prototype form in five years and operating commercially in ten.
- The heat energy created using this compact fusion reactor will drive turbine generators by replacing the combustion chambers with simple heat exchangers. In turn, the turbines will then generate electricity or the propulsive power for a number of applications.



http://www.eweek.com/news/lockheed-martin-claims-sustainable-fusion-is-within-its-grasp.html

http://www.lockheedmartin.com/us/products/compact-fusion.html

E-Cat

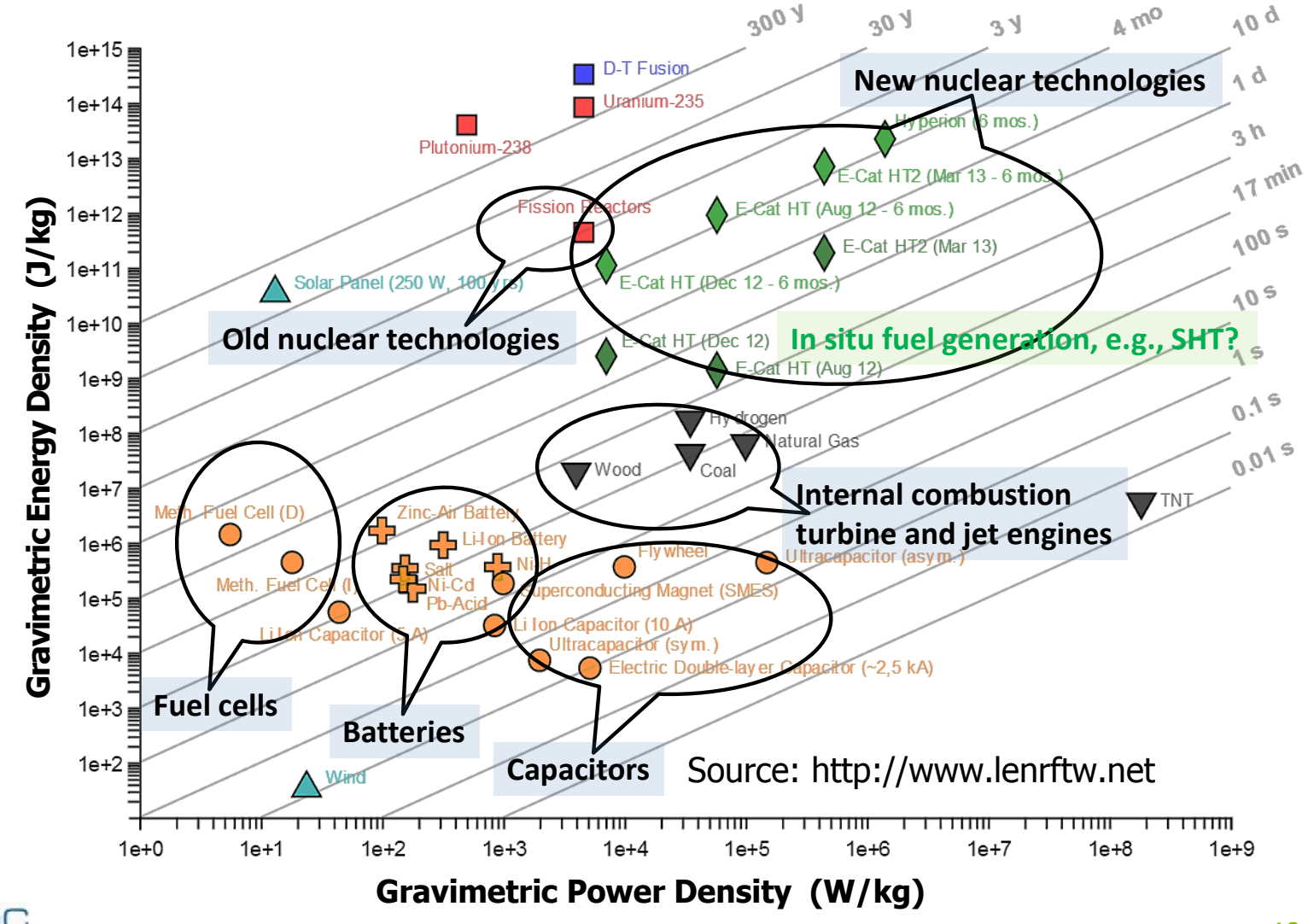
- Recent results from the third party independent E-Cat trials showed exceptional energy densities. When including internal plus external components the volumetric energy density observed was (3.6 104 ± 12%) MJ/L and the gravimetric energy density was (1.3 104 ± 10%) MJ/kg. The energy densities of gasoline are 32.4 MJ/L and 44.4 MJ/kg respectively. So the E-Cat is thousand times more volumetric energy dense and 293 times more gravimetric energy dense than gasoline.
- The conservative E-Cat gravimetric power density was (4.7 103 ± 10%) W/kg. Jet engines of Boeing 747 and Airbus A300 offer a power density 5.67 kw/kg. So the E-Cat is almost as gravimetric power dense as these jet engines. Wärtsilä RTA96-C 14-cylinder two-stroke turbo diesel engines display 0.03 kW/kg. So the E-Cat is 100 times more gravimetric power dense than these ship engines.
- The E-Cat fuel weight of the charge was 1 g. It delivered the following thermal energy density and power density: (1.6 106 ± 10%) Wh/kg or (5.8 106 ± 1 0%) MJ/kg, and (2.1 106 ± 10%) W/kg. These results place the E-Cat beyond any conventional source of energy. It is close to the energy densities of nuclear sources, such as U235, but it is lower than the latter by at least one order of magnitude.
- Currently running a 350-day demonstration.
- E-Cat X to be even more powerful.

