Future Energy Technologies

By Paul Labbé, Chief Scientist Office

"This presentation contains information which is provided to the participants of the Foresight Synergy Network (FSN) Monday 7 November 2016 (12 to 2 pm) @ room DMS 4165 of Ottawa U. It does not contain any formal recommendations or positions from the Government of Canada, DND, ADM(S&T) or DRDC."

Canada

Overview

- Organization: DND ADM(S&T) / DRDC
- A DND Strategy in Progress
- US Congress LENR Awareness
- Big challenge: sustainable, energy efficient, environment friendly
- Examples of future energy technologies
- Some energy technologies enabled by nanotechnologies
- Examples of possible sustainable future energy systems

LENR stands for Low Energy Nuclear Reactions, (or sometimes Lattice Enabled Nanoscale Reactions) and refers to the phenomenon where anomalous amounts of heat are created when certain metals (e.g. nickel, palladium) absorb hydrogen or deuterium and an external stimulus such as heat or an electric current is applied. See also: http://cradpdf.drdc-rddc.gc.ca/PDFS/unc207/p802902_A1b.pdf

DRDC's mission:

Provide a science, technology and knowledge advantage for Canada's defence and security

- DRDC has three core functions :
  - S&T Strategic **Planning** (led by COS)
  - S&T Program **Formulation** (led by DGSTPS)
  - S&T Program **Execution** (led by DGSTCO)
- We have integrated the R&D program across DRDC Research Centres to offer the best scientific support to DND and the CAF.

COS:
Chief of Staff

DGSTPS:
Director General Science and Technology Portfolios

DGSTCO:
Director General Science and Technology Centre Operations

DND: Department of National Defence
DRDC: Defence Research and Development Canada
CAF: Canadian Armed Forces

ADM(S&T) and Defence Research and Development Canada

Mission
Provide a science, technology and knowledge advantage for Canada's defence and security

Vision
DRDC is a national leader and an international partner in S&T critical to Canada's defence and security

Roles

- Delivers knowledge, analysis and advice based on science and technology
- Recruits new ideas, knowledge and solutions by engaging with national and international partners
- Performs research and development in classified, sensitive and strategic areas
- A well managed research organization that promotes a respectful and inclusive workplace

Impacts

- Build agile and adaptable forces to carry out missions across a wide spectrum of operations
- Assist and support CAF and civilian personnel before, during and after operations
- Enable the acquisition, sharing and use of critical information in support of situational awareness and decision-making
- Develop and implement solutions to maximize the affordability and sustainability of DND and the CAF
- Support public safety and security practitioners in their mission to protect Canadians
- Anticipate, prepare for and counter the emergence of future threats

New DND strategy for energy and environment

Defence Energy and Environment Strategy (DEES);
Harnessing energy efficiency and sustainability:
Defence and the road to the future

- Lead DND ADM(IE)
- Contributions from all affected DND/CAF units
- Expected to be completed soon, early 2017?

ADM(IE): Assistant Deputy Minister of Infrastructure and Environment

Low Energy Nuclear Reactions (LENR) Briefing

https://www.congress.gov/114/crpt/hrpt537/CRPT-114hrpt537.pdf see page 87

The committee is aware of recent positive developments in developing low-energy nuclear reactions (LENR), which **produce ultraclean, low-cost renewable energy** that have **strong national security implications**. For example, according to the Defense Intelligence Agency (DIA), if LENR works it will be a ‘‘disruptive technology that could revolutionize energy production and storage.’’ The committee is also aware of the Defense Advanced Research Project Agency’s (DARPA) findings that other countries including China and India are moving forward with LENR programs of their own and that Japan has actually created its own investment fund to promote such technology. DIA has also assessed that Japan and Italy are leaders in the field and that Russia, China, Israel, and India are now devoting significant resources to LENR development. To better understand the national security implications of these developments, the committee directs the Secretary of Defense to provide a briefing on the military utility of recent U.S. industrial base LENR advancements to the House Committee on Armed Services by September 22, 2016. This briefing should examine the current state of research in the United States, how that compares to work being done internationally, and an assessment of the type of military applications where this technology could potentially be useful.

National defense authorization act for fiscal year 2017 Report of the Committee on armed services House of representatives

https://www.loc.gov/loc/lcib/0310/canada.html Library of Congress, Anita Kunz

DTRA report http://lenr-canr.org/acrobat/MosierBossinvestigat.pdf (Access date 10 Nov. 2016)

US Defense Threat Reduction Agency Releases a LENR Report :

"Investigation of Nano-Nuclear Reactions in Condensed Matter" by Pamela Mosier-Boss of Space and Naval Warfare Systems Command (SPAWAR) Systems Center Pacific based in San Diego, Lawrence Forsely of Jay Wook Khim (JWK) International and Patrick K. McDaniel of the University of New Mexico. Excerpts follow:

"The Pd/D co-deposition process has been shown to provide a reproducible means of manufacturing Pd-D nano-alloys that induce low energy nuclear reactions (LENRs)," the report states (page 2). Pd stands for palladium, a metal widely used in some LENR processes.

"Besides LENR, the Pd/H(D) system exhibits superconductivity. Palladium itself does not superconduct. However, it was found that H(D)/Pd does and that the critical temperatures of the deuteride are about 2.5 K higher than those of hydride (at the same atomic ratios)." (page 2).

"Once understood, LENR has the potential to be a paradigm-shifting, 'game-changing' technology. Nuclear energy systems have power densities six orders of magnitude greater than chemically-based energy generation or storage systems. The ability to harness a new nuclear energy source for either thermal or electrical conversion, without the generation of penetrating energetic particles, would have a profound commercial and military impact ranging from small footprint power systems to mobile systems to larger stationary power systems." (page 81).

This report was circulated in the classified world, staid in limbo since 2012, after a Freedom of Information Act request to DTRA for the report, it was given approval for public release on Jun 7 2016 by the Public Affairs department of the DTRA.

http://www.e-catworld.com/2016/09/04/us-defense-threat-reduction-agency-releases-lenr-report-investigation-of-nano-nuclear-reactions-in-condensed-matter/comment-page-1/ (Access date: 8 Nov. 2016).

Some organisations involved in LENR

American Chemical Society
American Nuclear Society
Boeing
CERN
DTRA (U.S.)
Airbus https://www.lenr-forum.com/forum/index.php/Thread/3558-Airbus-LENR-Patent-Application/
EPRI
INFN (Italy)
Japan New Energy and Industrial Technology Development Organization
Mitsubishi Heavy Industries
NASA
National Natural Science Foundation of China
Nissan Motor Corp.
Royal Dutch Shell
Toyota Central Labs
Army Research Lab (U.S.)
SPAWAR (U.S.) (Program terminated 2011)
Canada??? Interest from scientists and institutions but no formal programs and funding!!!

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
- Others…

Examples of energy systems enabling technologies

- In situ hydrogen production:
  - Direct solar to H_2 or via electricity (PVs/CPVs)
  - Using radiation-free nuclear technologies, e.g., LENR
- 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

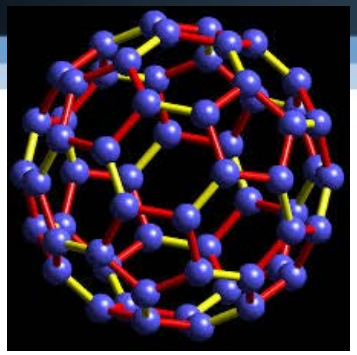
Nanotechnologies can put energy technologies on steroids!

