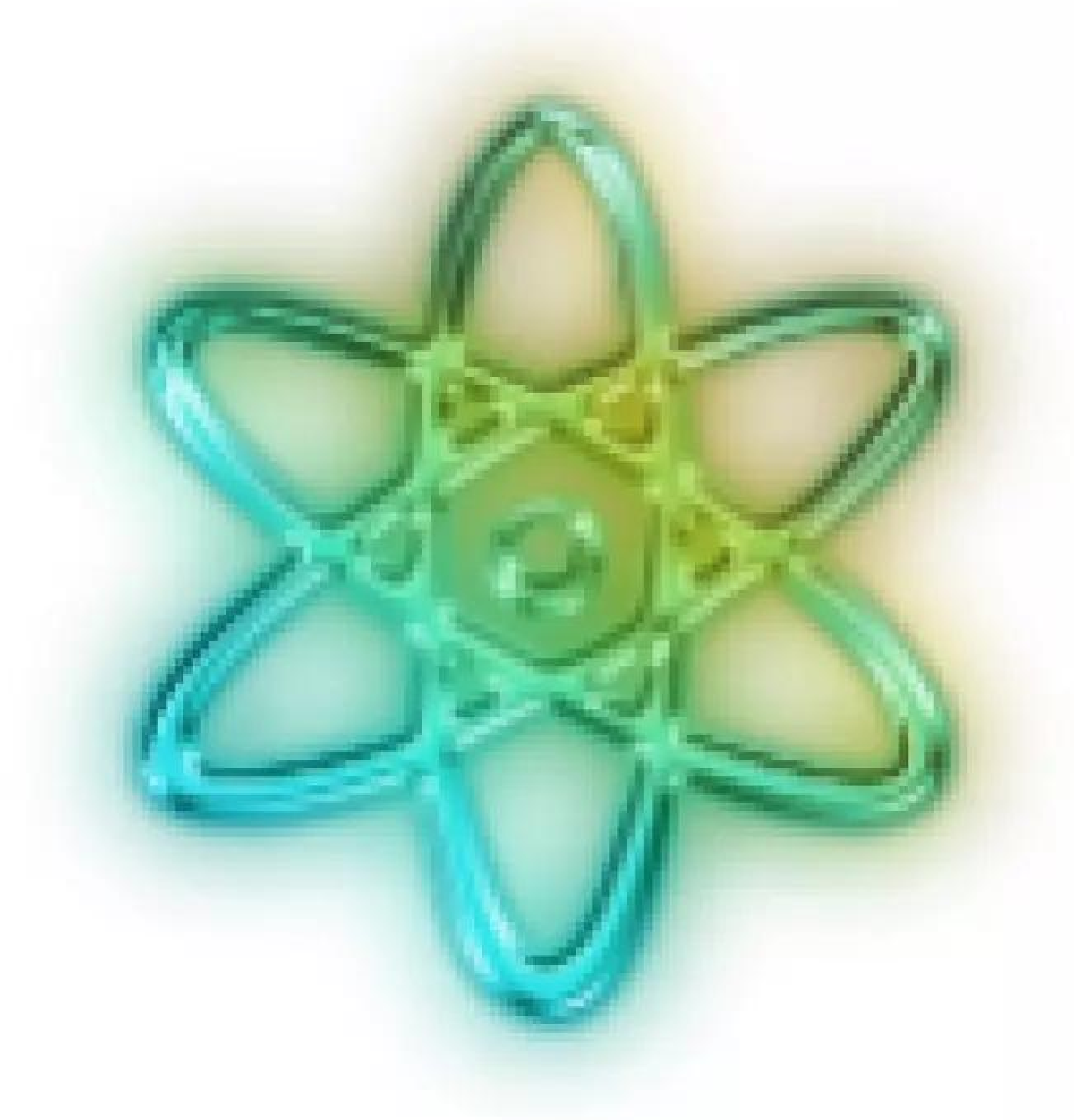
Strategic importance of accelerating commercialization of LENRs for green radiation-free nuclear power and propulsion



