Lattice Energy LLC

Commercializing a next-generation source of dense, affordable CO_2-free energy

Spreading LENR revolution: empowering the powerless and connecting the unconnected

Lewis Larsen, President and CEO

"Over 1.2 billion people - 20% of the world's population - are still without access to electricity worldwide, almost all of whom live in developing countries. This includes about 550 million in Africa, and over 400 million in India. Access to electricity must be environmentally and socially sustainable."

Source: The World Bank (2014)

http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTENERGY2/0,,contentMDK:22855502~pagePK:210058~piPK:210062~theSitePK:4114200,00.html

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

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

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Empowering the powerless and connecting the unconnected

A global societal imperative in the midst of world climate change

"Universal energy access also powers modern, growing economies. The transformation of natural energy assets into usable energy services allows not just for household lighting and electricity, but also modern infrastructures and industrial practices that have positive social impacts. Affordable energy is used to power tractors, create fertilizers, and power irrigation pumps, all of which improve agricultural yields and raise income. Cheap and reliable grid electricity allows factory owners to increase output and hire more workers. Electricity allows hospitals to refrigerate lifesaving vaccines and power medical equipment. It liberates children and women from manual labor and provides light, heat, and ventilation for the schools that educate the workforce."

"Our high energy planet - a climate pragmatism project" page 7
M. Caine *et al*.
The Breakthrough Institute (April 2014)
http://thebreakthrough.org/images/pdfs/Our-High-Energy-Planet.pdf

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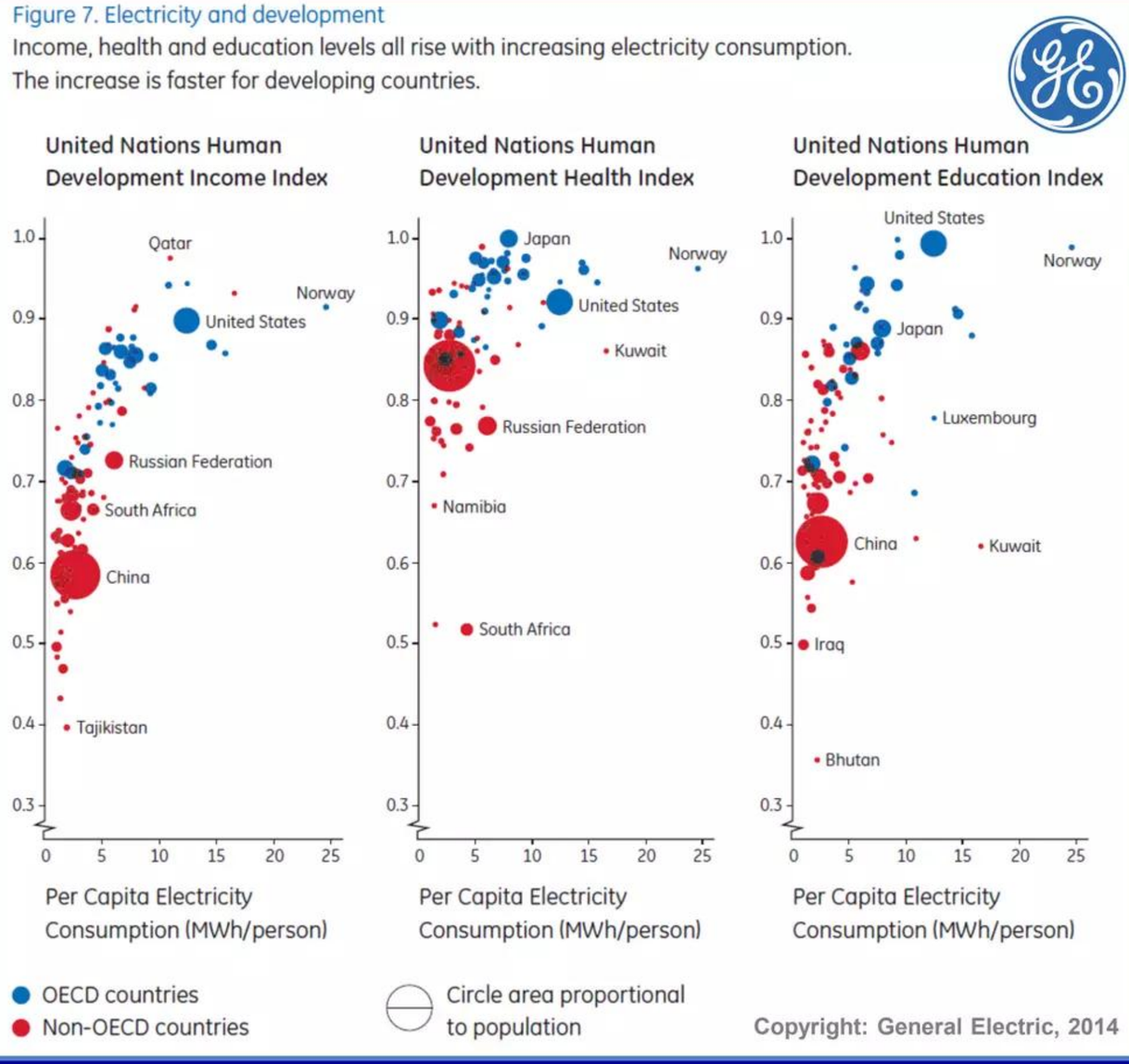
Empowering the powerless and connecting the unconnected

Quality of life is improved with increasing consumption of electricity

Data source: United Nations Development Programme Human Development Report 2013 and US Energy Information Administration

Figure 7. Electricity and development

Income, health and education levels all rise with increasing electricity consumption. The increase is faster for developing countries.



"The rise of distributed power" see Fig. 7 on page 32
B. Owens, General Electric - Ecomagination (February 2014)
http://www.eenews.net/assets/2014/02/25/document_gw_02.pdf

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LENRs: empowering the powerless and connecting the unconnected

Think different.

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

1-minute video: http://www.youtube.com/watch?v=Rzu6zeLSWq8

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Contents

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LENRs: empowering the powerless and connecting the unconnected

According to data ~1.5 billion people now lack electricity

Table 1. Electricity Access in 2008: Regional Aggregates (page 9)

Alliance for Rural Electrification	Population without electricity	Electrification rate	Urban electrification rate	Rural electrification rate
	million	%	%	%
Africa	589	40	66.8	22.7
- North Africa	*2*	*98.9*	*99.6*	*98.2*
-Sub-Saharan Africa	*587*	*28.5*	*57.5*	*11.9*
Developing Asia	809	77.2	93.5	67.2
- China and East Asia	*195*	*90.2*	*96.2*	*85.5*
- South Asia	*614*	*60.2*	*88.4*	*48.4*
Latin America	34	92.7	98.7	70.2
Middle East	21	89.1	98.5	70.6
Developing countries	**1453**	**72**	**90**	**58.4**
OECD and Transition economies	**3**	**99.8**	**100.0**	**99.5**
World	**1456**	**78.2**	**93.4**	**63.2**

Source: http://www.ruralelec.org/fileadmin/DATA/Documents/06_Publications/Position_papers/ARE_Mini-grids_-_Full_version.pdf

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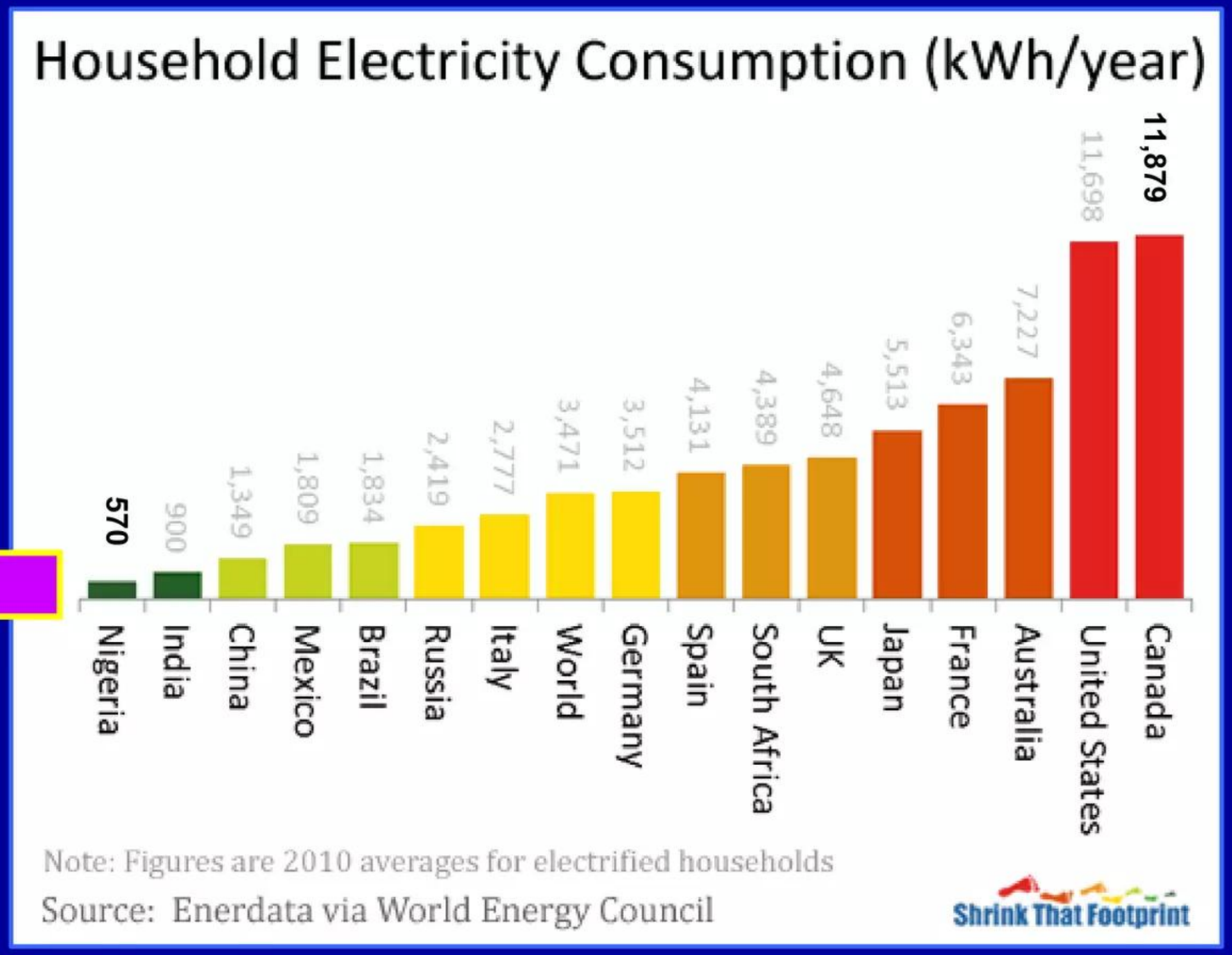
Huge disparity in electric consumption across entire world

Total usage ranges from 11,879 kWh/yr way down to 0.0 kWh/yr

For at least ~1.4 billion people annual consumption is = 0



Source: http://shrinkthatfootprint.com/average-household-electricity-consumption

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We need to democratize access to affordable clean energy

"The number of people without access to energy in sub-Saharan Africa is projected to rise to 90 to 100 million in 2030. Without access to energy service, the poor will be deprived of the most basic of human rights and of economic opportunities to improve their standard of living. People cannot access modern hospital services without electricity, or feel relief from sweltering heat. Food cannot be refrigerated and businesses cannot function. Children cannot go to school in rainforests where lighting is required during the day."

Source: The World Bank (2014)

Unnamed village in Tanzania: credit Steve Rosset (2011)

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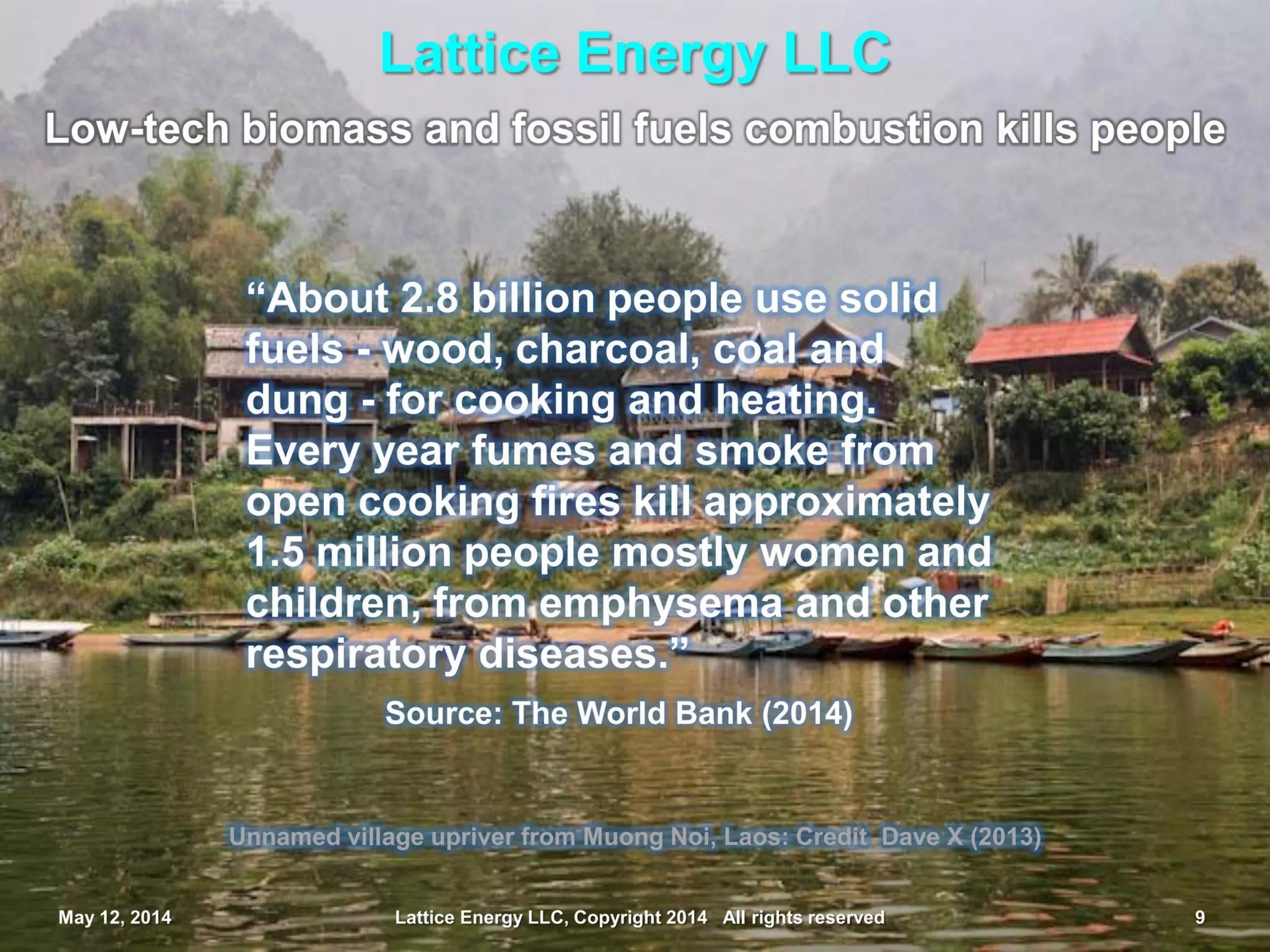
Low-tech biomass and fossil fuels combustion kills people



“About 2.8 billion people use solid fuels - wood, charcoal, coal and dung - for cooking and heating. Every year fumes and smoke from open cooking fires kill approximately 1.5 million people mostly women and children, from emphysema and other respiratory diseases.”

Source: The World Bank (2014)

Unnamed village upriver from Muong Noi, Laos: Credit Dave X (2013)

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Afghanistan exemplifies plight of world's rural energy-poor

"Most of Afghanistan's 25 million people have no access to modern forms of energy, such as electricity, gas, and liquid fuels. Traditional fuels meet more than 85% of energy needs, while commercial energy sources, such as oil, gas, coal, and hydropower, meet the remaining requirements. Fuel wood accounts for about 75% of total energy supplies. More than 80% of the population live in rural areas and depend on traditional fuels (fuel wood and crop residues) for cooking, heating water and kerosene for lighting … Women suffer from respiratory illnesses and eye irritation from the smoke of open fires employed for cooking and baking, and made worse by using kerosene lamps for light. Cow dung is used for cooking on a daily basis. Burns are very common".

"Rural Electrification in Afghanistan: How do we electrify the villages of Afghanistan?"
P. Meisen and P. Azizy, Global Energy Network Institute (2008)
http://www.geni.org/globalenergy/research/rural-electrification-in-afghanistan/Rural%20Electrification%20in%20Afghanistan.pdf

Village of Aranas, Nuristan district, Afghanistan
Credit: Spc. Eric Jungels, 10th Mountain Division, U.S. Army (2006)

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Extending existing grids may be uneconomic for rural areas

"Extreme poverty in rural areas is partially due to the lack of income earning opportunities. The productive use of electricity would help reduce poverty by enabling alternative sources of livelihoods. At present, the Afghan power infrastructure consists primarily of three isolated power systems. Electricity networks are located around major urban centers."

"The remoteness of rural locations and the country's topography would make it difficult to expand the electricity supply in these areas through a centralized grid system, and such an expansion might not be economically feasible. Therefore, an exploration of renewable, sustainable energy sources that can be maintained in a decentralized approach, and that the poor can afford, is urgently needed."

"Rural Electrification in Afghanistan: How do we electrify the villages of Afghanistan?"
P. Meisen and P. Azizy, Global Energy Network Institute (2008)
http://www.geni.org/globalenergy/research/rural-electrification-in-afghanistan/Rural%20Electrification%20in%20Afghanistan.pdf

Village, Northern Kunar Province, Afghanistan Credit: Bob Shepherd (2007)

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May 8, 2014: U.S. acknowledges plight of the powerless

House finally passes H.R. 2548 titled "The Electrify Africa Act of 2014"

While no hard dollar funding is provided by U.S. at least the issue is recognized

Sec. 3 Findings. Almost 70% of the population in sub-Saharan Africa (589 million people) does not have access to electricity. Roughly 30 African countries face endemic power shortages. Business leaders in the region say this lack of affordable and reliable power is one of the biggest constraints to economic growth. It also presents serious environmental and health risks.

Sec. 4 Statement of Policy. Declares the United States, in consultation with sub-Saharan African governments, will encourage: (i) the installation of an additional 20,000 megawatts of electrical power in the region by 2020, (ii) the provision of first-time access to electricity for at least 50 million people by 2020, and (iii) any reforms necessary to facilitate these goals. Declares that U.S. policy encourages private sector and international support for the construction of hydroelectric dams that offer low-cost clean energy.

"Section-by-section summary of legislation:

http://foreignaffairs.house.gov/sites/republicans.foreignaffairs.house.gov/files/HR%202548%20Section%20by%20Section%5B1%5D.pdf

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Electricity is now much less costly than price back in 1880

"Just wait a little while," prophesied Edison, "and we'll make electric light so cheap that only the wealthy can afford to burn candles." (*ca*. 1880)

ADEQUATE RELIABLE AFFORDABLE

"Edison lived [until 1931] to see lamps that gave four times as much light and cost one-fifth as much to buy."

General Electric Company newspaper advertisement

February 4, 1954

Source of background graphic is En-Act video at: http://vimeo.com/77599467

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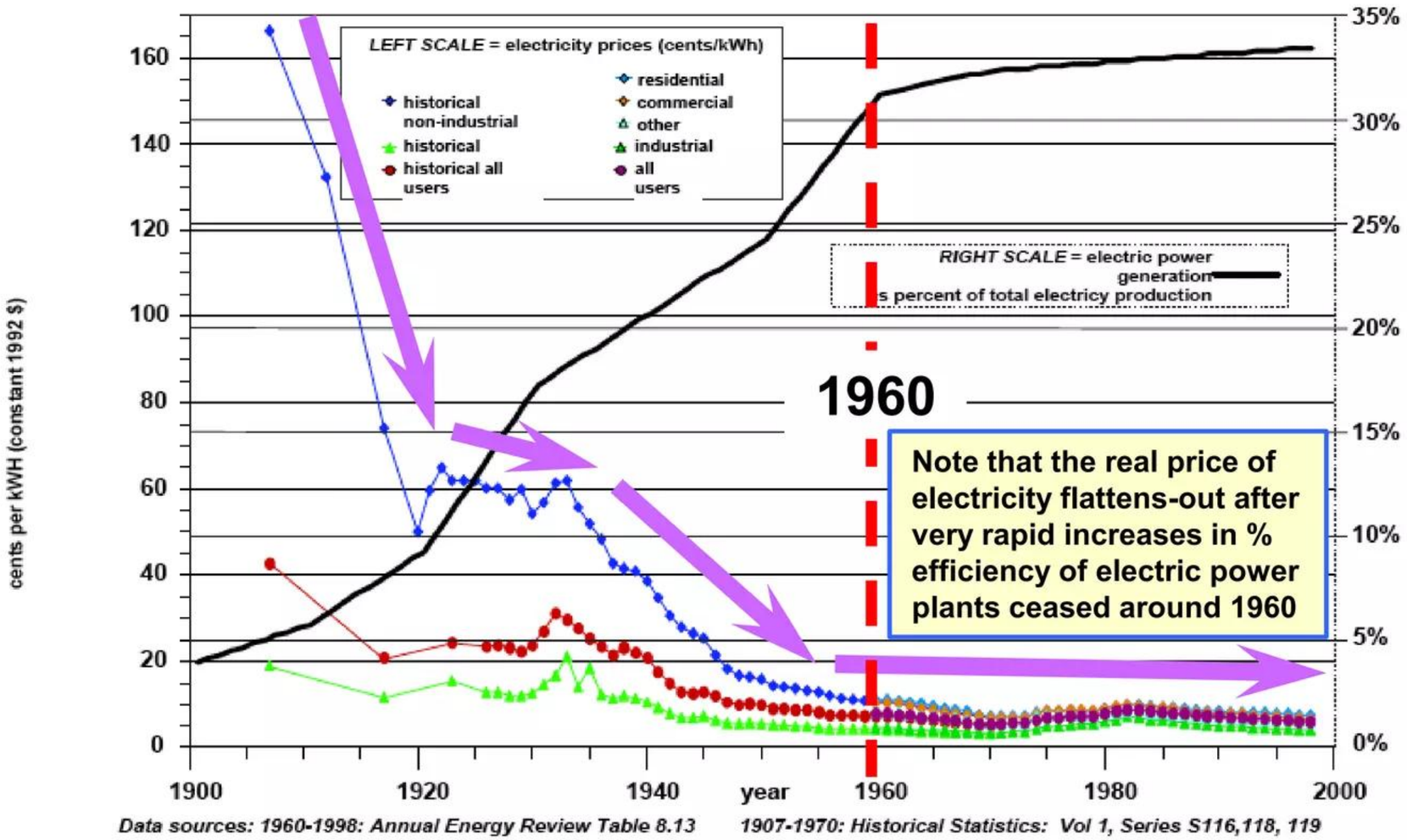
Edison's bold prophecy made back in 1880 was right

