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CLENR processes interoperate with everyday chemistry

Converting aromatic fractions of heavy oils and coal into CLENR fuels: no CO_2 and 5 million x more thermal energy

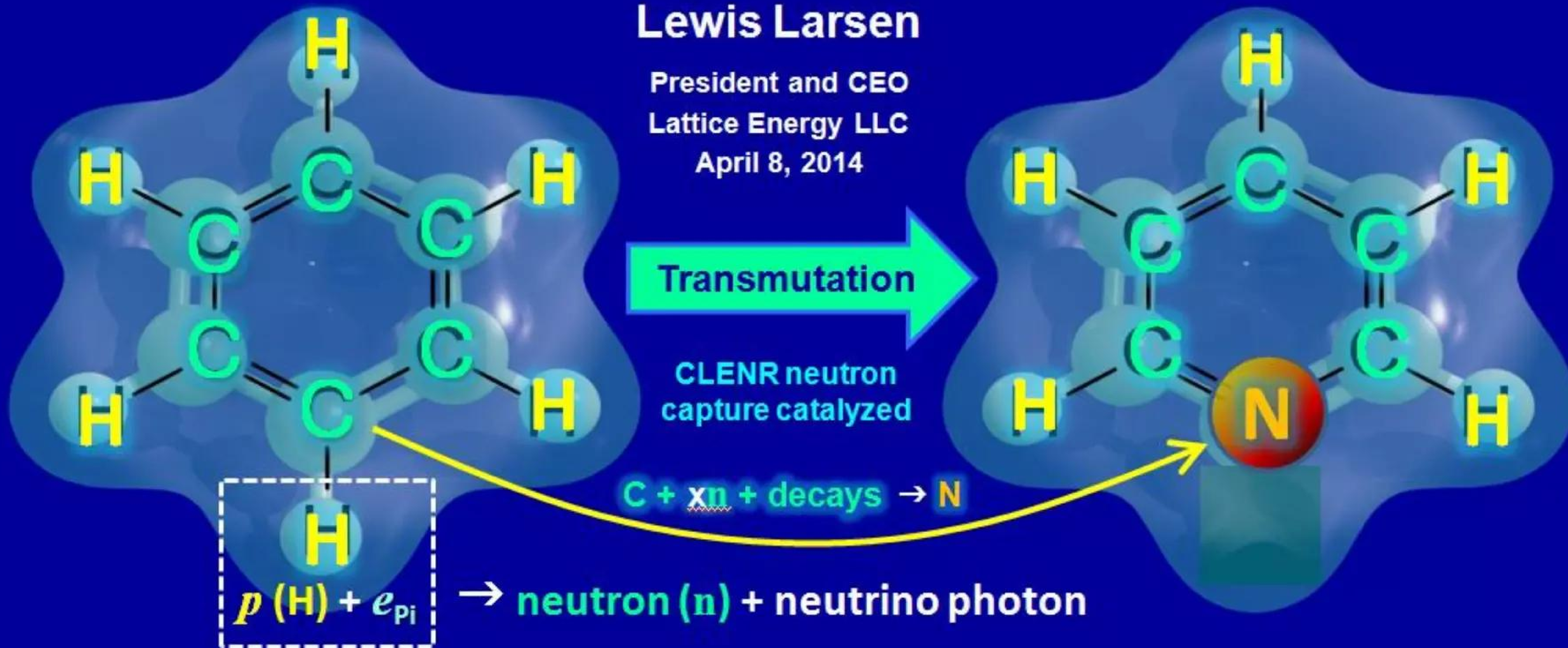
Clean low energy neutron reactions (CLENRs) transmute Carbon C atoms into other stable elements without emitting deadly radiation or creating radwastes

Lewis Larsen

President and CEO

Lattice Energy LLC

April 8, 2014



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Resurrection of Coal as a CO_2-free primary energy source

Coal and steam were handmaidens of the first Industrial Revolution

Could CLENRs reinvigorate coal and bring it into 21st century of energy?

Today


Early 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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CLENRs could provide new bridge to future for oil and coal

Oil and coal industries could partner with customers to adopt technology

- ✓ Potentially major future commercial opportunity would be to develop the capability to convert PAHs and other types of aromatics into CLENR fuels 'burned' in relatively unremarkable, compact metallic reactors that utilize selected segments of Carbon target transmutation network discussed herein to produce very low-cost process heat
- ✓ At that point in the development of the technology, various commercial versions of CLENR power generation systems would begin to physically resemble present day chemically fueled power sources without having any of their present problems, such as huge CO_2 emissions; CLENR-fired boilers for industry are obvious product 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 types of hydrocarbon chains suitable for vehicles, or in case of coal, simply burning pulverized coal with Oxygen to create process heat, H_2O, as well as CO_2 gas and dirty particulates
- ✓ If CLENRs' potential technological capabilities were realized, global oil and coal industries' even more profitable bridge to the future could include traditional extraction and processing of liquid hydrocarbons and bulk coal for use in today's fossil fuels and chemical feedstocks, as well as a new business: producing revolutionary CLENR fuels

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CLENR technology converts fossil fuels into green energy

Breakthroughs in physics and nanotechnology make this possible

Bitumen, heavy oil, and coal may be much more valuable with CLENRs

Canadian bitumen

Heavy viscous oil

Anthracite coal

Canadian Heavy Oil Association

Industry trade groups

ACC American Coal Council

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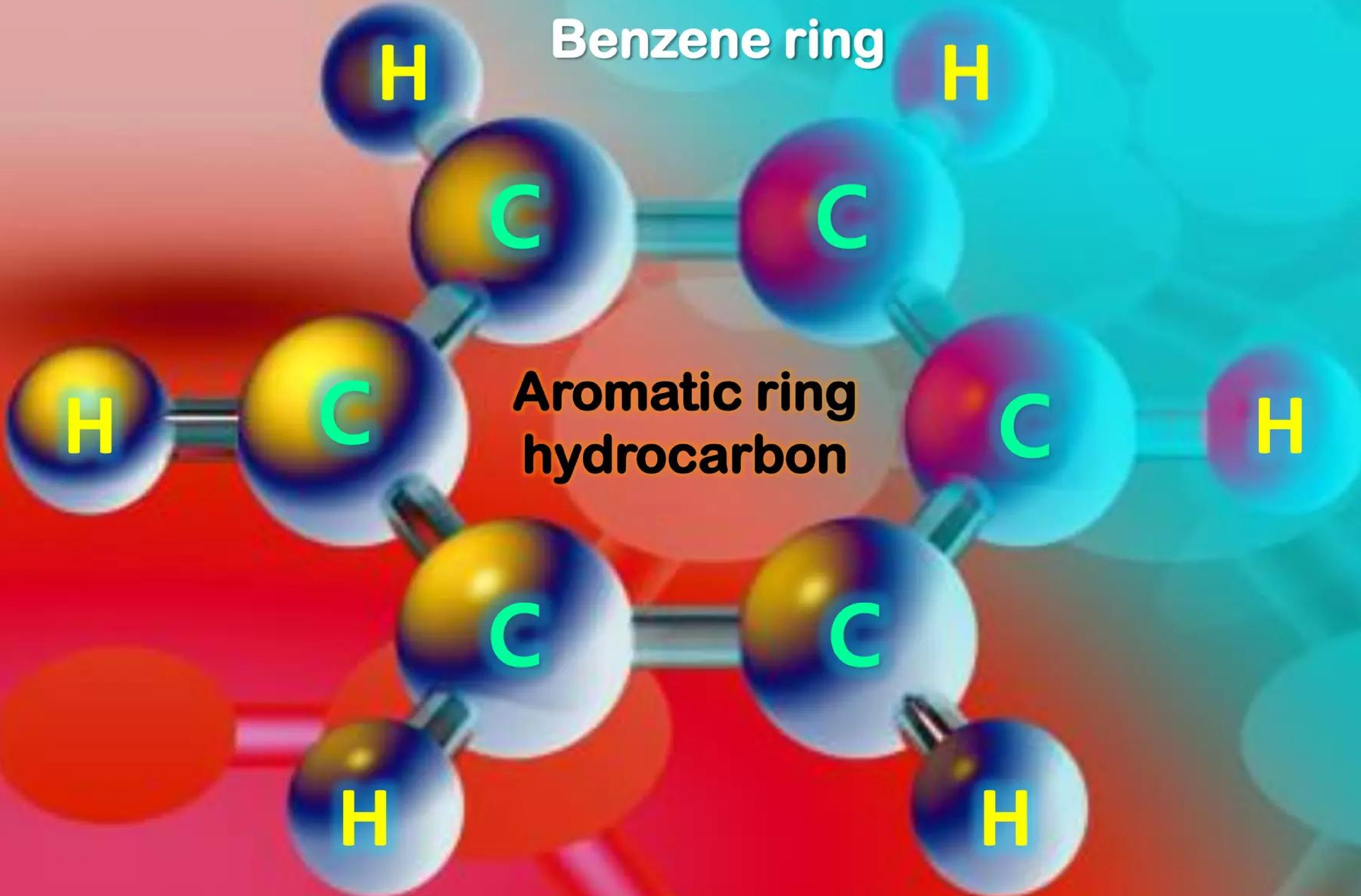

