# Lattice Energy LLC

**Commercializing a next-generation source of green nuclear energy**

# Compelling economics of transmutation vs. combustion of natural Carbonaceous energy sources


**Lewis G. Larsen**

**President and CEO**
**Lattice Energy LLC**


**January 14, 2015**


**Combustion with Oxygen**

**Evolution of energy technology**


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


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

**Green LENR Transmutation**

**Jan. 17, 2015 added Slides #20, 28, 29 re two new papers by Steffen *et al*. in *Science* and *The Anthropocene Journal***

# Revolutionary new source of dense $CO_2$-free energy

## LENR commercialization could enable sustainable economic growth

## Highly synergistic with vastly less energy-dense wind and solar power sources

- ✓ While solar PV and wind are $CO_2$-free and extremely biosafe, their intrinsic energy densities are much lower than today's fossil fuels and inherently intermittent - not continuous - sources of electrical and thermal power
- ✓ Nuclear fission power has high energy densities, does not produce $CO_2$ and operates continuously; but it emits huge quantities of deadly neutron and gamma radiation during operation and produces many long-lived radwastes
- ✓ D-T nuclear fusion, while better than fission in terms of producing much less radwaste, still emits very dangerous neutron and gamma radiation during operation; also, there is still no sign of it being commercialized after 60 years of huge effort and hundreds of billions of R&D $ spent worldwide. See July 31, 2014 *Nature* story on ITER by Elizabeth Gibney (see hyperlink below)
- ✓ Low energy neutron reactions (LENRs) are only primary energy technology on foreseeable horizon that can provide world with affordable dense green energy, connect the unconnected, and empower billions of powerless people

http://www.nature.com/news/five-year-delay-would-spell-end-of-iter-1.15621?WT.ec_id=NEWS-20140805

Image: NASA

# Key take-aways

## LENRs increase economic/BTU value of fossil Carbon by at least 500x

## Achieved without emitting any $CO_2$ while releasing vastly greater thermal energy

- ✓ Revolutionary LENR technology can potentially transform oil and coal into 'green' $CO_2$-free LENR fuels that possess >5,000x the energy density (Watt*hours/kg) of unleaded gasoline
- ✓ In LENR fuels derived from extraction and processing of aromatic fractions found in oil and coal, generation of usable heat (i.e. BTUs) occurs via clean radiation-free, neutron-catalyzed *transmutation* of Carbon into Nitrogen and Oxygen rather than chemical combustion with $O_2$
- ✓ We will show how applied LENR technology can potentially increase BTUs and economic $$$ values of natural fossil Carbonaceous energy sources by at least 500x; much of this increase in energetic and economic value comes from huge energy densities and BTUs produced by nuclear processes as compared to purely chemical energy processes such as combustion
- ✓ In British Petroleum's 63rd annual *Statistical Review of World Energy* (2014) they estimated that oil will run-out in ~53 years and coal in ~113 years. Given at least 500x increase in the energetic/economic value of LENR fuel, commercialization of LENRs on aromatic molecules would extend useful economic lifetime of fossil Carbon resources out to at least 25,000 years
- ✓ Aromatic-based LENRs would eliminate "Carbon Bubble" and "stranded assets" problems
- ✓ Small-scale LENR systems might seem light years away from being able to compete with huge 500 - 1,500 MW coal-fired and Uranium-fission power plant behemoths; that said, please recall the history of personal microprocessors (PCs) versus mainframes. When PCs were first introduced nearly 40 years ago, mainframe computer manufacturers regarded them as just little toys, information processing jokes of no real consequence. Less than 10 years later, big mainframe companies weren't laughing any more. Today, except for handful of survivors like IBM, mainframe and minicomputer dinosaurs are gone, replaced by microprocessor arrays

# Lattice Energy LLC

**LENRs are neither fission nor fusion**
**but something rather different and much better**

# LENRs potentially much better than fission or fusion

## Society should start hedging its bets on fusion as future power source

- ✓ Virtually all agree that development of lower-risk, ecologically benign, low cost sources of energy is crucial to future world economic growth and overall quality of life, especially for energy-poor people living in rural areas without electricity
- ✓ Over past 50 years, enormous financial investments have been made in D-T fusion technology, yet there are still no operating commercial power plants
- ✓ In last 25 years, tens of billions of dollars, euros, rubles, yuan, yen, and rupees were spent on fusion R&D; by contrast, less than ~US$250 million has gone into LENRs during that time --- vast majority of that money came from private sector
- ✓ Maybe it's time for society to slow down chasing the fusion rainbow and start making greater parallel investments in LENRs in addition to fusion and fission
- ✓ By pursuing multiple synergistic paths toward a goal of sustainable growth we should, as they say in the USA, "hedge our bets" on development of new, non-polluting, inexpensive energy sources that can ultimately supplant fossil fuels

# Widom-Larsen enables commercialization of LENRs

## Applied nanotechnology and LENRs are mutually joined at the hip

## Development risks can be reasonable thanks to Widom-Larsen and nanotech

**Guided by physics of the Widom-Larsen theory, an opportunity to commercialize LENRs as truly green $CO_2$-free nuclear energy source has been enabled by a unique juxtaposition of very recent parallel advances in certain very vibrant areas of nanotechnology (esp. plasmonics), quantum entanglement, new innovations in nanoparticle fabrication techniques, as well as an array of new discoveries in advanced materials science.**

# 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 → 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

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

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

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

Neutrons + atomic nuclei —Transmutation→ heavier elements + decay products

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

# LENRs are green: no energetic radiation or radwastes

## Lack of hard radiation obviates need for shielding and containment

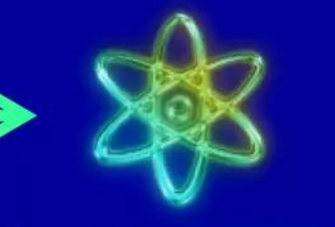
## Major opportunity to develop safe, battery-like portable LENR power sources

Fission and fusion processes both emit deadly MeV-energy neutron and gamma radiation

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

**Evolution of nuclear technology**

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




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

# Possible applications for potent LENR thermal sources

## Price/performance should outperform competing energy technologies

| Market Application Examples | More details about applications | Economic Advantages |
|---|---|---|
| LENRs enable safe, radiation- and $CO_2$-free free nuclear energy production and power generation at substantially lower cost vs. competing nuclear (fission or fusion) and chemical technologies. Vastly greater energy densities and longevity at a lower price per kWh compared to chemical power sources for producing electricity | Integrate LENR heat sources w. different types of energy conversion technologies: e.g., create battery-like devices using thermoelectrics that can convert raw heat directly into DC electricity; or use heat to rotate a shaft for direct motive propulsion and/or in power generation systems (e.g., steam turbines); scale-up by increasing LENR-active surface areas and/or volumetrically in case of dusty plasmas | SAFE - no radiation shielding or waste issues. Could someday enter huge unit-volume portable power markets and be able to compete directly against advanced chemical batteries, small fuel cells, and fossil fuel microgenerators |
| Create large quantities of inexpensive raw process heat for bitumen extraction, heavy oil recovery, and/or oil shale processing. Could eliminate burning of natural gas used to make steam employed in SAGD process for underground bitumen extraction in oil sands regions of Canada (big decrease in $CO_2$ footprint and extraction costs) | Long-lived LENR thermal sources lowered down well holes could be used to directly heat-up bitumen or heavy oil in underground reservoirs to reduce production costs and enhance % recovery. Could use LENR heaters for *in-situ* underground upgrading --- maybe up to mid-distillates. Can also produce clean, inexpensive process heat for many downstream petroleum operations such as refining | Major benefits to large oil and coal producers – can help increase long-term supplies of oil and reduce total production costs; shrink industry's global $CO_2$ emission footprint across all upstream and downstream operations |

# Lattice commercialization plan akin to computer chips

## Scale-up LENR system power outputs & integrate energy conversion

## Leverage existing nanotechnology to minimize product development time/risks

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

# Nuclear energy density is vastly larger than fossil fuels

## Energy density of LENRs is ~5,000 times greater than that of gasoline

| LENRs Versus Chemical Energy Sources: Batteries, Fuel Cells, and Microgenerators | | |
|---|---|---|
| **Source of Energy** | **Approximate Energy Density (Watt*hours/kg)** | |
| **Alkaline Battery** | **164** | Chemical Energy Sources |
| **Lithium Battery** | **329** | |
| **Zinc-Air Battery** | **460** | |
| **Direct Methanol Fuel Cell (35% efficient)** | **1,680** | |
| **Gas Burning Microgenerator (20% efficient)** | **2,300** | |
| **100% Efficient Combustion of Pure Methanol** | **5,930** | |
| **100% Efficient Combustion of Pure Gasoline** | **11,500** | |
| **LENRs** (based on an assumption of an average of 0.5 MeV per nuclear reaction in an LENR system) | **57,500,000** (maximum theoretical energy density – only a fraction would be achievable in practice) | LENRs |

