Lattice Energy LLC

Mystery wind drought hit the U.S. during first half of 2015

Total wind-powered electrical output down 6% while capacity went up 9%

Climate change disrupts prior weather patterns

If you believe wind and solar can someday totally replace short-notice sources of dispatchable power generation then think again, because they simply can't --- ever

Lewis Larsen

President and CEO

March 2, 2016

Contact: 1-312-861-0115 Chicago, Illinois USA

lewisglarsen@gmail.com

Scientists continue to issue warnings about climatic shifts

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

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

theguardian
Winner of the Pulitzer prize

Rate of environmental degradation puts life on Earth at risk, say scientists

Humans are 'eating away at our own life support systems' at a rate unseen in the past 10,000 years, two new research papers say

Oliver Milman in *The Guardian* online 14:00 EST on January 15, 2015

Milman's news story reports on two excellent papers published by Steffen *et al.*:

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

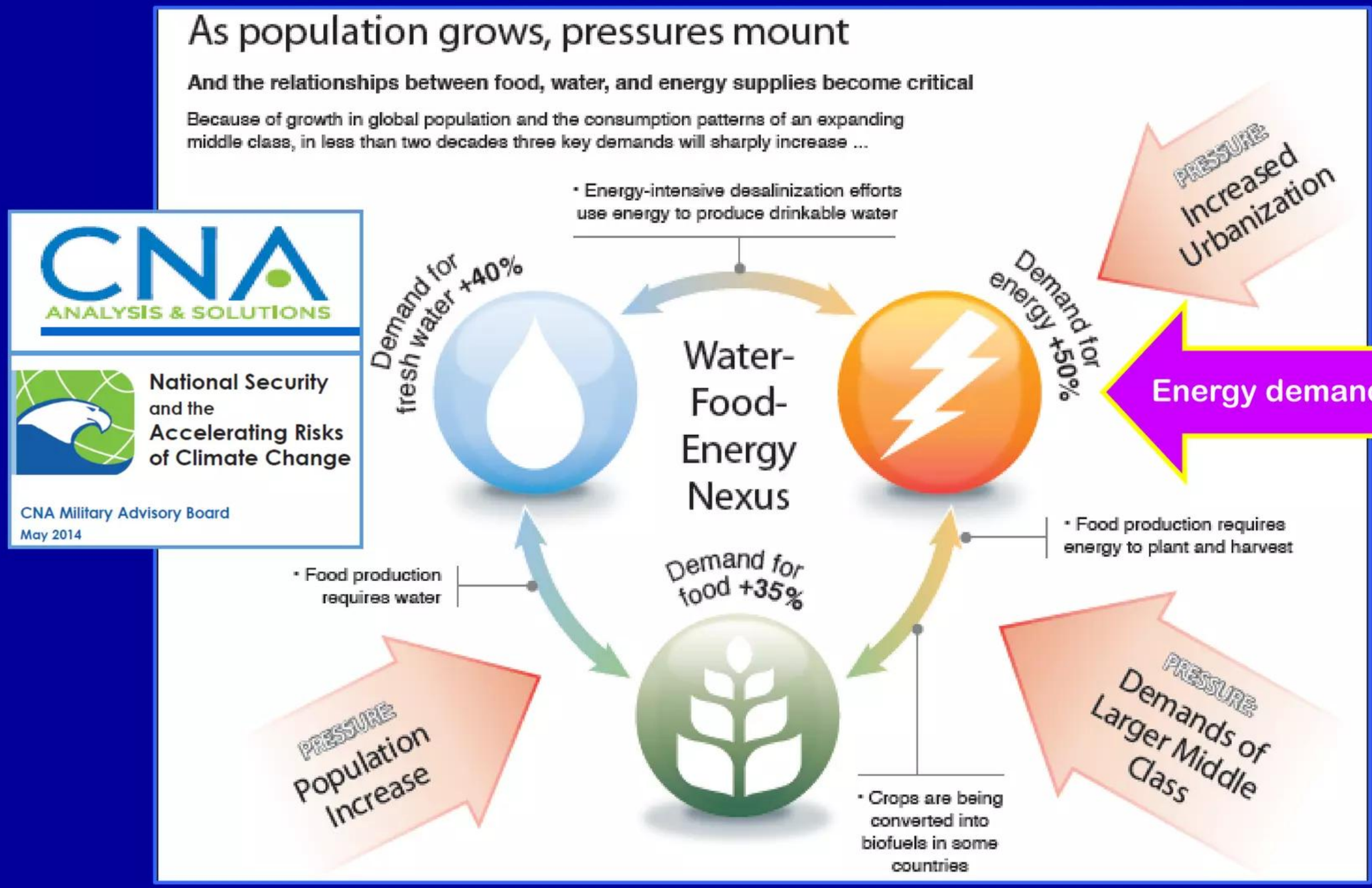
All of these changes are shifting Earth into a "new state" that is becoming less hospitable to human life, researchers said. "These indicators have shot up since 1950 and there are no signs they are slowing down," said Prof Will Steffen of the Australian National University and the Stockholm Resilience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

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

Retired U.S. military leaders worried about climate change

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

Source of chart: page 16 in 48-page CNA report released May 2014



http://www.cna.org/sites/default/files/MAB_2014.pdf

Contents

U.S. electricity production in CY 2014 by energy source

Independent Statistics & Analysis
U.S. Energy Information Administration

In 2014, the United States generated about 4,093 billion kilowatt hours of electricity. About 67% of the electricity generated was from fossil fuels (coal, natural gas, and petroleum). Major energy sources and percent share of total U.S. electricity generation in 2014:

Coal = 39%

Natural gas = 27%

Nuclear = 19%

Hydropower = 6%

Other renewables = 7%

- Biomass = 1.7%
- Geothermal = 0.4%
- Solar = 0.4%
- Wind = 4.4%

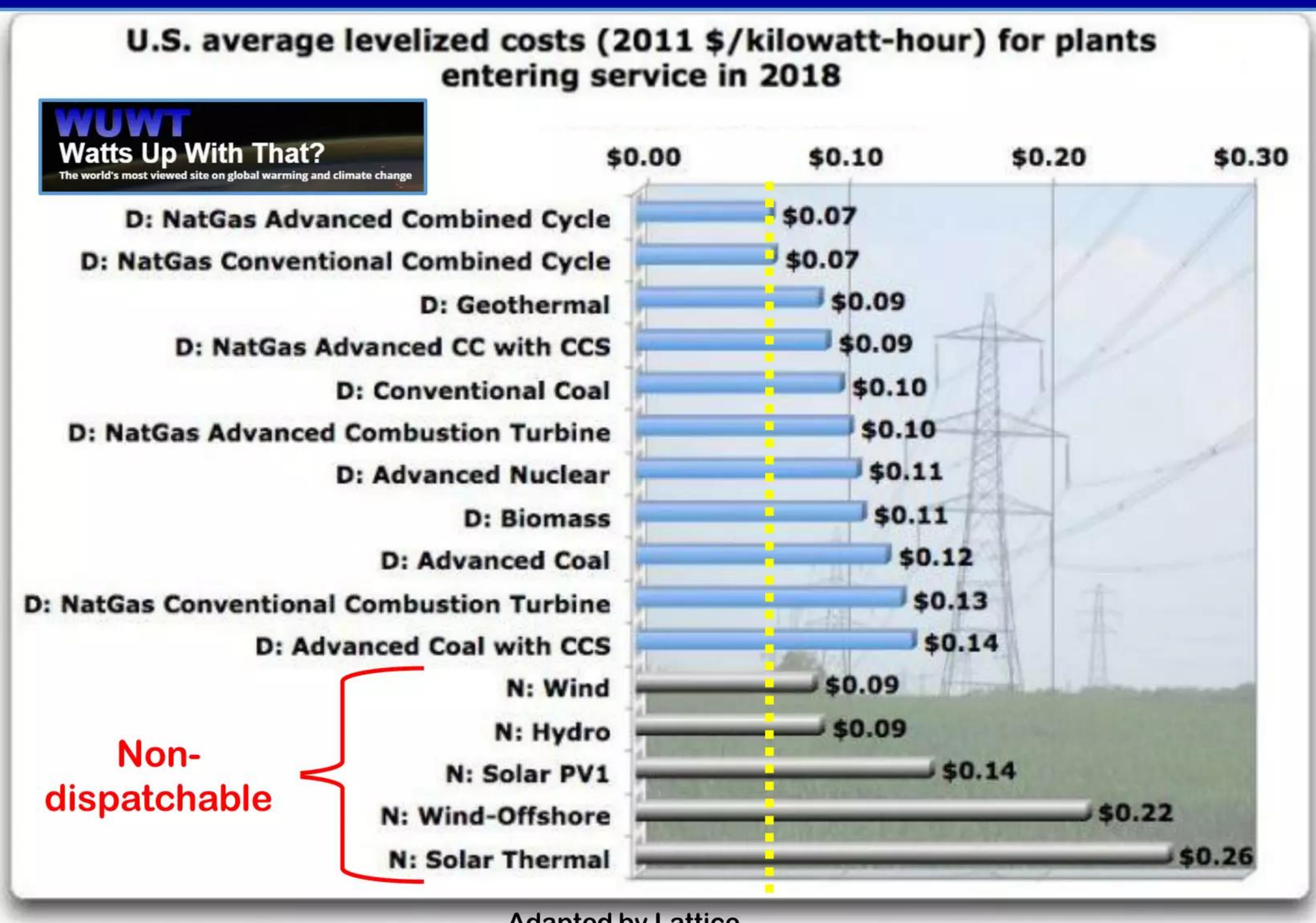
Petroleum = 1%

Other gases < 1%

Dispatchable natural gas is least $ expensive power source

The Levelized Cost of Electric Generation

Willis Eschenbach / February 16, 2014



Adapted by Lattice

http://wattsupwiththat.com/2014/02/16/the-levelized-cost-of-electric-generation/

"New wind energy is 3 times more expensive than … coal "

EIA data is misleading: doesn't account for intermittency of wind power

THE DAILY CALLER NEWS FOUNDATION

Michael Bastasch, Reader
June 30, 2015

http://dailycaller.com/2015/06/30/study-new-wind-energy-is-3-times-more-expensive-than-existing-coal-power/

"EPA regulations are forcing hundreds of coal-fired generators to prematurely retire, but replacing the existing coal fleet with new wind farms and natural gas-fired plants will burden Americans with higher cost electricity, according to a new study. The free-market Institute for Energy Research has released a new report showing that electricity from new wind farms is three times more expensive than power generated from existing coal plants and four times costlier than electricity from today's nuclear fleet. IER's study also shows that electricity from new natural gas plants is nearly twice as expensive as power from existing coal plants … 'This report solves that problem and shows that electricity from even the lowest-cost new plants is about twice as expensive as from existing coal and nuclear plants, on average,' Fisher said. EIA data has been used by green energy proponents to show that wind energy is more cost-effective than coal or even natural gas for electricity generation. But IER's report found this to be misleading, since EIA data doesn't take into account the intermittent nature of wind power and the fact that it's largely replacing cheaper coal power."

