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Commercializing a Next-Generation Source of CLENR Energy

Clean Low Energy Neutron Reactions (CLENRs)

Polycyclic aromatic hydrocarbons (PAHs), LENRs, and coal:
'Dirty coal' as a future source of CLENR fuels with zero CO_2 emissions?

Speculative possibilities about the potential future of coal and CLENR energy

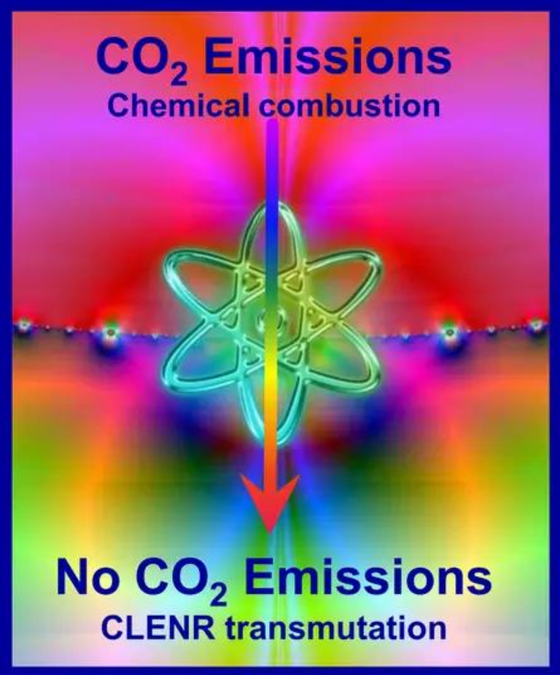
Lewis Larsen, President and CEO

March 21, 2012

If CLENR technology could be developed and applied to use coal as 'seed' fuel source, transmutation of Carbon atoms would release > 10^6 times more thermal energy without CO_2

"I have learned to use the word 'impossible' with the greatest caution."

Wernher von Braun



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Coal and steam - handmaidens of the Industrial Revolution

CO_2 from coal burning is now an issue; can new CLENR technology reinvigorate coal?

Today

1800s in England

Today

"Clean coal is an attempt by the coal industry to try and make itself relevant in the age of renewables. Existing CCTs do nothing to mitigate the environmental effects of coal mining or the devastating effects of global warming. Coal is the dirtiest fuel there is and belongs in the past."

Greenpeace policy statement, 2009

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Contents - I

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Commercializing a Next-Generation Source of CLENR Energy

Contents - II

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Coal now ~equal to natural gas as global energy source

Could CLENRs transform it from a presently dirty to a 'green' energy source?

% of Total Annual Energy Consumption		
Source	**US**	**World**
Oil	**40.6**	**36.8**
Coal	**22.9**	**25.2**
Natural Gas	**22.6**	**26.0**
Nuclear fission	**8.1**	**7.5**
Hydro	**2.7**	**2.4**
Biomass	**2.7**	**NA**
Geothermal	**0.4**	**0.4**
Solar (all)	**0.1**	**0.6**
Wind	**0.2**	**<0.1**
Ocean rel.	**~0.0**	**~0.0**
Year:	**2005**	**2001**
Data:	**EIA**	**IEA**

In the USA, coal is used to fuel ~50% of central station, grid-connected electrical power generation capacity

% of Total Annual Energy Consumption				
Alternative Primary Energy Sources			**US**	**World**
Carbon-based, CO_2-emitting: **'Old world' of energy** - mostly around since the Industrial Revolution in the 1800s; burning wood and other combustibles has been used since man discovered fire	**Carbon-based Primary Energy Sources**	**Oil**	**40.6**	**36.8**
		Coal	**22.9**	**25.2**
		Gas	**22.6**	**26.0**
	Carbon-Based Renewables	**Biomass**	**2.5**	**NA**
		Biofuels (ethanol)	**0.2 est.**	**NA**
	All Carbon-based	**Subtotal**	**88.8**	**88.0**
Nuclear fission and fusion: **'New world' of nuclear no-CO_2 emissions (ca. 1942)** – although 'greener' has serious environmental problems and proliferation issues	**Nuclear Electric Power**	**Fission**	**8.1**	**7.5**
"Green" carbon-free: **No CO_2 emissions** **'New world' of carbon-free energy** – hydroelectric power has been around since 1880s; remainder have been around in one form or another at various times thereafter; advanced solar PV most recent development	**'Green,' clean, renewable, and environmentally sustainable**	**Hydroelectric**	**2.7**	**2.4**
		Geothermal	**0.4**	**0.4**
		Solar (all)	**0.1**	**0.6**
		Wind	**0.2**	**<0.1**
		Ocean rel.	**~0.0**	**~0.0**
	New possibility	**CLENR coal**	**?**	**?**
	All CO_2-free	**Subtotal**	**3.4**	**<3.5**
Note: source for US data is the "Monthly Energy Review" of the Energy Information Administration (EIA) of the Dept. of Energy; world data is taken from annual reports of the International Energy Association (IEA).		**Year:**	**2005**	**2001**
		Data:	**EIA**	**IEA**

Apply CLENR technology to coal

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Estimated global coal reserves as of 2006

USA has the largest total reserves followed by Russia, China, and India

Proved recoverable coal reserves at end-2006 (million tons - teragrams)				
Country	Bituminous and anthracite	Sub-bituminous and lignite	TOTAL	Share
USA	**111,338**	**135,305**	**246,643**	**27.1**
Russian Federation	**49,088**	**107,922**	**157,010**	**17.3**
China	**62,200**	**52,300**	**114,500**	**12.6**
India	**90,085**	**2,360**	**92,445**	**10.2**
Australia	38,600	39,900	78,500	8.6
South Africa	48,750	0	48,750	5.4
Ukraine	16,274	17,879	34,153	3.8
Kazakhstan	28,151	3,128	31,279	3.4
Poland	14,000	0	14,000	1.5
Brazil	0	10,113	10,113	1.1
All others	20,285	24,111	28,802	3.2
TOTAL	**478,771**	**430,293**	**909,064**	**100**

67%

Source: adapted directly from Wikipedia at http://en.wikipedia.org/wiki/Coal

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Coal nanoparticles + triggering of CLENRs → green energy

Chemistry and modern nuclear science beget commercial alchemy

"There is first the groping after causes, and then the struggle to frame laws. There are intellectual revolutions, bitter controversial conflicts, and the crash and wreck of fallen philosophies."

Francis Venable "A Short History of Chemistry," pp. 1 D. C. Heath 1894

The field of chemistry has spent nearly 300 years distancing itself from the 'fallen angel' of alchemy. This 'safe distance' has been maintained until the present era, mainly because of wide disparities in energy scales between chemical and nuclear processes. Today, chemistry primarily involves the dynamics of outer valence electrons and bonding reactions between atoms of various elements on electron Volt (eV) energy scales. By contrast, nuclear physics mostly involves strong and weak interaction dynamics of nucleons and inner-shell electrons, as well as other types of energetic particles, with binding energies on scales ranging from kilo electron Volts (keVs) up to mega electron Volts (MeVs) and higher. "*Never the twain shall meet*." --- until now.

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Commercializing a Next-Generation Source of CLENR Energy

Coal and CLENRs: handmaidens of new energy revolution?

"Oh, East is East, and West is West, and never the twain shall meet."

Rudyard Kipling, "The Battle of East and West" (1889)

Since the inception of nuclear science, it has been widely believed that the only nuclear processes suitable for commercial power generation were strong interaction fission or fusion; it was also widely held that nuclear transmutation reactions could only take place within certain environments, e.g., in fission reactors, weapons, or stars. Pons & Fleischmann's 1989 discovery of what appeared to be nuclear processes operating inside what would otherwise be ordinary D_2O electrolytic chemical cells challenged long-established conceptual paradigms about nuclear science. Sadly, P&F rashly speculated that their observed radiation-free "excess heat" resulted from a D-D "cold fusion" process. That claim, coupled with irreproducible experimental results, resulted in sustained attacks on such work by mainstream science that have continued to the present. Starting with the release of our first arXiv preprint in 2005, the Widom-Larsen theory (WLT) of CLENRs has shown, using known physics, how energetic nuclear reactions can take place in ordinary chemical cells. According to WLT, key aspects of CLENRs involve weak interactions that can occur in a variety of different environments under relatively 'mild' physical conditions. Our theory posits that in condensed matter systems, many-body collective effects allow the otherwise disparate chemical and nuclear energy realms to interconnect in special, micron-scale regions on surfaces.

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Alternative dense sources of energy

CLENRs offer possibility of a new and 'greener' energy source

Combustion of fossil fuels (strictly chemical processes involving outer valence electrons of nuclei):

Comments: emits copious quantities of CO_2, a greenhouse gas; comprises vast majority of mankind's energy production today

Scale of energy release: eVs (chemical regime)

Alternate natural sources of fuel: primarily oil, coal, and biomass; basic reaction: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ + energy

Controlled release of nuclear binding energy (fission and fusion; mainly involve strong interaction):

Comments: no CO_2 emission; emit dangerous *energetic* radiation (γ, neutron); today <10% of global energy production

Scale of energy release: MeVs (nuclear regime) > 1,000,000x all chemical energy sources

Heavy-element fission (involves shattering heavy nuclei to release stored nuclear binding energy):

Comments: requires massive shielding and containment structures to handle radiation; major rad-waste clean-up

Alternate natural 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 isotopes) + energetic gamma radiation + energetic neutron radiation + energy

Fusion of light nuclei: (involves 'mashing' light nuclei together to release stored nuclear binding energy):

Comments: present multi-billion $ development efforts (e.g., ITER, NIF, Tokamaks) focusing mainly on D+T fusion reaction; requires massive shielding/containment structures to handle 14 MeV neutron radiation; minor rad-waste clean-up $ vs. fission

Natural sources of fuel: Deuterium and Tritium (two heavy isotopes of hydrogen)

Most likely commercial fusion reaction involves: D + T → He-4 (helium) + neutron + energy (total 17.6 MeV; ~14.1 MeV in neutron)

Low energy neutron reactions (LENRs=CLENRs; key distinguishing feature is neutron production via weak interaction; neutron capture + gamma conversion to IR + decays [α, β] release nuclear binding energy):

Comments: early-stage technology; no emission of energetic neutron or gamma radiation; no long lived rad-waste products; LENR systems do not require massive and expensive radiation shielding and containment structures → much lower $ cost

Natural sources of fuel: *any* element/isotope that can capture LE neutrons and release >0.78 MeV in nuclear binding energy

Involves complex, branching LENR nucleosynthetic transmutation networks that begin with neutron captures on 'seed nuclei' then proceed from lower to higher values of atomic mass (A); very similar to what happens in stars, only at low temps/pressures

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CLENR physics now understood and published - I

Technical papers on Widom-Larsen theory

"***Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces***" Eur. Phys. J. C **46**, pp. 107 (March 2006) Widom and Larsen – initially placed on arXiv in May 2005 at http://arxiv.org/PS_cache/cond-mat/pdf/0505/0505026v1.pdf; a copy of the final *EPJC* article can be found at: http://www.newenergytimes.com/v2/library/2006/2006Widom-UltraLowMomentumNeutronCatalyzed.pdf
"***Absorption of nuclear gamma radiation by heavy electrons on metallic hydride surfaces***" http://arxiv.org/PS_cache/cond-mat/pdf/0509/0509269v1.pdf (Sept 2005) Widom and Larsen
"***Nuclear abundances in metallic hydride electrodes of electrolytic chemical cells***" http://arxiv.org/PS_cache/cond-mat/pdf/0602/0602472v1.pdf (Feb 2006) Widom and Larsen
"***Theoretical Standard Model rates of proton to neutron conversions near metallic hydride surfaces***" http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf (v2. Sep 2007) Widom and Larsen
"***Energetic electrons and nuclear transmutations in exploding wires***" http://arxiv.org/PS_cache/arxiv/pdf/0709/0709.1222v1.pdf (Sept 2007) Widom, Srivastava, and Larsen
"***Errors in the quantum electrodynamic mass analysis of Hagelstein and Chaudhary***" http://arxiv.org/PS_cache/arxiv/pdf/0802/0802.0466v2.pdf (Feb 2008) Widom, Srivastava, and Larsen
"***High energy particles in the solar corona***" http://arxiv.org/PS_cache/arxiv/pdf/0804/0804.2647v1.pdf (April 2008) Widom, Srivastava, and Larsen
"***A primer for electro-weak induced low energy nuclear reactions***" Srivastava, Widom, and Larsen Pramana – Journal of Physics **75** pp. 617 (October 2010) http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf

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CLENR physics is now understood and published - II

Key factors for initiation and operation of CLENRs

- ✓ **Substantial quantities of Hydrogen isotopes must be brought into intimate contact with 'fully-loaded' metallic hydride-forming metals; e.g., Palladium, Platinum, Rhodium, Nickel, Titanium , Tungsten, etc.; please note that collectively oscillating, 2-D surface plasmon (SP) electrons are intrinsically present and cover the surfaces of such metals. At 'full loading' of H, many-body, collectively oscillating 'patches' of protons (p^+), deuterons (d^+), or tritons (t^+) will form spontaneously at random locations scattered across such surfaces**
- ✓ **Or, delocalized collectively oscillating π electrons that comprise the outer 'covering surfaces' of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave very similarly to SPs; when such molecules are hydrogenated, they can create many-body, collectively oscillating, 'entangled' quantum systems that, within context of W-L theory, are functionally equivalent to loaded metallic hydrides**
- ✓ **Born-Oppenheimer approximation breaks down in tiny surface 'patches' of contiguous collections of collectively oscillating p^+, d^+, and/or t^+ ions; enables E-M coupling between nearby SP or π electrons and hydrogen ions at these locations --- *creates local nuclear-strength electric fields*; effective masses of coupled electrons are then increased to some multiple of an electron at rest ($e \rightarrow e^*$) determined by required simultaneous energy input(s)**
- ✓ **System <u>must</u> be subjected to external non-equilibrium fluxes of charged particles or E-M photons that are able to transfer input energy directly to many-body SP or π electron 'surface films.' Examples of such external energy sources include (they may be used in combination): electric currents (electron 'beams'); E-M photons (e.g., emitted from lasers, IR-resonant E-M cavity walls, etc.); pressure gradients of p^+, d^+, and/or t^+ ions imposed across 'surfaces'; currents of other ions crossing the 'electron surface' in either direction (ion 'beams'); etc. Such sources provide additional input energy that is required to surpass certain minimum H-isotope-specific electron-mass thresholds that allow production of ULM neutron fluxes via $e^* + p^+$, $e^* + d^+$, or $e^* + t^+$ weak interactions**
- ✓ **<u>N.B.</u>: please note again that surface plasmons are collective, many-body electronic phenomena closely associated with interfaces. For example, they can exist at gas/metal interfaces or metal/oxide interfaces. Thus, surface plasmon oscillations will almost certainly be present at contact points between purely metallic surfaces and adsorbed 'target' nanoparticles composed of metallic oxides, e.g., PdO, NiO, or TiO_2, etc., or vice-versa**

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Certain key features of Widom-Larsen theory - I

Input energy is required to produce neutrons and trigger CLENRs

- ✓ **Input energy is required to create non-equilibrium conditions necessary for creating local populations of heavy-mass $e^{-}*$ electrons that can react with many-body surface 'patches' of p^{+}, d^{+}, or t^{+} to produce neutrons via $e^{-}* + p^{+} \rightarrow 1\ n$ or $e^{-}* + d^{+} \rightarrow 2\ n,$ etc. (cost = 0.78 MeV/neutron for H; 0.39 for D; 0.26 for T); includes (can be combined):**
  - **Electrical currents (i.e., an electron 'beam')**
  - **Ion currents across the interface on which SP electrons reside (i.e., an ion 'beam' that can be comprised of protons, deuterons, tritons, and/or other types of charged ions); one method used to input energy is by imposing a pressure gradient (Iwamura *et al.* 2002)**
  - **Coherent incident photon 'beams' (under the right conditions, SP electrons can be directly excited with a laser that is 'tuned' to emit at certain wavelengths); discovered by Letts & Cravens (2002); <u>also</u> resonant electromagnetic cavities**
  - **Organized magnetic fields at very, very high current densities**
- ✓ **Key feature of complex, multi-step CLENR transmutation networks is that large numbers of viable network pathways release more net nuclear binding energy from a combination of neutron captures (w. direct conversion of gammas into IR) and decays than input energy required to make the neutrons that enable a given path to operate**

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Certain key features of Widom-Larsen theory - II

Several processes create usable heat produced by CLENR networks

- ✓ **Conceptually, CLENR neutrons act like catalytic 'matches' that are used to 'light the logs' of 'fuel' nuclei. A neutron-catalyzed CLENR transmutation network operates to release nuclear binding energy that has been stored and locked away in 'nuclei fuel logs' since they were originally produced in nucleosynthetic processes of long-dead stars, many billions of years ago**
- ✓ **CLENR networks can produce usable process heat that arises mainly from:**
  - **Direct conversion of gamma photons (γ) into infrared photons (IR) by heavy electrons; e.g., γ from neutron captures or decays. IR is then scattered and absorbed by local matter, increasing its temperature**
  - **Nuclear decays in which energetic charged particles are emitted (e.g., alphas, betas, protons, deuterons, tritons); particles then transfer their kinetic energy by scattering on local matter, increasing its temperature**
- ✓ **Neutrino photons from weak interactions do not contribute to production of process heat; they essentially bleed-off a small portion of released nuclear binding energy into space; unavoidable neutrino emissions are part of the 'cost' of obtaining energy releases in CLENR networks from beta$^-$ decays**