# LENR technology can transform today's fossil fuels

## Breakthroughs in physics and nanotechnology make this possible

## Bitumen, heavy oil, and coal may be much more valuable as green LENR fuels

**All of these natural hydrocarbons contain aromatic molecules that can be stripped-out**

**Canadian bitumen**

**Heavy viscous oil**

**Anthracite coal**

Lattice has discovered that aromatic molecules can potentially be stripped-put and specially processed to be converted into green LENR fuels: no hard radiation emissions, no production of long-lived radioactive wastes or emission of gaseous $CO_2$ into the atmosphere but instead release > 5,000 times more thermal energy vs. combustion of Carbon-based molecules with Oxygen

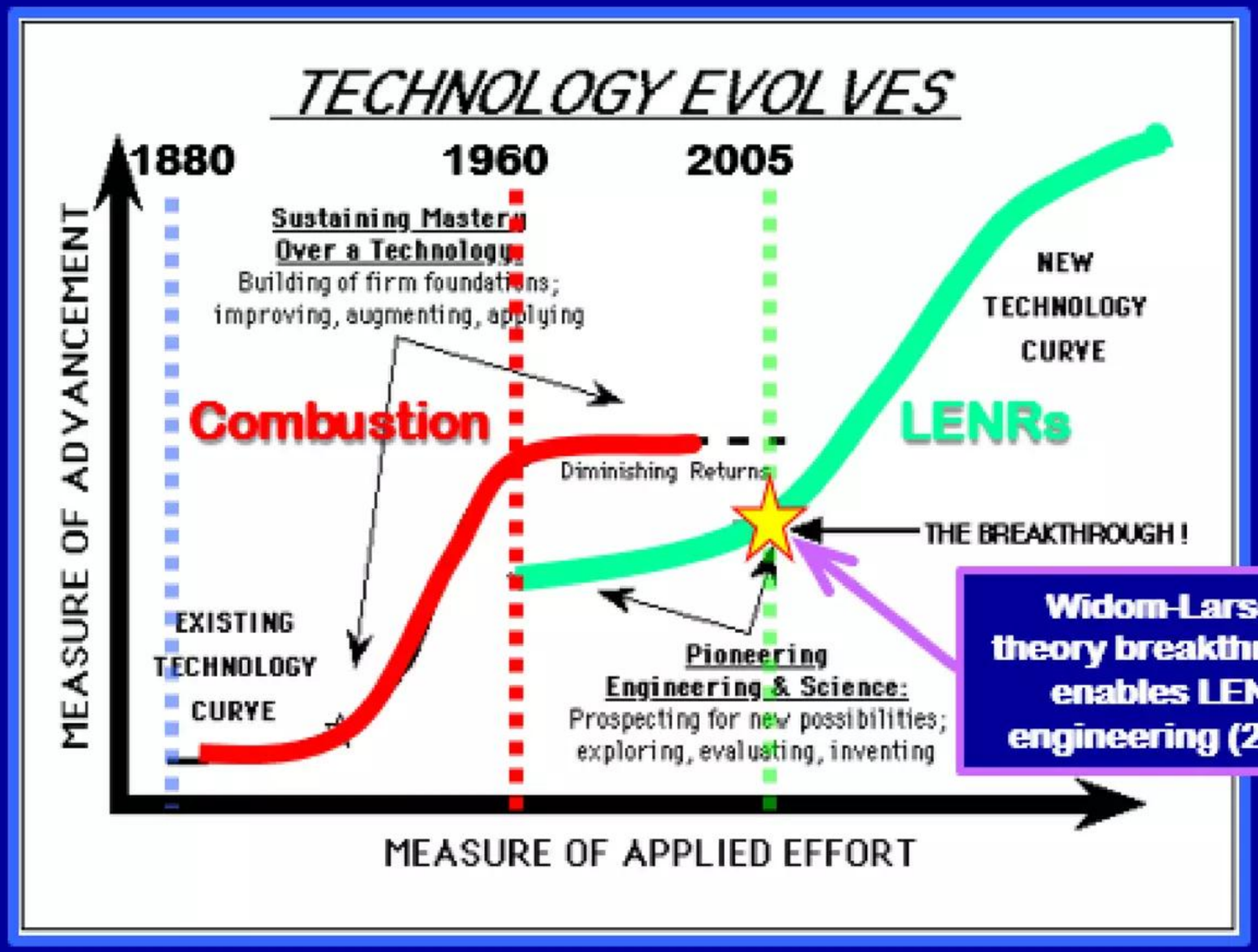
# Opportunity: transmute Carbon rather than combust it

## Help mitigate global warming and release vastly greater heat energy

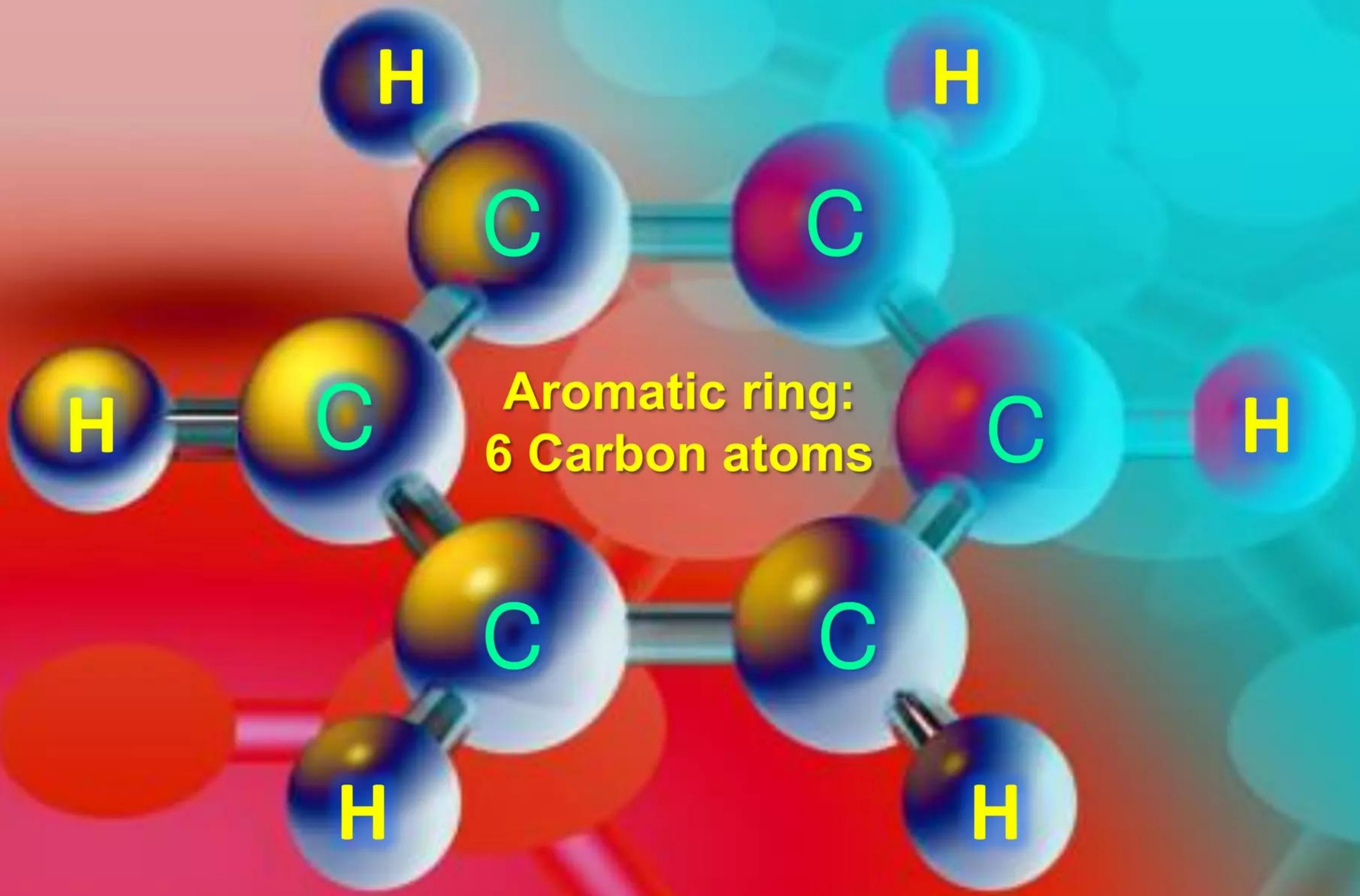
### Technology evolution S-curve: combustion vs. LENR transmutation of Carbon