What is nanotechnology?
Nanotechnology is the engineering of functional systems at the molecular scale. Scientists and engineers are discovering a wide variety of ways to change materials at the nanoscale to take advantage of new and remarkable properties, such as higher strength, lighter weight, enhanced conductivity, and greater chemical reactivity than their larger-scale counterparts.

It is any technology that contains components smaller than 100 nanometers.

For scale, a single virus particle is about 100 nanometers in width.

http://www.horizons.gc.ca/eng/content/when-energy-technology-goes-steroids
Peter Reinecke, Policy Horizons Canada



Comparing some particles sizes

Data table of particles sizes/dimensions

14 examples of atoms, molecules, nanoparticles and other 'things', Nos 6 to 10 are typical nanoparticle size

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
material	carbon atom	sulphur atom	water molecule	silver atom	glucose molecule	Buck-minster-fullerene	typical small protein	silver or titanium dioxide nano-particles	typical virus e.g. cold virus	typical carbon nanotube	wavelength of visible light (comparison)	typical bacteria	typical eukaryotic cell	width human hair
Symbol-formula	C	S	H_2O	Ag	$C_6H_{12}O_6$	C_{60}	******	Ag_n $(TiO_2)_n$	na	C_n	******	******	******	******
Size in nm - diameter or length	0.16	0.2	0.2	0.28	0.3 x 0.6	1	5-10	35-120	30-50	100 x 6	400-700	5000	50000	50000 - 100000
longest length or diameter m	1.6×10^{-10}	2×10^{-10}	2×10^{-10}	2.8×10^{-10}	$3 \times 10^{-10} \times 6 \times 10^{-10}$	1×10^{-9}	$5\text{-}10 \times 10^{-9}$	$3.5\text{-}12 \times 10^{-8}$	$3\text{-}5 \times 10^{-8}$	1×10^{-7}	$4\text{-}7 \times 10^{-7}$	5×10^{-6}	5×10^{-5}	$0.5\text{-}1.0 \times 10^{-4}$

http://www.docbrown.info/page03/nanochem01.htm#Data

Serendipity of nanofabrication and catalysis science

In a new twist to waste-to-fuel technology, scientists at the Department of Energy's Oak Ridge National Laboratory have developed an electrochemical process that uses tiny spikes of carbon and copper to turn carbon dioxide, a greenhouse gas, into ethanol. Their finding, which involves nanofabrication and catalysis science, was **serendipitous**.

"We discovered somewhat by accident that this material worked," said ORNL's Adam Rondinone, lead author of the team's study published in ChemistrySelect. "We were trying to study the first step of a proposed reaction when we realized that the catalyst was doing the entire reaction on its own."

The team used a catalyst made of carbon, copper and nitrogen and applied voltage to trigger a complicated chemical reaction that essentially reverses the combustion process. With the help of the nanotechnology-based catalyst which contains multiple reaction sites, **the solution of carbon dioxide dissolved in water turned into ethanol with a yield of 63 percent**. Typically, this type of electrochemical reaction results in a mix of several different products in small amounts.

October 12, 2016

https://www.ornl.gov/news/nano-spike-catalysts-convert-carbon-dioxide-directly-ethanol

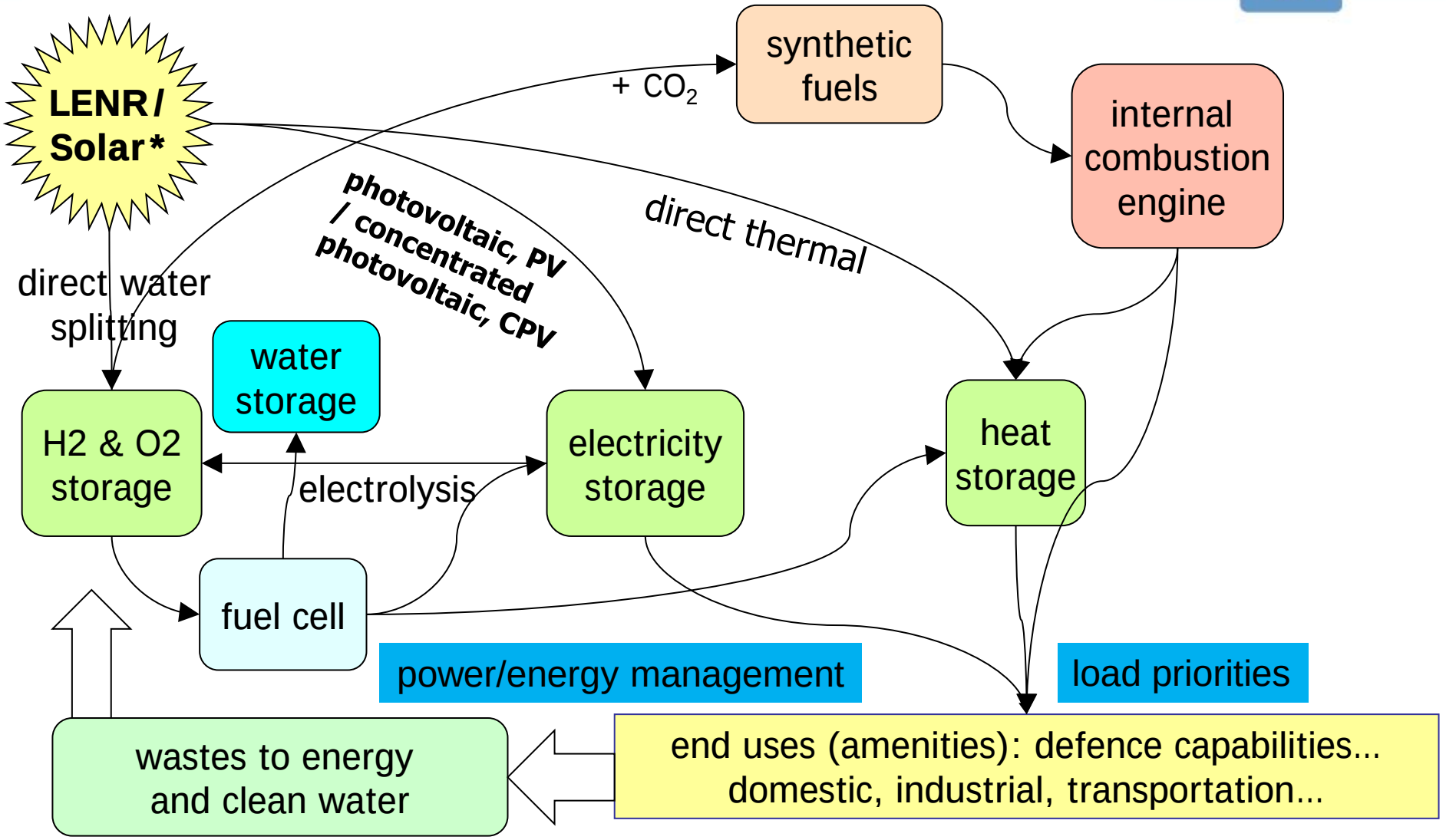
Increase conductance and flexibility using nanotechnologies

- 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.

