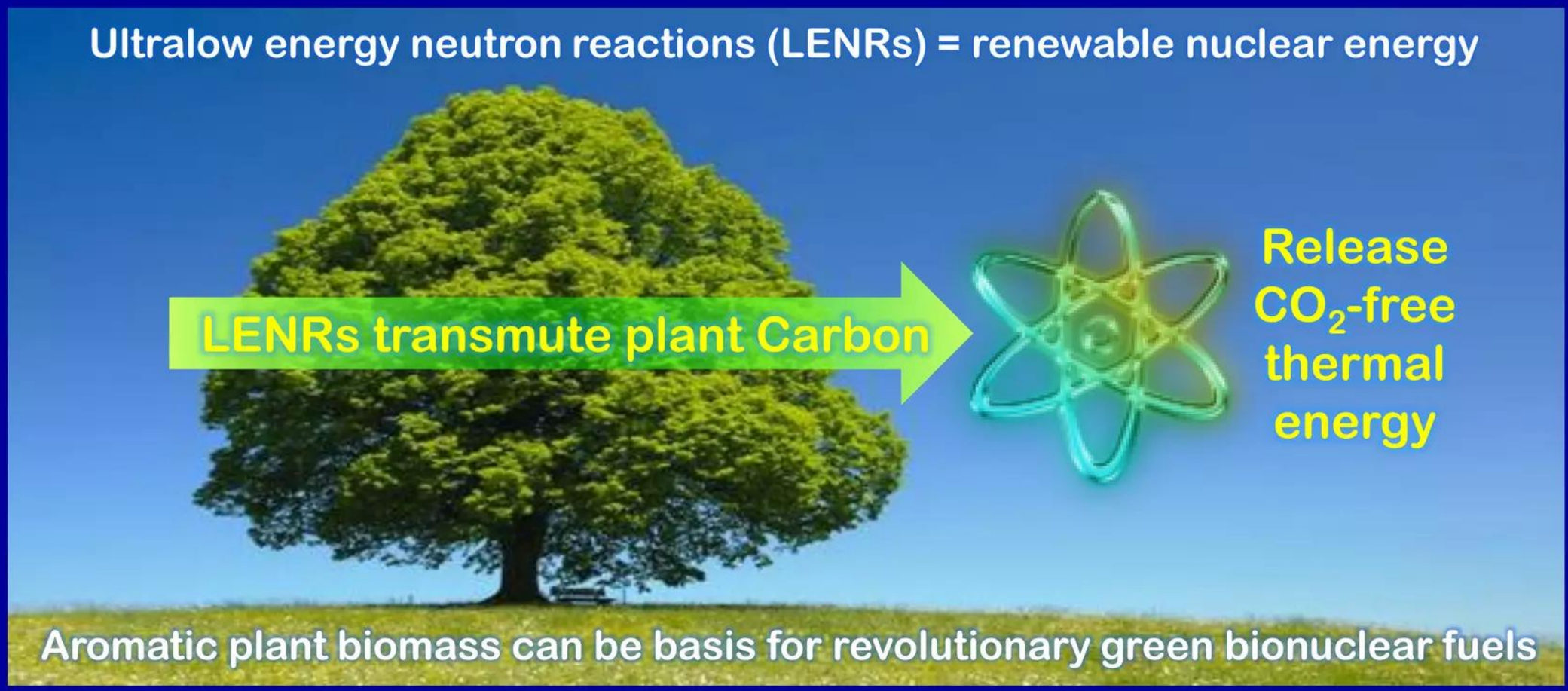
Lattice Energy LLC

Commercializing a next-generation source of green nuclear energy

Carbon-rich Lignin comprises 33% of total plant biomass

Lignin is composed of aromatic molecules that can be extracted

Convert aromatics to LENR fuels: >5,000x energy density of gasoline



Contact: 1-312-861-0115
lewisglarsen@gmail.com

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

Commercializing ultralow energy neutron reactions (LENRs)

for stationary, mobile, and portable power generation applications

Breakthrough in nuclear technology: no dangerous radiation or wastes

Widom-Larsen theory enables LENR power generation devices

- LENR fuels get transmuted by absorbing neutrons which releases enormous heat
- Sustainable CO_2-free transmutation of Carbon could replace combustion processes

Widom-Larsen

Evolution of nuclear technology

Theory of LENRs

Revolutionary new type of safe nuclear energy technology

Unique advantages of ultralow energy neutron reactions (LENRs)

Widom-Larsen theory rigorously explains all of these unique attributes

No deadly gamma radiation

No dangerous energetic neutron radiation

Insignificant production of hazardous radwastes

Vast increase in energy density vs. other technologies

Revolutionary, disruptive, and environmentally safe

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)

LENRs are green: no energetic radiation or radwastes

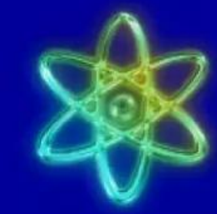
Lack of hard radiation obviates need for shielding and containment

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

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

Grand challenge: turn biomass into renewable nuclear fuels

Biomass contains substantial % of aromatic polymer called Lignin

Lignin can be chemically broken-up into smaller aromatic molecules

Green LENRs can be triggered on such molecules: become bionuclear fuels

- ✓ Two of three major components in biomass - cellulose and hemicellulose - are polymerized sugars that can readily be chemically fermented to create renewable biofuels (this is now occurring commercially); the third, Lignin, is much more resistant to chemical degradation into smaller aromatic molecules
- ✓ Until recently, Lignin was more-or-less ignored by industry and academic biotech researchers, being regarded more as just a waste product to be burned
- ✓ Importantly, Lignin is only known major natural source of renewable aromatics
- ✓ Out in Nature, Lignins are mainly broken-down by various fungi and bacteria
- ✓ Biotechnologists are now beginning to focus on improving various chemical and enzymatic processes that reduce Lignin to smaller molecules, e.g. aromatics
- ✓ In 2014, Larsen became aware of improvements in Lignin digestion methods
- ✓ Advances in chemical processing of Lignin to yield basic aromatic molecules opens-up future possibility of creating revolutionary CO_2-free LENR fuels with 5,000x greater energy density than gasoline from renewable biomass aromatics