Old technology - combustion: Carbon moieties + Oxygen → Carbon dioxide + water

New technology - LENR transmutation: Carbon + neutrons → Nitrogen → Oxygen



# Fossil Carbon can be transmuted rather than combusted




**Aromatic ring:**
**6 Carbon atoms**

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

# Fossil Carbon can be transmuted rather than combusted

## Heavy oil and coal could be processed to produce ‘green’ LENR fuels

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

Neutrons + target fuel atoms —Transmutation→ heavier elements + decay products

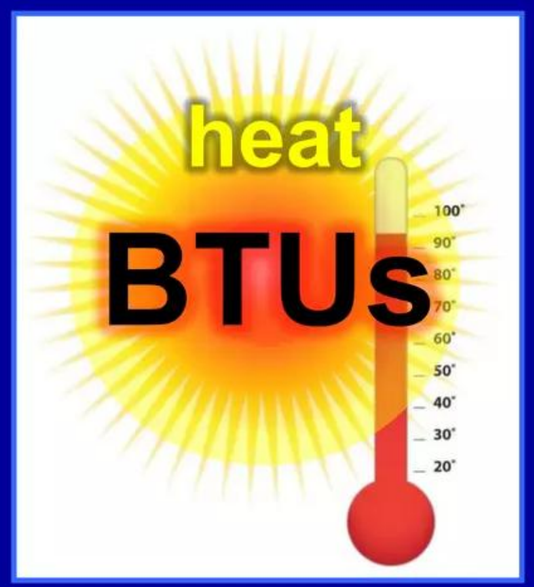
Neutron ‘match’


capture +

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


produces →

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

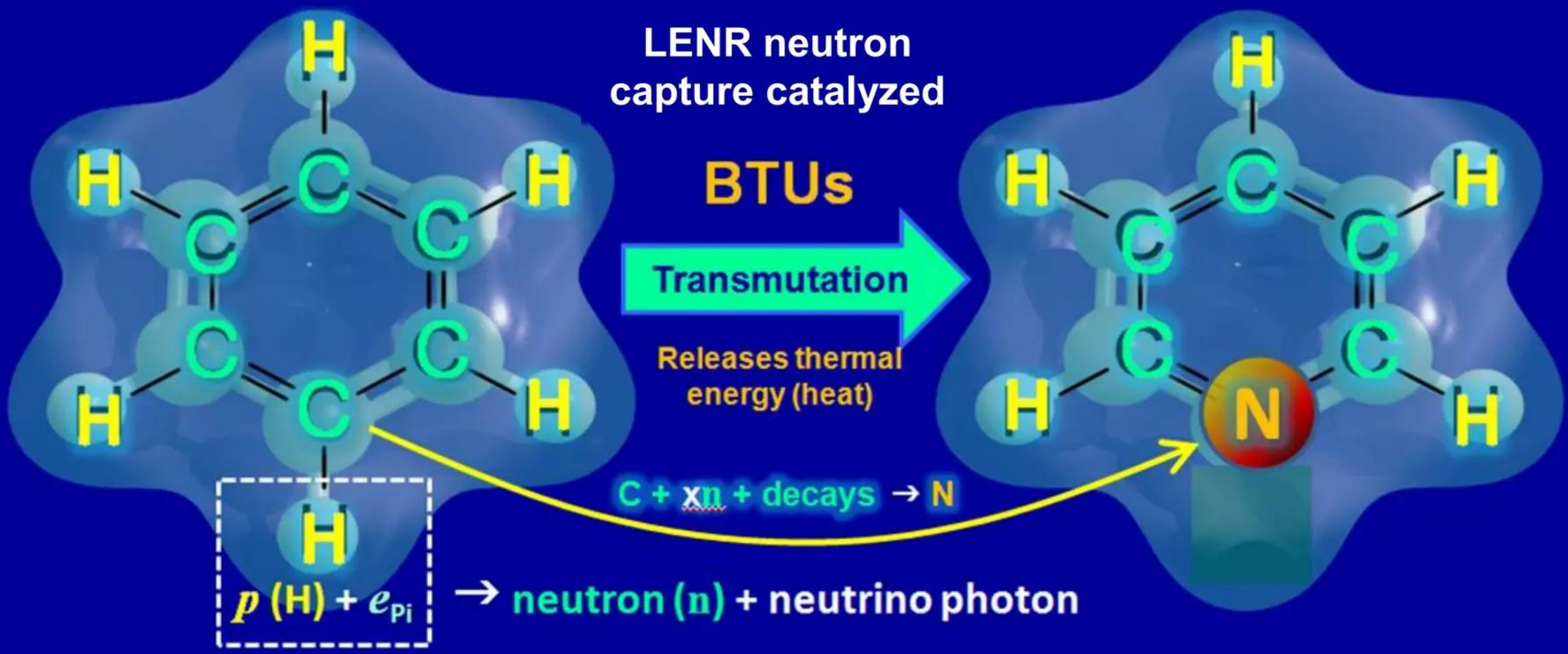



**Process does not emit any deadly radiation or produce troublesome radwastes**

# Convert ring Hydrogen atoms (protons) into safe neutrons

## Neutrons are captured by ring Carbon atoms that are then transmuted

### In this example a Carbon atom is transmuted into a Nitrogen with LENR process




**Process does not emit any deadly radiation or produce troublesome radwastes**

# LENR process transmutes Carbon into other elements

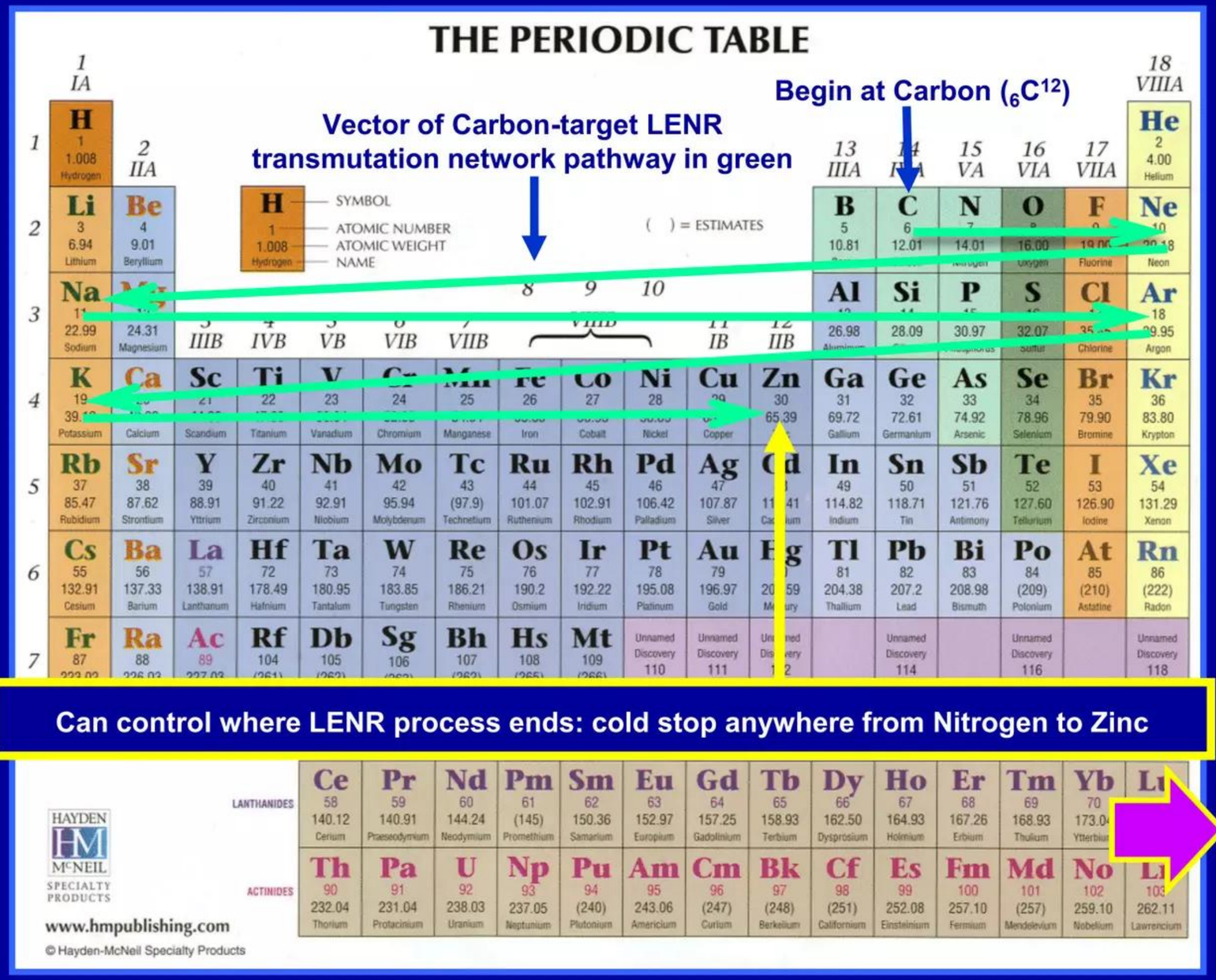
## Heavy oil and coal could be processed to produce green LENR fuels

### Carbon atoms found on aromatic rings are fuel for green transmutation process

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, LENR 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**

**LENRs presently occur both in Nature and in some industrial processes at extremely low rates**

# Future: retrofit existing coal plants with C → N → O boilers

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

## Retrofit strategy preserves earlier capital investments and minimizes disruption

**Today's fossil fuel inputs:**

Capital $

Bulk coal

Air ($O_2$)

Scrubber technology

vs.