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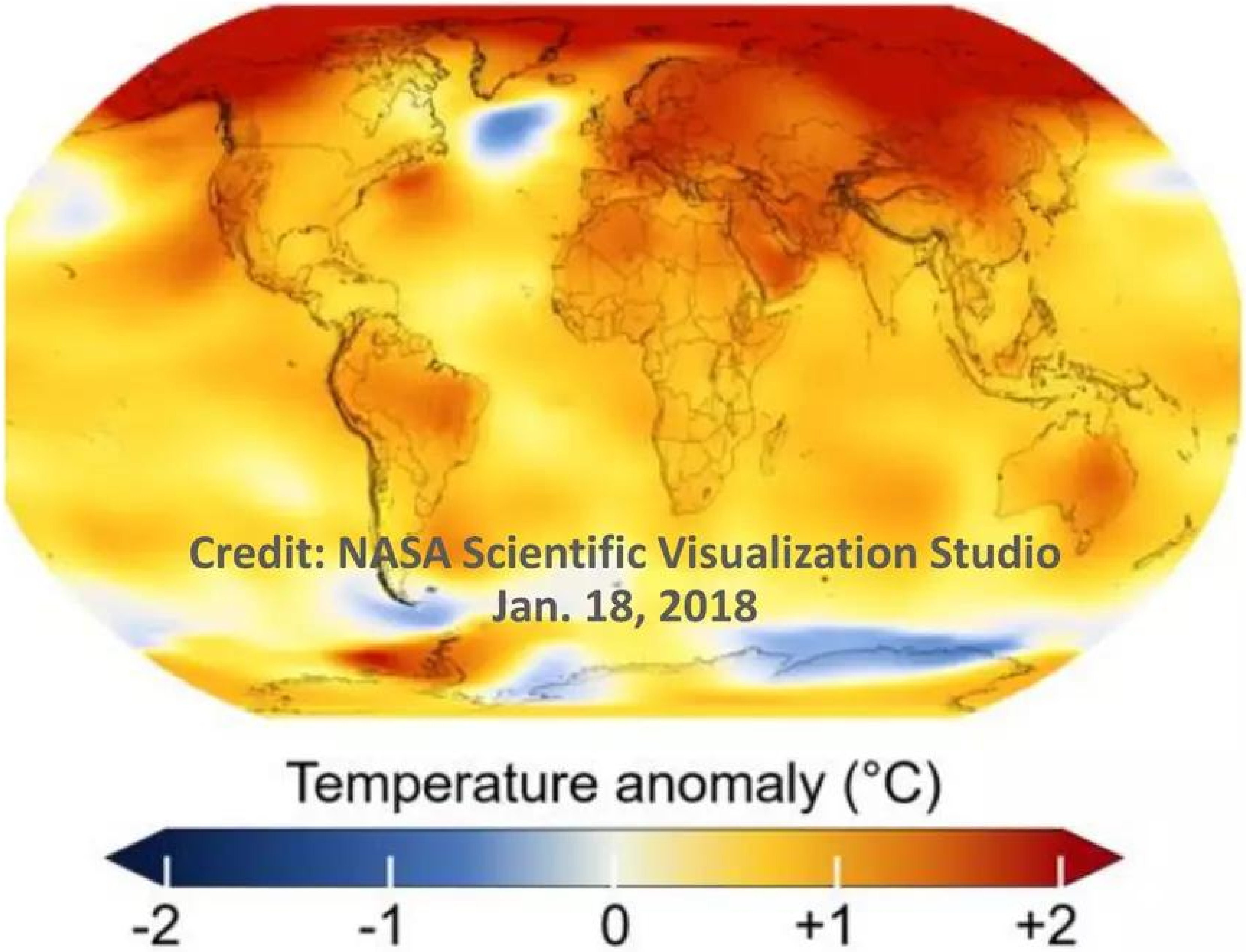
New technology called ultralow energy neutron reactions or LENRs

Better CO_2-free energy source than either nuclear fission or fusion

Decarbonization of global power generation and propulsion --- reduction of human-caused gaseous CO_2 emissions --- is a pressing unsolved problem

Climate change and ongoing global warming are arguably key drivers for rapidly finding solutions

Temperature Change in the Last 50 Years
(2014-2018 Average vs 1951-1980 Baseline)



Which energy technologies could help solve this problem?