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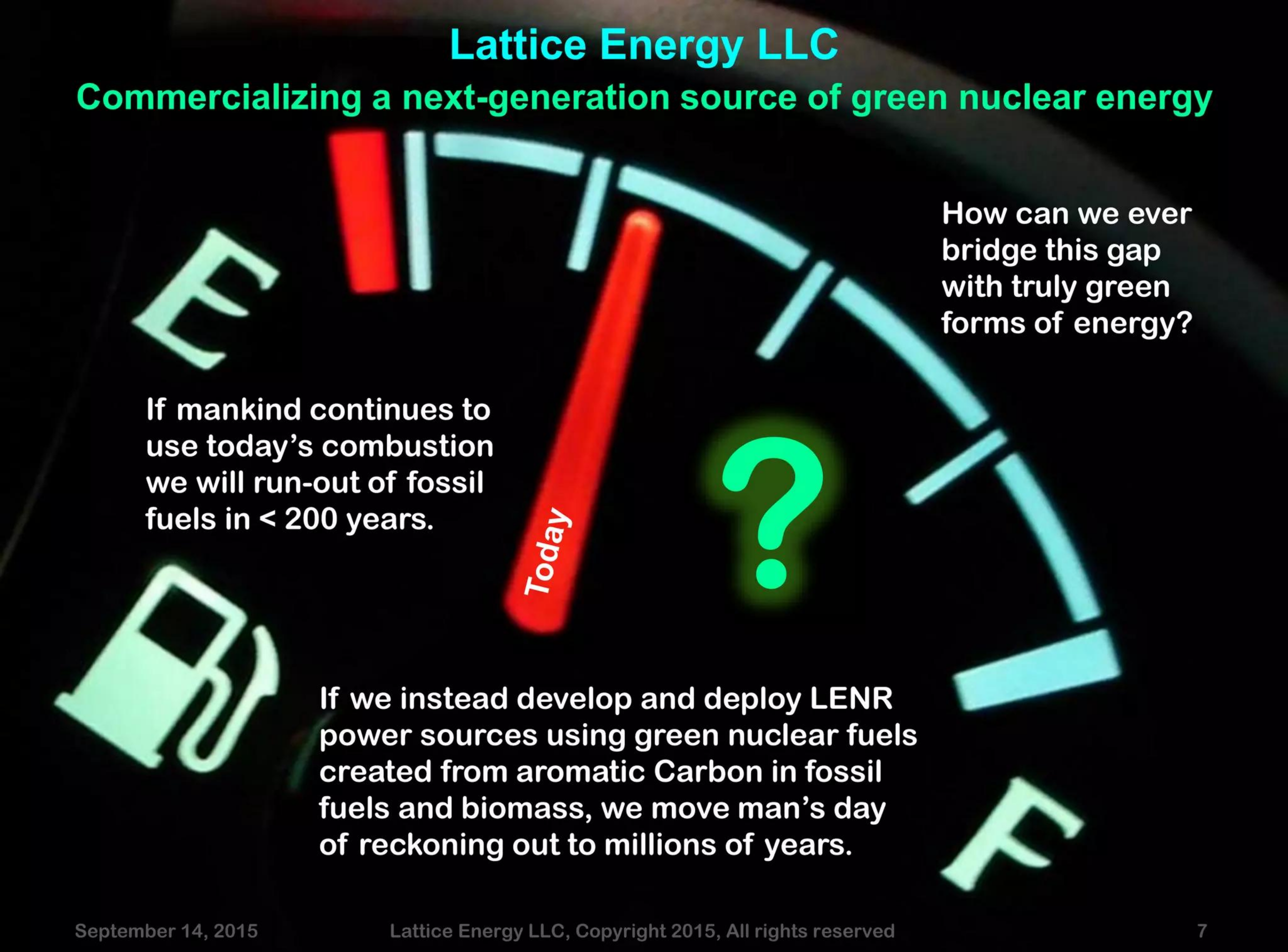
Commercializing a next-generation source of green nuclear energy



How can we ever bridge this gap with truly green forms of energy?

If mankind continues to use today's combustion we will run-out of fossil fuels in < 200 years.

If we instead develop and deploy LENR power sources using green nuclear fuels created from aromatic Carbon in fossil fuels and biomass, we move man's day of reckoning out to millions of years.

Fossil Carbon can be transmuted rather than combusted

Oil, coal, and lignin could be processed to produce CO_2-free LENR fuels

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

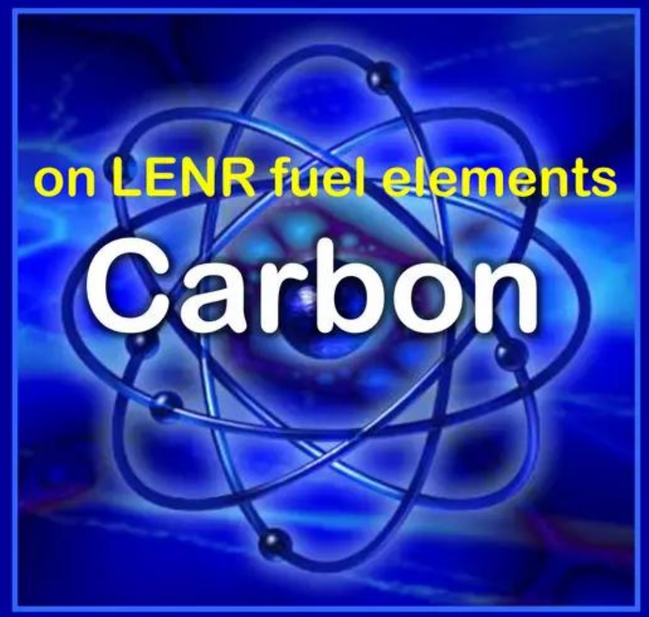
Radiation-free LENR transmutation

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

Catalytic neutron 'match'