Potentially enough energy and power to make EmDrives and other drives to work for months without the need of refuelling.

Summary of what is labelled “new nuclear technologies”

- The following chart provides the order of magnitudes of what new nuclear technologies may bring to our spectrum of options for future energy sources. It includes LENR and another possibility reported under ‘in situ fuel production’ as follows: The high rates of hydrogen production as claimed by Solar Hydrogen Trends (SHT) were confirmed by third party measurements (209 kL/h for 415 Wh, that generating hydrogen at an equivalent of 626 kWh, or a COP of 1500). The size and weight of tested devices were small, similar to LENR ones. So both LENR and SHT devices are in the bubble labelled ‘New nuclear technologies’ in the chart. This is enough energy to power large aircraft such as a 747 or C17 when the technology becomes commercially viable.
- The other contender of high energy density source is the compact fusion reactor (CFR) by Lockheed Martin which targets prototypes in five years and commercialisation in ten years. But we don’t have any trial result data.
- NASA considers such options for their LENR aircraft.
- As shown in the chart, LENR and SHT stacks up against electrochemical devices, chemical reactions, nuclear fission plants, fusion and renewables.

Notional Ragone chart modified to show selected categories of energy sources



Powering the capabilities of our future: Recommendations

- Investigate the cost effectiveness of clean nuclear- and hydrogen-based power systems for off-grid (installations, communities and military bases) and autonomous platforms (air, land, surface, under water and space)
- Confirm the extreme environmental advantage of such systems (low GHGs during its use) over legacy power systems using jet fuels or diesel especially when fuels need to be air lifted
- Confirm the reliability, dependability, safety and technology readiness of the components and the control of such systems

POCs

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Potential Collaborative Opportunities

- Integrated power solutions for dismounted soldiers, platforms, bases…
  - Energy storage
  - Energy production
  - Energy harvesting
  - Power demand profiles (consumption)
- Operational energy for deployed operations
  - Alternative energy
  - Energy storage (thermal and electrical)
  - Operational power demand profiles – options analysis
  - Wide operating temperature performance issues
  - Methodologies/technologies to reduce energy consumption


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