Modern electric grids require dispatchable power generation

Need grid-connected power sources not subject to vagaries of Nature

Grids with 100% renewables not feasible even with grid-scale flow batteries

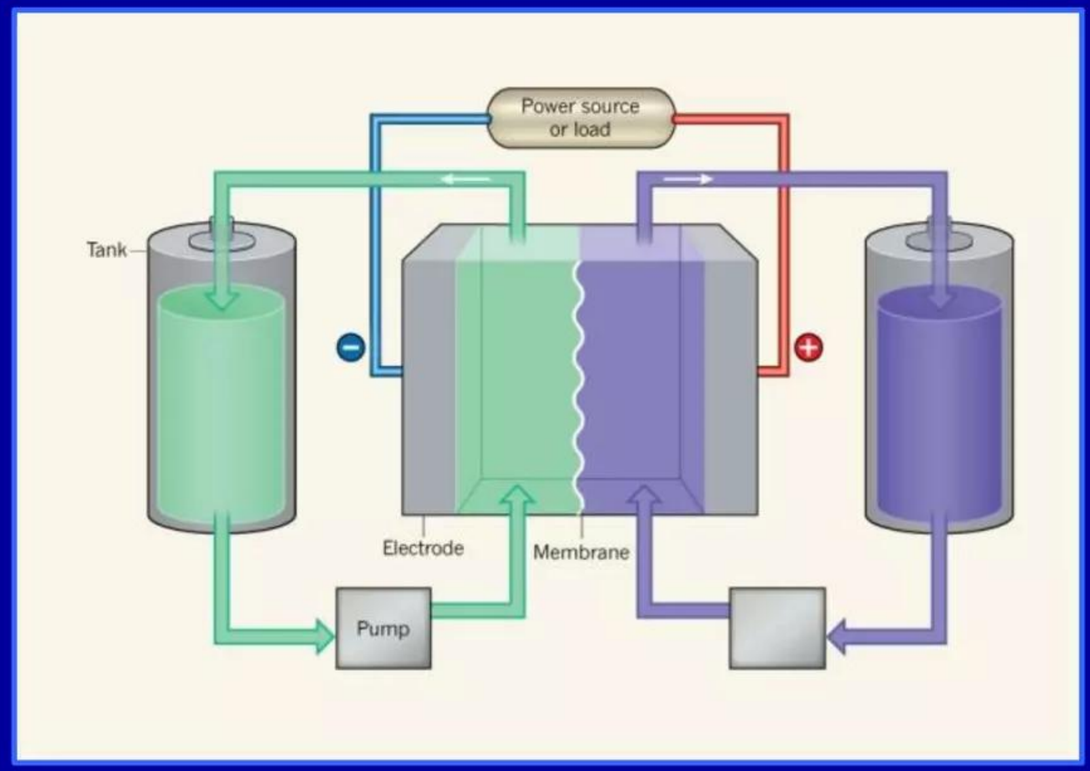
- ✓ Wind and solar power generation technologies, while decreasing in cost, are inherently non-continuous sources of thermal and electrical power --- wind speeds and intensity of the sun can vary dramatically intra-day or from week to week; importantly, presently ongoing climate change, whatever its cause, is making weather patterns even more --- not less --- variable than ever before
- ✓ For example, in Chicago the month of June 2015 was rainiest and cloudiest (>70% of days were cloudy) on-record since the 1880s; well, if the Chicago metropolitan area had been 50% dependent on solar, may have had problems
- ✓ Many naively believe that massive local deployment of giant grid-scale flow batteries could bridge the supply-demand gap in such situations; well, it might work for a few hours or a day, but certainly not days, weeks, or months
- ✓ What is needed is a new energy-dense, green power generation technology that is CO_2-free, dispatchable, highly scalable from kilowatts to grid-scale megawatt systems, and utilizes manufacturing technologies that can exploit the experience curve effect to further reduce price of energy for consumers
- ✓ Such a technology is being developed by Mitsubishi Heavy Industries, Toyota, Lattice Energy, and some others: ultralow energy neutron reactions (LENRs)

Grid-level storage for wind/solar intermittency and outages

Extremely large flow batteries touted as effective 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 temporal notice
- ✓ Wind and solar power sources are inherently intermittent in their output of electricity; modern wide-area grids could not function at 99⁺% availability if power generation was only provided by renewables
- ✓ Enter the possibility of flow batteries that are low-cost vs. Li-ion and can be scaled-up volumetrically to gigantic storage capacities
- ✓ Good technology within intrinsic limitations, largest being their intrinsically low energy density: newly discovered quinone-based chemistry only achieves ~50 Wh/kg versus 150 - 200 Wh/kg for commercial Lithium-ion

Conceptual schematic of a flow battery



Membrane separates charge-carrier liquids

Flow batteries can buffer wind or solar intermittency/outages

Concept: huge battery farms store electricity produced by wind or solar

Issue: flow batteries have fraction of Lithium-ion chemistry's energy density

Comparison: energy densities of flow batteries vs. other battery types

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

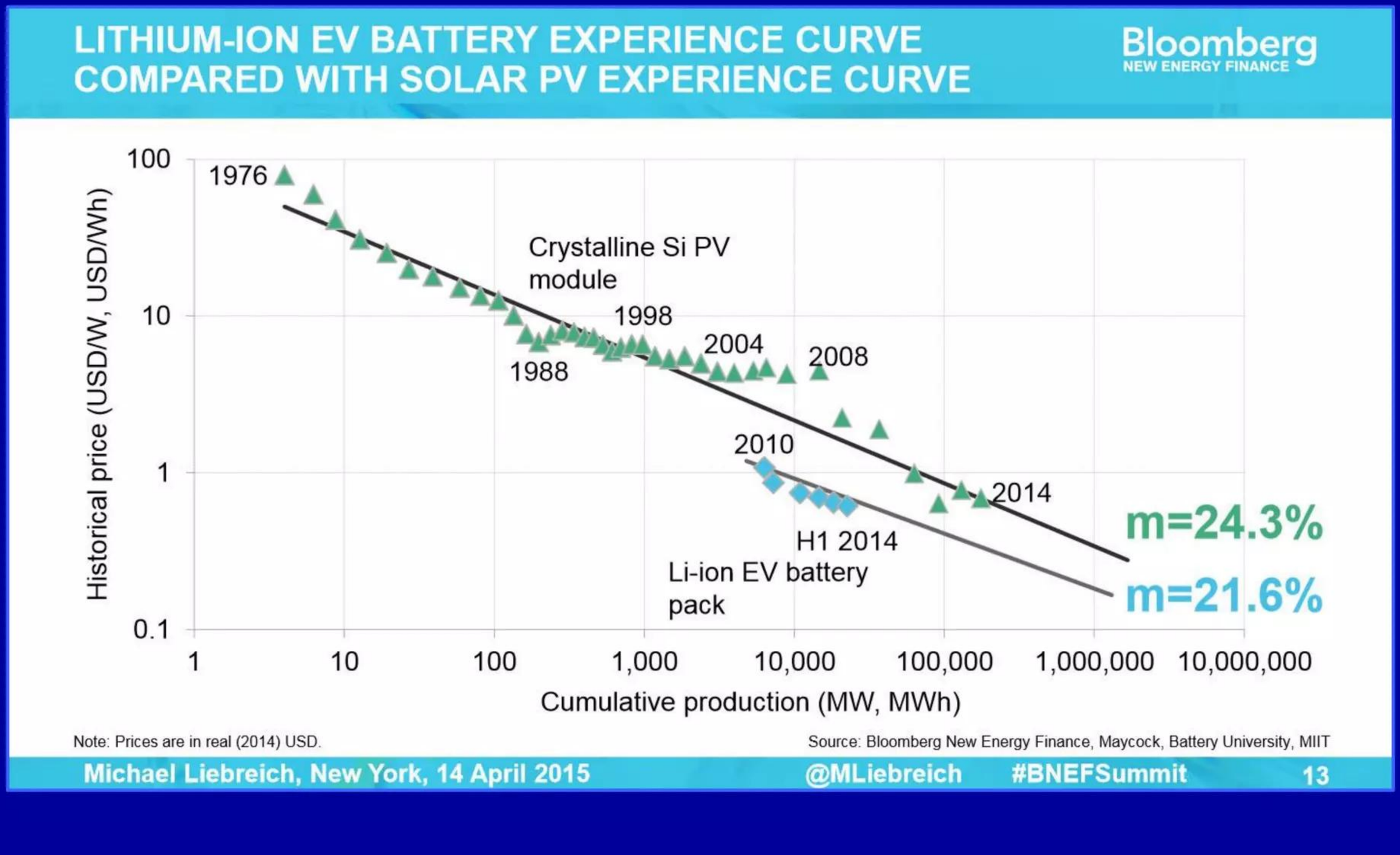
Table 1: Battery Comparison (based on data from [4]). The first five are flow batteries.

