LENRs could convert oil into green CO_2-free energy source

Ultralow energy neutron reactions (LENRs)

Safe radiation-free nuclear power generation

Early stage technology now ready for engineering

Future possibility to replace internal combustion engine

By embracing LENR technology fossil fuel producers could someday potentially increase revenues 500x from same barrel of oil

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Credit: Getty images

Compelling future value proposition for oil & gas companies

Technology of ultralow energy neutron reactions (LENRs) could enable conversion of aromatics derived from crude oil and natural gas into nanoparticulate LENR fuels with energy densities that are 5,000x greater than gasoline.

Achievement of this unprecedented capability could vastly increase performance of customers' power generation systems as well as enable the rapid future development of many types of revolutionary products suitable for array of key consumer and military markets.

LENR technology could also stretch useful economic lifetimes of today's remaining in-ground supplies of oil & gas from British Petroleum's 2016 estimate of < 53 years out to at least another 25,000 years further into far future.

LENRs superior to fission and fusion: safer and less costly

Fission, fusion, and LENRs all involve controlled release of nuclear binding energy (heat) for power generation: no CO_2 emissions; scale of energy release is MeVs (nuclear regime) > 1,000,000x energy density of chemical energy power sources

Heavy element fission: involves shattering heavy nuclei to release stored nuclear binding energy; **requires massive shielding and containment structures to handle radiation; major radioactive waste clean-up issues and costs;** limited sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development; **heavy element U-235 (fissile isotope fuel) + neutrons → complex array of lower-mass fission products** (some are very long-lived radioisotopes) + energetic gamma radiation + energetic neutron radiation + **heat**

Fusion of light nuclei: involves smashing light nuclei together to release stored nuclear binding energy; present multi-billion $ development efforts (e.g., ITER, NIF, other Tokamaks) focusing mainly on D+T fusion reaction; **requires massive shielding/containment structures to handle 14 MeV neutron radiation;** minor radioactive waste clean-up $ costs vs. fission

Two key sources of fuel: Deuterium and Tritium (both are heavy isotopes of Hydrogen)

Most likely to be developed commercial fusion reaction involves the following:

D + T → He-4 (helium) + neutron + heat (total energy yield 17.6 MeV; ~14.1 MeV in neutron)

Ultralow energy neutron reactions (LENRs): distinguishing feature is neutron production via electroweak reaction; neutron capture on fuel + gamma conversion to IR + decays [β^-, α] releases nuclear binding energy; early-stage technology; **no emission of energetic neutron or gamma radiation and no long-lived radioactive waste products; LENR systems would not require massive, expensive radiation shielding or containment structures → much lower $$$ cost;** many possible fuels --- any element/isotope that can capture LENR neutrons; involves **neutron-catalyzed transmutation of fuels into heavier stable elements; process creates heat**

LENRs are superior to fission and fusion technologies

Why build huge D-T fusion reactors if LENRs can be commercialized?

Greenness of LENRs could enable revolutionary portable nuclear power sources

- ✓ While LENRs do use safe ultralow energy neutrons to trigger release of nuclear binding energy (heat) from an enormous array of stable element target fuels, they are radically different from U and Th fission reactors that require criticality to operate properly. Unlike fission, LENRs don't involve multiplicative chain reactions with fuels that in turn release multiple neutrons which then explosively accelerate neutron production --- nuclear runaways are not a risk with LENRs
- ✓ D-T fusion reactors like ITER and other similar Tokamaks mainly create heat by harvesting the kinetic energy of deadly 14.1 MeV neutrons. Consequently, they require massive shielding and containment systems for safe operation and unsurprisingly have enormous costs and unavoidably huge physical size. Given that the Lithium LENR fuel cycle releases nearly 27 MeV versus a total Q-value of 17.6 MeV for the D-T fusion reaction, it is hard to imagine a sound economic argument for spending 100s of billions on commercial fusion reactors if LENR technology is successfully developed and scaled-up as we have outlined herein
- ✓ Lack of hard radiation and radioactive wastes permit *downward* scalability that could enable future development of revolutionary, compact battery-like portable LENR power sources that can compete directly on $ price/kwh with chemical batteries in many applications including power tools, tablets, and smartphones

NASA believes LENRs could be an "ideal energy solution"

Screenshot of 2014 document reveals that NASA is studying possible use of LENRs to power future advanced green subsonic aircraft

Background

LENR is a type of nuclear energy and is expected to be clean, safe, portable, scalable, and abundant. The expected benefits make it an ideal energy solution. When it is applied to aircraft, LENR removes the environmental impacts of fuel burn and emission from combustion. Excess energy can be used to reduce noise so that all three of NASA's technology goals for future subsonic vehicles are either eliminated or addressed. Furthermore, aviation impacts almost every part of our daily lives, civilian and military. A revolutionary technology like LENR has the potential to completely change how businesses, military, and the country operate as a whole, giving a tremendous financial, tactical, and resource advantage to the country that utilizes it in the most effective way.

LENR creates some unique capabilities as well as challenges for integration into aircraft. The LENR concept that has reported most of the success generates heat in a catalyst process that combines nickel metal (Ni) with hydrogen gas (H). The initial testing and theory show that radiation and radioisotopes are extremely short lived and can be easily shielded. Although nuclear fission has been looked at for use in aircraft, LENR is different. LENR has a higher energy density and no radioactive by products.

Success of this research will provide a firm foundation for future research and investment for LENR technology integration into aircraft. Key research and development areas will be identified with any gaps in the current technology research. This research will guide NASA on the most effective way to invest in LENR to be the world leader in LENR aircraft research.

http://nari.arc.nasa.gov/sites/default/files/attachments/17WELLS_ABSTRACT.pdf

Fossil Carbon could be converted into green LENR fuels

New breakthroughs in physics and nanotechnology make this possible

Bitumen, heavy oil, and coal may be much more valuable as CO_2-free LENR fuels

Able to understand LENR experiments that were conducted at Hokkaido University (Japan, 2008), by 2009 Lattice was able to figure-out how aromatic molecules could potentially be extracted, processed, and converted into green LENR fuels from which there would be no hard radiation emissions, no production of hazardous long-lived radioactive wastes or emission of gaseous CO_2 into atmosphere. **Would be able to release > 5,000 times more thermal energy versus combustion of Carbon-based molecules with Oxygen**

These fossil hydrocarbons contain aromatic ring molecules on which LENRs can be triggered

Canadian natural bitumen

Heavy viscous oils found in many fields

Various grades of coal

LENRs are strategic technology opportunity for oil & gas

- ✓ Ultralow energy neutron reactions (LENRs) are new type of clean, green CO_2-free nuclear energy source that has huge energy densities, vastly lower costs versus fission or fusion; they could enable truly sustainable economic growth
- ✓ Oil & gas companies' R&D organizations could have key development roles
- ✓ Should be possible to develop nanoparticulate LENR fuels derived from aromatic fractions present in oil as well as Carbon-aromatics produced from natural gas; would be suitable for use in many different customer applications that include stationary/portable power generation and vehicular propulsion
- ✓ Development and utilization of LENR thermal sources for process heat could also greatly reduce upstream and downstream costs for oil & gas producers; could also slash CO_2 emissions for customers using LENR-based green fuels
- ✓ LENRs would enable development of extremely wide range of new types of ultra-high performance fuel products for use in use low-cost, enormously versatile LENR power sources; these products could be produced by oil & gas companies and then sold to many customers located all over the world
- ✓ Existing crude oil refineries could someday be modified to add capability for future production of LENR fuels in parallel with traditional industry products
- ✓ LENRs are strategic opportunity for fossil fuel producers to greatly increase future revenue streams and stretch-out lifetime of reserves to 1,000s of years

Nanoparticulate LENR fuels could be used in many systems

Huge energy density advantages vs. fossil fuels & chemical batteries

Green LENR fuels energy densities could be 5,000x larger vs. gasoline

Consequence: an automobile powered by LENRs could travel around the entire world on a quantity of nanoparticulate fuel that fits into just a single FedEx box

LENR fuels would be inert and benign and could use existing package delivery systems for resupply; typical gasoline or diesel tanker truck carries ~5,000 - 12,000 US Gallons of liquid fuel; **LENR fuels producing same # of BTUs could be shipped in 1 - 2 FedEx boxes**

LENRs could increase product performance for customers

Energy densities of LENR fuels at least 5,000x > chemical processes

LENR-powered systems could easily achieve 10x - 100x chemical power

Enhancements in product range and endurance if LENR technology were commercialized

	Product Name	Present capabilities with today's power sources Range (endurance)	Vastly enhanced capabilities with future LENR-based power sources	
			10x chemical	100x chemical
Various aircraft	GreenWing e430	180 miles (~3 hours @ 60 mph)	1,800 (30)	18,000 (300)
	Airbus E-Fan 2.0	99 miles (1 hour @ 99 mph)	990 (10)	9,900 (100)
	Predator MQ-1	1,800 miles (24 hours @ 75 mph)	18,000 (240)	180,000 (2,400)
	Super Heron	est. ~4,000 miles (45 hours @ 89 mph?)	40,000 (450+)	400,000 (4,500)
	Springtail	184 miles (2.2+ hours @ 94 mph)	1,840 (200+)	18,400 (2,000+)
	Crazyflie	Speed not measured (3 - 10 minutes)	? (30 - 100 min.)	? (maybe 5 - 17 hrs.)
	InstantEye	est. ~8 miles (18 - 20 min @ 25 mph)	est. 80 (3.2 hrs.)	800 (32 hrs.)
	Tesla Model S car	~300 miles (4 - 5 hours @ 70 mph)	3,000 (40 - 50)	30,000 (400 - 500)
	Shkval torpedo	6.8 - 9.3 miles (1.8 - 2.4 min @230 mph)	68 - 93 (18 - 24 min)	680 - 930 (3 - 4 hrs)
	Exoskeletons and autonomous robots	Require tether cables connected to some type of external power source	Duration of autonomous activity might be extended up to weeks or even months	

Note: roughly 730 hours in a month and 8,760 hours in a year; average U.S. car's IC engine runs for ~5,000 hrs over lifetime

LENRs enable oil producers to increase future profits

Use LENRs to decrease costs; sell new CO_2-free fuels to customers

New LENR fuels could be produced and sold in parallel with today's products

- ✓ Commercial LENR thermal sources could provide CO_2-free, low-cost process heat for various upstream and downstream operations in oil & gas business:

  LENR-based thermal sources qualified for operating underground could also enable *in situ* heating and partial upgrading of bitumen and heavy oil reservoirs; in Canada, could eliminate burning of natural gas to make steam used in SAGD process and need for diluents. This could reduce production costs for Canadian oil sands, making downstream products more quality and price-competitive with WTI and Middle Eastern crudes produced in Saudi Arabia, Iraq, and Iran

- ✓ Aromatic fractions in oil and coal can potentially be converted into LENR fuels:

  When purchasing most types of carbonaceous fuels, end-user customers are effectively buying quantities of heat measured in British Thermal Units (BTUs). By working in partnership with, for example, vehicle manufacturers to facilitate adoption of vastly more energy-dense green LENR fuels, today's large oil & gas producers could have an incredible economic opportunity to increase future revenues and profits from exactly the same barrel of oil or ton of coal by many-fold compared to today when end-users are burning their fuels via combustion

- ✓ LENRs provide fossil fuel industry with smooth technological transition to 'green'

