Lattice Energy LLC

Commercializing a Next-Generation Source of Safe Nuclear Energy

Larsen's Webradio Interview with Sandy Andrew

Online: live 1-hour in-depth Q&A audio interview with graphics is available on YouTube

http://www.youtube.com/watch?v=OVRLcC21F14

"Widom Larsen Theory of LENRs . . . Energy Revolution?"
The Universal Learning Series with Sandy Andrew

N.B. - this is very definitely not a typical 'thin gruel' brain-dead media interview; Sandy invested considerable time studying the technical aspects of this subject matter in preparation for the professional Q&A session that originally 'aired' live on blogtalkradio.net on April 17, 2010. While two-way dialogue with Lewis Larsen is conducted in 'plain English' suitable for a general non-specialist audience, basics of the Widom-Larsen theory in condensed matter, its implications and applications are all discussed in non-trivial detail; even practicing scientists may find that much of the interview is conceptually useful.

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Larsen's Webradio Interview with Sandy Andrew

Online: live 1-hour in-depth Q&A audio interview with graphics is available on YouTube

Listeners: you may find it helpful to have the following slides in front of you while experiencing Sandy's lively one-hour Q&A session. When you're finished listening, we hope that you will have at least a rough conceptual grasp of the Widom-Larsen theory of LENRs and the exciting possibility that LENR technology might eventually help insure a low-cost, 'green', sustainable energy future for every inhabitant of this planet.

Thanks for your interest in our work.

Lewis Larsen, President and CEO, Lattice Energy LLC
Wednesday, July 11, 2012

Alternative dense sources of energy

LENRs 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; 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

Key features of Widom-Larsen theory

Several processes create usable heat produced by LENRs

- ✓ **Conceptually, LENR neutrons act like catalytic 'matches' that are used to 'light the logs' of 'fuel' nuclei. A neutron-catalyzed LENR 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**
- ✓ **LENR 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 LENR networks from beta$^-$ decays**