Source of Table 1: "Introduction to Flow Batteries: Theory and Applications," Bhaskar Garg, Stanford University, March 22, 2012

Solar PV and Li-battery prices have been falling over time

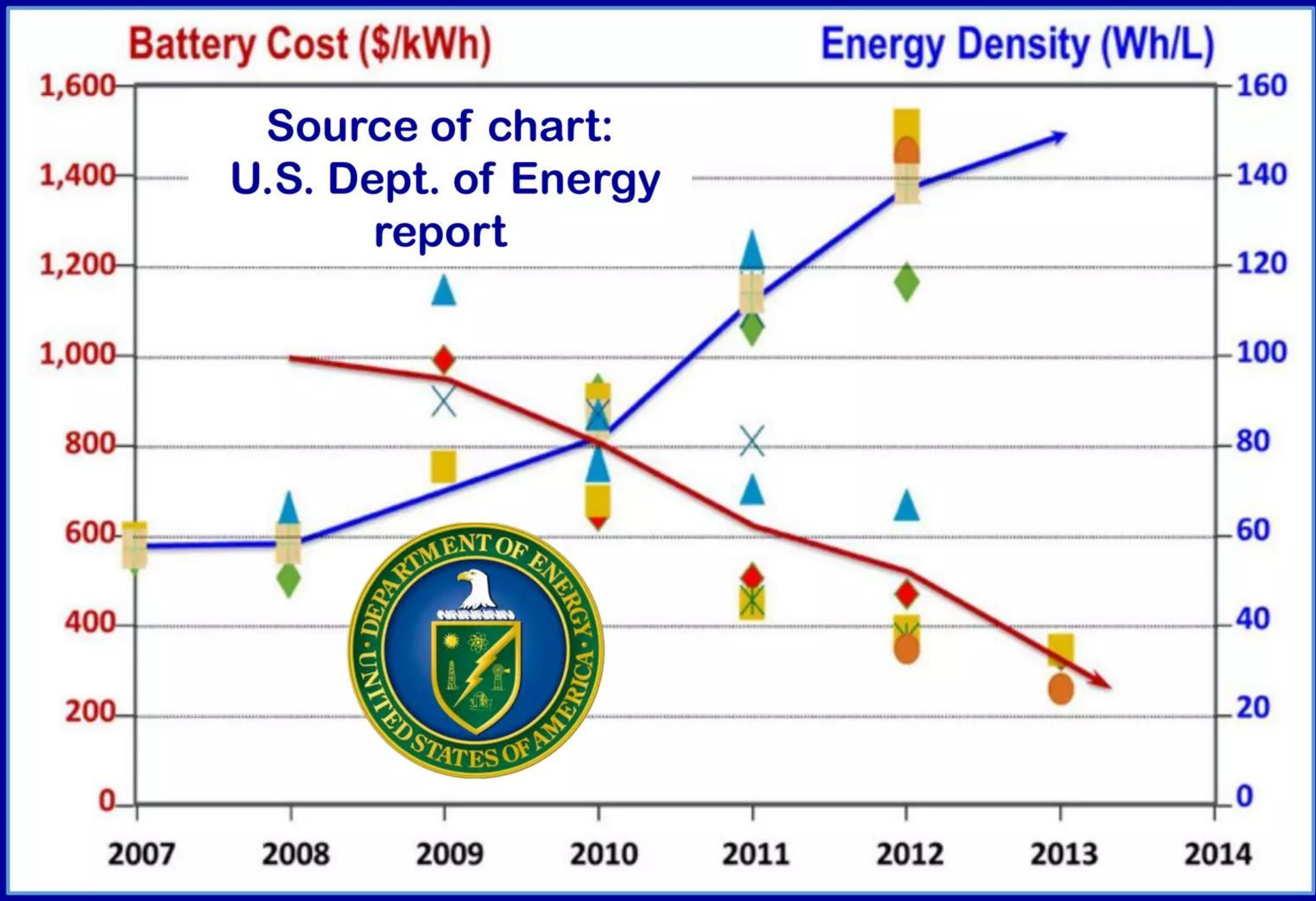
Chart shows how experience curve effect cut costs from 1976 to 2014

Cost reductions eventually flatten-out for all technologies as they hit their limits



Battery cost reduction tied to increases in energy density

If energy density increases slow down then cost reductions will stagnate



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

Lithium-air was widely touted as next great thing in batteries

Some have made wild claims that it might rival gasoline energy density

Major players abandoned Li-air; Lattice believes fire risks higher than Li-ion

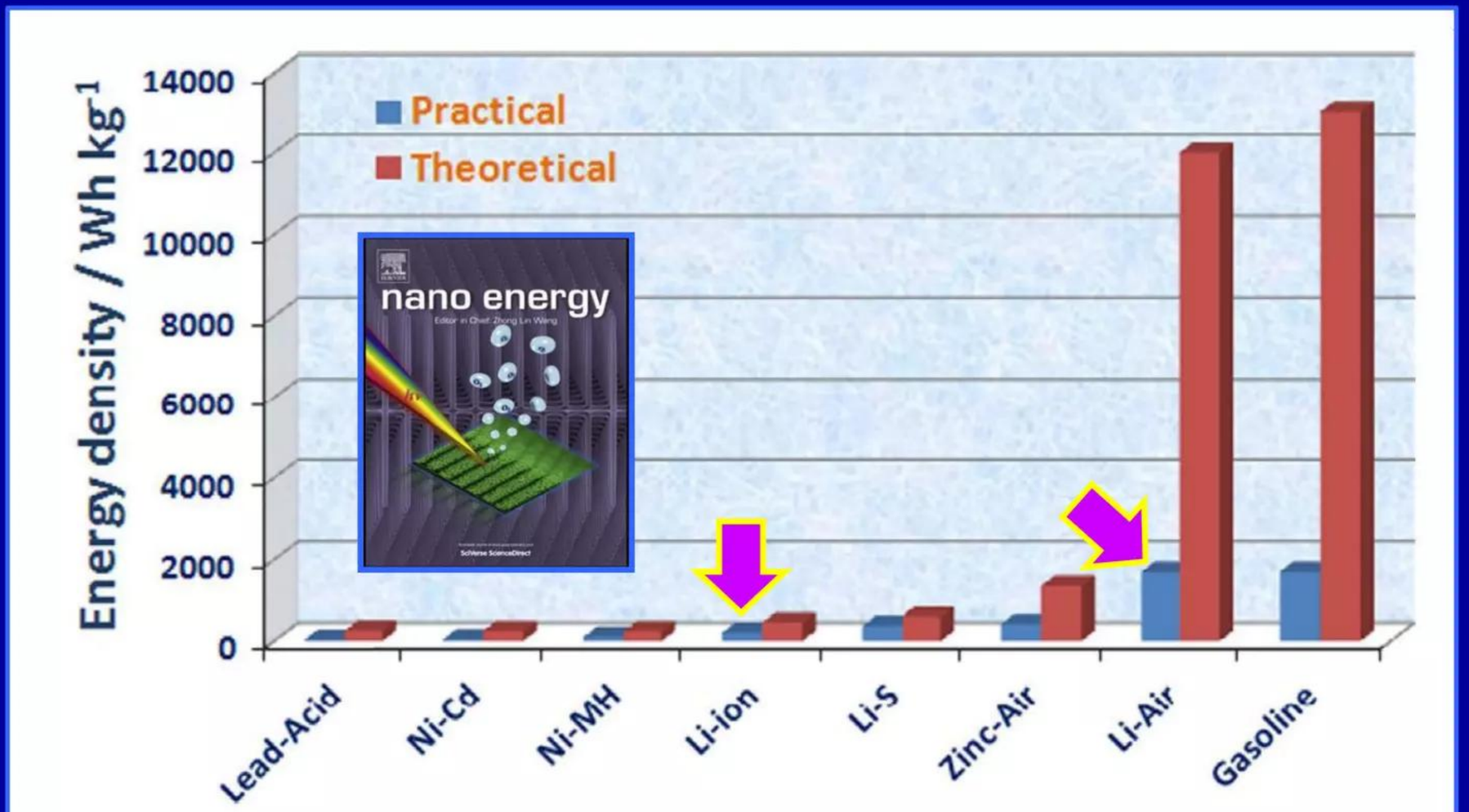


Figure 1 The gravimetric energy densities (Wh/kg) for various types of rechargeable batteries compared to gasoline.

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)

Two major players abandoned R&D on Lithium-air batteries

It was IBM and Joint Center for Energy Storage Research (JCESR)

"Two big labs step back from the most promising next-generation battery"

QUARTZ Steve Levine in *Quartz* on May 30, 2014

http://qz.com/214969/two-big-labs-most-promising-next-generation-battery-electric-car/

"In a sign of more gloom in the struggle for a better battery, two major US labs have quietly downgraded research on a technology until now widely believed to be the most promising path to a competitive electric car."

"IBM and the US-funded Joint Center for Energy Storage Research (JCESR) have ratcheted down or outright abandoned their work on the lithium-air battery, a concept in which oxygen would react with lithium to create electricity."