**LENR inputs:**

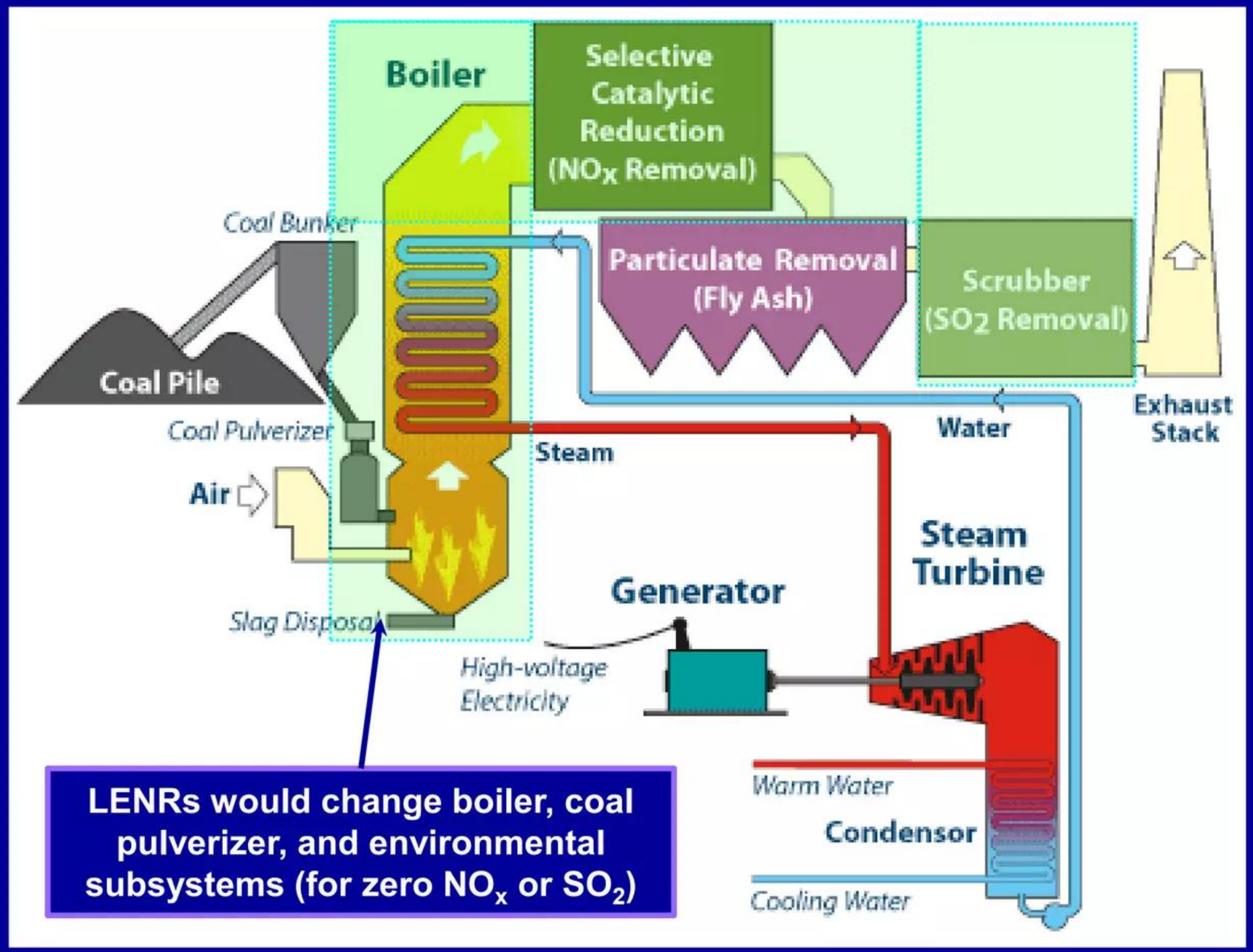
Capital $

Hydrogen

Electricity

LENR fuel:

Aromatic Carbon and base metals




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

**Today's fossil fuel 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)

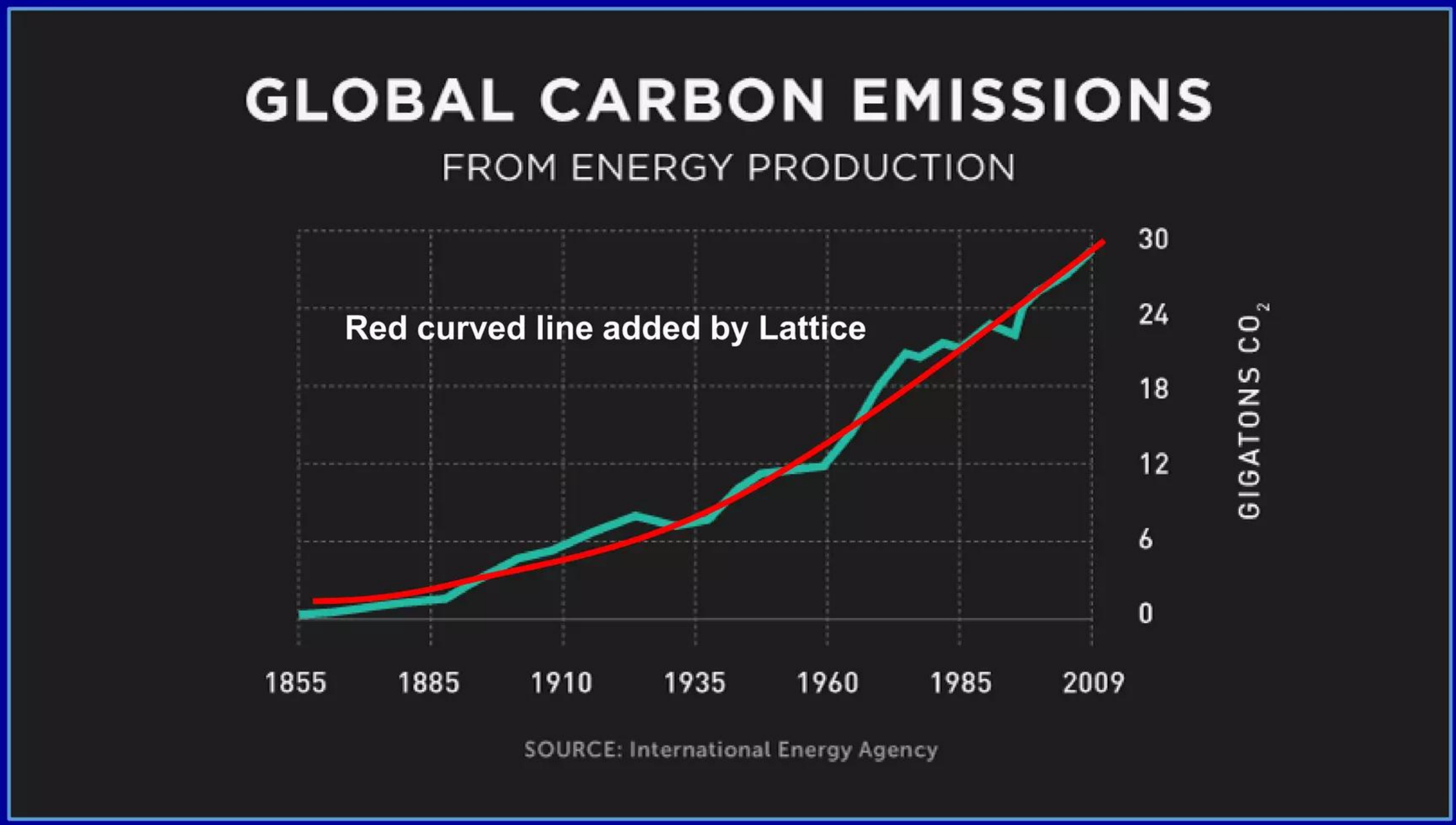
Particulates

**LENR power generation could be engineered to seamlessly replace older thermal systems**

# Growth of Carbon emissions exponential since 1855

## If today's global warming caused by $O_2$ combustion then must curb it

## May be a better way to use fossil Carbon: transmutation rather than combustion



# Green LENRs vs. combustion: not to decide is to decide

## Global energy use has been rising exponentially since the mid-1850s

## Combustion powered most of this growth: collision course with $CO_2$ emissions

"The trajectory of the Anthropocene: The great acceleration" W. Steffen *et al*.
*The Anthropocene Review* pp. 1 - 18 (OnlineFirst Jan. 16, 2015)