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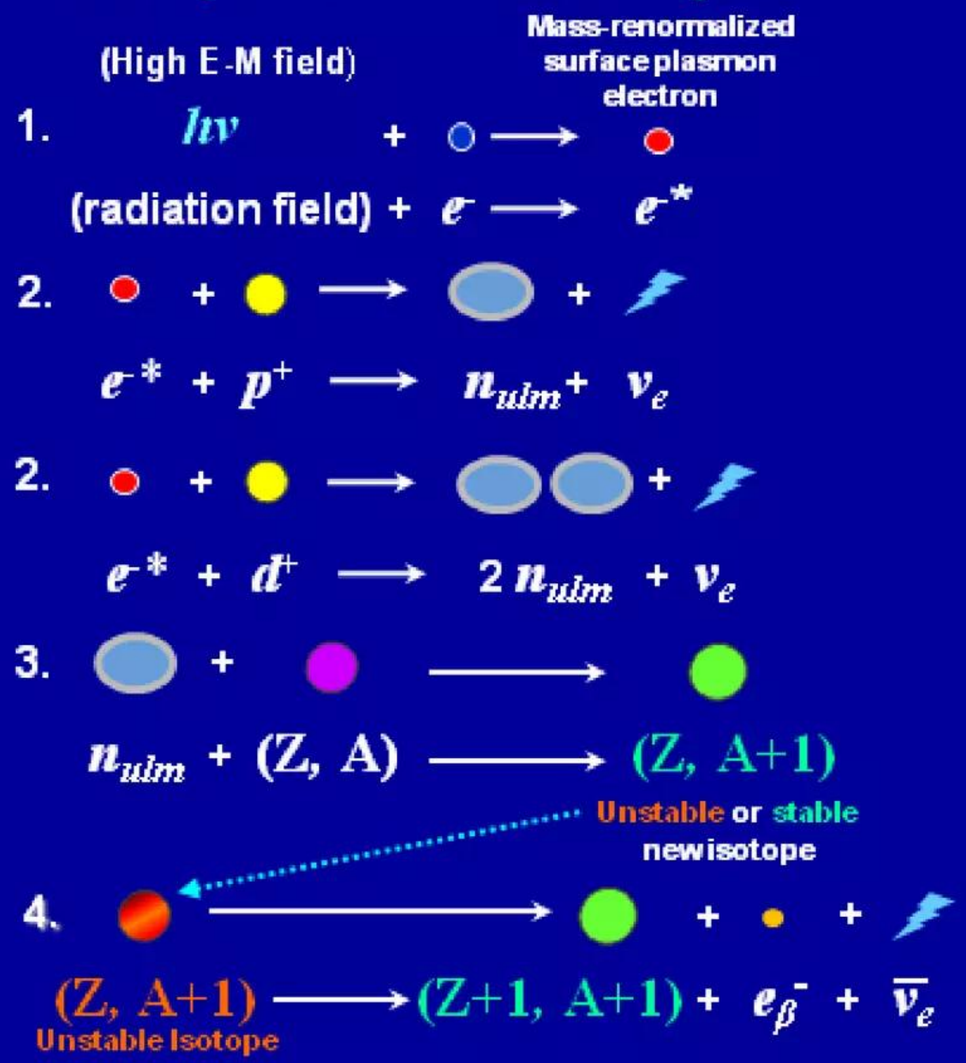
Certain key features of Widom-Larsen theory - III

Weak interaction production of neutrons in condensed matter

1. E-M radiation on metallic hydride surface increases mass of surface plasmon electrons
2. Heavy-mass surface plasmon electrons react directly with surface protons (p^+) or deuterons (d^+) to produce ultra low momentum (ULM) neutrons (n_{ulm} or 2 n_{ulm}, respectively) and an electron neutrino (ν_e)
3. Ultra low momentum neutrons (n_{ulm}) are captured by nearby atomic nuclei (Z, A) representing some element with charge (Z) and atomic mass (A). ULM neutron absorption produces a heavier-mass isotope (Z, A+1) via transmutation. This new isotope (Z, A+1) may itself be a stable or unstable, which will perforce eventually decay
4. Many unstable isotopes β^- decay, producing: transmuted element with increased charge (Z+1), ~ same mass (A+1) as 'parent' nucleus; β^- particle (e_{β^-}); and an antineutrino $\overline{\nu}_e$

Note: colored shapes associated with diagram on next Slide

No strong interaction fusion or heavy element fission occurring below; weak interaction $e^- + p$ or $e^- + d$



Weak interaction β^- decays (shown just above), direct gamma conversion to infrared photons (not shown), and α decays (not shown) produce most of the excess heat calorimetrically observed in LENR systems

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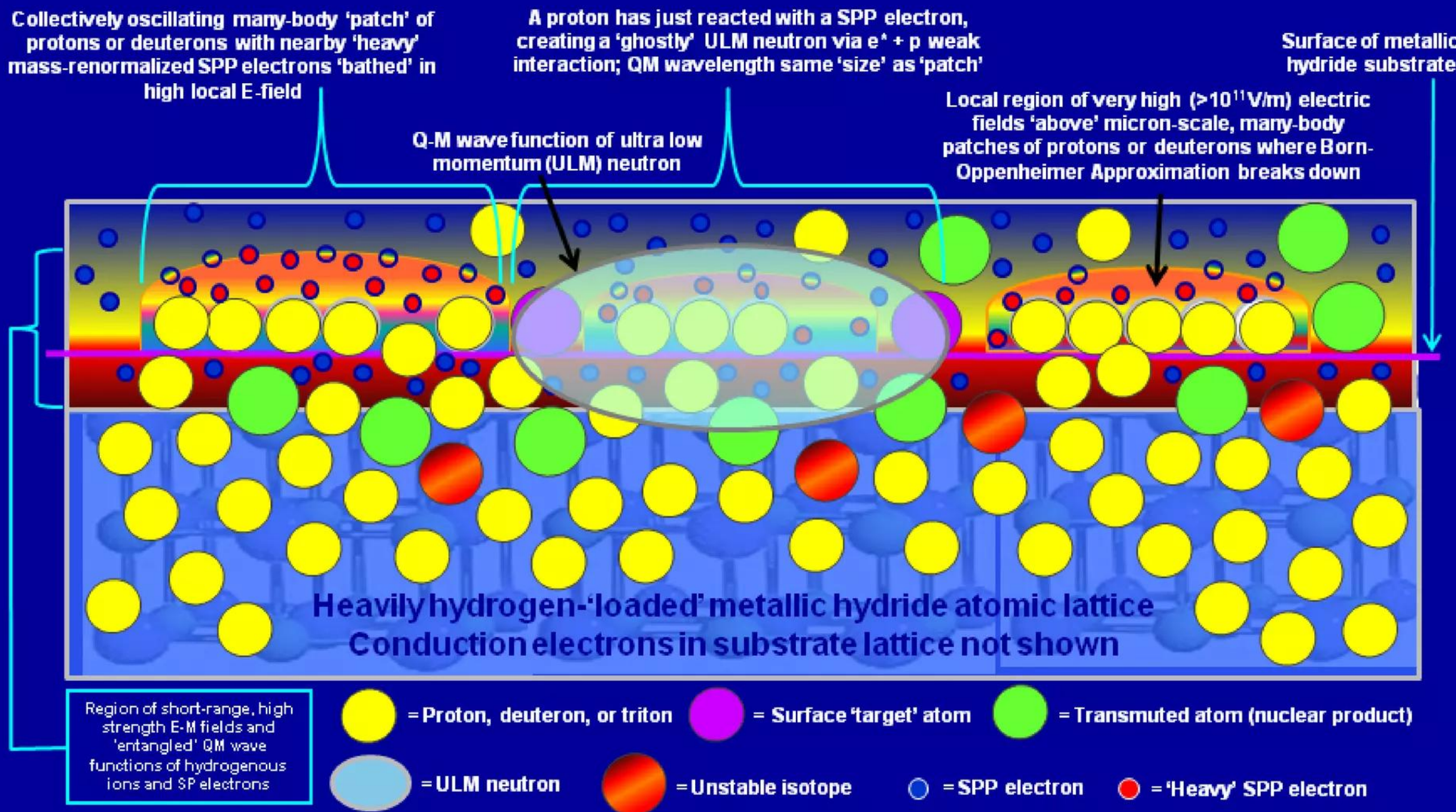
Certain key features of Widom-Larsen theory - IV

Conceptual graphic of many-body CLENR-active 'patches' on surface



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Certain key features of Widom-Larsen theory - V

Inputs, processes, and outputs in a CLENR-active 'patch'

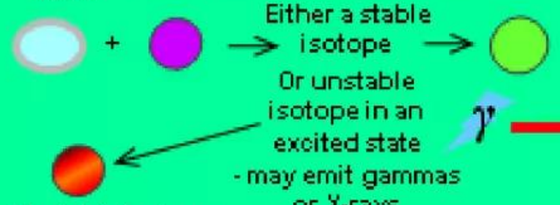
LENR Nuclear Realm (MeVs) Occurs within micron-scale 'patches'

"Hot spots:" reach 3,000 - 6,000* °C
'Craters' visible in post-experiment SEM images of LENR device surfaces

$\tilde{e}^- + p^+ \rightarrow n_{ulm} + \nu_e$

$\tilde{e}^- + d^+ \rightarrow 2\,n_{ulm} + \nu_e$

$n_{ulm} + (Z, A) \rightarrow (Z, A+1)$



Unstable isotope:

Which then subsequently undergoes some type of nuclear decay process

In the case of typical beta⁻ decay:

$(Z, A) \rightarrow (Z+1, A) + e^- + \bar{\nu}_e$

In the case of typical alpha decay:

$(Z, A) \rightarrow (Z-2, A-4) + {}^{4}_{2}\mathrm{He}$

Extremely neutron-rich product isotopes may also deexcite via beta-delayed decays, which also emit small fluxes of neutrons, protons, deuterons, tritons, etc.

'Transducer' regions: many-body collective effects, ~eV energies are 'collected' and 'summed' to MeV energies in micron-scale, many-body surface 'patches' by 'film' of SP electrons and p^+, d^+, t^+ ions in patches; all oscillate collectively

E-Menergy

Many-body, collectively oscillating surface' patches' of p^+, d^+, or t^+ ions

E-Menergy

Mass-renormalized surface plasmon (SP) electrons – also *convert* gammas to IR

E-Menergy

Normal-mass surface plasmon (SP) or π electrons on surfaces of certain carbon structures

Input

Gamma photons

γ → IR

Micron-scale surface regions with very high local electromagnetic fields

Surface 'film' of SP electrons inherently oscillates collectively

Born-Oppenheimer Approximation breaks down in many-body 'patches' of p^+, d^+, or t^+ on 'loaded' hydride surfaces

Two-way, collective energy transfers occur back-and-forth via E-M fields coupling the chemical and nuclear realms

Output

LENR final products: primarily stable isotopes, energetic β^-, α (He-4) particles, other charged particles, IR photons (with small 'tail' in soft X-rays), and neutrinos

End with: ν, γ, IR photons

Chemical Energy Realm (eVs) Everywhere else in LENR systems

Energy must be inputted to create high surface E-M radiation fields that are needed to produce ULM neutrons. Required input energy can be provided from one or a combination of: electron 'beams' (electric currents); ion 'beams', i.e., fluxes of ions across the surface 'film' of SP electrons (protons, deuterons, tritons, or other ions); and E-M photons, e.g., from lasers if nanoscale surface roughness coupling parameters are satisfied

Infrared (IR) photons

IR photons excite lattice phonons

ULM neutron captures on 'target fuel' elements and subsequent nuclear reactions all release nuclear binding energy – neutrons are the 'match' that lights the fuel 'on fire'

Heat

Output

Energetic charged particles excite lattice phonons

Neutrinos (ν) fly off into space at velocity c

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Details of CLENRs in condensed matter systems - I

300 nanoseconds in life of μm-scale LENR-active 'patch'

LENR-active surface sites in condensed matter are not permanent entities. In experimental or certain natural systems with sufficient input energy, when conditions are just right they will form spontaneously, operate for as little as 10 *ns* up to perhaps several hundred nanoseconds, and then suddenly 'die' (they effectively destroy themselves).

Over time or the course of a given experiment, many cycles of 'birth', nuclear binding energy release, and 'death' may be repeated over and over again at many different, randomly scattered *nm*-to *μm*-sized locations found on a given surface or interface; neutron-dose histories can vary greatly over small length-scales across an entire LENR-active surface. *Such spatial elemental/isotopic heterogeneity has often been observed by LENR researchers with SIMS.*

While ULM neutron production and local capture, gamma conversion to IR by heavy electrons, and subsequent nuclear decays are occurring, these tiny 'patches' temporarily become 'hot spots.' Their temperatures may briefly reach 4,000 - 6,000° K or perhaps even higher. That value is roughly as high as the 'surface' temperature of the Sun and hot enough to melt and/or even flash boil essentially all metals and alloys, including Tungsten (b.p. 5,666° C). For a brief time, a tiny dense 'ball' of very hot, 'nanodusty' plasma is created. Such intense local heating events can produce various types of distinctive explosive melting features and/or comparatively deep 'craters' that are often observed in post-experiment SEM images of LENR device surfaces; for Zhang & Dash's image of such surface features see Slide #69 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009

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Details of CLENRs in condensed matter systems - II

300 nanoseconds in life of μm-scale LENR-active 'patch'

ULM neutron production can begin in a given many-body 'patch' sometime after local E-field strengths exceed ~2 x 10^{11} V/m (i.e., e^{-}* mass renormalization ratio β is now greater than the minimum threshold ratio β_0) and an adequate number of mass-renormalized e^{-}* electrons have been created (enabled by local breakdown of the Born-Oppenheimer approximation in ~temporal conjunction with nonequilibrium energy inputs).

The e^{-}* + p^{+} or e^{-}* + d^{+} weak reactions appear to occur during many-body, collectively oscillating protons' brief moments of quantum coherence (i.e., effective entanglement within a 'patch'); duration of such proton coherence times are on the order of attoseconds (~10^{-18} sec); these times have been measured by Chatzidimitriou-Dreismann, 2005, cited in Slide #44 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

Once the e^{-}* mass renormalization 'set-up' process has completed and heavy e^{-}* electrons and p^{+} protons are finally ready to react (i.e., β now > β_0), subsequent weak reactions that follow only require ~10^{-19} to 10^{-22} sec to finish. ***Thus, while 'flickering' proton coherence times are relatively short, weak reactions that act to produce ULM neutrons operate on even faster nuclear time-scales, thus allowing local neutron production to proceed at substantial rates.***

When collectively produced neutrons are ULM, local neutron capture processes occur over time-horizons on the order of picoseconds (10^{-18} sec); not enough time for them to thermalize.

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Details of CLENRs in condensed matter systems - III

300 nanoseconds in life of μm-scale LENR-active 'patch'

Note that all of the many atoms located within a 3-D region of space that encompasses a given ULM neutron's spatially extended DeBroglie wave function (whose dimensions can range from 2 nm to 100 microns) will 'compete' with each other to capture such neutrons. ULM neutron capture is thus a decidedly many-body scattering process, not few-body scattering such as that which characterizes capture of neutrons at thermal energies in condensed matter in which the DeBroglie wave function of a thermal neutron is on the order of ~2 Angstroms. ***This explains why the vast majority of produced neutrons are captured locally and not commonly detected at any energy during the course of experiments; it also clearly explains why lethal MeV-energy neutron fluxes are characteristically not produced in condensed matter LENR systems.***

Half-lives of the most neutron-rich, unstable beta-decaying isotopes are generally rather energetic and relatively short , often on the order of milliseconds (10^{-3} sec). For example, very neutron rich Nitrogen-23 is unstable to beta decay with a measured half-life of ~14.5 milliseconds and Q-value of ~23 MeV; see Slide #12 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 Even so, ULM neutron capture processes generally occur at much faster rates than the decay rate of many beta- or alpha-unstable isotopes in LENR systems. If local ULM neutron production rates in a given 'patch' are high enough, this large difference in rates of beta decay versus neutron capture processes means that populations of unstable, neutron-rich isotopes can potentially accumulate locally during the typically brief lifetime of an LENR-active patch, prior to destroying itself.