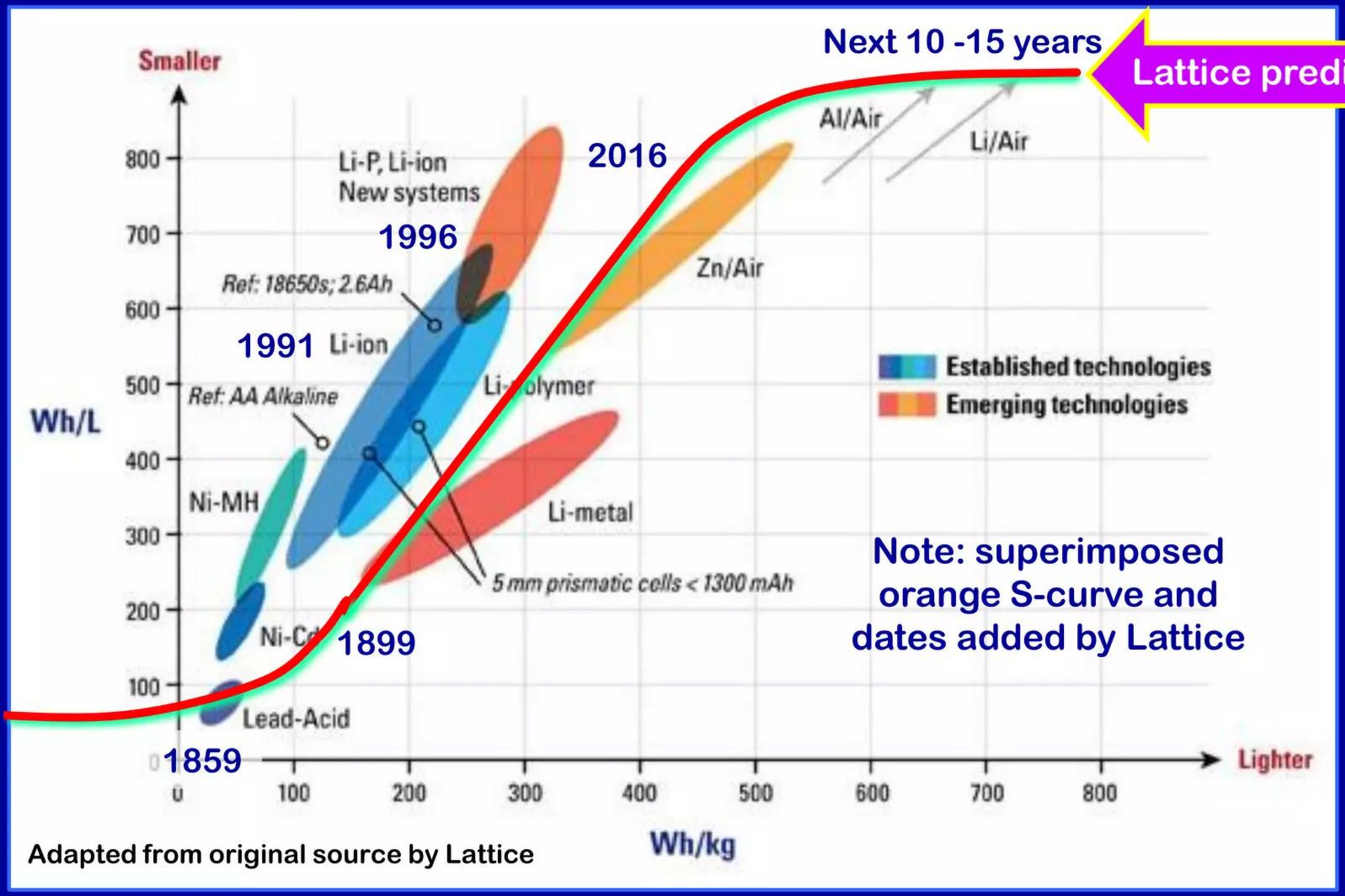
"In a little-remarked-upon article in March, *Nature* magazine reported that IBM's Winfried Wilcke, director of the Battery 500 Project, had a 'change of heart' about lithium-air and had turned his favor to a technology featuring sodium. In an electric car, a sodium-air battery, he said, stood a better chance of meeting the economics needed to compete with conventional cars. It was a dramatic move, with the most bullish player in lithium-air --- Wilcke himself --- calling it a day."

"About the same time, JCESR dropped its lithium-air project entirely. Like IBM, JCESR did not announce the decision publicly. Kevin Gallagher, a JCESR manager, said it concluded that the challenges were too overwhelming to resolve any time soon. 'The penalty of using gaseous reactions overwhelmed any advantage,' he told *Quartz*."

Batteries are maturing and approaching technological limits

Energy density increases and related cost reductions will slow down

Battery-like LENR power sources could have way-higher energy densities



http://www.estquality.com/technology

Fossil fuel reserves exhausted within <150 years per BP

Solar PV/wind: energy density insufficient to 100% replace fossil fuels

World will always need dense energy sources for transportation & portable power

Batteries for energy storage: flow batteries + solar/wind cannot rival fossil energy densities

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

Gasoline vastly more energy-dense

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)

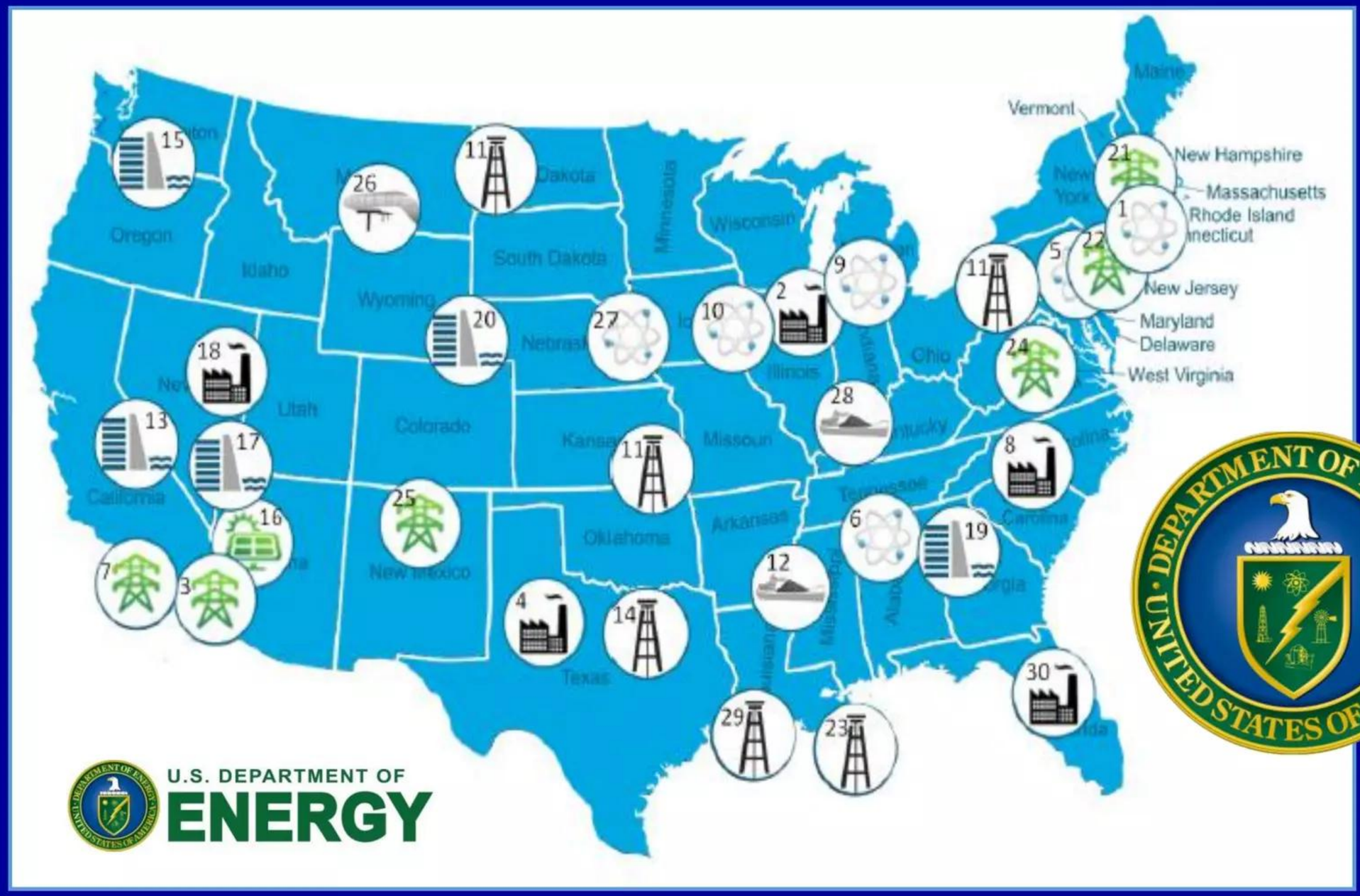
http://www.drexel.edu/~/media/Files/greatworks/pdf_sum10/WK8_Layton_EnergyDensities.ash