Many market applications for potent LENR thermal sources

LENRs could reduce costs and enhance production in oil & gas industry

Market Application Examples	More details about applications	Economic Advantages
LENRs enable safe, radiation- and CO_2-free free nuclear energy production and power generation at substantially lower cost vs. competing nuclear (fission or fusion) and chemical technologies. Vastly greater energy densities and longevity at a lower price per kWh compared to chemical power sources for producing electricity	Integrate LENR heat sources w. different types of energy conversion technologies: e.g., create battery-like devices using thermophotovoltaics that can convert infrared directly into DC electricity; or use heat to rotate a shaft for direct motive propulsion and/or in power generation systems (e.g., steam turbines); scale-up by increasing LENR-active surface areas and/or volumetrically in case of dusty plasmas	SAFE - no radiation shielding or waste issues. Could someday enter huge unit-volume portable power markets and be able to compete directly against advanced chemical batteries, small fuel cells, and fossil fuel microgenerators
Create large quantities of inexpensive raw process heat for bitumen extraction, heavy oil recovery, and/or oil shale processing. Could eliminate burning of natural gas used to make steam employed in SAGD process for underground bitumen extraction in oil sands regions of Canada (big decrease in CO_2 footprint and extraction costs)	Long-lived LENR thermal sources lowered down boreholes could be used to directly heat-up bitumen or heavy oil in underground rock formations to reduce production costs and enhance % recovery. Could use LENR heaters for *in-situ* underground upgrading --- perhaps up to mid-distillates. Could also produce clean, inexpensive process heat for downstream petroleum operations such as refining	Major benefits to large oil, gas, and coal producers – can effectively increase long-term supplies of fossil Carbon sources and reduce total production costs; shrink industry's global CO_2 emission footprint across all upstream and downstream operations

Convert fossil Carbon into green LENR energy sources

Aromatic fractions found in oil and coal can be turned into LENR fuels

LENR fuels would have energy densities 5,000x larger than unleaded gasoline

- ✓ Bitumen such as in Canadian oil sands, almost all oils, coals, and biomass (lignin) all naturally contain varying % of Carbon aromatic ring molecules; these include simple moieties like Benzene and more complex, multi-ring aromatics such as polycyclic aromatic hydrocarbons (PAHs). One example of a PAH is Phenanthrene, which is comprised of three bonded Benzene rings
- ✓ Using a mixture of traditional and recently developed chemical techniques, oil, coal, and renewable lignin-rich biomass can be processed to extract desired aromatic fractions; in theory, it should be possible to convert these aromatics into CO_2-free LENR fuels that would be 'burned' in new, proprietary types of radiation-free transmutation reactors that would not require shielding, containment, or expensive radioactive waste disposal
- ✓ Compared to combusting Carbon with Oxygen, using LENRs to instead *transmute* Carbon into stable Oxygen and Nitrogen can produce 5 million times more BTUs of thermal energy without emitting any gaseous CO_2
- ✓ Opportunity for fossil fuel producers selling BTUs to customers to vastly increase revenues/profits by engaging in production and sale of LENR fuels

Many moieties contain or are convertible into aromatics

LENR fuels can be created from many different types of Carbon sources

Base feedstock → Aromatic molecules → Nanoparticulate fuels

Contain aromatic molecules

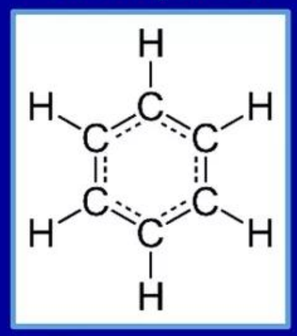
Examples:

- Heavy oils and natural bitumen — Extract
- Coal — Extract
- Lignin from renewable biomass — Digest
- CH_4 natural gas — Mo catalyst — LNG
- CO_2 → C nanofibers — Processing

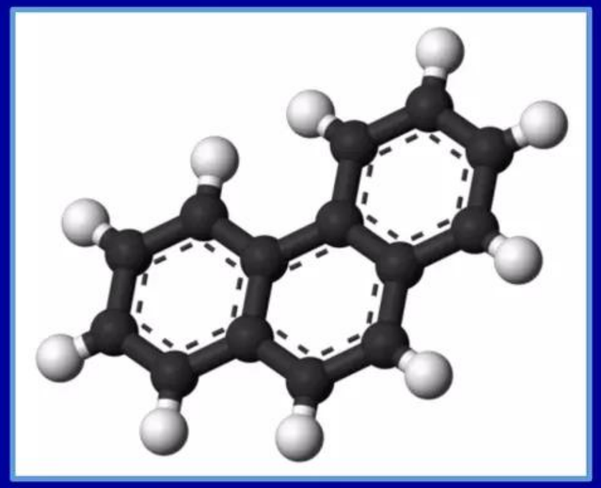
Chemical process

Variety of simple and complex aromatic molecules

Examples:



Benzene



Phenanthrene

Enormous gain in energy density makes processing conversions $$$ economic

Chemical processing plus nanotech

Process into

Green CO_2-free LENR fuels

5,000x greater energy density

Bottom line: just about any Carbon-based moiety can be converted into aromatic ring-structure molecules using a chemical process

From Old World combustion to New World of transmutation

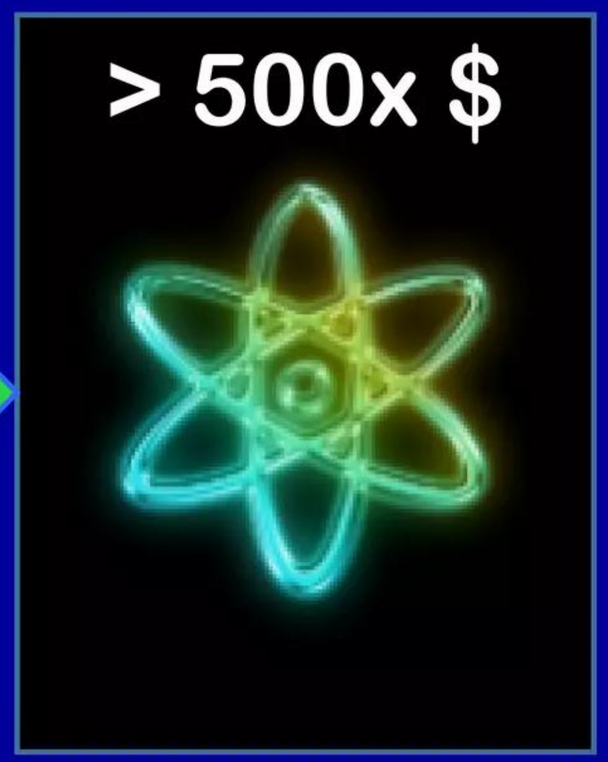
BTU values of fossil energy sources could increase by factor of ~ 5,000x

$$$ economic values of derived LENR fuels could increase to > 500x combustion

Combustion

Adoption of LENR technology

Transmutation



Today: barrel of crude oil priced at ~US$ 56

Tomorrow: LENR products from same barrel could be worth US$ 25,000

Transmutation is economically profitable versus combustion

LENRs increase net energy equivalent values of coal and oil by >500x

Oil is in barrels; Coal in short tons	Oil	Coal	Total adjusted economic value for oil + coal in US$
BP est. proven reserves as of the end of 2013	1,687,900,000,000	891,531,000,000	See BP's *Statistical Review of World Energy* (2014)
Percentage of proven reserves of a fossil fuel left in ground for whatever reasons (%)	0.33	0.80	See McGlade & Elkins in recent *Nature* article (2015)
Number of barrels of oil or short tons of coal deliberately left in the ground (reserves x %)	5.57007E+11	7.13225E+11	Hypothetical assumption for discussion purposes
For discussion purposes, simply assume price of oil and coal remains ~ same as it is today	US$ 50 bbl	US$ 55 ST	In fact, prices should rise as resources are depleted
Conservatively estimated economic value of reserves left-in-ground (US$ price x in-ground)	2.78504E+13	3.92274E+13	6.70777E+13
Assume that only 10% of in-ground oil and coal is recoverable as usable aromatic molecules	0.10	0.10	"Haircut" for non-aromatic fractions of oil and coal
Net economic value of green LENR fuels before adjusting for > energy density (value x .10)	2.78504E+12	3.92274E+12	Adjust for >>> larger LENR heat production in BTUs
Adjust energy equivalent economic value for higher LENR energy density (net value x 5,000)	1.39252E+16	1.96137E+16	3.35389E+16 US$

500x

Assumed proven reserves data is from the BP *Statistical Review of World Energy* (2014); assumptions re % of oil and coal left in ground (whether because of governmental fiats, voluntary restraint, taxation of extraction, or any combination thereof) taken from McGlade & Elkins (*Nature* 2015); assumption that net energy density (ED) of LENR fuels derived from aromatic rings found in oil and coal is ~5,000x > gasoline is probably quite conservative - very likely that an *additional* 10 - 12x increase may be achievable, i.e., >50,000x the ED of gasoline

Oil & gas companies have capital required to develop LENRs

- ✓ At this point, it is not clear exactly how or even whether rates of extraction and/or use of fossil fuels for combustion could be substantially reduced. That said, for purposes of discussion let's assume that leaving 33% of remaining oil and 80% of coal fallow in the ground might be a real possibility via governmental fiats. What would it be worth in terms of economic $$$ value for the oil and gas industry to be able to continue to extract potentially 'stranded' fossil Carbon resources and generate vastly more CO_2-free energy via LENRs? (please note: non-aromatic components of oil and coal would still be available for use as chemical feedstock) Answer to this question is provided in previous slide's Table: 3.35×10^{16} US$
- ✓ For purposes of discussion, let's arbitrarily assume that US$ 250 billion invested over 10 years would be needed to fully commercialize LENRs (Lattice strongly believes that much less than one-tenth of that number would be required). What multiple of a $250 b investment would the realized economic value of 3.35×10^{16} US$ represent; dividing that number by 2.5×10^{11} US$ yields ratio of 1.34×10^{5} – a stunning economic multiplier resulting from a 10-year US$ 250 b investment
- ✓ In 2014 alone, the global oil & gas industry collectively spent US$ 670 billion searching for and developing new fossil fuel resources. In 2013, just Chevron, ExxonMobil, and Royal Dutch Shell together spent more than US$ 120 billion on such activities. Lastly, drilling a single deep water oil well can cost US$100 million. Investment capital needed to fully commercialize LENR technology well-within financing capabilities of oil players such as ExxonMobil or Saudi Aramco

LENR Carbon transmutation could greatly benefit oil & gas

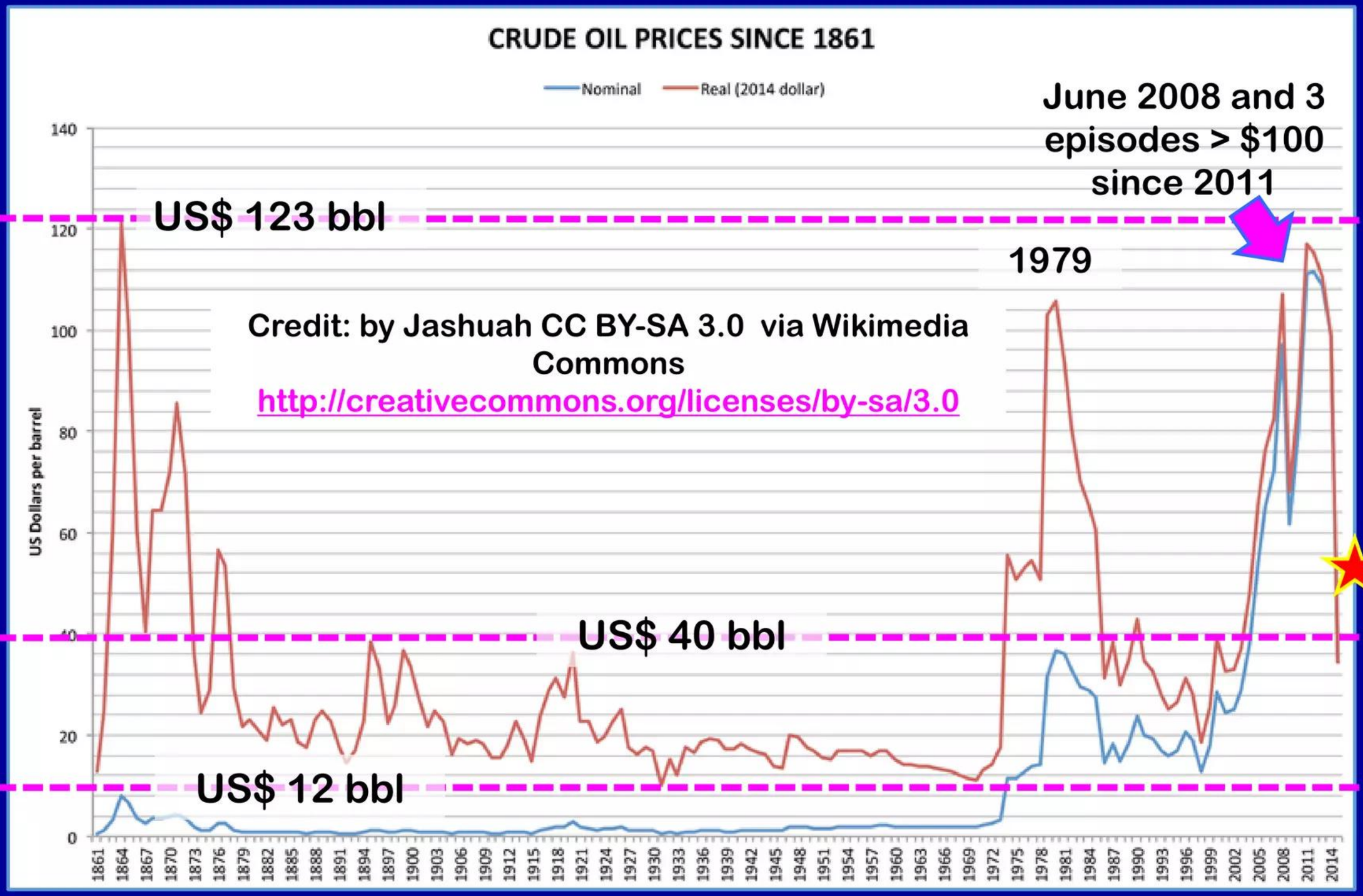
Adoption of LENRs could extend fossil fuels' effective economic lifetime

