Lattice Energy LLC

Commercializing a next-generation source of safe CO_2-free nuclear energy

LENR transmutation of Carbon is superior energy strategy

Slashes CO_2 emissions for vehicles as well as electric power generation

Unlike Obama plan: vastly increased energy density collapses real price of energy

Lewis Larsen

President and CEO

August 3, 2015

"Energy, broadly defined,
has become the most important
geostrategic and geoeconomic
challenge of our time."

Thomas Friedman
New York Times, April 28, 2006

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http://www.slideshare.net/lewisglarsen/presentations

President Barack Obama's new climate action plan

Announced publicly at White House press conference on August 3, 2015

https://www.whitehouse.gov/climate-change#section-clean-power-plan

https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf

- ✓ **Centerpiece of plan is to achieve a 32% reduction in gaseous Carbon (CO_2) emissions from US power plants by 2030**, much of it via decreasing the usage of coal by electric utilities, especially vs. natural gas, and by increased deployment of solar/wind renewable electricity generation and battery storage technologies
- ✓ Details of implementation are left for individual states to decide, who will operate within a broad range of Federal government guidelines outlined in plan
- ✓ While improved public health benefits from reduced noxious atmospheric particulates (that are mainly created by burning of coal) are mentioned, **claimed significant economic benefits in terms of reducing consumers' energy costs are notably absent from the plan,** other than a rather lame assertion that average consumers will **"… save nearly $85 on their annual energy bills in 2030."**
- ✓ Lattice comments: **while Obama's new clean power plan is certainly very well-intentioned, it implicitly throws the fossil fuel industry "under the bus," naively assumes that wind and solar power will take up the slack at reasonable $ cost, and does not really attempt to develop radical new sources of low-cost energy**

Fossil fuel reserves exhausted within <150 years per BP

Solar PV/wind power: insufficient density to 100% replace fossil fuels

World will still require dense energy sources for transportation & portable power

Batteries provide energy storage; batteries + solar/wind cannot rival fossil energy densities

Comparison of intrinsic energy densities

Table 1 Energy density

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

Gasoline is vastly more energy-dense

Petroleum energy density:
"A single gallon of gasoline contains approximately forty (40) 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.**"

Reference: B.E. Layton, *International Journal of Green Energy* 5 pp. 438 - 455 (2008)

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

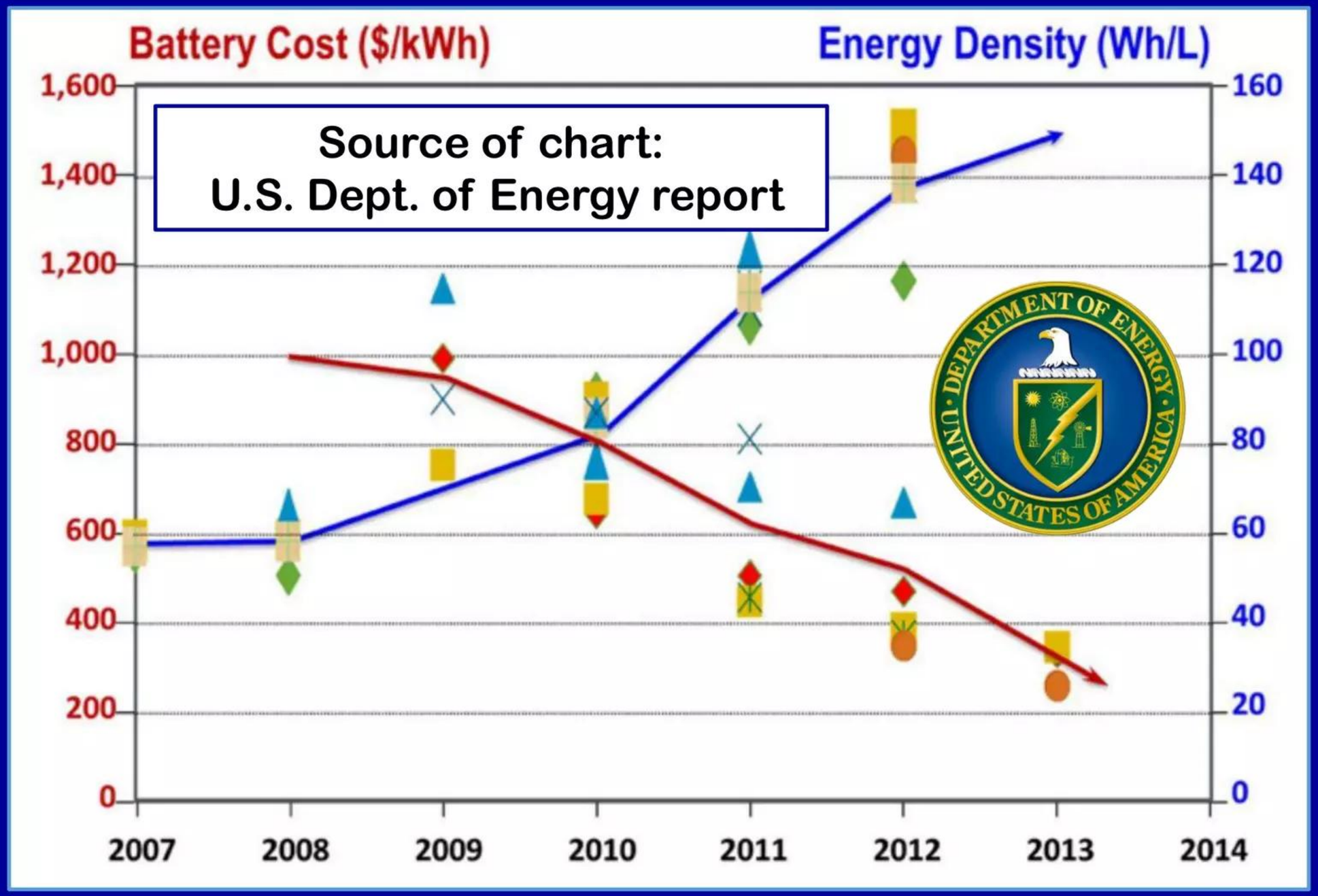
See: "BP Statistical Review of World Energy June 2015" released June 10, 2015

http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html

Battery cost reduction tied to increases in energy density

Chemical battery technology beginning to approach technological limits

Over next 10 - 15 years further cost reductions ($/kWh) likely to start leveling-out