See: "BP Statistical Review of World Energy June 2015" released June 10, 2015

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

U.S. Dept. of Energy: greater risks of infrastructure outages

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



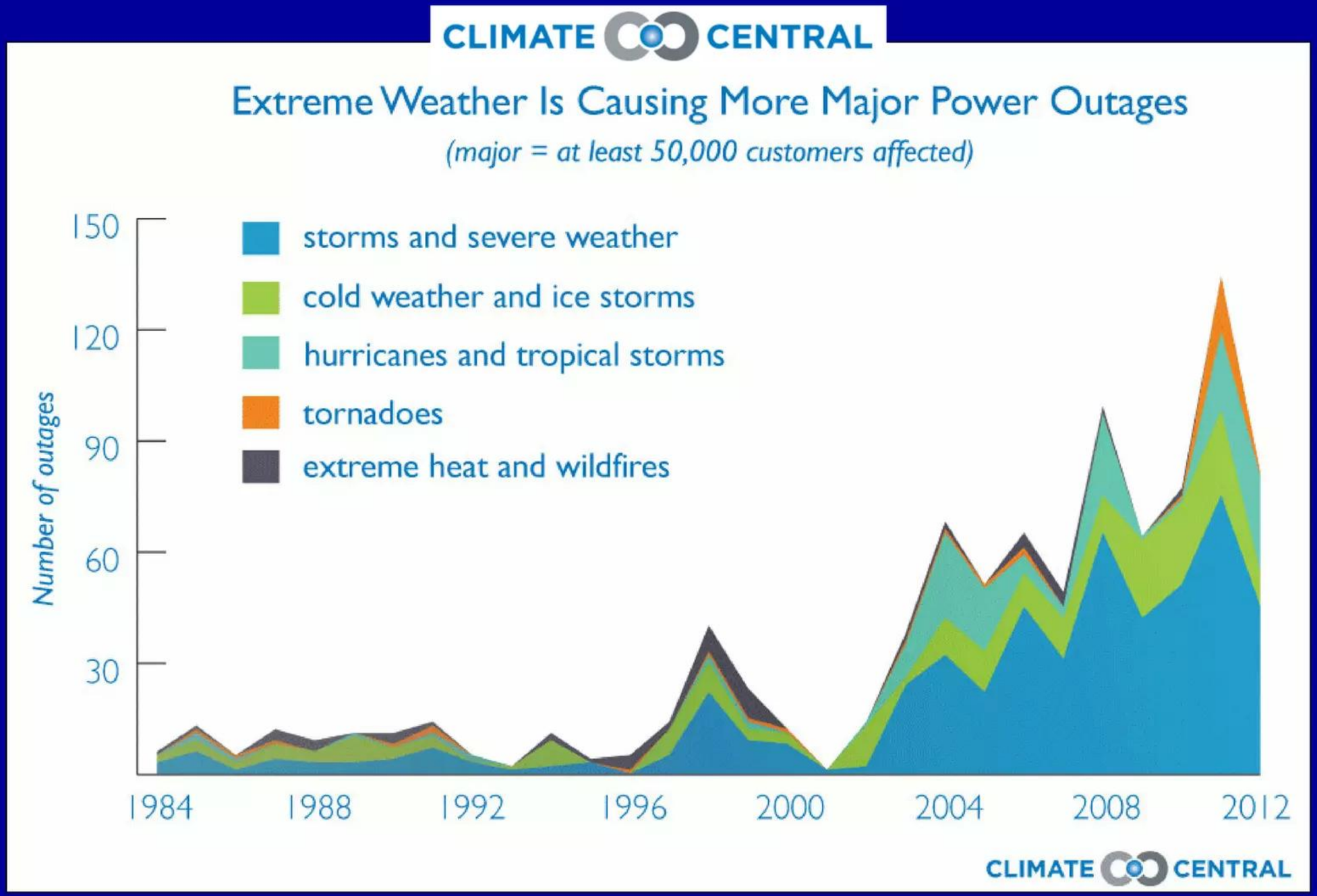
http://energy.gov/articles/climate-change-effects-our-energy#all

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

Weather-related blackouts have doubled just since 2003

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

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



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

“2015 turned out to be a terrible year for wind power”

Total wind-powered electrical output down 6% while capacity went up 9%

THE DAILY CALLER NEWS FOUNDATION

Andrew Follett, energy and environmental reporter
Feb. 24, 2016

http://dailycaller.com/2016/02/24/2015-turned-out-to-be-a-terrible-year-for-wind-power/#ixzz41bsV92Ev

“Wind turbines are pretty useless when there’s not much wind. That’s what the wind power industry learned in 2015 when lots of subsidized turbines were installed, but there was less wind to generate electricity. Average wind speeds were 20 percent below those of the previous year, and the trend appears set to continue in 2016, according to a Monday report by *New Scientist*. As a result, the amount of electricity produced by wind turbines dropped 6 percent even though lots of new turbines were built, according to Energy Information Administration (EIA) … Electricity from new wind farms is still three times more expensive than power generated from existing conventional power plants and four times more expensive than power from nuclear reactors. Wind power has been heavily subsidized since the 1980s and still gets 69 times more in subsidies than coal, oil, and natural gas per watt. Wind power still isn’t capable of providing electricity at predictable times. The output of a wind power plant is quite variable over time, but the times when wind power generates the most electricity don’t coincide with the times when power is most needed. Peak power demand also occurs in the evenings, when solar power is going offline.”

Major wind drought occurred in U.S. during first half 2015

DNV-GL operates in over 100 countries and employs 16,000 professionals

"Whither the winds in 2015? Analysis of the anomalously low winds in the U.S." Doc. #108917-RT-01-A Feb. 12, 2016

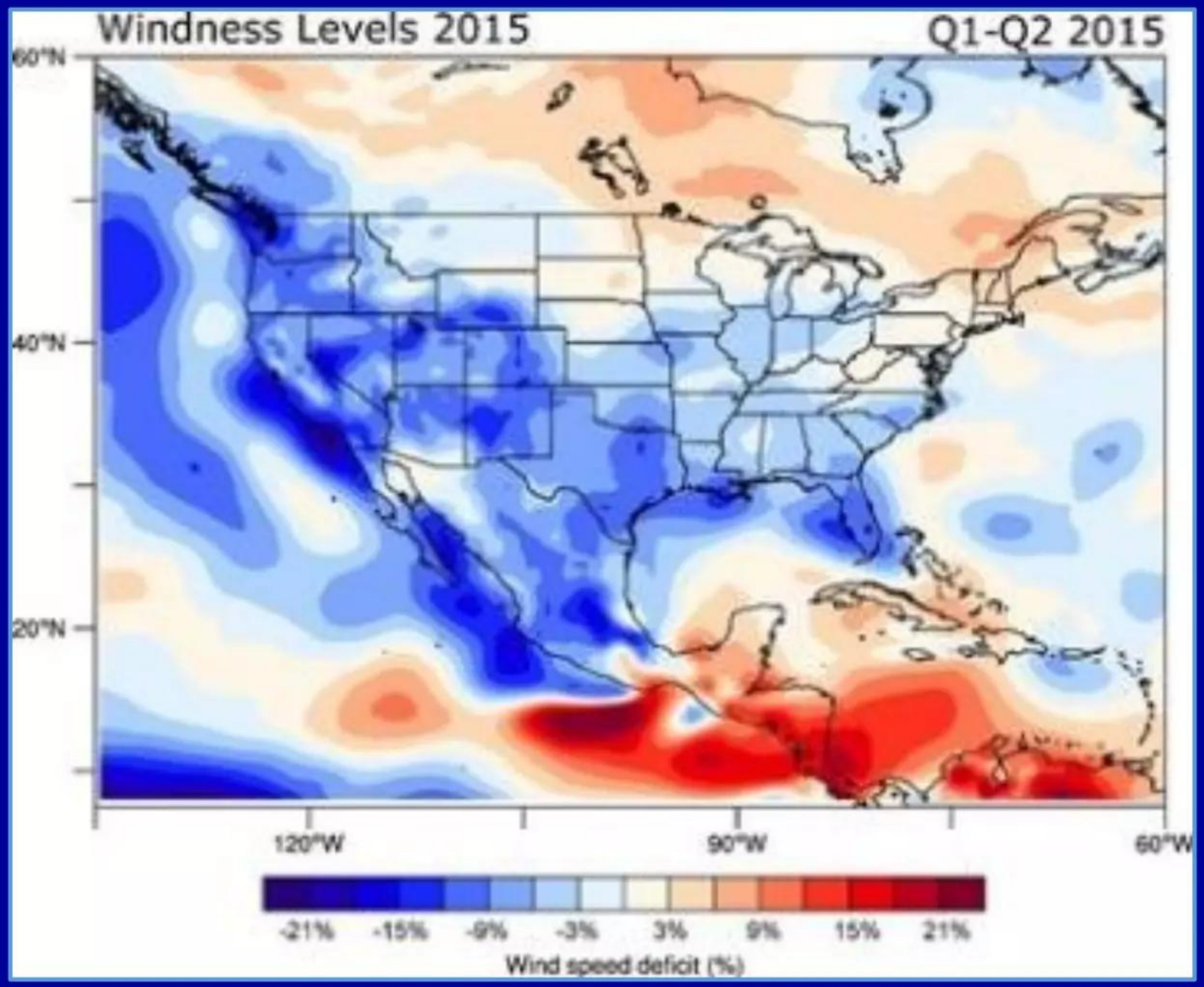
https://www.dnvgl.com/news/dnv-gl-study-el-nino-not-cause-of-2015-wind-drought--57798

"During the first half of 2015, large swaths of the United States (U.S.) experienced anomalously low winds, whose geographic extent and longevity eclipses any similar event in recent history. Ebbs in windiness are of course commonplace, driven by the passage of weather systems - some fair, some stormy - but rarely do so such lulls last beyond a few days. A number of claims and hypotheses have been made about the connection between the low winds and various climatic drivers - some are highly speculative. Unfortunately, such claims greatly outnumber established results. To help remedy this situation, this note attempts to illuminate the characteristics of the anomalous winds and, through careful quantitative analysis, offers one plausible explanation for their origin … wind speeds over much of the U.S. ranged from 6% below the long term mean to a deficit as high as 20%. Over California, Oregon, Washington, Nevada, Arizona, southeast Texas, and Florida, these are the lowest observed wind speeds within the entire 1979-present record. However, other regions were not nearly as affected, particularly the Great Plains which has a large installed capacity of operating wind farms. By mid-year, the winds returned to their more normal patterns of variability. It is natural to seek the root causes of this event, and to determine whether we will ever witness a so long-lived and so significant event in the future.

Fig. 2-1 in DNV-GL report "Whither the winds in 2015?"

Image shows departure from mean wind speeds for first half of 2015

Darkest shade of blue indicates greatest value for deviation from mean = ~21%



Data source: NASA (generated from MERRA)

Mystery wind drought that cut U.S. wind power is back

"Low-wind conditions have returned to the U.S." says Michael Brower

New Scientist

Fred Pearce in Daily News on Feb. 22, 2016

https://www.newscientist.com/article/2078374-mystery-wind-drought-that-cut-us-wind-power-in-2015-is-back/

"There's a still in the air – and it is bad news for North America's wind turbines. Last year saw the lowest average wind speeds in half a century across much of North America. There were long periods of motionless air across most of the Great Plains and the West, stretching through to Texas and Florida, and from Mexico to Canada. And weather watchers say the wind drought was back again in the early weeks of 2016. "Low-wind conditions have returned to the US," says Michael Brower of AWS Truepower, a consultancy for the country's wind-power industry … "The possibility of a prolonged wind drought is on the minds of many in the wind industry," says Brower … Most meteorologists believe that the persistent high pressure is at least partly a result of the Pacific Decadal Oscillation, a fluctuation that is similar to El Niño but lasts for decades. In the past two years, the oscillation has switched to its 'warm' phase, meaning that the wind drought could stick around through 2016 … So far, says Rife, the wind drought has not had a significant impact on investment in wind plants, which can now deliver 5 per cent or more of US electricity when the wind blows. But he adds that 'investors naturally want to understand what happened in 2015, and what to expect in the future'. Another year of wind drought could cause some to have second thoughts."