- ✓ Successful commercialization and broad deployment of LENR Carbon transmutation in power generation applications could increase the effective economic BTU $$$ value of remaining in-ground fossil Carbon resources by at least 500x by releasing thermal energy from Carbon atoms via CO_2-emission-free nuclear transmutation process rather than by continuing to rely on today's age-old chemical combustion technology used by man for 350,000 years
- ✓ So-called "stranded asset" fossil Carbon financial risk issues would disappear
- ✓ Carbon transmutation could substantially extend the effective economic lifetime of present in-ground fossil fuel resources from an estimated <150 years per British Petroleum out to at least another 25,000 years further into the future
- ✓ LENRs are therefore vastly more synergistic rather than competitive with fossil fuels [44 slides]: http://www.slideshare.net/lewisglarsen/lattice-energy-llc-compelling-economics-of-transmutation-vs-combustion-of-carbonaceous-energy-sources-jan-14-2015
- ✓ Rather than eventually replacing fossil fuels with solar, wind, and renewable energy sources over time, LENR technology instead enables oil, gas, and coal producers to convert fossil Carbon into cleaner, more valuable form of CO_2-free LENR energy --- energy producers, energy consumers, and Earth will all win

Nominal and real (2014 Dollars) crude oil prices since 1861

Brent crude oil (ICE) presently trading at price of roughly US$56 / barrel

Recent series of real price spikes > US$100 barrel indicative of resource scarcity



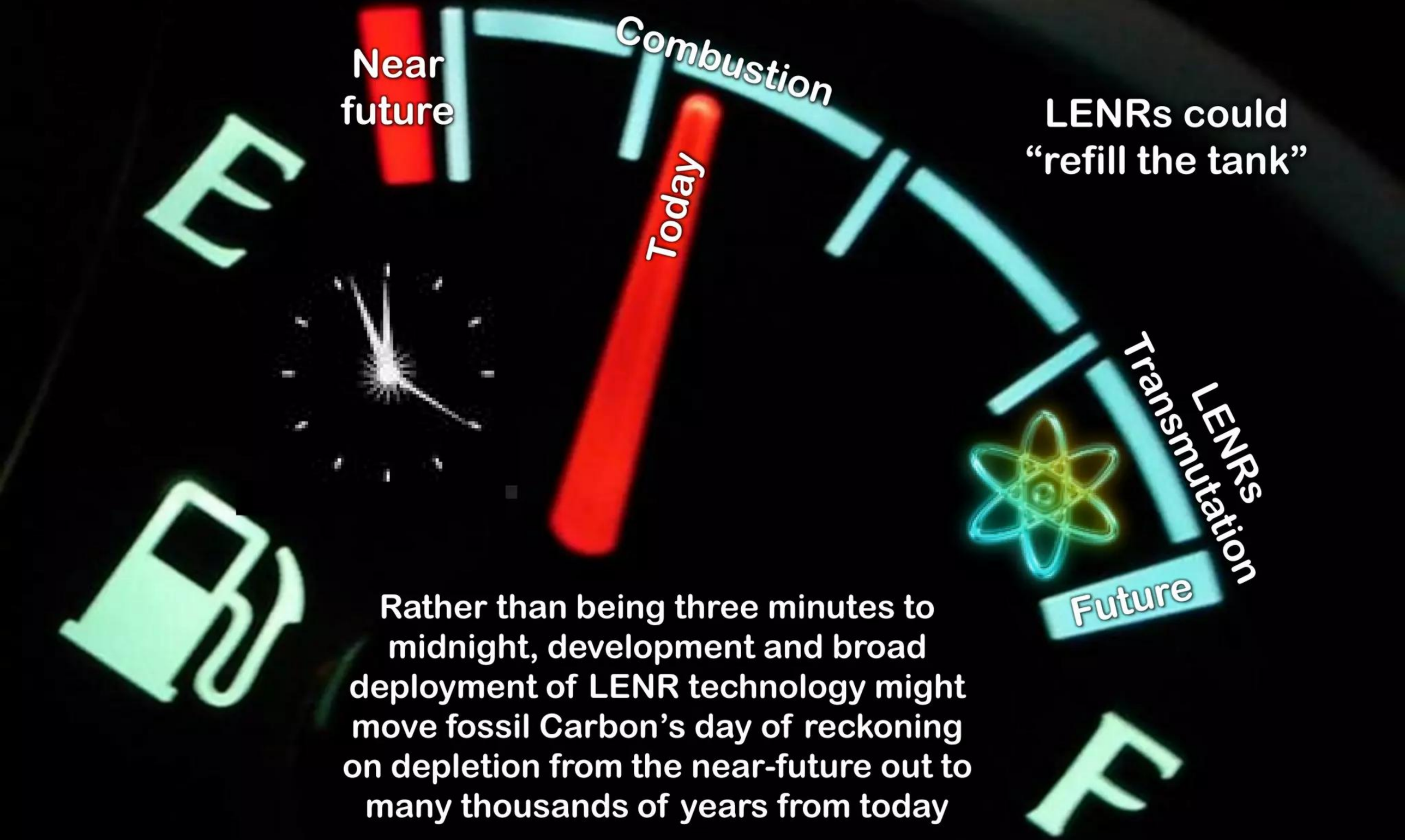
Dinosaurs dominated Earth's landscape for 160 million years

Toppled by catastrophic combination of impactor and volcanic eruptions

Combustion of fossil Carbon fuels --- starting with wood and more recently with coal and oil --- has dominated mankind's energy consumption since the discovery of fire some 350,000 years ago. These energy sources now threatened by resource depletion within 150 years as well as possibility of end-use-restriction stemming from efforts to reduce global human-related CO_2 emissions that might be accelerating what data suggests is progressive global warming.

BP projects end of fossil fuel age in relatively near future

Oil & gas will be exhausted in < 53 years at today's rates of consumption



LENRs could "refill the tank"

Rather than being three minutes to midnight, development and broad deployment of LENR technology might move fossil Carbon's day of reckoning on depletion from the near-future out to many thousands of years from today

Oil depletion will likely occur in the not-too-distant future

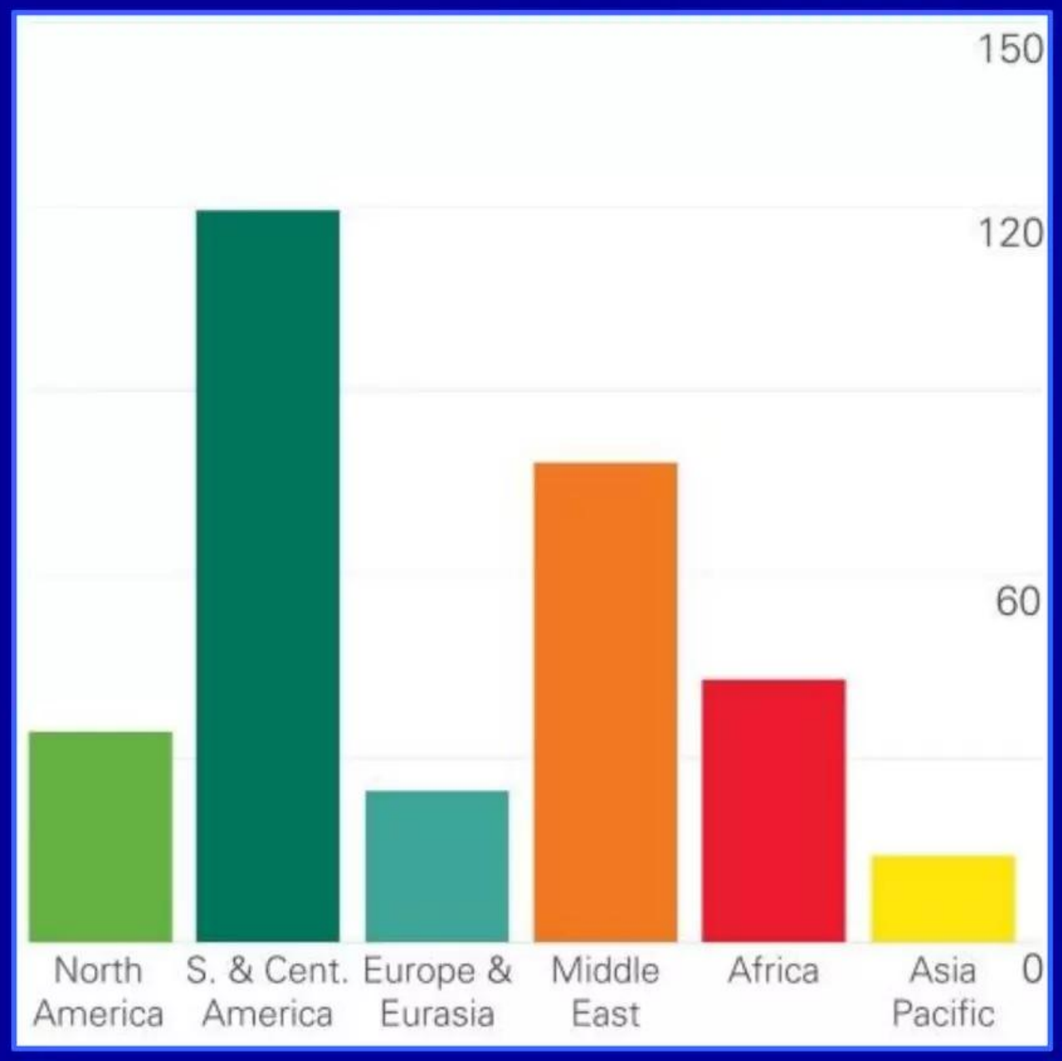
British Petroleum estimates exhaustion of world oil reserves in < 51 years