By 1910, the price of electricity was ~$1.60 per kWh (1990 dollars); from 1920s through mid-1930s it mostly averaged around $0.60 kWh; today, the price of electricity ranges from ~ $0.05 to 0.12 kWh

Average efficiency of coal-fired power plants has remained at ~32 - 34% since 1960

Electrical efficiency and the price of electricity: USA 1900-1998 (1990 dollars)



Source: http://tingilinde.typepad.com/starstuff/2009/05/the-historic-price-of-electricity-in-the-us.html

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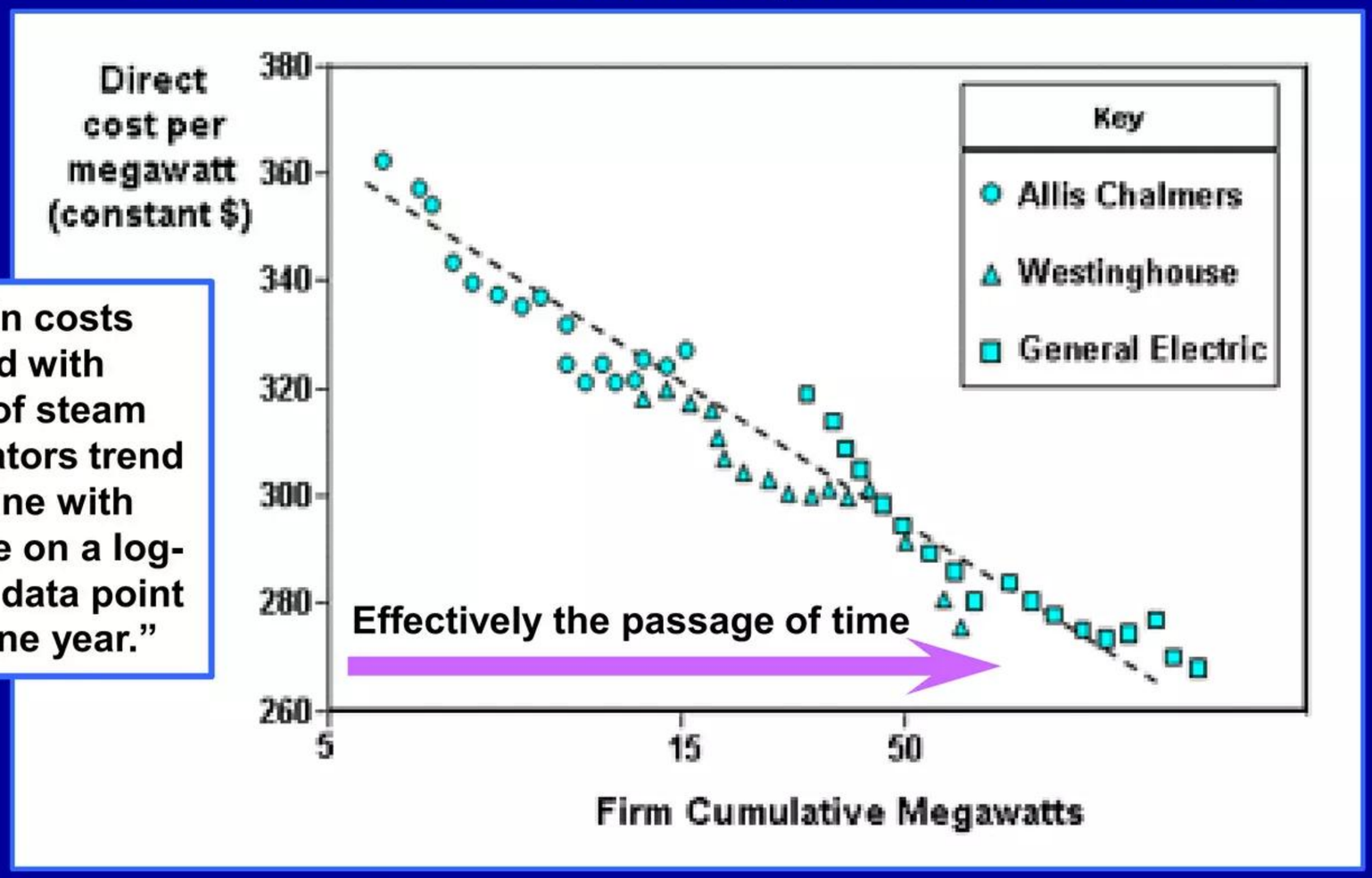
Grid electric power is produced by steam turbine generators

Decrease in electricity price over time mirrored decrease in cost/MW

Steam turbine technology has matured; direct cost is now flattening-out

Total direct cost per megawatt (constant $) vs. total cumulative megawatts of steam turbines sold and delivered by three OEM manufacturers



"Decrease in costs associated with production of steam turbine generators trend towards a line with constant slope on a log-log plot; each data point represents one year."

Source: Vectorstudy - http://vectorstudy.com/management-theories/experience-curve\

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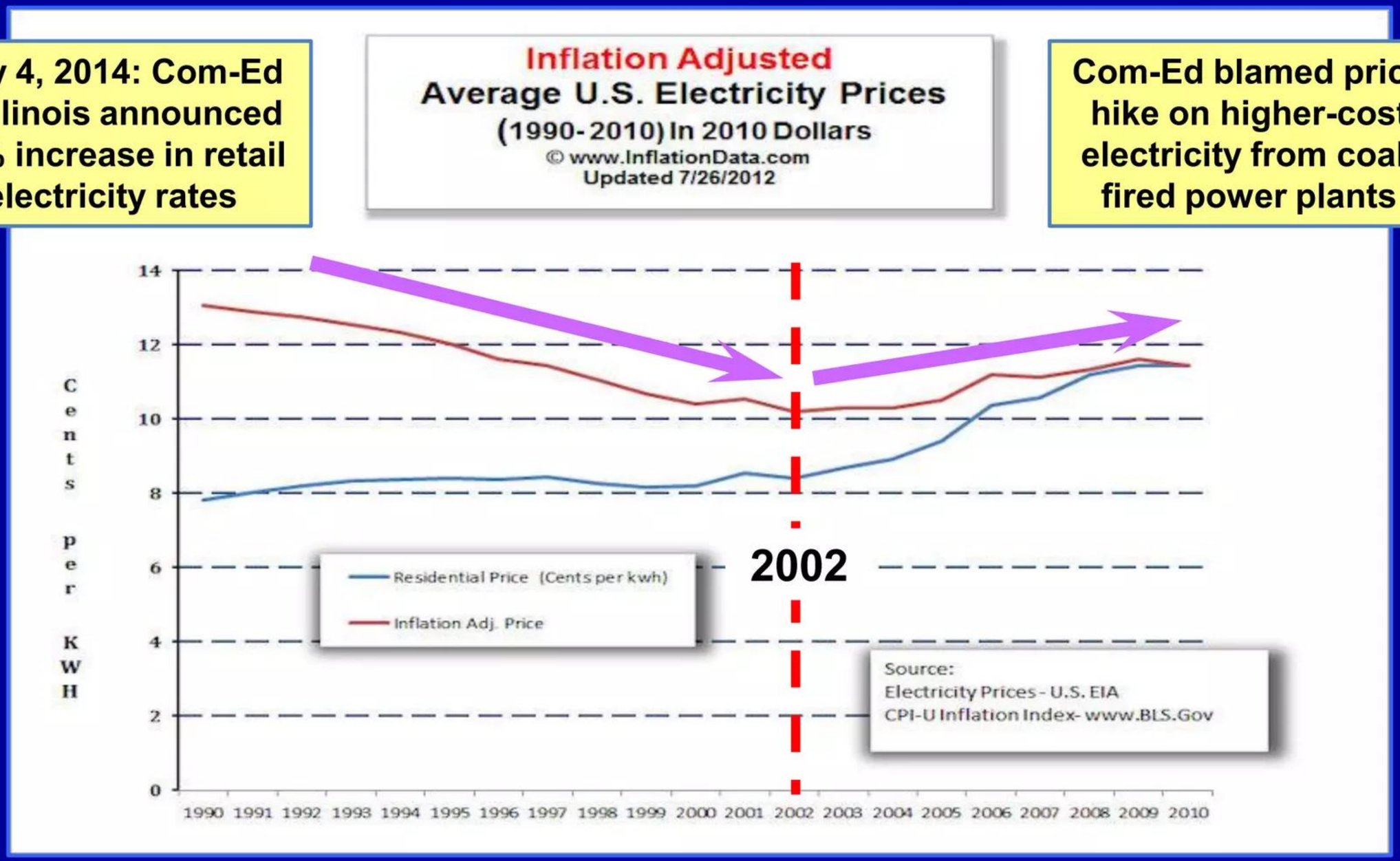
Electricity prices are now beginning to rise in United States

After 134 years of more-or-less steady declines since Thomas Edison made his prescient prophecy about future cheap electricity back in 1880, real prices in US may have finally bottomed-out

May 4, 2014: Com-Ed of Illinois announced 38% increase in retail electricity rates

Com-Ed blamed price hike on higher-cost electricity from coal-fired power plants



Source: http://inflationdata.com/articles/inflation-adjusted-prices/electricity-price-inflation-rate/

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LENRs: empowering the powerless and connecting the unconnected

Real price of ‘green’ energy is still too expensive worldwide

“The rich world gets just 1.2% of its energy from hugely expensive solar and wind technologies, and we would never accept having power only when the wind was blowing. Over the next two years, Germany will build ten new coal-fired power plants to keep the lights on.

In 1971, 40% of China’s energy came from renewables. Since then, it has powered its explosive economic growth almost exclusively with highly polluting coal, lifting 680 million people out of poverty. Today, China gets a trifling 0.23% of its energy from wind and solar. By contrast, Africa gets 50% of its energy today from renewables – and remains poor.

A new analysis from the Center for Global Development quantifies our disregard of the world’s poor. Investing in renewables, we can pull one person out of poverty for about $500. But, using gas electrification, we could pull more than four people out of poverty for the same amount. By focusing on our climate concerns, we deliberately choose to leave more than three out of four people in darkness and poverty.

Addressing global warming effectively requires long-term innovation that makes green energy affordable to all. Until then, wasting enormous sums of money at the expense of the world’s poor is no solution at all.”

Bjørn Lomborg
“The Poverty of Renewables”
Project Syndicate March 17, 2014
http://www.project-syndicate.org/commentary/bj-rn-lomborg-says-that-the-prevailing-solution-to-global-warming-is-hurting-the-poor-more-than-the-problem-is

Village of Afaur, Bihar's Saran district, India: credit NDTV (2012)

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Capital costs of renewables still more expensive vs. natural gas

Table 3: Overnight Capital Costs per MW by Technology (USD/MW)

Average	Sample of OPIC historical portfolio	DOE Meta-Study	CRS Estimates (US sample)
Natural Gas	591,909	768,750	1,200,000
Renewables (weighted average)*	3,726,049	3,650,250	3,567,000
Wind	1,383,333	1,700,000	2,100,000
Geothermal	8,260,000	3,825,000	3,200,000
Solar Thermal	5,650,892	4,883,333	3,400,000
Solar PV		6,000,000	6,600,000
Hydro	na	na	na
Biomass	2,952,976	3,012,500	3,000,000

Sources: CRS, DOE, author calculations based on public data from OPIC.

**Weighted renewables average calculated using IEA predictions for renewables mix most suited for extending energy access (28% wind, 36% solar, 21% biomass, 8% hydro, 7% others). Weights adjusted to account for lack of data on hydro technologies.*

"Maximizing Access to Energy: Estimates of Access and Generation for the Overseas Private Investment Corporation's Portfolio"
T. Moss and B. Leo
Center for Global Development (January 2014)
http://international.cgdev.org/sites/default/files/maximizing-access-energy-opic_1.pdf

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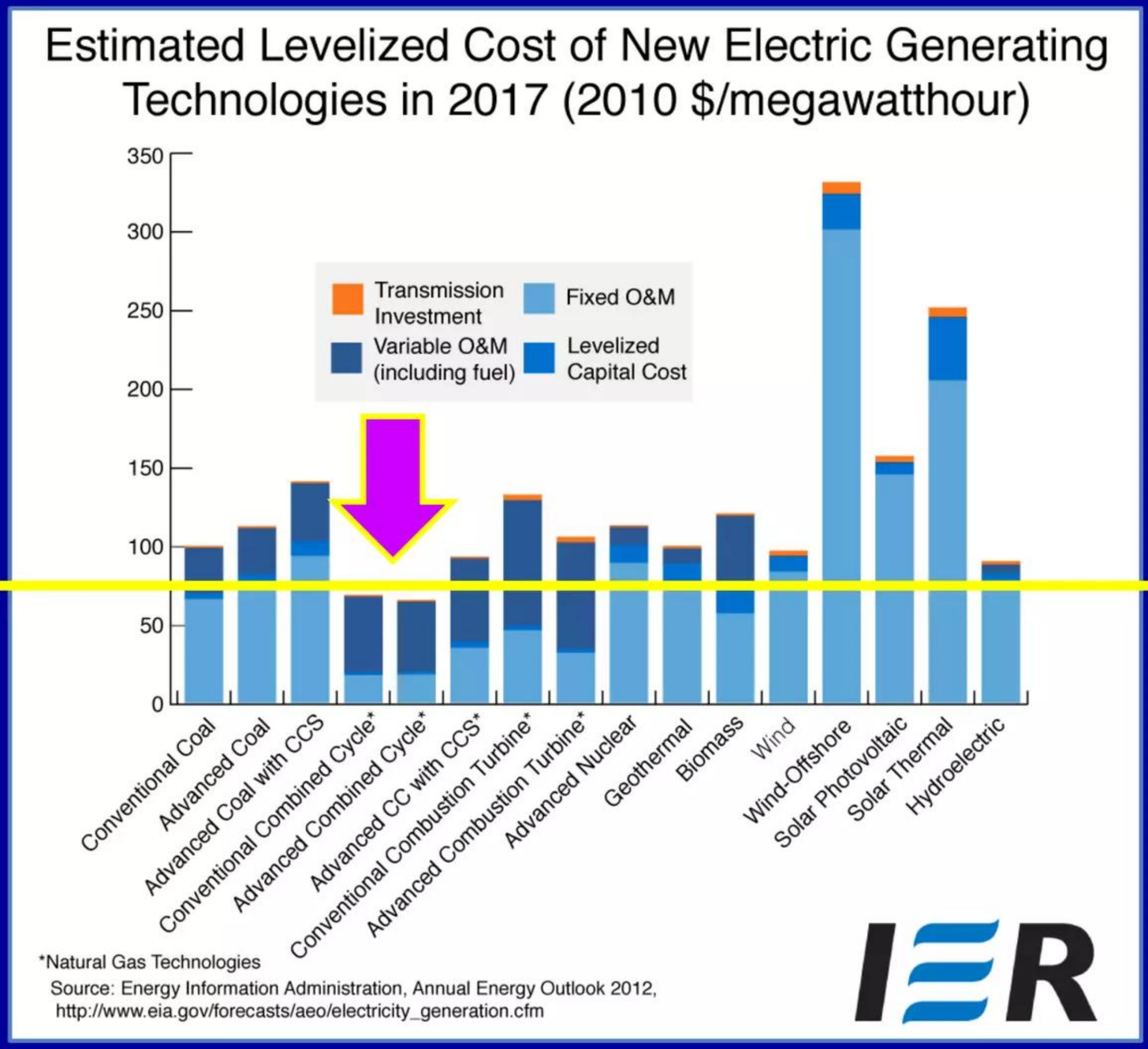
Fossil fuel sources still less expensive than solar and wind

Data shows combined cycle natural gas lowest cost amongst alternatives



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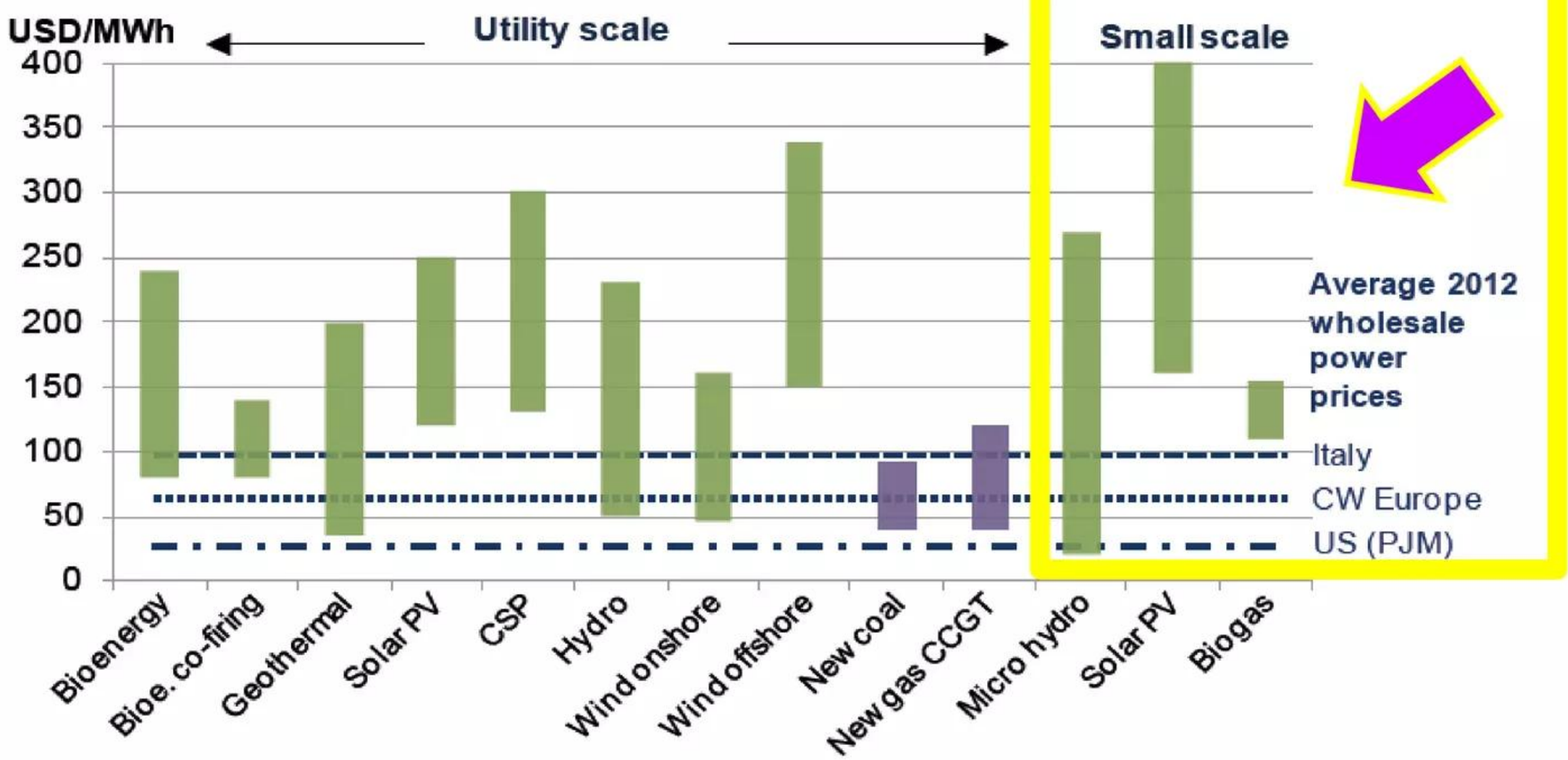
Small-scale power generally more costly than utility-scale

Need new green energy source that enables small scale to be <<< less expensive

Figure 3 Global levelised costs of power generation ranges, first quarter of 2013



Notes: costs are indicative and ranges reflect differences in resources, local conditions and the choice of sub-technology. CCGT = combined-cycle gas turbine. Central-Western (CW) Europe = Austria, France, Germany, Switzerland. United States (US). PJM = regional transmission organisation covering 13 states and the District of Columbia (DC).

Source: IEA analysis with power price data from Bloomberg LP, 2013.