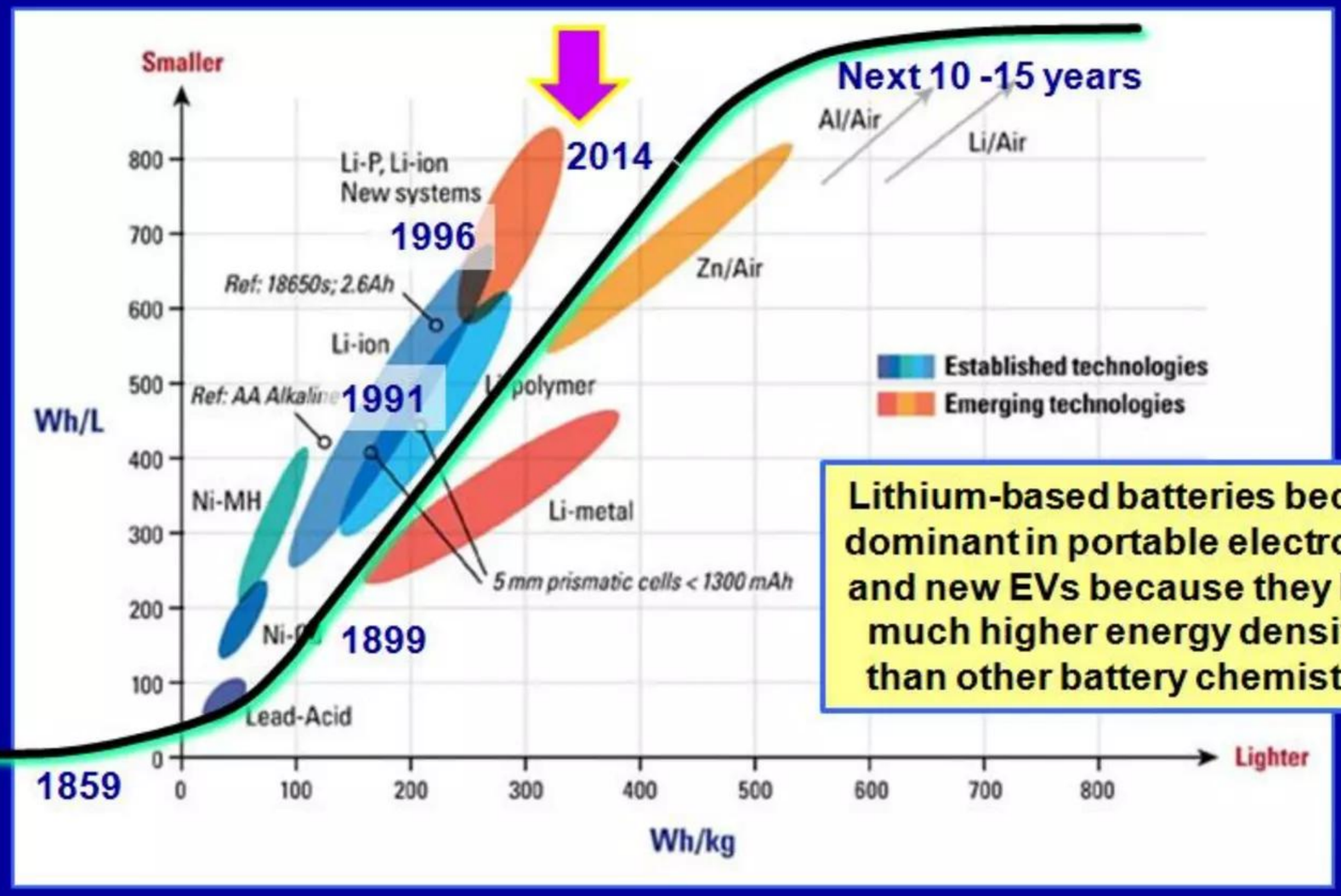
Source: http://theenergycollective.com/onclimatechangepolicy/347491/making-low-carbon-future-better-well-cheaper

Batteries cannot overcome the limitations of solar and wind

Batteries' energy densities limited and the technology now maturing

Will still need dense energy sources for transportation & portable power

Chemical energy density of batteries vastly lower than combustible fossil fuels



Source: http://www.estquality.com/technology Note: superimposed S-curve and dates were added by Lattice

Modern electric grids require dispatchable power generation

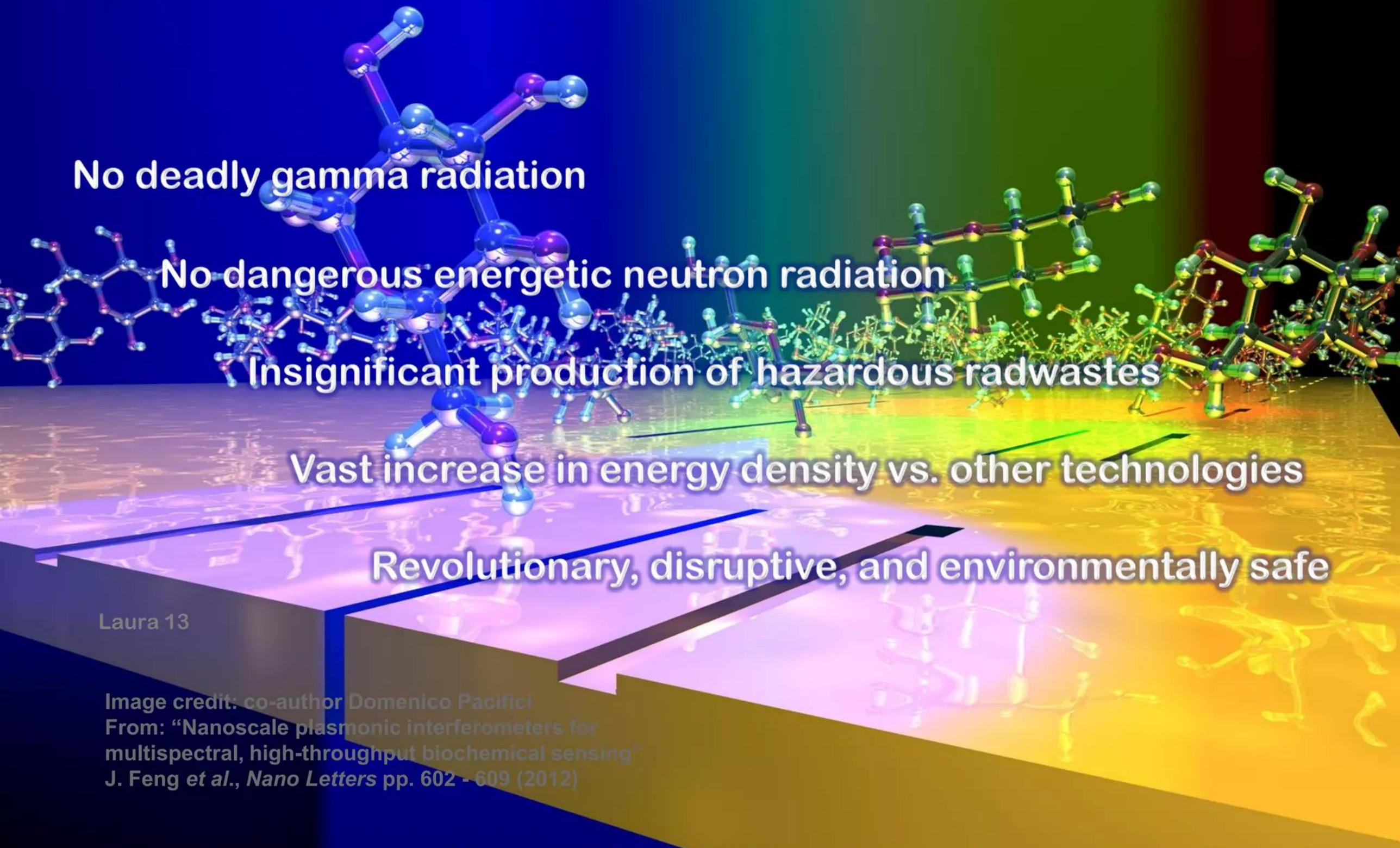
Need grid-connected power sources not subject to vagaries of Nature

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 is making these key parameters 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 just might work for a few hours or maybe one day, but certainly not days or weeks
- ✓ What is needed is a new type of energy-dense 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
- ✓ Such a technology is being developed by Mitsubishi Heavy Industries, Toyota, Lattice Energy, and some others: ultralow energy neutron reactions (LENRs)

Revolutionary new type of safe nuclear energy technology

Unique advantages of ultralow energy neutron reactions (LENRs)



Laura 13

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)

Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

Need input energy source such as electricity to drive LENR neutron production

electrons + protons (Hydrogen) → neutrons + neutrinos (benign photons, fly into space)

Require source(s) of input energy

Input energy creates electric fields > 2.5 x10^{11} V/m

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

Many-body collective electroweak neutron production

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

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

$$\text{Energy}_{\text{E-field}} + e^-_{sp} \rightarrow e^{-*}_{sp} + p^+ \rightarrow n^0 + \nu_e$$