http://anr.sagepub.com/content/early/recent

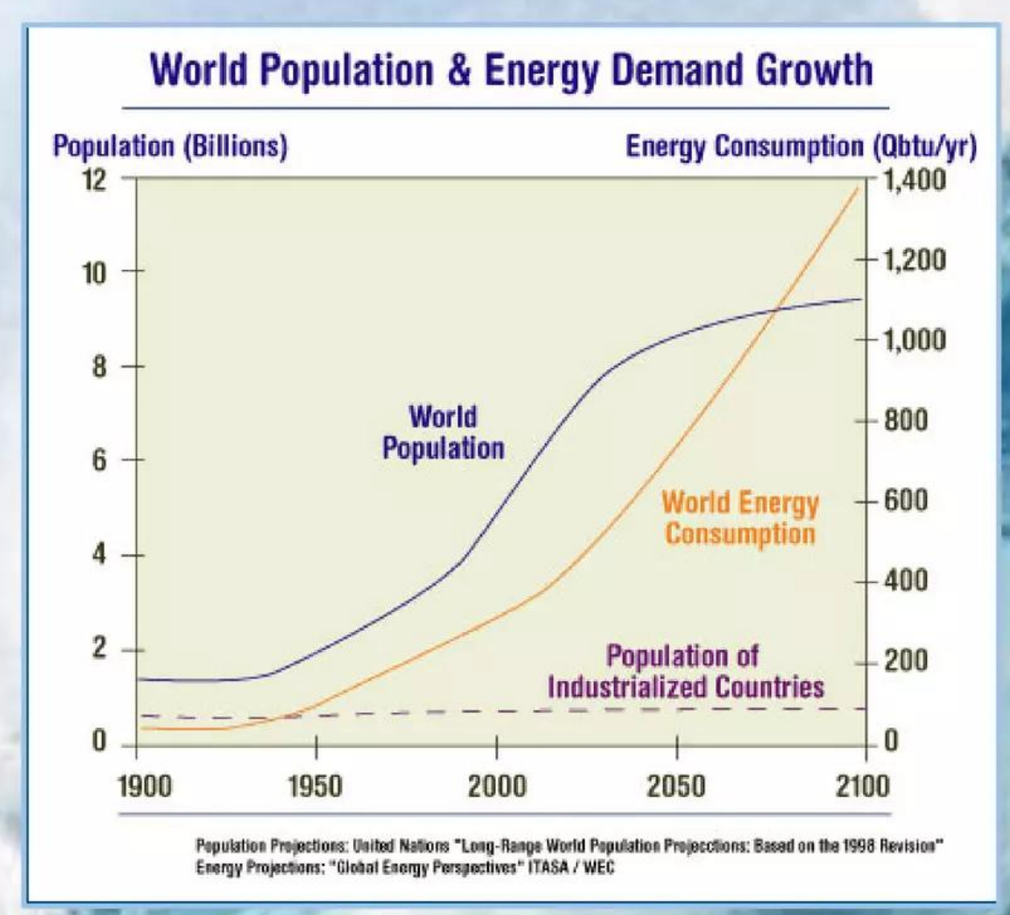
http://www.slideshare.net/IGBPSecretariat/great-acceleration-2015

"The dominant feature of the socio-economic trends is that the economic activity of the human enterprise continues to grow at a rapid rate. The Global Financial Crisis of 2008 - 2009 may be just discernible at the end of the global GDP curve but it is more clearly visible as a sharp downturn during the last decade in foreign direct investment. Recovery has been rapid, however. Also, there may be a slowing in the construction of new large dams. However, remaining global indicators show no signs of slowing in the most recent decade. Primary energy use shows the shape typical of the Great Acceleration trajectory but shows little or no evidence of an effect of the Global Financial Crisis."

# Oil companies facing turbulent period in near future

## Strategic issue: BP says oil supplies will likely run-out in ~53 years

## Besides resource depletion, climate change may force drop in fossil fuel usage




Population projections: United Nations
Energy consumption projections: IIASA / WEC

- ✓ Resource depletion: BP says oil will run-out in ~53 years and coal in ~113; what happens to energy markets after that?
- ✓ Climate change: emerging scientific consensus posits global warming is being caused by increasing $CO_2$ emissions from human activities; want huge cuts in $CO_2$
- ✓ Fear of global warming: has lead to speculation about somehow effecting radical decreases in man's $CO_2$ emissions to help mitigate further rise in average global temperature; restrict fossil fuels?
- ✓ These trigger concerns about a "Carbon bubble" that renders remaining in-ground fossil fuels "stranded" and ~ $$$ worthless

**Global energy demand has been increasing exponentially; will continue to do so**

# British Petroleum believes the Oil Age only has 53 years left

## Published in “The Christian Science Monitor” on July 14, 2014

The Christian Science Monitor

bp

## How long will world's oil reserves last? 53 years, says BP

The world has 53.3 years left to find an alternative to oil before current proved reserves run dry, according to BP. Of course, nations are finding new oil – meaning that number is rising – but new extraction methods are costly and can pose environmental threats.

**By Andy Tully**, OilPrice.com ▼ | JULY 14, 2014

According to BP, drivers whose vehicles rely on burning oil have a little more than a half-century to find alternate sources of energy. Or walk.

http://www.csmonitor.com/Environment/Energy-Voices/2014/0714/How-long-will-world-s-oil-reserves-last-53-years-says-BP

http://oilprice.com/Energy/Energy-General/BPs-Latest-Estimate-Says-Worlds-Oil-Will-Last-53.3-Years.html

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

# BP says only 14 years remain for Asia-Pacific oil reserves

## Published in "The Christian Science Monitor" on July 14, 2014

The Christian Science Monitor

bp

Such methods are helping the United States, for example, to achieve energy independence. But that won't apply to China, a huge customer for fossil fuels. BP says Asia-Pacific oil reserves will last only 14 years at current rates. That means China will have to keep importing oil, putting further strain on global reserves.

http://www.csmonitor.com/Environment/Energy-Voices/2014/0714/How-long-will-world-s-oil-reserves-last-53-years-says-BP

http://oilprice.com/Energy/Energy-General/BPs-Latest-Estimate-Says-Worlds-Oil-Will-Last-53.3-Years.html

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

# BP says only 113 years remaining for global coal reserves

## Published in BP's annual "Statistical Review of World Energy 2014"

bp

### Coal reserves

World proved coal reserves in 2013 were sufficient to meet 113 years of global production, by far the largest R/P ratio for any fossil fuel

The US, Russia and China hold the largest proved reserves. By region, Europe & Eurasia holds the largest proved reserves and has the highest R/P ratio 254 years, compared with 250 for North America.