Nuclear and renewable energy sources such as wind and solar do not emit gaseous CO_2 and could assist global decarbonization if rapidly expanded

Today's nuclear power plants use fission of Uranium-235; persistent issues with reactor safety, e.g. runaways, and long-lived radioactive waste disposal. In many countries, general public is fearful of fission

Problem: electric grid stability requires adequate baseload and dispatchable generation with 99^+ % uptime availability; that level *cannot* be provided by intermittent wind and solar. Today, grid stability is insured by nuclear and/or fossil energy (natural gas, coal)

Assume expanding nuclear fission power is not an option for decarbonization and insuring grid stability

Some contend that huge expansion of grid electrical backup storage using chemical batteries would insure necessary grid stability in absence of nuclear fission power plants

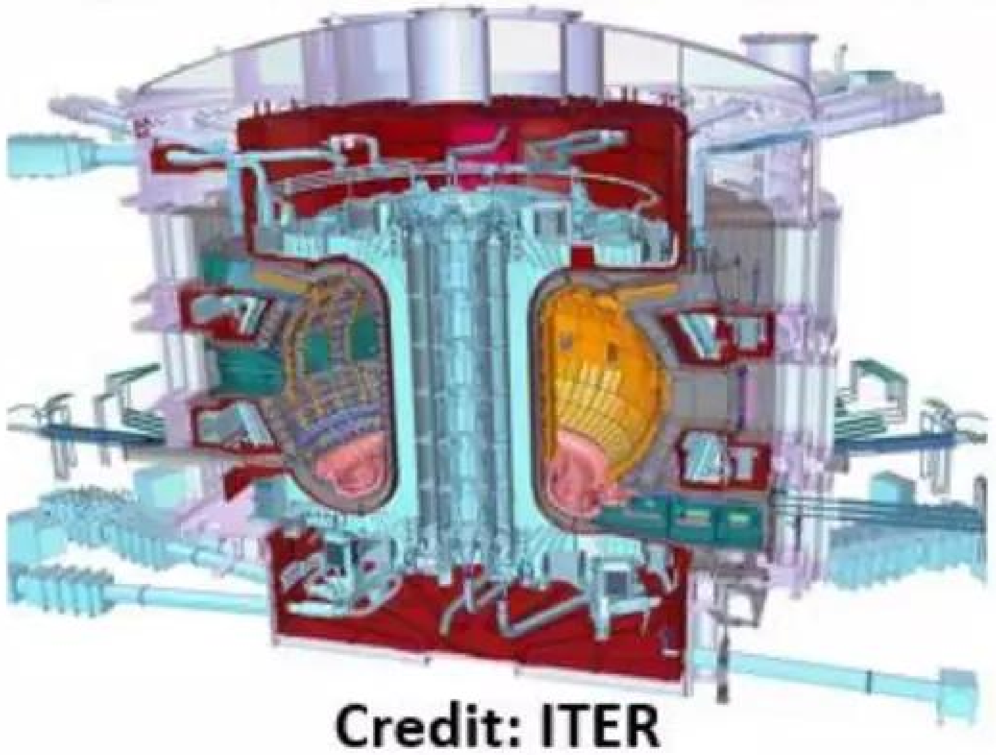
Problem: many recent studies showed battery grid backup for several hours up to one day would be very expensive; cost of battery backup for protracted wind or solar outages lasting weeks to months would be prohibitively expensive

Acceleration of efforts to develop nuclear fusion for power generation if expanding fission is not an option

International ITER project D+T test reactor should become operational in 2025; ITER is furthest along in development

Cutaway schematic : ITER D+T fusion reactor

ITER HQ estimate for total costs is 22 billion Euros



Credit: ITER

ITER D+T Tokamak reactor construction began in 2013

Major remaining issues: ITER reactor will *not* demonstrate production of any net excess power in 2025. That would be demonstrated years later by a follow-on D+T reactor *if* ITER testing program proves successful. Sagara *et al*. (2015) argue that success of ITER would only advance D+T fusion power generation technology to TRL-5 or 6 by ~2030; now at TRL-4$^+$

R&D on fusion power generation began in mid-1950s

Since mid-1950s, governments and recently, private sector, have invested an estimated total of ~$1 trillion (2019 $) in R&D on various fusion reactions: D+T, D+D, $p + {}^{11}B$, etc.