6 Carbon atoms arranged in hexagonal ring bonded to 6 Hydrogen atoms

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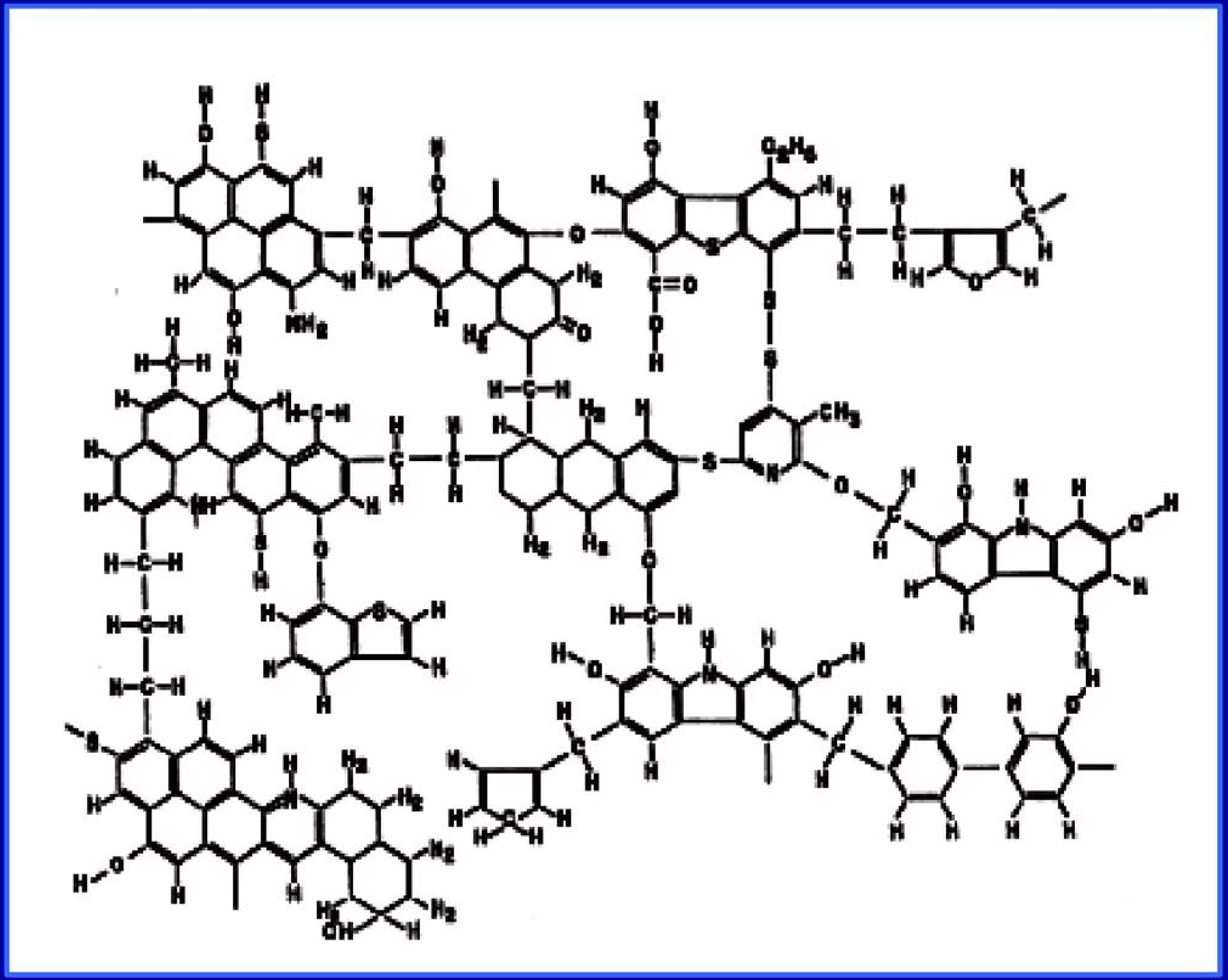
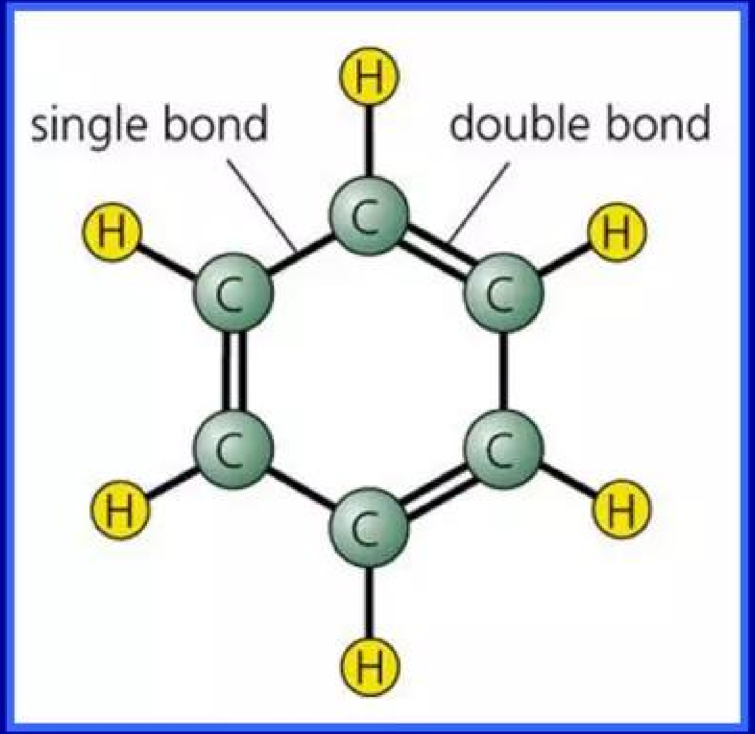
Oil and coal could be processed into CO_2-free CLENR fuels

Molecular structures shown for coal, benzene (aromatic) ring, and PAHs

Bituminous coal's very complex structure:



Benzene C_6H_6:



Multi-ring PAH:

Unsaturated Phenanthrene $C_{14}H_{10}$

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Carbon transmutation vastly better than Oxygen combustion

LENR process hard radiation-free; doesn't need shielding or containment

- ✓ Clean low energy neutron reactions (CLENRs) use safe, ultra low-energy neutrons to transmute atoms such as Carbon into other stable elements such as Nitrogen and Oxygen without emitting deadly energetic neutron or gamma radiation or producing hazardous radioactive wastes that need $$$ clean-up
- ✓ Safe, ultra low-energy CLENR neutrons are created from certain types of heavy-mass electrons and ordinary protons found in Hydrogen atoms using a simple reaction written as $e + p \rightarrow n$ + neutrino (benign photon); this is an "electroweak reaction" --- very different from what happens in fission and fusion reactions that release their thermal energy under extreme conditions
- ✓ Key differences between CLENRs vs. fission and fusion processes is that CLENR neutrons are 100% absorbed deep inside reactors, unreacted heavy electrons convert gamma radiation directly into useful infrared heat, and long-lived radioactive wastes are not produced in troublesome quantities
- ✓ CLENR reactors thus do not need radiation shielding and containment; potentially vastly less expensive and safer than fission or fusion systems

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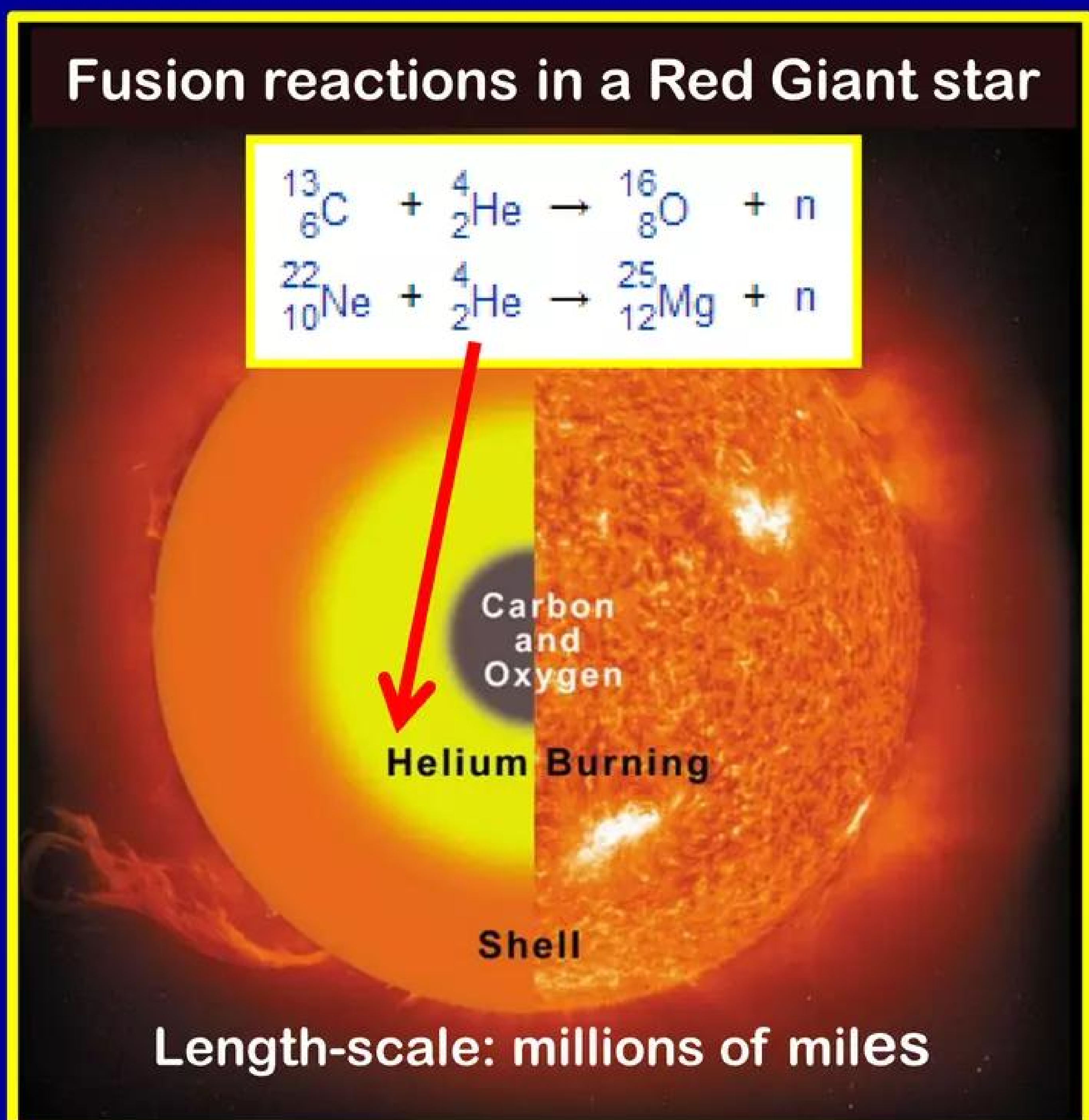
Unlike fission or fusion: ultra low energy neutrons are safe