Potential 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.**

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.
- Run a 350-day demonstration.
- E-Cat X to be even more powerful.

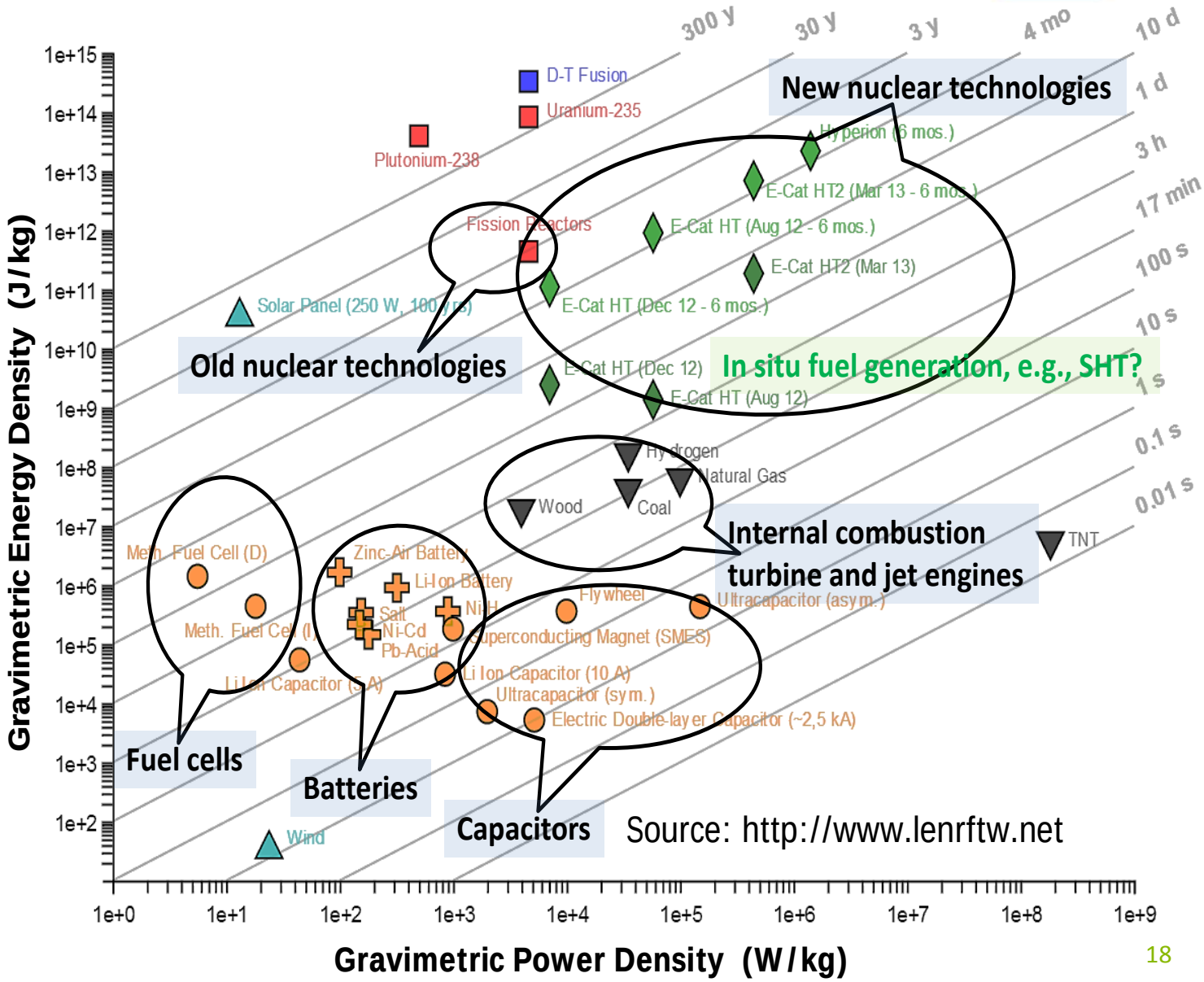
Potentially enough energy and power for an autonomous platform to work for months without the need of refuelling.

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.
- 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.

However no commercial LENR devices have been produced and certified for safe domestic or industrial applications yet.

Notional Ragone chart modified to show selected categories of energy sources



TRL of some LENR technologies

Both SunCell® and E-cat (QuarkX) are 4-5 TRL as they are attempting to license their technology.

Academia is reluctant to participate likely because LENR is missing the solid foundation to have full support and funding.

Technology readiness levels (TRL) are a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process.
https://en.wikipedia.org/wiki/Technology_readiness_level

E-Cat QuarkX Internal Report

Cylinder made with proper material: (estimated nickel weight: 0.21 gram)

•Dimensions: cylinder: length 30 mm, diameter 1 mm

•Energy produced: 100 Wh/h

•Energy consumed: 0.5 Wh/h

•Light produced (percentage of the energy produced): 0-50%

•Electric energy produced: 0-10%

•Heat produced: 0- 100%

Light, energy and heat can be modulated to modulate the percentages within the limits above listed, provided the combined percentages is limited to a total of 100%.

Extremely interesting is the blue light, the analysis of which has resolved theoretical problems related to the roots of the effect.

Temperature on the surface of the QuarkX: more than 1,500*C.

Note: 2 other QuarkX put in analogous situation gave the same results.

Further disclaimer:

This is not a third party report. It is an internal report related to measures made by Leonardo corporation.

Certification in progress. Tests for achieving the QuarkX's 5 sigma reliability.

http://ecat.com/news/ecat-quark-x-preliminary-report-findings

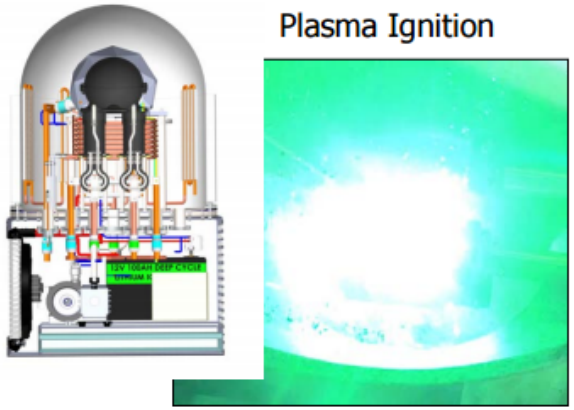
System Design of SunCell®

The SunCell® was invented and engineered to harness this clean energy source of optical power of thousands of Sun equivalents that can be directly converted to electrical output using commercial photovoltaic cells.