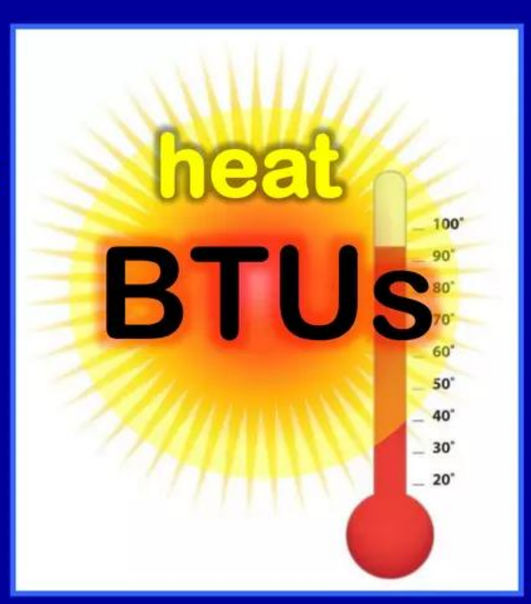
capture +

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



produces →

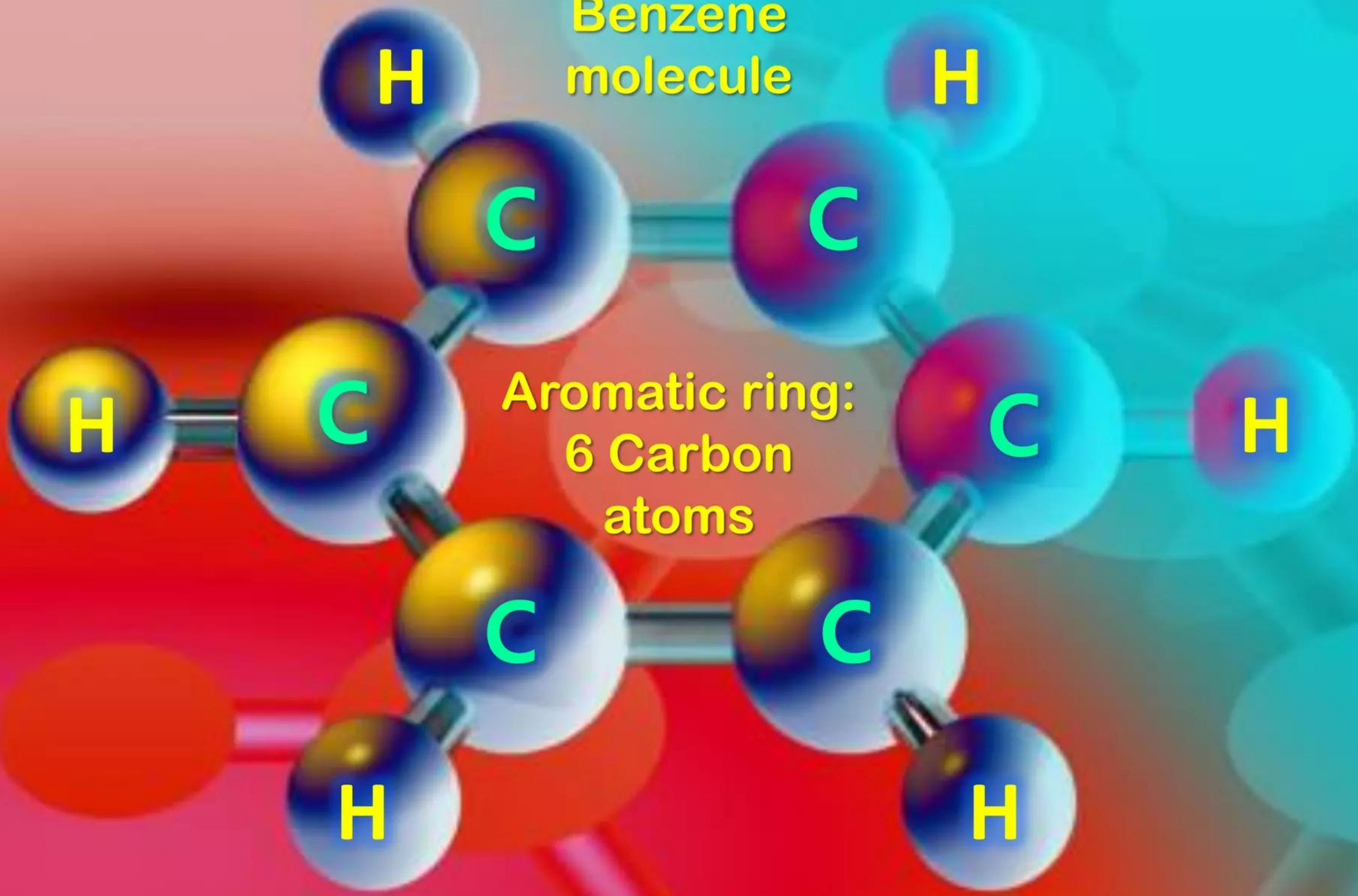
Direct conversion of neutron capture and decay-related gammas to IR and beta/alpha particles create heat



Process does not emit any deadly radiation or produce troublesome radwastes

Fossil Carbon can be transmuted rather than combusted

Benzene molecule



Aromatic ring: 6 Carbon atoms

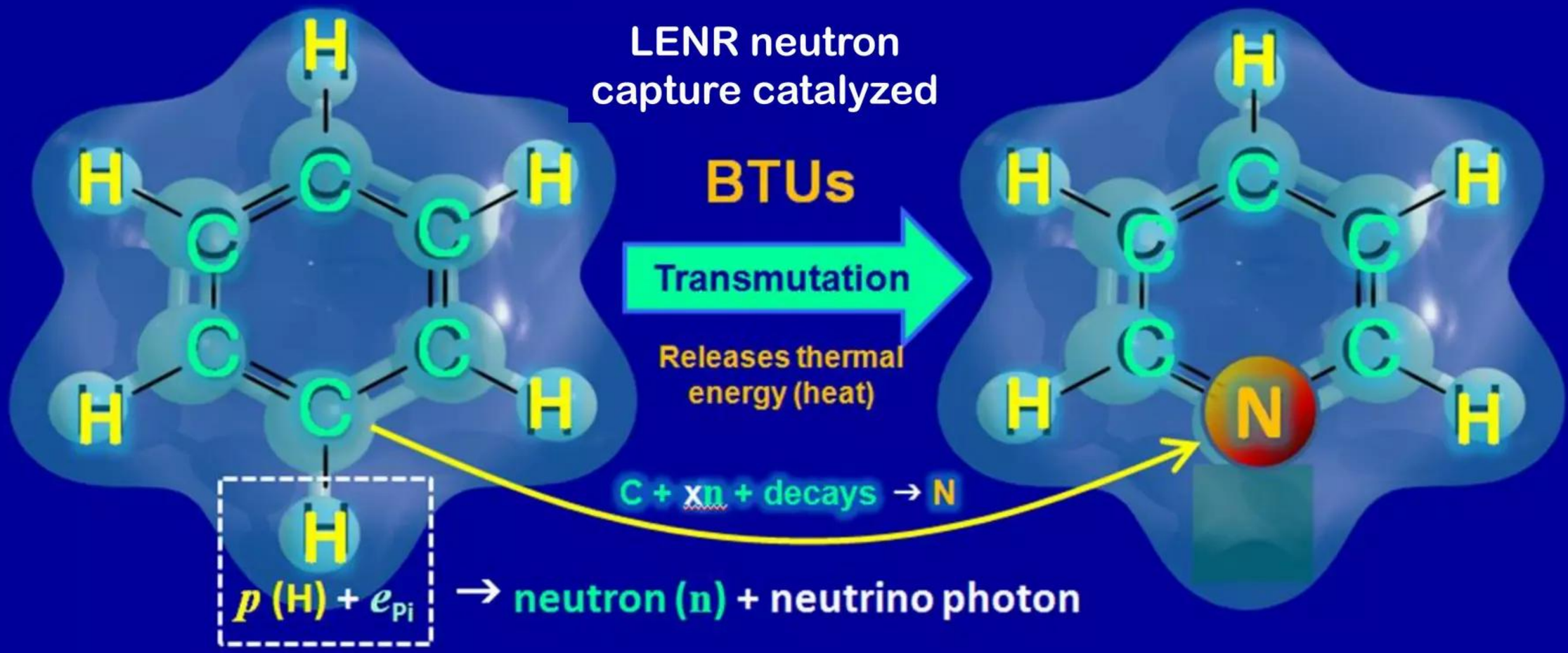
6 Carbon atoms arranged in hexagonal ring bonded to 6 Hydrogen atoms