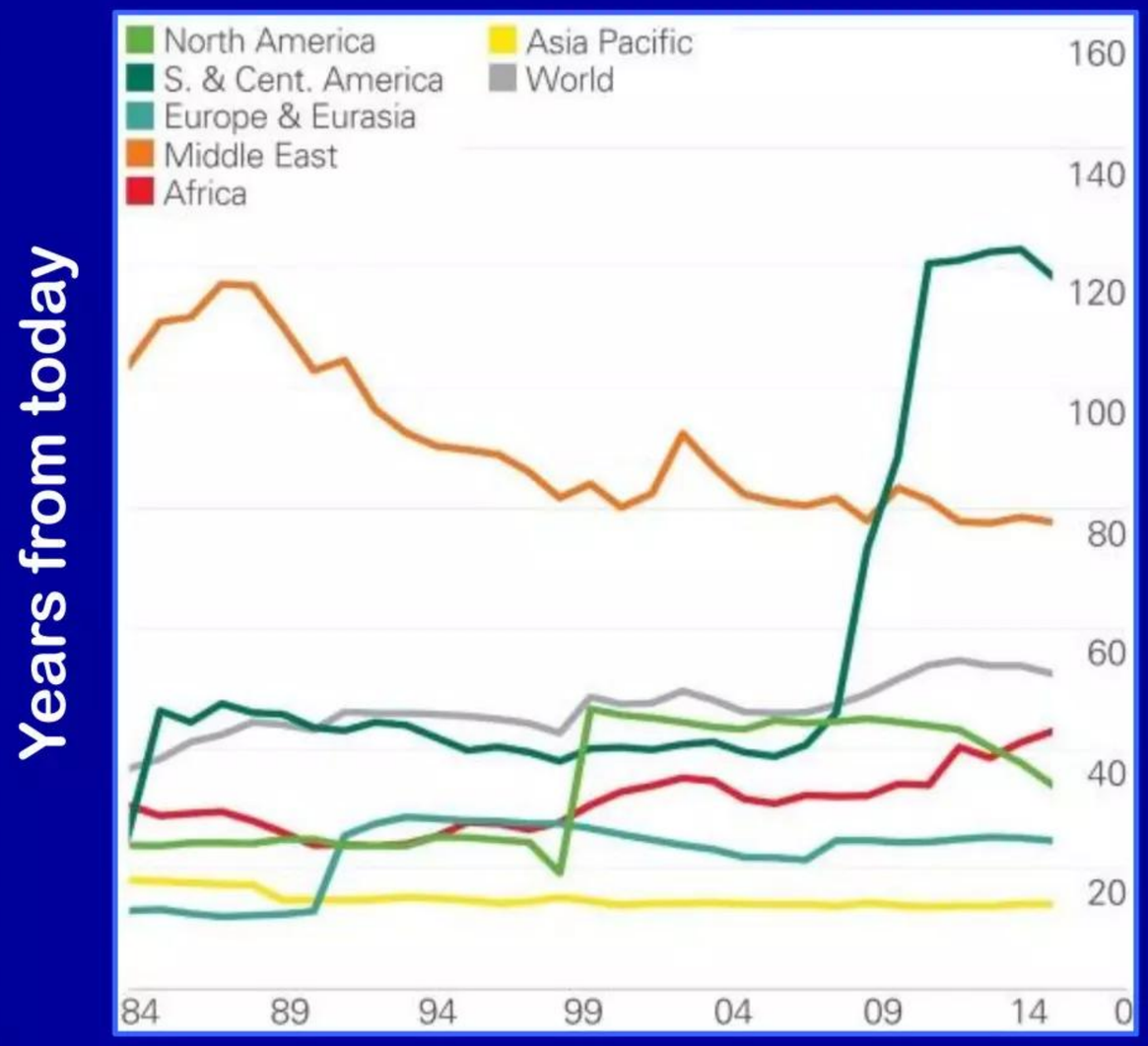
bp

Oil reserves

Global proved oil reserves in 2015 stood at 1697.6 billion barrels, sufficient to meet 50.7 years of current production

Credit: British Petroleum (June 2016 Annual Statistical Review)





https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf

Gas depletion will likely occur in the not-too-distant future

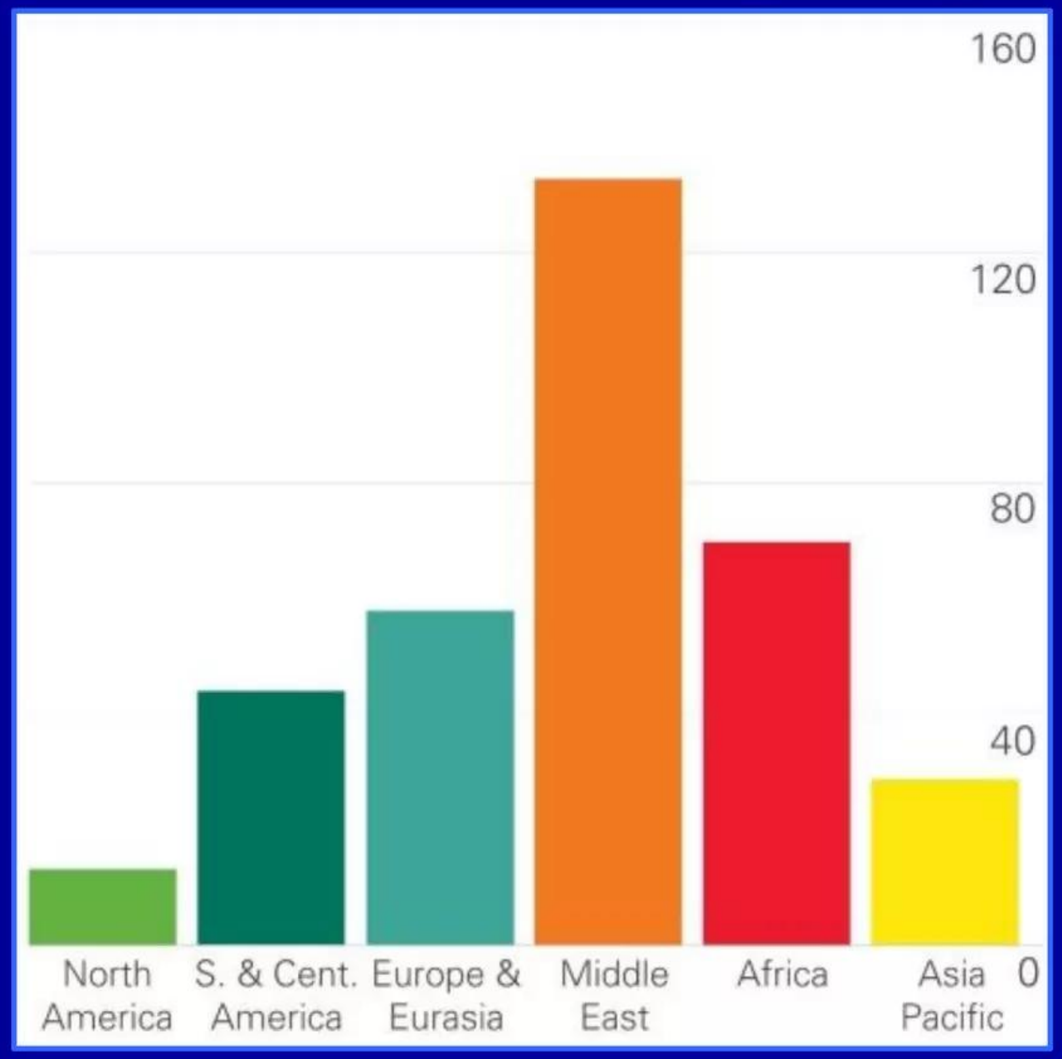
British Petroleum estimates exhaustion of world natural gas in < 53 years

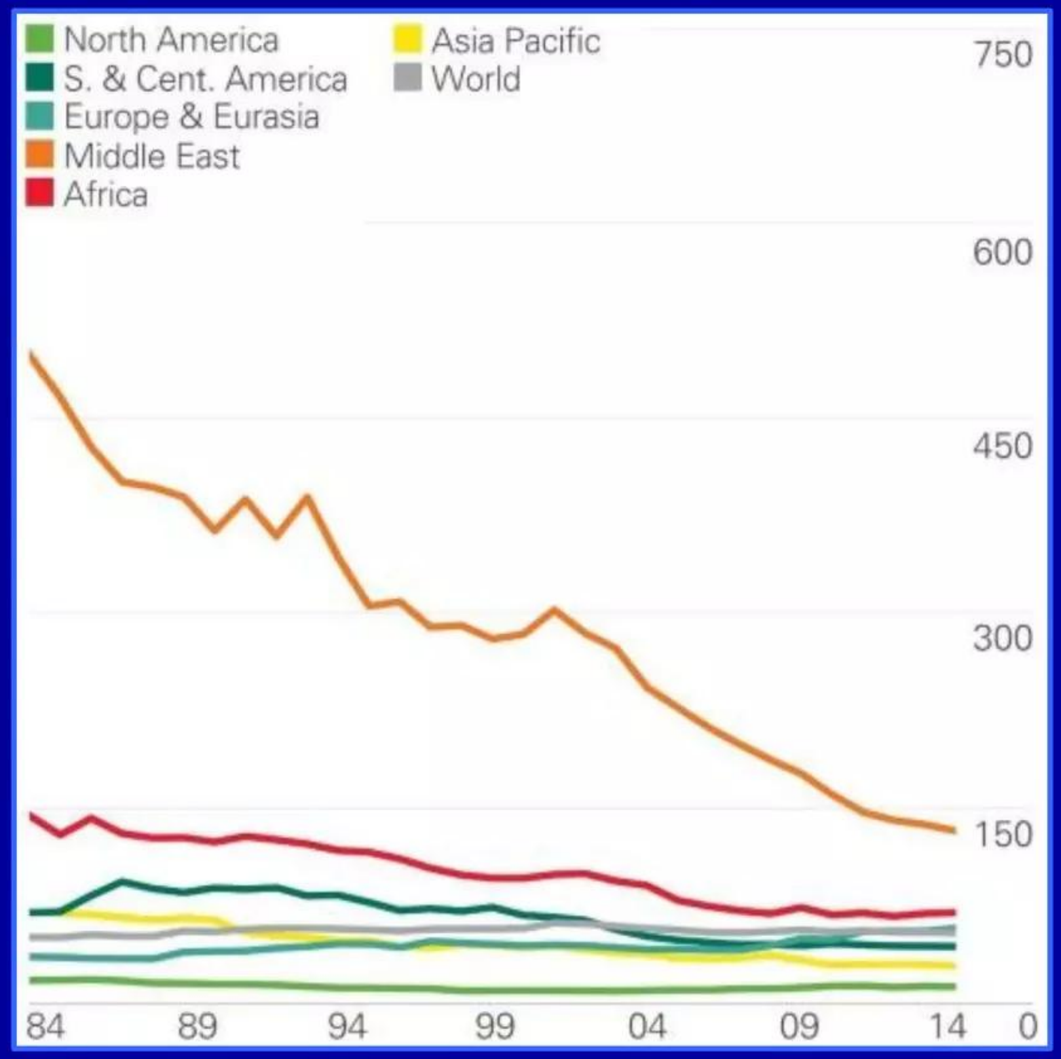
bp

Natural gas reserves

Global proved natural gas reserves in 2015 stood at 186.9 trillion cubic meters (tcm), sufficient to meet 52.8 years of current production

Credit: British Petroleum (June 2016 Annual Statistical Review)