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

Radiation-free LENR transmutation

Neutrons + fuel elements → heavier elements + decay products

Neutrons induce nuclear transmutations that release enormous amounts of clean, CO_2-free heat

Incredible variety of LENR fuels for many applications

Lithium fuel cycle releases more energy than ITER's D-T fusion reaction

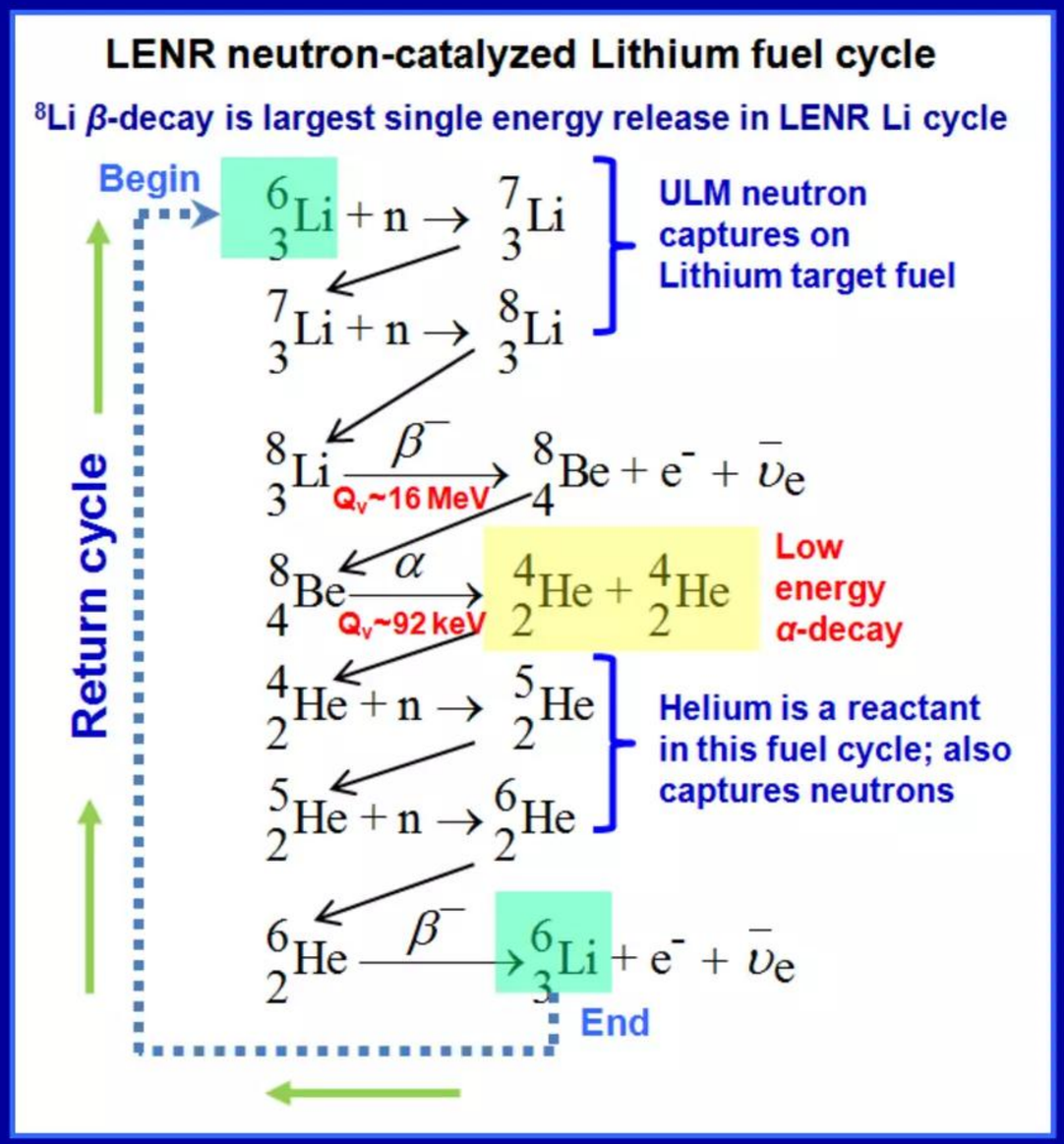
Any element that captures neutrons could serve as LENR fuel; Carbon also good

- ✓ Widom & Larsen's *European Physical Journal C* paper (2006) shows following LENR target fuel cycle using ordinary Lithium:

  Lithium-6 + 2 ULE neutrons → 2 Helium-4 + beta particle + 2 neutrinos + Q-value = 26.9 MeV

- ✓ Deuterium-Tritium (D-T) fusion reaction Q-value = 17.6 MeV creates dangerous high-energy neutrons

- ✓ LENR Lithium fuel releases larger amounts of heat energy and doesn't make any deadly gamma γ radiation



LENRs are green benign type of nuclear energy technology

Energy release greatly surpasses chemical but is less than fission

Some LENRs release > energy than D+T fusion without hard radiation

Less Energy Per Reaction

Reaction Type	Typical "Average" Energy Release		Relative Index of Energy Release
U-235 Conventional Fission (1938)	220 MeV	Nuclear: Strong Interaction	1000
H+H Fusion in Stars (1939)	27 MeV		123
D+T Fusion Reactors (1950s)	17. 6 MeV		80
LENRs today	~ 22 MeV (high side)		91
	~ 0.1 MeV (low side)	Nuclear: Weak Interaction	0.45
Blacklight Power's "Hydrinos" (1991)	max 0.02 MeV	?	0.09
Hydrogen Fuel Cells (1838)	0.0002 MeV		0.0001
Combustion of Gasoline (1876)	0.0001 MeV	Chemical	0.00005

Radiation

Benign

Chemical

Nuclear revolution

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

What is amazing consequence of being radiation-free?

Absence of deadly radiation enables portable nuclear power sources

LENRs seen for 100 years but unrecognized as nuclear because lack of radiation

- ✓ Lack of radiation enables development of quite long-lived, lightweight, very compact LENR power sources
- ✓ Systems would consist of LENR thermal sources integrated with various heat-to-electricity conversion subsystems and associated control electronics
- ✓ Examples of useful off-the-shelf energy conversion technologies include solid-state thermophotovoltaic devices, small-scale Rankine steam engines, etc.
- ✓ LENR manufacturing costs may be ~comparable to advanced batteries that use nanotech fab techniques
- ✓ Future commercial versions of portable battery-like LENR power sources could then compete directly with advanced types of chemical batteries and fuel cells

LENRs enable safe portable nuclear power systems

These could compete directly with chemical batteries and fuel cells

LENR-powered vehicles and aircraft would have 10x - 100x range vs. batteries

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)

Chemical Energy Sources

LENRs

Fossil fuels could be converted into green LENR fuels

Breakthroughs in physics and nanotechnology make this possible

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

In 2009 Larsen discovered that aromatic molecules can potentially be extracted and processed to be converted into green LENR fuels in which there would be no hard radiation emissions, no production of any long-lived radioactive wastes or emission of gaseous CO_2 into the atmosphere; would instead release **> 5,000 times more thermal energy versus combustion of Carbon-based molecules with Oxygen**

All of these fossil hydrocarbons contain aromatic ring molecules that can be extracted

Canadian bitumen

Heavy viscous oil

Anthracite coal

Fossil fuels and biomass can be converted into aromatics

Any element that captures neutrons could serve as an LENR target fuel

Conversion of Carbon into aromatic molecules can produce CO_2-free LENR fuels

Contain aromatic molecules

Examples:

- Heavy oils and natural bitumen
- Coal
- Lignin and other plant biomass
- Natural gas