Source: International Energy Agency (IEA) http://www.iea.org/Textbase/npsum/MTrenew2013SUM.pdf

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LENRs: empowering the powerless and connecting the unconnected

World also needs a dense CO_2-free primary energy source that is affordable, biosafe, scalable, and permits sustainable growth

- ✓ While solar PV and wind are decidedly CO_2-free and reasonably biosafe, their intrinsic energy densities are much lower than today's fossil fuels and they are intermittent --- not continuous --- sources of electrical and thermal power
- ✓ Renewable primary energy sources such as combustion of biomass are not the answer because they only have moderate energy densities and emit much CO_2
- ✓ Nuclear fission power has high energy densities, does not produce CO_2 and operates continuously; but emits copious quantities of very dangerous neutron and gamma radiation during operation and produces very long-lived radwastes
- ✓ Nuclear fusion power, while better than fission in terms of producing much smaller quantities of 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
- ✓ **Low energy neutron reactions (LENRs) are only primary energy technology on foreseeable scientific horizon that can provide world with dense 'green' energy, connect the unconnected, and empower billions of presently powerless people**

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Low Energy Neutron Reactions or LENRs

Truly green nuclear process: no deadly radiation or long-lived wastes

Were hidden in plain sight for 100 years because hard radiation is absent

2014: device physics now sufficiently understood to begin commercialization

1945

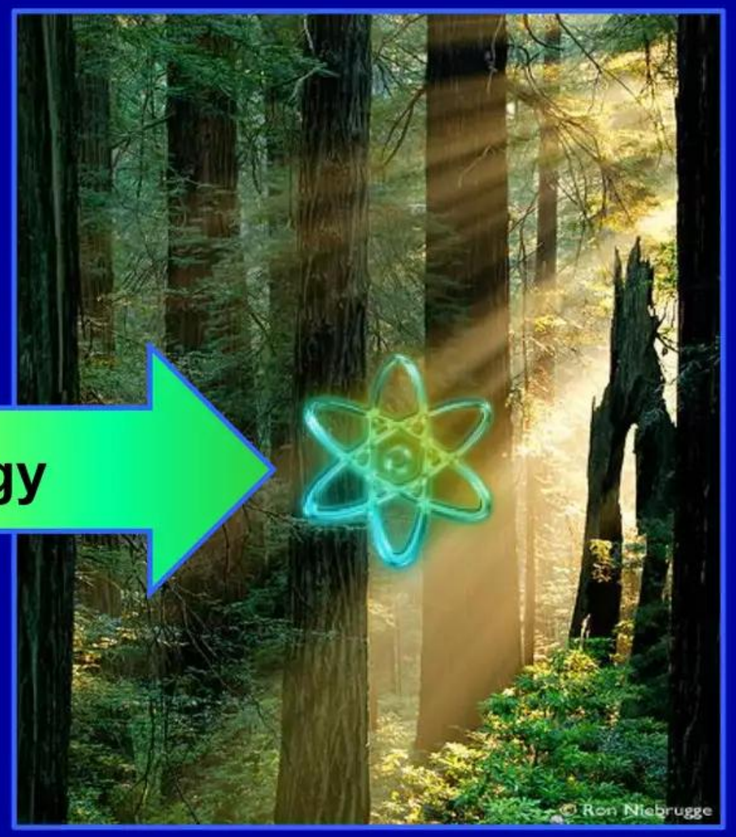
2005

Widom-Larsen theory of LENRs is developed

Evolution of nuclear technology

LENRs are safe and benignly green

2014



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LENRs: empowering the powerless and connecting the unconnected

World also needs a dense CO_2-free primary energy source that is affordable, biosafe, scalable, and permits sustainable growth

Low energy neutron reactions (LENRs) are 'green' energy

- ✓ No emission of deadly MeV-energy 'hard' gamma radiation
- ✓ No dangerous external emissions of energetic neutrons
- ✓ Insignificant production of bio-hazardous radwastes
- ✓ Revolutionary, disruptive, CO_2-free and environmentally safe
- ✓ Vast reduction in system cost versus fission or fusion
- ✓ **Intrinsically scalable system-level thermal outputs go from tiny devices up to megawatt-scale powerplants**

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Basic reactions in LENRs are very 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

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

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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LENRs enable new ultra high performance thermal sources

Heat produced by gamma conversion to IR and energetic particle decays

- ✓ Please note that LENRs do not involve any "free energy" --- there is a front-end cost in the form of input energy that is required to create ultra low energy neutrons which are subsequently absorbed by target fuel nuclei that in turn triggers release of large amounts of stored nuclear binding energy
- ✓ Produced ULM neutrons can be conceptualized as nuclear 'matches' that 'light the logs' of target fuel nuclei, which releases nuclear binding energy stored in such 'logs' since they were created in stars billions of years ago
- ✓ Excess heat produced by well-performing LENR systems comes from:
  - Energetic charged particles (e.g., alphas, betas, protons, deuterons, tritons) banging into the nearby environment, heating it by transferring kinetic energy
  - Direct conversion of dangerous gamma photons created by neutron capture and nuclear decay processes directly into useful infrared photons (heat) which are then absorbed by nearby matter; see Lattice's fundamental patent involving this amazing process: US# 7,893,414 B2 issued on February 22, 2011
  - Note: neutrino photons do not contribute to excess heat; they bleed-off excess nuclear energy into space by emission of totally benign radiation

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Neutron-catalyzed LENRs can have good energy-gain ratios

Target fuels for LENR systems are extremely varied and inexpensive

- ✓ LENRs occur in microscopic active sites located on surfaces onto which external energy is inputted to create neutron fluxes via e + p reactions; target fuel nanoparticles are pre-positioned in close proximity to micron-scale sites
- ✓ Collectively produced, ultra-low energy neutrons can be absorbed (captured) by nuclei/isotopes of almost any 'target' fuel element (Ti, Ni, Li, C, etc.); this triggers release of nuclear binding energy stored in such nuclei when they were originally created in super-hot cores of stars many billions of years ago
- ✓ If ordinary Hydrogen (protons) used the create such neutrons, it 'costs' 0.78 MeV per produced neutron in terms of the required amount of input energy
- ✓ Unlike more finicky fission and fusion processes, almost any stable element can be used as an LENR target fuel; however, some work much better than others in that they are able create LENR network pathways that release much more nuclear binding energy (in the form of energetic photons and charged particles that end-up creating thermal heat) for every neutron that is captured
- ✓ Stable Lithium is very good LENR target fuel; in a short sequence of nuclear reactions it enables the release of ~34x more thermal energy than it costs to make the neutrons that drive it; Carbon and transition metals also excellent

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NASA believes that LENRs are an "ideal energy solution"

"Potentially has over 4,000 times the density of chemical energy"

"Could enable … an abundance of inexpensive energy"

http://nari.arc.nasa.gov/sites/default/files/attachments/17WELLS_ABSTRACT.pdf

Two screenshots of 1-page pdf Abstract (continues on next slide)

Low Energy Nuclear Reaction Aircraft

Investigator(s): Doug Wells, NASA Langley Research Center

Purpose

The purpose of this research is to investigate the potential vehicle performance impact of applying the emergent Low Energy Nuclear Reaction (LENR) technology to aircraft propulsion systems. LENR potentially has over 4,000 times the density of chemical energy with zero greenhouse gas or hydrocarbon emissions. This technology could enable the use of an abundance of inexpensive energy to remove active design constraints, leading to new aircraft designs with very low fuel consumption, low noise, and no emissions. The objectives of this project are to: (1) gather as many perspectives as possible on how and where to use LENR for aircraft including the benefits arising from its application, (2) explore the performance, safety, and operational impacts to individual aircraft and the fleet, (3) evaluate potential propulsion system concepts, and (4) foster multi- disciplinary interaction within NASA.

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NASA believes that LENRs are an "ideal energy solution"

Technology is "expected to be clean, safe, portable, and abundant"

Background

LENR is a type of nuclear energy and is expected to be clean, safe, portable, scalable, and abundant. The expected benefits make it an ideal energy solution. When it is applied to aircraft, LENR removes the environmental impacts of fuel burn and emission from combustion. Excess energy can be used to reduce noise so that all three of NASA's technology goals for future subsonic vehicles are either eliminated or addressed. Furthermore, aviation impacts almost every part of our daily lives, civilian and military. A revolutionary technology like LENR has the potential to completely change how businesses, military, and the country operate as a whole, giving a tremendous financial, tactical, and resource advantage to the country that utilizes it in the most effective way.

LENR creates some unique capabilities as well as challenges for integration into aircraft. The LENR concept that has reported most of the success generates heat in a catalyst process that combines nickel metal (Ni) with hydrogen gas (H). The initial testing and theory show that radiation and radioisotopes are extremely short lived and can be easily shielded. Although nuclear fission has been looked at for use in aircraft, LENR is different. LENR has a higher energy density and no radioactive by products.

Success of this research will provide a firm foundation for future research and investment for LENR technology integration into aircraft. Key research and development areas will be identified with any gaps in the current technology research. This research will guide NASA on the most effective way to invest in LENR to be the world leader in LENR aircraft research.

Source: http://nari.arc.nasa.gov/sites/default/files/attachments/17WELLS_ABSTRACT.pdf

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Stars and physically gigantic reactors are unnecessary

Production with weak $e + p$ reaction creates safe low energy neutrons

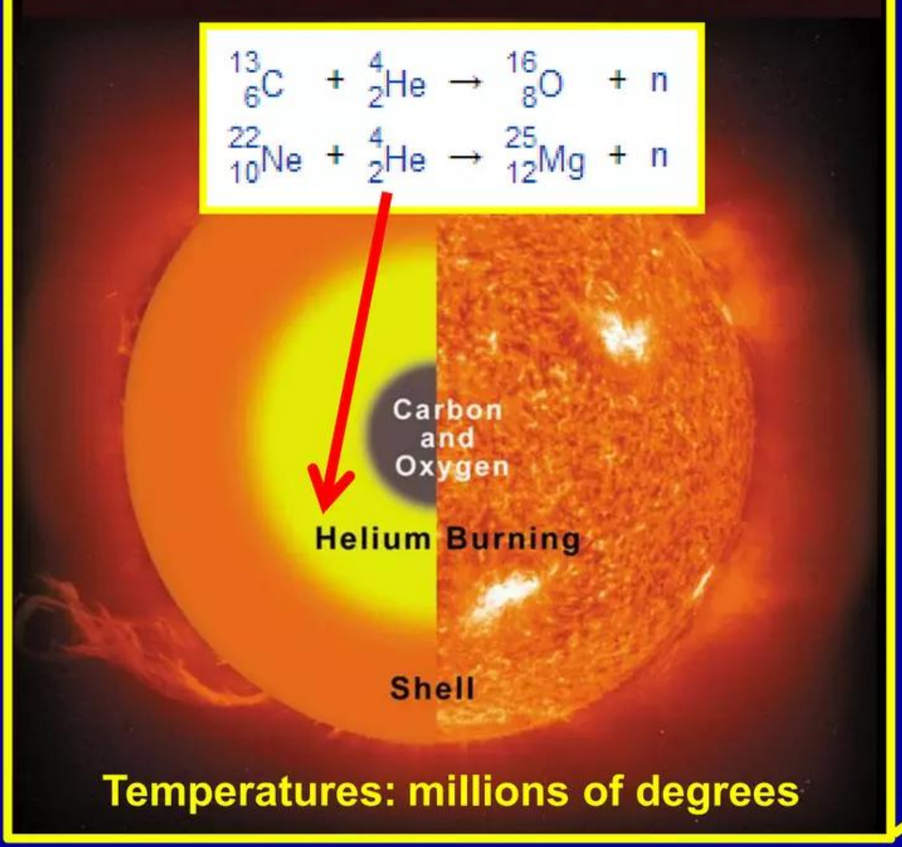
Ultra low energy neutrons are captured locally and do not escape reactors

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

Fusion reactions in a Red Giant star

$$^{13}_{6}C + {}^{4}_{2}He \rightarrow {}^{16}_{8}O + n$$

$$^{22}_{10}Ne + {}^{4}_{2}He \rightarrow {}^{25}_{12}Mg + n$$



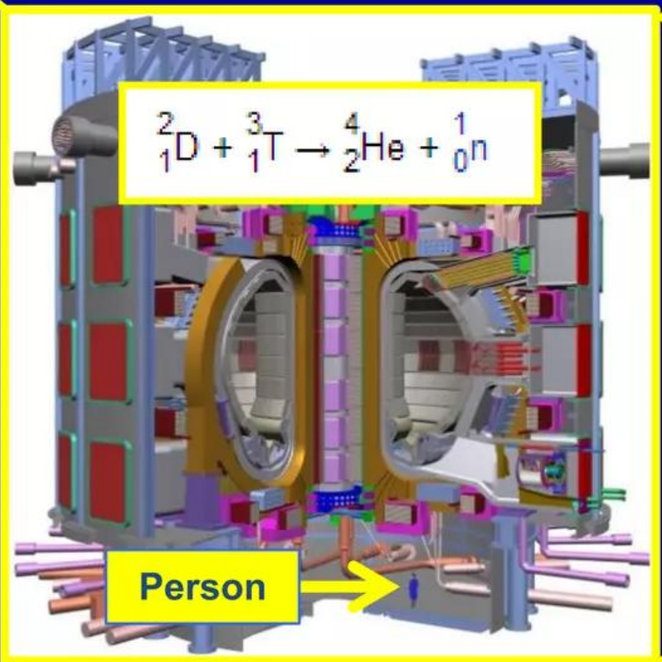
Temperatures: millions of degrees

Length-scale: millions of miles

Dangerous energetic 14.1 MeV neutrons

ITER: D+T fusion reactor

$$^{2}_{1}D + {}^{3}_{1}T \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$$

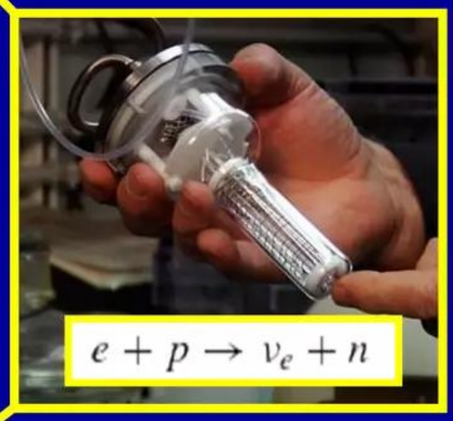


Length-scale: hundreds of feet

Temperatures: millions of degrees

These are safe!

LENR device



Length-scale: inches

Temperatures: thousands of degrees in microscopic regions

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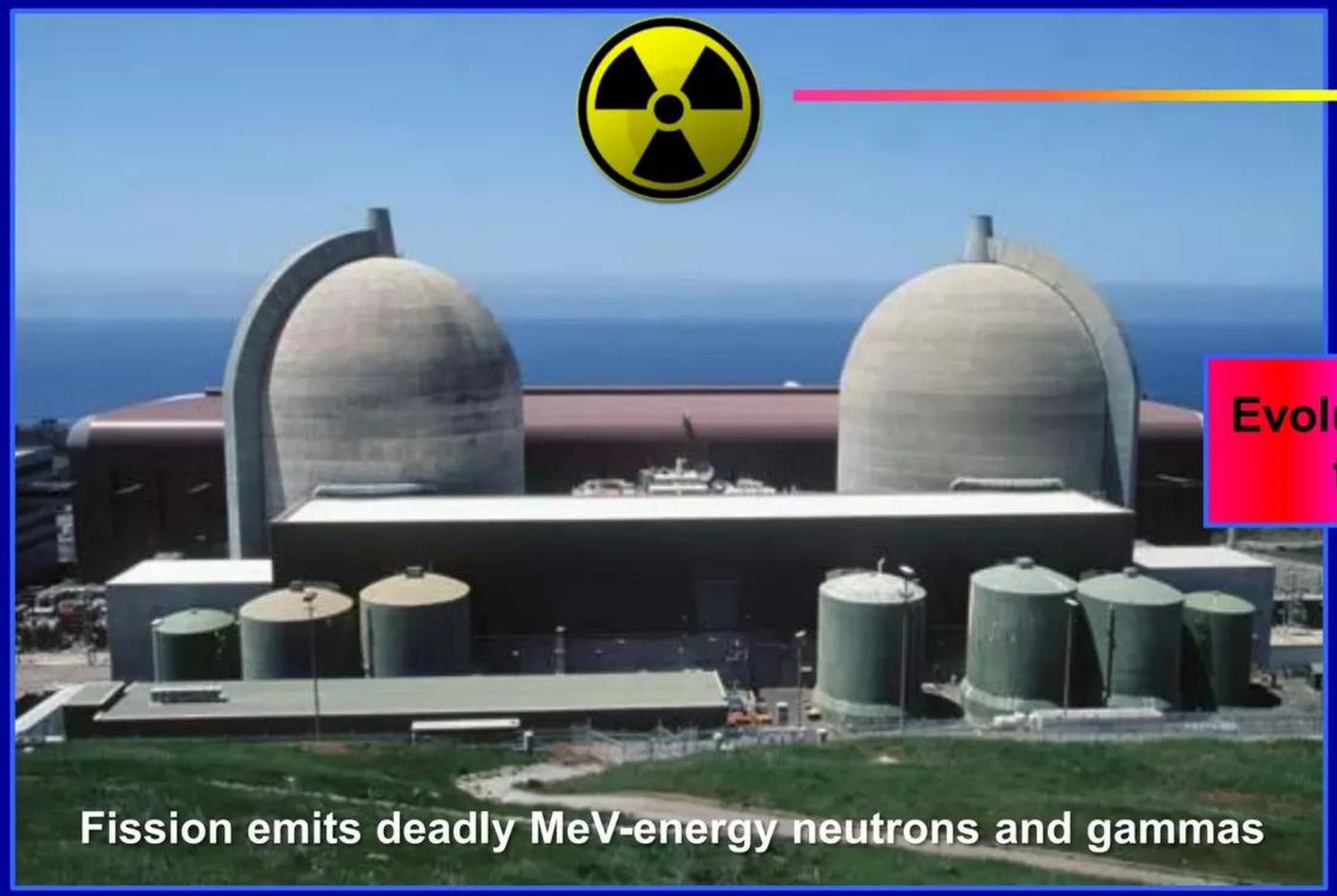
LENRs increase safety and shrink size of nuclear power

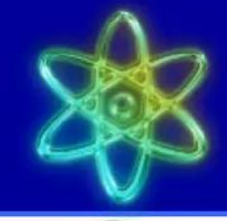
Lack of hard radiation obviates need for shielding and containment

Opportunity to develop safe, battery-like portable LENR 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



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



Evolution of nuclear technology

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

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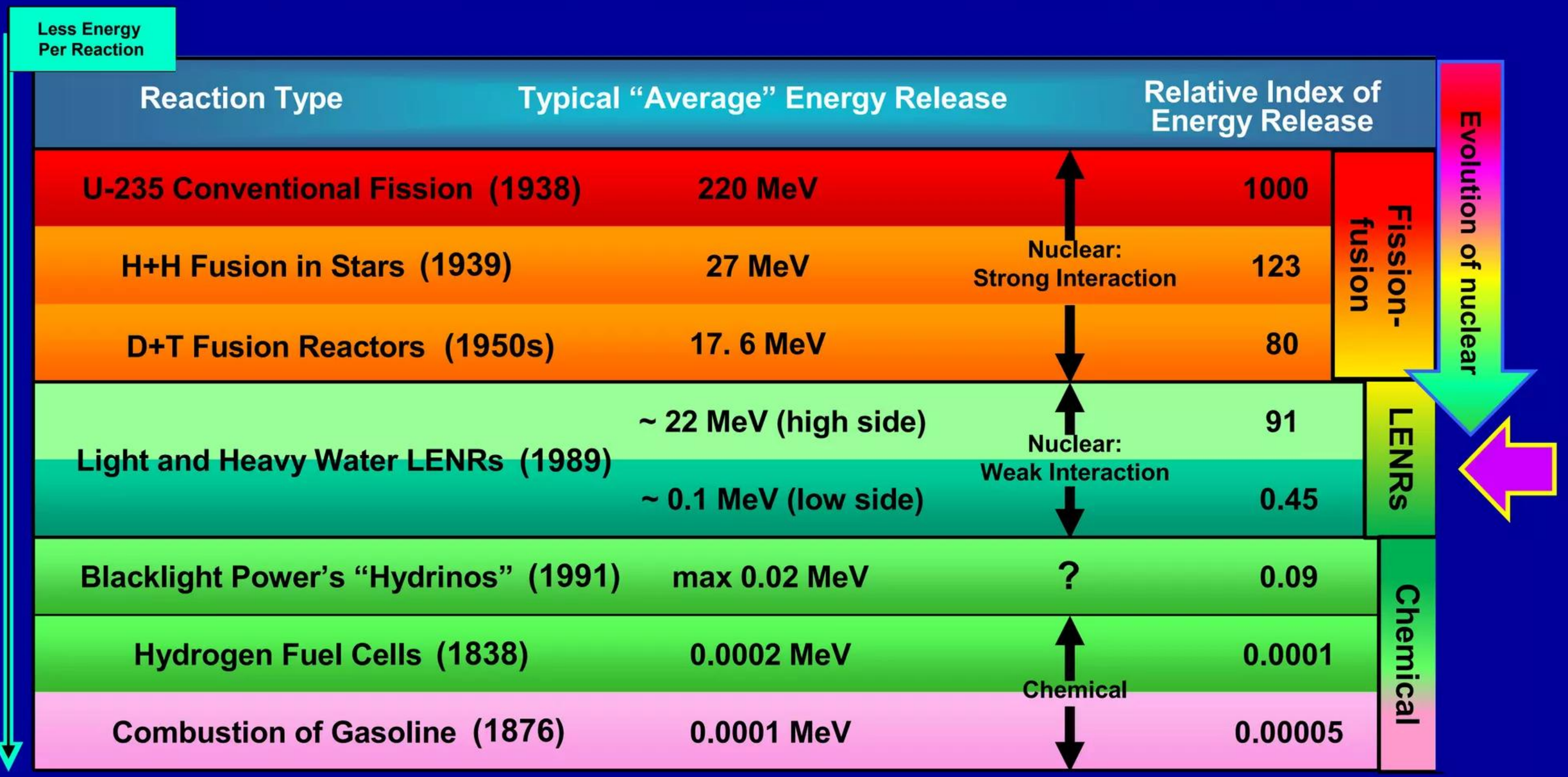
LENR energy density is a major competitive advantage

LENRs occupy sweet spot between fission and chemical power sources

Some LENRs release more energy than D+T fusion reactions



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LENR energy density is a major competitive advantage

Energy density of LENRs is ~5,000 times larger 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**
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)

Chemical Energy Sources

LENRs

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Lithium-air presently most energy-dense battery technology

Lithium-air = Lithium-oxygen: practical density much > than Li-ion

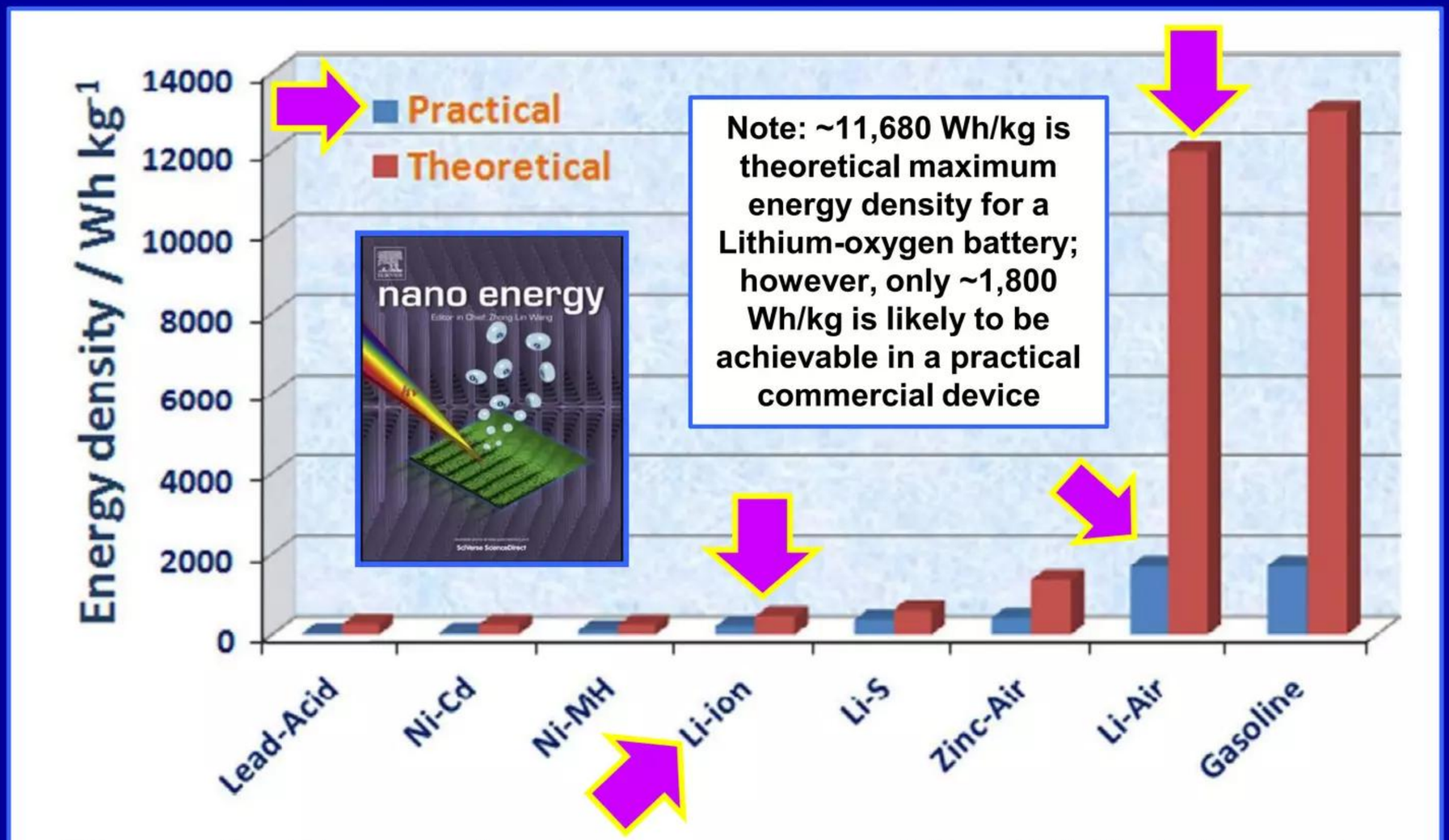


Figure 1 The gravimetric energy densities (Wh/kg) for various types of rechargeable batteries compared to gasoline.