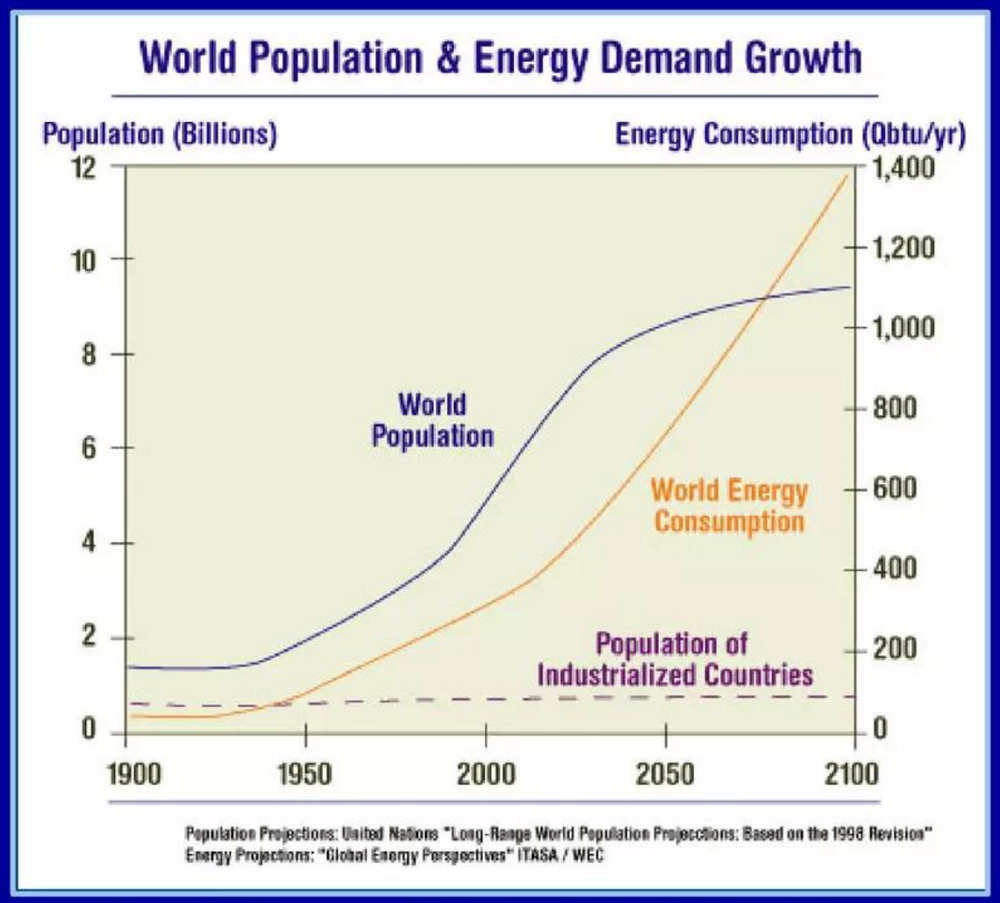
https://www.bp.com/content/dam/bp/pdf/energy-economics/statistical-review-2016/bp-statistical-review-of-world-energy-2016-full-report.pdf

Oil and gas producers facing turbulent times in near future

Strategic issue for all: BP says oil & gas will likely run-out in < 60 years

Besides resource depletion climate change may force big drop in fossil fuel usage

Global energy demand should remain very strong in future



Population projections: United Nations
Energy consumption projections: IIASA / WEC

- ✓ **Resource depletion:** BP says oil will run-out in ~53 years, natural gas in < 54; what will happen to oil & gas companies after that?
- ✓ **Climate change:** emerging scientific consensus posits global warming is being caused by increasing CO_2 emissions from human activities; need huge cuts in CO_2 ?
- ✓ **Fear of global warming:** has lead to speculation about somehow effecting radical decreases in man's CO_2 emissions to help mitigate further rise in average global temperature; restrict fossil fuels?
- ✓ Factors trigger concerns about a "Carbon bubble" that renders remaining in-ground fossil fuels "stranded" and ~ $$$ worthless

Global energy demand has been increasing exponentially; will likely continue to do so

Japanese automakers now have R&D programs in LENRs

Will not admit publicly but aiming to replace internal combustion engine

Lattice is leader in proprietary knowledge required for LENR device engineering

- ✓ We believe Lattice is the world-leader in proprietary knowledge about LENR device engineering required to develop high-performance, long lived, scalable power sources. Our published peer-reviewed theoretical papers rigorously explain the breakthrough physics of LENR processes, including absence of dangerous energetic neutron or gamma radiation and lack of long-lived radioactive waste production
- ✓ Since 2010, Lattice extended proprietary aspects of LENR theory to aromatic Carbon molecules. This recent technological advance opens-up possibility of future power generation via Carbon transmutation rather than combustion
- ✓ Little-discussed in media, Mitsubishi Heavy Industries, Toyota, Nissan, and now Renault (indirectly via Renault-Nissan Alliance) --- that altogether account for a sizeable percentage of global motor vehicle production --- are involved in R&D programs aimed to develop LENR technology for power generation applications
- ✓ One can only conclude that, even though these three Japanese companies are unwilling to admit it publicly, their long-term goal must be to someday replace the internal combustion engine. That would be technology leapfrog way beyond today's Lithium battery-powered EVs or cars powered by Hydrogen fuel-cells

Japan, Inc. hedges its bets on utilizing fission and fusion

Government of Japan has resumed funding of R&D in LENRs via NEDO

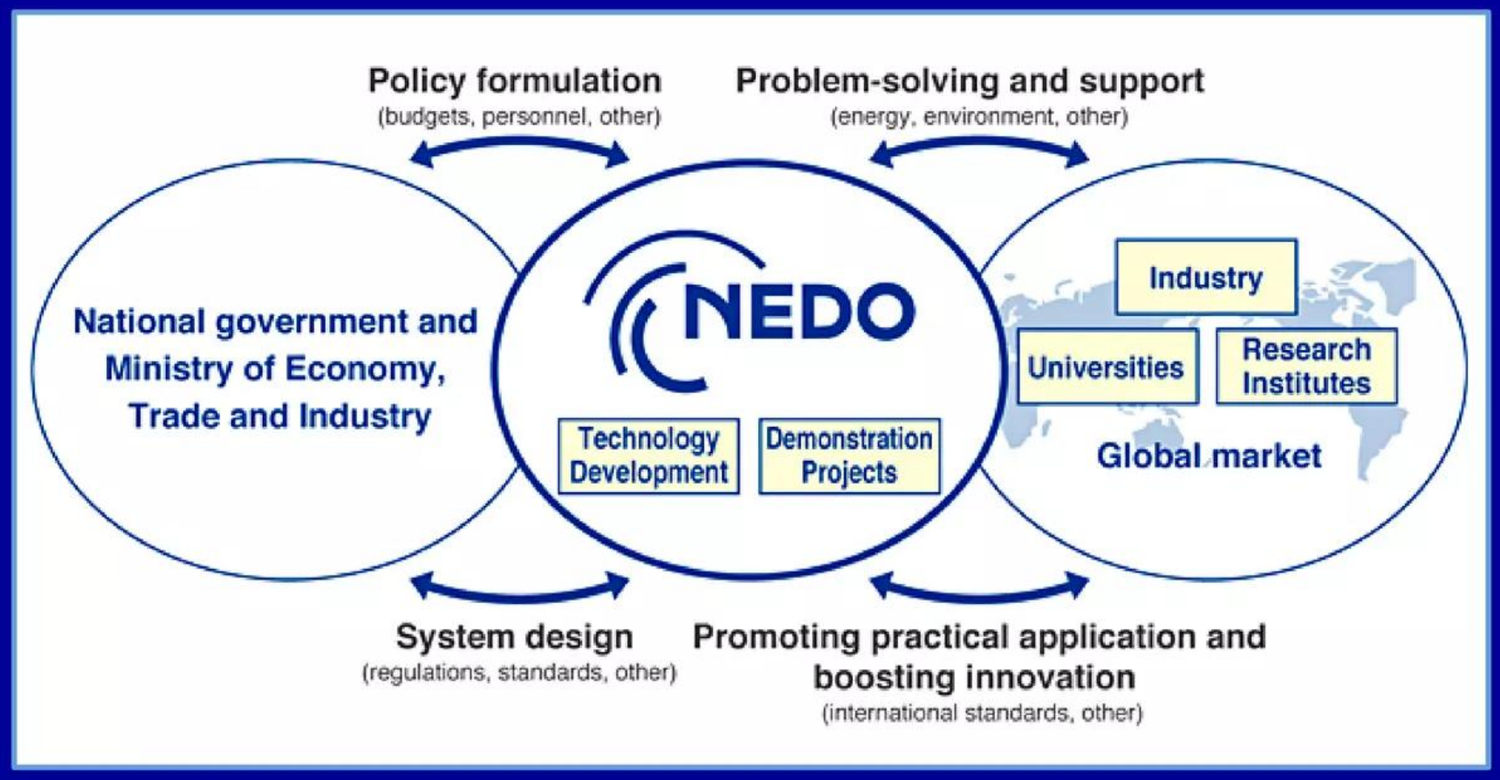
NEDO New Energy and Industrial Technology Development Organization

Combining the efforts of industry, government and academia and leveraging established international research networks, NEDO is committed to contributing to the resolution of energy and global environmental problems and further enhancing Japan's industrial competitiveness

http://www.nedo.go.jp/english/

Mode of operation – graphic is copied from home page of NEDO website

経済産業省 Ministry of Economy, Trade and Industry



MITSUBISHI

TOYOTA

NISSAN

U.S. House Armed Services Committee has requested

Briefing from the Secretary of the U.S. Department of Defense on the National security implications of ultralow energy neutron reactions or LENRs

" According to the Defense Intelligence agency … if LENR works it will be a 'disruptive technology that could revolutionize energy production and storage'."

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-us-house-armed-services-committee-requests-briefing-from-us-dod-on-lenrs-may-11-2016

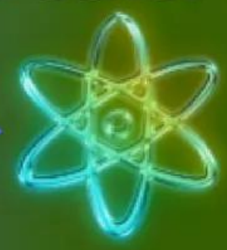
"The committee is aware of recent positive developments in developing low-energy nuclear reactions (LENR), which produce ultraclean, low-cost renewable energy that have strong national security implications. For example, according to the Defense Intelligence Agency (DIA), if LENR works it will be a ''disruptive 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."

Revolutionary ultralow energy neutron reactions (LENRs)

Radiation-free LENRs transmute stable elements to other stable elements

Fission and fusion

Evolution of nuclear technology



Safe green LENRs

Laura 13

No deadly MeV-energy gamma radiation

No dangerous energetic neutron radiation

Insignificant production of radioactive waste

Vastly higher energies vs. chemical processes

Revolutionary, no CO_2 , and environmentally green

Is fully explained by physics of Widom-Larsen theory

Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng et al., *Nano Letters* pp. 602 - 609 (2012)

LENRs are green: no energetic radiation or radwastes

Lack of hard radiation obviates need for shielding and containment

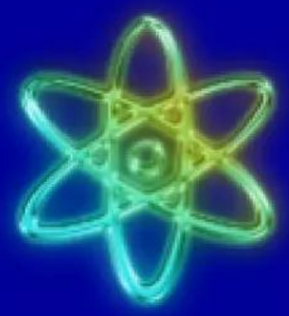
Major opportunity to develop safe, battery-like portable LENR power sources

Fission and fusion processes both emit deadly MeV-energy neutron and gamma radiation

Fission reactors need 1 foot of steel and 3 feet of concrete to protect humans from hard radiation and wastes emitted by reactor; makes systems intrinsically large and heavy

LENRs enable devices something like this: small, portable battery-like power sources that are safe and disposable

Revolution in green nuclear technology



Much larger LENR devices based on dusty plasma embodiments can potentially scale-up to megawatts; akin to today's power plants

Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

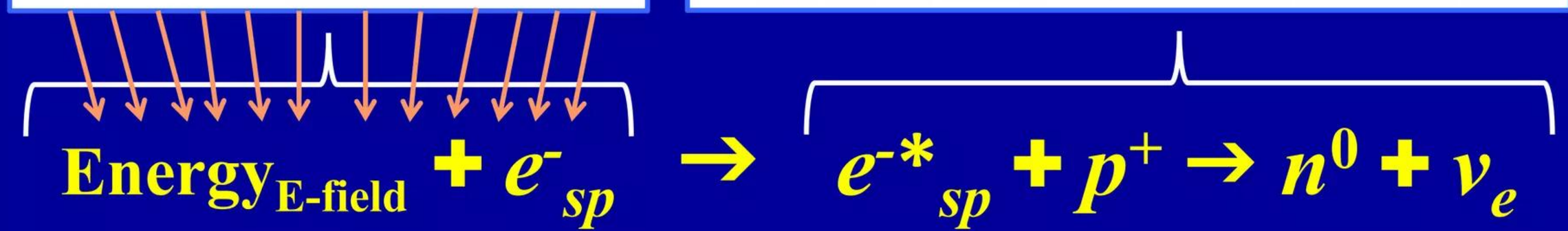
W-L explains how e + p reactions occur at substantial rates in condensed matter