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

Aromatic Carbon molecules from biomass become revolutionary bionuclear fuels



Process does not emit any deadly radiation or produce troublesome radwastes

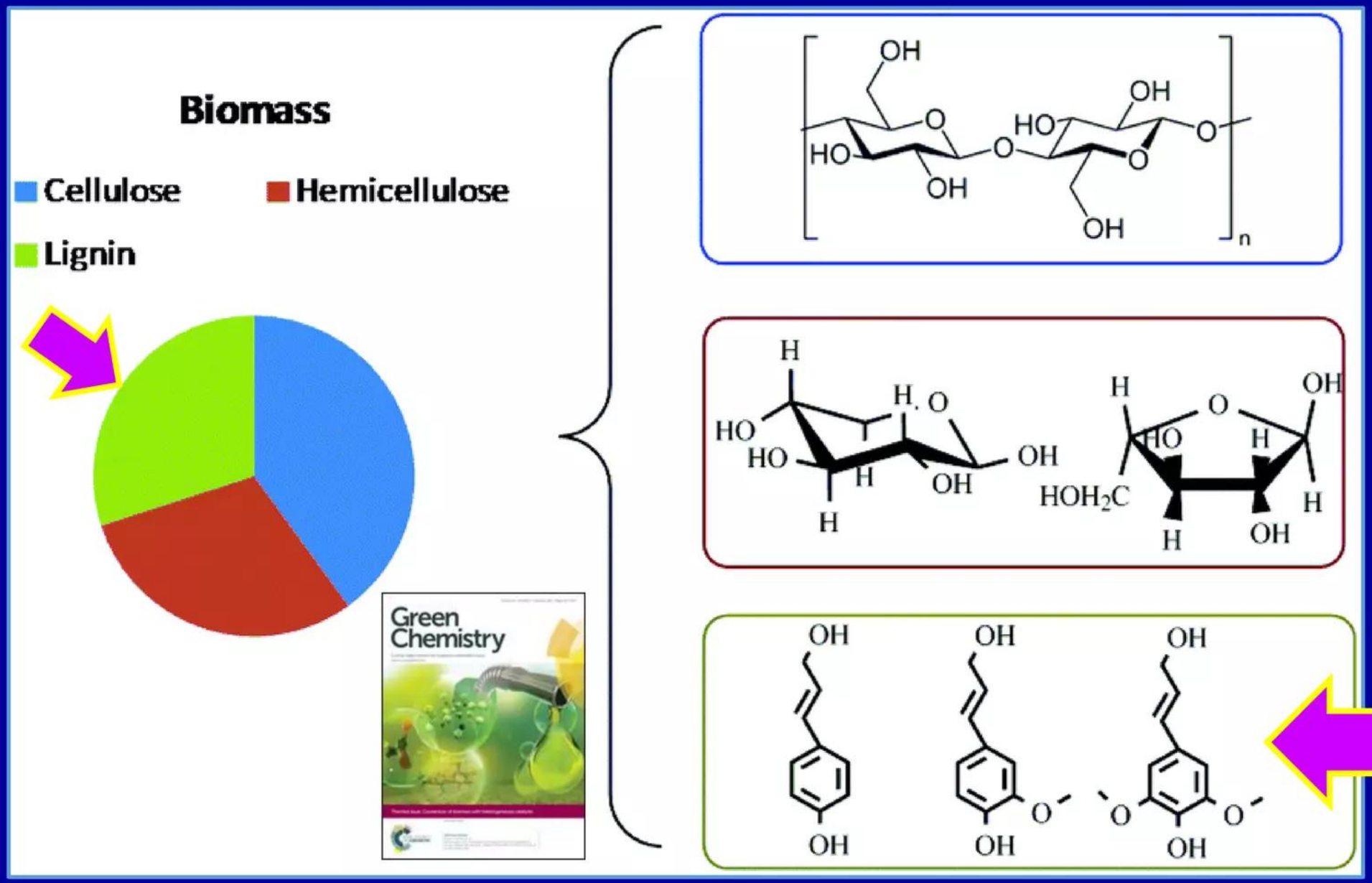
Lignin molecules comprise ~40% of cord of split hardwood

Who would have dreamed it might be converted into a bionuclear fuel?