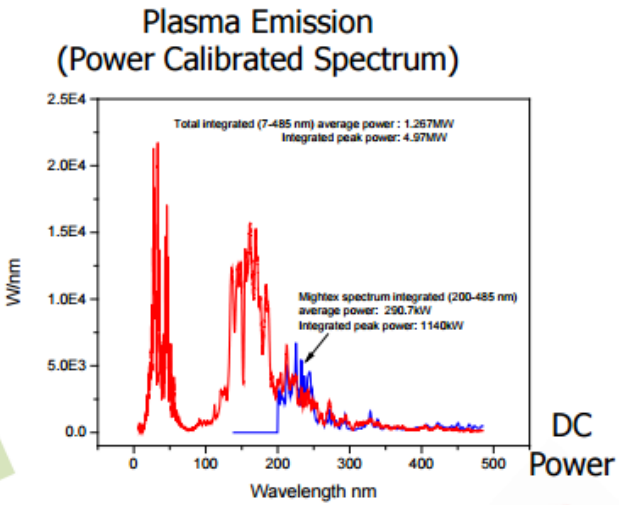
The SunCell® comprises six fundamental low-maintenance commercially available systems, some having no moving parts and capable of operating for a decade or more: (i) a start-up inductively coupled heater to first melt silver; (ii) a gas injector to inject hydrogen derived from water and an injection system comprising an electromagnetic pump to inject molten silver and a very stable solid source of oxygen that reacts with the hydrogen to form the hydrogen to hydrino catalyst; (iii) an ignition system to produce a low-voltage, high current flow across a pair of electrodes into which the molten metal and fuel are injected to form a brilliant light-emitting plasma; (iv) a blackbody radiator heated to incandescent temperature by the plasma; (v) a light to electricity converter comprising so-called concentrator photovoltaic cells that receive light from the blackbody radiator and operate at light intensity of over one thousand Suns; and (vi) a fuel recovery and a thermal management system that causes the molten metal to return to the injection system following ignition.

http://www.brilliantlightpower.com/wp-content/uploads/presentations/BrLP%20Industry%20Day%20102616rlm-web.pdf

Spectral Emission in the High Energy Region Only

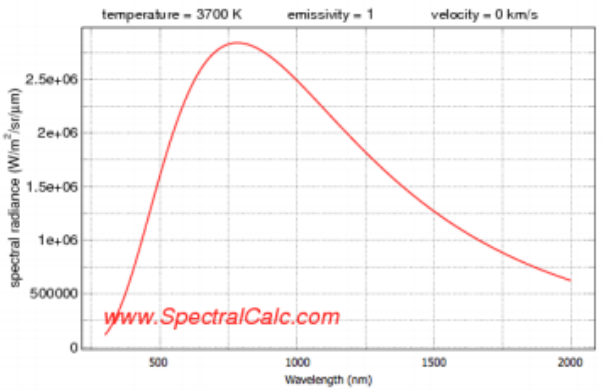


Measurement



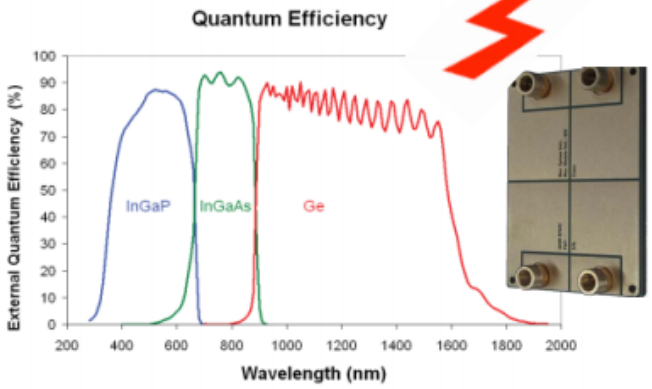
DC Power

Absorb to BB



SunCell Blackbody Radiator

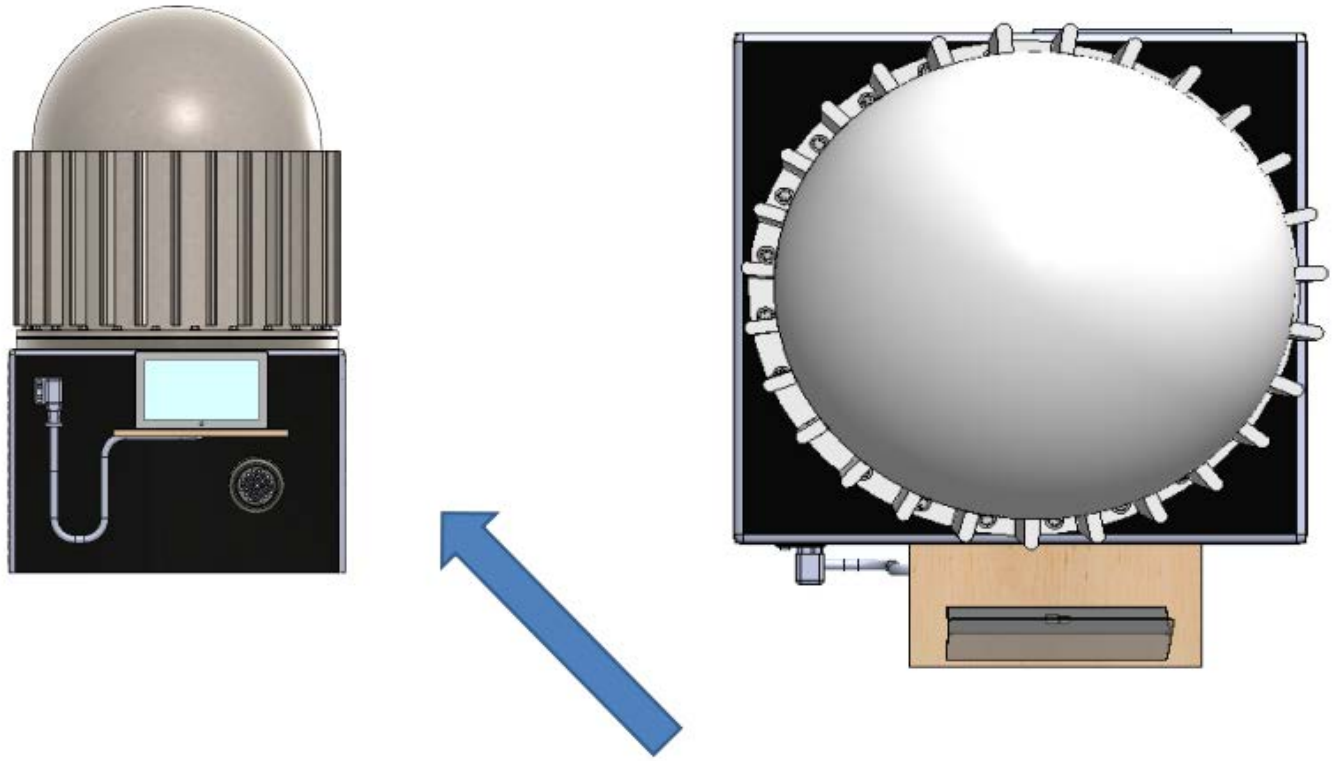
Re-emit to CPV



Concentrator PV
Power Conversion Spectrum

http://www.brilliantlightpower.com/wp-content/uploads/presentations/BrLP%20Industry%20Day%20102616rlm-web.pdf

250KW SUNCELL SURFACE AREA



SURFACE AREA = 27″ X 27″ =729 SQ.IN

http://www.brilliantlightpower.com/wp-content/uploads/presentations/BrLP%20Industry%20Day%20102616rlm-web.pdf

SunCell®

Feature	Est.
Power Output	10 kW, 100 kW, 250 kW DC or AC
DC Voltage	~380 or ~760
AC Inverter for 50/60 Hz	Option
SunCell dimensions (L,W, H)	0.5x0.5x0.5m
Photovoltaic Power Density	2000 Suns
Blackbody Radiator Power Density	10 MW/m2
Weight	100 kg
Warm-up Time	1 min
Self-consumption power	<3 kW
Response Time (standby to peak)	~100ms
Service Life	15 years
Noise Emission	Sound Proofed
Degree of protection (per IEC 60529)	
Climatic category (per IEC 60721-3-4)	

http://www.brilliantlightpower.com/wp-content/uploads/presentations/BrLP%20Industry%20Day%20102616rlm-web.pdf