Chemical process

Extract

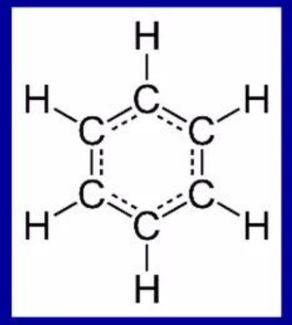
Extract

Extract

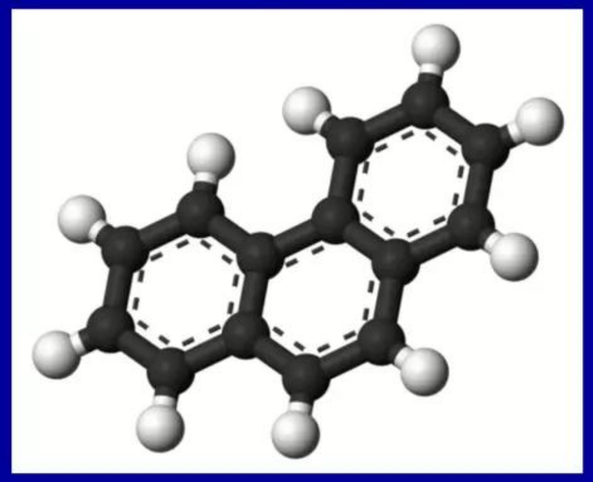
React w. Mo catalyst

Variety of simple and complex aromatic molecules

Examples:



Benzene



Phenanthrene

Chemical process

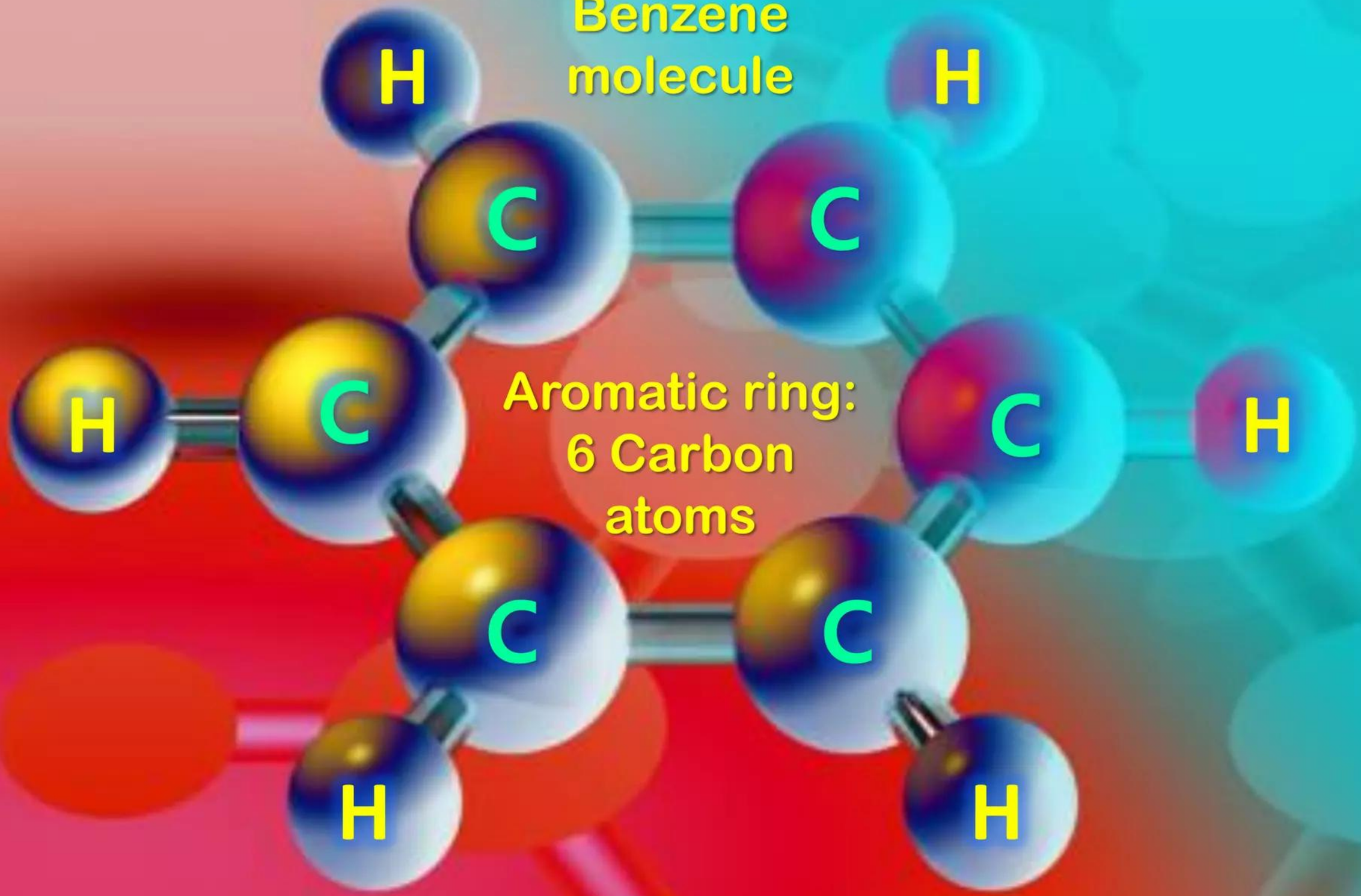
Process into

plus nanotech

Green CO_2-free LENR fuels

5,000x greater energy density

Fossil Carbon can be transmuted rather than combusted



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

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

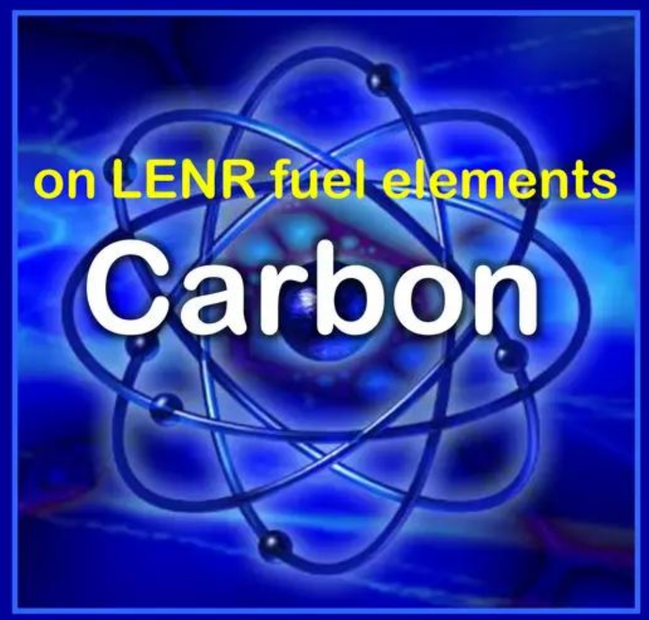
Radiation-free LENR transmutation

Neutrons + LENR fuel elements → heavier elements + decay products + heat

Catalytic neutron 'match'