Fission or fusion neutrons are energetic and deadly - need huge systems

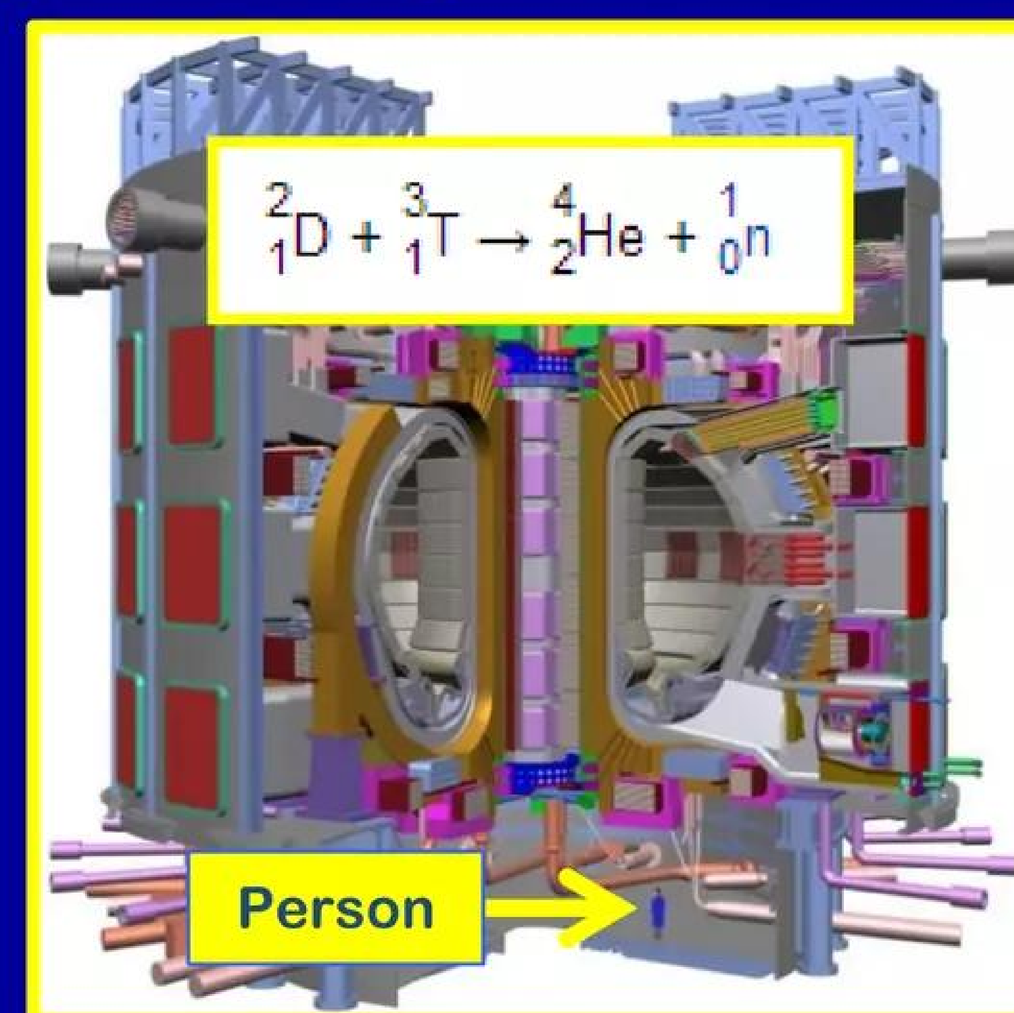
All of these fusion and CLENR nuclear reactions seen below create neutrons (n):



Temperature: ~15 million degrees C

ITER D+T hydrogen fusion reactor

Dangerous energetic 14.1 MeV neutrons



Length-scale: hundreds of feet

Temperature: many millions of degrees

These are safe

CLENR device

Length-scale: inches

Temperatures: thousands of degrees in microscopic regions

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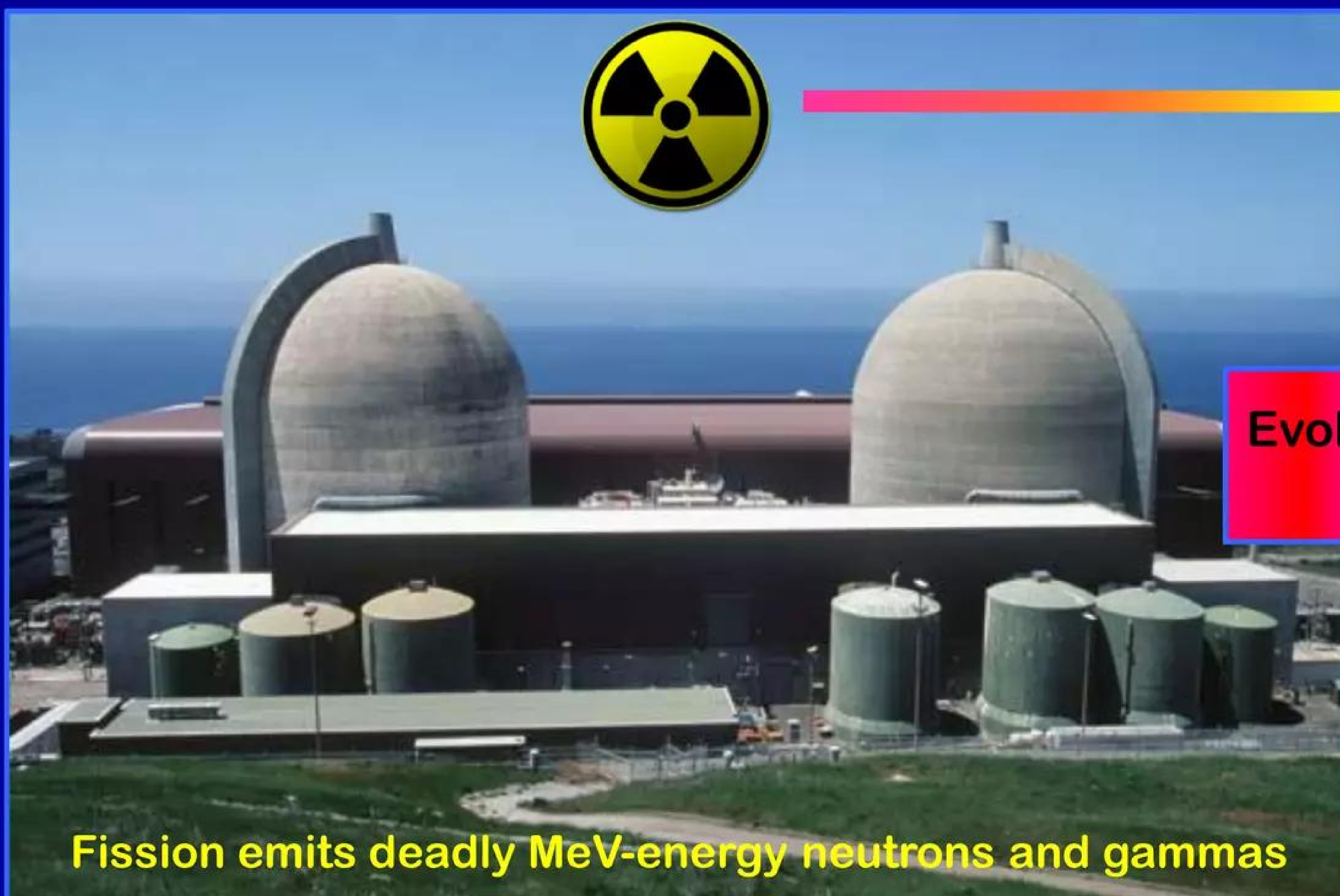
Lack of hard radiation enables CLENR systems to be small

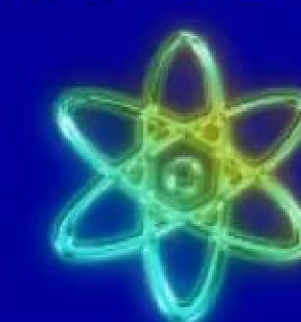
Enables creation of safe battery-like portable nuclear power sources

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

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



Evolution of nuclear technology



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

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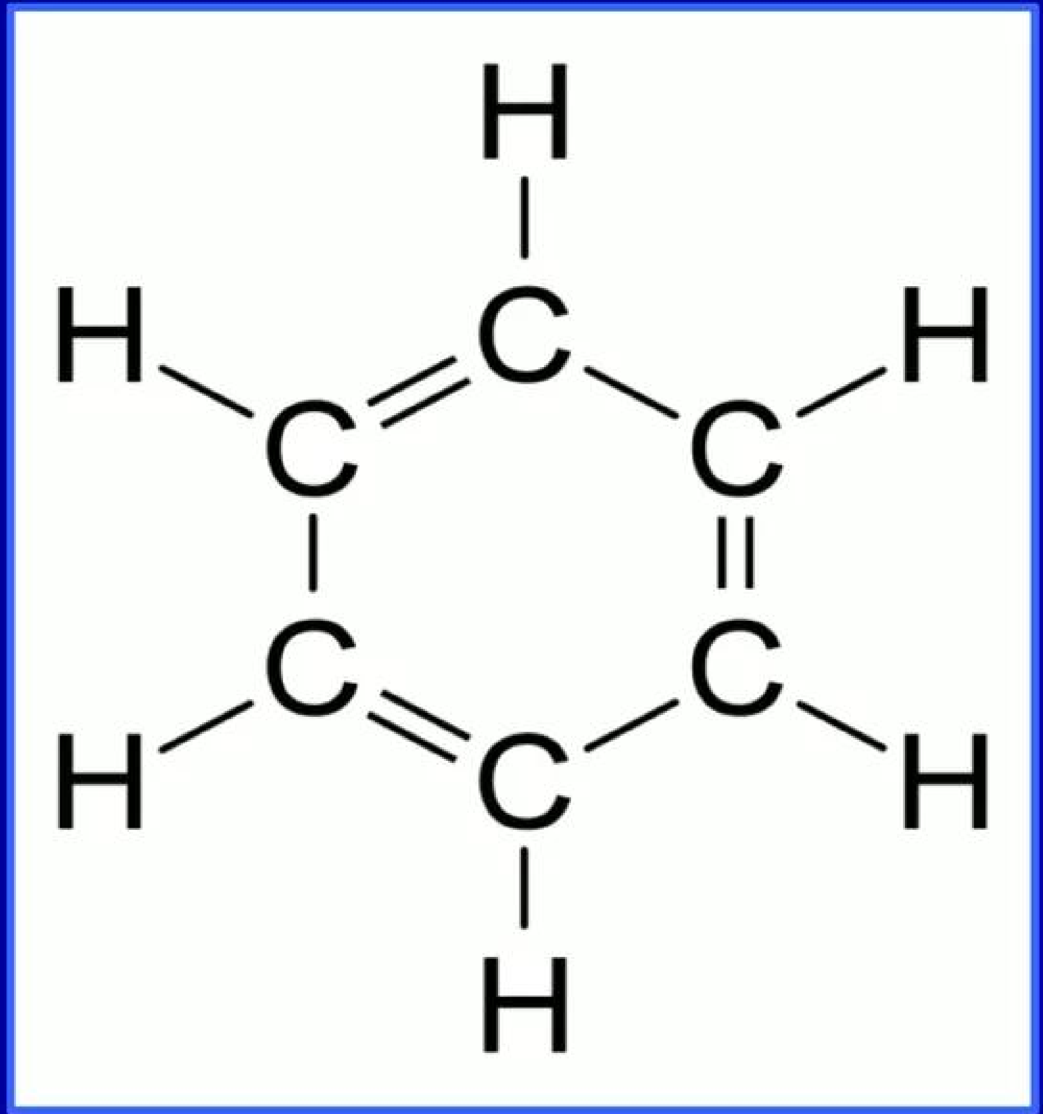
Convert ring protons (Hydrogen atoms) into ULE neutrons