Draw energy from electric fields > 10^{11} V/m

Heavy-mass e^{-}* electrons react directly with protons

Collective many-body quantum effects: many electrons each transfer little bits of energy to a much smaller number of electrons also bathed in the very same extremely high local electric field

Quantum electrodynamics (QED): smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds β_0 where they can react directly with a proton (or deuteron) ⟶ neutron and neutrino



ν_e neutrinos: ghostly unreactive particles that fly-off into space; n^0 neutrons capture on nearby atoms

Induces safe hard-radiation-free nuclear transmutation

Neutrons + atomic nuclei ⟶ heavier elements + decay products

Widom-Larsen theory of ultralow energy neutron reactions

Three key publications beginning in March of 2006 are referenced below

Peer-reviewed: *EPJC* and *Pramana* papers well-supported by experimental data

"Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces"
A. Widom and L. Larsen
***European Physical Journal C - Particles and Fields* 46 pp. 107 - 112 (2006)**

http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006

"Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces"
A. Widom and L. Larsen
***Cornell physics preprint arXiv:nucl-th/0608059v2* 12 pages (2007)**

http://arxiv.org/pdf/nucl-th/0608059v2.pdf

"A primer for electro-weak induced low energy nuclear reactions"
Y. Srivastava, A. Widom, and L. Larsen
***Pramana - Journal of Physics* 75 pp. 617 - 637 (2010)**

http://www.slideshare.net/lewisglarsen/srivastava-widom-and-larsenprimer-for-electroweak-induced-low-energy-nuclear-reactionspramana-oct-2010

Widom-Larsen enables commercialization of LENRs

Applied nanotechnology and LENRs are mutually joined at the hip

Development risks can be reasonable thanks to Widom-Larsen and nanotech

Guided by physics of the Widom-Larsen theory, an opportunity to commercialize LENRs as truly green CO_2-free nuclear energy source has been enabled by a unique juxtaposition of very recent parallel advances in certain very vibrant areas of nanotechnology (esp. plasmonics), quantum entanglement, new innovations in nanoparticle fabrication techniques, as well as an array of new discoveries in advanced materials science.

Nanotechnology and LENRs are mutually joined at the hip

Large length scales

What was formerly thought impossible becomes possible by utilizing Widom-Larsen and applying nanotechnology

Nuclear-strength electric fields in μ-sized LENR-active sites enable $e + p$ reaction

Huge array of new technological possibilities and opportunities open-up at micron to nanometer length-scales

Power densities of primitive experimental LENR devices

Device power densities of 4.28 x 10^3 W/m^2 same as thermal power plants

LENR system areas small: no shielding and fuel energy density > 5,000x gasoline

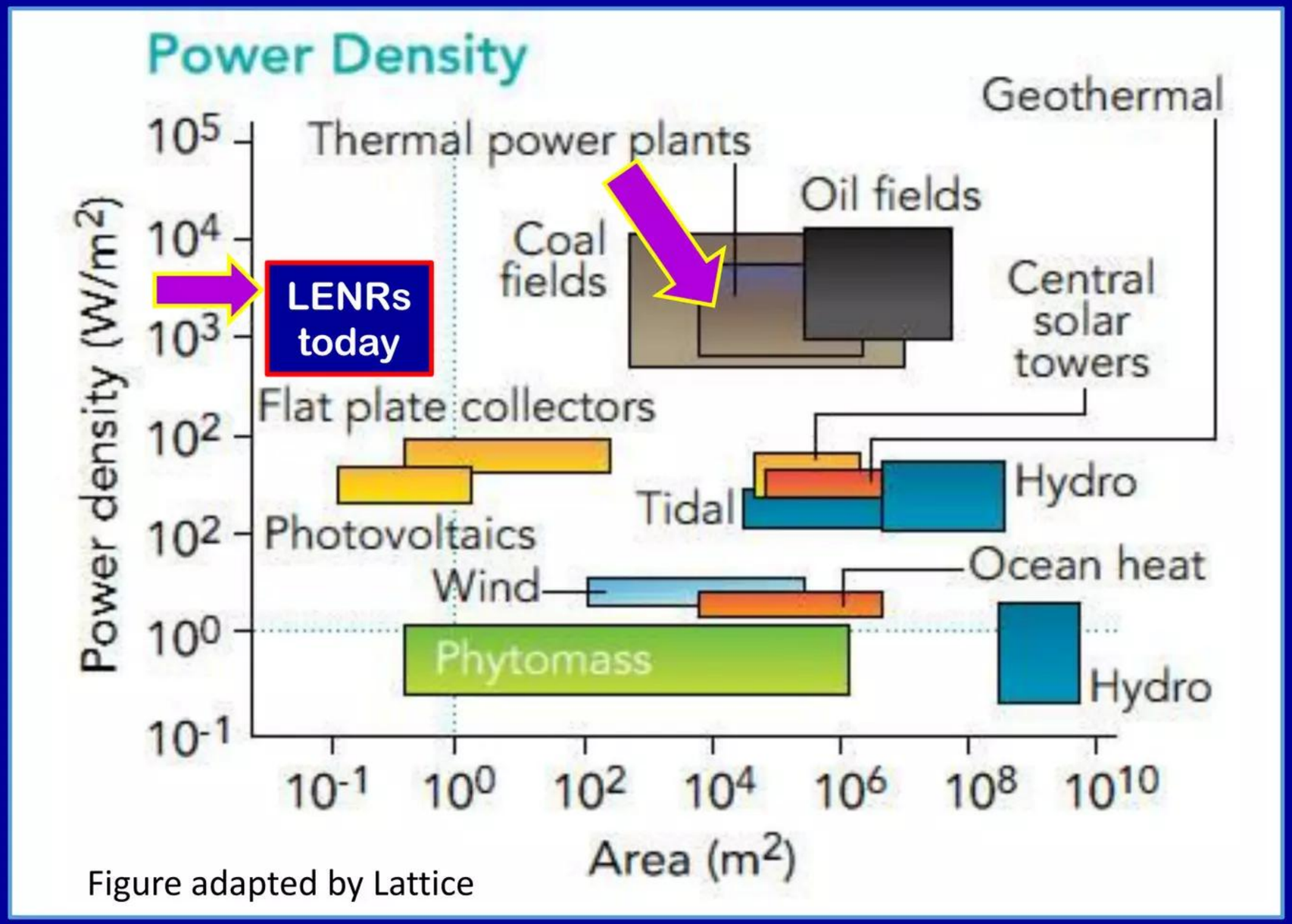


Figure adapted by Lattice

Source: "Do We Have the Energy for the Next Transition?" R. A. Kerr in *Science* 329, pp. 781 (2010)

Nuclear energy density surpasses any chemical technology

LENR-based power generation could have vast competitive advantage

Future possibility of converting Carbon aromatics to CO_2-free LENR fuels

LENRs Versus Chemical Energy Sources: Batteries, Fuel Cells, and Microgenerators

Source of Energy	Approximate Energy Density (Watt*hours/kg)
Alkaline Battery	164
Lithium Battery	329
Zinc-Air Battery	460
Direct Methanol Fuel Cell (35% efficient)	1,680
Gas Burning Microgenerator (20% efficient)	2,300
100% Efficient Combustion of Pure Methanol	5,930
100% Efficient Combustion of Pure Gasoline	11,500
LENRs (based on an assumption of an average of 0.5 MeV per nuclear reaction in an LENR system)	**57,500,000** (maximum theoretical energy density – only a fraction would be achievable in practice)

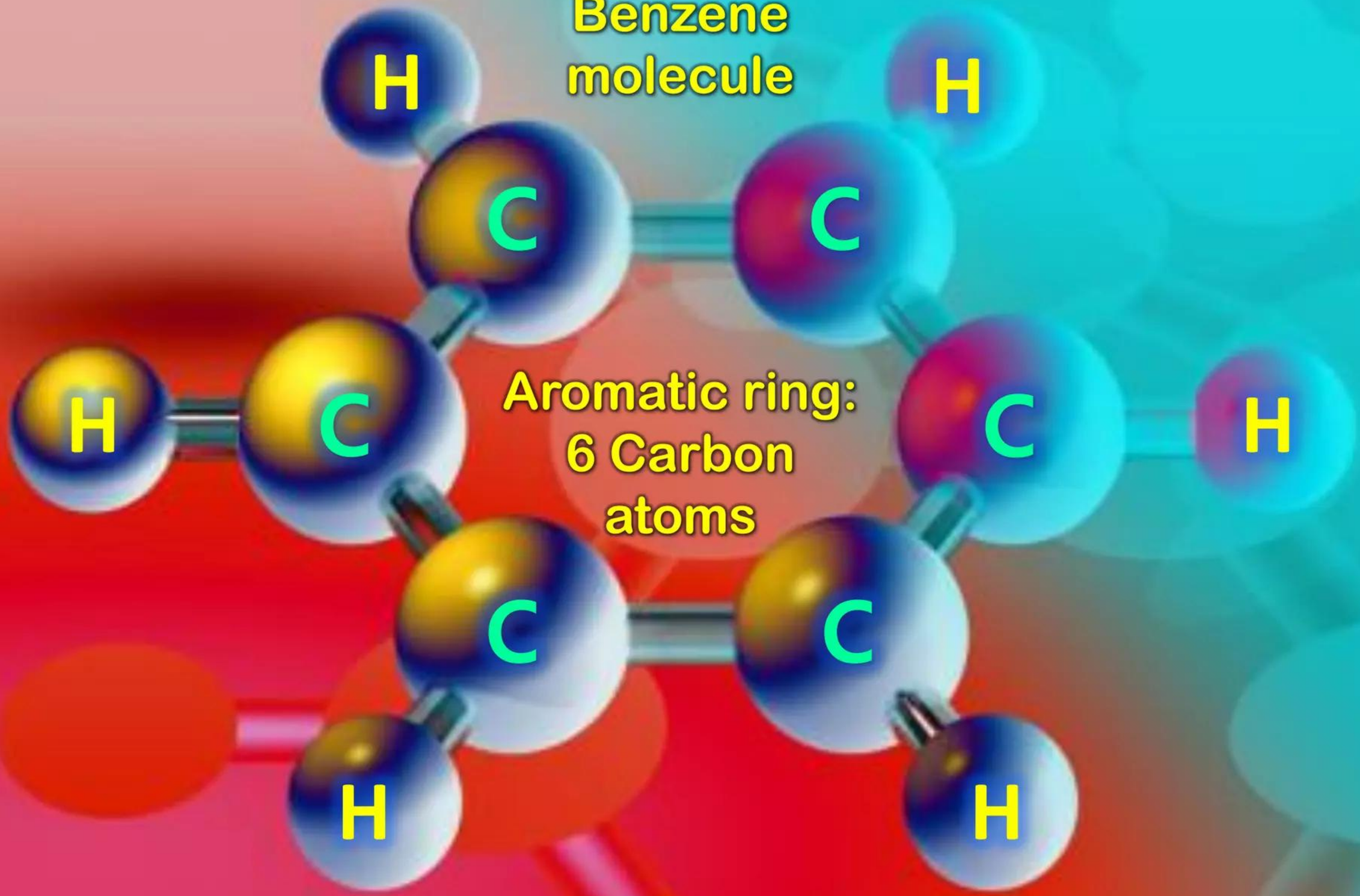
~2,000 Wh/kg someday might be practical with Lithium-air chemical battery