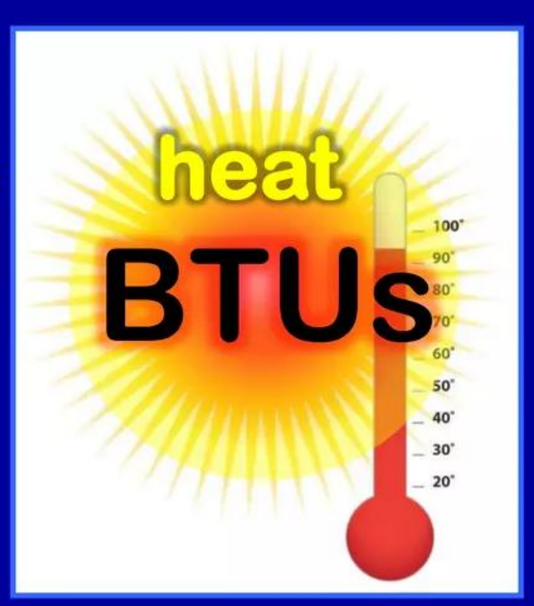
capture +

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

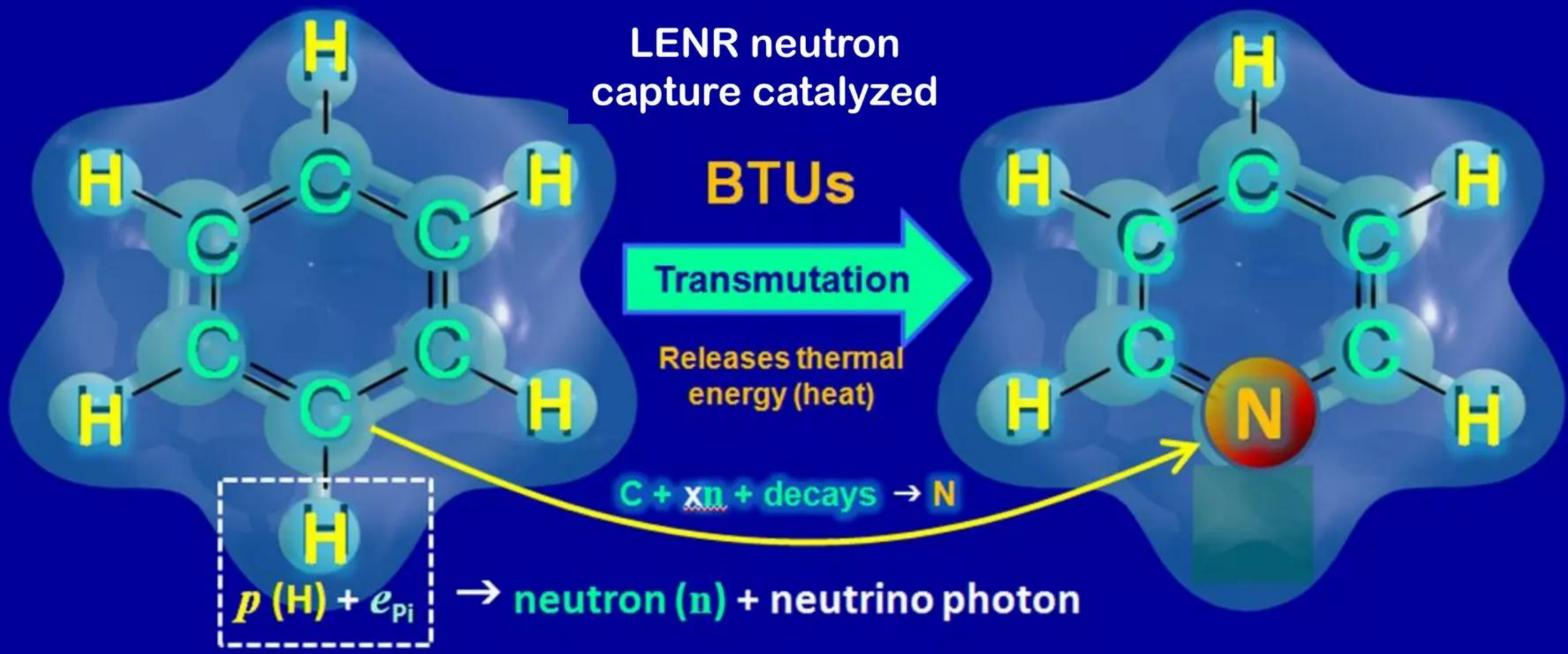


Process does not emit any deadly radiation or produce troublesome radwastes

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

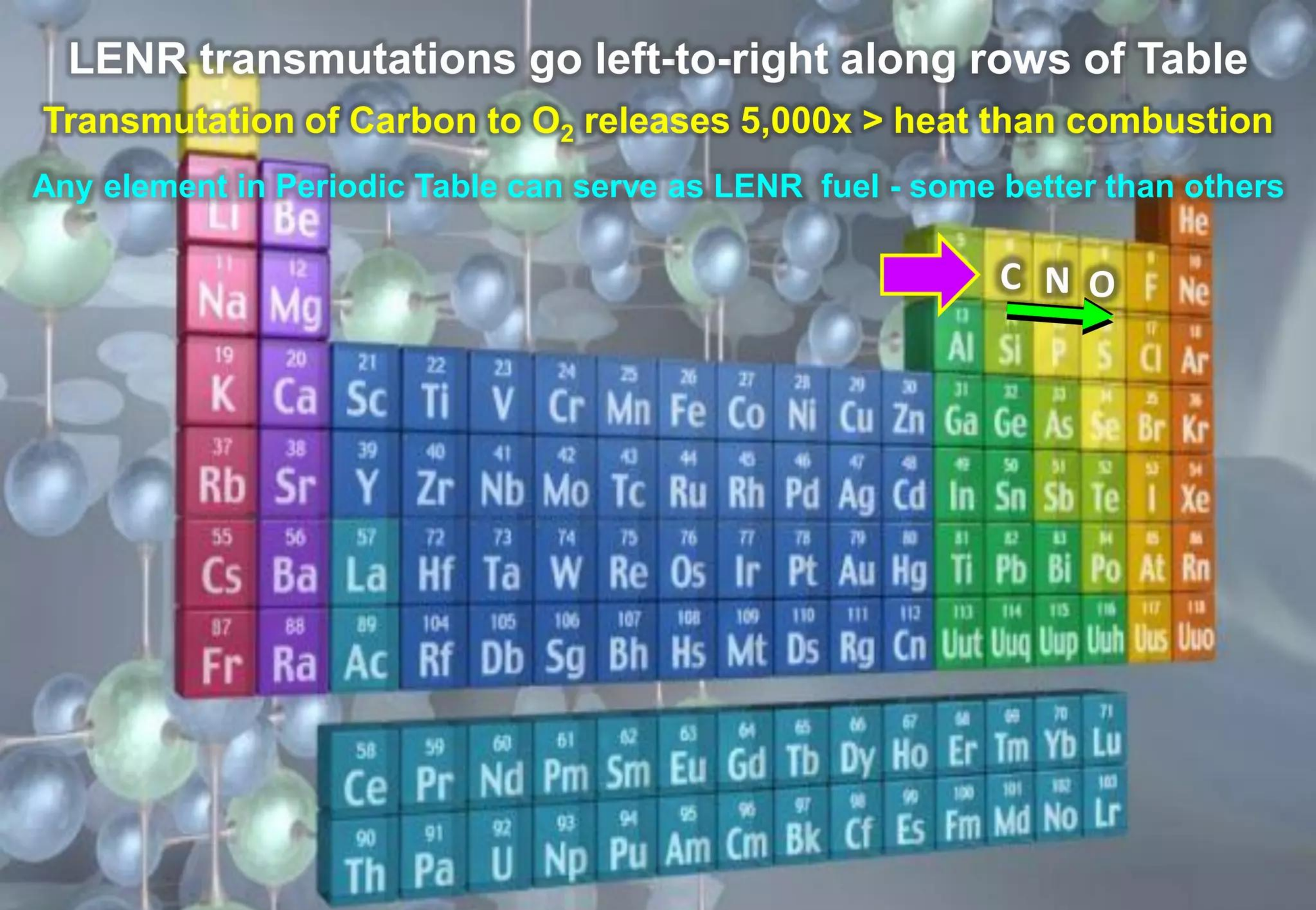


Process does not emit any deadly radiation or produce troublesome radwastes

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

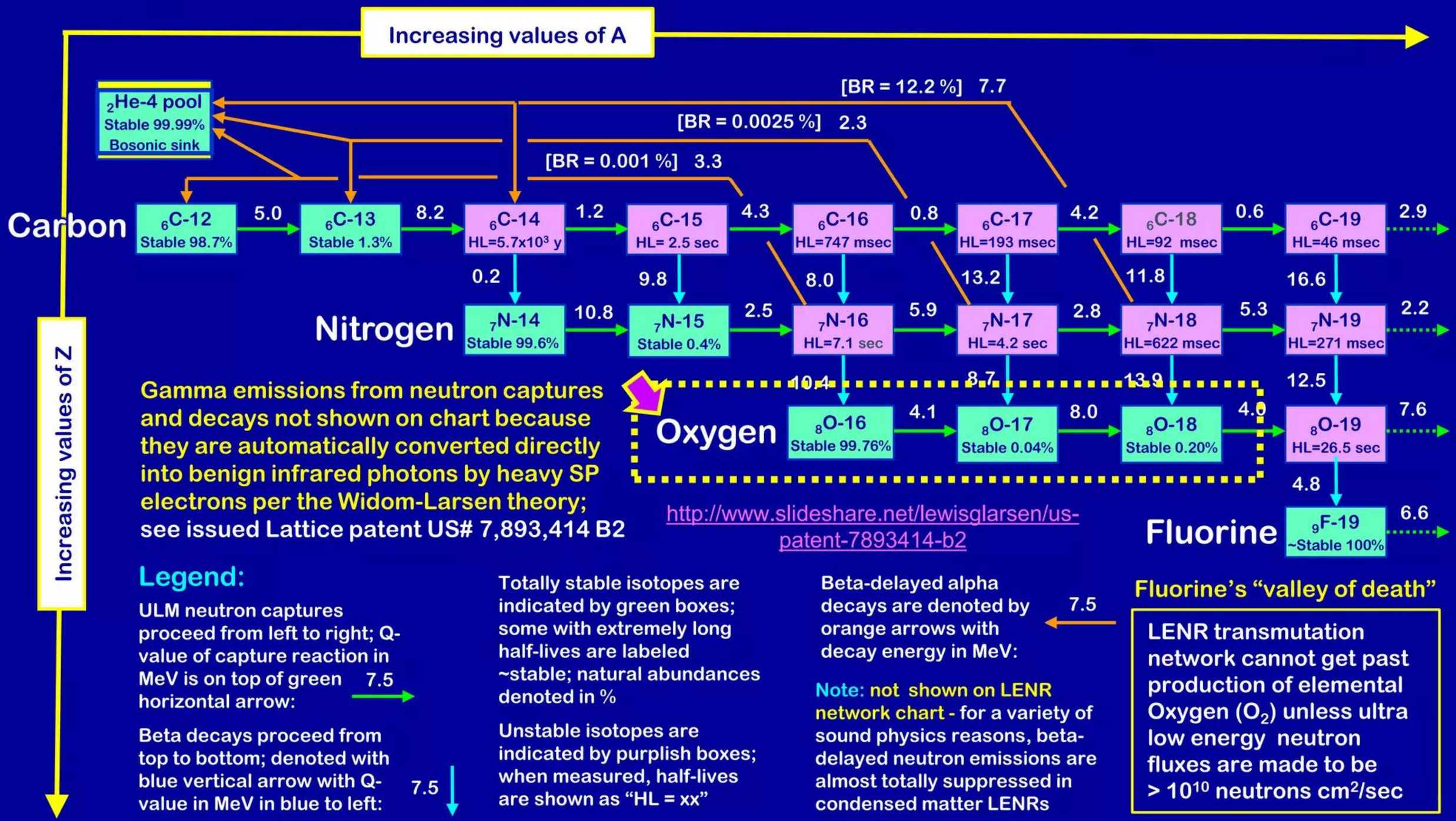
Transmutation of Carbon to O_2 releases 5,000x > heat than combustion

Any element in Periodic Table can serve as LENR fuel - some better than others



LENR C→N→O releases 5 million x more heat vs. burning

Carbon is transmuted to O_2 instead of being combusted with $O_2 \rightarrow CO_2$



Gamma emissions from neutron captures and decays not shown on chart because they are automatically converted directly into benign infrared photons by heavy SP electrons per the Widom-Larsen theory; see issued Lattice patent US# 7,893,414 B2

http://www.slideshare.net/lewisglarsen/us-patent-7893414-b2

Legend:

ULM neutron captures proceed from left to right; Q-value of capture reaction in MeV is on top of green horizontal arrow: 7.5

Beta decays proceed from top to bottom; denoted with blue vertical arrow with Q-value in MeV in blue to left: 7.5

Totally stable isotopes are indicated by green boxes; some with extremely long half-lives are labeled ~stable; natural abundances denoted in %

Unstable isotopes are indicated by purplish boxes; when measured, half-lives are shown as "HL = xx"

Beta-delayed alpha decays are denoted by orange arrows with decay energy in MeV: 7.5

Note: not shown on LENR network chart - for a variety of sound physics reasons, beta-delayed neutron emissions are almost totally suppressed in condensed matter LENRs

Fluorine's "valley of death"