Ultra low energy neutrons created collectively in an electroweak reaction

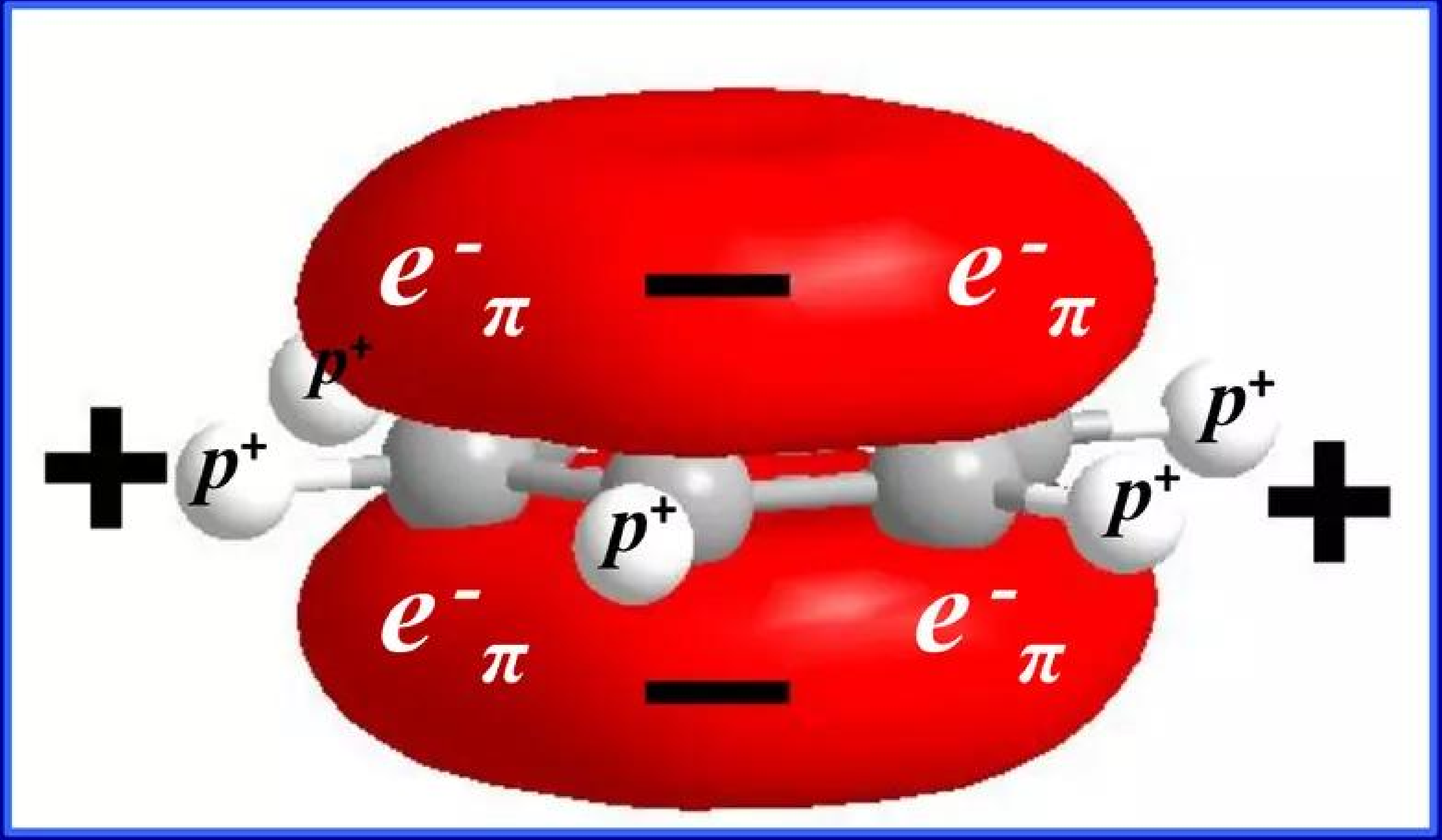
$$\text{Input energy}_{\text{electromagnetic field}} + e^{-}_{\pi} \rightarrow e^{-*}_{\pi} + p^{+} \rightarrow n^{0} + \nu_{e}$$

Each Hydrogen atom contains a single proton that is bound to the 6-Carbon ring



Benzene's 6-Carbon ring

Only handful of total number of π electrons are shown



Red indicates π (Pi) many-electron clouds on both sides of Benzene ring

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Convert ring protons (Hydrogen atoms) into ULE neutrons

Lattice was able to extend Widom-Larsen theory to aromatic molecules

- ✓ Experiments conducted at Hokkaido University (Japan) in 2008 demonstrated that production of CLENR neutrons and transmutation of Carbon can be triggered on benzene rings at very modest temperatures and pressures; these seemingly anomalous results of Mizuno explained by the Widom-Larsen theory
- ✓ Per Widom-Larsen, delocalized π (Pi) electrons e^-_π found on aromatic (benzene-like) rings are quantum mechanically entangled and behave like collectively oscillating surface plasmon electrons found on metallic surfaces and interfaces; similarly, protons p^+ (Hydrogen atoms) attached to ring Carbon atoms oscillate collectively and are also quantum mechanically entangled with each other
- ✓ Per Widom-Larsen, Born-Oppenheimer Approximation breaks-down on aromatic rings which enables local nuclear-strength electric fields that increase effective masses of some π electrons so that they can then react with one of the ring's protons to convert it into an ultra low energy neutron which is captured by a nearby ring Carbon atom. This begins the CLENR Carbon transmutation process
- ✓ Series of successive neutron captures and decays make Nitrogen, then Oxygen

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Predict surface plasmons on polycyclic aromatic hydrocarbons

Our conjecture recently confirmed by A. Manjavacas *et al*. (March 2013)

*"*Technical Overview - PAHs and LENRs*"*
L. Larsen, Lattice Energy LLC
November 25, 2009 (61 MS-PowerPoint slides)
http://www.slideshare.net/lewisglarsen/lattice-energy-llctechnical-overviewpahs-and-lenrsnov-25-2009

See: slides # 42 - 45

Synopsis: Widom-Larsen predicts that under proper conditions, energy can be inputted to hydrogenated PAH rings such that ultra low momentum neutrons are created from ring hydrogens (protons) via weak interaction; produced neutrons then capture on nearby ring carbon atoms, causing nuclear transmutation

"Tunable molecular plasmons in polycyclic aromatic hydrocarbons"
A. Manjavacas *et al.*
ACS Nano 7 pp. 3635 - 3643 (2013)
http://pubs.acs.org/doi/abs/10.1021/nn4006297

ABSTRACT: "We show that chemically synthesized polycyclic aromatic hydrocarbons (PAHs) exhibit molecular plasmon resonances that are remarkably sensitive to the net charge state of the molecule and the atomic structure of the edges. These molecules can be regarded as nanometer-sized forms of graphene, from which they inherit their high electrical tunability. Specifically, the addition or removal of a single electron switches on/off these molecular plasmons. Our first-principles time-dependent density-functional theory (TDDFT) calculations are in good agreement with a simpler tight-binding approach that can be easily extended to much larger systems. These fundamental insights enable the development of novel plasmonic devices based upon chemically available molecules, which, unlike colloidal or lithographic nanostructures, are free from structural imperfections. We further show a strong interaction between plasmons in neighboring molecules, quantified in significant energy shifts and field enhancement, and enabling molecular-based plasmonic designs. Our findings suggest new paradigms for electro-optical modulation and switching, single-electron detection, and sensing using individual molecules."

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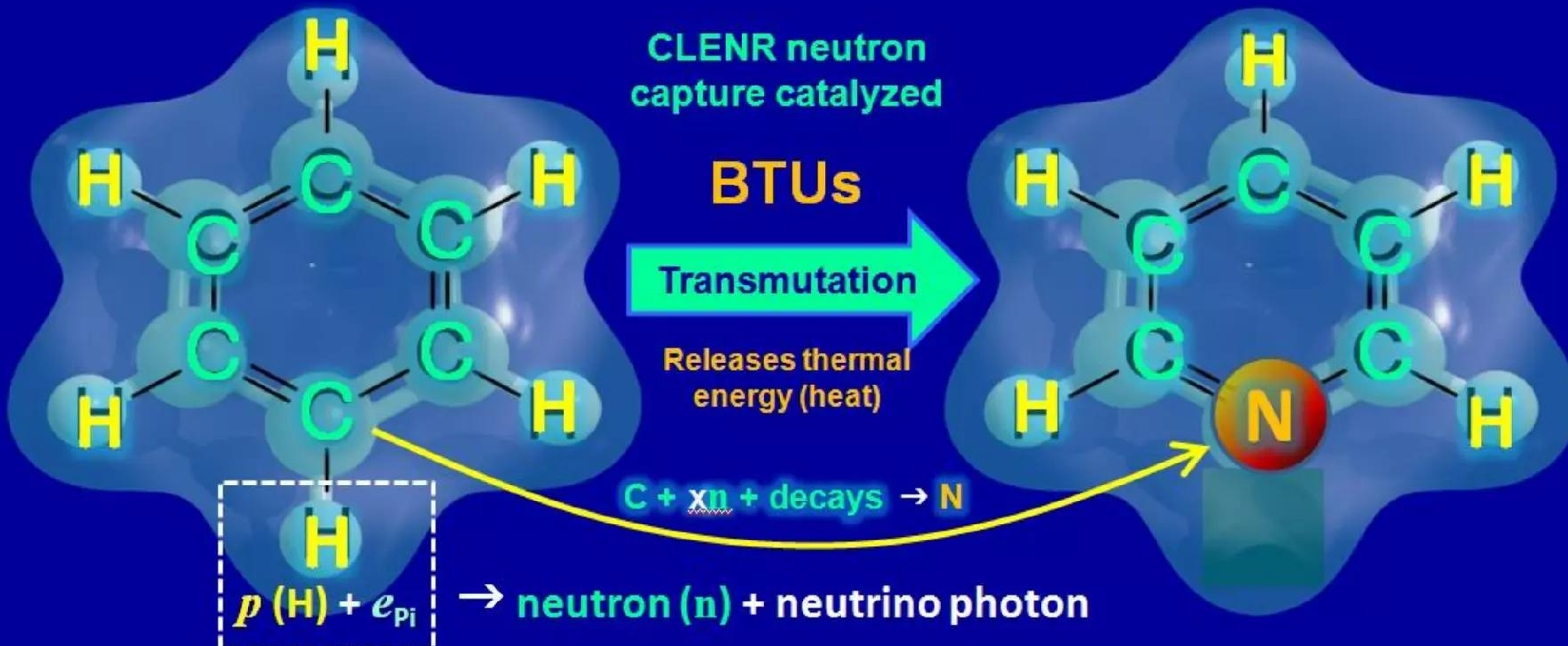
Key take-aways