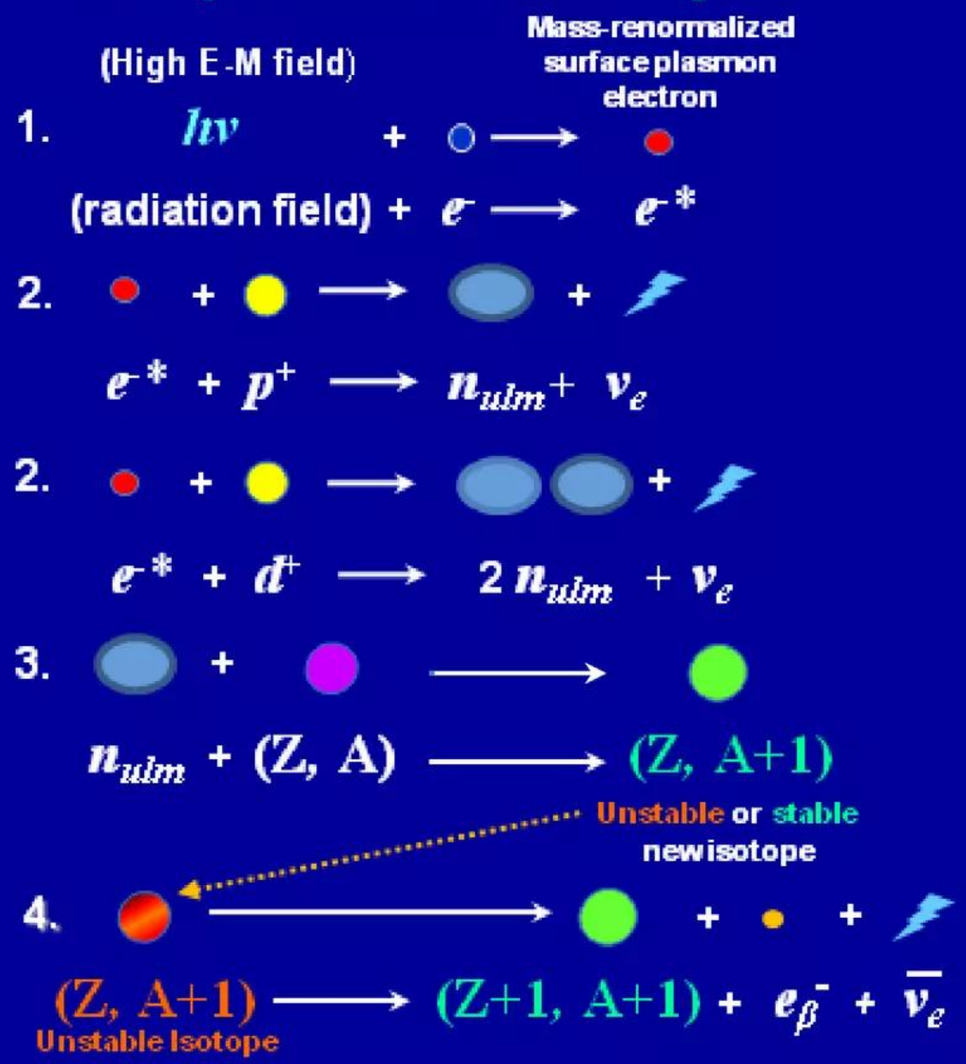
Key features of Widom-Larsen theory

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 $\bar{\nu}_e$

Note: colored shapes associated with diagram on next Slide

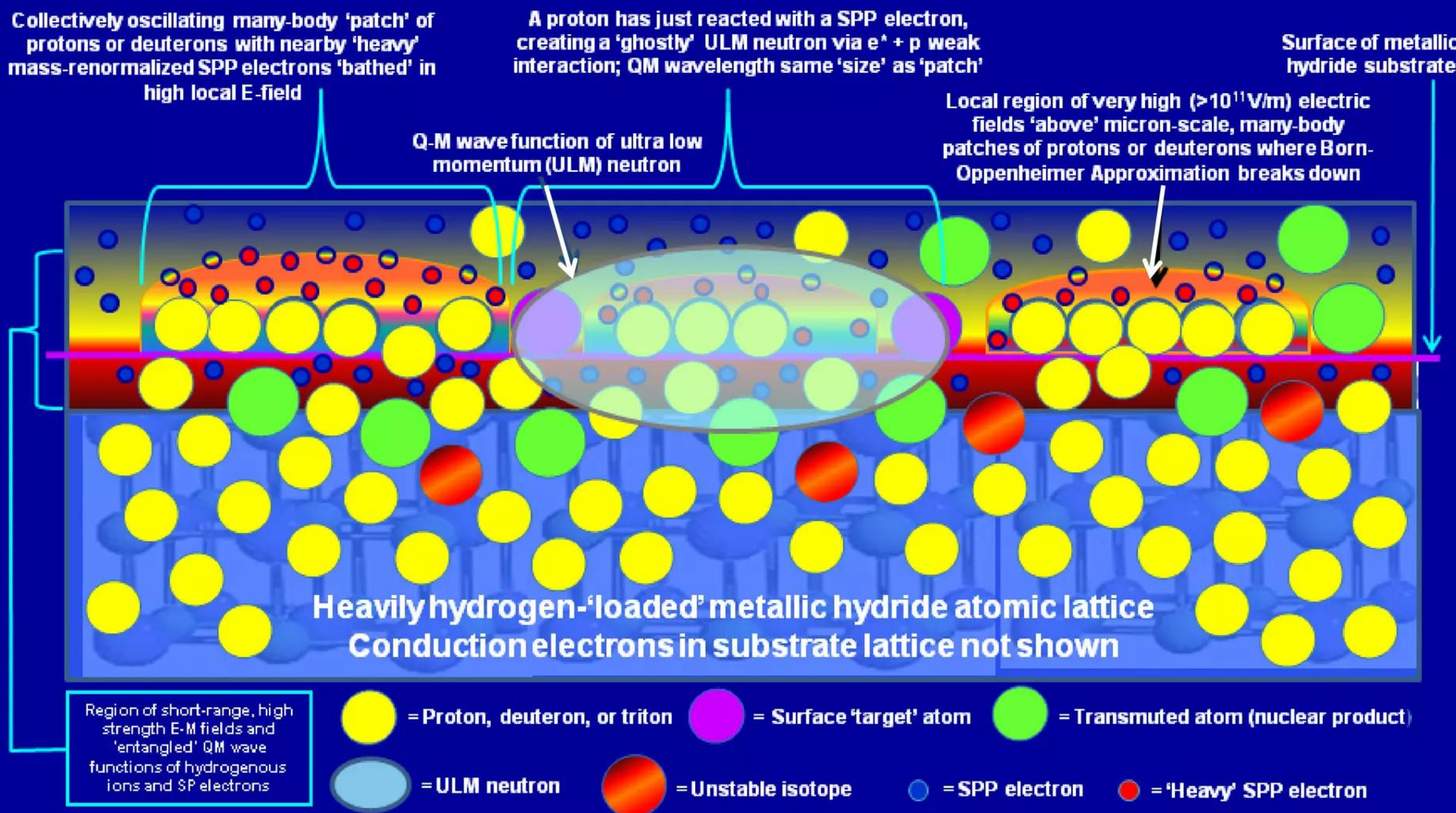
No strong interaction fusion or heavy element fission occurring below; weak interaction $e + p$ or $e + d$



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

Key features of Widom-Larsen theory

Conceptual graphic: many-body LENR-active 'patches' on surface



Key features of Widom-Larsen theory

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

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

'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

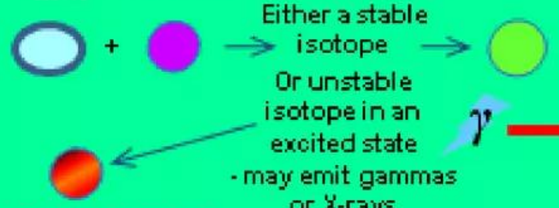
Chemical Energy Realm (eVs)
Everywhere else in LENR systems

"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.