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

# IPCC says global warming definitely occurring today

## "Warming of the climate system is unequivocal" – IPCC report 2014

## Societal response to global warming may restrict the combustion of fossil fuels


**"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen."**

**"Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century."**

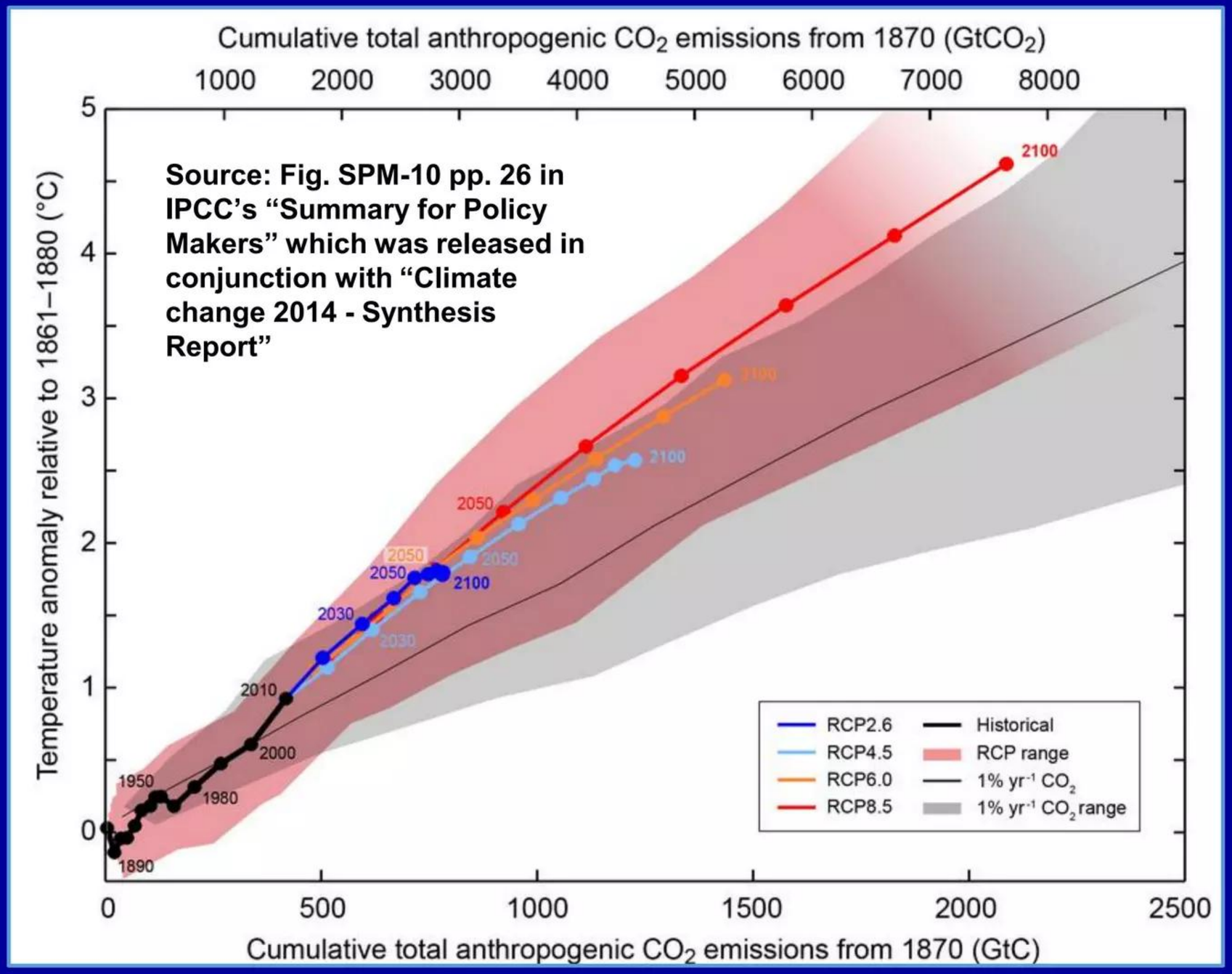
**"Cumulative emissions of carbon dioxide largely determine global mean surface warming by the late 21st century and beyond."**

http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_LONGERREPORT_Corr2.pdf

# IPCC says global warming definitely occurring today

## Impact of $CO_2$ emissions on temperature illustrated in IPCC chart

## Societal response to global warming may restrict the combustion of fossil fuels



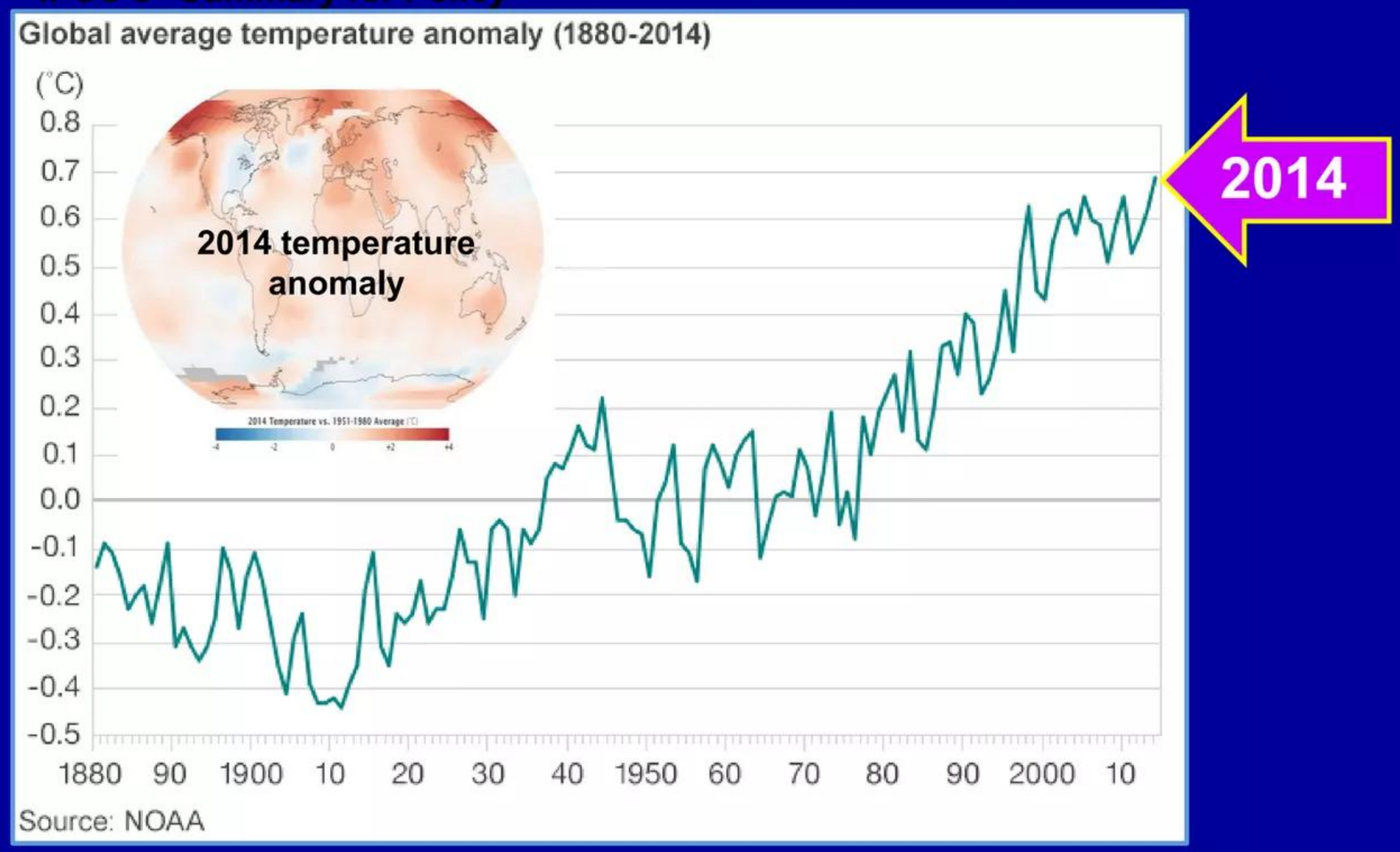
# 2014 was confirmed as the warmest year since 1880

## Jan. 16, 2015: NASA and NOAA announced results of analyzed data

## Independent studies by NASA and NOAA scientists reached same conclusion

**"This is the latest in a series of warm years, in a series of warm decades. While the ranking of individual years can be affected by chaotic weather patterns, the long-term trends are attributable to drivers of climate change that right now are dominated by human emissions of greenhouse gases," GISS Director Gavin Schmidt**

IPCC's "Summary for Policy




http://www.giss.nasa.gov/research/news/20150116/

# New research reiterates dire warnings re climatic shifts

## Concluded man-caused drivers show "no signs they are slowing down"

## Scientific data continues to accumulate that climate change is a pressing reality


**Quoted directly from news story by Oliver Milman, *The Guardian* online, January 15, 2015 at 14:00 EST**

**Milman's excellent news story reports on two new, just-published papers by Steffen *et al*.**

**Quoting excerpts directly from the *Guardian* story, Humans are "eating away at our own life support systems" at a rate unseen in the past 10,000 years by degrading land and freshwater systems, emitting greenhouse gases and releasing vast amounts of agricultural chemicals into the environment, new research has found.**

**All of these changes are shifting Earth into a "new state" that is becoming less hospitable to human life, researchers said. "These indicators have shot up since 1950 and there are no signs they are slowing down," said Prof Will Steffen of the Australian National University and the Stockholm Resilience Centre. Steffen is the lead author on both of the studies.**

http://www.theguardian.com/environment/2015/jan/15/rate-of-environmental-degradation-puts-life-on-earth-at-risk-say-scientists