Fig. 1 from: "Challenges and opportunities of nanostructured materials for aprotic rechargeable lithium-air batteries" J. Wang, Y. Li, and X. Sun, *Nano Energy* 2 pp. 443 - 467 (2013)

Lattice Energy LLC

Nuclear processes > million x larger than chemical energies

System-level LENR energy densities likely to be 5x to 50x gasoline

- ✓ Assuming an average energy release per reaction of only 0.50 MeV, Lattice has calculated an estimated theoretical maximum upper-bound intrinsic energy density for LENRs to be ~57,500,000 Wh/kg. Credible experimental data supports believability of estimate: Lattice and others have sometimes created laboratory LENR devices that produced larger measured thermal power densities than fuel rods in fission reactors
- ✓ Estimated upper-bound LENR energy densities simply cannot be achieved in feasible commercial systems; they would quickly become non-functional from intense excess heat that cannot be rejected fast-enough. Practically achievable LENR system-level energy densities will therefore be significantly lower than the theoretical upper bound
- ✓ If one percent (1.0% = .01) of estimated upper-bound energy release were achieved in commercial LENR-based systems, they could in principle have thermal energy density of ~575,000 Wh/kg. If it were only one-tenth of one percent (0.1% = .001) of theoretical maximum, system energy density would then = 57,500 Wh/kg. Compared to 100% efficient combustion of gasoline, practically achievable LENR-based system energy densities could conservatively be expected to range from ~50x gasoline to 5x gasoline. Based on proprietary knowledge, Lattice believes achievable energy densities in commercial LENR devices could be much greater than 0.1% of upper-bound; lower value of 57,500 Wh/kg x 20% heat-to-rotational power conversion efficiency = ~11,500 Wh/kg

Lattice Energy LLC

LENR energy density is a major competitive advantage

Lithium LENR target fuel cycle releases more energy than D+T fusion

No dangerous radiation emitted by Li cycle; already demonstrated in laboratory

Widom & Larsen's 2006 *European Physical Journal C* paper shows the following Lithium-seed LENR network cycle:

Lithium-6 + 2 ULM neutrons → 2 Helium-4 + beta particle + 2 neutrinos + Q-value = 26.9 MeV

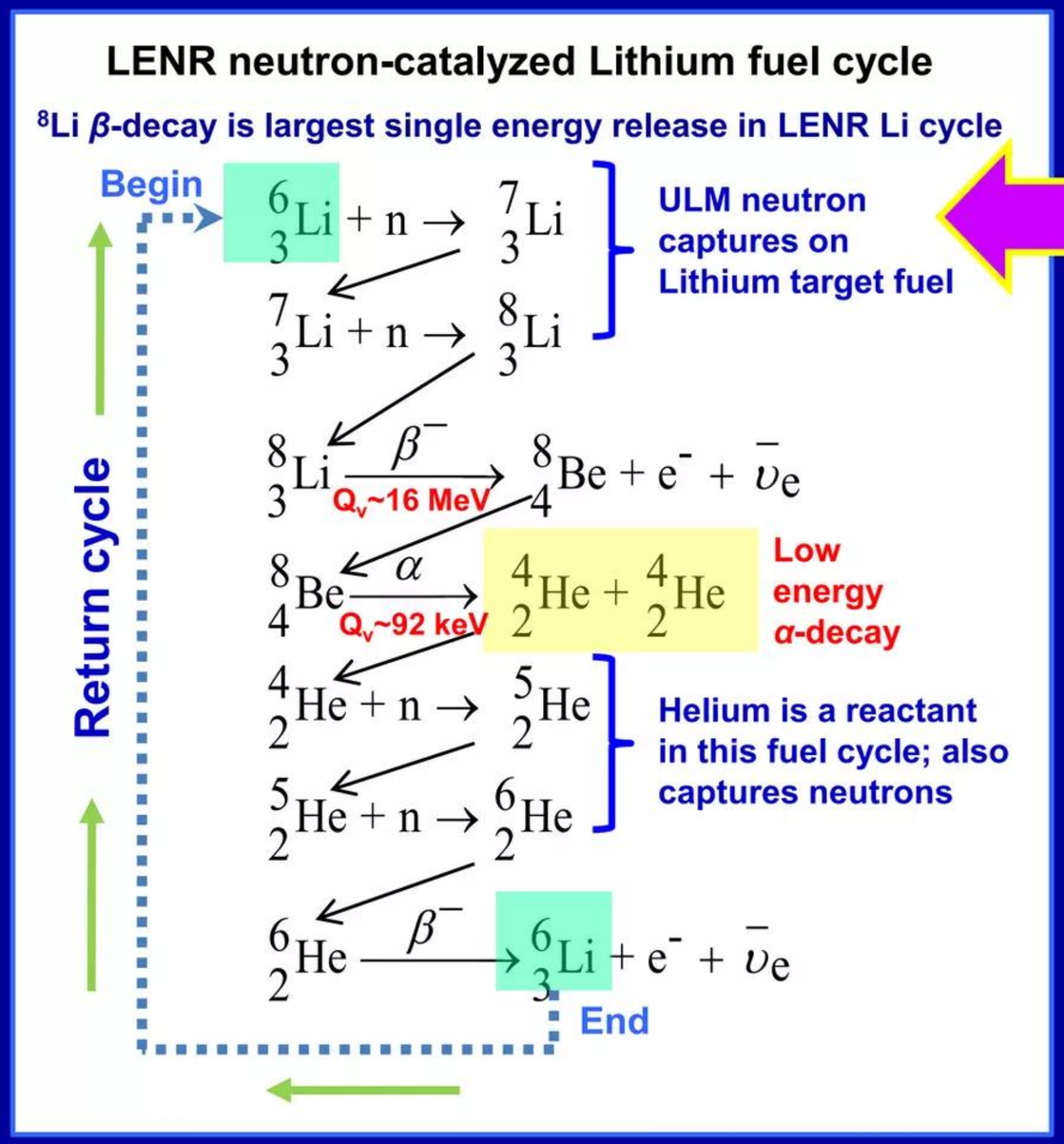
This particular cyclical LENR pathway can release about the same amount of energy as the D-T fusion reaction without creating any MeV-energy energetic neutrons, hard gamma radiation, or radioactive isotopes. Although a portion of the 26.9 MeV in excess nuclear binding energy released is lost (haircut) with emitted neutrinos, much of it still remains in the kinetic energy of the two helium atoms (which are low-energy alpha particles), and much more energetic beta particle.

In this particular case, local solid matter is heated-up by the scattering of low-energy alpha and much-higher-energy beta particles; heavy-mass electrons also present in LENR-active patches convert any locally produced hard gammas or X-rays (from whatever process) directly into infrared heat.

See: "Ultra low momentum neutron catalyzed nuclear reactions on metallic hydride surfaces" A. Widom and L. Larsen
European Physical Journal C – Particles and Fields 46 pp. 107-111 (2006)

ULMN-catalyzed LENR Lithium network cycle – from Eqs. 30 - 32

http://www.slideshare.net/lewisglarsen/widom-and-larsen-ulm-neutron-catalyzed-lenrs-on-metallic-hydride-surfacesepjc-march-2006



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LENR energy density is a major competitive advantage

Calculations illustrate potential for use in compact power sources

LENR system thermal output can be up to 34x input energy using Lithium fuel

- ✓ To simplify calculations, we will assume that conversion of input energy (in this case, an electric current) into energy available to produce LENR ULM neutrons is 100 percent efficient in order to estimate a theoretical upper bound on potential energy releases from a compact LENR heat source; will also assume that 100 percent of the ULM neutrons produced in the hypothetical device are absorbed locally (a pretty safe bet that is supported by 20^{+} years of experiments) and that they are only absorbed by a target fuel comprising isotopically pure Lithium-6, resulting in a series of nuclear reactions beginning with Lithium-6 and ending with Helium-4. Lastly, we will assume that the base fuel used to produce LENR ULM neutrons in our hypothetical device is deuterium and that it has an LENR-active working surface area of 1 cm^2

- ✓ Input energy required to produce 1 neutron/cm^2/sec from deuterium base fuel to react with the Lithium-6 target fuel is 0.39 MeV per neutron. However, we need two ULM neutrons to complete the entire series of reactions, so the required total input energy to the device is 0.78 MeV/cm^2/sec. The net energy release from that particular series of LENR reactions starting with Lithium-6 is 26.9 MeV/cm2/sec = 4.28 x 10^{-12} J/cm^2/sec (1 eV = 1.602 x 10^{-19} J); 26.9 MeV thus represents a theoretical maximum upper bound of ~ 34x total input power in case of Lithium fuel targets

Lattice Energy LLC

LENR energy density is a major competitive advantage

Calculations illustrate potential for use in compact power sources

Neutron flux of 1 x 10^{12} cm^2/sec predicts heat output seen in some lab devices

- ✓ As there are ~ 10^{14} of these 26.9 MeV energy releases taking place per second on the 1 cm^2 LENR device, the total energy release is 4.28 x 10^{-12} J/cm^2/sec x 10^{14} = 428 J/cm^2/sec. This represents 428 W/cm^2, a large device-level power density. At a lesser ULM neutron production rate of 1 x 10^{12} cm^2/sec, the overall energy production rate would drop down to 4.28 J/cm^2/sec or 4.28 W/cm^2. At a ULM neutron production rate of 1 x 10^{11} cm^2/sec, the energy production rate would drop down to 0.428 J/cm^2/sec or 0.428 W/cm^2, which is close to levels of excess heat output that are often observed in many electrolytic experiments with extremely primitive LENR devices that researchers deemed successful at making excess heat

- ✓ In this particular example, a heat generating rate of 428 W/cm^2 means 0.428 kWh/cm^2 produced in an hour for a Lithium-6-fueled 1 cm^2 LENR device, without releasing any CO_2. In comparison to minuscule nanogram (10^{-9} g) quantities of LENR reactants consumed, the complete combustion of 1 US gallon of gasoline (weighing 2.7 kg) with O_2 generates ~33.56 kWh of heat energy and releases ~8.8 kg of CO_2 into the atmosphere. Scaling up surface area of the idealized LENR device 1,000 fold could generate 428 kWh, while a 1 m^2 device would create a 4.28 Megawatt eco-green nuclear power source

Lattice Energy LLC

LENR energy density is a major competitive advantage

System-level energy densities with LENRs likely to be 5x - 50x gasoline

Solar PV and wind power are vastly less energy-dense versus fossil fuel sources

Comparison of intrinsic energy densities

Table 1 Energy density

Source	Joules per cubic meter
Solar	0.0000015
Geothermal	0.05
Wind at 10 mph (5m/s)	7
Tidal water	0.5–50
Human	1,000
Oil	45,000,000,000
Gasoline	10,000,000,000
Automobile occupied (5800 lbs)	40,000,000
Automobile unoccupied (5000 lbs)	40,000,000
Natural gas	40,000,000
Fat (food)	30,000,000

Source:
http://www.drexel.edu/~/media/Files/greatworks/pdf_sum10/WK8_Layton_EnergyDensities.ash

Petroleum energy density: "A single gallon of gasoline contains approximately forty (40) megajoules of chemical energy. Dividing energy by volume yields an energy density of ten billion joules per cubic meter. Gasoline is ten quadrillion times more energy-dense than solar radiation and one billion times more energy-dense than wind and water power."

Reference: B.E. Layton, *International Journal of Green Energy* 5 pp. 438 - 455 (2008)

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LENR energy density is a major competitive advantage

Lithium-target LENR fuels can release more energy than Tritium fusion

energy form	MJ/kg
Clock spring	0.0000003
Capacitor	0.000002
Water at 100 m dam	0.001
AA battery	0.59
Lithium (best) battery	2.54
TNT	4.61
Nitroglycerine	6.36
Wood	16
Mass of earth in orbit	33
Fat	33
Coal	24
Gasoline	46
Hydrogen	142
Pure Uranium fission	80,000,000
H-3 H-3 fusion	330,000,000
Antimatter	180,000,000,000

Credit: D. Semmler, Yale National Initiative (2014)

Tritium + Tritium (H-3 + H-3) fusion reactions release ~11.3 MeV of nuclear binding energy that is divided amongst reaction products that include a Helium-4 nucleus, two (2) energetic neutrons, as well as some energetic gamma radiation.

As shown in a previous slide, short sequence neutron-catalyzed LENR reaction networks starting with Lithium-target fuels release ~27 MeV of nuclear binding energy --- more than 2x T-T fusion without any emission of deadly radiation

Source: http://teachers.yale.edu/curriculum/viewer/initiative_12.07.08_u/print

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LENR energy density is a major competitive advantage

Very primitive LENR lab devices already produced .428 W/cm^2 (thermal)

Fully optimized commercial LENR devices should have >>> higher performance

Many Lithium-target LENR experiments have effectively produced measured neutron production rates of 10^{14} cm^2/sec which equate to heat production of 428 W/cm^2 ; just 10% conversion efficiency produces ~43 W/cm^2 electrical, vastly >>> than solar PV

Energy Source	Typical Energy Level Produced	Typical Application
Small solar panels	100s of mW/cm^2 (Direct Sunlight)	Handheld electronic devices
Small solar panels	100s of µW/cm^2 (Indirect Sunlight)	Remote wireless sensors
Seebeck devices (which convert heat energy into electrical energy)	10s of µW/cm^2 (Body heat)	Remote wireless sensors
Seebeck devices continued	10s of mW/cm^2 (Furnace exhaust stack)	Remote wireless actuators
Piezoelectric devices (which produce energy by either compression or deflection of the device)	100s of µW/cm^2	Handheld electronic devices or remote wireless actuators
RF energy from an antenna	100s of pW/cm^2	Remote wireless sensors

Source: http://www.rtcmagazine.com/articles/view/102133

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Battery energy cost in $/kWh much more expensive vs. grid

In general smaller form-factor batteries are progressively more $$$

Lattice's data from 2001; Semmler's 2014 data shows same principle

D. Semmler, Yale National Initiative (2014)

Table 1.2 Energy Cost in $ per KWH

Source	Direct Cost
Coal	0.03
Natural gas	0.05
Gasoline	0.11
Computer battery	4.00
AAA battery	1000.00
Solar panel	0.18
Nuclear fission	0.02
Hydro	0.03
Wind	0.03

Source:
http://teachers.yale.edu/curriculum/viewer/initiative_12.07.08_u/print

L. Larsen, Lattice Energy LLC presentation @ DOE/EPRI workshop (2004)

Battery-like Device Market Pricing	Price $/kWh
Long-lived nanopower for wireless sensors and nanodevices (Lattice estimate)	~ 3,000.00
Nanopower for MEMS and somewhat larger devices (Lattice estimate)	~ 2,000.00
Integrated power for small, portable electronic devices; small, uninterruptible backup power units	~ 1,000.00
Commodity AAA Non-rechargeable	890.00
Commodity AA Non-rechargeable	330.00
Commodity C Non-rechargeable	180.00
Commodity D Non-rechargeable	90.00
Commodity Li-ion 18650 rechargeable	24.00
Commodity NiMH AA rechargeable	19.00
Commodity Lead Acid (plastic) rechargeable	9.00
BB-390 military NiMH rechargeable	8.00
Commodity NiCd AA rechargeable	7.50
Bulk AC power from a utility (wall socket cost)	0.05 - 0.10

Lattice's price data is from I. Buchman, "The fuel cell: is it ready?" (2001) at: http://www.buchmann.ca/Article1-page1.asp

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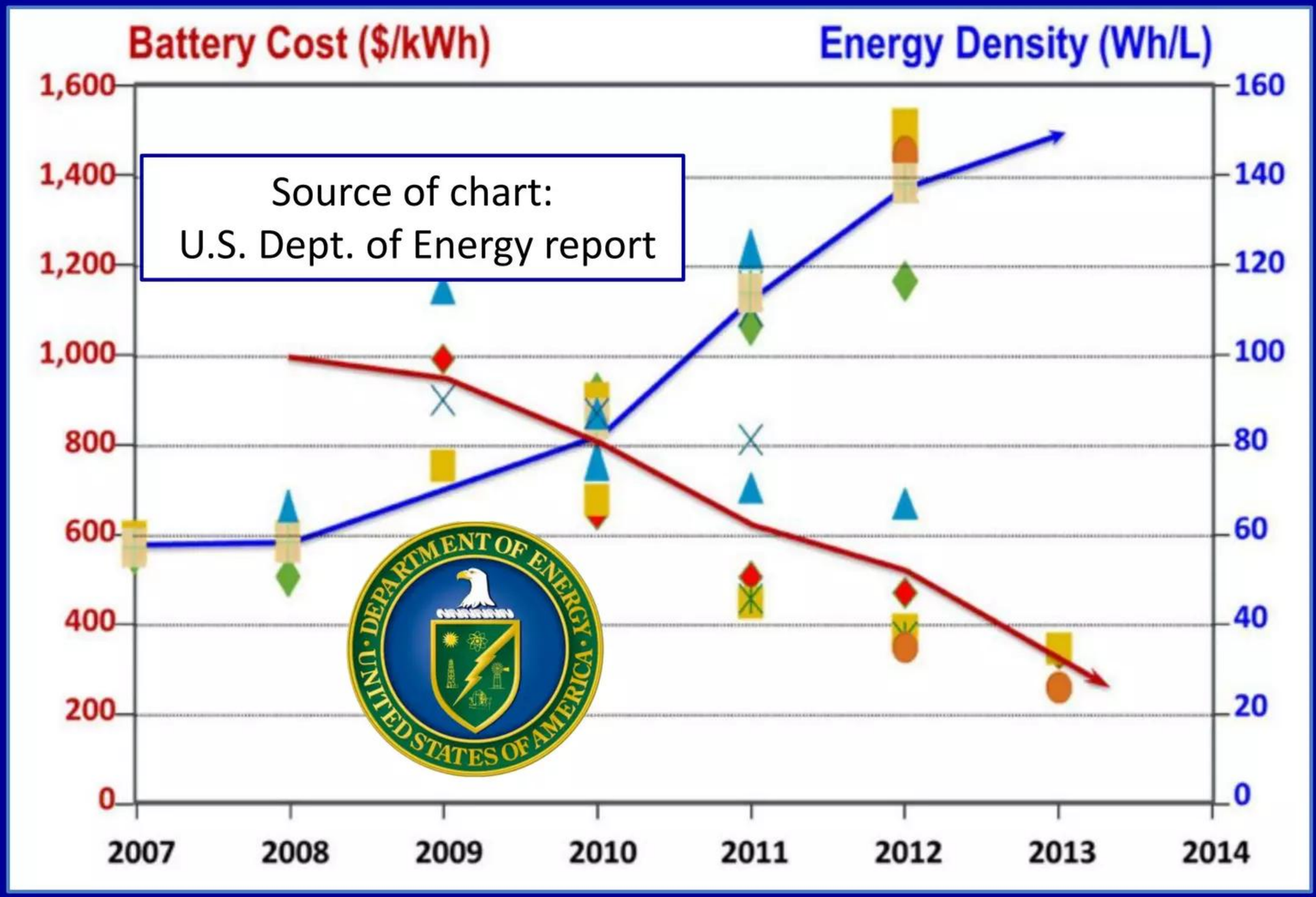
Battery cost reduction tied to increases in energy density



Source: http://theenergycollective.com/onclimatechangepolicy/347491/making-low-carbon-future-better-well-cheaper

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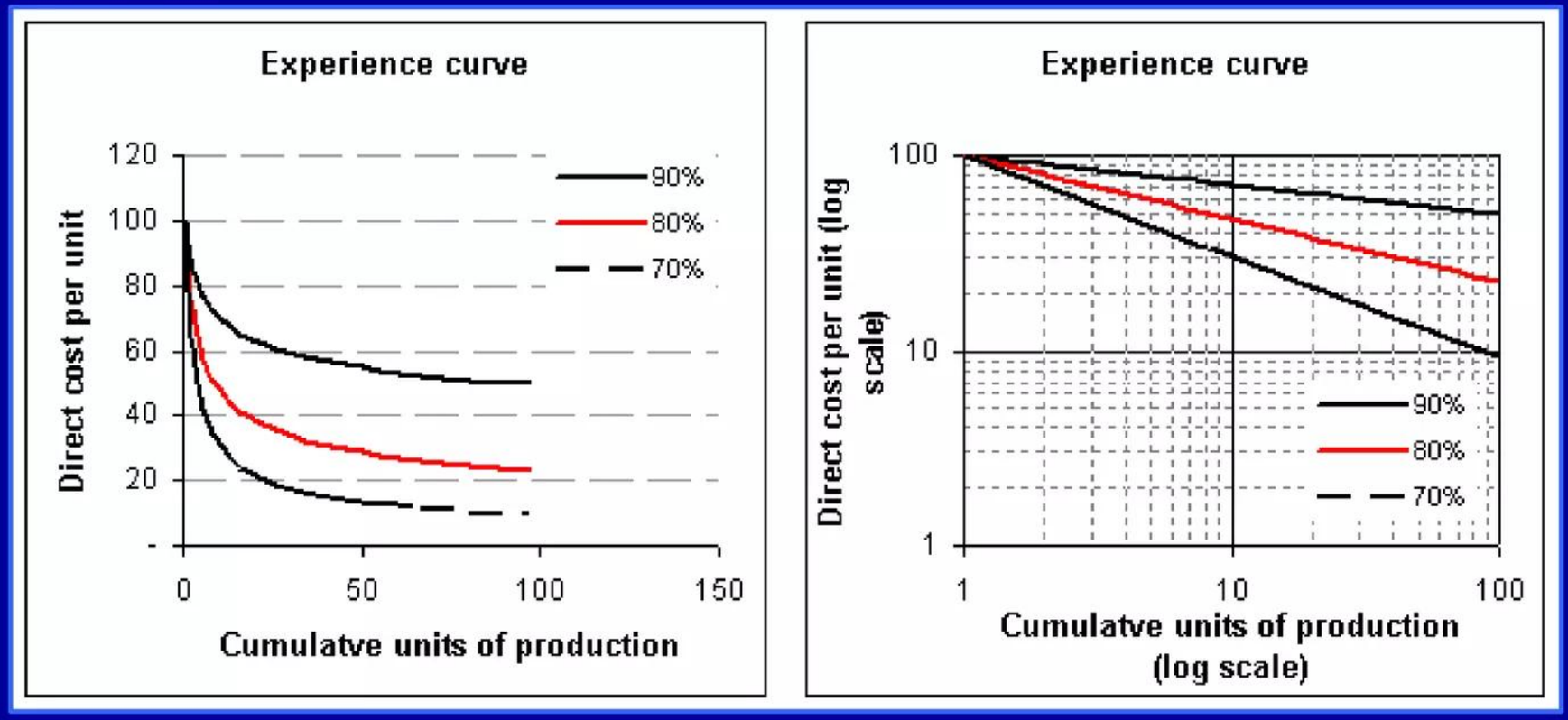
Experience curve cuts cost of producing/storing electricity

Lithium battery chemistry has ridden experience curve for 20+ years

Batteries now moving toward new chemistries to increase energy density

An experience curve, which differs somewhat from a so-called "learning curve," is a graphical representation of a price phenomenon that was developed and widely publicized as a corporate strategy tool by Bruce Henderson, founder of the Boston Consulting Group. Concept refers to effect that manufacturers learn from doing, which means that the higher the cumulative volume of production, the lower the direct cost per new unit of produced product. Thus, experience curves are innately convex and have downward slopes, as shown in two graphs below:

Idealized relationship between direct cost/unit and total cumulative unit production



Source: Wikipedia - http://en.wikipedia.org/wiki/Experience_curve_effects

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S-curves can describe the life cycles of major technologies

Joseph Gill of Journey of Innovation describes stages as follows

- ✓ **Ferment -** this is the when a product or industry is completely new. A dominant design has not been recognized and competition to create the dominant design is fierce.
- ✓ **Takeoff -** if a dominant design has been determined and the innovation crosses the chasm of death you will see a rapid period of growth as the innovation moves towards full market acceptance.
- ✓ **Maturity -** the product or industry has become a completely accepted by the general public and has matured. It is at this point that only a few large players exist and the markets are clearly defined. This is also the point when products become completely standardized and the products are less and less unique.
- ✓ **Discontinuity -** once a product has reached maturity it runs that risk of being discontinued by newer technologies a great example of this was the transition from film cameras to digital cameras.