Carbon transmutation with neutrons creates benign stable elements

Hydrocarbon aromatic rings can serve as nanoscale CLENR reactors

Clean low energy neutron reactions (CLENRs) transmute Carbon C atoms into other stable elements without emitting deadly radiation or creating radwastes



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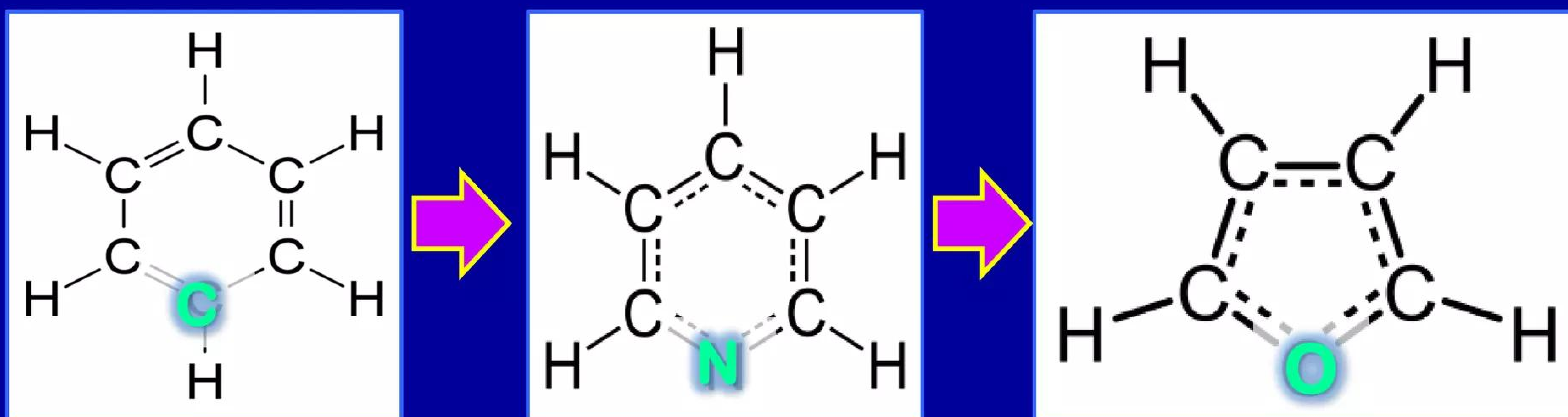
Radiation-free transmutation of Carbon → Nitrogen → Oxygen

Equivalent to CNO cycle of stars but doesn't require star-like conditions

Aromatic molecular chemistry changes in parallel with Carbon transmutation

CLENRs interoperate with ordinary chemical reactions on surfaces



Benzene **Pyridine** **Furan**

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Extract aromatic oil/coal aromatics; convert into CLENR fuels

Release millions of x more BTUs from same barrel of oil or ton of coal

- ✓ Tar-like bitumen such as Canadian oils sands, heavy viscous oils, and high-grade coking coal all naturally contain varying % of aromatic ring molecules; these include simple moieties like Benzene and more complex, multi-ring aromatics such as polycyclic aromatic hydrocarbons (PAHs). One example of a PAH is Phenanthrene, which is comprised of three bonded Benzene rings
- ✓ Using a mixture of traditional and recently developed chemical techniques, oil and coal can be processed to extract desired aromatic fractions; in theory, it should be possible to further process these aromatics into CLENR fuels that would be 'burned' in new, proprietary types of radiation-free transmutation reactors that would not require shielding, containment, or radwaste disposal
- ✓ Compared to combusting Carbon with Oxygen, using CLENRs to instead transmute Carbon into other stable, non-toxic elements can produce 5 million times more BTUs of thermal energy without emitting any CO_2 into atmosphere
- ✓ Opportunity for oil and coal companies selling BTUs to customers to vastly increase revenues/profits by engaging in production and sale of CLENR fuels

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Opportunity: oil/coal companies vastly increase future profits

Utilize lower cost process heat; sell 5,000x more energetic green fuels

- ✓ Commercial CLENR thermal sources could provide CO_2-free, low-cost process heat for various upstream and downstream operations in petroleum business:

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

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

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

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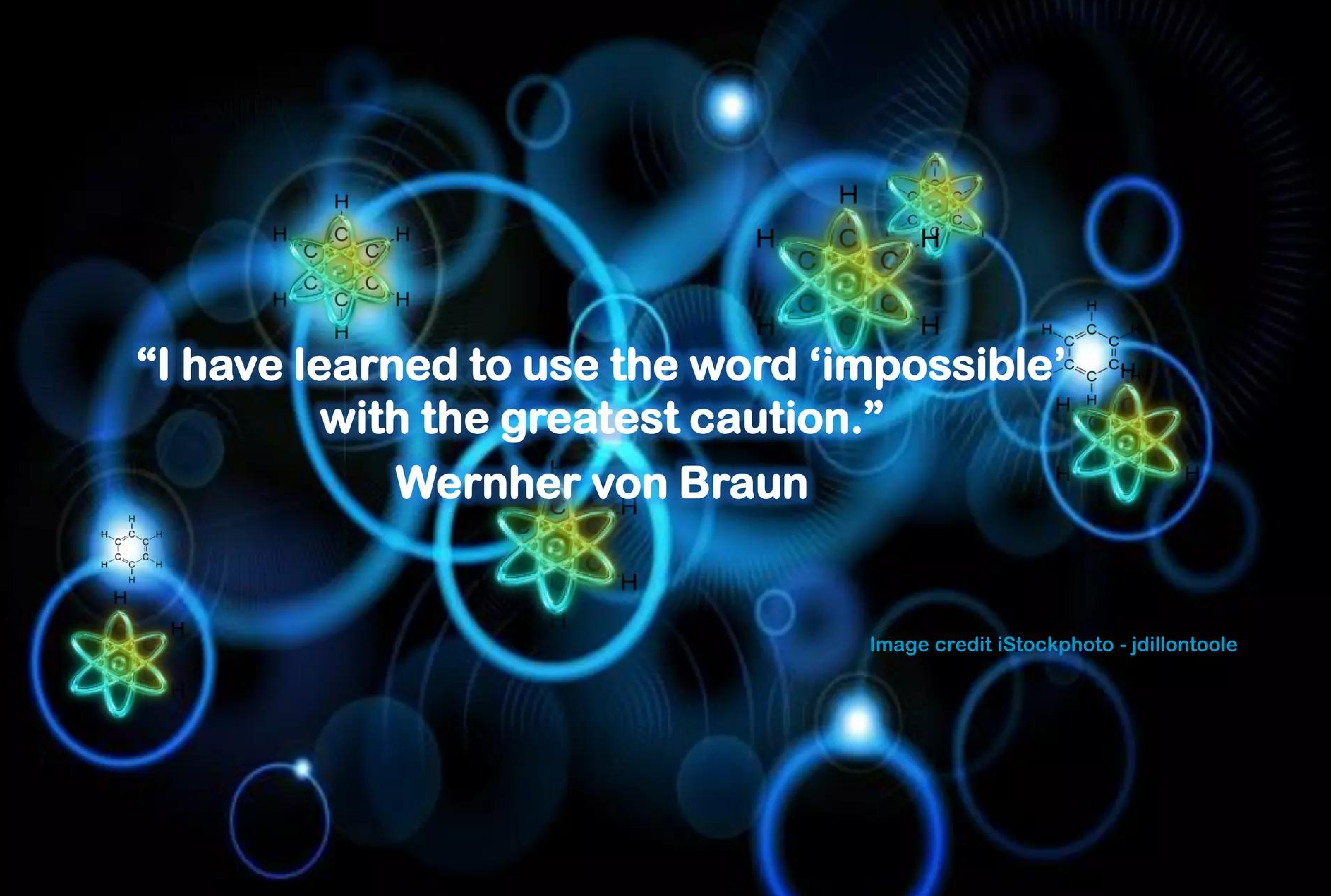

"I have learned to use the word 'impossible' with the greatest caution."