# New research reiterates dire warnings re climatic shifts

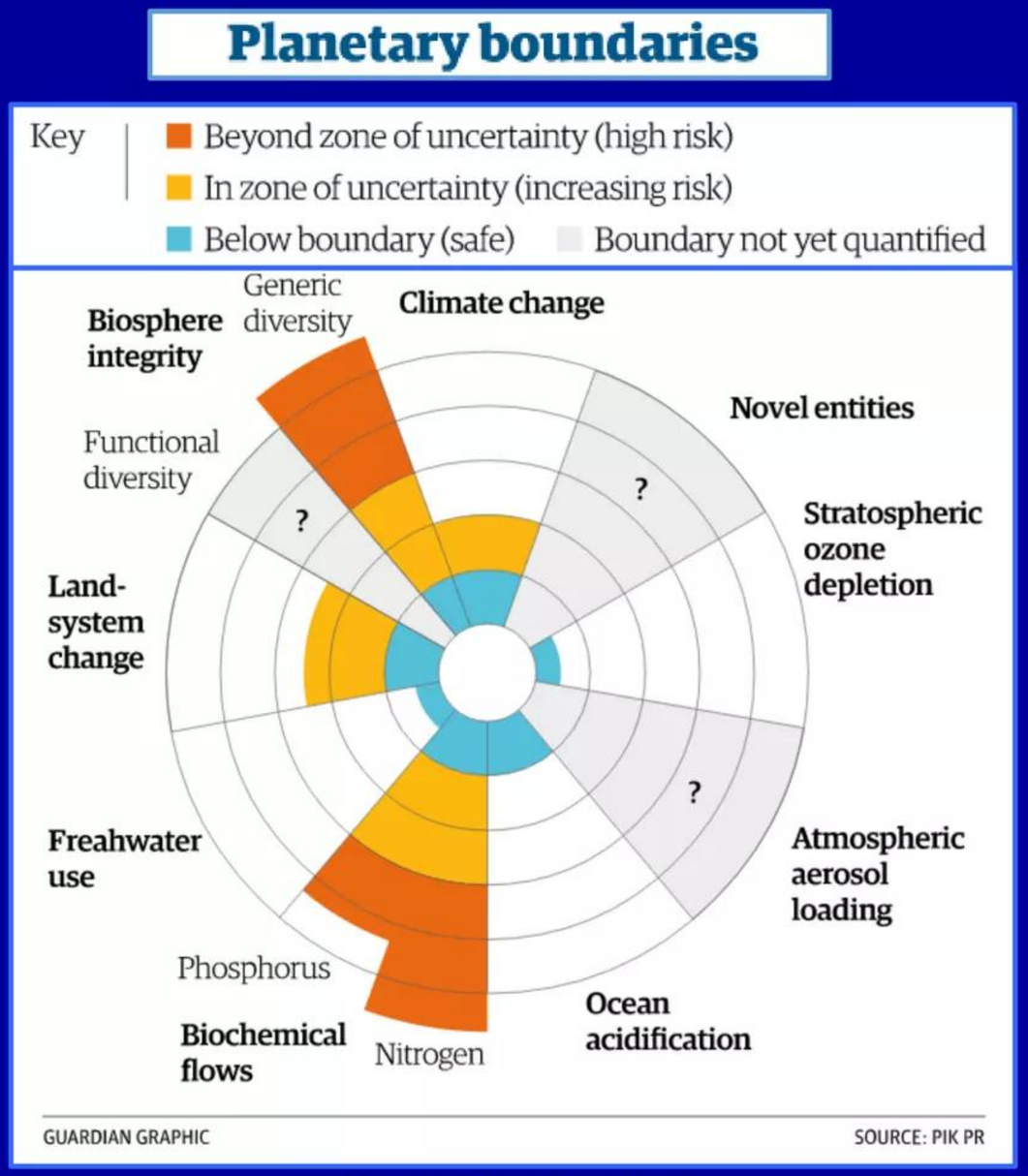
## Many key planetary boundaries moving into zones having higher risks

## "[Large] changes could compromise Earth's ability to sustain human societies"

**"Planetary boundaries: Guiding human development on a changing planet"**
**W. Steffen *et al.*, *Science* online Jan. 15, 2015**

**http://www.sciencemag.org/content/early/2015/01/14/science.1259855.abstract**

**Abstract:** "The planetary boundaries framework defines a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the Earth System. Here, we revise and update the planetary boundaries framework, with a focus on the underpinning biophysical science, based on targeted input from expert research communities and on more general scientific advances over the past 5 years. Several of the boundaries now have a two-tier approach, reflecting the importance of cross-scale interactions and the regional-level heterogeneity of the processes that underpin the boundaries. **Two core boundaries - climate change and biosphere integrity - have been identified, each of which has the potential on its own to drive the Earth System into a new state should they be substantially and persistently transgressed."**




Source: *The Guardian*

**http://www.theguardian.com/environment/2015/jan/15/rate-of-environmental-degradation-puts-life-on-earth-at-risk-say-scientists**

# LENRs solve issue of future “Carbon bubble” asset risk

## Bank of England *et al*. weigh risks of “stranded” in-ground fossil fuels

## Not only will such risks disappear but LENRs increase energetic value by >500x


theguardian
Winner of the Pulitzer prize

Bank of England investigating risk of 'carbon bubble'

Enquiry to assess chances of an economic crash if climate change rules render coal, oil and gas assets worthless

**Quoted directly from news story by Damian Carrington, *The Guardian* online, December 1, 2014 at 08:47 EST**

**"The Bank of England is to conduct an enquiry into the risk of fossil fuel companies causing a major economic crash if future climate change rules render their coal, oil and gas assets worthless."**

**"The concept of a 'carbon bubble' has gained rapid recognition since 2013, and is being taken increasingly seriously by some major financial companies including Citibank, HSBC and Moody’s, but the Bank’s enquiry is the most significant endorsement yet from a regulator."**

**"The concern is that if the world’s government’s meet their agreed target of limiting global warming to 2º C by cutting carbon emissions, then about two-thirds of proven coal, oil and gas reserves cannot be burned. With fossil fuel companies being among the largest in the world, sharp losses in their value could prompt a new economic crisis.”**

**http://www.theguardian.com/environment/2014/dec/01/bank-of-england-investigating-risk-of-carbon-bubble**

# Transmutation is economically attractive vs. combustion

## LENRs increase BTUs and economic $ values from coal and oil by >500x

| Oil is in barrels; Coal in short tons | Oil | Coal | Total adjusted economic value for oil + coal in US$ |
|---|---|---|---|
| BP est. proven reserves as of the end of 2013 | 1,687,900,000,000 | 891,531,000,000 | See BP's *Statistical Review of World Energy* (2014) |
| Percentage of proven reserves of a fossil fuel left in ground for whatever reasons (%) | 0.33 | 0.80 | See McGlade & Elkins in recent *Nature* article (2015) |
| Number of barrels of oil or short tons of coal deliberately left in the ground (reserves x %) | 5.57007E+11 | 7.13225E+11 | Hypothetical assumption for discussion purposes |
| For discussion purposes, simply assume price of oil and coal remains ~ same as it is today | US$ 50 bbl | US$ 55 ST | In fact, prices should rise as resources are depleted |
| Conservatively estimated economic value of reserves left-in-ground (US$ price x in-ground) | 2.78504E+13 | 3.92274E+13 | 6.70777E+13 |
| Assume that only 10% of in-ground oil and coal is recoverable as usable aromatic molecules | 0.10 | 0.10 | "Haircut" for non-aromatic fractions of oil and coal |
| Net economic value of green LENR fuels before adjusting for > energy density (value x .10) | 2.78504E+12 | 3.92274E+12 | Finally adjust for vastly >>> LENR production of heat |
| Adjust energy equivalent economic value for higher LENR energy density (multiply x 5,000) | 1.39252E+16 | 1.96137E+16 | 3.35389E+16 US$ |

500x

Assumed proven reserves data is taken from the BP *Statistical Review of World Energy* (2014); assumptions re % of oil and coal possibly left in ground (whether because of governmental fiats, voluntary restraint, taxation on extraction, or any combination thereof) taken from McGlade & Elkins (*Nature* 2015); assumption that energy density (ED) of LENR fuels derived from aromatic rings found in oil and coal is ~5,000x > gasoline is probably quite conservative - very likely that an *additional* 10 - 12x increase in BTU output could be achievable, i.e., >50,000x ED of gasoline

# Transmutation is economically attractive vs. combustion

- ✓ **At this point, it is not clear exactly how or even whether rates of extraction and/or use of fossil fuels for combustion could be substantially reduced.** That said, for purposes of discussion let's assume that leaving 33% of remaining oil and 80% of coal fallow in the ground might be a real possibility via governmental fiats. **What would it be worth in terms of economic $$$ value for the oil and coal industry to be able to extract those potentially 'stranded' fossil Carbon resources and generate vastly more $CO_2$-free energy via LENRs?** (note: non-aromatic components of oil and coal would still be available for use as chemical feedstock) **Answer to this question is provided in previous slide's Table: $3.35 \times 10^{16}$ US$**

- ✓ For purposes of discussion, let's arbitrarily assume that US$ 250 billion invested over 10 years would be needed to fully commercialize LENRs (Lattice believes it is ~2 - 3 orders of magnitude *less* than that number). **What multiple of that investment would the realized economic value of $3.35 \times 10^{16}$ US$ represent; dividing that number by $2.5 \times 10^{11}$ US$ yields ratio of $1.34 \times 10^{5}$ – huge economic multiplier resulting from a 10-year US$ 250 b investment**

- ✓ In 2014 alone, the global oil & gas industry collectively spent US$ 670 billion searching for and developing new fossil fuel resources. In 2013, just Chevron, ExxonMobil, and Royal Dutch Shell together spent more than US$ 120 billion on such activities. Lastly, drilling a single deep water oil well can cost US$100 million. **Investment capital that is needed to fully commercialize LENR technology is well-within the financing capabilities of major oil players**