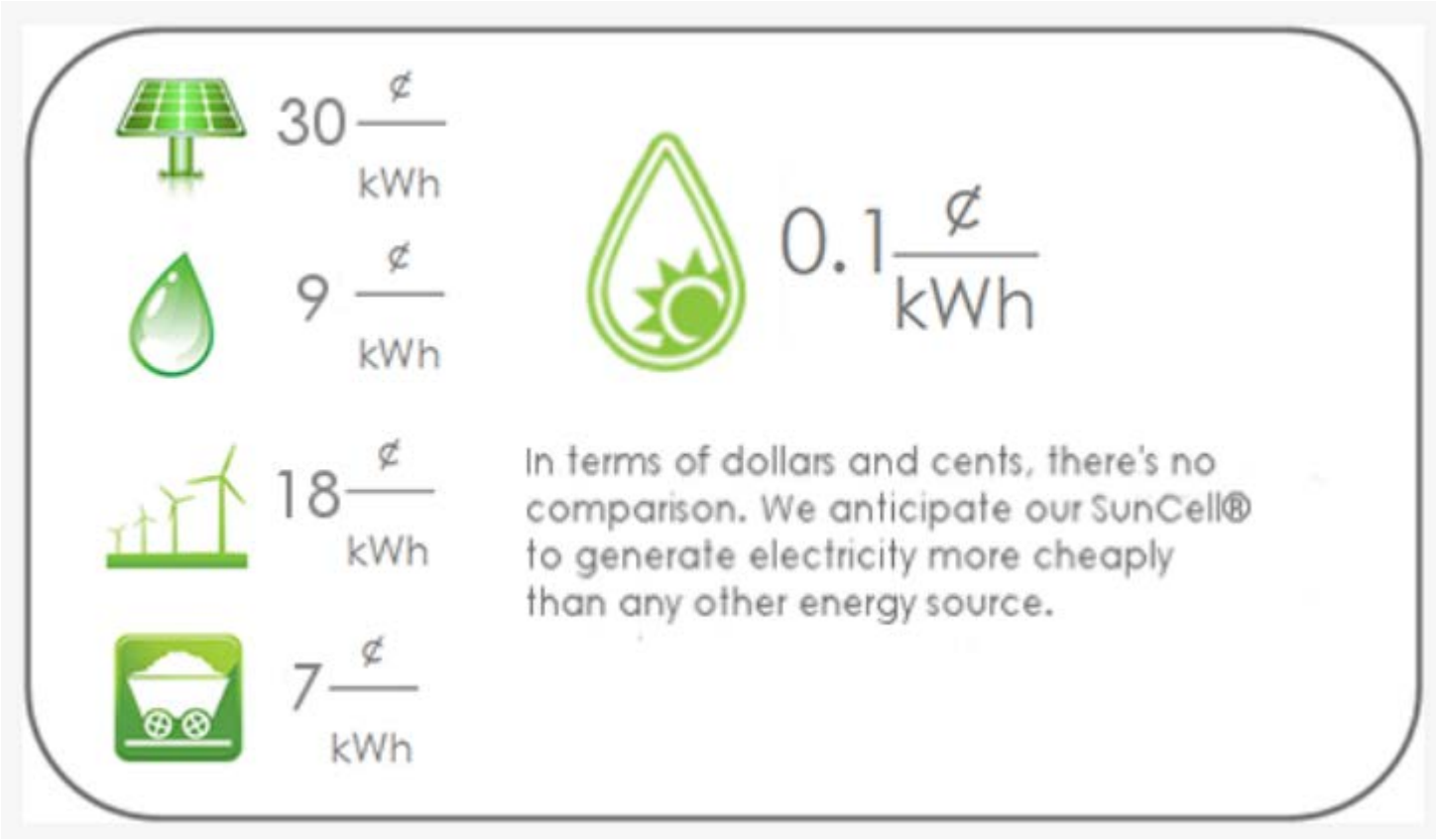
COST ANALYSIS FOR FIRST OF A KIND 250KW (2000 Suns)

250KW SUN CELL COST ANALYSIS	
DESCRIPTION	**TOTAL COST AT SUB ASSY LEVEL**
BELL JAR VACUUM CHAMBER ASSY	$1,891.47
RESERVOIR ASSEMBLY	$484.17
INDUCTION COIL ASSEMBLY	$800.00
PIPING ASSY	$900.00
EM MAGNET ASSY	$380.00
ELCTRODE ASSEMBLY	$0.00
REACTION CHAMBER ASSY	$530.00
PV CELL ASSEMBLY	$15,000.00
BASE SKID	$400.00
VACCUM PUMP & WATER PUMP	$4,600.00
MISC (RADIATOR)	$236.00
DESCRIPTION	TOTAL COST 250KW
TOTAL COST	$25,221.64

36

http://www.brilliantlightpower.com/wp-content/uploads/presentations/BrLP%20Industry%20Day%20102616rlm-web.pdf