Wernher von Braun

Image credit iStockphoto - jdillontoole

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Basic reactions in Widom-Larsen theory are simple

Protons or deuterons react directly with electrons to make neutrons

Neutrons are then captured by other atoms and catalyze nuclear transmutations

Collective many-body quantum effects: many electrons each donate little bits of energy to a much smaller number of electrons that are also embedded in same high electric field

Quantum electrodynamics (QED): smaller number of electrons that absorb energy from electric field can increase their effective masses ($m = E/c^2$) to point where they can react directly with protons (or deuterons) to make neutrons and neutrinos

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

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

Neutron-capture-catalyzed transmutations release energy stored in atoms:

Neutrons + atomic nuclei → heavier elements + decay products

Releases vast amounts of stored nuclear binding energy as energetic particles/photons that create heat

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Widom-Larsen theory explains CLENRs

Transmutation: electroweak neutron production, captures, and decays

Nuclear-strength local electric fields provide energy for neutron production

Collective effects + input energy = aikido:

$Energy_{E\text{-}field} \rightarrow e^{-*} + p^{+} \rightarrow n + \nu_e$ [chemical cells]

$Energy_{B\text{-}field} \rightarrow e^{-} + p^{+} \rightarrow lepton + X$ [solar flares]

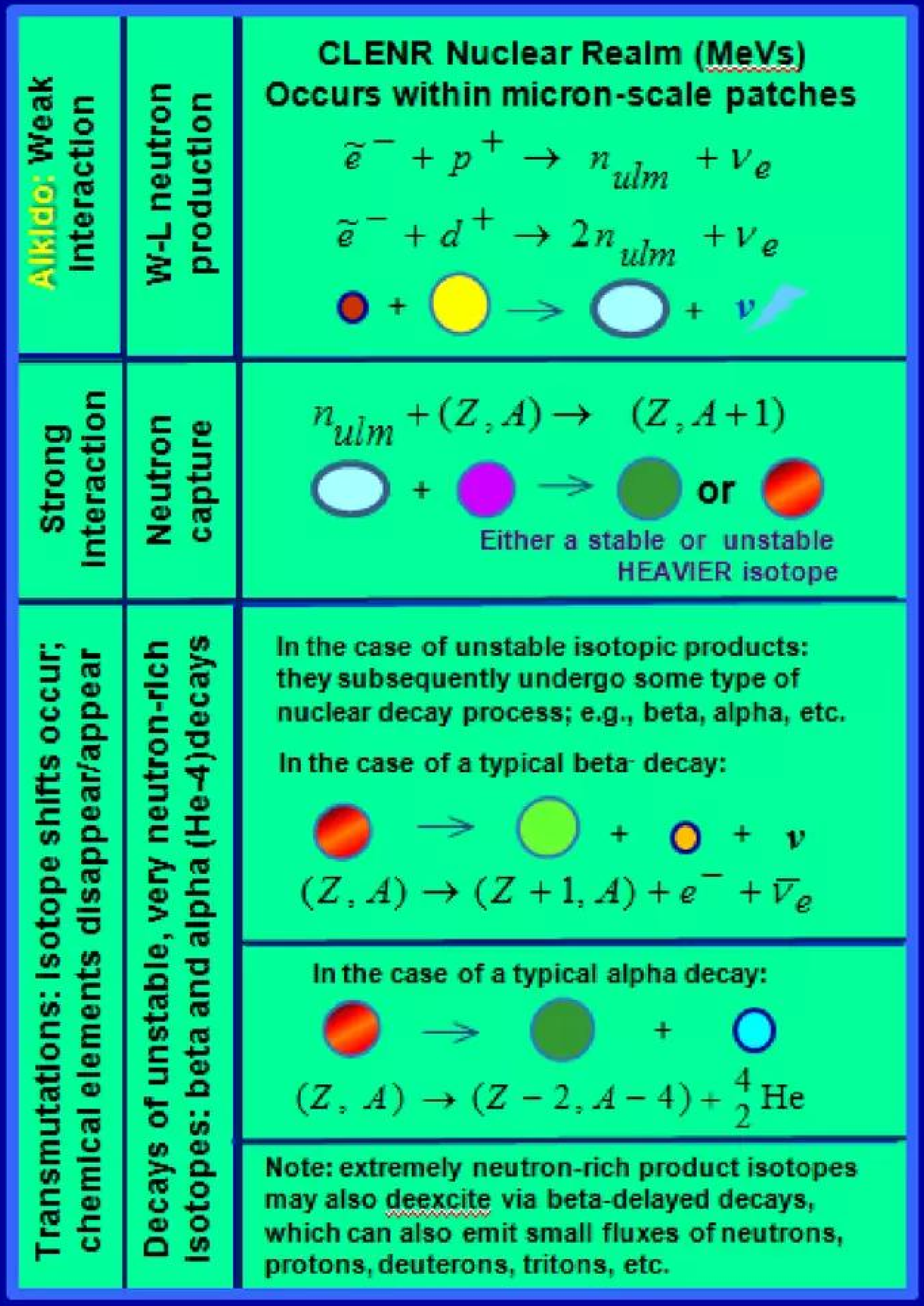
Collective electroweak production of neutrons in condensed matter and large-scale magnetic regimes

Afterwards neutrons capture on targets:

$n + (Z, A) \rightarrow (Z, A+1)$ [neutron capture]

$(Z, A+1) \rightarrow (Z+1, A+1) + e_{\beta}^{-} + \nu_e$ [beta$^-$ decay]

Mainly β^- decays of neutron-rich isotopic products



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Widom-Larsen theory enables device engineering

Production of CLENR neutrons requires certain types of input energy

- ✓ **Input energy is required:** to create non-equilibrium conditions that enable nuclear-strength local E-fields which produce populations of heavy-mass e^{-*} electrons that 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 of one sort or another can serve as input source
  - **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 ion flux caused by imposing a pressure gradient (Iwamura *et al.* 2002)
  - **Incoherent and coherent E-M photon fluxes -** can be incoherent E-M radiation found in resonant electromagnetic cavities; with proper coupling, SP electrons can also be directly energized with coherent laser beams emitting photons at appropriate resonant wavelengths
  - **Organized magnetic fields with cylindrical geometries -** mainly at very high electron currents; includes organized, non-ideal so-called dusty plasmas --- scales way-up to stellar flux tubes
- ✓ **Key feature of complex multi-step CLENR transmutation networks:** large numbers of viable network pathways can release more net nuclear binding energy that arises from a combination of neutron captures (with direct conversion of resulting prompt and delayed gammas into IR per W-L theory) and nuclear decays (e.g., α, β, etc.) vs. input energy that is required to produce total numbers of neutrons required for network pathway(s) to operate

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Widom-Larsen theory enables device engineering

CLENRs, E-M and chemical processes all interoperate on surfaces

- ✓ CLENR hot spots create intense local heating and variety of striking surface features such as craters: over time, CLENR-active surfaces inevitably experience major micron-scale changes in local nanostructures and elemental/isotopic compositions. On such substrate surfaces, a myriad of different complex, nanometer-to micron-scale electromagnetic (E-M), chemical, and nuclear processes operate in conjunction with and simultaneously with each other. CLENRs involve interactions between surface plasmon and π electrons, E-M fields, and many different types of nanostructures and aromatic molecules with varied geometries, surface locations relative to each other, different-strength local E-M fields, and varied chemical and isotopic compositions; chemical and nuclear processes interoperate extensively on such surfaces
- ✓ To varying degrees, many of these complex, time-varying surface interactions are electromagnetically coupled on many different physical length-scales: thus, mutual E-M resonances can be very important in such systems. In addition to optical frequencies, SP and π electrons in condensed matter often also have some absorption and emission bands in infrared (IR) and UV portions of E-M spectrum. Well, walls of gas-phase metallic or glass CLENR reaction vessels can emit various wavelengths of E-M photon energy into the interior space; glass tubes with inside surfaces coated with complex phosphors can function as resonant E-M cavities. Target nanostructures, nanoparticles, and/or molecules located inside such cavities can absorb IR, UV, or visible photons radiated from vessel walls if their absorption bands happen (or are engineered) to fall into same spectral range as E-M cavity wall radiation emission; complex two-way E-M interactions between targets and walls occurs

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Carbon transmutation releases > 1 million x more BTUs

Oil and coal can potentially be processed into CO_2-free CLENR fuels

Instead of burning Carbon with Oxygen simply transmute it into other elements

- ✓ What we will refer to as target fuel nuclei are simply stable elements (which are themselves initially comprised of some number of natural isotopes) that serve as initial starting points for complex, neutron-capture-driven CLENR transmutation reaction networks; unlike fission, CLENR target fuels are cheap and non-radioactive

- ✓ What engineers call a "fuel cycle" in nuclear fission power industry is essentially the same as what we call a CLENR 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 (less problematic Thorium fuel cycles are still under development). By contrast, the possibilities for CLENR fuel cycles are almost limitless --- literally any target element that will capture neutrons might be used (but some are much better than others; for example, Carbon or Lithium are good targets)

- ✓ We will now show a segment of a hypothetical Carbon-target CLENR network that could be commercially usable at some point in the future if presently troublesome aromatic hydrocarbons found naturally in heavy oils and coal can be processed into nanoparticulate forms in which CLENRs can be triggered. In Lattice's new concept, Carbon atoms present in oil and coal would be transmuted rather than oxidized

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Carbon transmutation releases > 1 million x more BTUs