Fusion is a very attractive alternative to fission because: runaways are impossible; dangerous, very long-lived radioactive waste products are not produced in reactors

Problem: compared to triggering fission, fusion is vastly more technically difficult. Plasmas must be heated-up to temperatures above 100 million degrees and somehow confined long-enough to sustain nuclear fusion reactions

Inconvenient fact: as of 2019, no experimental fusion reactor of *any* type has ever exceeded breakeven, i.e. produced net excess power *above* required input power

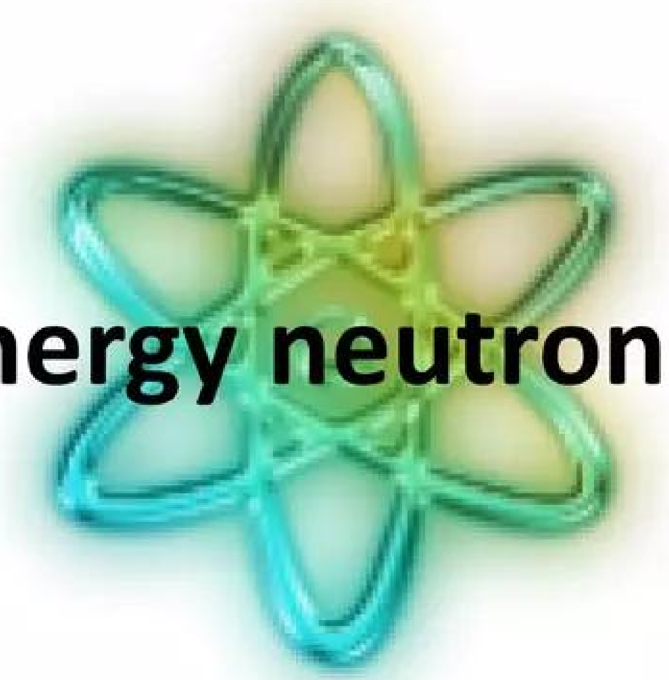
Eventual commercialization of fusion not at all certain

Warning: many critical technical and economic hurdles remain to be surmounted before grid-connected fusion reactors become a reality. Failure to achieve any one of these milestones could greatly delay or completely derail present efforts to commercialize nuclear fusion technology

Final verdict on commercialization could require decades

What if fusion power cannot ever be commercialized?

Are there any other newer, perhaps even better nuclear technologies that might be commercialized?



Yes: ultralow energy neutron reactions or LENRs

Green radiation-free ultralow energy neutron reactions

Experimentalists have episodically observed LENR-related effects for over 100 years. Until 1989-90, most scientists did not realize they were encountering nuclear processes because dangerous energetic neutron and/or gamma radiation emissions that characterize all known fission and fusion reactions were absent. Inexplicable experimental data triggered insightful theorizing by Albert Einstein back in 1951

LENRs not fully understood theoretically until 2006 with publication of the Widom-Larsen theory, which unwittingly incorporated key elements of Einstein's "lost hypothesis"

"Einstein's lost hypothesis: is a third-act twist to nuclear energy at hand?" Mark Anderson, *Nautilus* pp. 21 - 29 Nov. 28, 2013

http://nautil.us/issue/7/waste/einsteins-lost-hypothesis

Green radiation-free ultralow energy neutron reactions

Much older
Fission and fusion

Disruptive new energy source

Evolution of greener nuclear technology

Much newer
LENRs

Advantages of LENR technology:

- **No deadly MeV-energy gamma radiation**
- **No dangerous energetic neutron radiation**
- **No production of long-lived radioactive waste**
- **Vastly higher energies versus chemical processes**
- **Revolutionary, no CO_2 , and environmentally green**
- **Fully explained by the physics of Widom-Larsen theory**
- **Better than fission and fusion for nuclear power generation**

Green LENRs compared to fission and fusion technologies

TRL = technology readiness level MeV = Megaelectron Volt = 1 million (10^6) eV
IR = infrared radiation (heat) Chemical reactions only release eVs or ~1,000,000x less than nuclear

Nuclear energy process	Deadly MeV gamma γ radiation?	Deadly MeV neutron radiation?	Long-lived radioactive waste products?	Basic description of nuclear process that produces excess heat	Energy release per reaction (MeVs)
Fission: TRL-9^+ $Uranium^{235}$	Yes	Yes	Yes Thousands of years	Heavy Uranium-235 atoms capture neutrons; shatter into many lighter elements	~ 200 MeV many different end-products
Fusion: TRL-4^+ 2019 ITER D+T reactor in France 2025	Yes All fusion reactions	Yes Esp. D+T and D+D reactions	No Waste products decay in <100 years	Gigantic temperatures enable two light ionized atoms to smash together and then fuse into heavier chemical elements	Depending on specific fusion reaction, value ranges from ~ 3 to ~ 24 MeV
LENRs: TRL-4 2018: Japanese had best-ever LENR excess heat	No Heavy electrons convert γ rays to IR	No Virtually all ULE neutrons captured locally	No Neutron-rich waste products *rapidly* decay into stable elements	Input energy creates ultra low energy neutrons (via $e + p$ reaction) that capture on target fuels. Gammas from neutron capture are converted to IR. LENRs much safer than fission and fusion reactions	Depending on fuels and subsequent reactions as well as decays, values range from ~ 0.1 MeV up to ~ 22 MeV

protons (p: +1 charge), neutrons (n: 0), and electrons (e: -1) comprise electrically neutral atoms