Abnormally high global temperatures persist in early 2016

January: "most anomalously warm month in 135 years of recordkeeping"

CLIMATE CENTRAL

January Smashed Another Global Temperature Record

Brian Kahn, February 16, 2016

"The calendar may have turned to 2016, but temperatures are picking up where 2015 left off. January was record warm, according to data released this week by NASA. You may recall that last year was the hottest on record for the globe. And by NASA's accounting, it ended with a bang. This past December was the warmest December on record and the most abnormally warm month on record, too. That is until now."

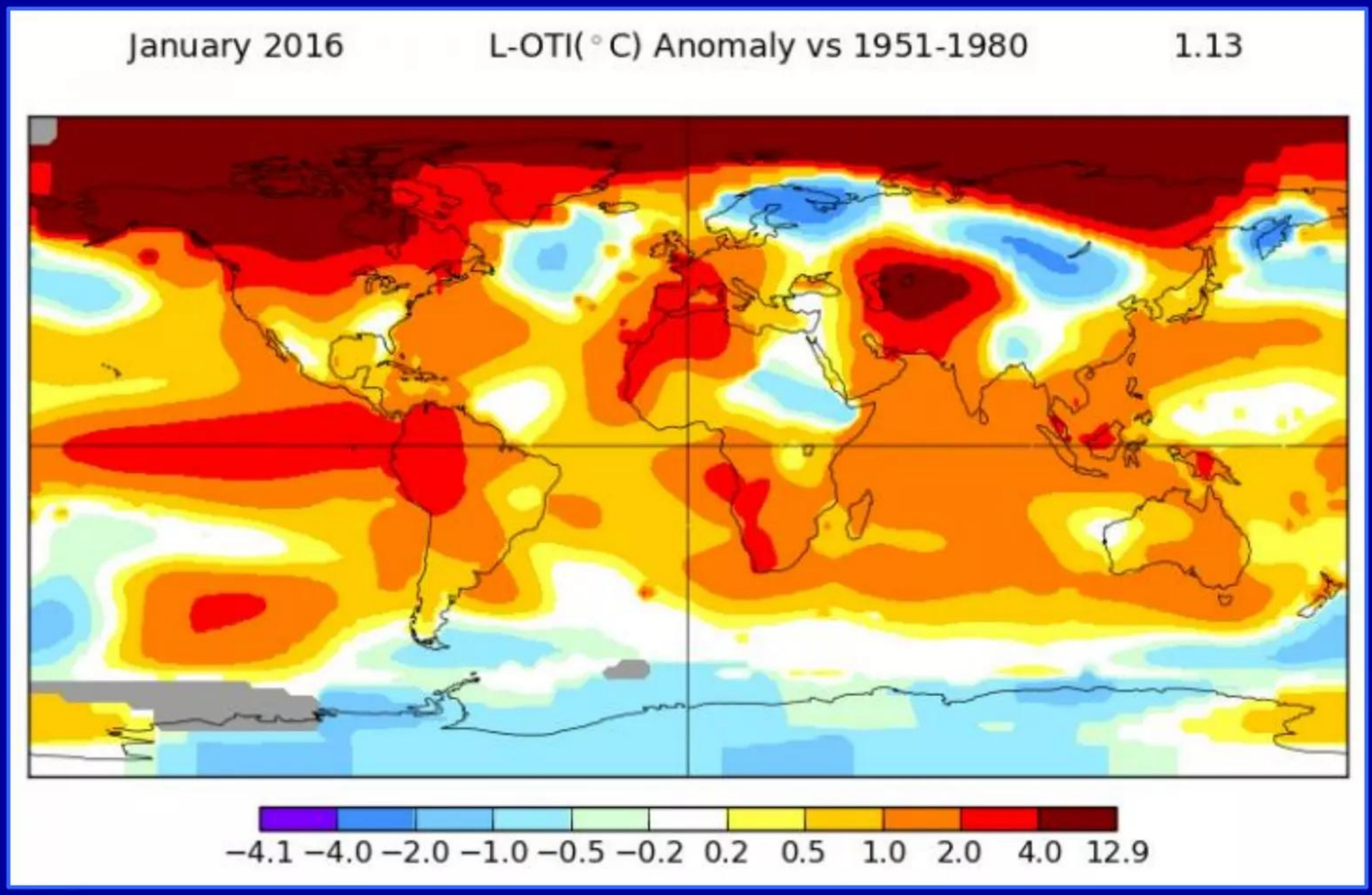
"This January was the warmest January on record by a large margin while also claiming the title of most anomalously warm month in 135 years of record keeping. The month was 1.13°C — or just a smidge more than 2°F — above normal. That tops December's record of being 1.11°C — or just a smidge below 2°F — above average. It marks the fourth month in a row where the globe has been more than 1°C (1.8°F) above normal. Incidentally, those are the only four months where the globe has topped that mark since record keeping began."

http://www.climatecentral.org/news/january-global-temperature-record-20035

Abnormally high global temperatures persist in early 2016

January: “most anomalously warm month in 135 years of recordkeeping”

January 2016 temperatures across the earth **Credit: NASA GISS**



http://www.climatecentral.org/news/january-global-temperature-record-20035

2014 was confirmed as the warmest year since 1880

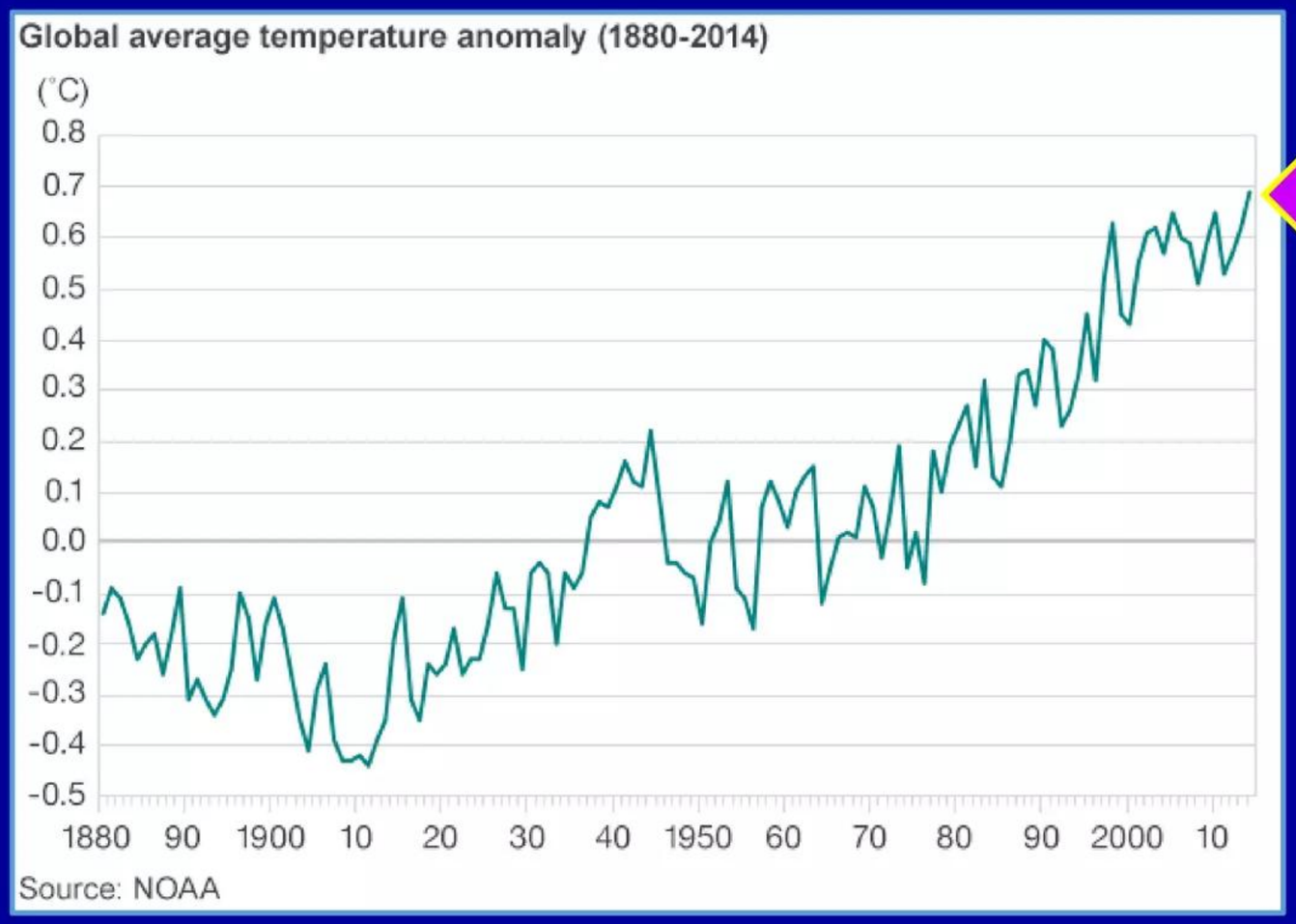
Jan. 16, 2015: NASA and NOAA announced results of analyzed data