Biomass is composed of ~33% Lignin: an aromatic polymer

Figure source: T. Wang *et al.*, *Green Chemistry* 16 pp. 548 - 572 (2014)

Biomass has three major components: Cellulose, Hemicellulose, Lignin

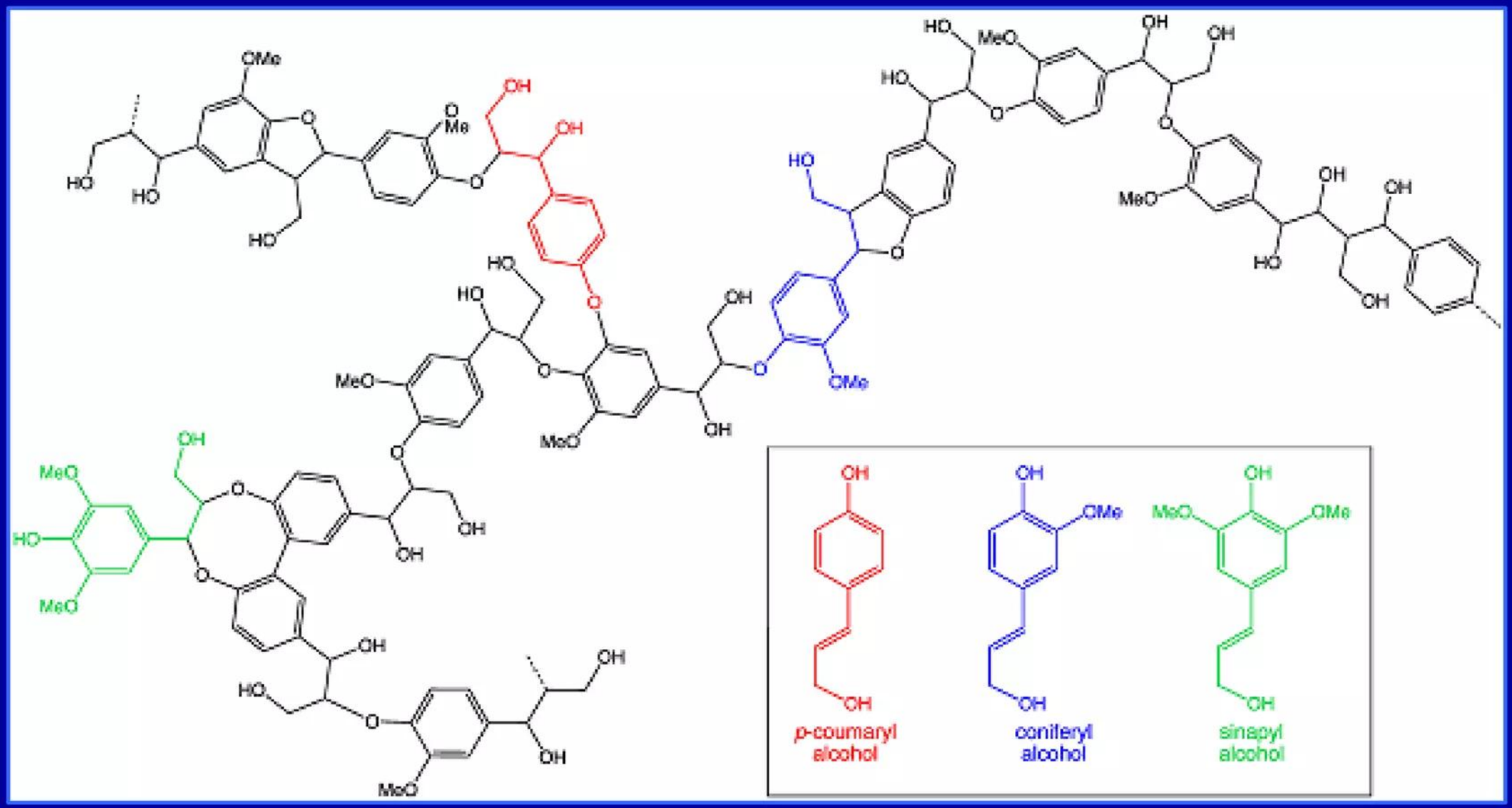


http://pubs.rsc.org/en/content/articlelanding/2013/gc/c3gc41365a#!divMetrics

Lignins are large complex molecules with structural variants

Can comprise up to ~40% of biomass in woody deciduous trees

Key function in plants: provide sturdy structural support material

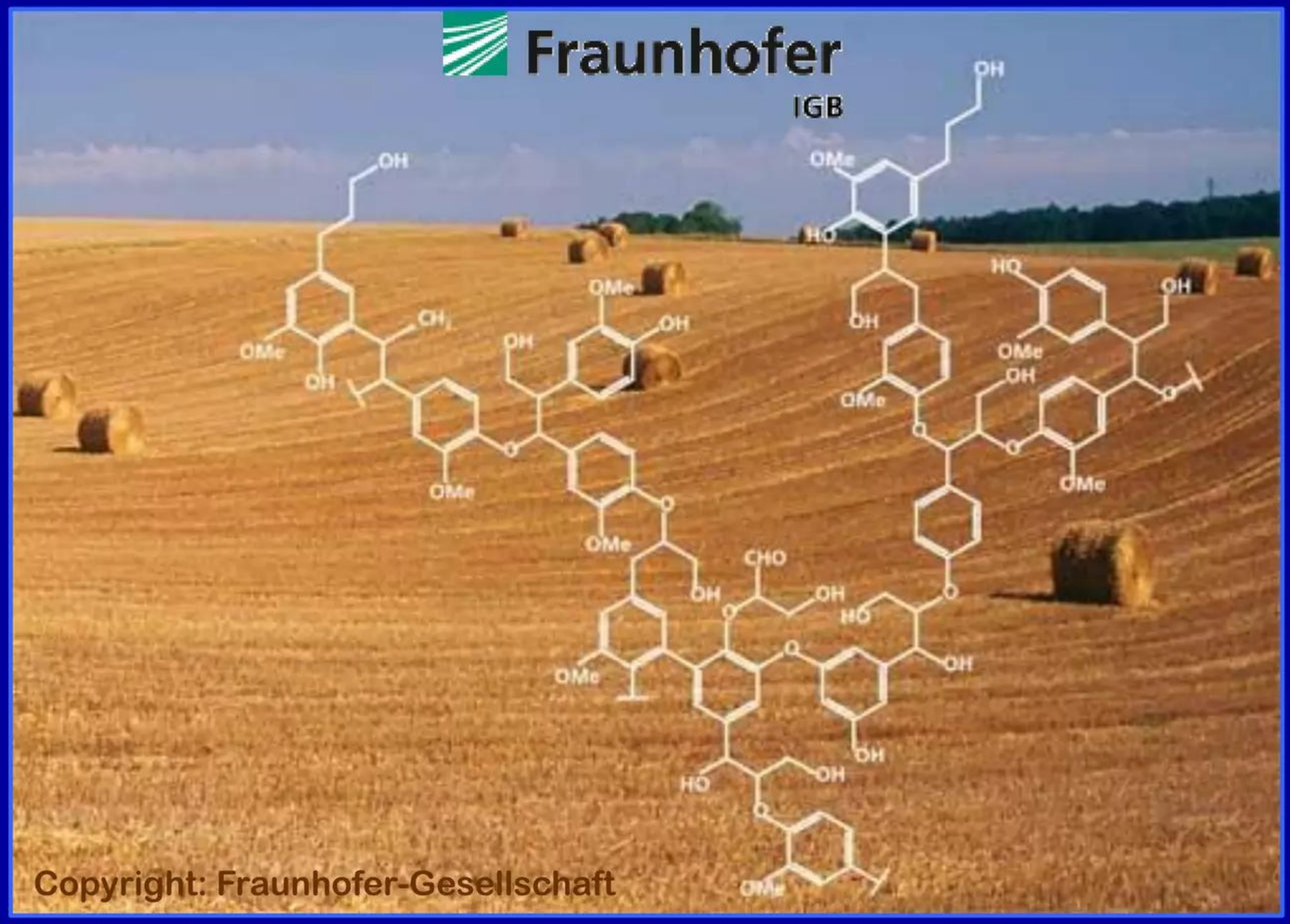


Source: http://study.com/academy/lesson/lignin-definition-properties-function.html

Lignin: complex molecule and major constituent of biomass

Technically speaking it is a natural, renewable aromatic polymer

Must digest it into smaller aromatic molecules to make LENR fuels



http://www.igb.fraunhofer.de/en/competences/molecular-biotechnology/industrial-biotechnology/aromatic-lignin-monomers.html

Chemists create improved Lignin digestion techniques

New papers reporting advances in methods now occurring more often

Most methods would probably be useful in development of renewable LENR fuels

Selected examples of relevant information sources:

Patent # US 8,969,534 B2 Issued March 3, 2015 Assignee: W.A.R.F.
"Simple aerobic alcohol oxidation method for conversion of Lignin into simple aromatic compounds"
Abstract: "Described is a method to oxidize lignin or lignin sub-units. The method includes oxidation of secondary benzylic alcohol in the lignin or lignin sub-unit to a corresponding ketone in the presence of unprotected primary aliphatic alcohol in the lignin or lignin sub-unit. The optimal catalyst system consists of HNO_3 in combination with another Brønsted acid, in the absence of a metal-containing catalyst, thereby yielding a selectively oxidized lignin or lignin sub-unit. The method may be carried out in the presence or absence of additional reagents including TEMPO or TEMPO derivatives