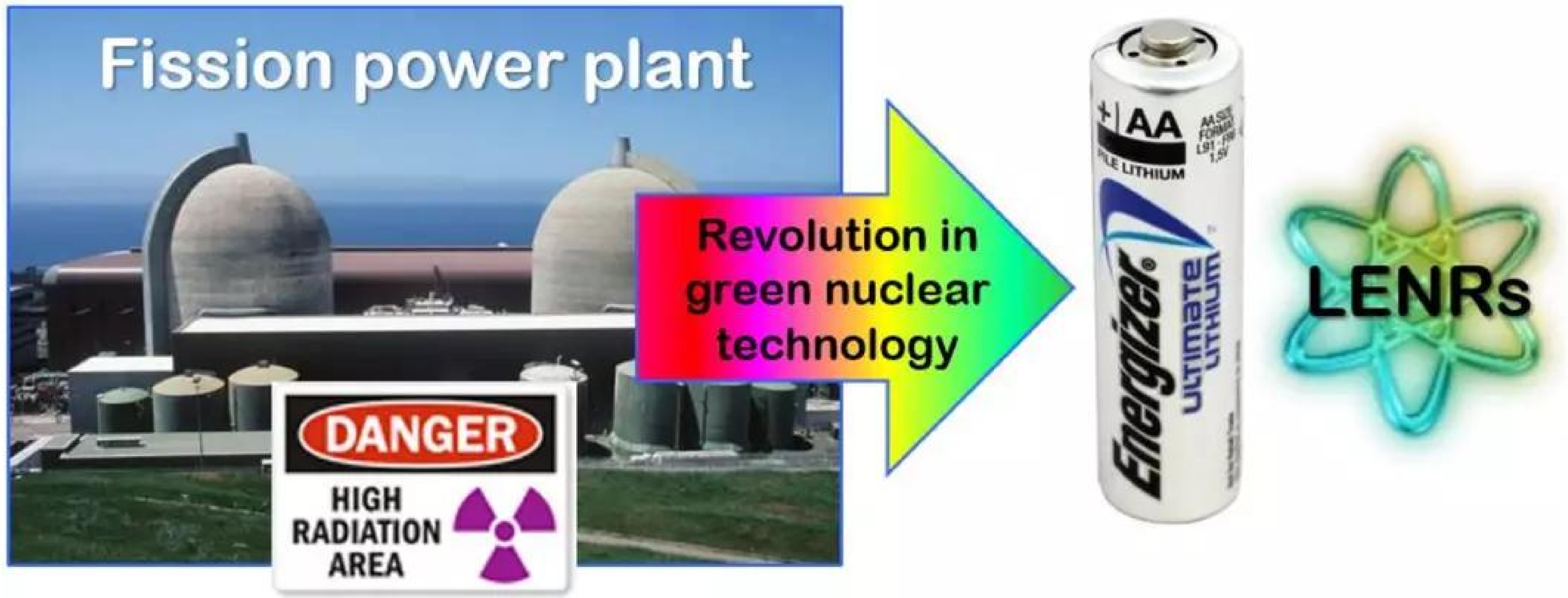
Specific energy of LENRs >>>> chemical fuels and batteries