Above bullets quoted directly from source: http://innovajourney.blogspot.com/2012/05/s-curve.html

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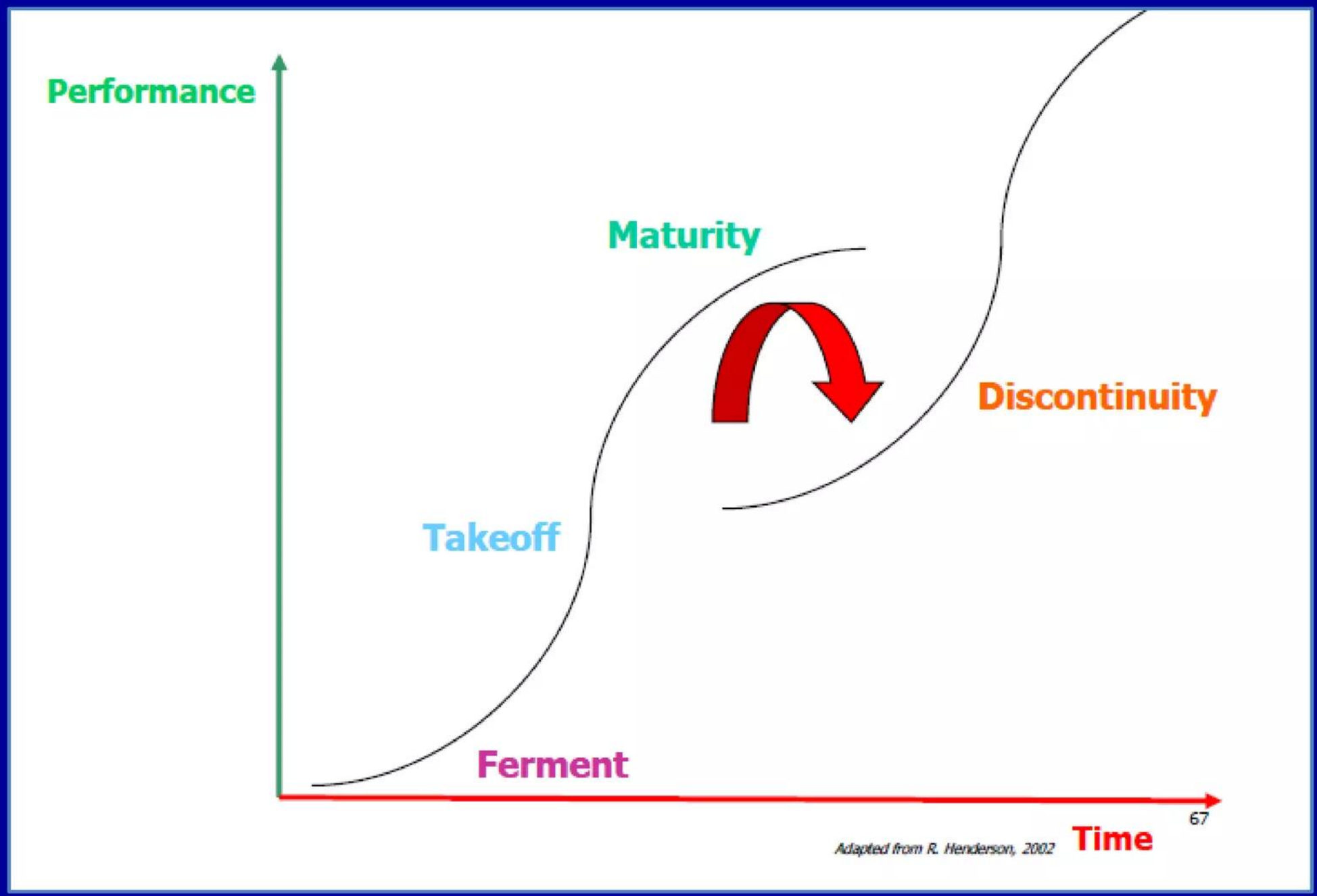
Cost reductions slow and flatten-out as technology matures



Source of graphic is Joseph Gill at: http://innovajourney.blogspot.com/2012/05/s-curve.html

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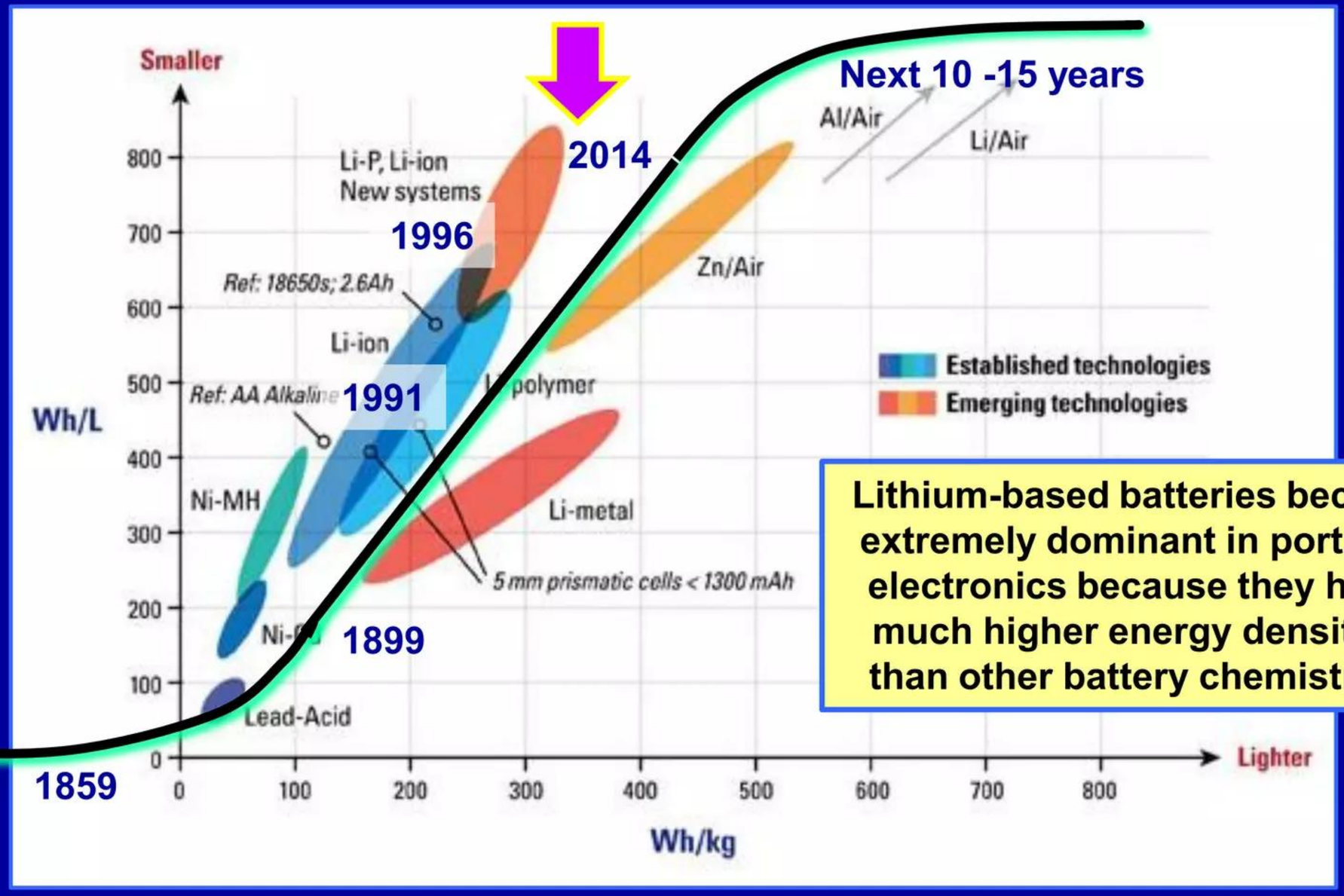
Batteries maturing and approaching technological limits

Energy density increases and related cost reductions are slowing down



Source: http://www.estquality.com/technology

Note: superimposed S-curve and dates added by Lattice

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Maturity of combustion and battery technologies is upon us

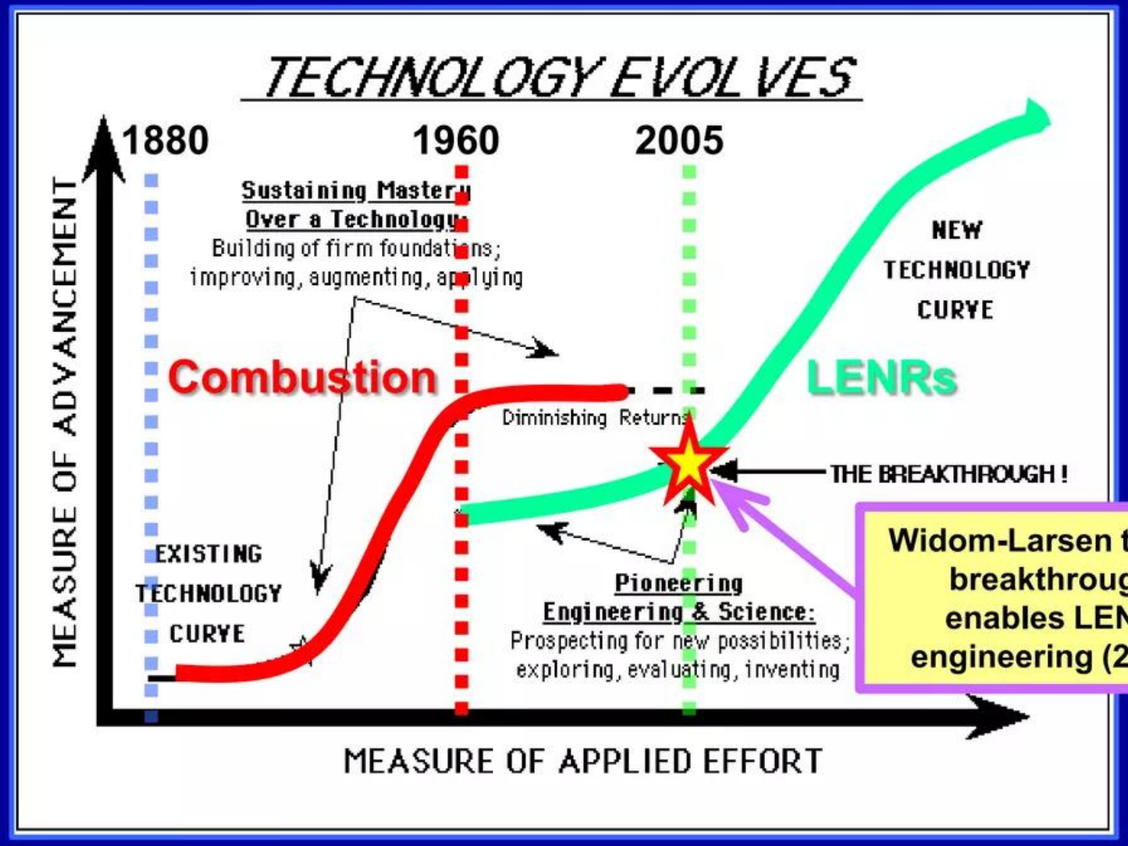
Creates opportunities for entry of newer and even better technologies

Wind/solar: CO_2-free and renewable but low energy density and intermittent

To greatly reduce energy costs need breakthrough energy-dense technology: LENRs

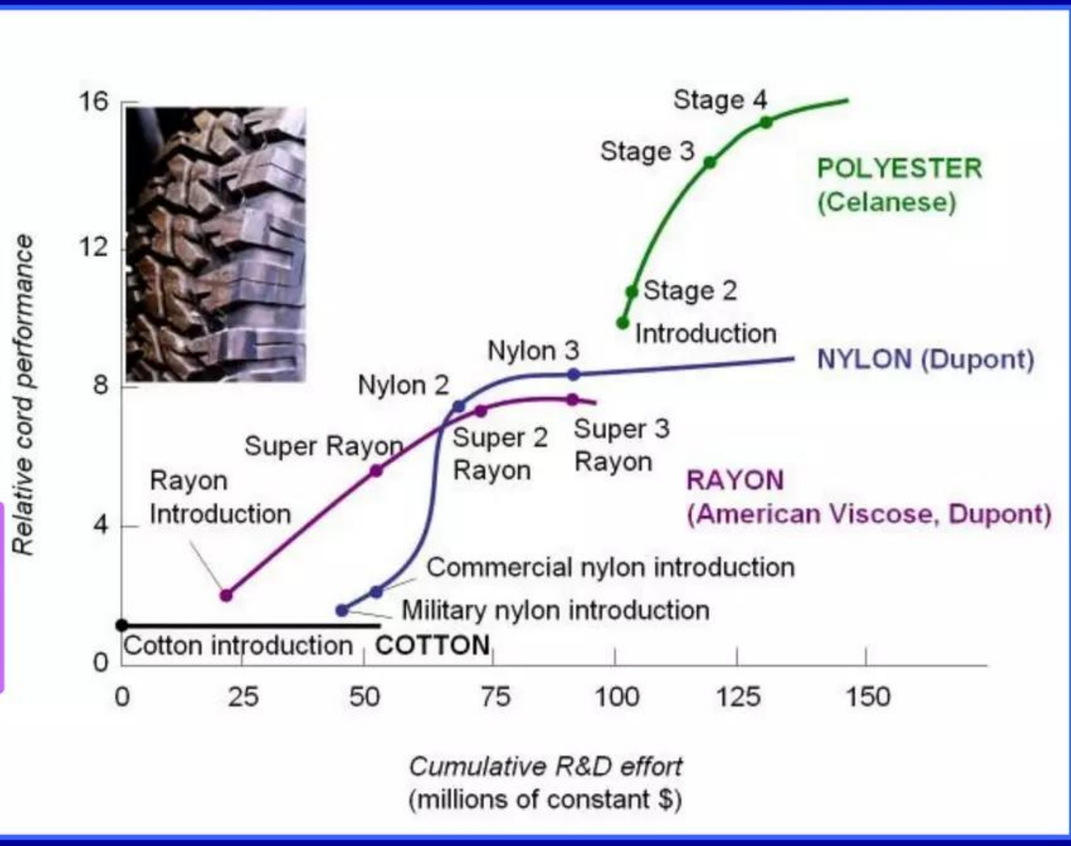
LENRs complement wind and solar and are highly synergistic with them

Technology S-curves for combustion vs. LENRs:



Widom-Larsen theory breakthrough enables LENR engineering (2005)

S-curve concept and tire cord technology:



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Lattice's commercialization strategy

Scale-up LENR system power outputs and integrate energy conversion

- ✓ **LENRs can presently reach temperatures of 4,000 - 6,000° K and boil refractory metals in limited numbers of microscopic LENR-active hot spot sites on laboratory device surfaces.** Lattice plans to use its unique proprietary knowledge of LENR engineering physics and key operating parameters (e.g., achieving and maintaining very high local surface electric fields) to first get heat production working well microscopically. That is: reproducibly trigger LENRs on specific, purpose-designed nanoparticulate structures with dimensions ranging from nanometers to microns that are fabricated using existing, off-the-shelf nanotech processes and then deliberately emplaced at what will become LENR-active sites located on Hydrogen-loaded substrate 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

Lattice Energy LLC

Lattice's commercialization strategy

Maximize unit volumes and ride cost curve to dominate target markets

- ✓ Over time, plan to ride down manufacturing experience cost curve; similar to build-cost reduction and market penetration strategies used by electronics manufacturers; e.g., microprocessors, memory chips, PCs, and smartphones
- ✓ As product manufacturing experience accumulates and internal build costs are progressively reduced, leverage enormous energy density/longevity advantages of LENRs (>million times larger than chemical); price LENR-based systems to drastically undercut price/performance provided by competing thermal sources and chemically-based power generation systems --- this strategy can be applied to portable, distributed stationary, mobile, and central station power markets
- ✓ Small-scale LENR systems might seem to be light years away from being able to compete with huge 500 - 1,500 MW coal-fired and Uranium-fission power plant behemoths; however, please recall history of personal computers versus mainframes. When PCs were first introduced 35 years ago, mainframe computer manufacturers regarded them as just toys, information processing jokes of no consequence. Less than 10 years later, mainframe companies weren't laughing any more. Today, except for just a handful of survivors like IBM, mainframe and minicomputer dinosaurs have disappeared, replaced by microprocessor arrays

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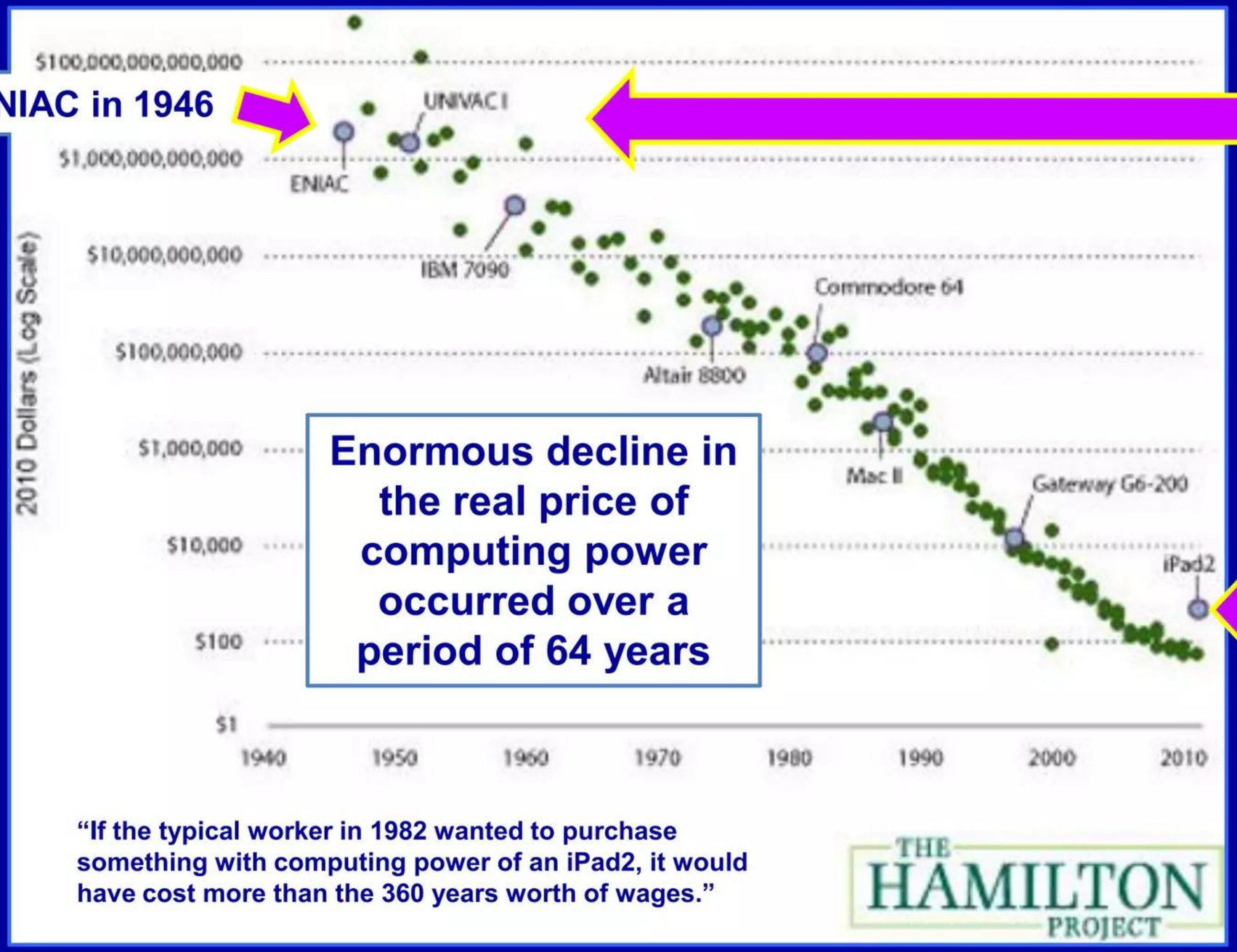
Drive down heating and electricity costs just like computers

"Cost of computing power equal to an iPad2" (2011)



Source: http://www.hamiltonproject.org/multimedia/charts/cost_of_computing_power_equal_to_an_ipad2/

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LENRs enable cost-effective distributed power generation

Brandon Owens of GE concludes that DG is the wave of the future

CHAPTER VII CONCLUSION

VII. CONCLUSION

After decades of both technology progress and future promise, distributed power is now poised for growth across the globe. Technology innovations have reduced the cost of distributed power technologies while increasing its flexibility and performance. The digital wave and the "Industrial Internet" promise to enhance the capability of distributed power systems. At the same time, distributed power systems are positioned to overcome barriers that are inhibiting the growth of large-scale power plants. There is a strong need for energy solutions across the globe, and by meeting this need, distributed power has become part of a virtuous cycle of human and economic development.