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 ← 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

Gamma photons → IR → Infrared (IR) photons → IR photons excite lattice phonons

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

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'

Energetic charged particles excite lattice phonons

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**

Output → Neutrinos (*ν*) fly off into space at velocity c

End with:  *ν*, *γ*, IR photons

W-L theory extends to aromatic carbon rings

Aromatic hydrocarbons adsorbed on metallic surfaces

- ✓ **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, LENRs 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."

Oil and coal fractions as LENR 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' LENR 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 LENR 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' LENR 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. LENR-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 LENR 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' LENR fuels.**

New energy Saudi Arabias of the future?

Bitumen-rich countries could profit from 'green' LENR 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 LENR-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* LENR 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. *LENRs could thus reduce extraction and production costs, as well as vastly reduce the total 'carbon footprint' versus today***

Natural bitumen

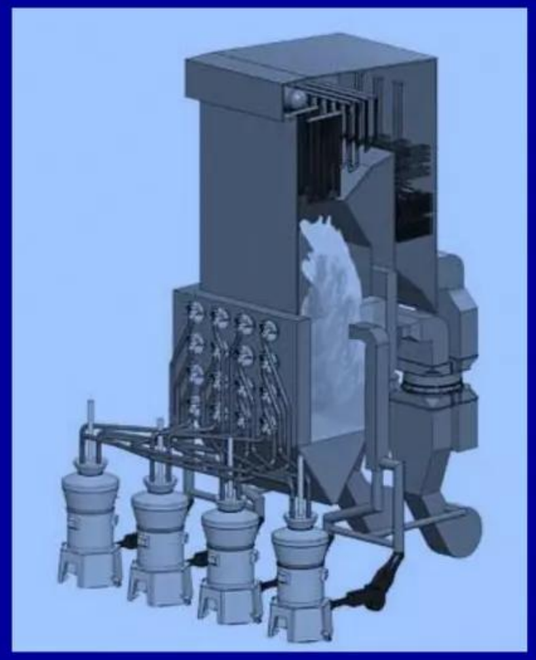
Special note: PAHs are naturally found in significantly higher concentrations in bitumen or "oil sands" of which the largest known deposits are located in Canada and Venezuela. Unlike conventional crude oil, bitumen does not flow freely: it is heavier than water and more viscous than molasses. Today, 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.

New energy Saudi Arabias of the future?

Coal-rich countries could benefit greatly from 'green' LENR fuels

- ✓ **As of 2006, the United States, Russian Federation, China, and India together accounted for ~67% of total estimated global coal reserves.**
- ✓ **If LENR technology were successfully commercialized and LENR-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 LENRs transpired, universal access to low-cost energy would be democratized --- everybody wins, including Mother Earth.**

Anthracite coal

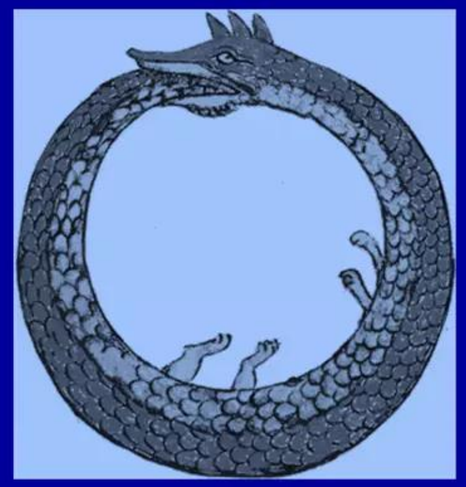


Present pulverized coal boiler

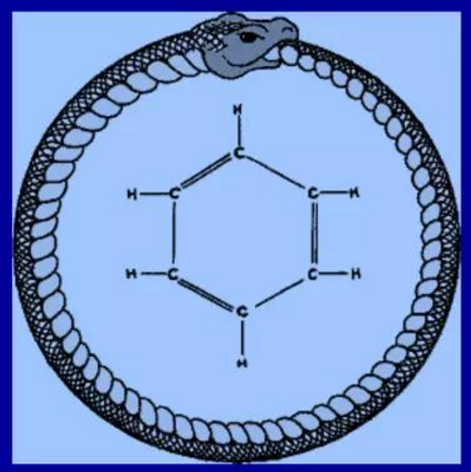
New world of transmutations and chemistry

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

- ✓ **LENR 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 LENR 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 LENRs 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 LENR 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 every great while, did some alchemist, somewhere in the world, see something real? We may never really 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?

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

Popular articles 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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"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