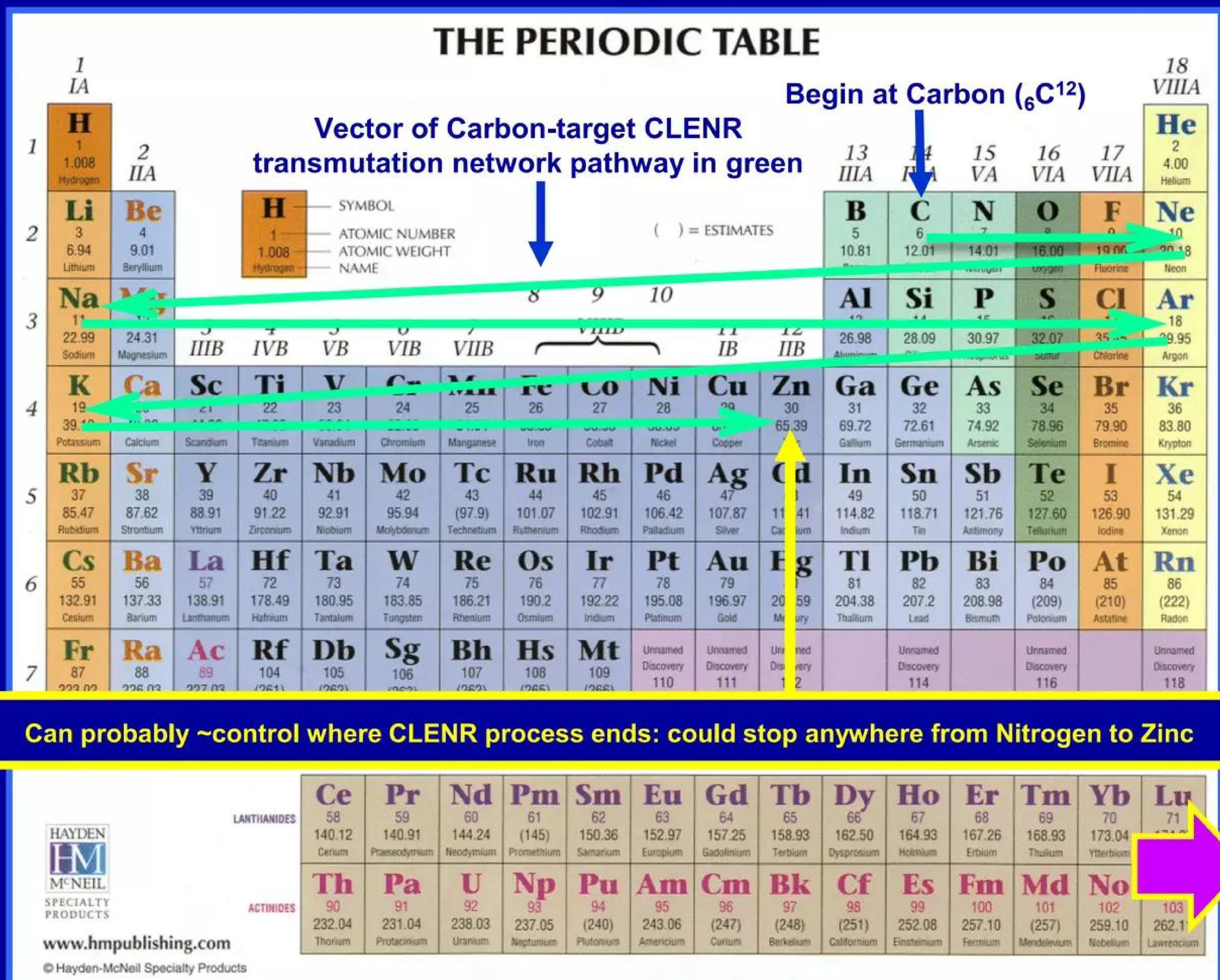
CLENR transmutation pathways tend to follow rows of Periodic Table

Stable elements produced by CLENR network can range 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 (CCS)

Additional issues with coal's varied 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 oil and 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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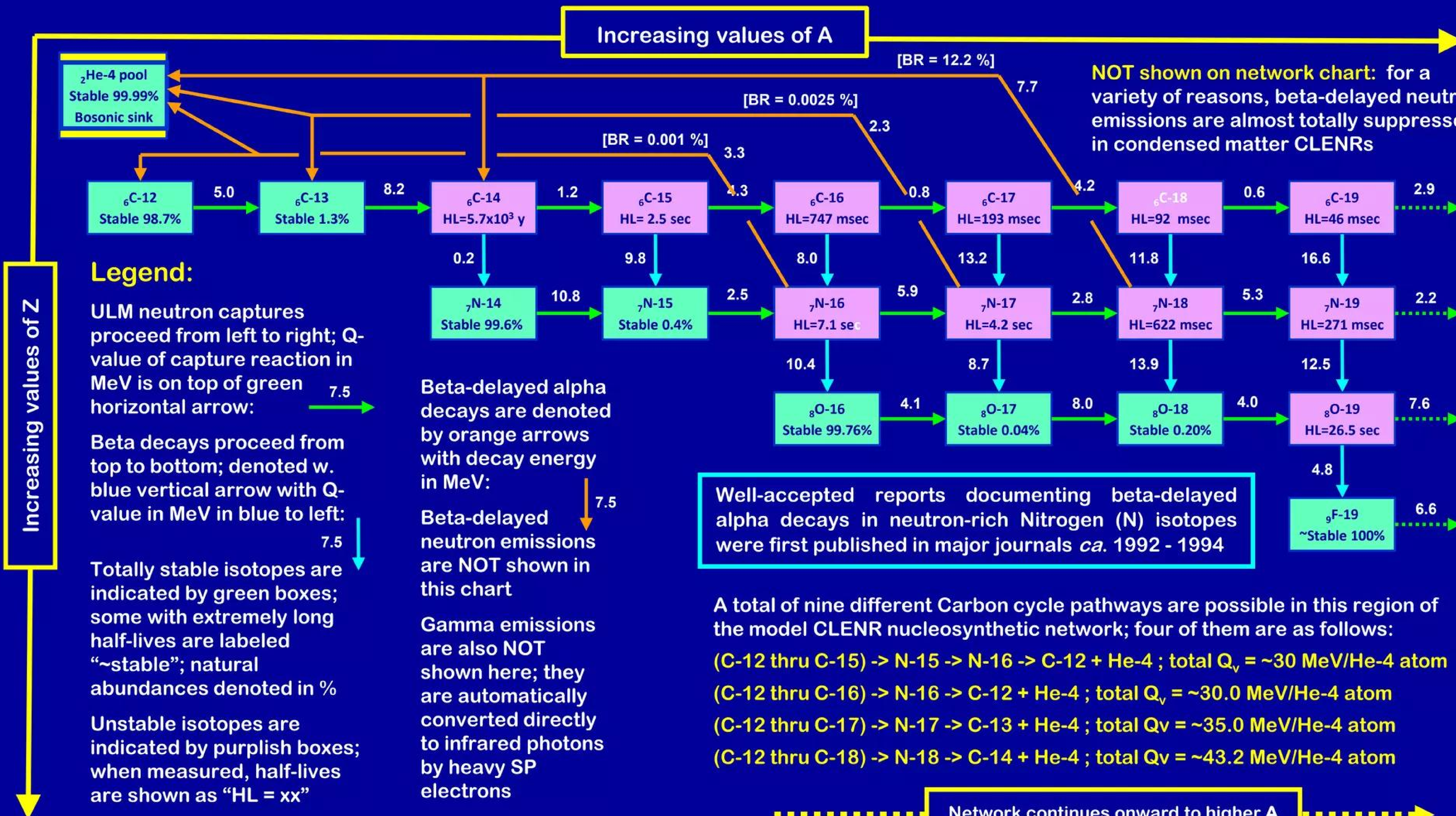
Carbon transmutation releases > 1 million x more BTUs

Carbon atoms are transmuted into Nitrogen then Oxygen and so forth



A total of nine different Carbon cycle pathways are possible in this region of the model CLENR nucleosynthetic network; four of them are as follows:

(C-12 thru C-15) -> N-15 -> N-16 -> C-12 + He-4 ; total Q_v = ~30 MeV/He-4 atom

(C-12 thru C-16) -> N-16 -> C-12 + He-4 ; total Q_v = ~30.0 MeV/He-4 atom

(C-12 thru C-17) -> N-17 -> C-13 + He-4 ; total Qv = ~35.0 MeV/He-4 atom

(C-12 thru C-18) -> N-18 -> C-14 + He-4 ; total Qv = ~43.2 MeV/He-4 atom

Network continues onward to higher A

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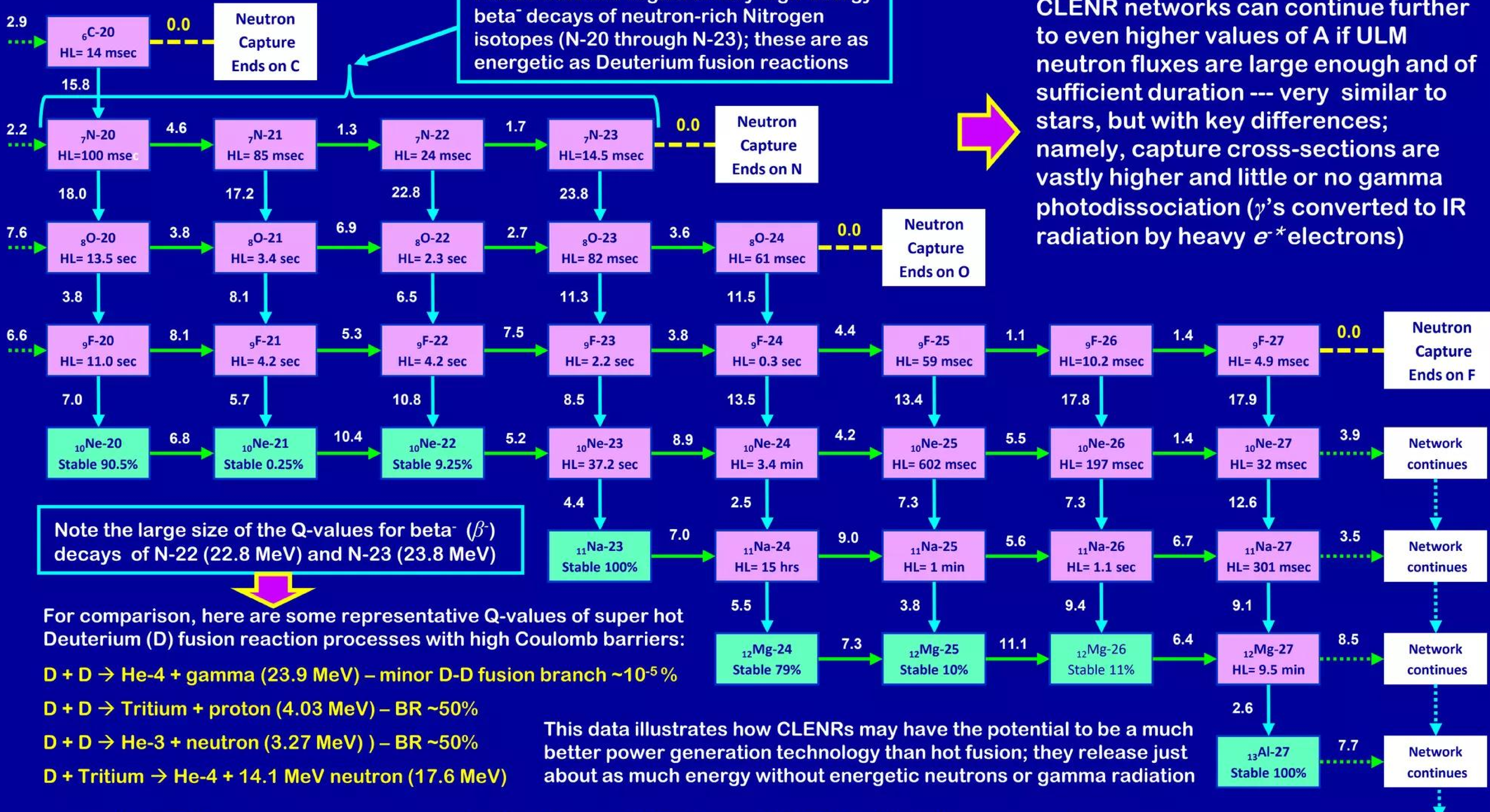
Carbon transmutation releases > 1 million x more BTUs