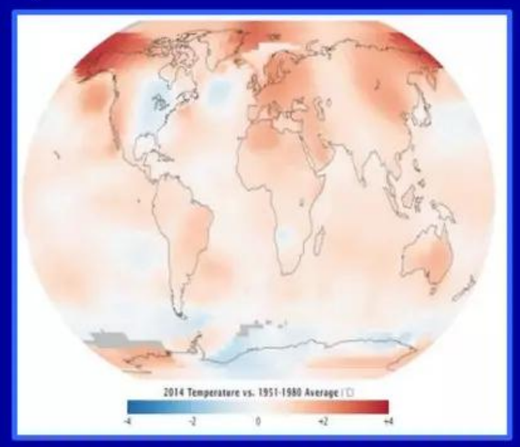
Independent studies by NASA and NOAA scientists reached same conclusion

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

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

Fig. SPM-10 pp. 26 in IPCC's "Summary for Policy Makers" which was released in conjunction with "Climate change 2014 - Synthesis Report"





2014 temperature anomaly

Solar power can be adversely impacted by climate change

Higher-than-normal cloudiness like Chicago in June 2015 reduces output

Volcanic eruptions inject huge amounts of aerosols and dust that reduce sunlight

Noor I concentrated solar thermal power plant is located near Ouarzazate, Morocco on the edge of the great Sahara desert; Phase I output is 160 MW

Credit: Fadel Senna/AFP/Getty images

Volcanic eruptions can reduce sunlight at Earth's surface

Increases amount of sunlight reflected (albedo) - can affect large regions

Ability to generate solar power can be substantially reduced for long time periods

Mount St. Helens (Oregon, USA) eruption on May 18, 1980 - photo taken from a small aircraft

Photo credit: Richard Bowen (1980)

Series of minor volcanic eruptions can reduce sunlight

Reduction can cause measurable decreases in solar power generation

nature geoscience
LETTERS
PUBLISHED ONLINE: 23 FEBRUARY 2014 | DOI: 10.1038/NGEO2098

"Volcanic contribution to decadal changes in tropospheric temperatures"
B. Santer *et al.*, *Nature Geoscience* 7 pp. 185 - 189 (2014)

https://dspace.mit.edu/openaccess-disseminate/1721.1/89054

"We were able to show that part of the cause of the recent lack of temperature increase is the large number of minor volcanic eruptions during the last 15 years. The ash and chemicals from these eruptions caused less sunlight than usual to arrive at the Earth's surface, temporarily reducing the amount of temperature increase we measured at the surface and in the lower troposphere. The most recent round of climate models studied for the IPCC report did not adequately include the effects of these volcanoes, making their predictions show too much warming. For climate models to make accurate predictions, it is necessary that the input data that is fed into the model is accurate. Examples of input data include information about changes in greenhouse gases, atmospheric particles and solar output."

http://www.theguardian.com/environment/climate-consensus-97-per-cent/2014/feb/25/global-warming-slowdown-volcanoes-contribute

Huge volcanic eruptions drastically impact Earth's climate

Toba eruption 74,000 years ago reduced sunlight at surface for 10 years

National Aeronautics and Space Administration
Goddard Institute for Space Studies

Goddard Space Flight Center
Sciences and Exploration Directorate
Earth Sciences Division

Science Briefs

Super-Eruptions, Climate and Human Survival

By Drew Shindell — July 2009

http://www.giss.nasa.gov/research/briefs/shindell_12/

"Roughly 74,000 years ago, a 'super-eruption' took place in Indonesia, the largest known eruption in the past 100,000 years. The Toba eruption was enormous, throwing out roughly 1,000 times as much rock as the 1980 eruption of Mt. St. Helens. Dust trapped in polar ice cores shows that ejected material spread around the globe, indicating that the eruption injected substantial material into the stratosphere, where it can strongly affect climate … Recently we used state-of-the-art climate models to examine this question … Among the most interesting findings was that in response to the reduced sunlight able to penetrate the think blanket of ash and particles in the atmosphere, broadleaf evergreen trees and tropical deciduous trees virtually disappeared for several years. However, the Earth's climate returned to near-normal conditions within a decade in most simulations."

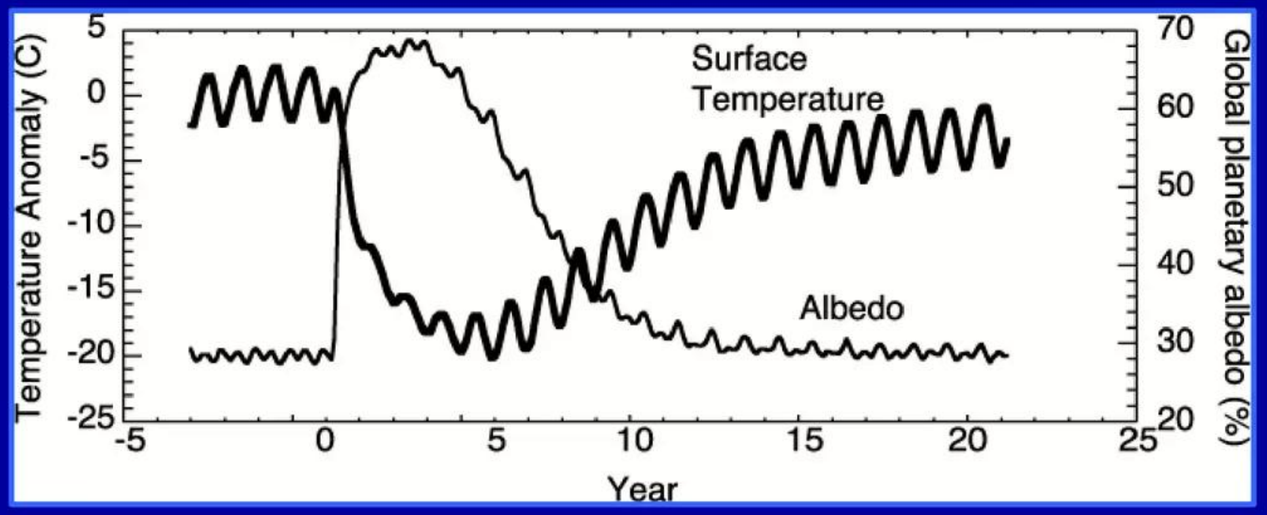
Toba eruption 74,000 years ago hugely impacted climate

Researchers used climate models to simulate effects of this eruption

"Did the Toba eruption of ~ 74 ka B.P. produce widespread glaciation?"
A. Robock *et al.*, *Journal of Geophysical Research* 114 pp. D10107 (2009)

http://pubs.giss.nasa.gov/docs/2009/2009_Robock_etal_1.pdf

Fig. 2: response of global mean surface air temperature and albedo (reflectivity) following the eruption of Toba (at year 0)



" … a Toba-like eruption could certainly produce a decade-long volcanic winter, with serious effects on plant and animal life … While our results show that indeed the eruption could have produced great stress on humans and their environment, it would have been quite concentrated in the few very dark, cold, and dry years immediately following the eruption … it is probable that the sudden dark, cold, and dry conditions that followed the super-eruption of Toba about 74,000 years ago could have largely destroyed the food supplies of humans and therefore caused a significant reduction in population sizes."

IPCC: global warming is definitely an ongoing process

"Warming of the climate system is unequivocal" --- IPCC report 2014

Societal response to global warming may be to restrict combustion of fossil fuels

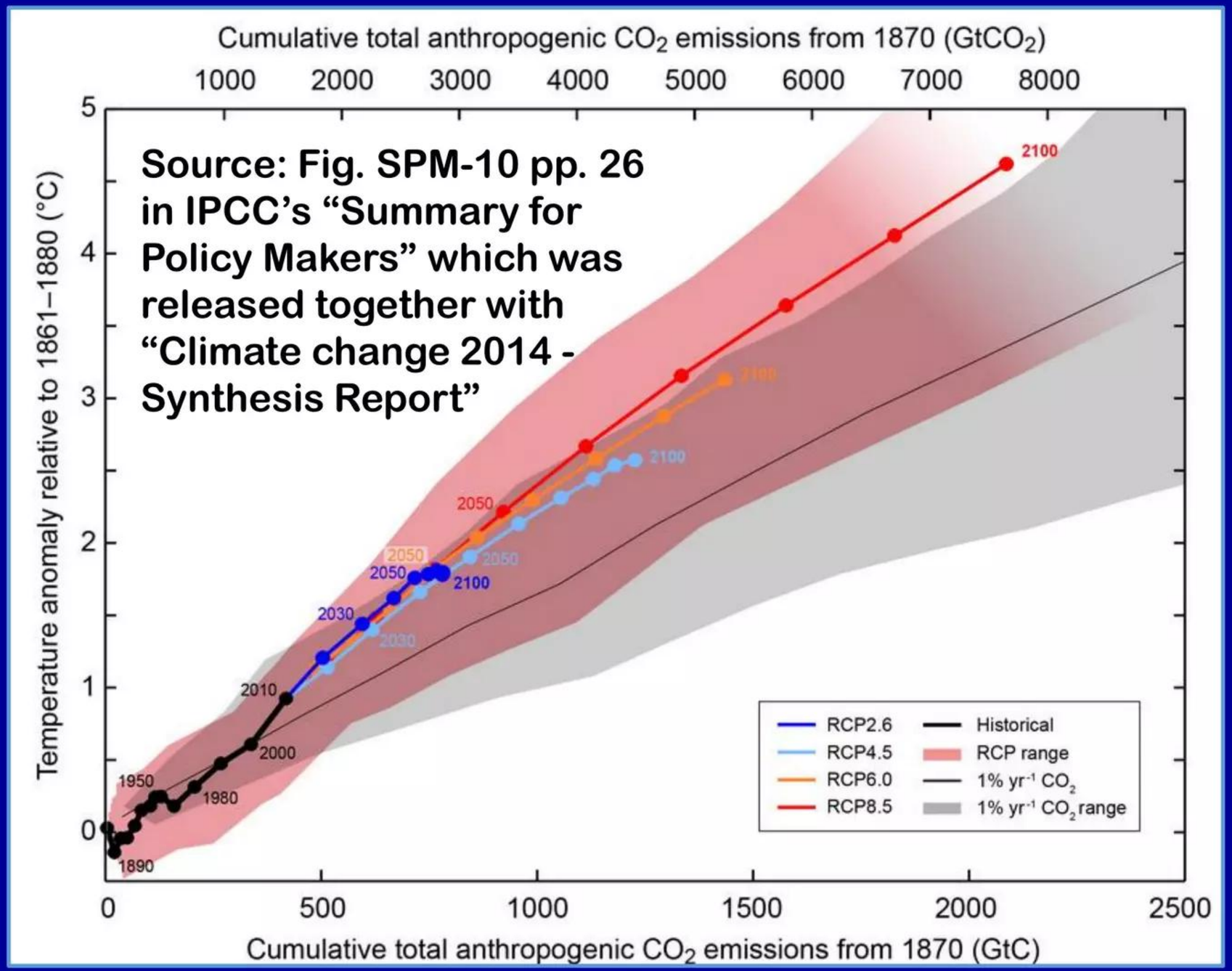
"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen … Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century … Cumulative emissions of carbon dioxide largely determine global mean surface warming by the late 21st century and beyond."