"The rise of distributed power," B. Owens, General Electric, page 39 (2014)

Lattice Energy LLC

LENRs enable cost-effective distributed power generation

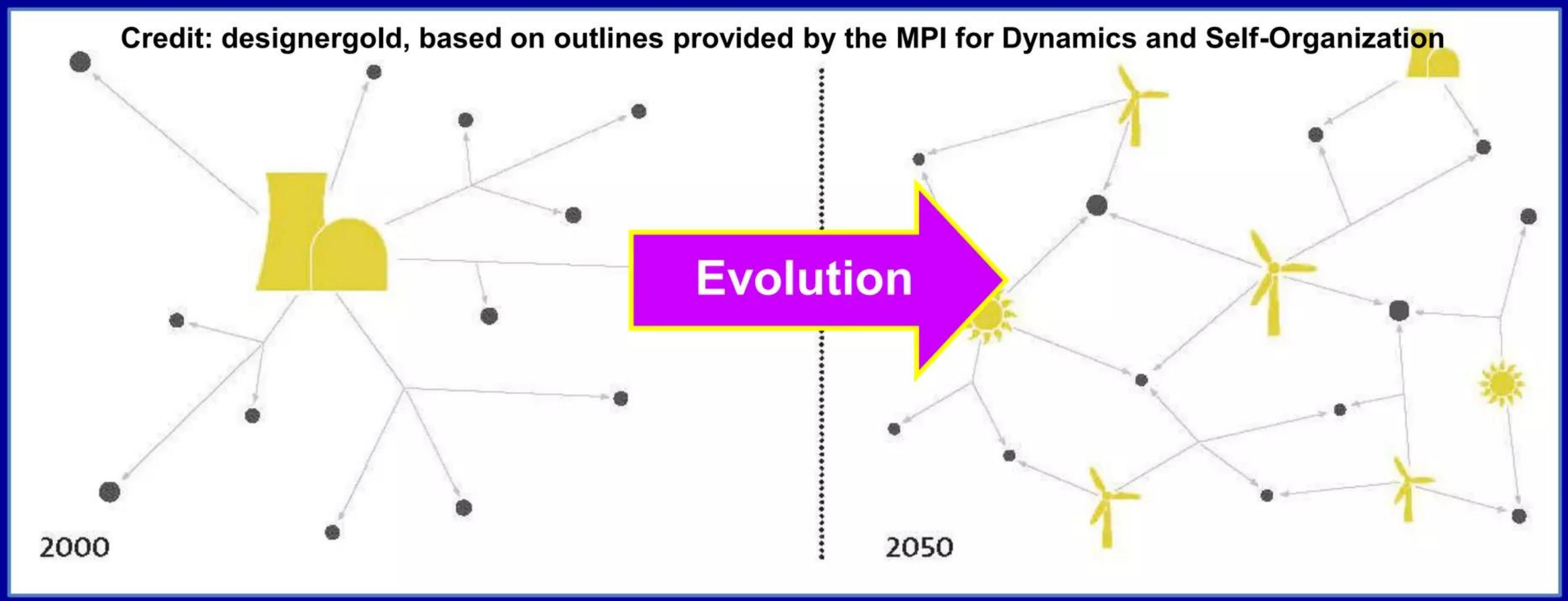
Strategy advantageous in developed countries and grid-less areas

- ✓ At system power outputs of just 3 - 10 kW, cost-effective modular LENR-based distributed power generation systems could provide enough heat and electricity to potentially satisfy the stationary energy requirements of a majority of urban and rural households and smaller businesses worldwide
- ✓ At system power outputs of just 50 - 200 kW, LENR-based systems could begin to power steam or all-electric vehicles, breaking oil's stranglehold on transportation; could also provide high-quality heat for industrial processes
- ✓ Although they could very likely be designed and built, megawatt LENR 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 case, grid-based centralized power generation would gradually be displaced by vast numbers of smaller, lower-cost distributed systems in smarter grids

Lattice Energy LLC

Modeling suggests decentralization is probably beneficial

Phys.org Sep 14, 2012: "The Network Dynamics Group, headed by Marc Timme at the Max Planck Institute for Dynamics and Self-Organization in Göttingen has now discovered, synchronization in a decentralized power grid may actually be easier than previously thought, as a grid with many generators finds its own shared rhythm of alternating current."



"Solar and wind energy may stabilize the power grid" *Phys.org* Sep 14, 2012
Source: http://phys.org/news/2012-09-solar-energy-stabilise-power-grid.html

Lattice Energy LLC

LENRs enable cost-effective distributed power generation

Strategy advantageous in developed countries and grid-less areas

Increases robustness/stability of urban grids and brings power to the powerless

Bold visions of the future of distributed power generation and microgrids:

- ✓ **"Micropower: the next electrical era"**
  Seth Dunn, Worldwatch Institute (2000)
  http://www.worldwatch.org/system/files/EWP151.pdf

- ✓ **"Perfect power: how the microgrid revolution will unleash cleaner, greener, and more abundant energy"**
  Bob Galvin and Kurt Yeager, McGraw-Hill (2008)
  http://www.amazon.com/PERFECT-POWER-Microgrid-Revolution-Abundant/dp/0071548823

- ✓ **"The rise of distributed generation"**
  Brandon Owens, General Electric - Ecomagination (2014)
  http://www.eenews.net/assets/2014/02/25/document_gw_02.pdf

Over 1.4 billion people now have no access to electricity: http://vimeo.com/77599467

Lattice Energy LLC

Centralized grid architecture has dominated for 100 years

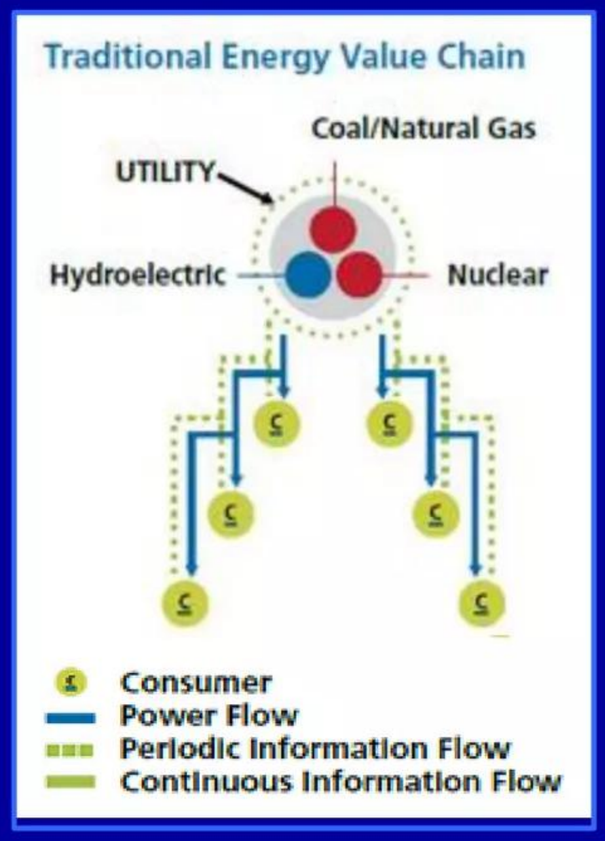
Climate change is making this model more vulnerable to major outages

- ✓ Highly centralized architecture (see IBM graphic to right) with large central station electric power generation plants and little storage has dominated large electricity grids worldwide since early 1900s
- ✓ While enabling large reductions in the real price of electricity over that time by exploiting significant economies of scale, it can be fragile to disruption by natural forces such as very violent storms as well as by catastrophic "black swan" events that can arise from random disturbances in transmission systems
- ✓ Climate change increasing frequency of bad storms:

Solution to this climate change-related issue is to reduce level of centralization by distributing electricity generation and storage across much larger number of nodes in electric transmission grid networks; doing this requires having "smart grids"

GENERATING INSIGHTS
ACCELERATING INTO A NEW ERA IN ENERGY
SPONSORED BY IBM

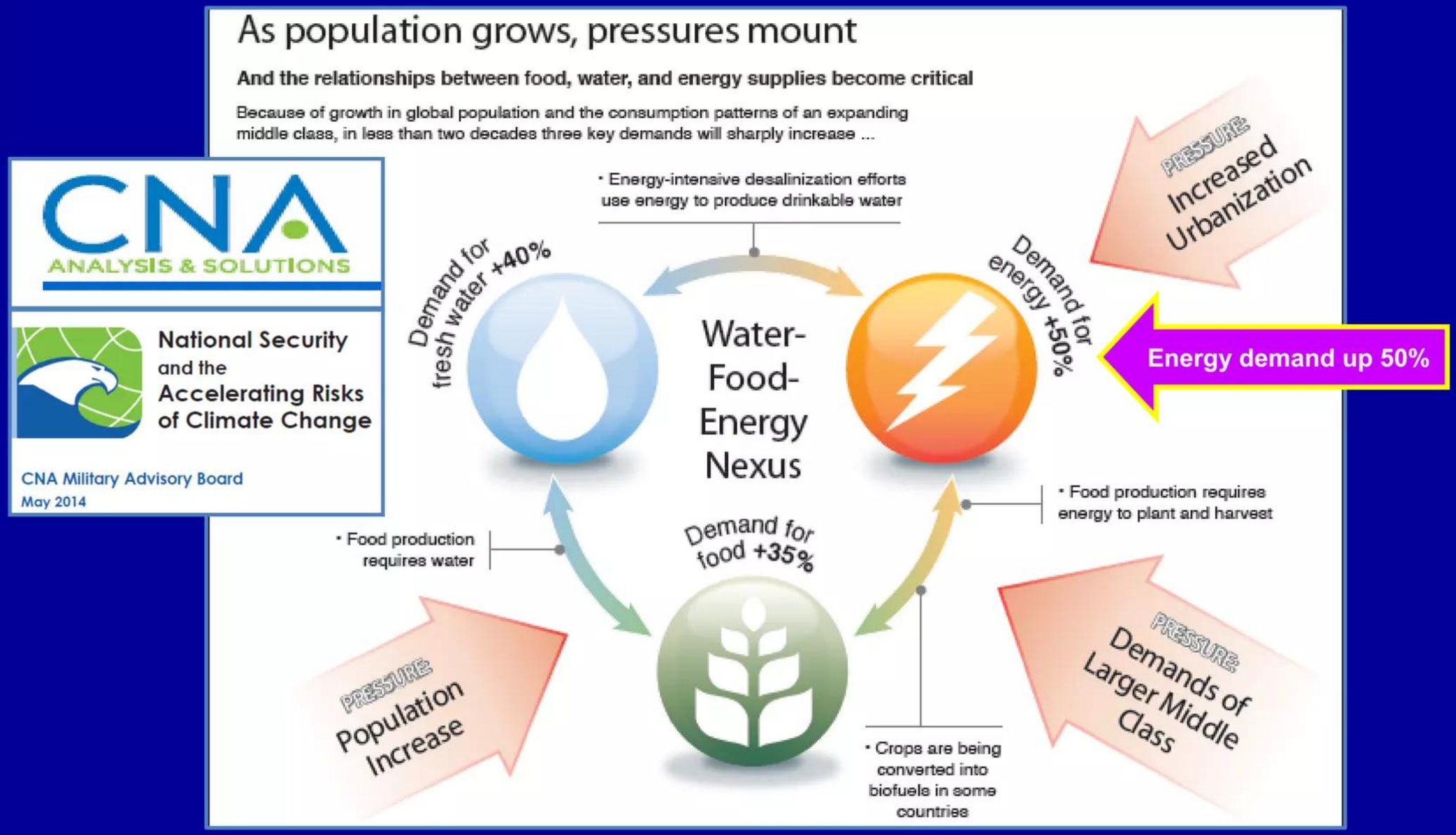
Source: M. Rosenfield, IBM
http://www.generatinginsights.com/index.php



Lattice Energy LLC

Retired U.S. military leaders worried about climate change

Center for Naval Analyses report: energy demand could rise 50%



Source - page 16 in above 48-page CNA report released May 2014: http://www.cna.org/sites/default/files/MAB_2014.pdf

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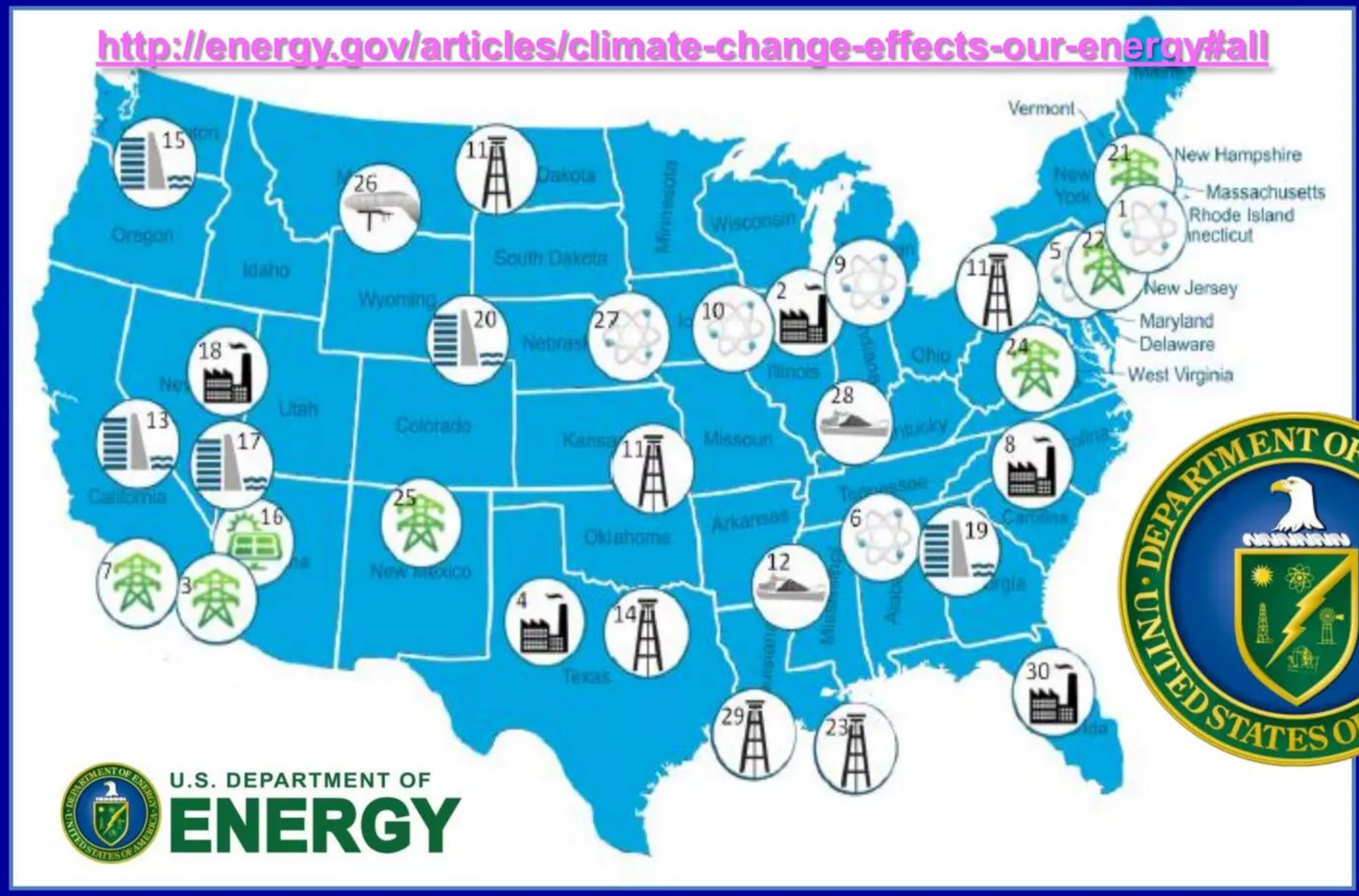
U.S. Dept. of Energy: greater risks of power plant shutdowns

Figure 1. Selected events over the last decade illustrate the U.S. energy sector's vulnerabilities to climatic conditions (Source: DOE July 2013)



Source: http://www.energy.gov/sites/prod/files/2013/07/f2/20130716-Energy%20Sector%20Vulnerabilities%20Report.pdf

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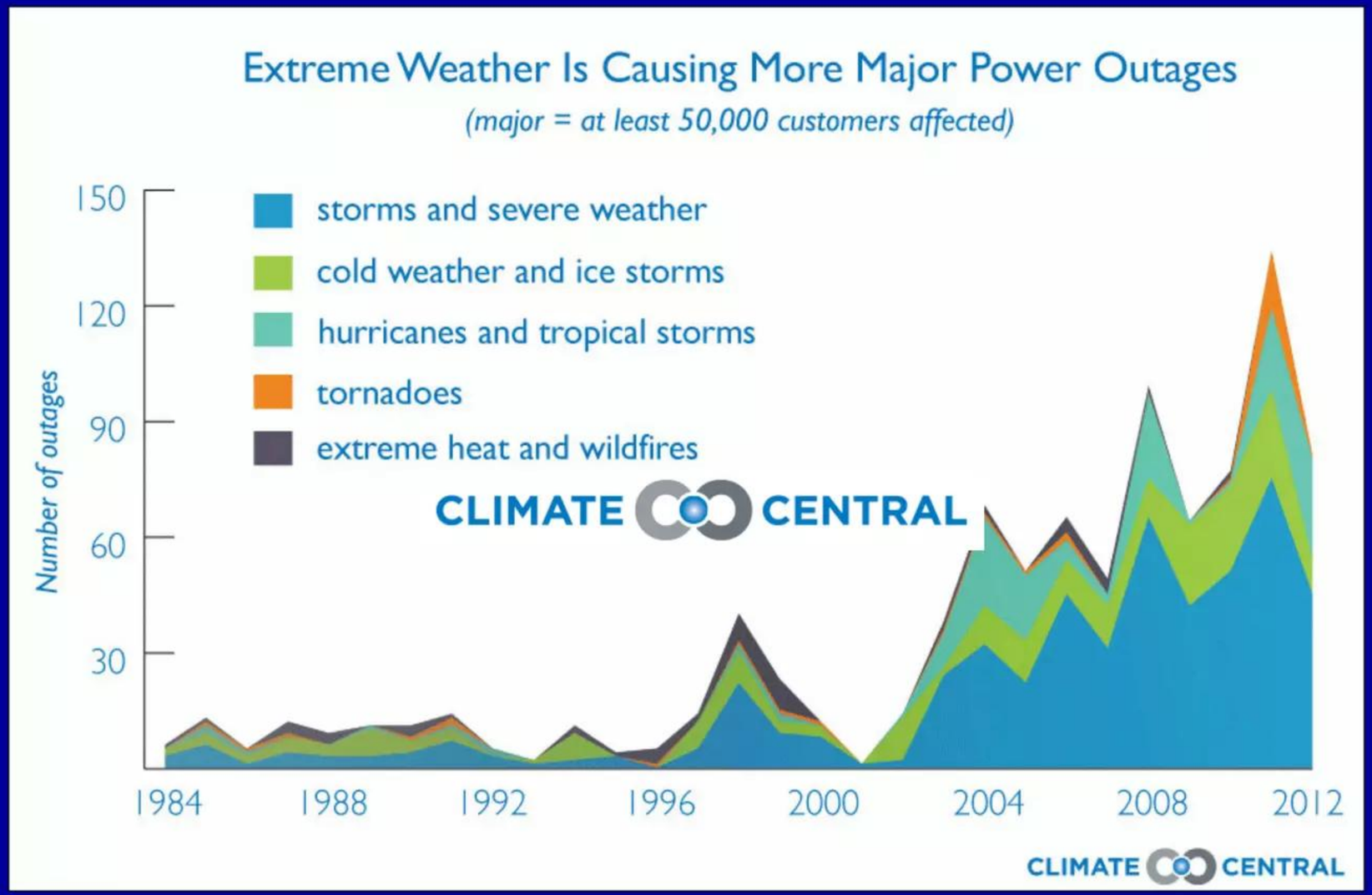
Weather-related blackouts doubled since 2003: new report

"Blackout: extreme weather, climate change and power outages"

A. Kenward and U. Raja, Climate Central (2014)



Source: http://assets.climatecentral.org/pdfs/PowerOutages.pdf

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May 13, 2014: Deloitte released its survey of U.S. consumers

18% had more outages: 53%* blamed weather, 32%** did/will buy genset

Data suggests future demand for backup generators will likely increase

Press release: http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/Energy_us_er/us_er_reSources2014_summary_May2014.pdf

Credit: Deloitte

Weather most frequently blamed

- Turning to back up generators still most common remedy to dealing with the problem

Reason for electric outages*: 2014

More extreme weather	53%
My electric company does not adequately maintain its system	31%
My electric company does not have enough capacity during periods of peak electricity usage	21%
Other	10%
I have no idea	14%

Steps taken as a result of the increase in electrical outages: 2014**

I have complained to my electric company.	27%	
I have purchased a back-up generator.	20%	32%
I have not purchased a back-up generator, but plan to in the next 6 months.	12%	
I have not installed solar panels on my roof, but I plan to in the next 6 months.	8%	
I have installed solar panels on my roof.	5%	
Other	6%	
I have not really done anything in response to the increased outages.	42%	

~18% of all utility customers had more outages: *within that subgroup*, 53%* blamed weather ; 32% did or will buy gensets**

Source: http://www.utilitydive.com/news/do-utilities-know-what-their-customers-really-want/262952/

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Grid-level storage for wind/solar intermittency and outages

Extremely large flow batteries promoted as a technological solution

- ✓ Large present-era 'dumb' power grids require continuous production of electricity that ideally matches demand on a second-by-second basis as well as large standby power generation facilities that can be dispatched on very short notice
- ✓ Wind and solar power sources are inherently intermittent in their output of electricity; today's wide-area grids could not function properly if generation was only provided by such renewables
- ✓ Enter flow batteries which are low-cost and can be scaled-up volumetrically to gigantic capacities
- ✓ Good technology within its limitations, largest being intrinsically low energy density: newly discovered quinone-based chemistry only achieves ~50 Wh/kg versus 150 - 200 Wh/kg for commercial Lithium-ion

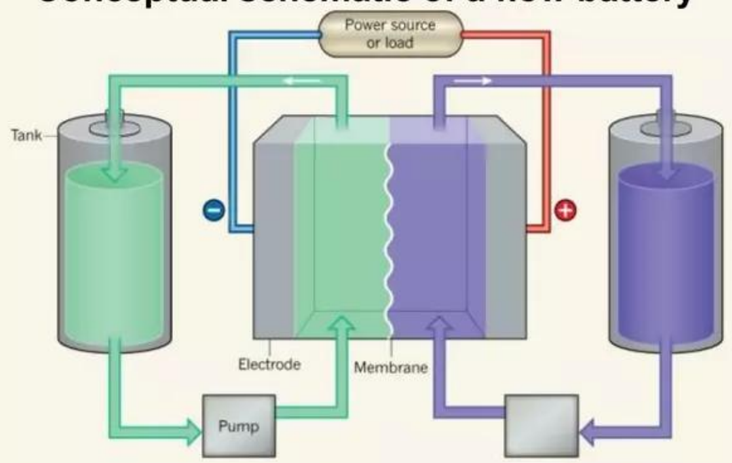
Source of Table 1: "Introduction to Flow Batteries: Theory and Applications," Bhaskar Garg, Stanford University, March 22, 2012 http://large.stanford.edu/courses/2011/ph240/garg1/

Comparison: energy densities of flow batteries

Batteries	Energy Density (Wh/L)	Power Density (W/L)
Bromine-polysulfide	20-35	60
Vanadium-vanadium	20-35	60-100
Vanadium-bromine	20-35	50
Zinc-bromine	20-35	40
Zinc-cerium	20-35	50
Lead-acid	60-80	230
Lithium-ion	150-200	275
Nickel metal hydride	100-150	330

Table 1: Battery Comparison (based on data from [4]). The first five are flow batteries.