Comparative cost



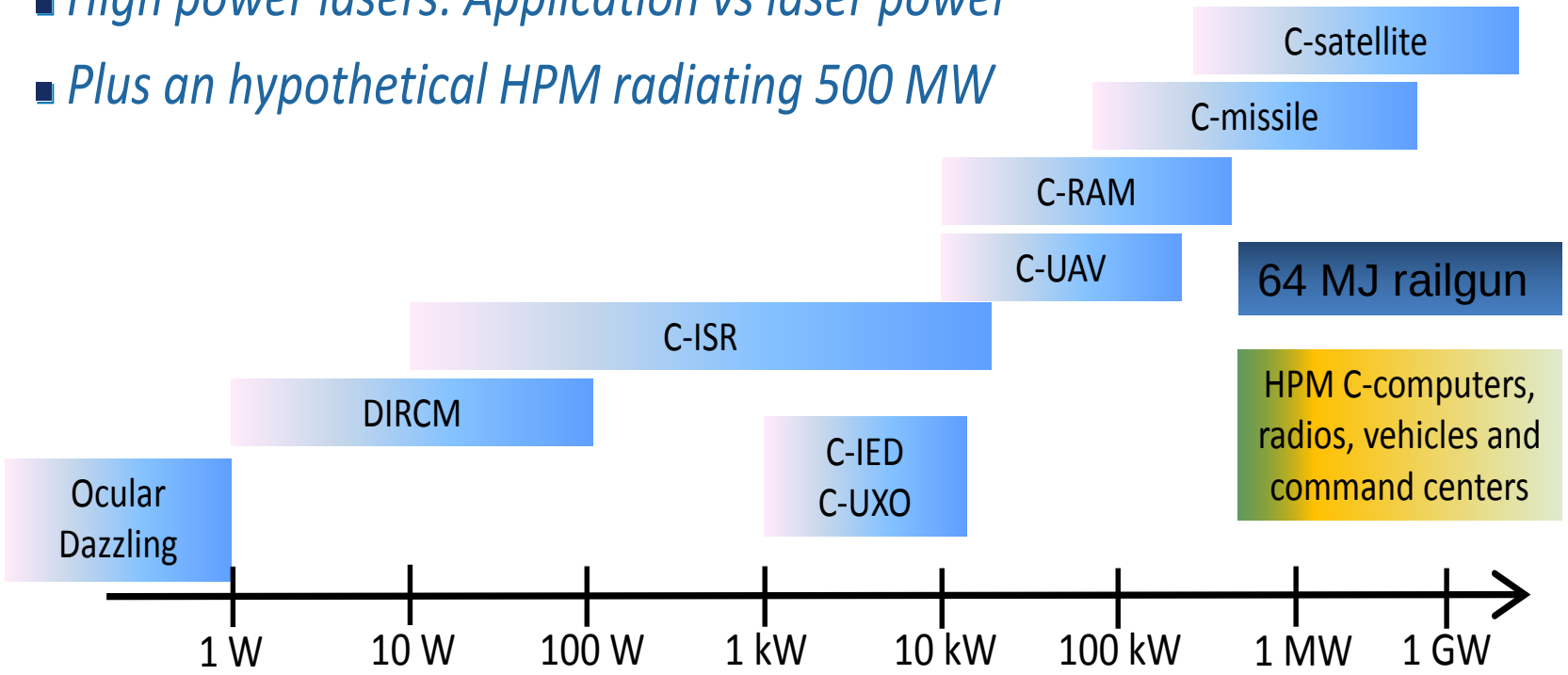
http://brilliantlightpower.com/

Examples of energy demand

Typical radiating power required for specific counter attack

C for counter

- *High power lasers: Application vs laser power*
- *Plus an hypothetical HPM radiating 500 MW*



DIRCM: Directional InfraRed Countermeasures; ISR: Intelligence, Surveillance, Reconnaissance;
UAV: Unmanned Aerial Vehicles; RAM: Rockets, Artillery, Mortars;
IED: Improvised Explosive Devices; UXO: Unexploded Ordnance
HPM: high-power microwave weapon

http://cradpdf.drdc-rddc.gc.ca/PDFS/unc207/p802902_A1b.pdf "DND/CAF Energy Horizons from Historical Data to the Potential Exploitation of Emerging Technologies"

Electricity demand for new weapon technologies versus information technologies and sensors

New weapon technologies are power hungry while persistent surveillance and C4ISR ones are energy hungry.

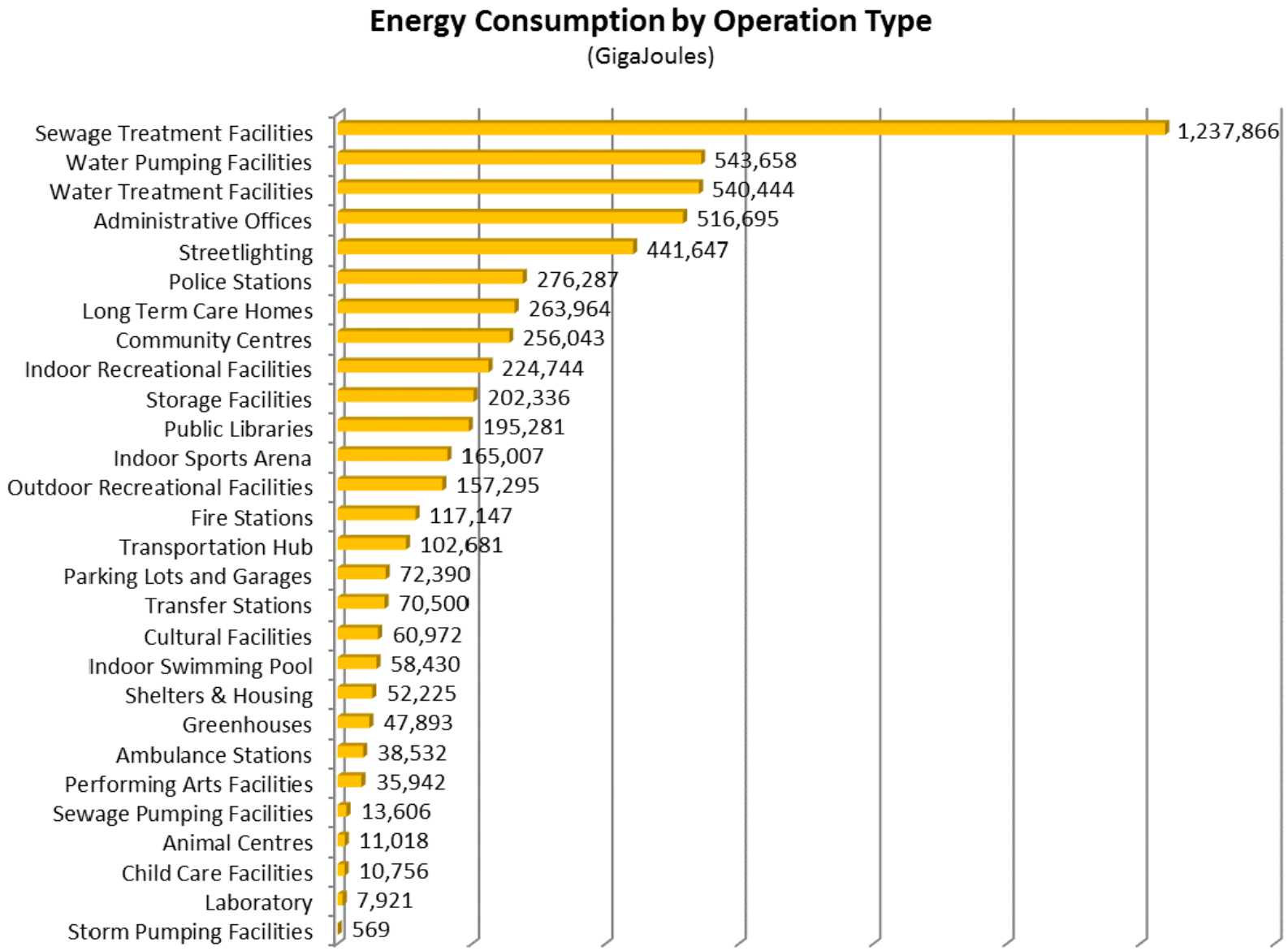
Electricity end use is growing faster than fuel direct use

According to Richard G. Newell and Stuart Iler as stated in "The Global Energy Outlook" "In terms of end-use energy consumption, electricity is growing much faster than direct use of fuels."

Similarly, future DND/CAF electricity demand from new technologies, such as C4ISR and weapon systems, is expected to increase at a faster pace than the direct use of fuel especially for the fleets and off-grid installations.

This is the most critical point that DND/CAF must address to insure sustainable capabilities to fulfill their mandate here and abroad.