http://www.warf.org/documents/ipstatus/P130104US01.PDF

"Making the most from Carbon in plants"
Pacific Northwest National Laboratory Released: September 9, 2015
Abstract: "Researchers are looking for more effective ways to get at all the carbon in biomass to create more energy and biochemicals. However, a lot of the carbon is in lignin - support tissues in plants, which makes up about a third of the biomass. International teams of scientists are working together to better understand how lignin can be efficiently deconstructed to release its carbon for a more renewable and sustainable energy future."
http://www.sciencedaily.com/releases/2015/09/150909091224.htm

Many moieties contain or are convertible into aromatics

LENR fuels can be created from many different natural Carbon sources

Base feedstock → Aromatic molecules → Nanoparticulate fuels

Contain aromatic molecules

Examples:

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

Chemical process

Extract

Extract

Digest

- CH_4 natural gas

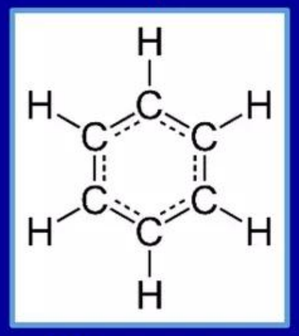
Mo catalyst

- CO_2 → C nanofibers

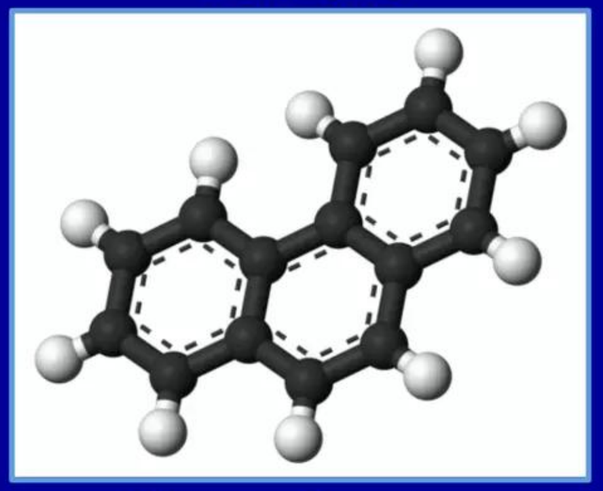
Processing

Variety of simple and complex aromatic molecules

Examples:



Benzene



Phenanthrene

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

Chemical processing

Process into

plus nanotech

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

Nanoparticulate LENR fuels could be used in many systems

Huge energy density advantages vs. fossil fuels & chemical batteries

Bionuclear 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

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 - 6,000° 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

LENRs could enable vast increases in product performance

Intrinsic energy density of LENRs at least 5,000x > chemical processes

Commercial LENR systems could easily achieve 10x - 100x chemical systems

Enhancements in product range and endurance if LENR technology were commercialized