Conceptual schematic of a flow battery



Membrane separates charge-carrier liquids

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LENRs are both competitive and synergistic with batteries

Batteries needed to supply input energy for LENR systems' start-up

- ✓ Although compact, battery-like portable LENR power sources would compete directly with high-end batteries in ultra high performance applications, LENRs also require batteries or ultracapacitors for both start-up and rapid load-leveling
- ✓ LENR-based portable power generation systems of all sizes will thus will most likely have batteries and/or ultracapacitors as subsystems tightly integrated into their architectures
- ✓ Alternatively, wind or solar power sources could also be used during start-up and ongoing operation of stationary LENR systems; conceptually, one could use LENRs as type of power amplifier for wind- and solar-generated electricity
- ✓ LENRs will never totally displace batteries; note that Lead-acid starter batteries are still being used in most IC vehicles
- ✓ LENRs enable new applications that could never be handled by any conceivable battery; e.g., autonomous exoskeletons and humanoid robots or UAVs with months-long endurance

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Battery-like LENR devices similar to betavoltaic batteries

Differences: LENRs need input energy for start-up & gamma conversion

LENRs have vastly higher energy densities and can turn nuclear process on/off

Betavoltaic batteries directly harvest energetic electrons produced by unstable beta-decaying isotopes; radioisotope thermal generators (RTGs) based on variety of different isotopes harvest heat - subsystem converts it into electricity

Raytheon

Type	Power (mW)	Total Energy (mWh)	Volume (cm^3)	Weight (g)	Total Energy Density (mWh/g)
Lithium AA Battery	~1 (1.5 V)	4,350	7.9	14.5	300
Betavoltaic 1 cm^2	~0.3 (2 V)	10,512	0.025	0.08	131,400

Table 1. Comparison of a lithium AA battery with conceptual betavoltaic power source. Source: M.V.S Chandrashekhar, et al., "Design and Fabrication of a 4H SiC Betavoltaic Cell," Cornell University.

Raytheon

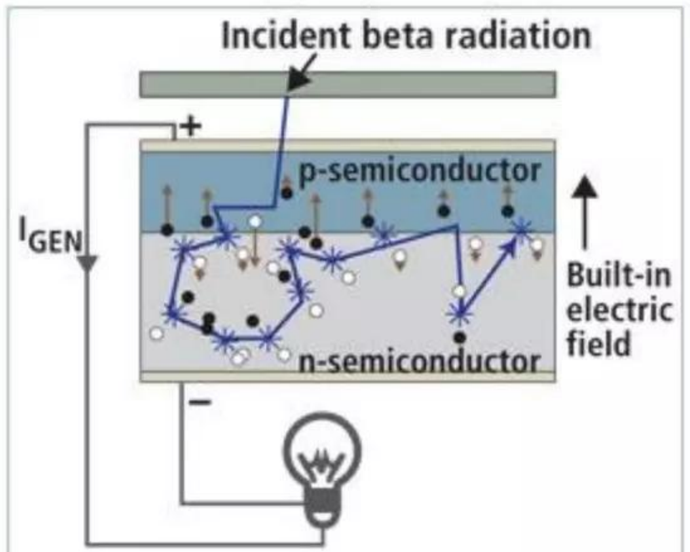

Figure 2. Schematic betavoltaics P-N junction power source. One betavoltaic conceptual design configuration is based on "direct conversion" that derives small currents from electron-hole pairs produced by impinging beta rays in P-N junction depletion zones.

Article titled "Power sources that last a century" at: http://www.raytheon.com/newsroom/technology_today/2011_i1/power.html

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- ✓ **Modular LENR-based 3 - 10 kW thermal sources would be ideal for providing uninterruptible power to the powerless; depending on type of basic system being architected, could integrate different types of energy conversion subsystems to generate either DC or AC electricity and heat**
- ✓ **Very high system-level energy densities of LENR-based power systems would help minimize total weight of components first being transported**
- ✓ **Extraordinarily high intrinsic energy densities of CO_2-free LENR target fuels (target fuel nanoparticles + substrates immersed in carrier liquids or gases) would make the weight of initially delivered fuel simply minuscule in comparison to everything else being transported to remote locations**
- ✓ **Energy densities of LENR fuels *all by themselves* could easily be 5,000x larger than gasoline (1/5,000; i.e., 6 lbs of LENR fuel = BTUs from burning 5,000 gallons of gasoline); collapses fuel resupply logistics pipeline to tiny amounts of weight that must be transported onsite - could be carried on a person's back or delivered by UAV drones. This would be revolutionary**

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LENRs are CO_2-free and dramatically reduce size of logistics tail for fuel

BTU equivalent of tanker truck full of gasoline ships overnight in a FedEx box

LENR target fuels are inert and benign and can use existing package delivery systems for resupply; typical gasoline or diesel tanker truck carries ~5,000 - 12,000 US Gallons of liquid fuel; LENR fuels producing same # of BTUs could be shipped in 2 FedEx boxes

Astounding possibility illustrates the benefits of exploiting huge nuclear energy densities

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UAV drones are ideal for delivering LENR fuels to customer sites worldwide

December 2013: Amazon unveiled its plan for package delivery via UAV drones

- ✓ **Drone-based systems similar to Amazon's PrimeAir concept could be used for automatic resupply of LENR fuels to customers in rural areas of the world**
- ✓ **Drones themselves could be powered by LENR-based propulsion systems; see Lattice document: http://www.slideshare.net/lewisglarsen/lattice-energy-llc-revolutionary-lenrs-could-power-future-aircraft-and-other-systems-feb-16-2014**
- ✓ **Tactical Robotics' *InstantEye* system claims to have solved aerial stability issue for small autonomous drones in high winds: http://www.psitactical.com/**
- ✓ **LENR-powered drones with long endurance and range capabilities could be used to rapidly deliver LENR fuel and critical medicines to rural locations**

Amazon video: http://www.youtube.com/watch?v=98BIu9dpwHU

CBS news story: http://www.cbsnews.com/news/amazon-unveils-futuristic-plan-delivery-by-drone/

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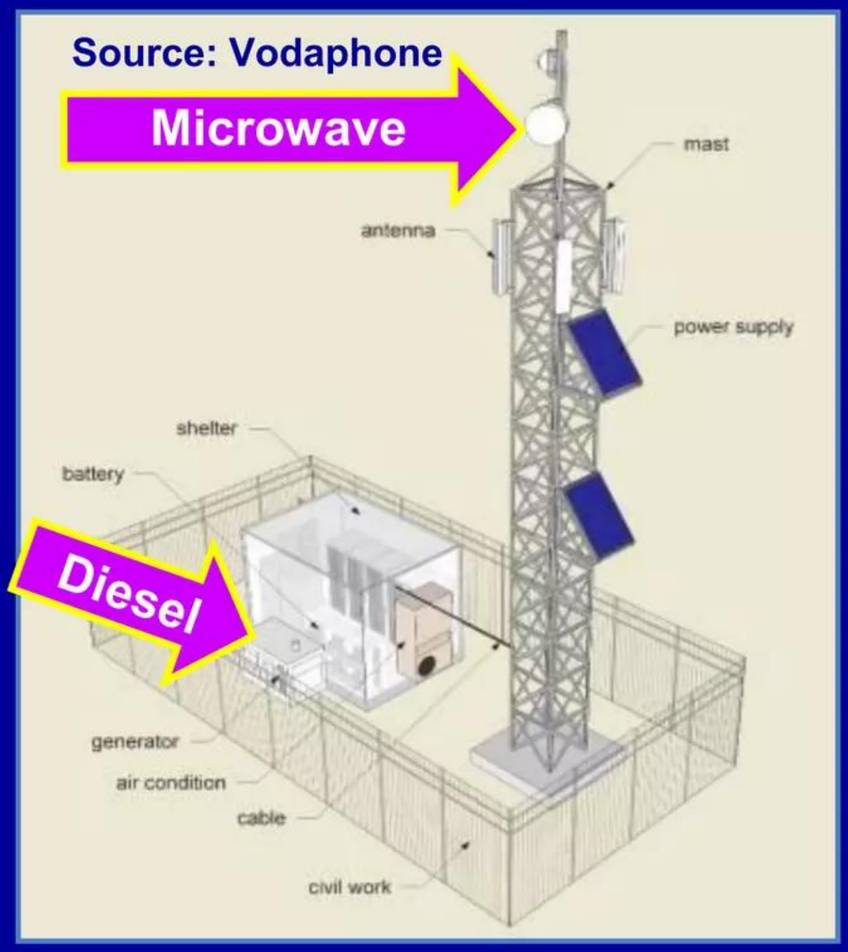
Diesel electric generators commonly power cell base stations in rural areas

LENRs could provide ample power for communications and local heat/electricity

- ✓ **For the past 30 years, wireless communications infrastructures and evolving GSM/CDMA network protocols experienced massive global growth, especially in the developing world where hardwired landline stage of development was leapfrogged to minimize capital costs of building-out networks**
- ✓ **Besides cellphone handsets, technological linchpin of such networks outside of cities are local base stations with enclosed sheds and antenna masts**
- ✓ **Wireless base stations need significant amounts of electrical power to operate. If it is not obtained from grids, out in rural areas must come from some local power source: today, mainly diesel generator sets**
- ✓ **Opportunity for LENRs to power such base stations**



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Diesel generators need resupplies of fuel; in some areas simply impossible

Wind and solar power generation now utilized in areas where diesels are unfeasible

- ✓ **Internet now globally accessible via compact smartphones like iPhones and larger wireless-equipped devices like iPads**
- ✓ **So if person has such a portable cellphone, they can access the Internet from anywhere in world if they can connect locally with a wireless network that recognizes their personal handheld device**
- ✓ **Thus most modern wireless base stations provide Internet access**
- ✓ **In or near urban areas, hard 'wires' (fiber, DSL) or antenna-directed microwave transmissions from base stations provide backhaul connectivity to core networks; this is not feasible in remote areas where other wireless (sub 6 GHz) or even various satellite systems must be used to connect local base stations to wider network world**
- ✓ **Opportunity to develop low-cost, LENR-powered base stations that can provide local power for both people and communications (CHP)**

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Venture opportunity to develop new LENR-powered multi-use base stations

Documents discuss power requirements, diesel emissions, and network issues

- ✓ **"Alternative power for mobile telephony base stations"**
  Motorola Solutions, Motorola Reach Solutions Paper (2007)
  http://www.motorolasolutions.com/web/Business/Solutions/Technologies/WiMax/Access%20Services%20Network/_Documents/_Static%20Files/6682_MotDoc.pdf?localeId=82

- ✓ **"Cellular base stations: infrastructure sharing, carbon emissions and CDM project opportunities"**
  NGOBOX, Renalysis, Knowledge Series (2013)
  http://www.ngobox.org/wp-content/uploads/2013/06/Cellular-Base-Stations-Infrastructure-Sharing-Carbon-Emissions-CDM-Project-Opportunities.pdf

- ✓ **"Measuring the environmental impact of power generation at GSM base station sites"**
  A. Anayochukwu and E. Nnene, *Electronic Journal of Energy & Environment* 1 (2013)
  http://repositoriodigital.uct.cl:8080/xmlui/bitstream/handle/123456789/1466/06-anayochukwu-03.pdf?sequence=1

- ✓ **"The village base station"**
  K. Heimerl and E. Brewer, Proceeding NSDR '10 in *Proceedings of the 4th ACM Workshop on Networked Systems for Developing Regions*, Article No. 14, ACM New York, NY (2010)
  http://www.cs.berkeley.edu/~kheimerl/pubs/vbts_nsdr10.pdf

- ✓ **"Cost-effective rural GSM, LTE and backhaul"**
  Lotus^{GSM} White Paper, Lotus Solutions and Services (2011)
  http://www.gsma.com/membership/wp-content/uploads/2012/03/LotusGSM_White_Paper.pdf

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Ideal: rugged, modular, expandable with local communications connectivity

Stage 1: LENR power sources with integrated cooking surfaces & charging outlets

- ✓ **Idea:** design and engineer simple, robust, easy-to-use modular turnkey CHP systems that are reliable and rugged enough to be airdropped into remote locations
- ✓ **CHP systems provide:** (1) **local electrical power** via AC outlets that can also be used to charge battery-powered devices; and (2) **integrated heat sources** that can be used for cooking food, boiling water, heating
- ✓ Electrical power generation accomplished with thermoelectrics (low efficiency but reliable) or small Rankine or Brayton cycle turbines (see later slides)
- ✓ **No communications mast included (so no Internet access) but first shipments could also include two-way radios for local peer-to-peer communications as well as battery-powered devices shown on next slide**

Peer-to-peer two-way radios

Midland LXT600VP3 two-way radio specs: 36 transmit/receive channels; Xtreme Range™ up to 30 miles; longer range is possible in open rural areas with very few obstructions; HI/LO power settings and adjustable transmit power; includes both rechargeable battery packs and desktop charger plus AC adapter; **compatible with other brands of FRS/GMRS two-way radios**

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Ideal: rugged, modular, expandable with local communications connectivity

Stage 1: variety of rechargeable battery devices are then usable with turnkey power

Coleman® PowerChill™ 40 quart thermoelectric Cooler

Chills inside contents to 40° F below surrounding temperature; 9.5 to 14.4 Volts DC draws 4 amps; dimensions: 21.75 in. (55.2 cm) x 15 in. (38.1 cm) x 17.125 in. (43.5 cm); weighs 19.5 lbs.

Rugged tablets

Interior LED lighting systems

LED flashlights

Garmin GPS

Modular power tools

Portable water pumps

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Ideal: rugged, easy-to-use, modular, expandable, and connection to Internet

Stage 2: backbone antenna mast + additional turnkey modular LENR power systems

- ✓ **Idea is to utilize a near off-the-shelf, very strong Carbon-fiber (very low weight) telescopic mast that can be hand-cranked up-and-down for initial deployment and later servicing and upgrading of modular antennas used for connecting to different local and backhaul networks**
- ✓ **Would not be mounted on vehicle as shown to right but instead on a multi-legged Carbon-fiber base that does not require any excavation, can be weighted down with rocks or cemented, add anchored guy wires, and leveled**
- ✓ **Electrical connectors at base of mast linked to LENR-based power systems via heavy-duty armored cable**
- ✓ **Idea is this antenna mast and base comprise permanent 'backbone' of the communication system that can easily be upgraded as network connections evolve and change**

Carbon-fiber telescopic mast

Cobham EXB or EXL carbon-fiber telescopic masts- can be hand cranked

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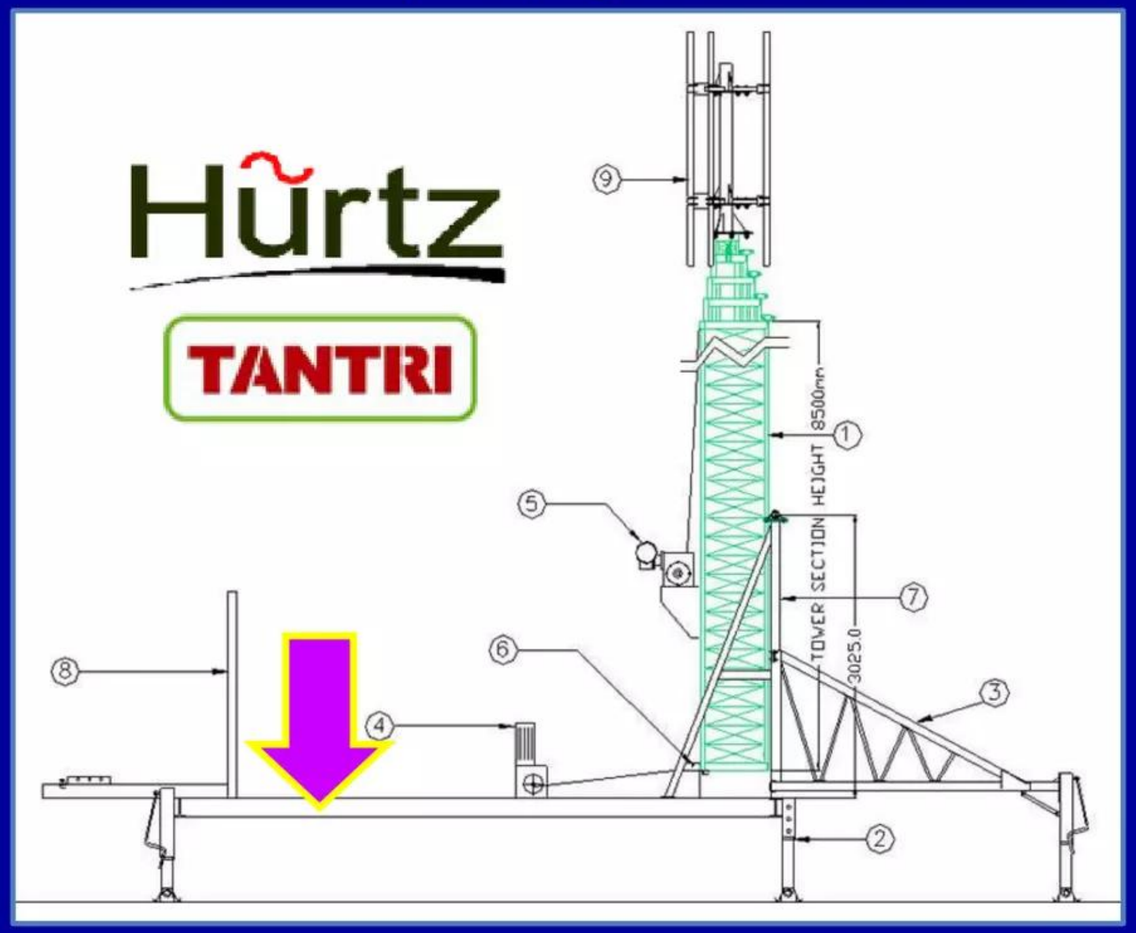
Stage 2: backbone antenna mast + additional turnkey modular LENR power systems

Hurtz GRDL rapid deployment tower with base



Telescoping tower with cell and Iridium antennas

http://www.hurtzz.com/?page_id=43

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Stage 2: backbone antenna mast + additional turnkey modular LENR power systems

According to these references and depending on actual site configuration, base stations have electrical power requirements that can range from ~1 kWh up to as much as ~11 kWh

Application	Site Power Required	Example Solar and Wind solution
GSM Base Station 2/2/2	600-1800W	4KW Solar Array and 6KW turbine depending upon conditions
GSM Base Station 4/4/4	900 – 2300W	6KW Solar Array and 6KW turbine depending upon conditions
UMTS Node B Macro/Fiber 2/2/2	750 – 1000W	3KW Solar Array and 2.5KW turbine depending upon conditions
UMTS Node B Macro/Fiber — 4/4/4	1300 – 1700W	4KW Solar Array and 2.5KW turbine depending upon conditions
Large WiMax Base Station	1.3kW (4 Sector)	4KW Solar Array and 2.5 or 6KW turbine depending upon conditions
Metro WiFi	<30W, includes a backhaul solution	100W Solar Array and small turbine depending upon conditions
P2P link (two heads)	110W for two units	1KW Solar Array and 600W or 2.5KW turbine depending upon conditions

Ref.: Motorola Solutions (2007)

"A base station consumes 3 to 4 kW of electricity to run the equipment, generators and cooling system as presented in figure 2. A fully utilized tower with four operators may require 8 kW of electrical power from either the utility grid or a diesel generator."