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Details of CLENRs in condensed matter systems - IV

300 nanoseconds in life of μm-scale LENR-active 'patch'

Please note that the Q-value for neutron capture on a given beta-unstable isotope can sometimes be larger than the Q-value for the alternative *β*- decay pathway, so in addition to being a faster process than beta decay it can also be energetically more favorable. This can help to create local populations of neutron-rich isotopes. There is indirect experimental evidence that such neutron-rich isotopes can be produced in complex ULM neutron-catalyzed LENR nucleosynthetic (transmutation) networks that set-up and operate during the lifetime of a 'patch'; for example see the Carbon-seed network on Slides # 11 - 12 and especially on Slide #55 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 and a Tungsten-seed network segment on Slide # 60 in http://www.slideshare.net/lewisglarsen/cfakepathlattice-energy-llc-len-rs-in-liion-battery-firesjuly-16-2010

Beginning with so-called 'seed' or 'target' starting nuclei upon which ULM neutron captures are initiated, complex, very dynamically changing LENR nucleosynthetic networks are established in LENR-active 'patches.' These ULM neutron-catalyzed LENR networks exist for the lifetime of the particular 'patch' in which they were created; except for any still-decaying transmutation products that may linger, such networks typically 'die' along with the LENR-active 'patch' that originally gave birth to them. *'Seed' nuclei for such networks can comprise any atoms in a substrate underlying an LENR-active patch and/or include atoms located nearby in various types of surface nanoparticles or nanostructures that are electromagnetically connected to a 'patch.'*

Lattice Energy LLC

Details of CLENRs in condensed matter systems - V

300 nanoseconds in life of μm-scale LENR-active 'patch'

For an example of a Carbon-seed LENR network please see Slides # 11 - 12 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 ; for a Potassium-seed LENR network see Slide # 57 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 for a Palladium-seed LENR network see Slides # 52 - 53 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickelseed-lenr-networksapril-20-2011 for a Nickel-seed LENR network see Slides # 20 - 22 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickel-seed-wl-lenr-nucleosynthetic-networkmarch-24-2011 ; and lastly for a Thorium-seed LENR network see Slides # 3 - 4 in http://www.slideshare.net/lewisglarsen/thoriumseed-lenr-networkfigslattice-energydec-7-2010-6177745

Per WLT, once ULM neutron production begins at high rates, populations of unstable, very neutron-rich 'halo' isotopes build-up locally in LENR-active 'patches' found on ~2-D condensed matter surfaces. As explained in Slide #24 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 , such nuclei likely have somewhat retarded decays because they can have a difficult time emitting beta electrons, neutrons, or even neutrinos (all of which happen to be fermions) into locally unoccupied fermionic states. Consequently, such unstable halo nuclei may often continue capturing ULM neutrons until they finally get so neutron-rich, or a previously occupied state in the local continuum opens-up, that 'something breaks' and *spontaneous beta decay cascades ending in stable isotopes are initiated.*

Lattice Energy LLC

Details of CLENRs in condensed matter systems - VI

300 nanoseconds in life of μm-scale LENR-active 'patch'

Depending on half-lives of intermediate isotopes, β- decay chain cascades can very rapidly traverse rows of the periodic table; thus, long-running LENR experiments with large ULMN fluxes can produce a broad variety of different stable elements in surprisingly short periods of time. For example, in one unrepeatable yet nonetheless spectacular experiment, Mizuno (Hokkaido University, Japan) went from Potassium (K) to Iron (Fe) in less than 2 minutes; see Slides # 54 - 59 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewjune-25-2009 For examples of beta-decay cascades see Slide #19 in http://www.slideshare.net/lewisglarsen/lattice-energy-llcnickel-seed-wl-lenr-nucleosynthetic-networkmarch-24-2011

LENR transmutation network pathways comprising series of picosecond neutron captures interspersed with serial beta-decay cascades can release substantial amounts of nuclear binding energy, much of it in the form of usable thermal process heat; e.g., there is a multi-step Carbon-seed LENR transmutation network pathway that can release ~386 MeV over an 'average' period of ~3.4 hours. This total energy release is comparable to fission (U-235 is ~190 MeV) but without any 'hard' neutron or gamma emission or production of long-lived radioactive isotopes; see Slide #55 in http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009 When neutron-creating energy inputs cease, then decay processes begin to dominate in an LENR system; namely, serial cascades (chains) of fast beta decays from unstable neutron-rich intermediates all the way down to stable isotopes/elements. *Importantly, few long-lived radioisotopes would remain after these rapid decay processes complete. This is precisely why LENR-active 'patches' have a strong tendency to produce stable isotopes as end-products.*

Lattice Energy LLC

Coal might become much 'greener' energy source - I

Transmute $_{6}C^{12}$ in coal with CLENRs instead of burning it with oxygen

- ✓ **What we will refer to as 'seed' or 'target' nuclei are simply stable elements (which are themselves initially comprised of some number of natural isotopes) that serve as initial starting points for complex, dynamic neutron-capture-driven LENR transmutation reaction networks**

- ✓ **What nuclear engineers call a "fuel cycle" in the nuclear power industry is essentially the same as what we call an LENR network. Major difference is that there are only very limited number of fuel cycles used in today's commercial fission reactors and they are based on Uranium isotopes (Thorium fuels under development). By contrast, the possibilities for LENR fuel cycles are almost limitless --- literally *any* 'seed' that will capture neutrons might be used (but some are much better than others --- see Lithium in our 2006 *EPJC* paper)**

- ✓ **Since we are focusing on coal herein, we will now examine a *partial segment* of a hypothetical Carbon-seed LENR network that might be commercially usable at some point in the future if ordinary coal can be processed into specially prepared nanoparticulate forms in which CLENRs can be triggered. *In this new scheme, carbon atoms present in coal would be transmuted rather than burned.***

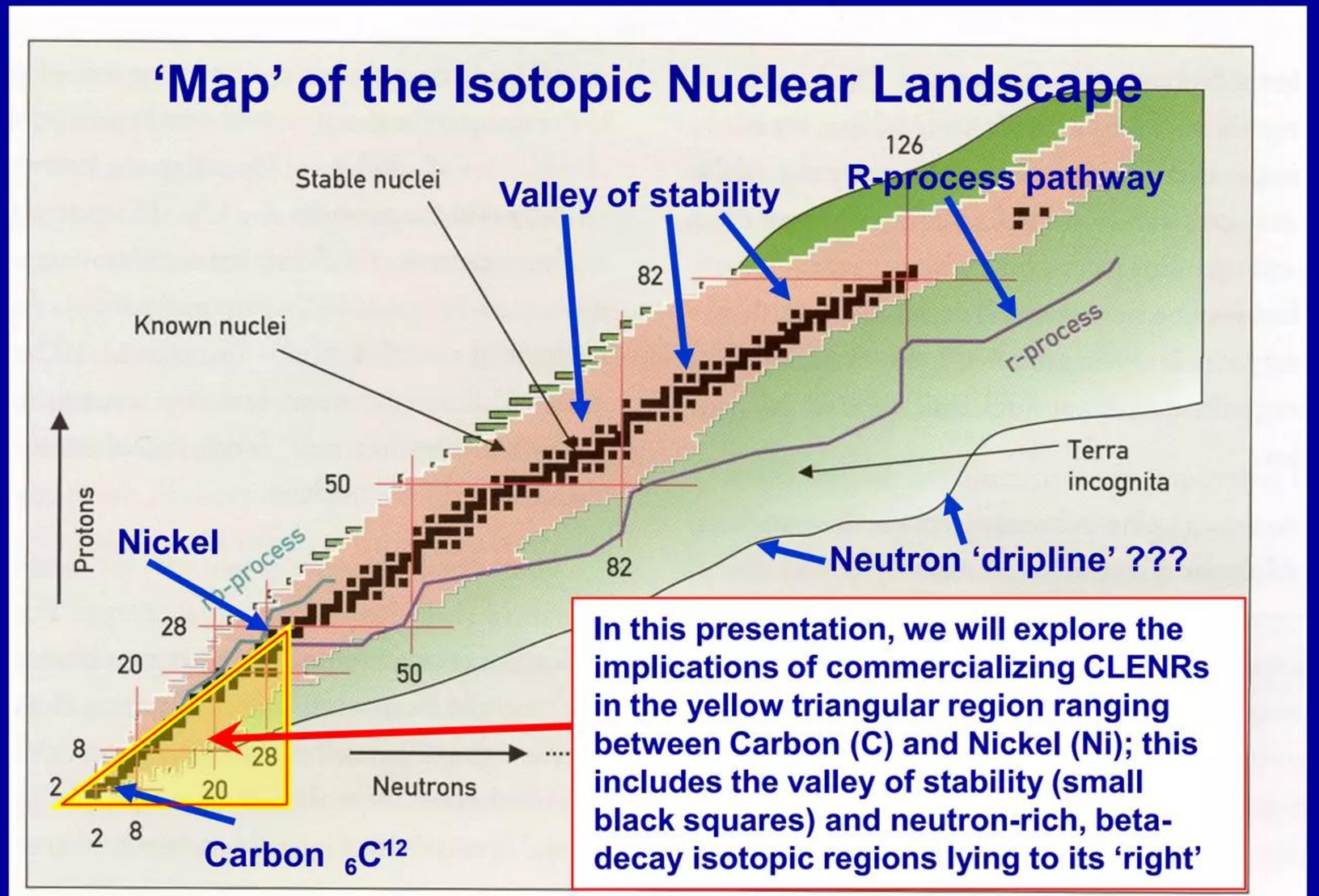
Lattice Energy LLC

Coal might become much 'greener' energy source - II

Transmute $_6C^{12}$ in coal with CLENRs instead of burning it with oxygen

Can potentially transmute Carbon to other stable elements in the Periodic Table

The neutron-catalyzed "r-process" (see path on chart) that astrophysicists believe occurs mainly in stellar supernova explosions is thought to produce most of the nuclei heavier than Iron (Fe). It operates in the neutron-rich region of the nuclear landscape to the right of the valley of stability to beta⁻ decay. Extremely neutron-rich isotopes have a much wider variety of available decay channels in addition to 'simple' β⁻ decay.



While differing from stars in key ways, experiments have shown indirectly that LENR systems can produce large fluxes of a variety of unstable, very neutron-rich isotopes (from low to very high values of A) that beta decay into stable elements. Thus, LENRs could potentially be developed into a future commercial technology capable of producing any valuable stable element in the periodic table at a competitive cost . Truly a medieval alchemist's dream.

Lattice Energy LLC

Coal might become much 'greener' energy source - III

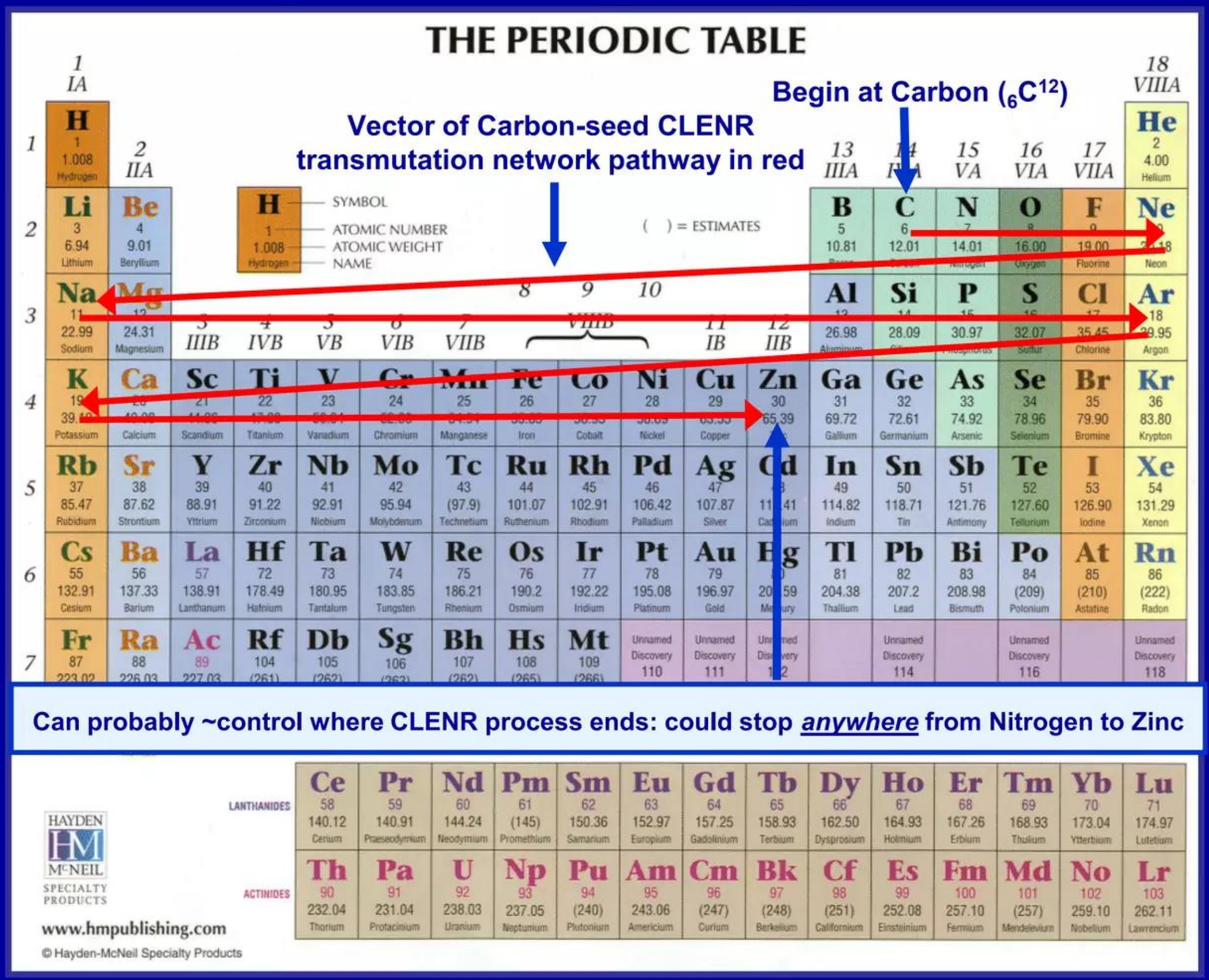
Transmute $_6C^{12}$ in coal with CLENRs instead of burning it with oxygen

Stable transmutation products could be created from Carbon all the way up to Zinc

Combustion of Carbon atoms in fossil fuels with Oxygen O_2 produces CO_2 and H_2O; CO_2 gas emissions are a problem, which has led to schemes like Carbon capture and sequestration (CCT)

Additional issues with coal's trace elements

Scale of energy release from chemical reaction combustion processes are on the order of eVs



Depending on where nuclear process was stopped, CLENR transmutation of Carbon atoms in coal could produce a wide variety of stable elements up through Zinc; gaseous emissions might be limited to Neon, Argon, Nitrogen and/or preferably Oxygen

Scale of energy release is in MeV; or >10^6 larger than chemical reactions

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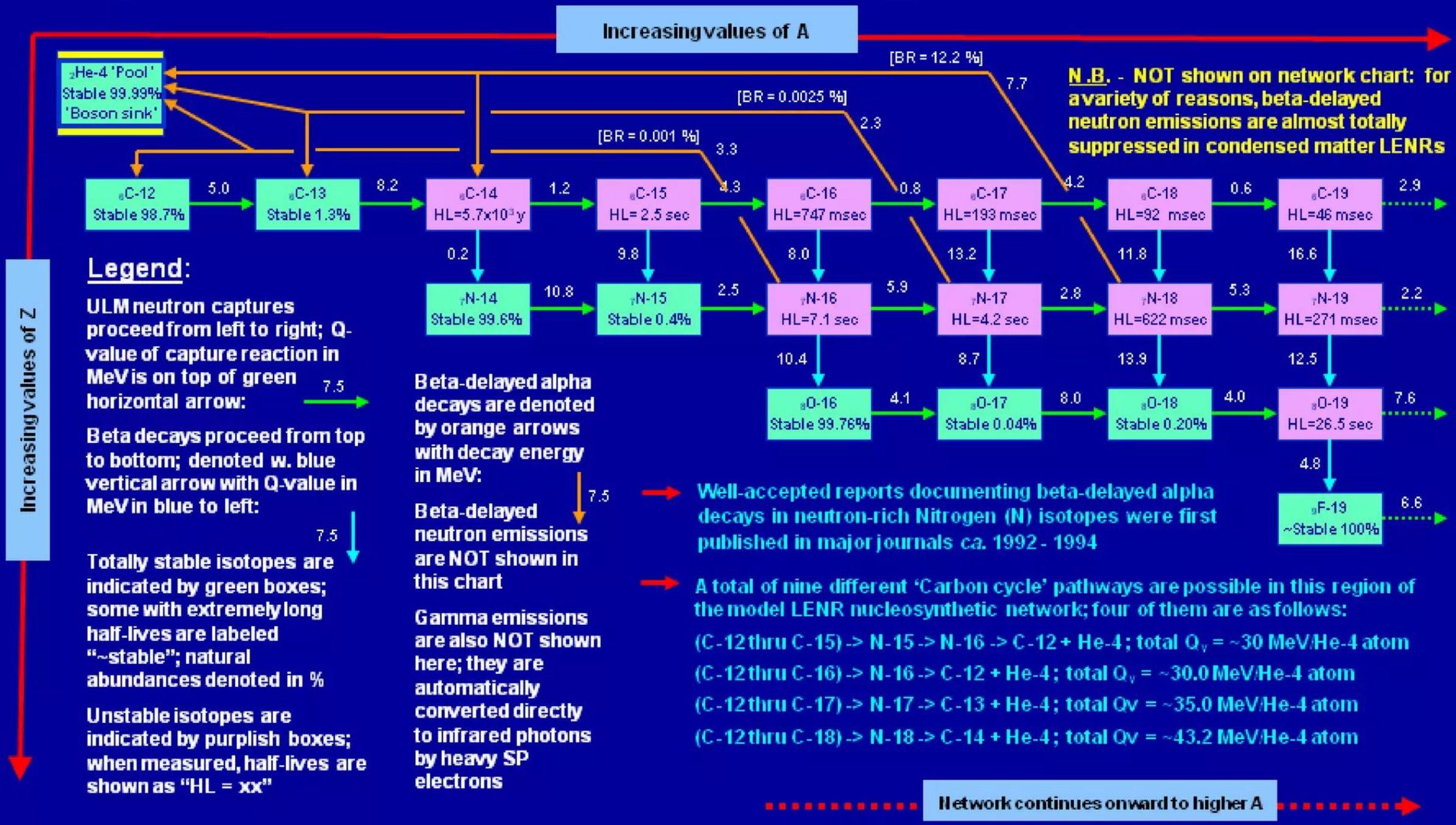
Carbon $_6C^{12}$ seed CLENR transmutation network - I