Carbon-target CLENR network produces progressively heavier elements

Please note this region of very high-energy beta⁻ decays of neutron-rich Nitrogen isotopes (N-20 through N-23); these are as energetic as Deuterium fusion reactions

CLENR 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 super 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 CLENRs 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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CLENRs and the future of global power generation

5 -10 kW distributed power sources can revolutionize energy production

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

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

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CLENRs and the future of global power generation

Broad deployment could end energy poverty for billions of people

- ✓ Development of low cost CLENR-based portable and small-scale stationary systems could revolutionize green CO_2-free distributed power generation worldwide; it could potentially enable near-ubiquitous CLENR system deployment, and eventually permit universal global electrification at readily affordable societal costs
- ✓ Use of a distributed CLENR power generation strategy to provide full rural electrification could save countries like China and India many hundreds of billions if not trillions of yuan and rupees in investments that would otherwise have to be made to expand geographic coverage of presently limited-area electrical grids. The same is true for rural Africa, as well as hinterlands of the Middle East and South America
- ✓ Achievement of that goal would end energy poverty for over one billion people presently living in rural areas of our world that do not have any non-battery sources of local electric power generation --- grid-based, distributed stationary, mobile fossil-fueled generators, or otherwise

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CLENRs and the price of green power generation

Real price of power could be reduced just like prices of computers

- ✓ Small-scale 5 - 10 kW CLENR systems might seem to be very far from being able to compete with 500 - 1,000 MW coal-fired and Uranium-fission power plant behemoths. However, please recall the recent history of personal computers versus mainframes in which PCs drastically reduced real price of computation:

  When PCs were first introduced 35 years ago, mainframe computer manufacturers regarded them as little toys; information processing technological jokes of little or no consequence. Less than 10 years later, mainframe companies weren't laughing any more. Quite the opposite.

  Today, except for a handful of survivors like IBM, most mainframe and minicomputer dinosaurs have disappeared. In fact, most of today's so-called 'mainframes' contain internal arrays of commodity PC microprocessors

- ✓ Using a similar business strategy that combines high-volume manufacturing, aggressive pricing and distributed generation, the economic costs of electric power generation via combustion processes vs. transmutation of Carbon with CLENRs could potentially reach real-price parity in the not-too-distant future

Opportunity for CLENR power: retrofitting coal-fired boilers

Transmutation of coal-derived fuels better than chemical combustion

Complete combustion of coal with Oxygen: $CH_4 + 2\ O_2 \longrightarrow CO_2 + 2\ H_2O$ + energy

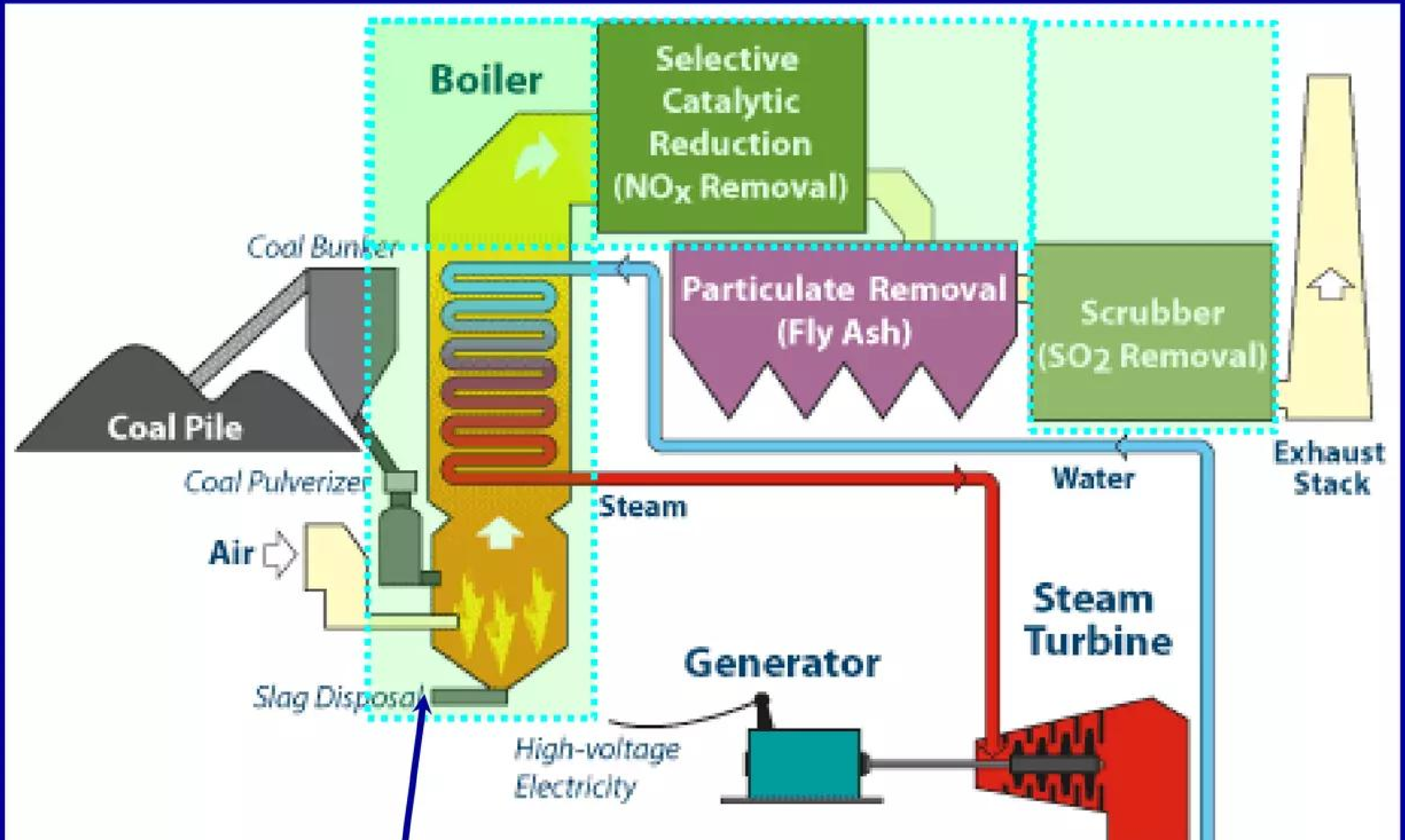
Today's inputs:

Capital $
bulk coal
air (O_2)

vs.

LENR inputs:

Capital $
Hydrogen
LENR fuel
electricity
base metals



CLENRs would change boiler, coal pulverizer, and environmental subsystems (for zero NO_x or SO_2)

Today's outputs:

Heat
electricity
CO_2
NO_x and SO_2
slag, particulates

vs.

LENR outputs:

Heat
>> electricity
N_2, O_2, etc.
waste (valuable $$$ elements)
particulates

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CLENRs could radically alter the future of green energy

Democratization of universal human access to affordable clean power

- ✓ Potentially very disruptive to portable power markets, e.g. Lithium batteries
- ✓ Synergistic with oil and coal industries in both the near- and far-futures
- ✓ Assuming that they could be successfully built, multi-megawatt output, retrofitted CLENR power plants could potentially be 54 - 74% less costly vs. natural gas plants; small-scale distributed generation could obviate this
- ✓ Potential to gradually replace vehicles' internal combustion engines over next 30 - 60 years; enable substantial reduction of man-made CO_2 emissions and someday, energy independence from burning petrol in transportation
- ✓ Widespread global deployment of CLENR technologies, together with synergistic large- and small-scale photovoltaic and wind-power systems, could create a less expensive, greener energy future for humanity
- ✓ CLENRs and portfolio of other types of carbon-free renewable energy technologies together have the potential to substantially reduce the real price of electricity over time and thus democratize future universal access to a wide variety of clean, affordable power sources throughout the world

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By the world very gradually switching power generation technologies from presently dominant chemical combustion processes to instead using transmutation of CLENR carbon-based fuels derived directly from petroleum and coal, we have an opportunity to dramatically extend the effective longevity of today's remaining in-ground fossil fuel resources.

Achieving this goal could postpone mankind's day of reckoning on continuing to have abundant, very affordable supplies of energy-dense, nonpolluting, CO_2-free power for perhaps thousands of years.

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Additional reading for the technically inclined

Lattice document that provides a broad-based overview about CLENR technology and its potential:

"Truly green nuclear energy exists – an overview for everybody: no deadly gammas … no energetic neutrons … and no radioactive waste"
L. Larsen, Lattice Energy LLC, v. 5 updated and revised through March 5, 2014 [108 slides]

http://www.slideshare.net/lewisglarsen/powering-the-world-to-a-green-lenr-future-lattice-energy-llcapril-11-2013

Index to large collection of documents about LENR theory, experimental data, and the technology:

"Index to key concepts and documents" v. #19
L. Larsen, Lattice Energy LLC, May 28, 2013 [119 slides] Updated and revised through August 19, 2014

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-index-to-documents-re-widomlarsen-theory-of-lenrsmay-28-2013

Peer reviewed paper covers all theoretical aspects of basic Widom-Larsen theory published to date:

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

Abstract: "Under special circumstances, electromagnetic and weak interactions can induce low-energy nuclear reactions to occur with observable rates for a variety of processes. A common element in all these applications is that the electromagnetic energy stored in many relatively slow-moving electrons can (under appropriate circumstances) be collectively transferred into fewer, much faster electrons with energies sufficient for the latter to combine with protons (or deuterons, if present) to produce neutrons via weak interactions. The produced neutrons can then initiate low-energy nuclear reactions through further nuclear transmutations. The aim of this paper is to extend and enlarge upon various examples analyzed previously, present order of magnitude estimates for each and to illuminate a common unifying theme amongst all of them."

http://www.ias.ac.in/pramana/v75/p617/fulltext.pdf