Chemical

LENRs

Fossil Carbon can be transmuted rather than combusted

Benzene molecule



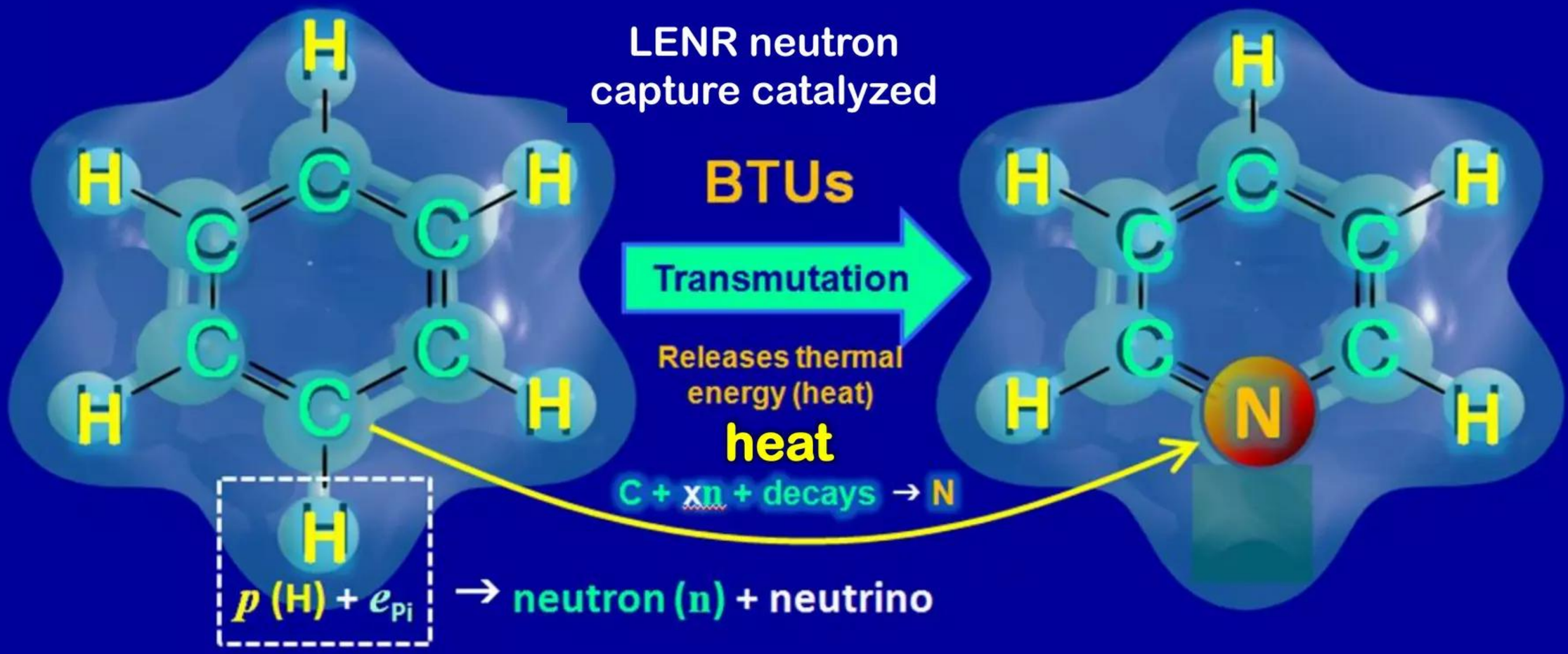
Aromatic ring: 6 Carbon atoms

6 Carbon atoms arranged in hexagonal ring bonded to 6 Hydrogen atoms

Convert ring Hydrogen atoms (protons) into safe neutrons

Neutrons are captured by ring Carbon atoms that are then transmuted

In this example a Carbon atom is transmuted into a Nitrogen with LENR process



Process does not emit any deadly radiation or produce troublesome radwastes

Fossil Carbon can be transmuted rather than combusted

Heavy oil and coal could be processed to produce CO_2-free LENR fuels

Carbon atoms found on aromatic rings good fuel for radiation-free transmutation

Hard radiation-free LENR transmutation

Neutrons + target fuel atoms → heavier elements + decay products + heat

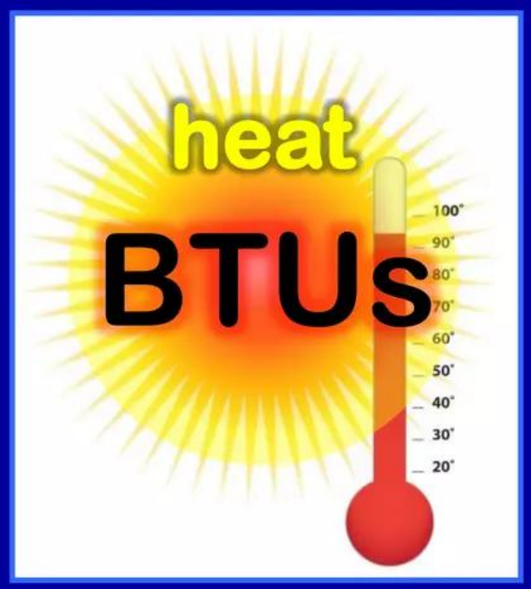
Catalytic neutron 'match'

capture +

Neutrons are readily absorbed by LENR fuels such as inexpensive Nickel, Titanium, Lithium, or Carbon atoms

produces →

Direct conversion of neutron capture and decay-related gammas to IR and beta/alpha particles create heat

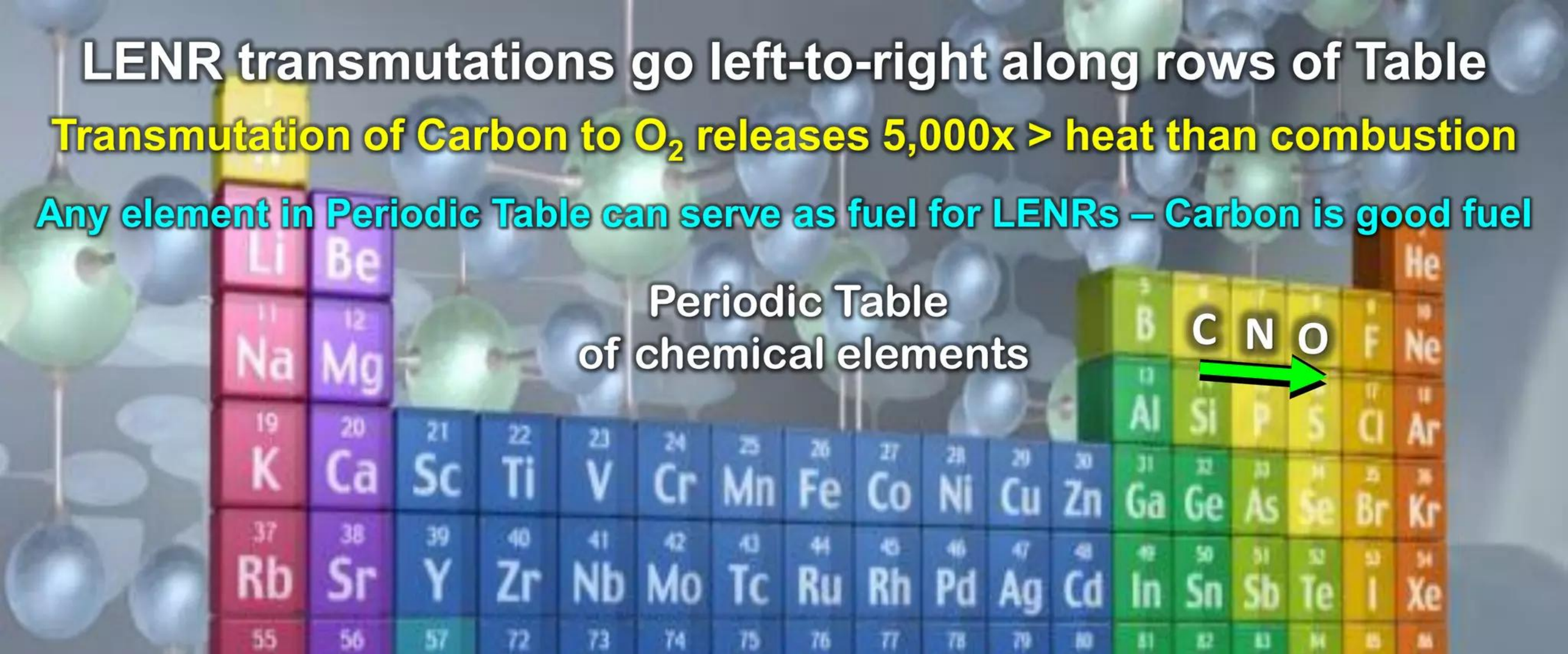


Process does not emit any deadly radiation or produce troublesome radwastes

LENR transmutations go left-to-right along rows of Table

Transmutation of Carbon to O_2 releases 5,000x > heat than combustion

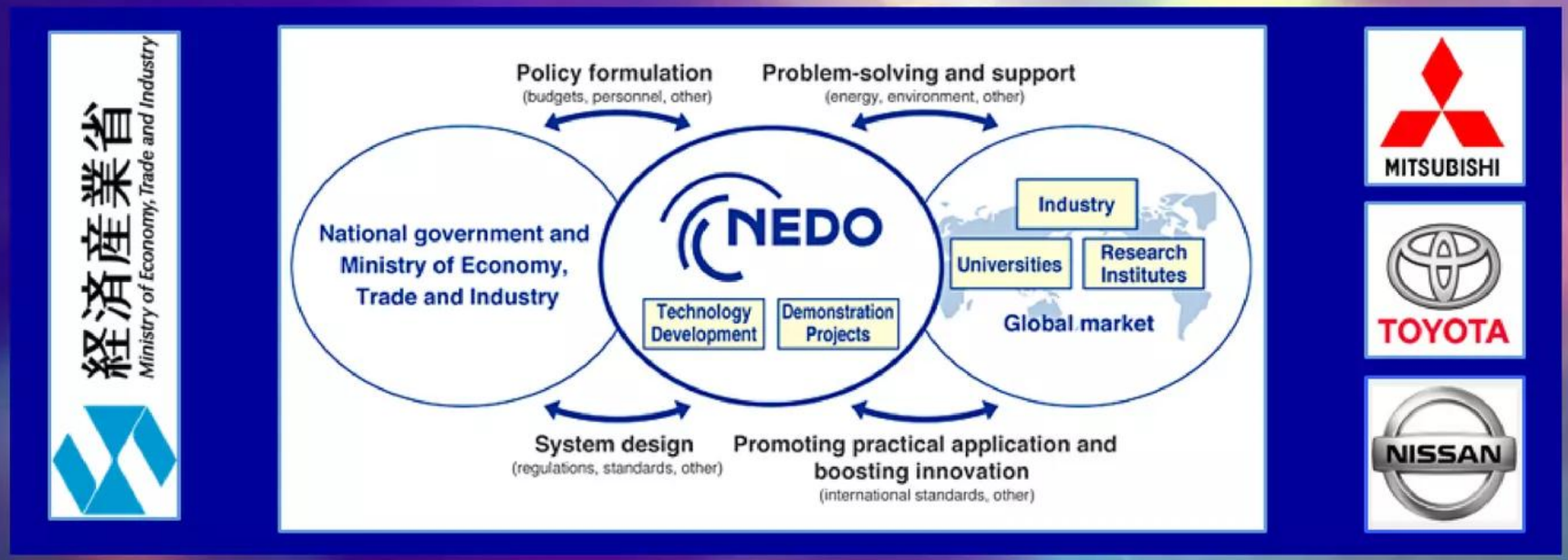
Any element in Periodic Table can serve as fuel for LENRs – Carbon is good fuel



Achieve future deep decarbonization of both the electric power generation and transportation sectors

LENRs are only energy technology on foreseeable horizon that could potentially enable future deep decarbonization of both electric power generation and transportation sectors at reasonable total economic $ cost

Mitsubishi Heavy Industries, Toyota, and Nissan Motors now conducting R&D programs and developing LENRs to someday replace the internal combustion engine



Entangled particles - Credit: Getty Images

LENR systems energy-dense and would readily scale-up

Energy density is a key advantage of LENRs vs. chemical combustion

Solar or wind - innately low energy densities; must be collected and concentrated