Capture on carbon 'seed', neutron-rich isotope production, and related decays



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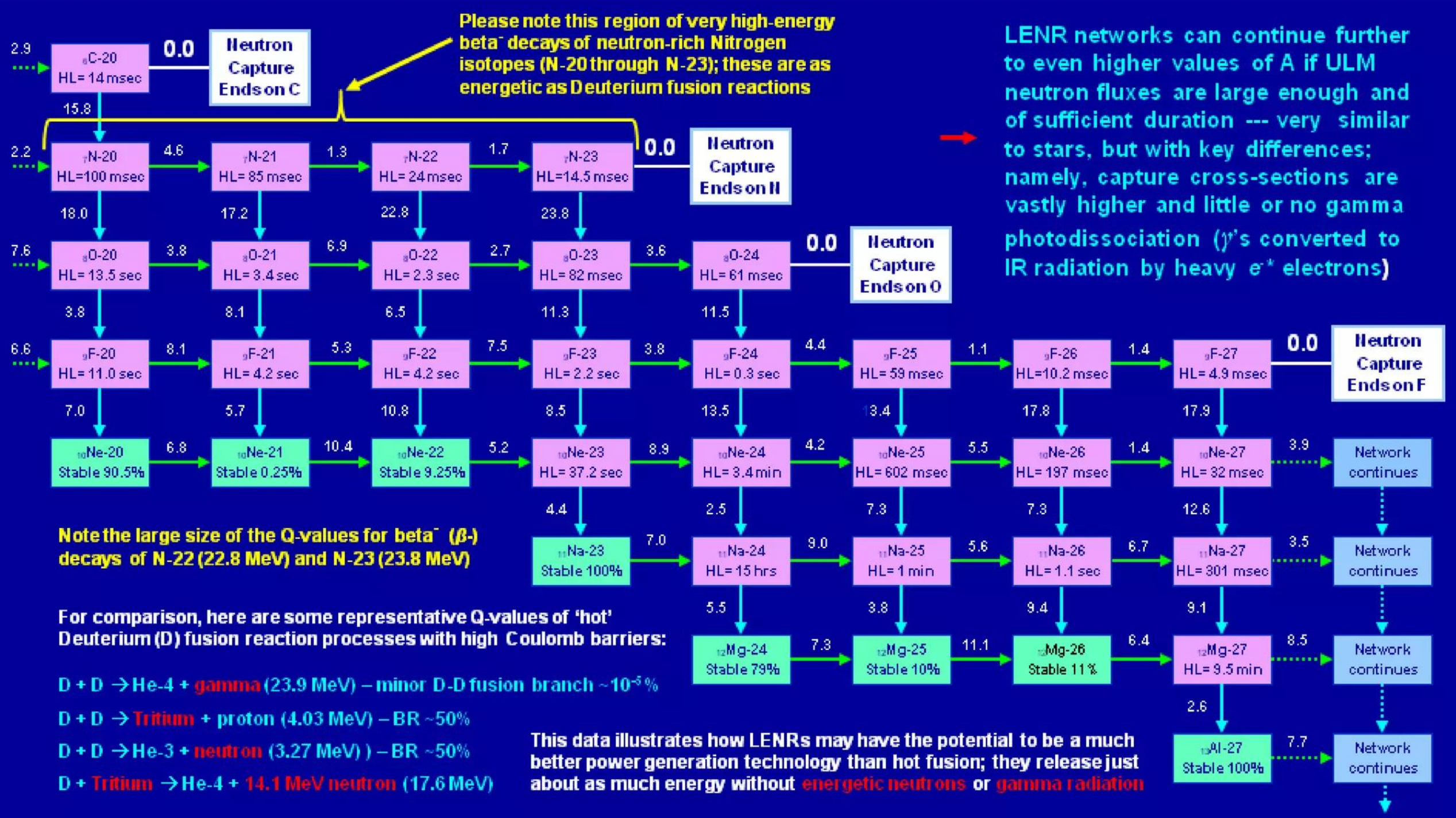
Carbon $_6C^{12}$ seed CLENR transmutation network - II



LENR networks can continue further to even higher values of A if ULM neutron fluxes are large enough and of sufficient duration --- very similar to stars, but with key differences; namely, capture cross-sections are vastly higher and little or no gamma photodissociation (γ's converted to IR radiation by heavy e^{-*} electrons)

Note the large size of the Q-values for beta⁻ (β^-) decays of N-22 (22.8 MeV) and N-23 (23.8 MeV)

For comparison, here are some representative Q-values of 'hot' Deuterium (D) fusion reaction processes with high Coulomb barriers:

- D + D → He-4 + gamma (23.9 MeV) – minor D-D fusion branch ~10^{-5} %
- D + D → Tritium + proton (4.03 MeV) – BR ~50%
- D + D → He-3 + neutron (3.27 MeV)) – BR ~50%
- D + Tritium → He-4 + 14.1 MeV neutron (17.6 MeV)

This data illustrates how LENRs may have the potential to be a much better power generation technology than hot fusion; they release just about as much energy without energetic neutrons or gamma radiation

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Carbon $_6C^{12}$ seed CLENR transmutation network - III

Nine different 'carbon cycle' pathways can occur in this partial network

- ✓ **Model nucleosynthetic network shown has a total of nine possible pathways that function as 'leaky' carbon cycles, regenerating C-12, or C-13, or C-14 and producing one He-4 atom (alpha particle) per cycle**
- ✓ **Total 'raw' Q-values for the model's 9 different carbon cycles range from ~30.0 MeV/He-4 to ~43.2 MeV/He-4; when you adjust for the energetic 'cost' of making ULM neutrons, net Q_vs range from ~28.4 to ~40.9 MeV/He-4**
- ✓ **These LENR carbon cycles are 'leaky' in that they are an incidental byproduct of a ULM neutron-driven CLENR transmutation network that is constantly 'trying' to produce stable nuclei at higher and higher values of A**
- ✓ **He-4 is a boson; has no 'Fermi pressure' issues with occupied local states like neutrons and electrons. Can serve as a 'bosonic sink' in LENR systems; also can readily leave nuclear-active sites in the form of a gas**
- ✓ **LENR carbon cycles will continue to operate as long as ULM neutrons are available to 'drive' reaction network**

→ ***Please see the Wikipedia article about the CNO 'carbon cycle' in stars at: http://en.wikipedia.org/wiki/CNO_cycle***

In stars hotter and more massive than our sun, CNO-I cycle produces 26.77 MeV/He-4

→ ***Adjusted net Q_vs (assume D used to make ULM neutrons; 'gross' Q_v is adjusted to reflect an input energy 'cost' of 0.39 MeV/neutron) for the model's nine different carbon cycle pathways are calculated as follows (in MeV): 40.86, 40.86, 33.05, 40.76, 32.95, 28.44, 40.76, 32.95, and 28.44/He-4***

Note: some pathways have identical net Q_v

→ ***Based on branching values measured in isolated RNB fragments (12.2% for N-18) the four ~40 MeV paths might appear to be most probable. However, it appears very likely that these branching ratios could have very different values in operating LENR systems; for discussion purposes, let's assume that is true. Note that model's Q_vs fall into two groups: four high-energy paths (avg. net Q_v = 40.81) and five lower-energy paths (avg. net Qv = 31.17 MeV/He-4). A simple average of the two group average Q_vs is 35.99 MeV/He-4. Also note: all values larger than CNO-I hot fusion in stars***

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Fission and fusion vs. CLENR transmutation networks

CLENRs potentially much better than fission or fusion technologies

- ✓ **Good news about Uranium and Plutonium fission reactions is that they have Q_vs of ~190$^+$ MeV, releasing most of their energy on a time scale of ~10^{-19} seconds in the form of prompt neutron and gamma radiation as well as fast moving, neutron-rich, asymmetric fission fragments comprising unstable products that undergo further decays; bad news is production of large quantities of prompt 'hard' MeV radiation and hazardous long-lived radioactive isotopes; massive, expensive shielding is mandatory**

- ✓ **Good news about 'cleaner' (relative to fission) D-T fusion reactions in commercial power reactors is Q_v of ~17.6 MeV; bad news is that much of the energy released is in the form of hard to manage 14.1 MeV neutrons along with gammas and neutron-induced radioactivity in apparatus; huge temps create big engineering problems**

- ✓ **Good news about LENR-based nucleosynthetic networks is that they do not produce biologically significant quantities of hard gamma/neutron radiation or hazardous long-lived radioactive isotopes; in contrast to fission/fusion, no bad news for CLENRs**

- ✓ **Many scientists mistakenly believe that 'weak' interactions are weak energetically; that view is incorrect. In the Carbon-seed CLENR transmutation network shown, N-17 and N-18 beta$^-$ decays release 22.8 and 23.8 MeV, respectively; this is comparable to fusion reactions but without any need for enormous temperatures and pressures.** ***Little or no shielding, containment, or clean-up would be needed for CLENR systems.***

Lattice Energy LLC

Do conjectured $_6C^{12}$ seed CLENR networks exist? - I

Have already been observed in laboratory experiments and in Nature

Early reports involved electric arc discharge experiments published in mid-1990s

1994: Texas A&M University and BARC experiments with carbon-arcs in H_2O - I

- ✓ **For detailed references and in-depth discussion of these fascinating experiments see:**

Technical Overview - Carbon Seed LENR Networks **[specifically see Slides #38 - 56]**
Lewis Larsen, Lattice Energy LLC, September 3, 2009 [65 slides – not refereed]

Includes reanalysis of SRI Case Pd/D/C experiments - W-L theory predicts MeV/He-4 results within ~1% - much more accurate than any D-D fusion hypothesis; explains carbon-arc/H_2O transmutation experiments conducted in 1990s at Texas A&M University (Chemistry Dept.) and Bhabha Atomic Research Center (India) that were published in the ANS journal, *Fusion Technology*

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009

These two sets of extraordinarily similar experiments were reported in *Fusion Technology* (name since changed to *Fusion Science and Technology*), a peer-reviewed technical journal still published by the American Nuclear Society as follows:

"Anomalous reactions during arcing between carbon rods in water"
R. Sundaresan and J. O'M. Bockris
Fusion Technology 26 pp. 261 - 265 1994

"Verification of the George Oshawa experiment for anomalous production of iron from Carbon arc in water"
M. Singh, M. Saksena, V. Dixit, and V. Kartha
Fusion Technology 26 pp. 266 - 270 1994

Lattice Energy LLC

Do conjectured $_6C^{12}$ seed CLENR networks exist? - II

Have already been observed in laboratory experiments and in Nature

First apparently observed in electric arc discharge experiments published in mid-1990s

1994: Texas A&M and BARC experiments with carbon-arcs in H_2O - II

- ✓ **Conclusions re *Fusion Technology* papers: in all their experimental procedures, these researchers took extraordinary precautions to try to eliminate and/or control potential sources of elemental contamination that could create 'false positives' in their assays for presence of potential CLENR transmutation products.**

  In both *Fusion Technology* papers, reported data suggests it is likely that Iron (Fe) was produced as a nuclear transmutation product arising from Carbon 'seed nuclei' present in ultra-pure graphite rods used as electrodes in high-current underwater electrical arcing experiments.

  In the case of BARC experiments #1 - 3, production of anomalous "*excess iron*" occurred in parallel with production of significant amounts of anomalous Ni and Cr, neither of which were present in any materials within the apparatus at the beginning of experiments. By any reasonable standard, simultaneous production of all three anomalous elemental products within less than six hours of arcing in apparatus containing compositionally well-characterized materials appears to be strong experimental evidence for operation of nucleosynthetic transmutation pathways C → Cr → Fe → Ni, which can occur in the Carbon $_6C^{12}$ seed CLENR network

  Additional tip-off that WLT mechanism was involved: following earlier work *ca*. 1965 by Oshawa, S&B verified that anomalous Fe production did not occur when liquid H_2O was replaced with Nitrogen gas. Mistakenly believing that the nuclear process in their carbon-arcs was C-O fusion, they thought that the absence of Oxygen had prevented fusion reactions from occurring; Sundaresan & Bockris did not realize what was *really* needed were the protons found in water --- per the WLT, protons are a crucial reactant required to make neutrons: $e + p \rightarrow n + \nu$

- ✓ **If these data are correct, the *only way* that Fe can be produced from Carbon as quickly as was seen (i.e., becoming analytically detectable within an hour or two) is via network pathways that involve extremely neutron-rich isotopes and only if the Carbon $_6C^{12}$ seed CLENR transmutation network were in fact operating.**

Lattice Energy LLC

Do conjectured $_6C^{12}$ seed CLENR networks exist? - III

Have already been observed in laboratory experiments and in Nature

Additional experimental evidence in very different type of system reported in late-1990s

1999: Replication of earlier Case experiment by McKubre at SRI - I

- ✓ **For detailed references and in-depth discussion of these interesting experiments see:**

  Technical Overview - Carbon Seed LENR Networks [specifically see Slides #19 - 37]
  Lewis Larsen, Lattice Energy LLC, September 3, 2009 [65 slides – not refereed]

  Includes reanalysis of SRI Case Pd/D/C experiments - W-L theory predicts MeV/He-4 results within ~1% - much more accurate than any D-D fusion hypothesis; explains carbon-arc/H_2O transmutation experiments conducted in 1990s at Texas A&M University (Chemistry Dept.) and Bhabha Atomic Research Center (India) that were published in the ANS journal, *Fusion Technology*

  http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009

- ✓ **This data was reported in conference papers (never published in a refereed journal) and in a document specially prepared for a DOE Review of the field that occurred in 2004:**

  "The emergence of a coherent explanation for anomalies observed in D/Pd and H/Pd system: Evidence for ^4He and ^3He production," M. McKubre *et al.*. ICCF-8 Conference, Lerici, Italy (2000)

  http://www.lenr-canr.org/acrobat/McKubreMCHtheemergen.pdf

  Re DOE Review document also see: P. Hagelstein et al., "*New physical effects in metal deuterides*" (see Section 3. "*Helium and excess heat*" on pp. 7 - 10, especially Fig. 6 on pp. 8 showing helium increase vs. estimated energy, as well as the long discussion found in Appendix B. "*Results for the Case experiment at SRI*" from pp. 18 - 21)

  http://www.lenr-canr.org/acrobat/Hagelsteinnewphysica.pdf

Lattice Energy LLC

Do conjectured $_6C^{12}$ seed CLENR networks exist? - IV

Have already been observed in laboratory experiments and in Nature

Additional experimental evidence in very different type of system reported in late-1990s

1999: Replication of earlier Case experiment by McKubre at SRI - II

- ✓ **Goals of Case replication experiments at SRI were to measure the following parameters over the duration of a given experiment: (a.) excess heat with calorimetry; and (b.) production of Helium (He-4) with mass spectrometry – by design, no other types of nuclear transmutation products were measured or assayed during the experiments. Measured excess heat production was found to be correlated with He-4 production.**

Commercial preparations of 'activated' Carbon powder (ordinary charcoal, containing 0.4 - 0.5% of finely-divided, nano/micron-sized particles of Pd) were placed in steel vessels, after which they were filled with D_2 or H_2 gas under 1- 3 atm. of pressure and sealed tightly. They were then heated up to 170 - 250º C and left to 'cook' for up to 45^+ days inside a sealed stainless steel reaction vessel. Heat evolution was measured continuously with calorimetry; Helium-4 production was measured either by taking samples at intervals or at the end of a given experiment

N.B. - common factor among stainless steel reaction vessels is that, on some length scales, resonant electromagnetic (E-M) cavities exist inside all of them. According to the WLT, under exactly the right conditions, when such vessels also happen to contain hydrogen isotopes in some chemical form in the presence of certain metallic catalysts (e.g., Ni, Pd, Pt, etc.) and/or aromatic rings, in conjunction with application of thermal energy (heating a vessel), and/or increasing operating pressures, and passage of sufficient time, CLENR transmutation networks can form spontaneously and operate as long as nonequilibrium energy inputs and/or reactants persist. Thus, transmutation products, e.g., C-13, N-15, and He-4 may be produced in parallel with other products of ordinary chemical reactions