Ref.: NGOBOX (2013)

"According to this model, a site consumes 10.7 kWh of electricity"

Ref.: Anayochukwu and E. Nnene (2013)

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Ideal: rugged, easy-to-use, modular, expandable, and connection to Internet

Stage 2: backbone antenna mast + additional turnkey modular LENR power systems

Small steam turbine developed by Green Turbine; ideal for integration with LENR-fired boilers

Credit: Green Turbine

Technical Description Green Turbine 15 kW

http://www.greenturbine.eu/en/home.php

Dimensions:	length: 37 cm, width: 26 cm (14.6 x 10 in)
Weight:	25 kg (882 oz)
Inlet conditions:	Superheated Steam 10 - 12 bar abs. Temp. 200-220°C (392-428°F)
Outlet conditions	0,1 bar abs. 40° C (104 °F)
Steam consumption for 15 kW	0,04 kg/sec
Basic steam rate:	9,8 kg/kWh (steam to electricity after rectification)
Power output:	3 phase AC 1000 Hz, after rectification: DC. Voltage depends upon type of generator. Default is 500 V
Design speed:	26.000 rpm
Speed of steam after nozzle:	> 1000 m/sec
Temperature of turbine housing:	45°C (113 °F)

GREEN TURBINE

Credit: Green Turbine

IFC International Finance Corporation World Bank Group

GSMA

Green Power for Mobile

In partnership with the Netherlands

White paper: "Community power: using mobile to extend the grid"
D. Taverner, published by GSMA (2010)
http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/05/Community-Power-Using-Mobile-to-Extend-the-Grid-January-2010.pdf

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Systems integration opportunities for turnkey modular LENR power systems

Use thermal-to-electric conversion systems developed for concentrated solar power

- ✓ Earlier in presentation we discussed how commercial versions of LENR thermal sources could likely produce neutron fluxes of 1 x 10^{14} cm^2/sec that can create thermal power fluxes of ~ 428 W/cm^2 using a Lithium target fuel
- ✓ Thermal fluxes created at focus receivers of concentrated solar power (CSP) systems can reach values on the order of roughly 200 - 400 W/cm^2 ; ~ matches LENR fluxes above
- ✓ Google, Abengoa Solar, Brayton Energy, and others have investigated and/or developed Brayton cycle thermal-to-electric conversion systems for use in CSP applications
- ✓ Minimizing technology development risks, similarity in sizes of thermal fluxes creates potential opportunities to adapt and integrate such Brayton cycle CSP systems for use in modular LENR-based power generation systems

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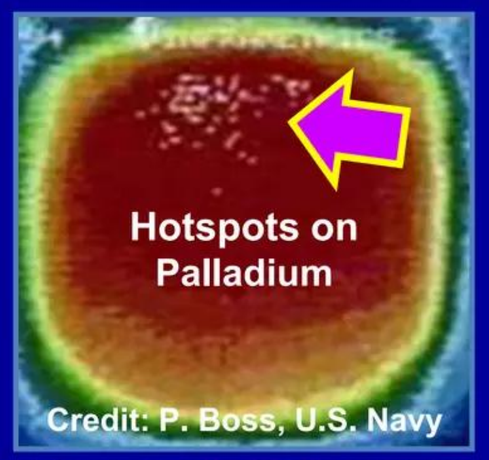
Systems integration opportunities for turnkey modular LENR power systems

LENRs engineered to create thermal fluxes suitable for thermal-to-electric systems

- ✓ **LENRs intrinsically occur in localized micron-scale LENR-active sites on ~planar surfaces or curved surfaces of nanoparticles**
- ✓ **Tiny LENR-active sites only 'live' for 200 - 400 nanoseconds before being destroyed by intense heat; local peak temps range from 3,700 - 5,700° C; LENR-active sites will spontaneously reform under right conditions in properly engineered devices**
- ✓ **Microscopic 100-micron LENR hotspot can release 5⁺ Watts of heat in less than 400 nanoseconds; create crater-like features on surfaces that are visible in SEM images and showing clear evidence for flash-boiling of precious and refractory metals**
- ✓ **Peak local LENR power density can hit > 1.0 x 10^{21} Joules/sec·m^3**
- ✓ **Control temps in LENR systems by regulating input energy and/or total area/volumetric densities of LENR-active sites**

100 μ crater in Palladium

IR video of LENR hotspots



http://www.youtube.com/watch?v=OUVmOQXBS68

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Systems integration opportunities for turnkey modular LENR power systems

Effective efficiencies of CHP Brayton cycle LENR power systems might hit ~80 - 90%

- ✓ **Google investigated development of Brayton cycle for CSP system because Brayton does not require any water to produce power or for cooling (air in, air out) and design could scale up to 1 Megawatt; they estimated Brayton engine efficiency by itself at 37% and integrated system efficiency at ~30%; abandoned project for many reasons**
- ✓ **As we have shown, LENRs get extremely hot; limitations on macroscopic working temperatures in LENR systems would mostly be determined by thermal tolerances of materials used in system. If its components can reliably withstand extremely high temperatures over long periods of time, LENRs could provide whatever temperatures are necessary, well-tailored to specific application requirements. This opens-up a possibility to maybe develop combined cycle LENR-based power systems that scale from a few kilowatts up to megawatts; then might achieve 50 - 60% overall efficiencies**
- ✓ **Since no combustion, external venting of exhaust gases is unnecessary; thus LENR-based Brayton-cycle-only power systems could safely be used indoors for combined heat and power (CHP); effective application efficiencies could then approach 80 - 90%**

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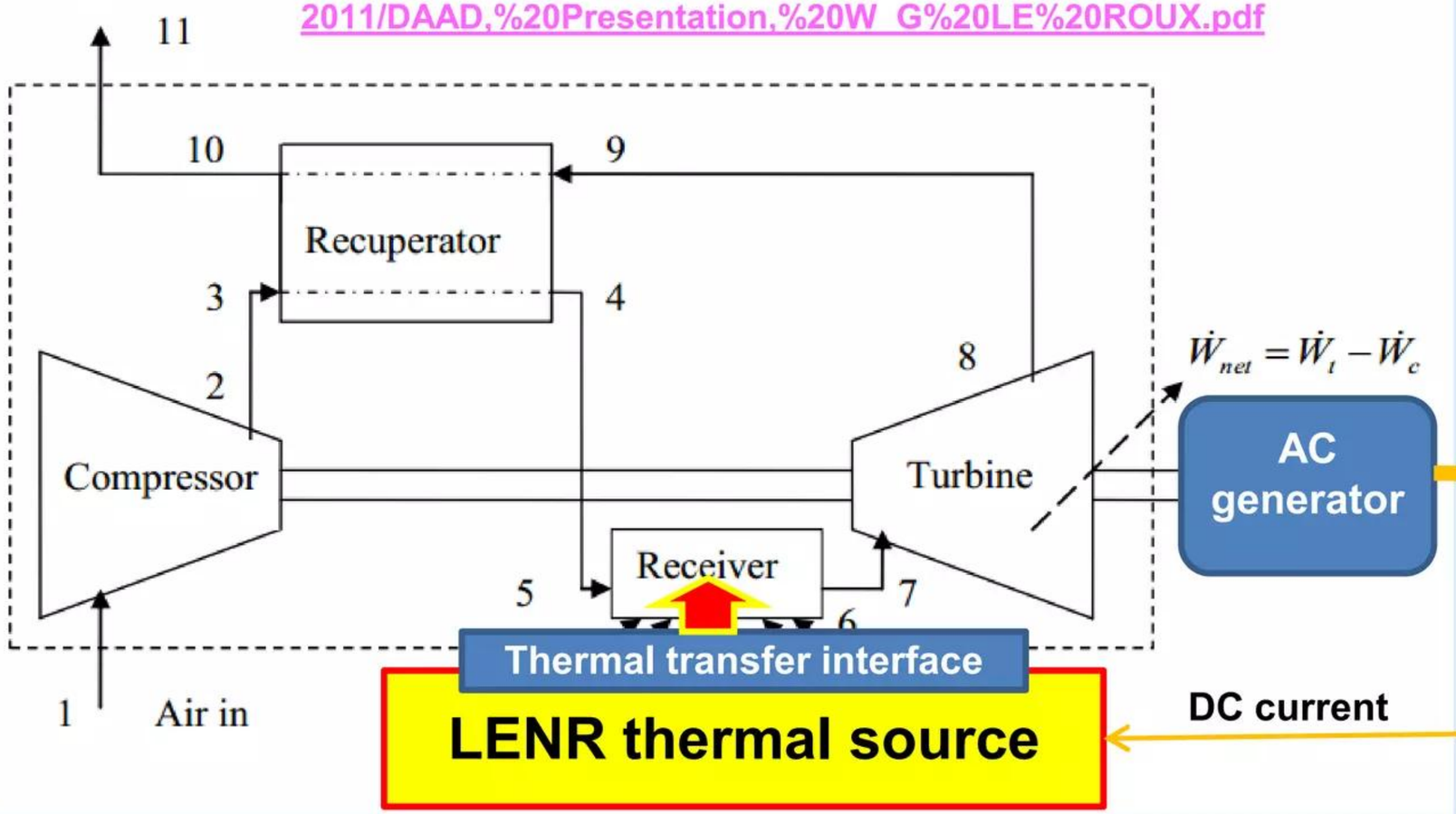
Systems integration opportunities for turnkey modular LENR power systems

Schematic system block diagram of LENR-based Brayton cycle power generator

Adapted from Slide #31 in W. le Roux *et al*. (2013) at:
https://web.up.ac.za/sitefiles/file/44/1026/2163/news-2011/DAAD,%20Presentation,%20W_G%20LE%20ROUX.pdf



Lithium LENR target fuel has a maximum theoretical electrical input vs. thermal output energy gain-ratio of ~34x; at least a ~10x to 15x gain should be achievable in practice. Breakeven gain ratio is ~3x with 33% thermal-to-electric conversion efficiency; is then self-sustaining until fuel gone

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Ideal: rugged, easy-to-use, modular, expandable, and connection to Internet

Stage 2: options for backhaul from backbone antenna mast - satellite and wireless

- ✓ **Hard-wired DSL/fiber or microwave pathways not feasible backhaul options in remote areas located way beyond any urban infrastructures**
- ✓ **Present alternatives are mainly sub 6 GHz radio frequencies and various GEO/LEO communication satellite connections, e.g., Iridium, etc.; most options quite expensive**
- ✓ **New types of airborne connections may be available in near future *a la* gigabit Internet access via high-altitude drones as planned by Google and Facebook; Moscow startup Yaliny aims to offer low-cost LEO access**
- ✓ **New base station would be designed so it can take advantage of new backhaul alternatives**

Solar-powered UAV drones serve as wireless platforms

YALINY **Moscow, Russia**

http://www.youtube.com/watch?v=xeg7dBbRPOs

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Ideal: very rugged, modular, Internet access with enhanced local networks

Stage 3: options to expand geographic range of local area wireless connectivity

- ✓ **Base station's local wireless network connections should be upgradeable; lots of new innovation is occurring in this exciting area of communications**
- ✓ **Wi-Fi is a relatively mature option and reasonably low in cost but has limited range outdoors**
- ✓ **Would be desirable to be able to upgrade base stations if secure, longer-range local wireless network options emerge at some point in future**
- ✓ **One such possibility is a new product category under development that is called Flutter**
- ✓ **Company claims that transceivers would be low-cost and have an outdoor range of one mile; see: http://www.flutterwireless.com**

Flutter Pro Transceivers

Source: Flutter Wireless

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Existing transport systems deliver turnkey Stage #1 or #2 - 3 systems to people

Trucks and helicopters could readily deliver such basic systems to remote locations

Mercedes-Benz Unimog

http://www.youtube.com/watch?v=V1UfJ6Cqz7g

Boeing CH-47D/F Chinook

http://www.youtube.com/watch?v=l51w3_bWZMA

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Existing transport systems deliver turnkey Stage #1 or #2 - 3 systems to people

New advances in controlling airdrop systems can deliver heavy cargoes precisely

"Smart tech paraglides tons of airdropped cargo from high altitudes to meter-sized targets - the Army's Precision Airdrop System aims to save lives"

POPULAR SCIENCE **Rebecca Boyle *Popular Science*, July 14, 2011**

"Any airdrop system … can be outfitted with new control software developed by Draper Laboratory."

Lockheed C-130 Hercules dropping cargo

Credit: Lockheed-Martin

"JPADS: making precision air-drops a reality"
By *Defense Industry Daily* staff, April 27, 2014
http://www.defenseindustrydaily.com/jpads-making-precision-airdrop-a-reality-0678/

Airborne Systems' Firefly cargo paraglider

Credit: U.S. Army Natick Soldier Research Engineering Center

Source: http://www.popsci.com/technology/article/2011-07/armys-new-precision-airdrop-tech-could-help-protect-troops-plus-build-better-uavs?dom=PSC&loc=recent&lnk=1&con=IMG

Lattice Energy LLC

Empowering the powerless and connecting the unconnected

Delivering rural electrification and Internet revolution across the world

New types of air cargo transport systems deliver turnkey power to the people

Hybrid airships being developed could augment helicopters and fixed-wing aircraft

COMPOSITESWORLD

"Don't call it a blimp!"

HIGH-PERFORMANCE Composites May 2014

"The builders of this variable-buoyancy craft count on carbon fiber/epoxy trusswork to enable a new era of air transport"

Sara Black *Composites World* May 2014

Company - Worldwide Aeros Corp. (Montbello, Calif.): quoting " ... central design element [is] Aeros' patent-pending 'control of static heaviness (COSH)' system. Similar to a submarine's buoyancy system .... it features a pumping system that can capture the helium within the vessel's envelope and compress it inside numerous holding tanks. When compressed, the gas becomes much heavier, and its containment creates a partial vacuum inside the airship envelope. Air is permitted to enter that void and inflate four large 'expansion bladders' positioned along the vessel sides. The air inside the bladders plus the weight of the compressed helium causes a decrease in buoyancy, and the craft descends. When the helium is released back into the envelope, forcing the air bladders to empty, the airship ascends. Airship elevation is maintained and rate of ascent/descent is controlled via the helium's tank vs. envelope balance. The system renders ground tethering crews and ballasting unnecessary, and opens the way for cargo transport to remote and unimproved locations."

Source: http://www.compositesworld.com/articles/dont-call-it-a-blimp

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aeros INNOVATION NEVER STOPS

Aeros Corp.'s half-scale prototype *Dragon Dream* outside hangar

Credit: Worldwide Aeros Corp.

COMPOSITESWORLD

"Aeros thinks big: Even the *Dragon Dream* prototype is 266 ft/82m long with a wingspan of 110 ft/34m, and more than 50 ft/15.4m tall. But two mammoth cargo craft have been designed:

One 550 ft/169m long with a wingspan of 177 ft/54.5m and height of 120 ft/37m, will carry 132,000 lb (59.9 metric tonnes) of cargo, and a second, larger craft that will haul 500,000 lb (226.8 metric tonnes)."

Sara Black, *Composites World*

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New types of air cargo transport systems deliver turnkey power to the people

Hybrid airships could potentially be powered by LENR-based propulsion systems

Lockheed Martin P-791 LTA ACLS prototype hybrid air vehicle

"Hybrid Airships introduce the next revolution in affordable transportation directly to the 'point of need,' enabling tactical airlift, strategic airlift, humanitarian assistance, disaster relief and ultra-persistence. Hybrid Airships offer large capacity transportation capability with significant fuel economy and reduced operating costs. They can operate from existing infrastructure or service remote 'points of need' with austere infrastructure. **Lockheed Martin is working with the commercial market to bring the first generation commercial Hybrid Airship to the market in 2014."** - Lockheed Martin website

http://www.lockheedmartin.com/us/products/HybridAirship.html

Lockheed Martin video of P-791 test flight (~1 min): http://www.youtube.com/watch?v=W3n5cUaG5fg

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Unlocking human capital via the Internet: distance learning

Developing more skills to become better local and distance workers

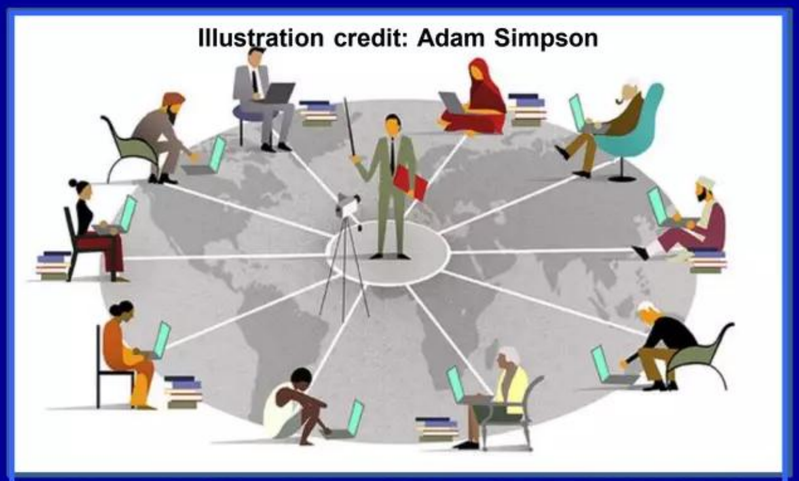
Higher levels of skills improve income prospects and quality of life

Samsung solar-powered school shines in rural South Africa

CNET News *Green Tech* *October 31 2012*

http://financialpress.com/2012/10/31/samsung-solar-powered-school-shines-in-rural-south-africa/

- ✓ **Samsung demonstrated a turnkey solar-powered Internet school in rural South Africa in 2012**
- ✓ **In Korea as of 2010, 'friendly' robots are being used to help schools teach English to students:** http://www.cnn.com/2010/TECH/innovation/10/22/south.korea.robot.teachers/
- ✓ **In Chicago, Illinois, on May 10, 2014, Google donated 500 'Finch' robots to Chicago Public Library that help teach computer programming to young children:** http://abclocal.go.com/wls/story?section=news/local/chicago_news&id=9533745
- ✓ **Air-conditioned turnkey schools or medical clinics with integrated LENR-based power and wireless connectivity to base stations could be created from used intermodal containers and transported to remote sites via ground/air**



Credit: Samsung

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Unlocking human capital via the Internet: distance workers

Making vastly more money locally by working electronically from afar

Better-paid workers become more affluent consumers - grow economies

- ✓ U.S. companies' remote call centers in India, e.g., computer technical support, were economically successful and increased Indian employment
- ✓ Language differences gradually becoming less important as result of more distance learning, computer/robot-assisted instruction, and Internet browsers' increasingly accurate automatic on-the-fly foreign language translation capabilities
- ✓ Team management via Internet is getting better
- ✓ Globalization of e-connected distance knowledge workers will become vastly more geographically dispersed into today's remote, energy-poor areas

Indian employees at corporate call centers provide service support to international customers in southern city of Bangalore.

If this revolution succeeds, sustainable global economic growth will become a reality

Lattice Energy LLC

Additional reading for a broad audience

"Revolutionary green LENRs could potentially power future versions of advanced subsonic aircraft and UAVs - What happens to aircraft, vehicles, and homes if LENRs achieve >10x chemical?"
L. Larsen, Lattice Energy LLC, February 16, 2014 (77 slides) **Impact of LENRs on various types of products**

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-revolutionary-lenrs-could-power-future-aircraft-and-other-systems-feb-16-2014

"LENRs vs. nuclear fission and natural gas for power generation"
L. Larsen, Lattice Energy LLC, July 22, 2013 [56 slides] **Compare LENRs vs. fission/nat. gas for grid power**

http://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenrs-vs-nuclear-fission-and-natural-gas-for-power-generationjuly-22-2013

"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, Institute of Science in Society, London, UK (2009) **Overview published by UK environmental group**

http://www.i-sis.org.uk/LENRsReplacingCoal.php

"Widom-Larsen theory of LENRs . . . energy revolution?"
Aired on the public webradio program, *The Universal Learning Series* with Sandy Andrew

https://www.youtube.com/watch?v=OVRLcC21F14 **One hour in length; audio with accompanying graphics**

Comment: this is definitely not a typical cursory media interview; Sandy invested some considerable time studying the technical aspects of this subject matter in preparation for the live session that originally aired on his Internet webradio talk show on April 17, 2010. While the discussion tone is relaxed and informal and avoids technical mumbo-jumbo, it is in-depth and provides a good layman's overview of LENR technology

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Additional reading for the technically inclined

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

"Truly green nuclear energy exists – an overview for everybody: no deadly gammas … no energetic neutrons … and no radioactive waste" Broad-brush overview about history of nuclear power and potential of LENRs
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. #17 Handy reference document if you're trying to survey info
L. Larsen, Lattice Energy LLC, May 28, 2013 [113 slides] Updated and revised through January 12, 2014

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

Review paper that covers all theoretical aspects of basic Widom-Larsen theory published to date:

"A primer for electro-weak induced low energy nuclear reactions" Theorists should start with this paper
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

Lattice Energy LLC

Working with Lattice

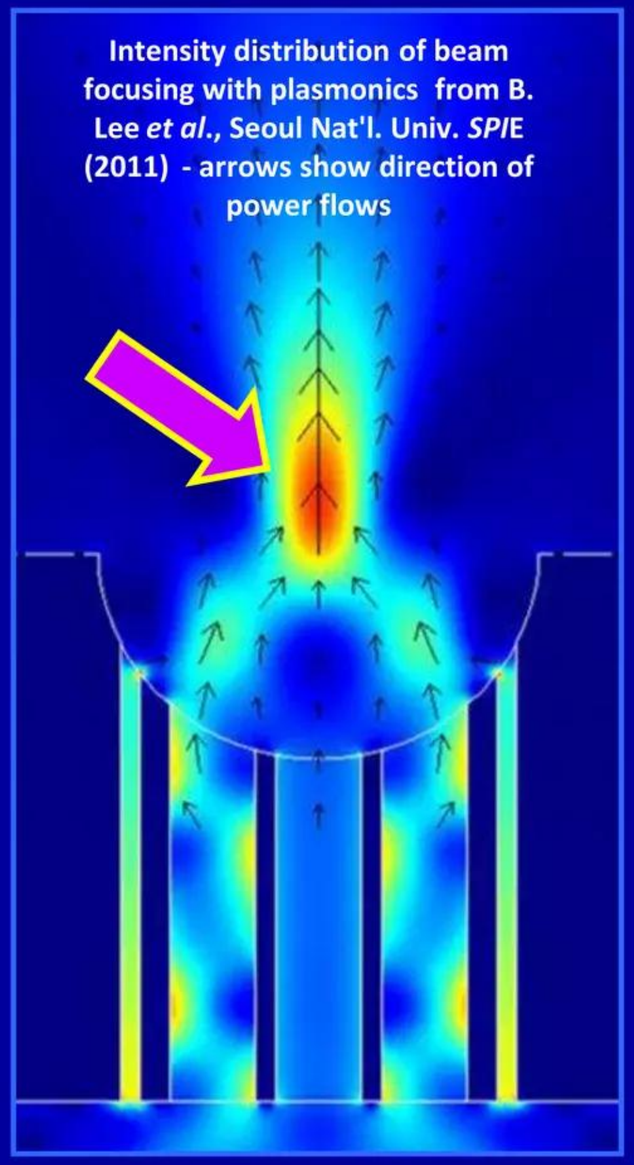
Commercializing LENRs and consult to advance LENR technology

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

- ✓ **Lattice welcomes inquiries from established companies and other types of private or government organizations**
- ✓ **Lattice also selectively engages in some fee-based third-party consulting. We will consult on any subject matter in which we have unique knowledge and expertise as long as it does not involve disclosing any proprietary engineering details that would be applicable to Lattice's planned family of LENR-based power generation systems**
- ✓ **Consulting is subservient to company's main goal: commercializing LENRs for applications in ultra-high energy density portable, mobile, and stationary power generation systems; are looking for corporate partners**
- ✓ **Larsen c.v.:**

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

Concentrating E-M energy in resonant electromagnetic cavity



http://spie.org/documents/Newsroom/Imported/003435/003435_10.pdf

Lattice Energy LLC

LENRs: empowering the powerless and connecting the unconnected

"No single solution will defuse more of the Energy-Climate Era's problems at once than the invention of a source of single solution abundant, clean, reliable, and cheap electrons. Give me abundant clean, reliable, and cheap electrons, and I will give you a world that can continue to grow without triggering unmanageable climate change. Give me abundant clean, reliable, and cheap electrons, and I will give you water in the desert from a deep generator-powered well. Give me abundant clean, reliable, and cheap electrons, and I will put every petrodictator out of business. Give me abundant clean, reliable, and cheap electrons, and I will end deforestation from communities desperate for fuel and I will eliminate any reason to drill in Mother Nature's environmental cathedrals. Give me abundant clean, reliable, and cheap electrons, and I will enable millions of the earth's poor to get connected, to refrigerate their medicines, to educate their women, and to light up their nights."

Thomas Friedman, "Hot, Flat, and Crowded" pp. 186 (2008)

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LENRs: empowering the powerless and connecting the unconnected

Stretch out your mind to humanity

How many tomorrows can you see?

“Sit with the Guru”
Album: “Wake up, it’s tomorrow.”
Strawberry Alarm Clock, UNI Records (1968)

http://www.youtube.com/watch?v=CfB70r9DrHE

Image credit: NASA - Ron Garan – sunrise in LEO captured with HD digital camera from International Space Station window (2011)