LENR transmutation network cannot get past production of elemental Oxygen (O_2) unless ultra low energy neutron fluxes are made to be > 10^{10} neutrons cm^2/sec

Lattice's commercialization strategy akin to computer chips

Scale-up LENR system power outputs and integrate energy conversion

Use existing nanotech and power conversion to cut development time/risks

- ✓ **LENRs can presently reach temperatures of 4,000 - 6,000º K and boil refractory metals in limited numbers of microscopic LENR-active hot spot sites on laboratory device surfaces.** Lattice plans to use its unique proprietary knowledge of LENR engineering physics and key operating parameters (e.g., achieving and maintaining very high local surface electric fields) to first get heat production working well microscopically. That is: reproducibly trigger LENRs on specific, purpose-designed nanoparticulate structures with dimensions ranging from nanometers to microns that are fabricated using existing, off-the-shelf nanotech processes and then deliberately emplaced at what will become LENR-active sites located on Hydrogen-loaded substrate or nanoparticle surfaces
- ✓ **In principle, output of such LENR heat sources could be readily scaled-up:** either by fabricating larger area-densities of affixed nanostructures that facilitate formation of LENR-active hot spots on device surfaces, or by injecting larger quantities of specially designed fuel nanoparticles into volumetrically larger reaction chambers containing turbulent dusty plasmas, with or without spatially organized magnetic fields present
- ✓ **A variety of off-the-shelf energy conversion subsystems could potentially be integrated with commercial versions of LENR-based heat sources. These include thermoelectric; thermophotovoltaic cells; steam engines; Rankine cycle steam turbines; Brayton cycle gas turbines, boilers, etc.** Other speculative possibilities involve new types of direct energy conversion technologies that are still under development, e.g. harvesting of β^-