- ✓ **McKubre *et al.* reported measured values of 31 and 32 MeV/He-4, both +/-13 MeV (avg. 31.5 MeV/He-4). Those particular values are well-explained by assuming that these experiments operated in lower-energy group of CLENR carbon-seed network cycles discussed on Slide #28 of this document. Assuming equal participation of those network segments, WLT would predict value = ~31.2 MeV/He-4, in good agreement with observation.**

Lattice Energy LLC

Do conjectured $_6C^{12}$ seed CLENR networks exist? - V

Have already been observed in laboratory experiments and in Nature

Experiments involving aromatic carbon ring molecules w. reactor similar to 1999 SRI

2008: Mizuno reports transmutations w. Phenanthrene (PAH) and Pt catalyst system - I

- ✓ **For detailed references and in-depth discussion of these interesting experiments see:**

Technical Overview - PAHs and LENRs [specifically see Slides #26 - 40]
Lewis Larsen, Lattice Energy LLC, November 25, 2009 [61 slides - not refereed]

Condensed matter nuclear science meets chemistry - Mizuno experiments with polycyclic aromatic hydrocarbon (PAH - phenanthrene). Aromatic fractions found in oil sands' bitumen might someday be transmuted directly as 'green' LENR nuclear fuels; worth many times more that way that burning it via combustion with O_2

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

This data was reported in conference papers (never published in a refereed journal) :

"*Anomalous heat generation during hydrogenation of carbon (phenanthrene)* " T. Mizuno and S. Sawada, ICCF-14 Conference, Washington, DC (2008)

http://www.lenr-canr.org/acrobat/MizunoTanomaloushb.pdf

A differently reported version can be found in: H. Kozima and T. Mizuno, "*Nuclear transmutations in hydrocarbons: polyethylene (XLPE) films and phenanthrene on Pt mesh substrate*," *Reports of CFRL* (Cold Fusion Research Laboratory), 8-4, pp. 1 - 18, October 2008

http://www.geocities.jp/hjrfq930/Papers/paperr/paperr18.pdf

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Do conjectured $_6C^{12}$ seed CLENR networks exist? - VI

Have already been observed in laboratory experiments and in Nature

Experiments involving aromatic carbon ring molecules w. reactor similar to 1999 SRI

2008: Mizuno reports transmutations w. Phenanthrene (PAH) and Pt catalyst system - II

- ✓ **Primary goals of the experiments were to measure: (a.) excess heat with crude calorimetry based on temperature differentials observed between 4 calibrated R-type thermocouples (87% Pt; 13% Rh); (b.) nuclear transmutation products using an ULVAC REGA201 mass spectrometer; and (c.) high energy photon (X-ray or gamma) emissions, if any, using an Aloka TCS-161 NaI scintillation detector**

  Solid phenanthrene (1 gram- 99.5% pure) and Pt "catalyzer" (5 cm x 10 cm rectangular mesh weighing ~27.8 gms - 99.99% pure) were placed into stainless steel reactor vessel; top lid was then bolted shut. Hydrogen gas (99.99% pure: impurities in ppm were O_2 = 5; N_2 = 50; CO = 1; CO_2 = 21; hydrocarbons <1) was then admitted into the reactor vessel (Inconel 625 is 56 mm OD, 26 mm ID, 160 mm in length, 0.1 L volume, rated for 500 atm; SUS 316L vessel is 15 mm OD, 9 mm ID, 300 mm in length, 0.02 L volume, rated for <200 atm) experimental pressures ranged from 37 - 60 atm

  After filling with pure hydrogen, an Inconel 625 or SUS 316L reactor vessel was heated with 2 kW electric furnace; maximum temperatures reached was ~700^o C. Reactor vessel then allowed to 'cook' at various temperatures for varying periods ranging up to ~10 days. During that time, heat production and radiation were monitored. At the end of a given experiment, gas and residues remaining in the metallic reactor vessel were analyzed with mass spectroscopy

  Relatively large produced quantities of N-14 (Nitrogen, N_2) observed in these experiments likely result from a CLENR transmutation process; Mizuno's great care in rigorously characterizing compositions of materials as well as high pressures inside the reaction vessels mitigate strongly against possibility that anomalous Nitrogen observed resulted from some type of external N_2 contamination. Substantial production of stable Carbon-13 was also observed

- ✓ **While minor details are still unclear, the array of transmutation products observed in Mizuno's Phenanthrene experiments appear to be consistent with what would be expected from the operation of a Carbon $_6C^{12}$ seed CLENR transmutation network. Given their potential importance, expts. should be repeated by third parties.**

Lattice Energy LLC

Do conjectured $_6C^{12}$ seed CLENR networks exist? - VII

Have already been observed in laboratory experiments and in Nature

Other publications reporting significant isotopic shifts involving crude oil or coal

Publication: **"*Hydrous pyrolysis of crude oil in gold-plated reactors,"*** J.A. Curiale *et al*., *Organic Geochemistry* **18** pp. 745 - 756 (1992)

Also see related Lattice document: ***"Mystery of the missing Nickel and Vanadium,"*** L. Larsen (2011) at: http://www.slideshare.net/lewisglarsen/lattice-energy-lcc-mystery-of-the-missing-nickel-and-vanadiumnov-6-2011

Comment: natural V and Ni trace metals anomalously disappear from crude oil samples undergoing pyrolysis at high temperatures in Gold-lined sealed steel reactor vessel ; in Iraq oil, significant Carbon-13 isotopic shifts occurred in parallel with disappearance of metals. *Please see in-depth discussion found in above SlideShare document.*

Publication: ***"Isotope effects in plasma arcing experiments with various Carbon anodes,"*** L. Pang *et al*., *Energy & Fuels* **9** pp. 704 - 706 (1995)

Comment: laboratory experiments involved arcing samples of high-moisture brown coal from the Loy Yang mine in Australia in Helium gas; they then measured shifts in Carbon-13 under various experimental conditions. Quoting directly, *" ... A number of groups including ours have shown that if reactive gases, e.g., hydrogen, methane, and chlorine, are added to helium, polynuclear aromatics ... formed in the soot."* They concluded that, *" ... during the process the coal must become isotopically heavy during pyrolysis ..."* and that the, *" ... applied current appears to affect this fractionation."* So is it "fractionation" or CLENR transmutation?

Publication: ***"Potential of stable Nitrogen isotope ratio measurements to resolve fuel and thermal NO_x in coal combustion,"*** C. Snape *et al*., *Fuel Chemistry Division Prep*rints **48** pp. 3 - 5 (2003)

Comment: measured Nitrogen-15 isotope shifts in NO_x derived from burning liquid transport fuels vs. NO_x derived from combustion of coal char and found very significant differences (BTW: unlike coal, transport fuels *by design* contain vary low levels of aromatics). Fascinating isotopic data is published in this paper. Quoting, *"... Pyrolysis chars from each coal were prepared in the drop tube reactor ... In all cases, the nitrogen stable isotope ratios of the chars are heavier than those of coals and range from 3 to 7 ‰."* In other words, Nitrogen got isotopically heavier when coal samples were pyrolyzed. Finally, they concluded that, "*differences of up to ca. 20 ‰ can exist between thermal and PF fuel (char) NOx isotopic values.*" In other words, Nitrogen isotopes got heavier when coal was involved vs. just truck fuel being burned in air. Again, is it simply chemical "fractionation" or CLENR transmutation?

Lattice Energy LLC

Do conjectured $_{6}C^{12}$ seed CLENR networks exist? - VIII

Have already been observed in laboratory experiments and in Nature

- ✓ **Summary: we have just reviewed selected experimental data involving high-current underwater electric arcs with Carbon electrodes, as well as ordinary stainless steel reaction vessels that only use metals, hydrogen, temperature, pressure, and passage of time to trigger transmutations. Altogether, these seemingly disparate experimental results suggest that conjectured $_{6}C^{12}$ seed CLENR networks do exist and operate in laboratory systems.**

  At this juncture, it should also again be carefully noted that hydrogen-loaded metallic hydrides are not the only types of substrate surfaces on which the Born-Oppenheimer Approximation breaks down and CLENRs may be triggered with appropriate types of nonequilibrium energy inputs. Earlier, on Slide #11 we said that, " ... delocalized collectively oscillating π electrons that comprise the outer 'covering surfaces' of fullerenes, graphene, benzene, and polycyclic aromatic hydrocarbon (PAH) molecules behave very similarly to surface plasmon electrons; when such molecules are hydrogenated, they can create many-body, collectively oscillating, 'entangled' quantum systems that, within context of W-L theory, are functionally equivalent to loaded metallic hydrides." In previously released Lattice SlideShare technical documents we have provided detailed explanations about how the Widom-Larsen theory can be conceptually extended to cover such cases; see:

  Technical Overview - Carbon Seed LENR Networks Sept. 3, 2009 [specifically see Slides #58 - 60]

  Technical Overview - PAHs and LENRs, Nov. 25, 2009 [specifically see Slides #42 - 45]

- ✓ **In the case of 1990s carbon-arc experiments, CLENRs were likely triggered on hydrogenated fullerene and/or graphene nanostructures; in the 1999 SRI experiments, Carbon atoms (in close proximity to Deuterium-loaded Pd nanoparticles) captured ULMN neutrons; and finally in the 2008 Phenanthrene experiments, ULMN neutrons were produced directly on aromatic molecules and captured by Carbon atoms comprising the 'host' six-carbon aromatic rings.** ***Since we are interested in coal herein, we will now focus on the aromatic case in more detail.***

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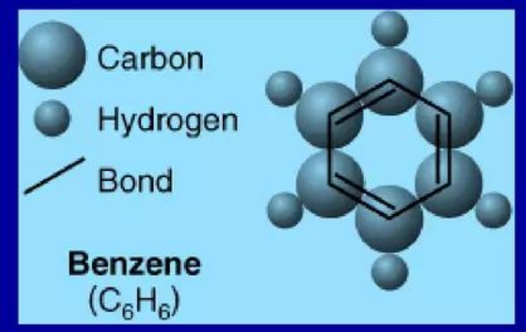
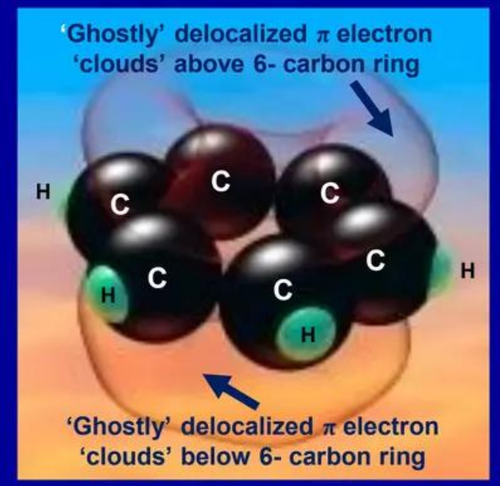
Widom-Larsen theory extends to aromatic carbon rings

Aromatic hydrocarbons adsorbed on metallic surfaces - I

✓ **Hypothesis is as follows:**

- Delocalized π electrons found above and below 6-carbon benzene (aromatic) ring structures, that also happen to be in very close physical proximity to protons (hydrogen atoms directly attached to the ring's carbon atoms), all oscillate collectively;
- Hydrogen atoms (protons) that are also attached to the ring structure's carbon atoms also oscillate collectively with each other;
- Quantum mechanical wave functions of aromatic ring π electrons and attached ring protons are thus, respectively, effectively entangled;
- There is a local breakdown of the Born-Oppenheimer approximation in and around aromatic ring structures that enables electromagnetic (E-M) coupling and energy transfers between collectively oscillating ring structure π electrons and nearby protons, creating very high nanoscale electric fields;
- When an aromatic structure is adsorbed onto the surface of a metallic catalyst, it spontaneously orients itself as it approaches so that the 'flat surface' of the carbon ring itself is parallel to the catalyst's 'flat' surface. Born-Oppenheimer also breaks down there, enabling further E-M coupling and energy transfers between C-ring π electrons and a 'sea' of surface plasmon polariton (SP) electrons covering the entire catalyst surface;
- This situation is analogous to what happens when CLENRs occur with SP electrons that are found on loaded metallic hydride surfaces. In this case, the entire carbon ring structure effectively becomes a many-body, LENR active 'patch' in which ULM neutrons can be produced collectively via the weak interaction; ULM neutrons tend to capture on nearby ring Carbons.





Benzene showing π electron 'clouds': π electrons, carbon atoms and protons (H) all in very close physical proximity

Unsaturated phenanthrene ($C_{14}H_{10}$)

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Widom-Larsen theory extends to aromatic carbon rings

Aromatic hydrocarbons adsorbed on metallic surfaces - II

✓ **Present evidence for the hypothesis is as follows:**

- **Born-Oppenheimer approximation is now known to break down on surfaces of carbon fullerene structures and graphene (directly observed by Bushmaker et al, 2009);**
- **Carbon-arc experiments of Bockris & Sundaresan and Singh et al. provide evidence that the WLT carbon-seed CLENR transmutation network can occur in presence of complex mixtures of fullerenes/graphene (Larsen 9/3/09)**
- **Born-Oppenheimer is well known to break down on metal surfaces; quoting Yale Prof. John Tully, "Breakdown of the Born-Oppenheimer assumption is the rule rather than the exception in electron transfer reactions, photochemistry, and reactions at metal surfaces." (please see his website at right)**
- **Born-Oppenheimer is also known to break down on benzene rings in conjunction with quantum entanglement of protons on those rings (see Chatzidimitriou- Dreismann & Mayers, 2002). Quoting from their paper, "… our NCS results …indicate that the physical meaning of … Born-Oppenheimer [approximation] should be critically reconsidered … at least for chemical processes in the …femtosecond time scale … [we also] demonstrate that short-lived protonic quantum entanglement and decoherence are of much broader significance than realized thus far."**

→ Bushmaker et al., *"Direct observation of Born-Oppenheimer approximation breakdown in carbon nanotubes"* in *Nano Letters* 9 (2) pp. 607 (2009)

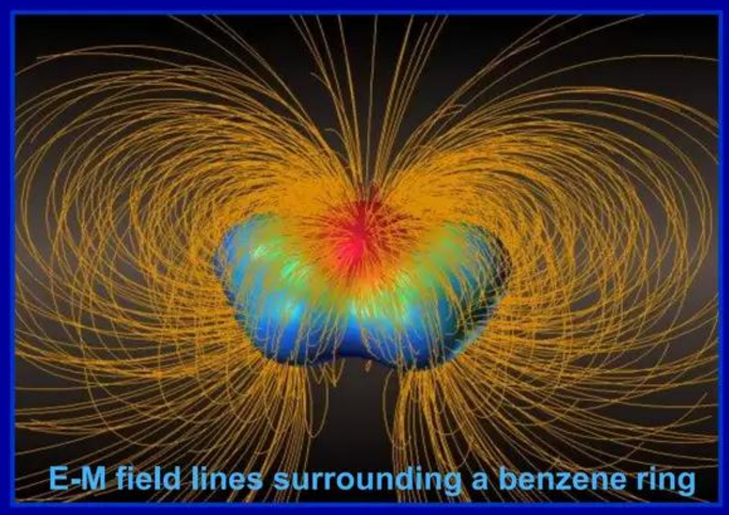
→ See Lattice Energy LLC SlideShare presentation dated September 3, 2009, at:

http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewcarbon-seed-lenr-networkssept-3-2009

→ See Prof. John Tully's Yale website at:

http://www.chem.yale.edu/~tully/research.html

→ Chatzidimitriou- Dreismann & Mayers, *"Sub-femtosecond dynamics and dissociation of C-H bonds in solid polystyrene and liquid benzene," Journal of Chemical Physics* 116 (4) pp. 1617-1623 (2002)



E-M field lines surrounding a benzene ring

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Widom-Larsen theory extends to aromatic carbon rings

Aromatic hydrocarbons adsorbed on metallic surfaces - III

✓ **Present evidence for the hypothesis (continued):**

Protons found within a wide variety of many-body molecular systems spontaneously oscillate coherently/collectively; their quantum mechanical (QM) wave functions are thus effectively entangled with each other and also with nearby collectively oscillating electrons; amazingly, this behavior occurs even in comparatively 'smaller,' 'simpler' molecular systems such as $(NH_4)_2PdCl_6$, ammonium hexachlorometallate (see Krzystyniak *et al.,* 2007 and Abdul-Redah & Dreismann, 2006). Quoting from the paper by Krzystyniak et al., "… different behaviors of the observed anomaly were found for LaH_2 and LaH_3 … As recognized by Chatzidimitriou-Dreismann et al. Coulombic interaction between electrons and protons may build up entanglement between electrons and protons. Such many body entangled states are subject to decoherence mechanisms due to the interaction of the relevant scattering systems with its environment … one can conclude that the vibrational dynamics of NH_4^+ protons as fairly well decoupled from the dynamics of the [attached] heavier nuclei."