Toronto 2013



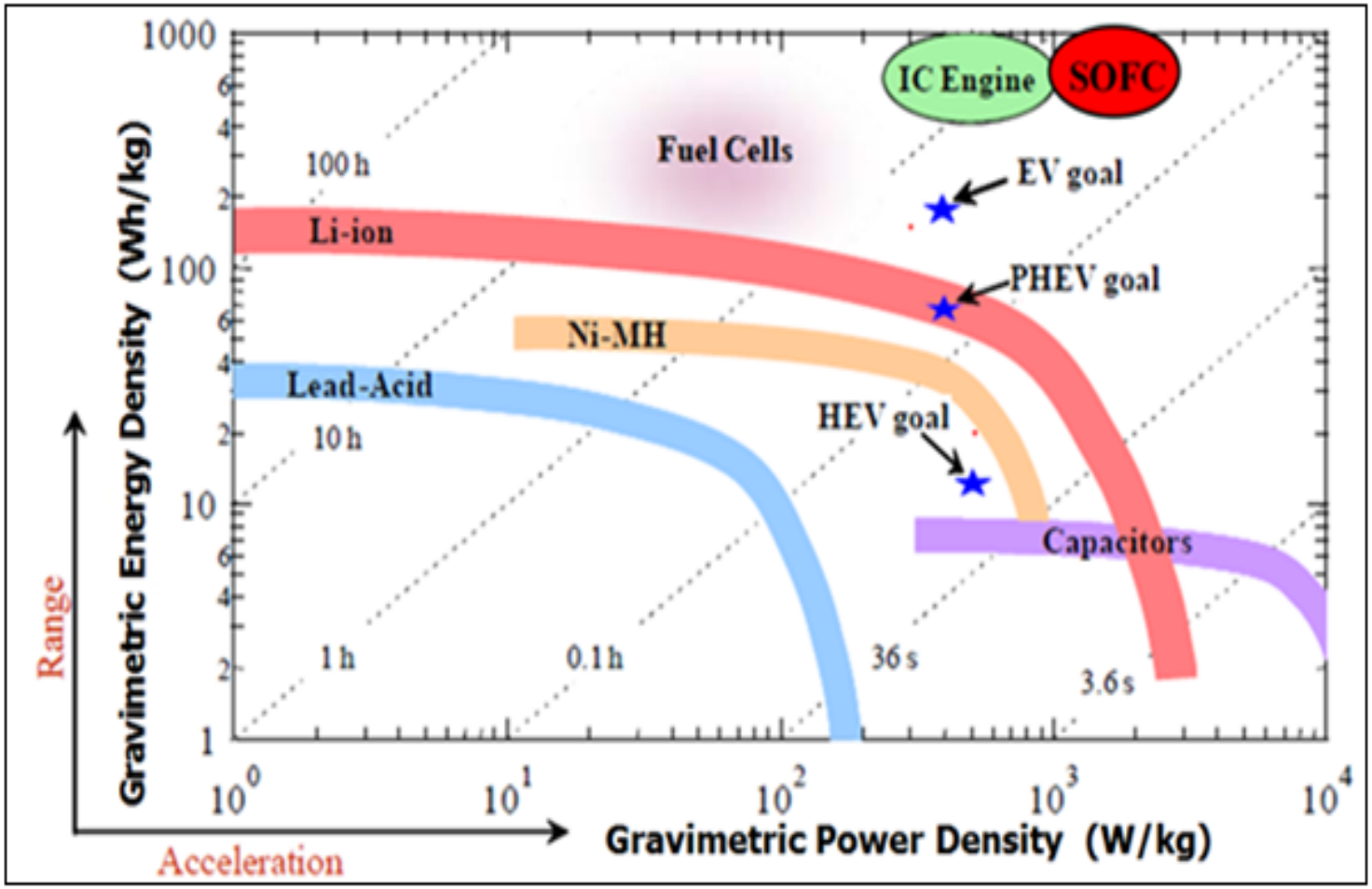
Examples of energy conversion efficiency

Energy conversion device	Energy conversion	Typical efficiency[9]
Electric heater	Electricity to thermal	~100%[10]
High-efficiency gas furnace	Chemical to thermal	~98%
Large electric generator	Mechanical to electricity	>95%
High-efficiency electric motor	Electricity to mechanical	>90%
Battery	Chemical to electricity	>90%
Water turbine	Potential-kinetic to mechanical	>90%
Permanent-magnet alternator	Mechanical to electricity	60-90%
Fuel cell	Chemical to electricity	Up to 85%
Large diesel engine generator[11]	Chemical to electricity	≥60%
Diesel engine (car/truck/ship)	Chemical to mechanical	30-50%
Gas turbine, jet engine	Chemical to mechanical	Up to 40%[12]
Solar cell	Sun radiation to electricity	10%, up to 40%
Light-emitting diode (LED)	Electricity to light	Up to 35%
Thermophotovoltaic (TPV)	Heat-infrared to electricity	8-30%
Firearm (.300 Hawk ammunition)	Potential to kinetic	~30%
Gasoline engine (car/truck)	Thermal to mechanical	10-30%
Fluorescent lamp	Electricity to light	20%
Incandescent lamp	Electricity to light	5%

[11] https://arpa-e.energy.gov/?q=events/small-scale-distributed-generation-workshop (Access date: 8 Nov. 2016)
Not a typical value: ARPA-E target of efficiency: 200-500kWe: ≥60% fuel-in-to-electricity-out efficiency.
Typical should read 42%.

[9] Information sources include http://en.wikipedia.org/wiki/Energy_conversion_efficiency (Access date: 17 Sept. 2013).
[10] Using a thermopump, this could be increased by a factor of three using a ground-water loop.
[11] http://arpa-e.energy.gov/?q=arpa-e-events/small-scale-distributed-generation-workshop (Access date: 17 Sept. 2013)
[12] This needs to be adjusted by the propulsive efficiency η_p for specific jet parameters.

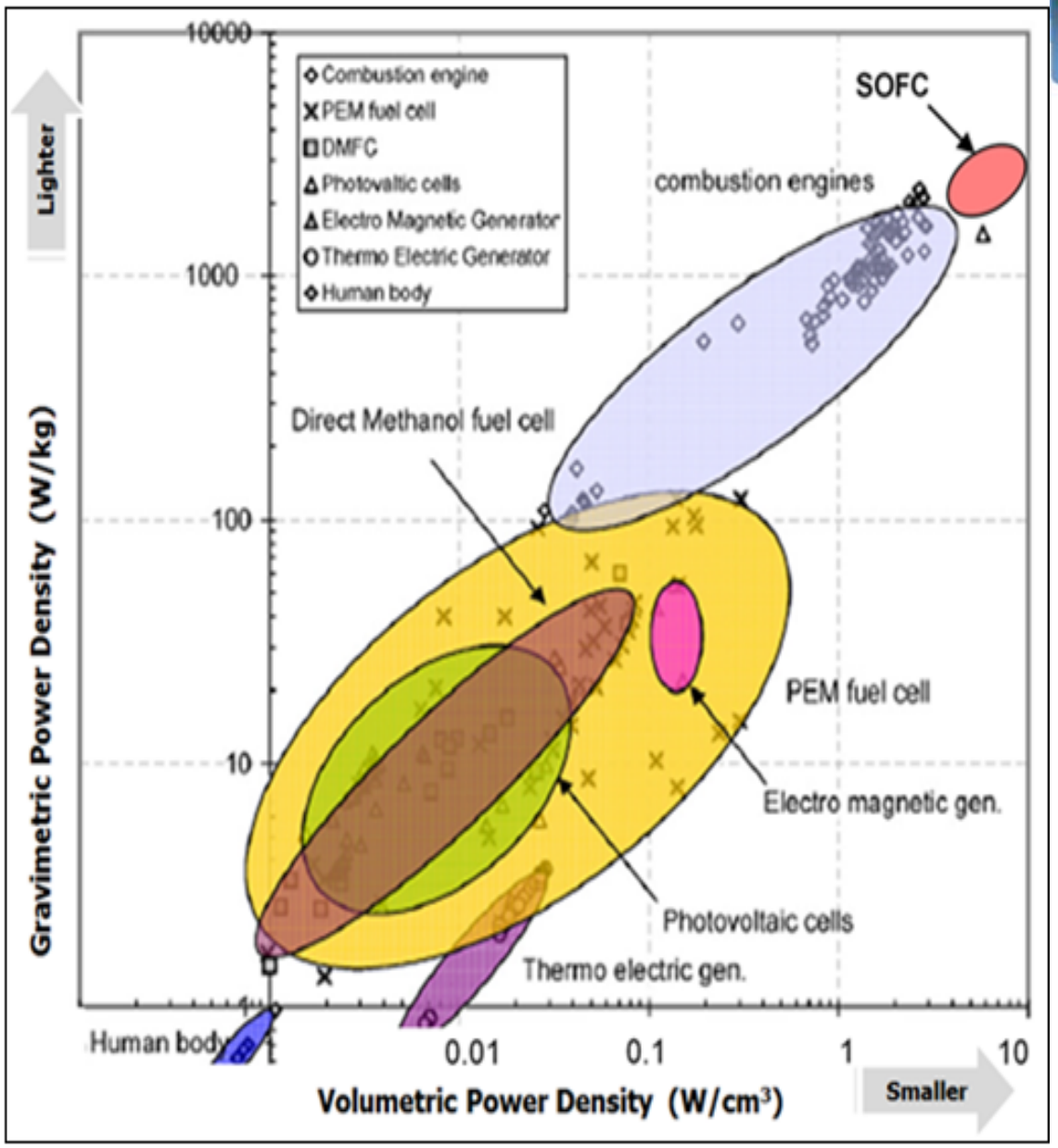
Balance between gravimetric energy and power densities (range versus acceleration) requirement