Lattice's market penetration strategy akin to computer chips

Maximize unit volumes and ride experience curve to attack markets

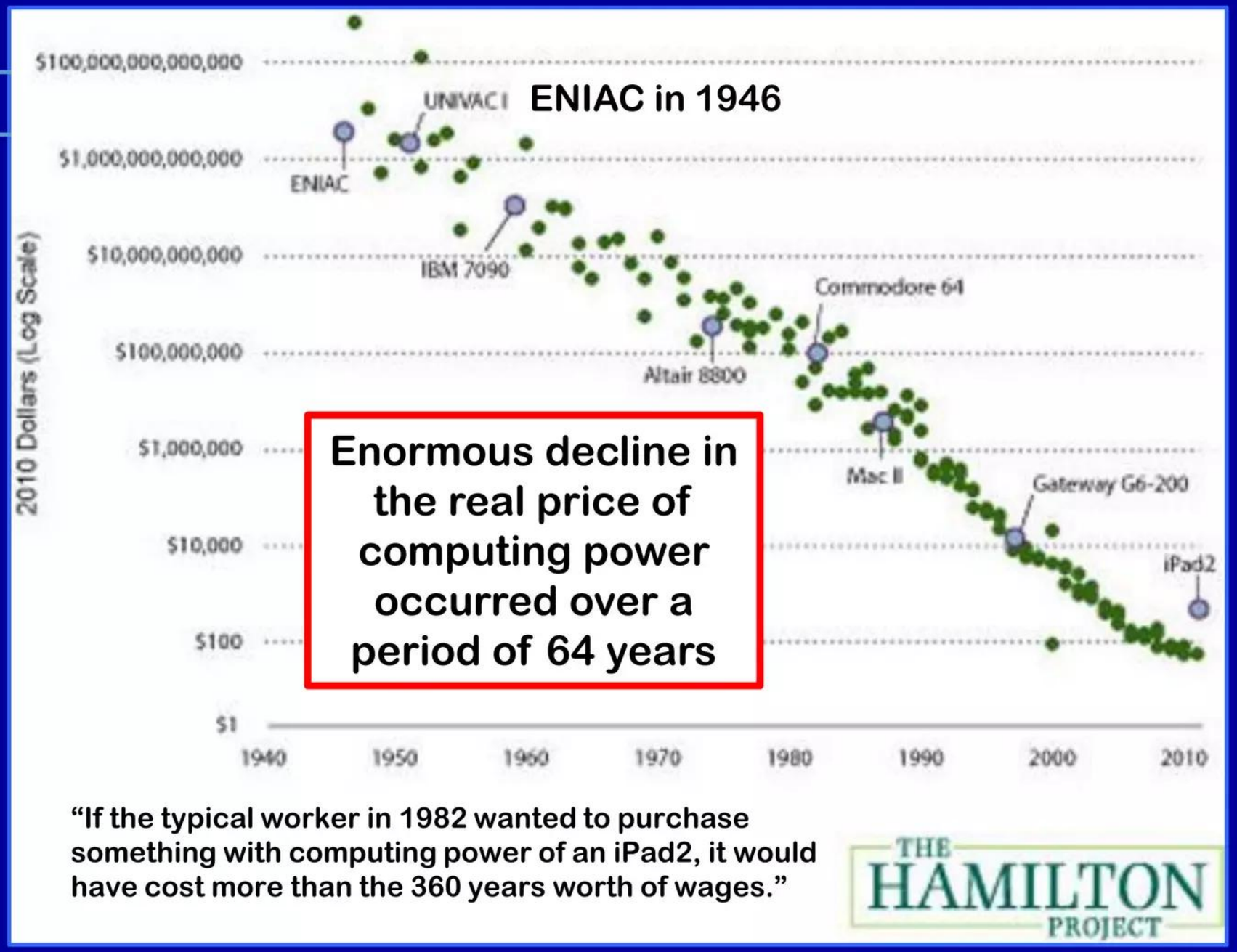
LENR technology enables opportunity to create a Moore's Law for energy

- ✓ Over time, plan to ride down manufacturing experience cost curve; similar to build-cost reduction and market penetration strategies used by electronics manufacturers; e.g., microprocessors, memory chips, PCs, and smartphones
- ✓ As product manufacturing experience accumulates and internal build costs are progressively reduced, leverage enormous energy density/longevity advantages of LENRs (> 5,000x larger than any chemical); price LENR-based systems to drastically undercut price/performance provided by competing thermal sources and chemically-based power generation systems --- this strategy can be applied to portable, distributed stationary, mobile, and central station power markets
- ✓ Small-scale LENR systems might seem to be light years away from being able to compete with huge 500 - 1,500 MW coal-fired and Uranium-fission power plant behemoths. However, please recall history of personal computers versus large mainframes. When PCs were first introduced 35 years ago, mainframe computer manufacturers regarded them as just toys, information processing jokes of no consequence. Less than 10 years later, mainframe companies weren't laughing any more. Today, except for just a handful of survivors like IBM, mainframe and minicomputer dinosaurs have disappeared, replaced by microprocessor arrays

Lattice's market penetration strategy exploits Moore's Law

Broad deployment of LENRs could collapse real price of heat/electricity

"Cost of computing power equal to an iPad2" (2011)



ENIAC - 1946
> $1 trillion

2015
Apple iPad2
$200

Source: http://www.hamiltonproject.org/multimedia/charts/cost_of_computing_power_equal_to_an_ipad2/

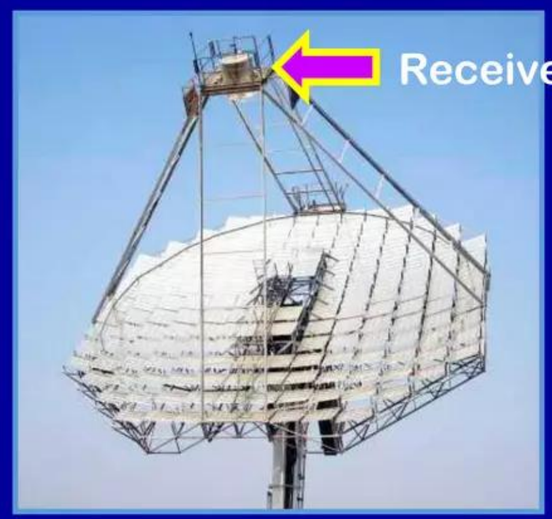
LENR dusty plasma systems should scale-up to MWs

Lattice scramjet concept outlines a possibility for large power sources

Can use solar electricity as input power for LENR systems: huge energy amplifier

- ✓ LENRs can be triggered on target fuel nanoparticles injected into dusty plasmas; should readily scale-up volumetrically to megawatt (MW) total thermal outputs
- ✓ Concept as applied to a scramjet engine is outlined in 6/13/2014 Lattice document: http://tinyurl.com/kubdjc9
- ✓ LENR thermal sources could likely produce neutron fluxes of 1 x 10^{14} cm^2/sec that can then create thermal power fluxes of ~428 W/cm^2 using Lithium fuel targets
- ✓ Total thermal fluxes created at focus receivers of concentrated solar power (CSP - see right) systems can reach values on the order of roughly 200 - 400 W/cm^2 ; this ~ matches LENR heat sources noted above that use Lithium
- ✓ Could potentially adapt Brayton cycle CSP systems for use in large LENR-based multi megawatt dusty plasma reactors
- ✓ Could also develop hybrid wind or solar + LENR power generation systems; renewable electricity used as input power for LENRs - huge amplification of energy release