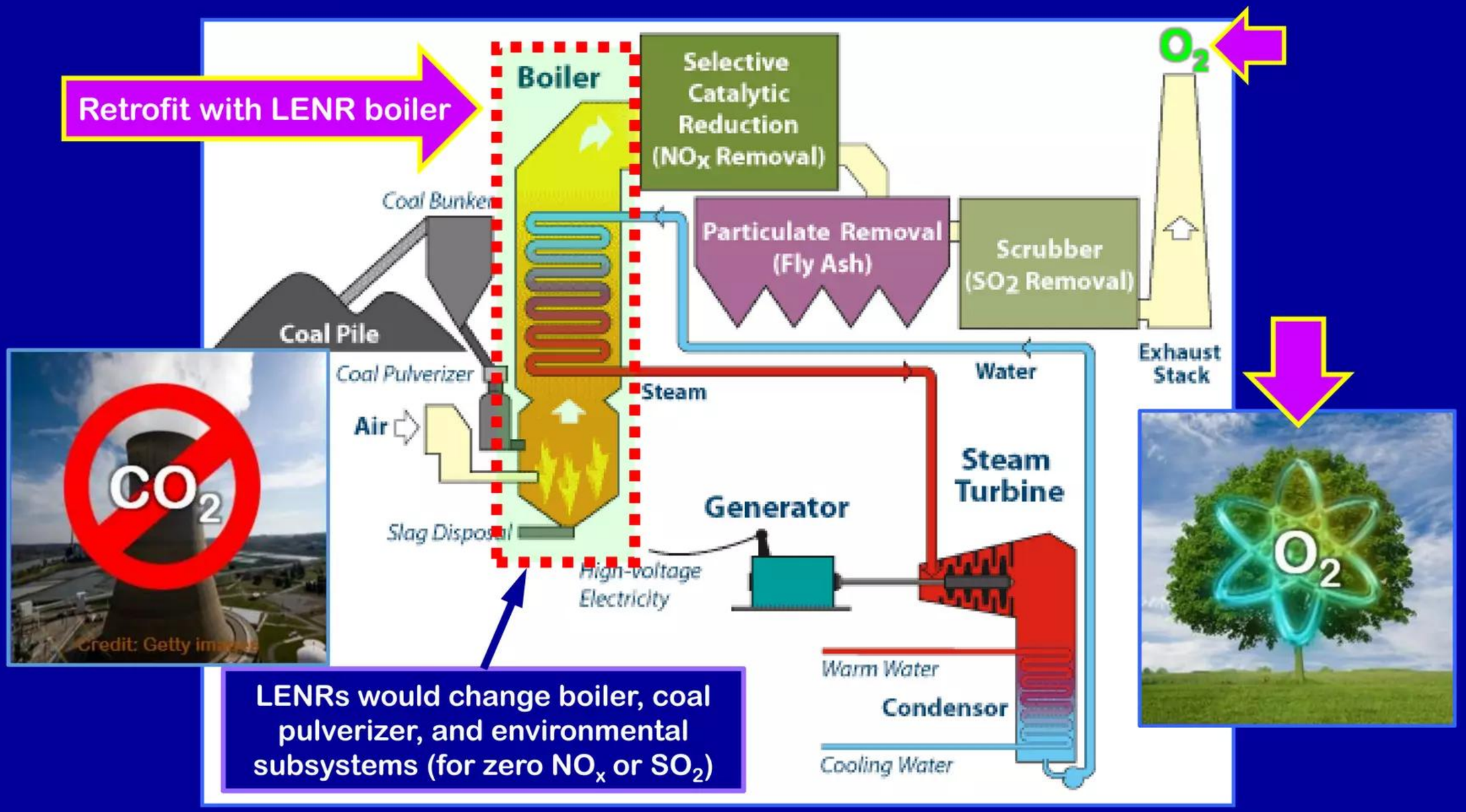
	Product Name	Present capabilities with today's power sources Range (endurance)	Vastly enhanced capabilities with future LENR-based power sources	
			10x chemical	100x chemical
Various aircraft	GreenWing e430	180 miles (~3 hours @ 60 mph)	1,800 (30)	18,000 (300)
	Airbus E-Fan 2.0	99 miles (1 hour @ 99 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

Opportunity: retrofit old 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

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Think different.

“Think different" was an advertising slogan for Apple Inc. (formerly Apple Computer Inc.) in 1997 created by the Los Angeles office of advertising agency TBWA\Chiat\Day (unreleased version narrated by Steve Jobs himself)

https://www.youtube.com/watch?v=GEPhLqwKo6g

Widom-Larsen theory of ultralow energy neutron reactions

Three key publications that start in March 2006 referenced below

Many-body collective quantum effects enable electroweak catalysis

"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

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

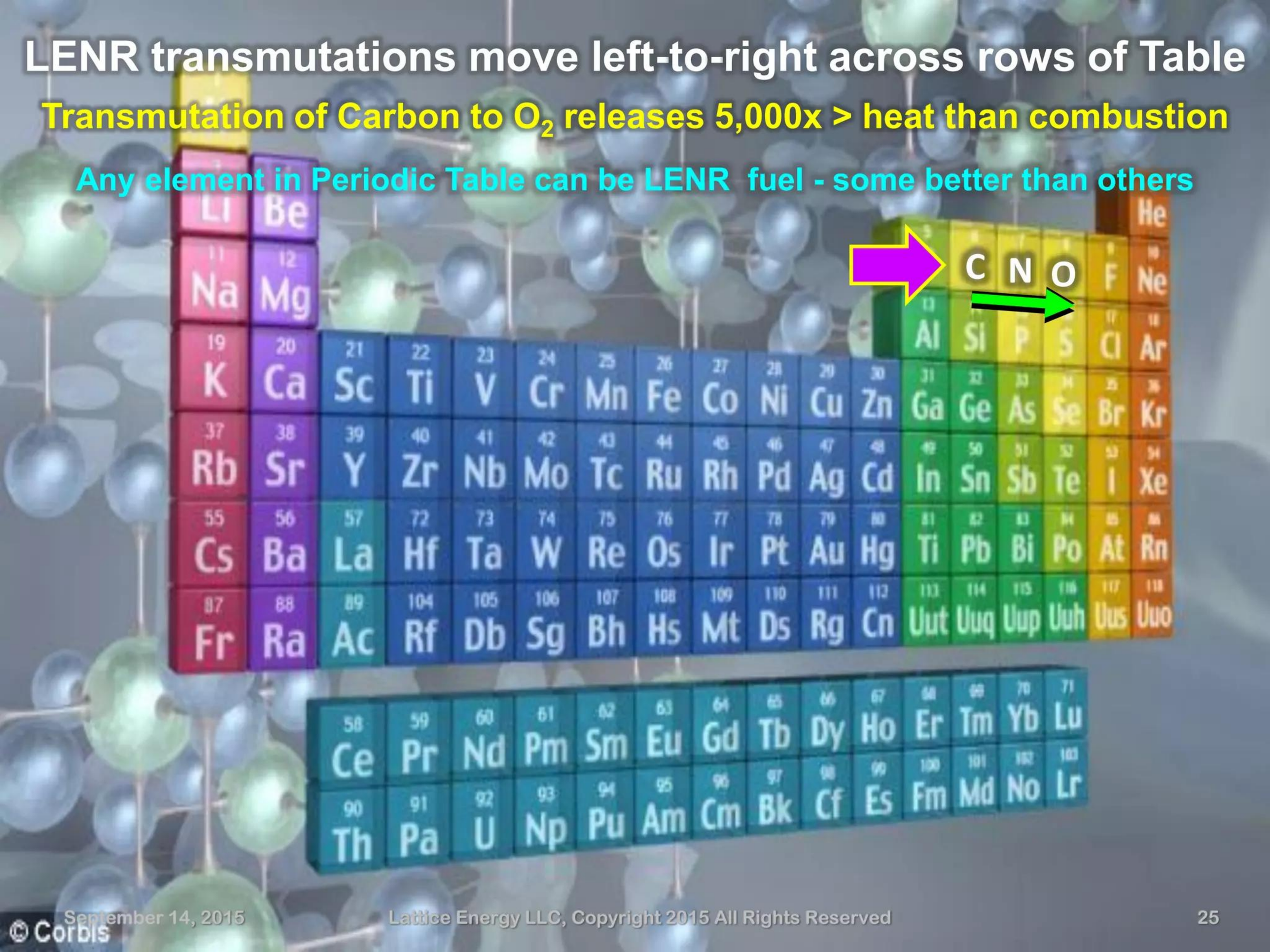
Neutrons + fuel elements → heavier elements + decay products