- ✓ **LENRs have not yet been successfully commercialized but the science behind it is certainly real** --- what remains to be accomplished is mainly device engineering and scale-up of system power outputs. Besides Lattice and NASA in USA, Mitsubishi Heavy Industries and Toyota in Japan have experimental R&D programs, are filing patents, and are publishing some of their results in peer-reviewed scientific journals. **Given the very attractive economic proposition that has been outlined herein, more major companies will very likely enter the LENR technology race and eventually, somebody or somebodies, somewhere, will succeed**

# Major strategic opportunity for oil and coal industries:

## Extending economic usefulness of fossil Carbon to thousands of years

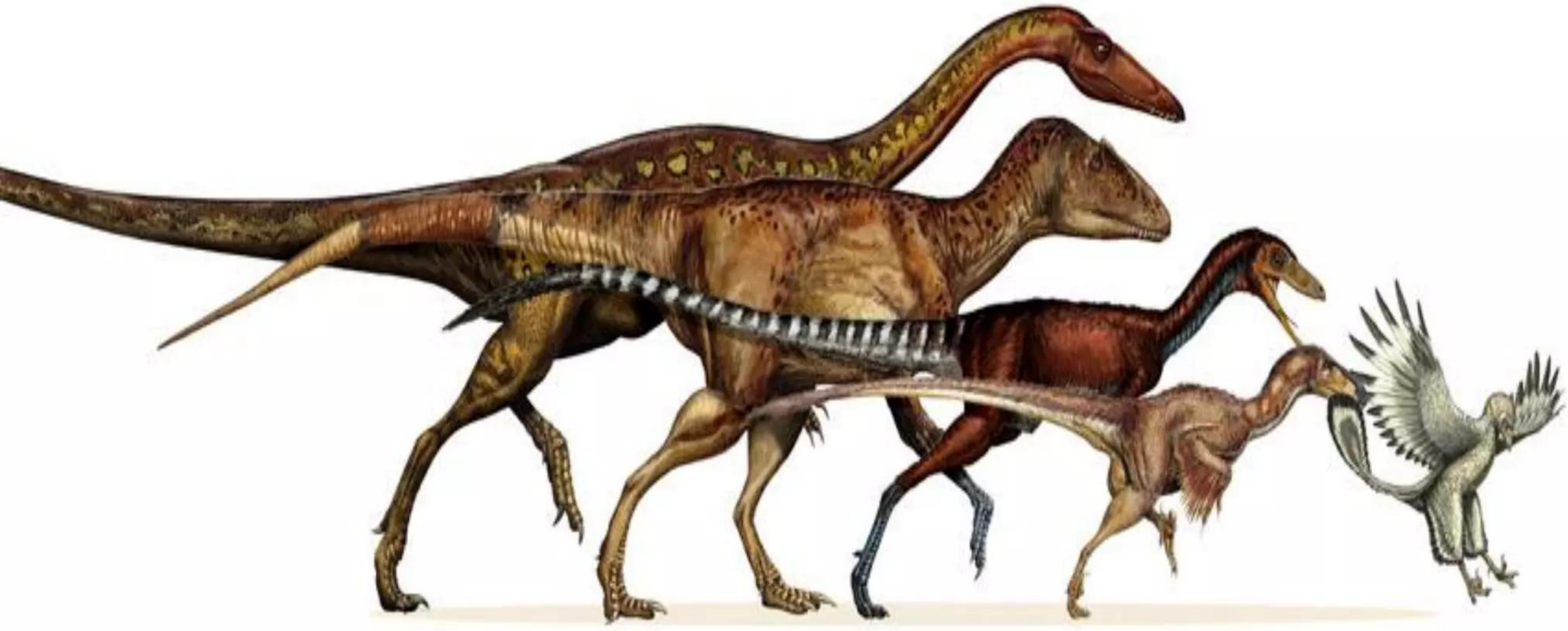
Oil and coal companies do not have to be aging technological fossil fuel dinosaurs threatened with potential extinction.

They can seize a LENR opportunity to adapt and evolve into vibrant green energy suppliers of the far future.

Laura13

# Some Dinosauria survived Cretaceous by evolving into birds

## LENRs could save fossil Carbon resources from twin asteroid strikes of resource depletion and mitigation of potential climate change



# Oil and coal industries can become eagles in a New World with vastly less combustion used for power generation

## LENRs provide longer and more profitable pathway into future

# Transmutation of Carbon could enable sustainable growth

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

Achieving this goal could postpone mankind's day of reckoning on energy for thousands of years, enable high rates of sustainable global economic growth, and allow future consumers to enjoy abundant supplies of affordable, nonpolluting, $CO_2$-free energy

It is a risk to develop LENRs.

What if it doesn't work out?

Ah ..... but what if it does?

Adapted from a quotation of American book author Peter McWilliams (1949 - 2000)

Coal power plant, Grosskrotzenburg, Germany – image credit: Reuters/Kai Pfaffenbach/files (2007)

# LENRs: disruptive, paradigm-shifting energy technology

## Unique proprietary knowledge about LENRs and their potential impact

**Larsen cv:** http://www.slideshare.net/lewisglarsen/lewis-g-larsen-cv-june-2013

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

- ✓ **Lattice's primary goal is commercializing LENRs for a variety of power generation applications**
- ✓ **In addition to serving as President and CEO of Lattice, Lewis Larsen also selectively engages in fee-based third-party consulting that does not compromise Lattice's proprietary intellectual property relating to LENR power sources. As a result of his having very strong foundations in business as well as chemistry and theoretical physics, he is uniquely qualified to assist energy companies, institutional investors, and a variety of government organizations in assessing strategic business, investment, and technology issues related to and tightly interwoven with the fascinating subject matter discussed herein**

Concentrating E-M energy in resonant electromagnetic cavity

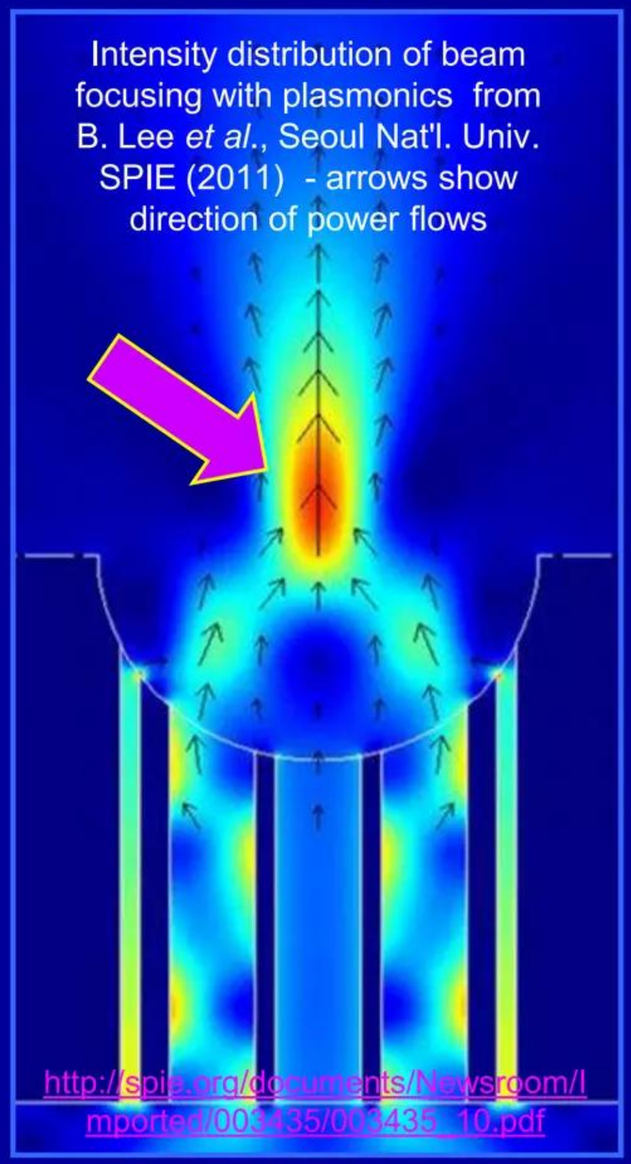


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Image credit: Jim Olive

# “Power”

By John and Johanna Hall - Siren Songs (BMI) first recorded on “No Nukes” CD (1980) in reaction to Three Mile Island (1979)

“Everybody needs some power I'm told
To shield them from the darkness and the cold.”

“I know that lives are at stake
Yours and mine and our descendants in time
There's so much to gain, so much to lose
Every one of us has to choose.”

“We are only now beginning to see
How delicate the balance of nature can be
The limits of her ways have been defined
And we've crossed that line.”

Performed by PP&M at their 25th anniversary concert (1986)

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

Running time 2:55