Fuel	Energy Type	Specific energy (MJ/kg)	Applications
Uranium (breeder) U-235 fission	Nuclear fission	80,620,000	Nuclear reactors: grid electric power generation plants and submarine propulsion
Thorium (breeder) Th-232 → U-233 fission	Nuclear fission	79,420,000	Thorium reactors under development for grid electric power generation plants
Electrons, protons (Hydrogen), and LENR target fuels such as Ni, Li, and aromatic Carbon	LENRs: neither fission nor fusion; transmutation of target fuels	Nickel target fuel est. ~3,817,235	Stationary, mobile, and portable power generation systems; electric power plants
Hydrogen (compressed to 70 MPa)	Chemical combustion	142	Rocket and automotive engines; grid storage and conversion
Diesel/Fuel oil	Chemical combustion	48	Automobile engines; certain types of power generation systems, e.g. diesel gensets
Jet Fuel	Chemical combustion	46	Aircraft
Gasoline (Petrol)	Chemical combustion	44.4	Automotive engines; other types of power generation systems
Best batteries today	Electrochemical	Barely > 1	Energy storage as electricity
Lithium-ion batteries	Electrochemical	0.4 – 0.9	Energy storage as electricity

LENR reactors will not require any shielding or containment

Absence of energetic neutron and gamma radiation and lack of long-lived radioactive wastes would enable LENR reactors to operate safely without having any heavy, bulky, expensive radiation shielding and containment subsystems

This implies future LENR power generation systems would be vastly less expensive to manufacture and operate vs. fission or fusion reactors. Microscopic size of LENR active sites should enable system outputs to be scaled upward *and* downward, allowing development of portable battery-like systems that can compete with batteries and fuel cells



LENR technology development is presently at TRL-4 level

European Commission

Technology Readiness Levels

TRL 0: Idea. Unproven concept, no testing has been performed.

TRL 1: Basic research. Principles postulated and observed but no experimental proof available.

TRL 2: Technology formulation. Concept and application have been formulated.

TRL 3: Applied research. First laboratory tests completed; proof of concept.

TRL 4: Small scale prototype built in a laboratory environment ("ugly" prototype).

TRL 5: Large scale prototype tested in intended environment.

TRL 6: Prototype system tested in intended environment close to expected performance.

TRL 7: Demonstration system operating in operational environment at pre-commercial scale.

TRL 8: First of a kind commercial system. Manufacturing issues solved.

TRL 9: Full commercial application, technology available for consumers.

LENR technology was stagnated at TRL-3 from 2000 - 2015

TRL 3: **Applied research**. First laboratory tests completed; proof of concept.

During that time, typical best-performing LENR experiments were DC current-driven H_2O or D_2O electrochemical cells with bulk metal ~cm^2 99% pure Pd cathodes, 99% pure Pt anodes, and various salts in electrolytes. Calorimetrically measured excess heat production in such experiments ranged from several milliwatts to 0.5 Watts; values > 1 Watt were rare. Experimental repeatability and duration of excess heat production varied greatly. "Successful" experiments had erratic heat production at milliwatt levels that only lasted for several days. Excess heat production of 100s of milliwatts for a week or more and *at best* 10-20% repeatability for given batch of electrodes were considered state-of-the-art results

Milliwatt = .001 = 1/1000 of a Watt

Japanese government-funded LENR project: TRL-3 → TRL-4

NEDO New Energy and Industrial Technology Development Organization

Quote from website: **"Combining the efforts of industry, government and academia and leveraging established international research networks, NEDO is committed to the resolution of energy and global environmental problems and further enhancing Japan's industrial competitiveness."**

Project Funding	NEDO	US$ 54 million 2015 - 2018
Managed by	Technova Inc.	Controlled by Toyota
MITSUBISHI	TOYOTA	NISSAN