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

LENR transmutations move left-to-right across rows of Table

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

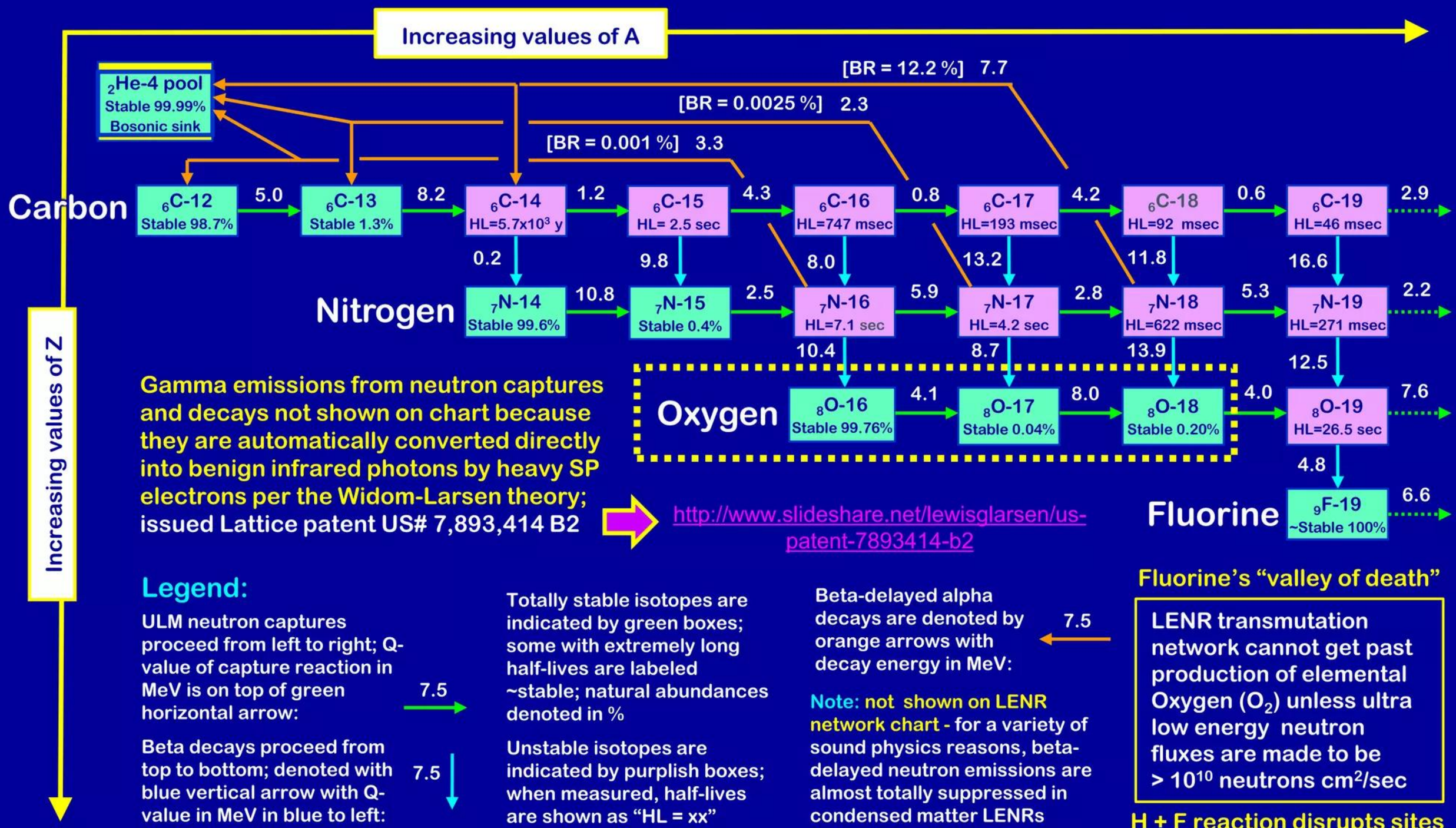
Any element in Periodic Table can be LENR fuel - some better than others



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

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

Aromatic Carbon transmutation naturally stops at Oxygen - akin to plants



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; 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

H + F reaction disrupts sites

Further in-depth reading for those who wish to learn more

Incredible opportunity to develop green renewable nuclear power

LENR fuels derived from biomass --- an inexhaustible energy source

"LENR transmutation of Carbon is superior energy strategy - Slashes CO_2 emissions for vehicles as well as electric power generation" [32 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenr-transmutation-of-carbon-better-energy-strategy-than-obama-clean-power-plan-aug-3-2015

"Compelling economics of transmutation vs. combustion of carbonaceous energy sources" [44 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-compelling-economics-of-transmutation-vs-combustion-of-carbonaceous-energy-sources-jan-14-2015

"Transmutation vs. combustion - Are LENRs a Chicxulub for fossil fuel dinosaurs?" [49 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-transmutation-vs-combustion-are-lenrs-chicxulub-for-fossil-fuel-dinosaurs-oct-6-2014

"Index and User Guide to the Widom-Larsen theory and ultralow energy neutron reactions (LENRs)" [133 slides]
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-hyperlinked-index-to-documents-re-widomlarsen-theory-and-lenrs-september-7-2015