- ✓ Vast majority of vehicles are now powered by internal combustion engines burning gasoline or diesel fuels with O_2 because effective energy densities are much higher than all-electric vehicles powered by advanced chemical batteries
- ✓ At the present time, vehicles with internal combustion engines have substantially lower total lifetime $ costs than all-electric vehicles
- ✓ LENRs would be at least 5,000x more energy-dense than gasoline
- ✓ If LENRs can be scaled-up to power vehicles, have opportunity to displace internal combustion

Petroleum energy density: "A single gallon of gasoline contains approximately forty megajoules of chemical energy. Dividing energy by volume yields an energy density of ten billion joules per cubic meter. **Gasoline is ten quadrillion times more energy-dense than solar radiation and one billion times more energy-dense than wind and water power."**

Table 1 Energy density — Source: B.E. Layton, *International Journal of Green Energy* 5 pp. 438 - 455 (2008)

Source	Joules per cubic meter
Solar	0.0000015
Geothermal	0.05
Wind at 10 mph (5m/s)	7
Tidal water	0.5–50
Human	1,000
Oil	45,000,000,000
Gasoline	10,000,000,000
Automobile occupied (5800 lbs)	40,000,000
Automobile unoccupied (5000 lbs)	40,000,000
Natural gas	40,000,000
Fat (food)	30,000,000

Renewables

Fossil fuels

http://www.drexel.edu/~/media/Files/greatworks/pdf_sum10/WK8_Layton_EnergyDensities.ash

Ongoing climate change disrupts prior weather patterns

Mystery wind drought hit U.S. during first half of 2015 - returned in 2016

2015: wind-powered electrical output down 6% while capacity went up 9%

If you believe wind and solar can someday totally replace short-notice sources of dispatchable power generation then think again, because they simply can't --- ever

Modern electric grids require dispatchable power generation

Need grid-connected power sources not subject to vagaries of Nature

Grids with 100% renewables not feasible even with grid-scale flow batteries

- ✓ Wind and solar power generation technologies, while decreasing in cost, are inherently non-continuous sources of thermal and electrical power --- wind speeds and intensity of the sun can vary dramatically intra-day or from week to week; importantly, presently ongoing climate change, whatever its cause, is making weather patterns even more --- not less --- variable than ever before
- ✓ For example, in Chicago the month of June 2015 was rainiest and cloudiest (>70% of days were cloudy) on-record since the 1880s; well, if the Chicago metropolitan area had been 50% dependent on solar, may have had problems
- ✓ Many naively believe that massive local deployment of giant grid-scale flow batteries could bridge the supply-demand gap in such situations; well, it might work for a few hours or a day, but certainly not for days, weeks, or months
- ✓ What is needed is a new energy-dense, green power generation technology that is CO_2-free, dispatchable, highly scalable from kilowatts to grid-scale megawatt systems, and utilizes manufacturing technologies that can exploit the experience curve effect to further reduce price of energy for consumers
- ✓ LENR technology being developed by Mitsubishi Heavy Industries, Toyota, Nissan, and Lattice Energy could provide key piece of the future energy mix

Dispatchable power generation will always be needed

LENR powertech could be key component in long-term future of energy

- ✓ Given innate variability in power output of renewable green energy sources, substantial amounts of short-notice dispatchable generation capacity are an unavoidable necessity and key asset for maintaining modern high-availability electricity grids that ideally provide customers with 99^{+} % uptime. This crucial requirement would continue to exist even if --- sometime in the future --- wind and/or solar renewables happened to be substantially *less* expensive than fossil-fueled or nuclear fission central station power plants
- ✓ Separately, from a risk management perspective maintaining adequate dispatchable generation capacity would represent a reasonable investment that could also help ameliorate an immense societal catastrophe in the unlikely event of an enormous "Black Swan" volcanic dust eruption that could sharply reduce Earth's sunlight and wind velocities for months or even several years
- ✓ Having adequate dispatchable power generation capacity is thus an invaluable asset in maintaining reliable energy production and prudent risk management. It is also prudent to reduce future CO_2 emissions from power generation. This will eventually happen anyway because at current rates of consumption, in 2016 BP estimated oil, gas, and coal resources will be exhausted in < 114 years
- ✓ LENR-based power plants would be dispatchable and would not emit any CO_2. If commercialized, vast expansion of LENR power generation may be inevitable and could be a key strategic component in the long-term future of green energy

Jenkins & Thernstrom agree on need for dispatchable power

"Low-Carbon dispatchable baseload resources are indispensable"

"DEEP DECARBONIZATION OF THE ELECTRIC POWER SECTOR INSIGHTS FROM RECENT LITERATURE"

Energy Innovation Reform Project
Affordability · Reliability · Safety · Security

JESSE D. JENKINS AND SAMUEL THERNSTROM
MARCH 2017

EIRP
ENERGY INNOVATION REFORM PROJECT

http://innovationreform.org/wp-content/uploads/2017/03/EIRP-Deep-Decarb-Lit-Review-Jenkins-Thernstrom-March-2017.pdf

Quoting from their conclusions; this is a must-read paper:

"There is strong agreement in the recent literature that deep decarbonization --- reaching zero or near-zero CO_2 emissions --- is best achieved by harnessing a diverse portfolio of low-Carbon resources."

"In particular, low-Carbon dispatchable baseload resources such as nuclear, biomass, hydropower, or CCS, are an indispensable part of any least-cost pathway to deep decarbonization. Recent literature indicates that removing this dispatchable base from the generation portfolio, relying instead on variable renewable energy resources such as wind and solar, would significantly increase the cost and technical challenge of decarbonizing power systems."

"In addition, reaching zero emissions requires a significantly different capacity mix than achieving comparatively more modest goals."

Strategy: retrofit fossil fuel plants with LENR-powered boilers

Cost of retrofitted facility could be ~74% less than new natural gas plant

"Will low natural gas prices eliminate the nuclear option in the US?"

Values in Table are from R. Graber and T. Retson (released July 2013)

Table 2: Cost Components of Levelized Costs ($/MWh) ($2012)				Lattice estimates
Cost Component ($/MWh)	**Nuclear**	**Natural Gas (No Environmental cost)**	**Natural Gas (With $25/Ton CO_2)**	**Retrofit nat. gas or coal plants**
Capital	$ 57.78	$ 12.72	$ 12.72	**$ 2.54**
O&M	$ 10.03	$ 3.46	$ 3.46	**$ 5.02**
Fuel	$ 5.55	$ 46.99	$ 46.99	**$ 1.00**
Taxes[1]	$ 9.79	$ 10.39	$ 10.39	**$ 10.39**
Decommissioning	$ 1.46	-	-	**-0-**
Waste Disposal	$ 1.00	-	-	**$ .10**
Environmental Compliance	-		$ 9.80	**-0-**
TOTAL	**$ 85.61**	**$ 73.55**	**$ 82.35**	**$ 19.05**

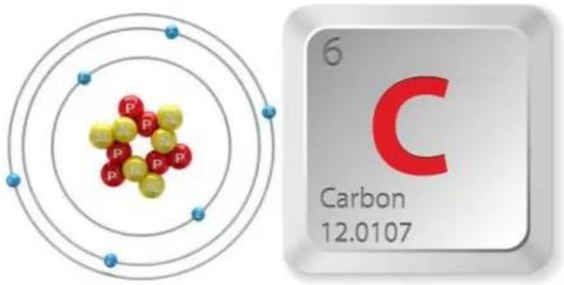
Graber & Retson's numbers in above Table were presented at conference and differ slightly from values at URL below

Source: http://www.energybiz.com/article/13/10/will-low-natural-gas-prices-eliminate-nuclear-option-us

Some Dinosauria escaped extinction by evolving into birds

Oil producers could utilize LENRs to enter New World of transmutation

LENRs could stretch useful economic life of oil & gas to thousands of years



Carbon → Nitrogen → Oxygen

Combustion replaced by transmutation

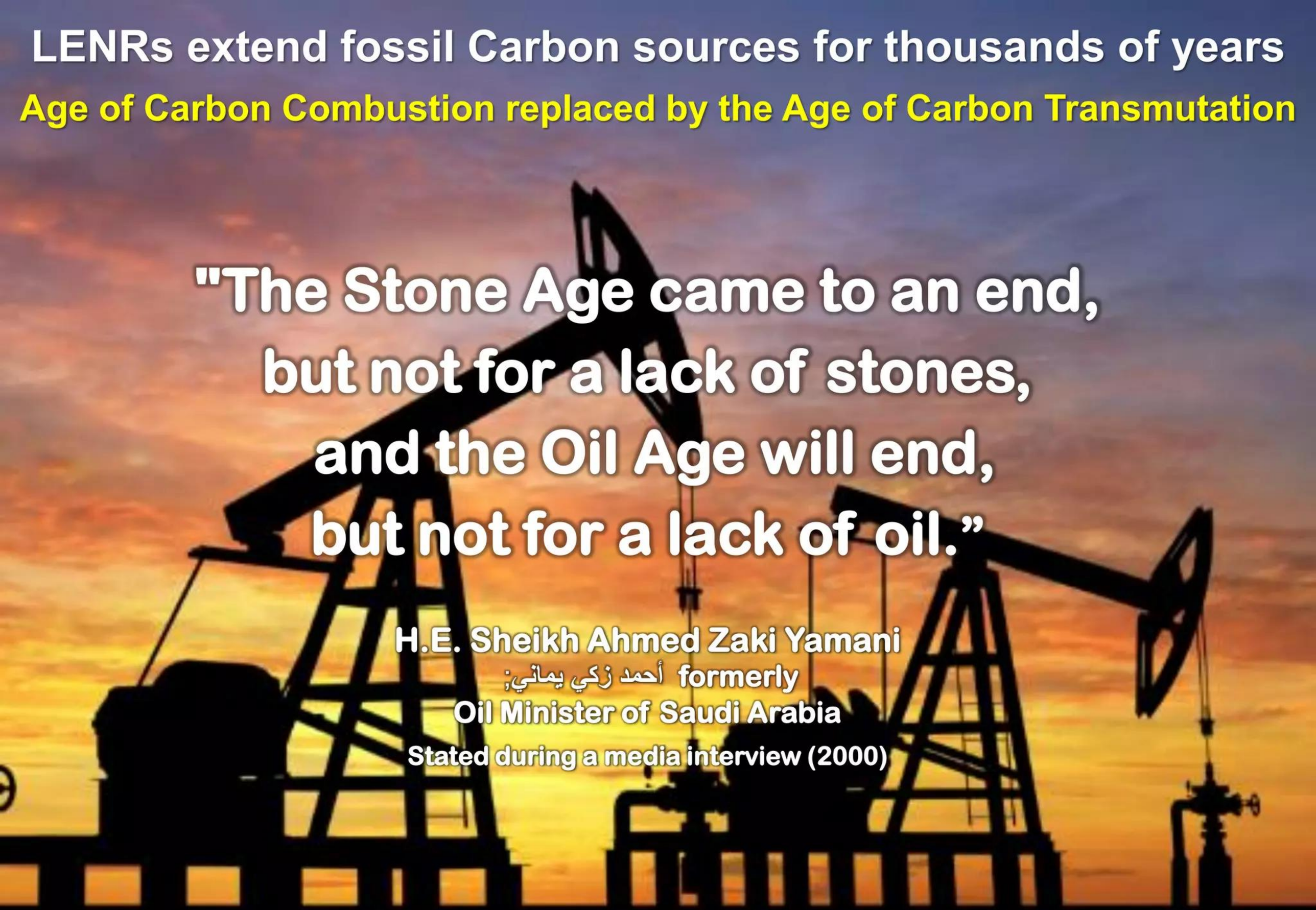
Neutron catalyzed LENRs

Oil & gas companies could soar in a New World of energy

LENRs bridge Old World of combustion to New World of transmutation

LENRs extend fossil Carbon sources for thousands of years

Age of Carbon Combustion replaced by the Age of Carbon Transmutation



"The Stone Age came to an end,
but not for a lack of stones,
and the Oil Age will end,
but not for a lack of oil."

H.E. Sheikh Ahmed Zaki Yamani
أحمد زكي يماني; formerly
Oil Minister of Saudi Arabia
Stated during a media interview (2000)