TOHOKU UNIVERSITY | NAGOYA UNIVERSITY | KOBE UNIVERSITY | KYUSHU UNIVERSITY

NEDO project: breakthrough experimental results by 2018

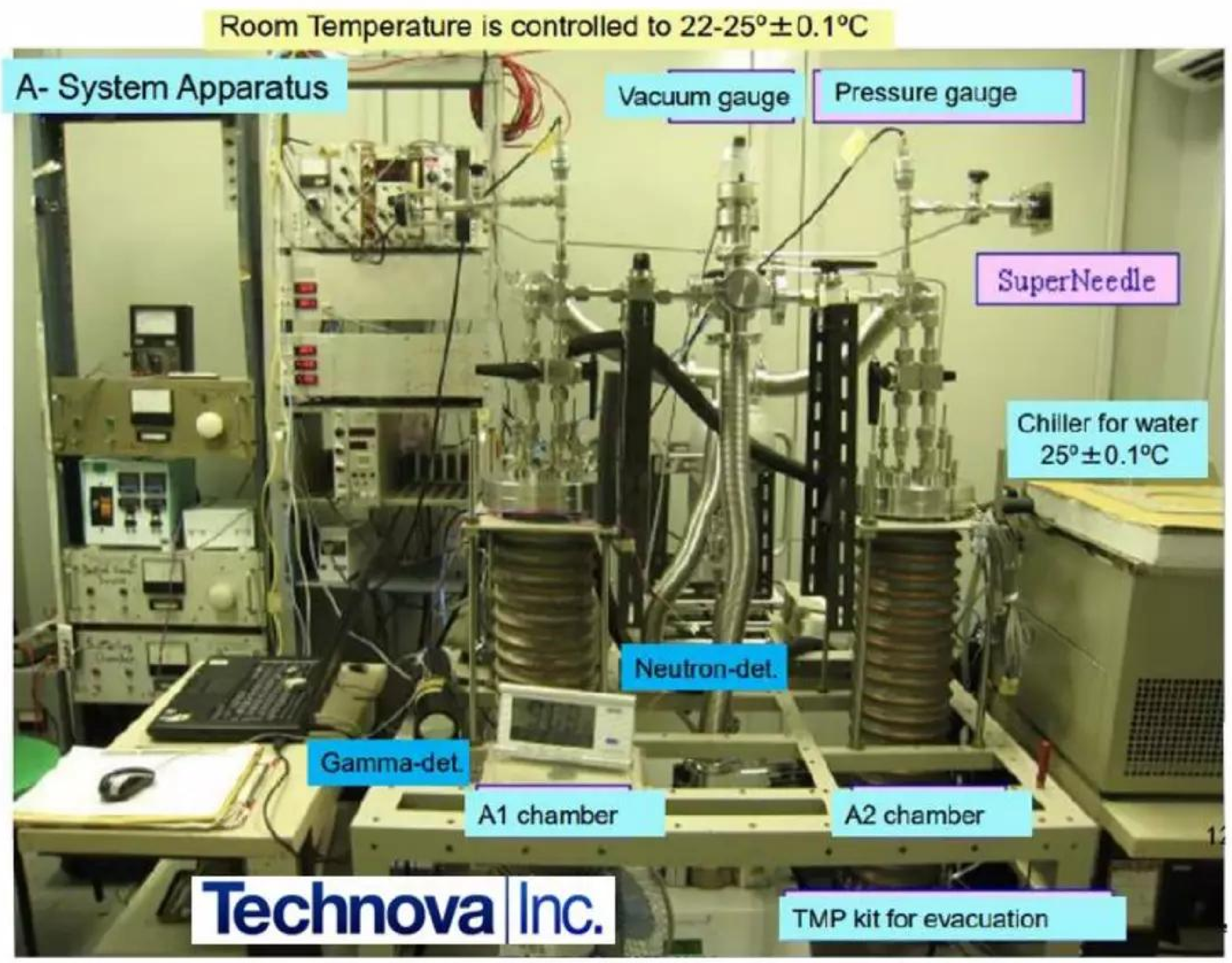
Departing with the past and aware of Widom-Larsen theory, NEDO project utilized Hydrogen gas-loading reactors and state-of-the art knowledge about materials science and nanotech fabrication/engineering techniques to break 15-year logjam and thus advance LENR technology up to TRL-4

NEDO project greatly increased LENR device excess heat production from milliwatts to avg. ~5 Watts for up to 45 days; this is 1,000x better thermal performance versus prior results. Repeatability of excess heat production was increased from paltry 10 - 20% beforehand up to > 70 - 80%

NEDO project overcame intractable repeatability and excess heat production issues that plagued LENRs since 1989-90. It also illuminated fruitful R&D pathway toward commercializing LENRs for power generation & propulsion

NEDO project's TRL-4 "ugly" prototype LENR reactors in lab

Duplicate Hydrogen/Deuterium gas-loading reactors. No energetic neutron or gamma radiation detected during excess heat production. Demonstrated LENRs are green and radiation-free, as predicted by Widom-Larsen theory



Technova Seminar 2018/3/2

Global competitive landscape: Who leads? Who lags?