✓ **Elaborating (Chatzidimitriou-Dreismann, 2005), "Further NCS experiments confirmed the existence of this effect in quite different condensed matter systems, e.g., urea dissolved in D_2O, metallic hydrides, polymers, 'soft' condensed matter, liquid benzene, and even in liquid H_2-D_2 and HD." N.B. - this is an important observation.**

→ Krzystyniak et al., *"Anomalous neutron Compton scattering cross sections in ammonium hexachlorometallates," Journal of Chemical Physics* **126** pp. 124501 (2007)

→ Abdul-Redah & Chatzidimitriou-Dreismann, *"Irreversible hydrogen quantum dynamics and anomalous scattering behavior in liquids and solids," International Journal of Hydrogen Energy* **31** pp. 269 - 276 (2006)

→ *Chatzidimitriou-Dreismann, "Attosecond protonic quantum entanglement in collision experiments with neutrons and electrons" Laser Physics* **15** (6) (4) pp. 780 -788 (2005)

→ Please also see a book chapter by Chatzidimitriou-Dreismann et al., *"Attosecond effects in scattering of neutrons and electrons from protons", in Decoherence, Entanglement, and Information Protection in Complex Quantum Systems* Akulin *et al.* eds., NATO Science Series II Vol. 189 Springer Netherlands (2005)

With regard to the dynamics and orientation of benzene molecules and polycyclic aromatic hydrocarbons as they are adsorbed on a metallic catalyst's surface please see:

→ S. J. Jenkins, *"Aromatic adsorption on metals via first-principles density functional theory," Proceedings of the Royal Society* **465** pp. 2949 - 2976 (2009) – quoting, "[Benzene] adopts a flat-lying … geometry, binding to the surface through donation of electrons through one or both of its degenerate HOMOs and back-donation into one or both of its two degenerate LUMOs."

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Widom-Larsen theory extends to aromatic carbon rings

Aromatic hydrocarbons adsorbed on metallic surfaces - IV

✓ **Many-body collective oscillations and quantum entanglement of protons (as well as deuterons and tritons) and electrons (e.g., SPPs on metallic surfaces), in conjunction with a breakdown of the Born-Oppenheimer approximation, appear to be relatively common in nature, occurring in many different types of systems**

While these many-body collective processes chronicled by Chatzidimitriou-Dreismann et al. operate very rapidly and nanoscale coherence can only persist for time spans on the order of femtoseconds (10^{-15} sec) to attoseconds (10^{-18} sec), nuclear processes such as weak interaction ULM neutron production and neutron capture operate on even faster time-scales: 10^{-19} to 10^{-22} sec. Therefore, CLENRs as explained by the Widom-Larsen theory can easily take advantage of such many-body collective quantum effects as an integral part of their amazing dynamical repertoire

✓ **It is well-known that metallic surface nanostructures and SP electrons can have configurations that are able to effectively absorb E-M energy over a wide area, transfer and concentrate it, and in conjunction with contiguous surface 'patches' of collectively oscillating protons, create extremely high local electric fields. According to W-L theory, ULM neutron production may then follow. If Mizuno is proven correct and aromatic organic molecules can support LENRs, it further bridges a long-assumed energetic gulf between chemical and nuclear processes, reuniting chemistry with modern 'alchemy' after 300 years of rancor and estrangement**

→ C. A. Chatzidimitriou-Dreismann (Technical University of Berlin) and his collaborators have published extensively on collective proton dynamics since 1995. Please also see:

→ *"Attosecond quantum entanglement in neutron Compton scattering from water in the keV range"* (2007); can be found at

http://arxiv.org/PS_cache/cond-mat/pdf/0702/0702180v1.pdf

"Several neutron Compton scattering (NCS) experiments on liquid and solid samples containing protons or deuterons show a striking anomaly, i.e. a shortfall in the intensity of energetic neutrons scattered by the protons; cf. [1, 2, 3, 4]. E.g., neutrons colliding with water for just 100 − 500 attoseconds (1 as = 10^{-18} s) will see a ratio of hydrogen to oxygen of roughly 1.5 to 1, instead of 2 to 1 corresponding to the chemical formula H_2O. … Recently this new effect has been independently confirmed by electron-proton Compton scattering (ECS) from a solid polymer [3, 4, 5]. The similarity of ECS and NCS results is striking because the two projectiles interact with protons via fundamentally different forces, i.e. the electromagnetic and strong forces."

→ Also, J. D. Jost *et al., "Entangled mechanical oscillators" Nature* 459 pp. 683 – 685 (4 June 2009), in which "... mechanical vibration of two ion pairs separated by a few hundred micrometres is entangled in a quantum way."

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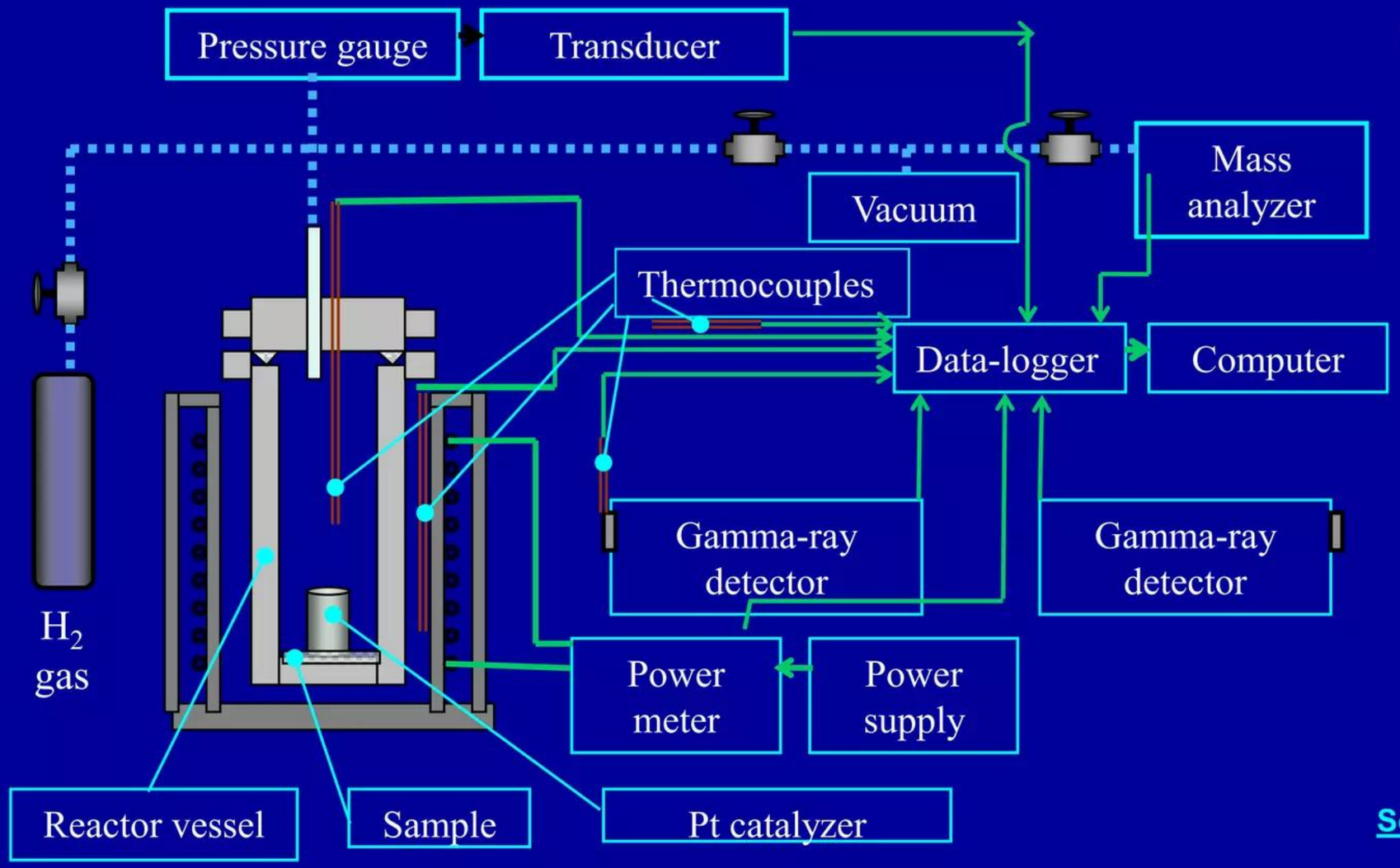
Mizuno triggered CLENRs using this ordinary apparatus

Schematic diagram of Mizuno's experimental setup



Photos of both SS reactor vessels

Source: Mizuno ICCF-14 presentation

Note: graphic adapted from Mizuno's 2009 ICCF-15 conference presentation

Source: T. Mizuno, ICCF-15 Presentation, Frascati, Italy October 2009, at http://iccf15.frascati.enea.it/ICCF15-PRESENTATIONS/S7_O8_Mizuno.pdf

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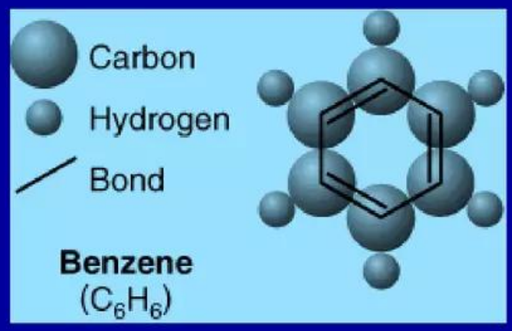
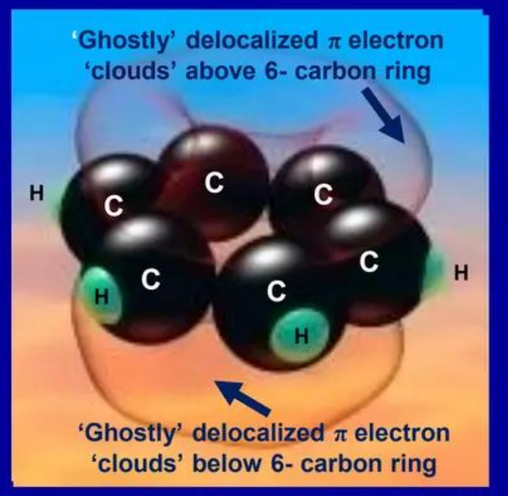
Mizuno: H_2 'loading' of Phenanthrene with Pt catalyst

Under certain conditions transmutation can accompany hydrogenation

- ✓ **These are very innovative and different types of CLENR experiments; have not previously been reported in the field**
- ✓ **Showed that hydrogenation of very common type of polycyclic aromatic hydrocarbon, phenanthrene, appears to be associated with $_6C^{12}$ seed CLENR networks and transmutations**



Phenanthrene is member of large family of C-H organic molecules: polycyclic aromatic hydrocarbons (PAHs); they are distinguished by having from two up to ten 6-carbon benzene rings bonded along their 'edges' – are pollutants produced during incomplete combustion of hydrocarbons, e.g., industrial processes such as pyrolysis



Benzene showing π electron 'clouds': π electrons, carbon atoms and protons (H) all in very close physical proximity

Unsaturated phenanthrene has the chemical formula $C_{14}H_{10}$; additional hydrogen atoms (effectively protons) can be added to 'load' or 'saturate' its three benzene rings via catalytically assisted hydrogenation which consists of heating solid phenanthrene under pressure in the presence of hydrogen gas and a Pt catalyst in a sealed stainless steel reactor vessel (functions as a resonant E-M cavity)

- ✓ **Assisting hydrogenation of aromatic molecules is one role of Pt in Mizuno's experiments; in this system it is analogous to loading H/D into Palladium (Pd) cathode in an electrolytic cell**

Unsaturated phenanthrene ($C_{14}H_{10}$)

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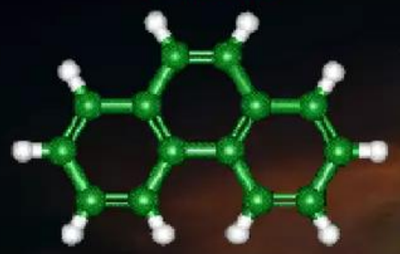
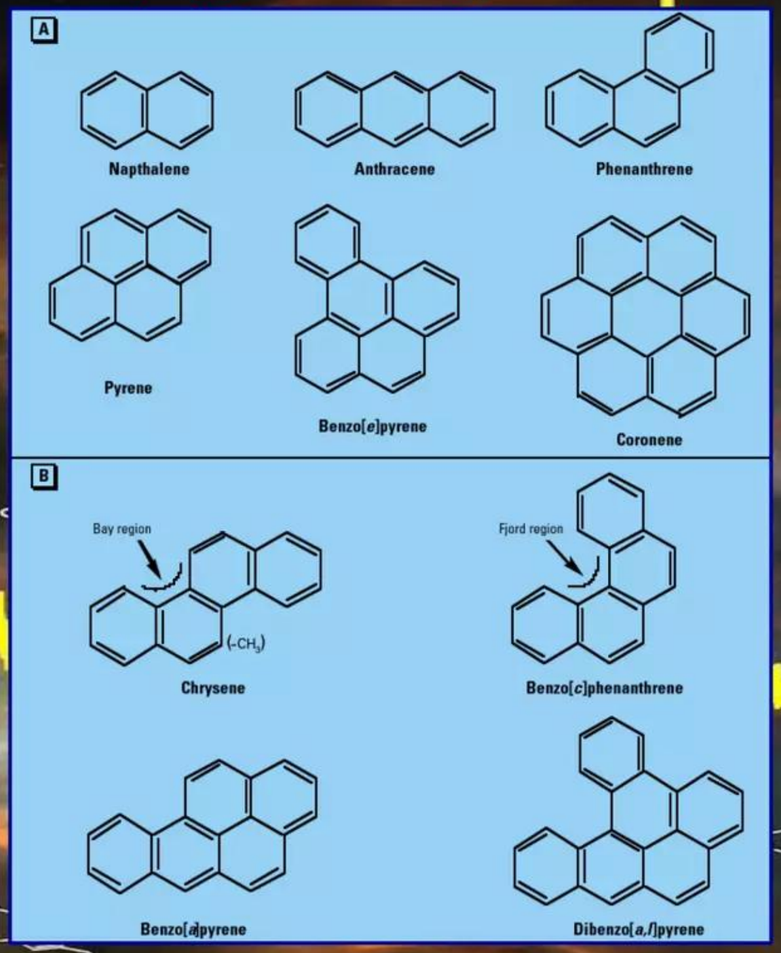
Aromatic carbon ring compounds very common in Nature

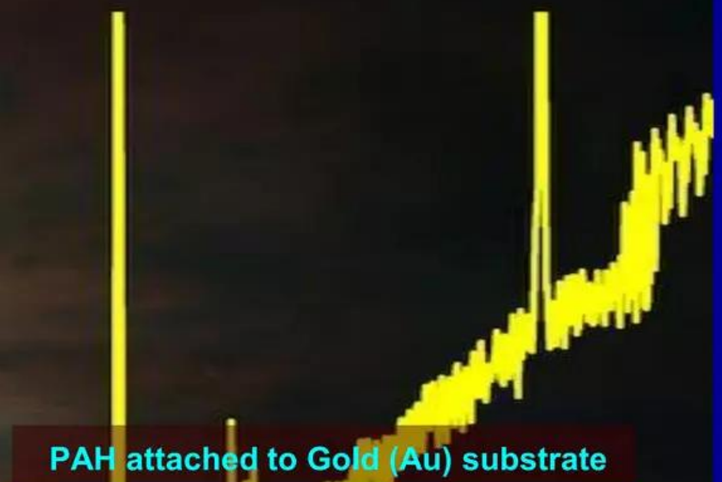
Random examples of aromatic and polycyclic hydrocarbon molecules

Unsaturated phenanthrene
($C_{14}H_{10}$)



Various polycyclic aromatic hydrocarbons (PAHs)





PAH attached to Gold (Au) substrate

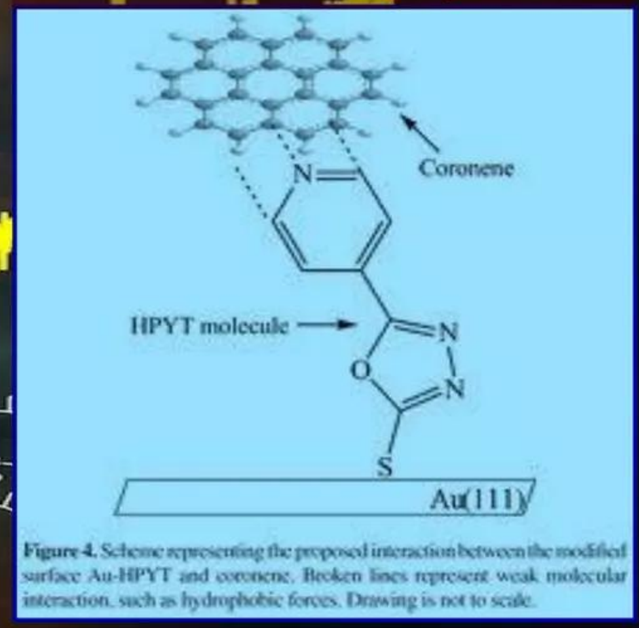


Figure 4. Scheme representing the proposed interaction between the modified surface Au-HPYT and coronene. Broken lines represent weak molecular interaction, such as hydrophobic forces. Drawing is not to scale.