Legend: solid oxide fuel cell (SOFC); internal combustion (IC) engine; nickel–metal hydride battery (Ni-MH); hybrid-electric vehicles (HEV); electric vehicles (EV); and plug-in hybrid-electric vehicles (PHEV).

Selected energy sources illustrating size and weight at play

(form factor)

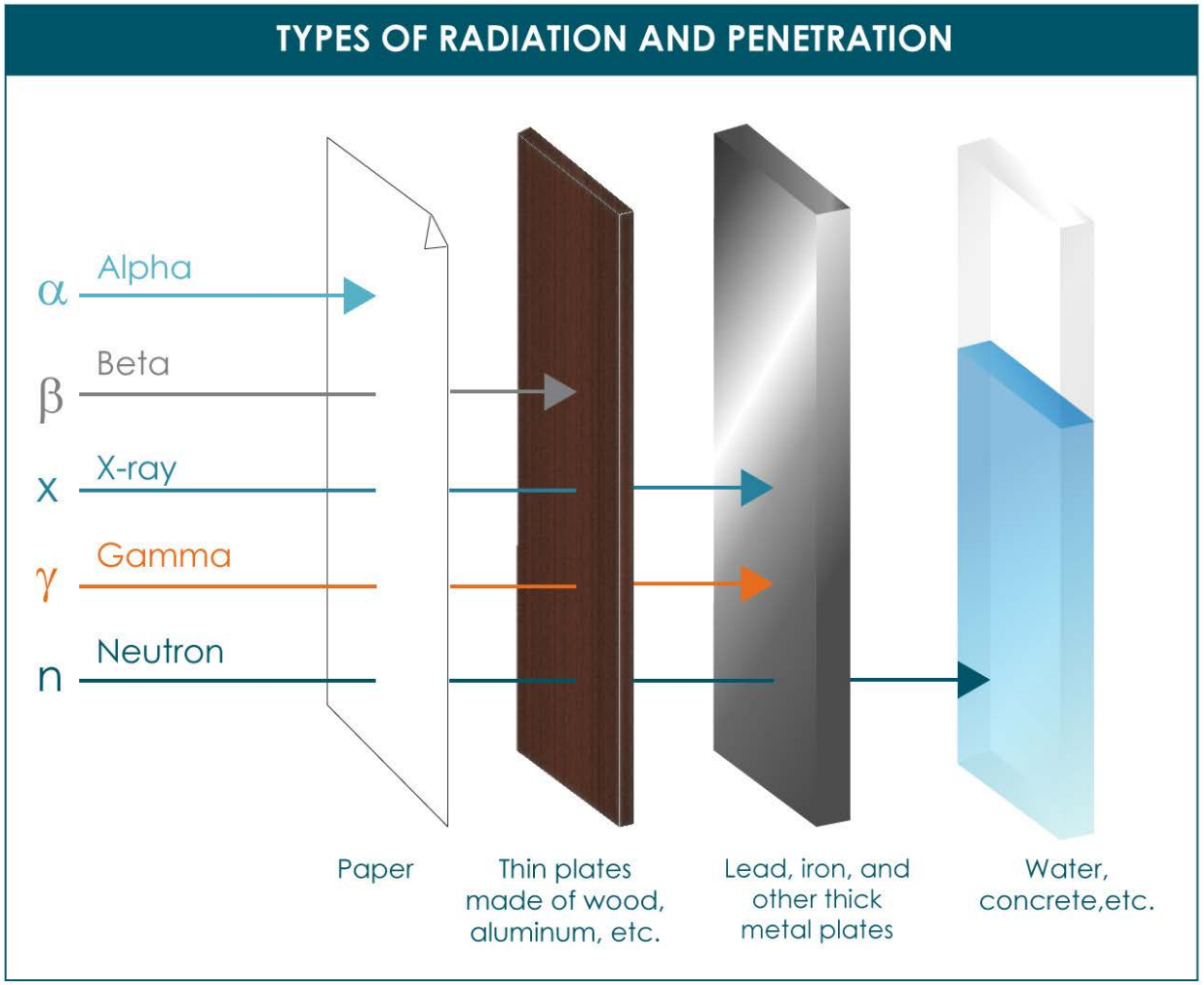


Legend: proton exchange membrane (PEM) fuel cell; and solid oxide fuel cell (SOFC).

To power current and future capabilities

- Investigate the cost effectiveness of LENR and hydrogen-based power systems for off-grid installations and communities, 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

Additional information



https://www.mirion.com/introduction-to-radiation-safety/types-of-ionizing-radiation/

Discussion, your suggestions are welcome.

- Innovate using such technologies
- Competing in advancing this technology
- Competing by using a different technology
- Policies and potential impact
- Using facts such as:
  - October 25 (SeeNews) - Saint-Augustin Canada Electric Inc (STACE), a former General Electric business unit located in St-Augustin, near Québec City, has acquired the concentrating photovoltaic (CPV) technology of French semiconductor materials maker Soitec (EPA:SOI).

    http://renewables.seenews.com/news/canadian-stace-buys-solar-business-of-french-soitec-report-544321 … http://semimd.com/blog/tag/soitec/ Oct 10, 2016 - Soitec announces new world record for solar cell efficiency at 46%.
  - Apparently, the QuarkX exhibits a blueish light. May be using a CPV as for the SunCell could allow it to produce electricity more efficiently using solid state instead of the Carnot cycle.

POC

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