Dish CSP system



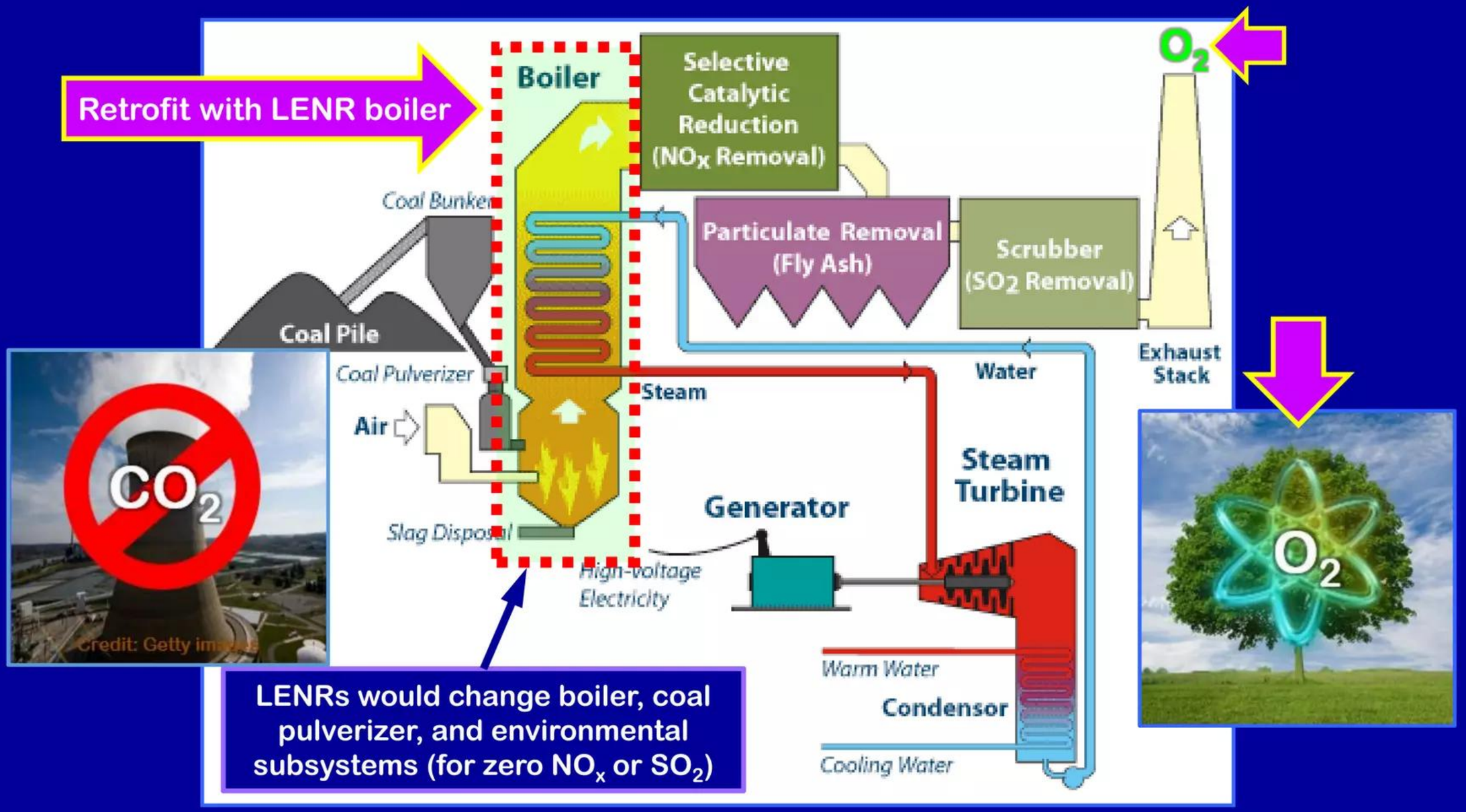
Tower CSP system

Ivanpah - California, USA

Strategy: retrofit existing coal plants with C → N → O boilers

LENRs could end combustion of coal: $CH_4 + 2\ O_2 \longrightarrow CO_2 + 2\ H_2O$ + heat

Retrofit strategy conserves capital; LENR plants would emit oxygen O_2 like trees



New LENR-powered boilers could be engineered to seamlessly replace original coal-fired boilers

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

Modular 30 kW (thermal) LENR systems ideal for homes

Distributed generation works well in urban as well as remote rural areas

Increases the stability of urban grids; enables low-cost global rural electrification

- ✓ Small steam turbines (see to the right) have been developed that would be ideal for use in homes; could be integrated with boilers heated by LENRs
- ✓ Enough LENR fuel for a year of operation could probably be shipped overnight in large FedEx box
- ✓ If a 30 kW LENR thermal source were integrated with heat-to-electricity energy conversion system that was only 20% efficient, home power system could produce ~6 kWh electrical and 24 kW heat; satisfy energy demand for 95+% of homes in world
- ✓ Distributed generation helps to stabilize existing urban grids; also enables very cost-effective global rural electrification for presently powerless people

Green Turbine™ steam generator
1.2 to 15 kWh

See: http://www.greenturbine.eu/GT15.html

LENRs enable cost-effective distributed power generation

Brandon Owens of GE has concluded that DG is the wave of the future

"The rise of distributed power" by B. Owens, General Electric, page 39 (2014)

VII. CONCLUSION

After decades of both technology progress and future promise, distributed power is now poised for growth across the globe. Technology innovations have reduced the cost of distributed power technologies while increasing its flexibility and performance. The digital wave and the "Industrial Internet" promise to enhance the capability of distributed power systems. At the same time, distributed power systems are positioned to overcome barriers that are inhibiting the growth of large-scale power plants. There is a strong need for energy solutions across the globe, and by meeting this need, distributed power has become part of a virtuous cycle of human and economic development.

http://www.ge.com/sites/default/files/2014%2002%20Rise%20of%20Distributed%20Power.pdf

LENRs and the future of global power generation

5 -10 kwh LENR-based power systems revolutionize energy production

Systems with total output measured in megawatts not needed to accomplish this

- ✓ At system power outputs of just 5 - 10 kwh, modular LENR-based distributed power generation systems providing combined heat and electricity (CHP) could potentially satisfy the requirements of a majority of urban and rural households and smaller businesses worldwide, including today's powerless
- ✓ At system power outputs of just 50 - 200 kwh, LENR-based systems could begin to power steam or electric vehicles, breaking oil's stranglehold on transportation; provide high-quality heat for many industrial processes
- ✓ Although they could very likely be designed and built, megawatt LENR systems are not mandatory to change the world of energy for the better
- ✓ If widespread deployment of small-scale distributed generation could be achieved, nowhere near as many new, large fossil-fired and/or fission power generation systems would have to be built to supply competitively priced electricity to regional grids serving urban and many rural areas. Under that scenario, grid-based centralized power generation would be very gradually displaced by vast numbers of smaller, lower-cost distributed power systems

Key take-aways

LENR technology could enable future clean energy at reasonable cost

- ✓ 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 fuel resources by at least 500x by releasing thermal energy from Carbon via CO_2-emission-free transmutation rather than by continuing to rely on today's age-old chemical combustion technology
- ✓ 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 fuels into cleaner, more valuable form of CO_2-free LENR energy --- energy producers, energy consumers, and Mother Earth all win

Key take-aways

LENR technology could enable future clean energy at reasonable cost

- ✓ While solar PV and wind are CO_2-free and extremely biosafe, their intrinsic energy densities are much lower than today's fossil fuels and inherently intermittent --- not continuous --- sources of electrical and thermal power
- ✓ Solar and wind renewables simply cannot 100% replace fossil energy sources without enormous economic disruption and gigantic increases in energy costs
- ✓ Nuclear fission power has high energy densities, does not produce CO_2 and operates continuously; but it emits huge quantities of deadly neutron and gamma radiation during operation and produces many long-lived radwastes
- ✓ D-T nuclear fusion, while better than fission in terms of producing much less radwaste, still emits very dangerous neutron and gamma radiation during operation; also, there is still no sign of it being commercialized after 60 years of huge effort and hundreds of billions of R&D $ spent worldwide. See July 31, 2014 Nature story on ITER by Elizabeth Gibney: http://tinyurl.com/mlk5d5k
- ✓ LENRs are the only primary energy technology on foreseeable horizon that could provide the world with affordable dense green energy, connect the unconnected, and empower billions of now powerless, energy-poor people
- ✓ Lattice's strategy for replacing today's combustion with LENR transmutation of Carbon saves the fossil fuel industry yet is highly synergistic with renewables, enables sustainable economic growth, and helps to ameliorate climate change

Widom-Larsen theory of ultralow energy neutron reactions

Three key publications that begin in March 2006 are referenced below

Many-body collective effects enable electroweak catalysis in condensed matter

"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.ias.ac.in/pramana/v75/p617/fulltext.pdf