Credit: NASA, C.R. O'Dell and S.K. Wong (Rice University)

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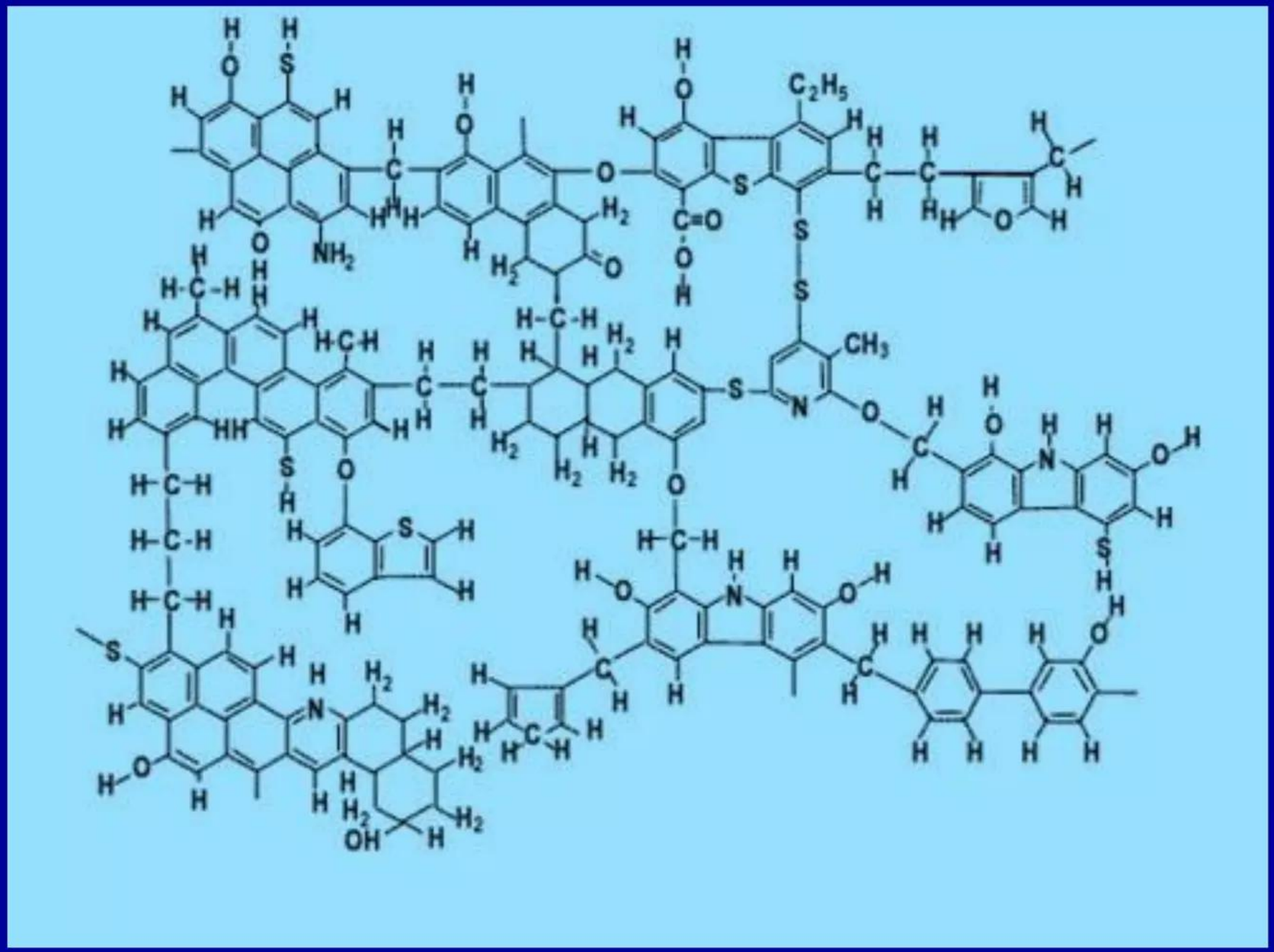
Behold the complex and fascinating structure of coal

Bituminous coal's representation as a molecular structure



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Why is coal potential feedstock for $_6C^{12}$ seed CLENR fuel?

Coal's complex molecular structure has many aromatic carbon rings

- ✓ As one can readily see from simple visual inspection of bituminous coal's thought-to-be molecular structure (as shown on the previous slide), coal of all kinds is innately chock-full of aromatic carbon rings of one kind or another
- ✓ Herein, we have previously shown that $_6C^{12}$ seed CLENR networks exist and have been observed in the laboratory. That being the case, the presence of aromatic rings in the molecular structure of coal implies that there is a potential commercial opportunity for coal to be specially processed into $_6C^{12}$ CLENR fuels; please note that:
  - At today's modern coal-fired power plants, bulk coal from one or more origins is delivered to the facility via ship, barge, or rail, for local storage prior to its use. Before being injected into coal-fired boilers, macro-sized chunks of coal must be mechanically broken-up into much smaller particles by a machine called a coal pulverizer. Optimum burnable sizes of coal particles vary by boiler type; the smallest today get down to 'average' diameters on the order or "200 mesh" or ~74 *μm* (microns).
  - In many power plants, coals of different types from multiple origins are blended in specific ratios to comply with regulated minimums for elements naturally present in coal that have potential environmental issues in excessive amounts, e.g., mercury, sulfur, uranium, transition metals, etc.
- ✓ However, present smallest coal particle sizes of 74 *μm* in diameter *(*74,000 nanometers - *nm*) are just too large and wasteful for practical use as feedstock for further chemical processing that will produce usable $_6C^{12}$ CLENR fuels; first step in creating coal-based CLENR fuels is to use a second-stage fracturing process that further reduces average coal particle sizes by >10x, i.e., down to *no more than* ~7 - 8 *μm* (preferably smaller, if possible)

Lattice Energy LLC

How might one go about triggering CLENRs in coal? - I

Lattice can't disclose proprietary information but will provide hints

Hint #1: once sufficiently funded, Lattice plans to pursue a two-track parallel R&D and engineering of CLENR device and system-level embodiments suitable for small, portable heat sources (engineered 'target' nanoparticles affixed to specific preferred types of substrate surfaces) and extraordinarily scalable large heat sources (injection of 'fuel' nanoparticles into highly organized dusty plasmas)

Hint #2: based on extensive use of nanotechnology, CLENR-based power generation systems can in principle scale-up power outputs from milliwatts all the way up to Megawatts, depending on what type of energy conversion technologies are integrated with CLENR heat sources. This flexibility enables an unusually broad range of potential commercial applications for CLENRs ranging from battery-like portable devices, to stationary power units, to vehicles (steam power could potentially return), to very large power plants (recall that shielding is unnecessary)

Hint #3: condensed matter CLENRs and the interdisciplinary field of nanotechnology are effectively 'joined at the hip'; also, collective many-body classical, and coherent Q-M, effects occur in both. Deep knowledge of nanotechnology, plasmonics, and advanced materials science is mandatory

Lattice Energy LLC

How might one go about triggering CLENRs in coal? - II

Lattice can't disclose proprietary information but will provide hints

Hint #4: rates of CLENRs can be increased substantially in non-natural environments: fortunately, using conceptual insights provided by the WLT, experimental conditions in condensed matter systems and 'dusty' plasmas can be technologically 'tweaked' to increase rates of weak reaction neutron production far above whatever levels might ever be attainable in analogous systems found at random out in Nature or in the vast majority of CLENR laboratory experiments conducted to date.

Technologically, many-body collective electroweak neutron production rates can be manipulated by: (1) controlling total numbers and density of $e^{-}{}^{*}p^{+}$ pairs on a given surface (which is ~equivalent to controlling the area-density and dimensions of many-body, collectively oscillating surface 'patches' of protons or deuterons); and (2) controlling the rate and total quantity of appropriate form(s) of nonequilibrium energy input into LENR-active 'patches'; appropriate forms of input energy can go directly into high electric fields that 'bathe' SP electrons in a 'patch' --- it determines the number and effective masses of e* electrons present in a given 'patch' whose increased masses are at values somewhere above the minimum mass-renormalization threshold ratio, β_0 that is required for initiating $e^{-}{}^{*} + p^{+}$ or $e^{-}{}^{*} + d^{+}$ weak reactions.

The term $(\beta - \beta_0)^2$ in our published rate equation reflects the degree to which mass renormalized $e^{-}{}^{*}$ electrons in a given 'patch' exceed the minimum threshold ratio for neutron production β_0. Details of this are explained in our first principles ULM neutron production rates calculation paper found on the Cornell arXiv at: http://arxiv.org/PS_cache/nucl-th/pdf/0608/0608059v2.pdf

Simply put, all other things being equal, the higher the density of $e^{-}{}^{*}p^{+}$ reactants and the greater the rate and quantity of appropriate forms of nonequilibrium energy input, the higher the rate of ULM neutron production in *μm*-scale LENR-active 'patches' in an appropriately pre-configured condensed matter system

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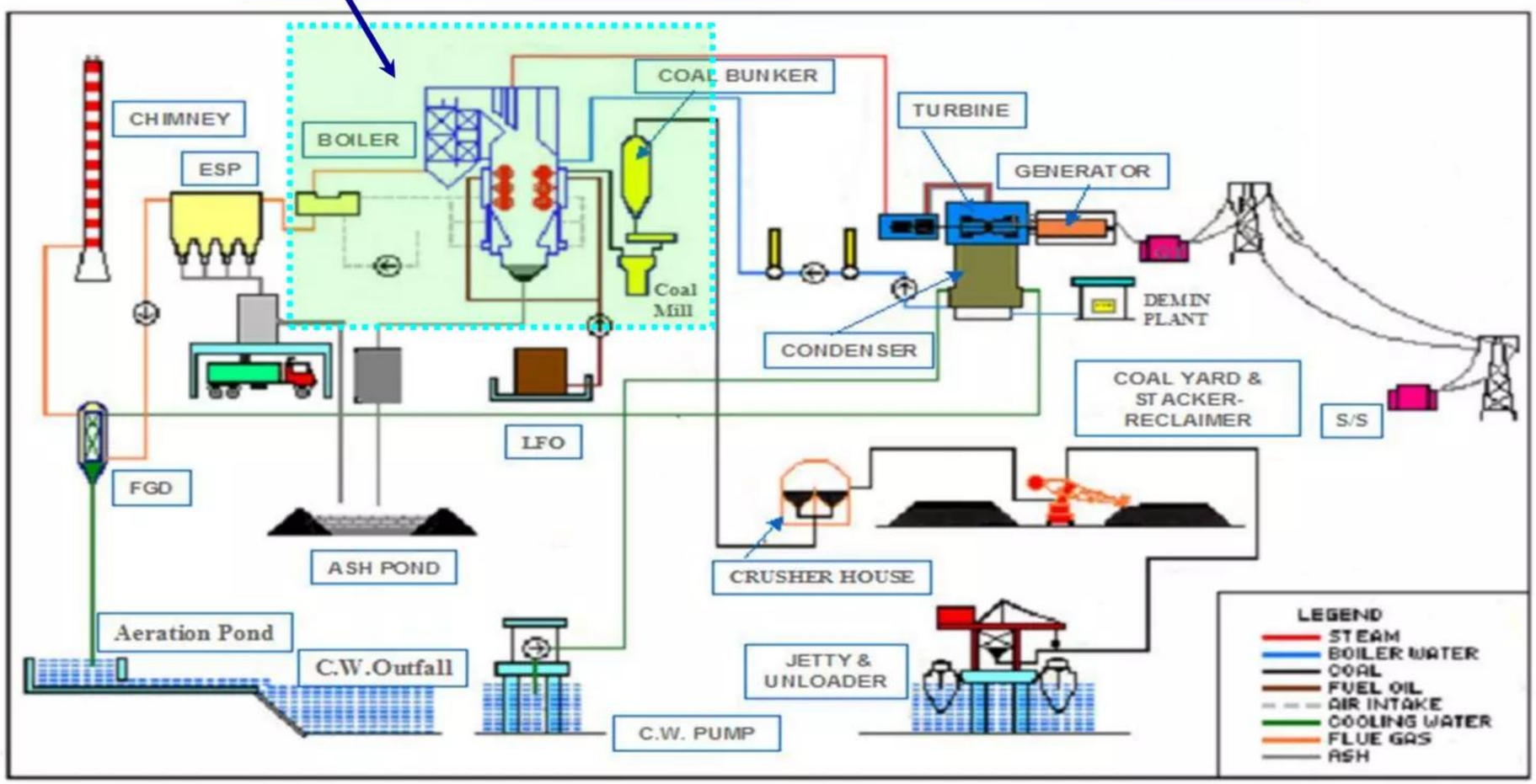
Future CLENR systems vs. today's coal-fired generation - I

Coal plant system diagram: boiler is small part of total $ investment

e·on | UK

COAL-FIRED POWER PLANT PROCESS

CLENRs impact the boiler and coal pulverizer subsystems



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Future CLENR systems vs. today's coal-fired generation - II

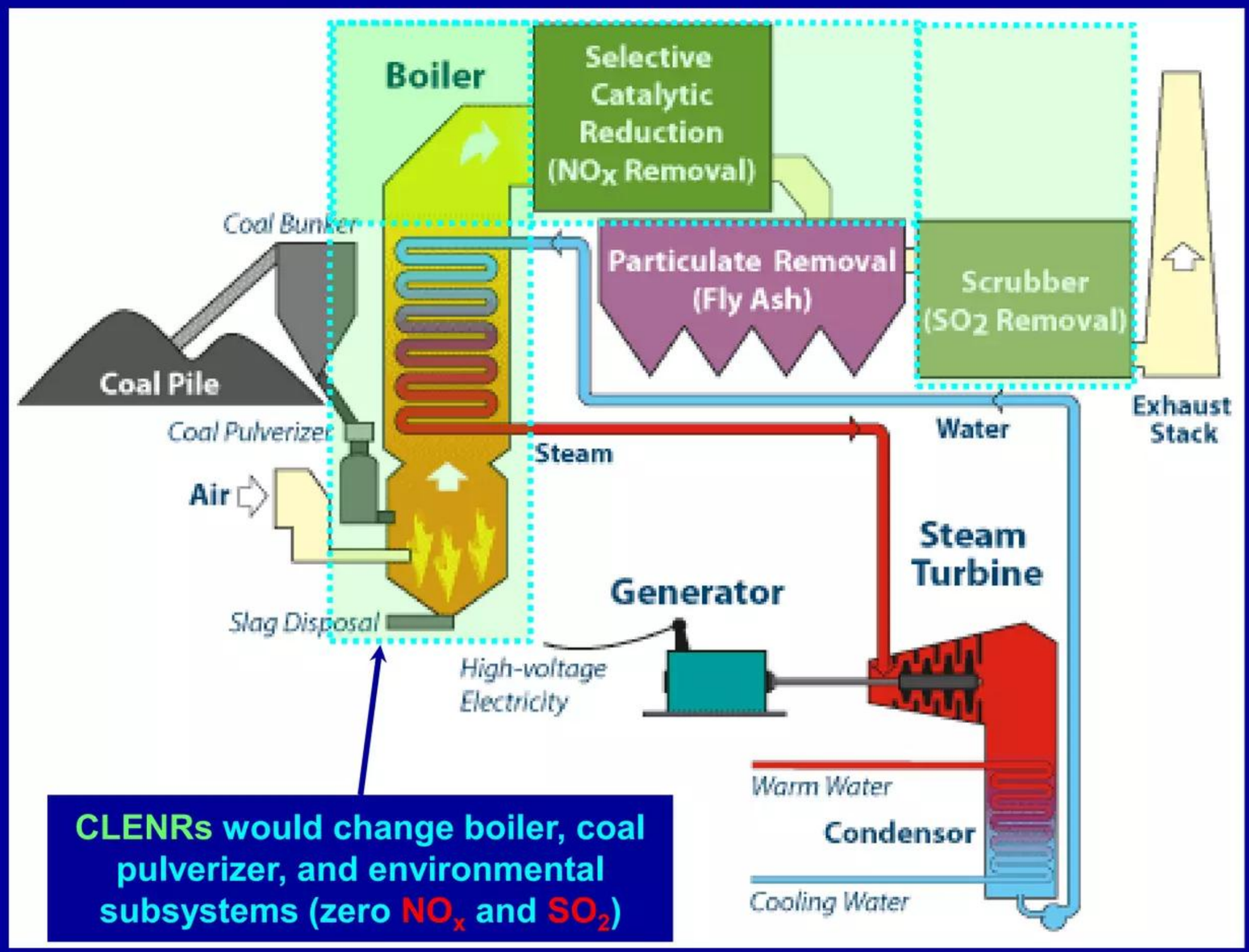
Coal-fired plant: inputs, processing to release energy, and outputs

CLENR transmutation of coal $_6C^{12}$ seed fuel is much 'greener' than combustion with O_2

Complete combustion of coal: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$ + energy

Today's Inputs:

- Capital $
- Bulk coal
- Air (O_2)



Today's Outputs:

- Heat
- Electricity
- CO_2
- NO_x
- SO_2
- Slag
- Particulates

CLENR Inputs:

- Capital $
- Bulk coal
- Electricity
- Metals

CLENR Outputs:

- Heat >>Electricity
- O_2 or N_2 or 'Slag' (incl. $$ elements)
- Particulates

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Future CLENR systems vs. today's coal-fired generation - III

Adoption could be relatively painless and not prohibitively expensive

- ✓ **Limited changes to basic configurations of existing coal-fired power generation systems:** amazingly, an engineer working at a typical electric utility coal-fired power plant in 2012 would probably still feel quite familiar and 'at home' in a CLENR-based $_{6}C^{12}$ seed plant of the future. While the boilers would look very different; there would be an additional onsite facility where CLENR fuels are made from pulverized coal; and there might be little or nothing in the way of visible vapor coming out of the plant's smokestack; appearance wise, it would nevertheless look similar to today's modern plants.