- **Japan is unquestionably the world experimental leader in LENR commercialization.** Major companies are already involved in LENR development: Mitsubishi Heavy Industries, Toyota, and Nissan. Judging from these major players, replacing internal combustion engine appears to be one unstated objective of this effort
- **U.S. experimentalists are now 5 - 10 years behind Japan's NEDO project.** No indications that U.S. government is presently providing significant internal or academic funding for LENRs; ditto for large U.S. companies, except Google ($10 million: 2015 -2019)
- **No evidence that governments elsewhere in world are funding significant R&D in LENRs.** Same situation for large companies, except for Airbus, which has a small modestly funded program
- **Only $300 million was spent worldwide on LENRs since 1989-90**
- **Increased funding needed to accelerate LENR commercialization**

Further key milestones in commercialization of LENRs

Additional nanotech engineering is needed to advance from TRL-4 protype reactors to TRL-9 commercial LENR power generation systems. Must achieve high-volume/low-cost fabrication of nanostructures hosting large numbers of LENR active site precursors. These nanostructures must then be emplaced on working surfaces of LENR reactors in locations near nanoparticulate target fuels, e.g. Lithium, Nickel, aromatic Carbon (Benzene), etc.

Once high-yield good device fabrication, 99^{+} % triggering, and extended longevity are achieved, LENR reactor output can be scaled-up by (1) increasing area-densities of precursors to LENR active sites on fabricated nanostructures; and/or (2) injecting larger quantities of target fuel nanoparticles hosting precursors into larger reaction chambers containing Hydrogen or Deuterium gas

Suitable off-the-shelf energy conversion subsystems could be selected and integrated with various commercial LENR excess heat sources to create new, very competitive power generation products

LENR-based products would have big competitive advantage

Tanker trucks like this Shell vehicle carry ~5,000 to 12,000 US Gallons of gasoline or diesel fuel. Nanoparticulate LENR fuels producing same number of BTUs would fit into FedEx box and provide enough energy to power a car for > 25,000 miles

LENR-based power generation systems could be ferociously competitive across extremely broad range of markets, power outputs, and applications because system and fuel energy densities would be orders of magnitude larger than any competing chemical technologies. Consequently, potential market size for all LENR-based products could be trillions of $

Revolutionary impact on transportation and aerospace

Advantage of LENR propulsion technology is that energy densities of LENR fuels would be >5,000x gasoline or jet fuel. Such energy density would enable onboard fuel fractions at takeoff to be cut by >90%; enough LENR fuel to power SR-71 mission would also fit into one FedEx box

LOCKHEED MARTIN

SR-71 Blackbird carried ~12,000 gallons of JP-7 aviation fuel with full tanks; permitted unrefueled range of 3,250 miles flying @ Mach 3 (2,284 mph)

Fuel fraction = onboard fuel as % of an aircraft's total weight at takeoff:

Ford F-150 truck only 3%

Boeing 737-600 27%
F-22 Raptor 29%
Predator MQ-1 drone 30%
Eurofighter 31%
F-35 Lightning JSF 33%
Airbus A380 44%
Mig-31 Foxhound 45%
Concorde SST 50%
B2 Spirit bomber 50%
SR-71 Blackbird 65%
Rutan Voyager 72%
V.A. GlobalFlyer 83%

Missiles (typical) > 85%
Saturn-5 (moon) 96%

Benefits from commercialization of LENR technology

- **Rapid decarbonization for many parts of global economic activity, including the transportation and aerospace sectors**
- **Dramatically reduce dependence on fossil energy. Age-old CO_2-producing combustion of fossil fuels could be replaced by LENR *transmutation* of aromatic Carbon to Nitrogen and Oxygen; aromatic Carbon can be extracted from fossil fuels**
- **Geopolitical impact would be substantial: any country with access to LENR technology could be energy independent**
- **Military impact: country with military powered by LENRs would have huge advantage versus adversaries without it**
- **Grid stability insured without fission, fusion, or fossil fuels**
- **Consumers could directly access unprecedented amounts of extremely energy dense, low-cost, safe, CO_2-free power**

Lattice is world-leader in proprietary knowledge of LENRs

We believe Lattice is world-leader in proprietary knowledge about LENR device engineering required to develop high-performance, long lived, scalable power sources. Our peer-reviewed theoretical papers rigorously explain breakthrough device physics of LENR processes, including absence of dangerous energetic neutron or gamma radiation and lack of long-lived radioactive waste production. Proprietary theoretical extensions provide valuable guidance for R&D on LENR thermal device nanoengineering

Lattice welcomes inquiries from large established organizations interested in discussing possibility of becoming one of Lattice's strategic capital and/or technology development partners

Lewis Larsen also consults on variety of energy-related subjects such as battery safety, grid stability, and strategic impact of LENRs

Hyperlinked document references

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