- ✓ **Capital-efficient path to adoption of CLENR technology:** importantly, to minimize economic costs of adopting new LENR-based heat generation technology in the power generation business, it would seem likely that existing coal-fired power plants in reasonable condition could readily be retrofitted with physically compatible CLENR-based boilers that would make hot steam to turn a plant's existing steam turbine generators. Not very much else in a retrofitted coal-fired power plant would have to be changed, other than the addition of a processing facility that would convert 'raw' *μm*-sized coal particles produced by existing types of in-plant pulverizers into specially processed nanoparticulates, i.e., $_{6}C^{12}$ seed CLENR fuels, which are then burned' in new types of high technology CLENR-fired boilers.

  To recoup part of the front-end investment involved in retrofitting CLENR technology and further help-out the global environment, a retrofitted coal-fired power plant's existing pollution abatement equipment for removing NO_x and SO_2 from emitted smokestack gases could perhaps be dismantled and then sold/shipped used, as-is to commercial operators in third world countries who are still running 'dirty' older coal-fired power plants that do not use pollution control equipment.

  By retrofitting existing (otherwise very usable) licensed and operating plants, the vast majority of the substantial billion $ front-end capital investment in a utility's coal-fired power generation facility could be conserved and protected. Upgrading existing coal-fired power plants with CLENR boiler technology could thus potentially be much less expensive over the long-run than the other alternatives of either building brand new, turn-key CLENR-based plants, or equipping conventional coal-fired plants with expensive carbon capture and sequestration technology (CCT) that might ultimately have untoward environmental consequences, e.g., CO_2 leaking out of underground reservoirs into the earth's atmosphere.

- ✓ **If this proved to be an economically attractive market penetration strategy, worldwide adoption could be rapid**

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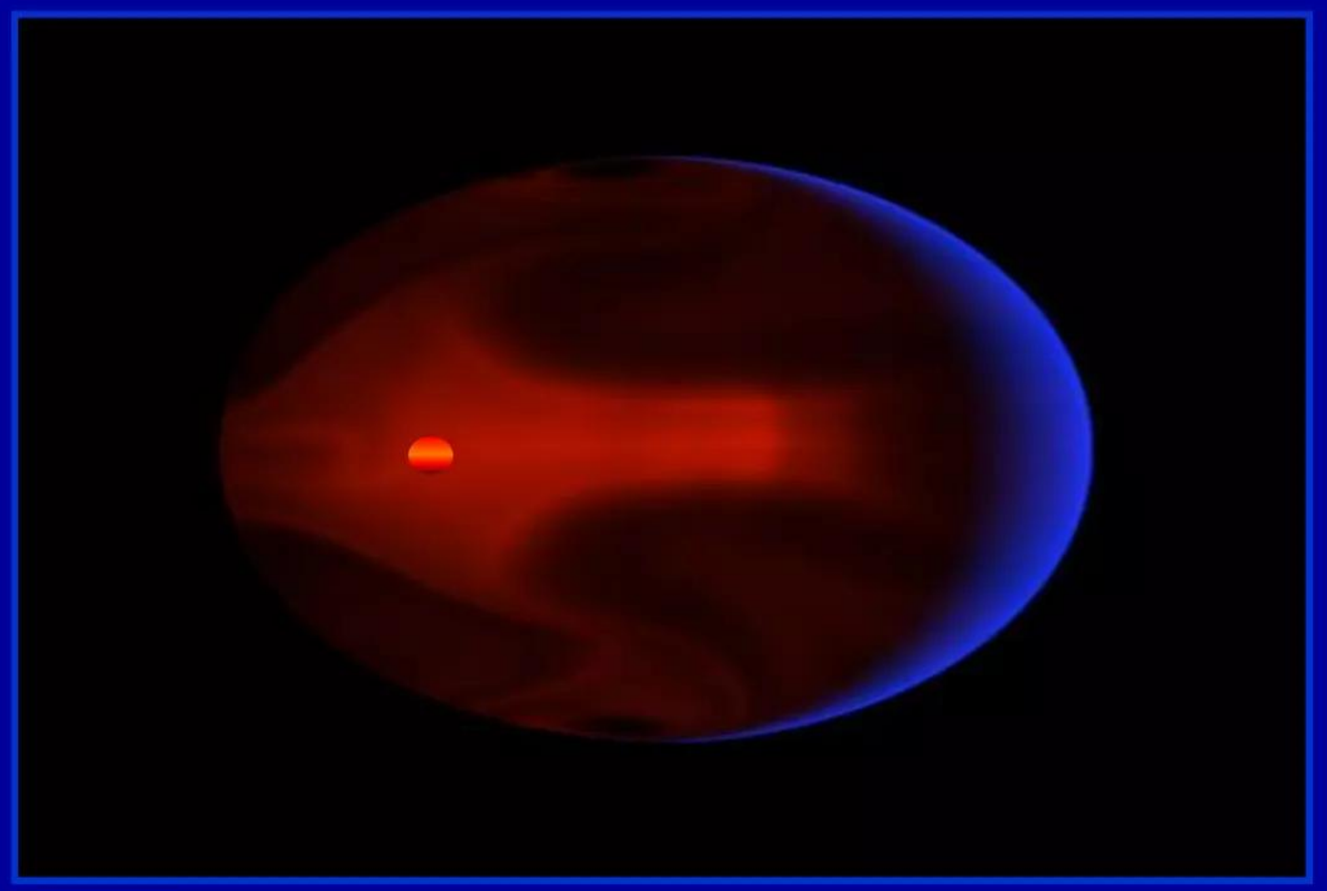
Commercializing a Next-Generation Source of Safe CLENR Energy

Further thoughts and possibilities for the future



"Tight-lipped, guided by reasons only,
Cautiously let us step into the era of the unchained fire."

Czeslaw Milosz, poem "Child of Europe," New York, 1946

Lattice Energy LLC

Bridge to the future: oil & coal fractions as CLENR fuels?

At least 10^6 times more clean energy released from same mass of fuel

- ✓ **Bitumen (i.e., oil sands), heavy oils, and coal intrinsically contain larger aromatic ring fractions than light 'sweet' crude oils presently produced around much of the Persian Gulf. Such fractions could potentially be extracted from crude oil and coal and undergo further processing to be suitable for use as vastly more energy-dense, 'greener' CLENR fuels.**
  - **If Mizuno's transmutation results for Phenanthrene are independently confirmed by third parties, a potentially major future commercial payoff would be to develop the capability to 'burn' PAHs and other types of aromatics as CLENR fuels in relatively unremarkable metallic reactors or boilers that utilize selected segments of the $_6C^{12}$ seed transmutation network discussed herein to produce usable process heat.**
  - **At that point in the development of the technology, various commercial versions of 'green' CLENR power generation systems would begin to more closely resemble present day chemically fueled power technologies without having any of their present problems, such as huge CO_2 emissions. CLENR-fired boilers are an obvious possibility.**
  - **On an energy-equivalent BTU basis, PAHs and related aromatics might easily be worth a million times more $ as CLENR fuels, as opposed to their being used to produce chemical feedstocks or to undergo 'cracking' of the aromatic rings to create hydrocarbon chains suitable for fuels, or in the case of coal, simply burning pulverized coal with Oxygen to create process heat, H_2O, as well as various gases and particulates.**
- ✓ **If such technological capabilities were eventually realized, the global energy industry's new, even more profitable bridge to the future could involve extracting and processing liquid hydrocarbons and coal for use in present-era fossil fuels, in chemical feedstocks, and in 'green' CLENR fuels.**

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New energy Saudi Arabias of the future? - I

Bitumen-rich countries could profit from 'green' CLENR fuels

- ✓ **Some experts believe that the two largest-known sources of bitumen (found in Alberta, Canada, and in Venezuela) each contain more petroleum than the entire proven conventional oil reserves of the Persian Gulf**

- ✓ **Today, synthetic crude oil produced from bitumen accounts for ~28% of Canada's total oil production. However, compared to conventional oil (obtained from traditional, easily accessible sources such as Saudi Arabia, Iraq, and Iran), synthetic crude produced from bitumen is now significantly more expensive and complicated to produce using today's best available extraction and processing technologies**

- ✓ **Whether surface-mined or extracted through well-holes, in Canada natural gas is presently burned to make steam which is used to heat bitumen-containing sands so liquid oil can flow out of pores between rock particles. Surface mining of oil sands and related environmental disturbances may be unnecessary if LENRs can be commercialized. To eliminate burning of natural gas for heat, high performance, cost-effective CLENR-based 'green' nuclear heaters with duty cycles of 5,000 - 10,000 hours between scheduled refueling/maintenance breaks could potentially be developed and mass produced. *In situ* CLENR heat sources would be small enough to be lowered down existing well-holes to reach desired locations in oil-bearing formations where long-lived, controllable production of intense heat is required for recovery. *CLENRs could thus reduce extraction and production costs, as well as vastly reduce the total 'carbon footprint' versus today***

Natural bitumen

Special note: PAHs are naturally found in significantly higher concentrations in bitumen or "oil sands" of which the largest known deposits are located in Canada and Venezuela. Unlike conventional crude oil, bitumen does not flow freely: it is heavier than water and more viscous than molasses. Today, it has to be heated with steam to liquefy it before it can be pumped out of the ground. Bitumen also contains up to 5% sulfur by weight, and small amounts of oxygen, various heavy metals and other contaminants.

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New energy Saudi Arabias of the future? - II

Coal-rich countries could benefit immensely from 'green' CLENR fuels

- ✓ **As of 2006, the United States, Russian Federation, China, and India together accounted for ~67% of total estimated global coal reserves.**
- ✓ **If CLENR technology were successfully commercialized and CLENR-based grid-connected central station (Megawatt output) as well as off-grid distributed (up to several hundred kilowatts) electrical power generation systems were cost-effective to purchase and broadly deployed, the following benefits (among many other things) could accrue to these countries and the world writ large:**
  - **China and India together account for ~40% of the world's present population; today, roughly 400 million people living just in rural India have no local sources of electricity whatsoever except for non-rechargeable batteries. Ubiquitous access to low-cost 'green' energy in just these two great countries would make an immeasurable contribution to human health and well-being, reduce global CO_2 emissions, and enable vast amounts of fully sustainable, long-term economic growth in India and China, as well as in the rest of the world.**
  - **United States, Russia, China, and India could all finally achieve the long-elusive, nebulous political and economic goal of "*energy independence*" along with vastly decreased usage and little reliance on combustion of fossil fuels, no less.**
  - **Enormous reduction in global geopolitical competition for access to dense sources of energy, e.g., crude oil. Wars might well be fought in this possible future, but unlike today, the *casus belli* probably would not involve energy.**
- ✓ **If an age of CLENRs transpired, universal access to low-cost energy would be democratized --- everybody wins, including Mother Earth.**

Anthracite coal

Present pulverized coal boiler

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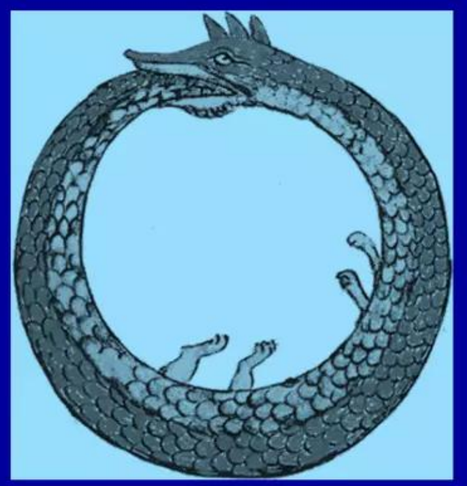
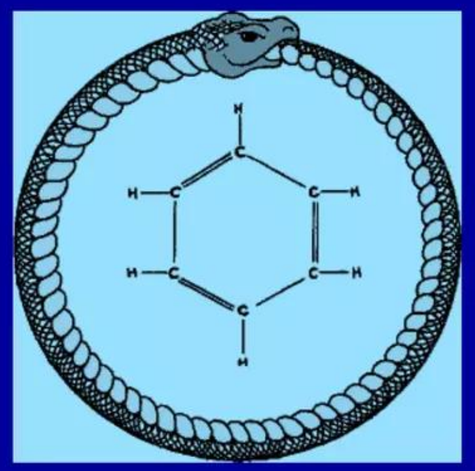
Final remarks about transmutations and chemistry

CLENRs are clean, 'green,' ubiquitous, and hidden in plain sight

- ✓ **CLENR transmutations are not a fevered alchemical delusion. As we have shown herein, they may be widespread in Nature, allowing nucleosynthetic processes to take place in many different types of 'milder' environments besides the hot cores of stars, nuclear weapons, and fission reactors**
- ✓ **Unlike fission and fusion reactions, naturally occurring CLENR processes are intrinsically benign because they make extensive use and are enabled by many-body collective effects, quantum phenomena, and the weak interaction. As a result, they typically do not emit dangerous 'hard' photon or neutron radiation, nor do they produce large amounts of long-lived radioactive isotopes. Thus they are clean, 'green,' ubiquitous, and hidden in plain sight**
- ✓ **If CLENRs can be successfully commercialized at some point in the future, they have the potential to help solve many of the world's long term energy problems. If aromatics can someday be used as CLENR fuel, it would allow humanity to release more than a million times more energy from carbon molecules without injecting any Carbon dioxide into the earth's environment**
- ✓ **Lastly, if a medieval alchemist were magically transported from the past into Mizuno's lab in Japan, after a discussion he would readily recognize metal reaction vessels as "*athanors*." That begs a question: were alchemists wrong about everything? Were 17 centuries of effort, including research by Newton and Bacon, all for naught? Or once in a while, did someone, see something real? *We may never know ...***



Ouroboros by Theodoros Pelecanos, in alchemical tract titled ,"*Synosius"* (1478).



Modern interpretation of the Ouroboros; did August Kekule dream about it when he hypothesized that benzene was a cyclic compound?

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Is development of CLENR fuels based on coal & oil certain?

No, and it won't necessarily be easy - but
We will never know whether it is possible if we don't even try

Quoting from a speech given by U.S. President John F. Kennedy at Rice University back in 1962:

"We choose to go to the Moon in this decade and do the other things, not because they are easy - but because they are hard.

Because that challenge is one we are willing to accept, one we are unwilling to postpone and one we intend to win."

Science of CLENR networks is real: mankind can potentially do this - What's left to achieve requires capital, engineering, and hard work by many

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Commercializing a Next-Generation Source of Safe CLENR Energy

Early CLENR transmutation experiments in 1924-25

Prof. Hantaro Nagaoka, famous Japanese physicist (1865 - 1950)

A visionary man far ahead of his own time

"The [high-current electric arc] experimental procedure here sketched cannot be looked upon as the only one for effecting transmutation [of other elements into Gold]; probably different processes will be developed and finally lead to industrial enterprises … Experiments with various elements may lead to different transmutations, which will be of significance to science and industry. Meagre as is the result, I wish to invite the attention of those interested in the subject so that they may repeat the experiment with more powerful means than are available in the Far East."

Prof. Hantaro Nagaoka in *"Letters to the Editor," Nature*, July 18, 1925

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Popular articles on CLENRs written for a general audience

Published by Institute of Science in Society, London, UK

"Low energy nuclear reactions for green energy - how weak interactions can provide sustainable nuclear energy and revolutionize the energy industry"
L. Larsen (November 13, 2008)
http://www.i-sis.org.uk/LENRGE.php

"***Widom-Larsen theory explains low energy nuclear reactions & why they are safe and green - all down to collective effects and weak interactions***"
L. Larsen (December 4, 2008)
http://www.i-sis.org.uk/Widom-Larsen.php

"***Portable and distributed power generation from LENRs - power output of LENR-based systems could be scaled up to address many different commercial applications***"
L. Larsen (December 10, 2008)
http://www.i-sis.org.uk/PortableDistributedPowerFromLENRs.php

"***LENRs for nuclear waste disposal - how weak interactions can transform radioactive isotopes into more benign elements***"
L. Larsen (December 11, 2008)
http://www.i-sis.org.uk/LENR_Nuclear_Waste_Disposal.php

"***Safe, less costly nuclear reactor decommissioning and more - how weak interaction LENRs can take us out of the nuclear safety and economic black hole***"
L. Larsen (January 26, 2009)
http://www.i-sis.org.uk/safeNuclearDecommissioning.php

"***LENRs replacing coal for distributed democratized power - low energy nuclear reactions have the potential to provide distributed power generation with zero carbon emission and cheaper than coal***"
L. Larsen (January 27, 2009)
http://www.i-sis.org.uk/LENRsReplacingCoal.php

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Commercializing a Next-Generation Source of Safe CLENR Energy

"Led by a new paradigm, scientists adopt new instruments and look in new places … during revolutions scientists see new and different things when looking with familiar instruments in places they have looked before. It is rather as if [they] had been suddenly transported to another planet where familiar objects are seen in a different light and are joined by unfamiliar ones as well."

Thomas Kuhn, "The Structure of Scientific Revolutions ," 1962