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

IPCC: global warming is definitely an ongoing process

Effect of increasing CO_2 emissions on temperature is shown in chart

Societal response to global warming may be to restrict combustion of fossil fuels



Study published in *Nature* in 2015 supports IPCC's report

Impact of CO_2 increases in Pliocene era provides insight about today

"Earth's temperature should increase by 1.5 K to 4.5 K per doubling of CO_2 levels

"Evidence from warm past confirms recent IPCC estimates of climate sensitivity"

http://www.sciencedaily.com/releases/2015/02/150204134115.htm

"Today the Earth is still adjusting to the recent rapid rise of CO_2 caused by human activities, whereas the longer-term Pliocene records document the full response of CO_2-related warming," says Southampton's Dr Gavin Foster, co-author of the study.

"Our estimates of climate sensitivity lie well within the range of 1.5 to 4.5° C increase per CO_2 doubling summarised in the latest IPCC report. This suggests that the research community has a sound understanding of what the climate will be like as we move toward a Pliocene-like warmer future caused by human greenhouse gas emissions."

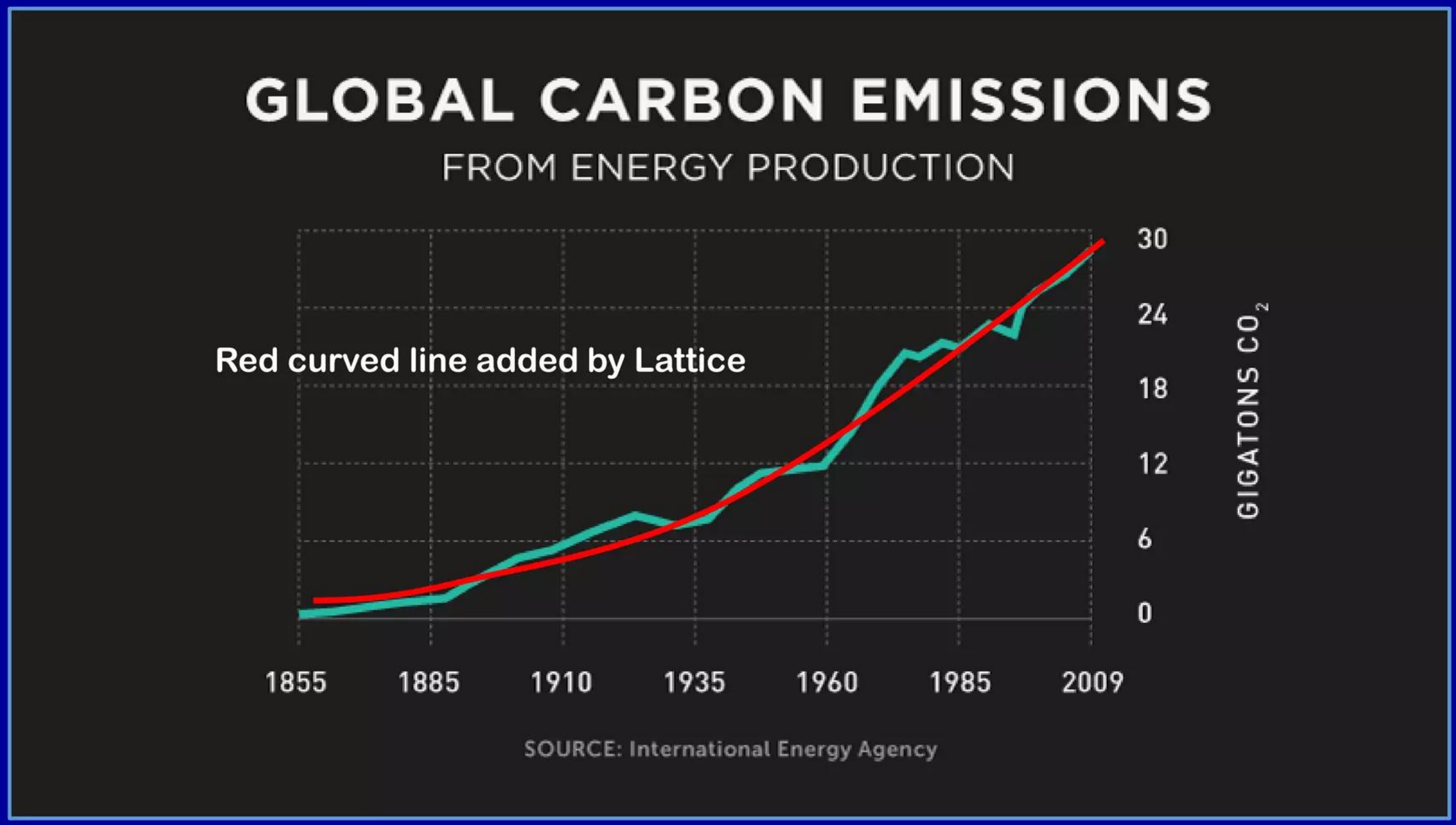
"Plio-Pleistocene climate sensitivity evaluated using high-resolution CO_2 records" M. Martinez-Boti *et al.*, *Nature* 518 pp. 49 - 54 (2015)

http://www.nature.com/nature/journal/v518/n7537/full/nature14145.html

Growth of Carbon emissions exponential since 1855

If global warming caused by fossil fuel combustion then must curb it

As long as $$$ costs aren't too high, vastly reducing CO_2 emissions couldn't hurt



Should try to reduce CO_2 emissions from power generation

Dispatchable power generation is synergistic with renewable energy

- ✓ While some harbor doubts about degree to which human activities contribute to or exacerbate climate change, published data suggests that increases in atmospheric CO_2 levels are reasonably well-correlated with increases in mean global temperatures. Consequently, attempting to combat climate change by decreasing CO_2 emissions from power generation is a desirable technological goal as long as the long-term economic costs for society can be reasonable
- ✓ Solar photovoltaic (PV), concentrated solar power (CSP), and wind generation are CO_2 -free and output can be substituted for fossil-fueled dispatchable central station power plants to cut CO_2 emissions. However, renewable energy sources are inherently intermittent. This intrinsic vulnerability to vagaries of Nature was underscored by the unexpected arrival of a mysterious U.S. wind drought in early 2015 which lasted for 6 months before vanishing, only to apparently reappear again in January 2016. During this 6-month drought event, total electricity produced by wind power in the U.S. dropped over 15%
- ✓ It would be uneconomic to build a sufficient excess of wind power generation capacity and/or enormous amounts of flow battery storage capacity to handle multi-month episodes of substantially reduced wind velocity that could slash electricity production by wind turbines. Fortunately, short-notice dispatchable power generation resources can readily provide low-cost electricity to fill such supply gaps and thereby function as an essential component of modern grids

Dispatchable power generation will always be needed

Nuclear power could be key component in long-term future of energy

- ✓ Given innate variability in power output of renewable green energy sources, substantial amounts of short-notice dispatchable generation capacity are an unavoidable necessity and key asset for maintaining modern high-availability electricity grids that ideally provide customers with 99^{+} % uptime. This crucial requirement would continue to exist even if --- sometime in the future --- wind and/or solar renewables happened to be substantially *less* expensive than fossil-fueled or nuclear fission central station power plants
- ✓ Separately, from a risk management perspective maintaining adequate dispatchable generation capacity would represent a reasonable investment that could also help ameliorate an immense societal catastrophe in the unlikely event of an enormous "Black Swan" volcanic dust eruption that could sharply reduce Earth's sunlight and wind velocities for months or even several years
- ✓ Having adequate dispatchable power generation capacity is thus an invaluable asset in maintaining reliable energy production and prudent risk management. It is also prudent to reduce future CO_2 emissions from power generation. This will eventually happen anyway because at current rates of consumption, it is estimated that fossil fuel resources will be totally exhausted in < 150 years
- ✓ Nuclear power plants are dispatchable and do not emit any CO_2. Like it or not, major worldwide expansion of nuclear power generation is probably inevitable and could be a key strategic component in the long-term future of green energy

Nuclear energy is CO_2-free could help reduce emissions

NEA/IEA report: nuclear should double by 2050 to curb global warming

CLIMATE CENTRAL

NEA Nuclear Energy Agency

iea International Energy Agency
Secure • Sustainable • Together

"Nuclear power needs to double to meet warming goal"

By Bobbie Magill, Climate Central, January 29, 2015

"International Energy Agency and the Nuclear Energy Agency suggest in a report released Thursday that nuclear will have such a significant role to play in climate strategy that nuclear power generation capacity will have to double by 2050 in order for the world to meet the international 2°C (3.6°F) warming goal … To accomplish the needed CO_2 emissions cuts to keep warming no greater than 2°C, the IEA says global nuclear power generation capacity needs to increase to 930 gigawatts from 396 gigawatts by 2050."

http://www.climatecentral.org/news/nuclear-power-needs-to-double-to-meet-warming-goal-18610

http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapNuclearEnergy.pdf

Revolutionary new type of safe nuclear energy technology

Unique advantages of ultralow energy neutron reactions (LENRs)

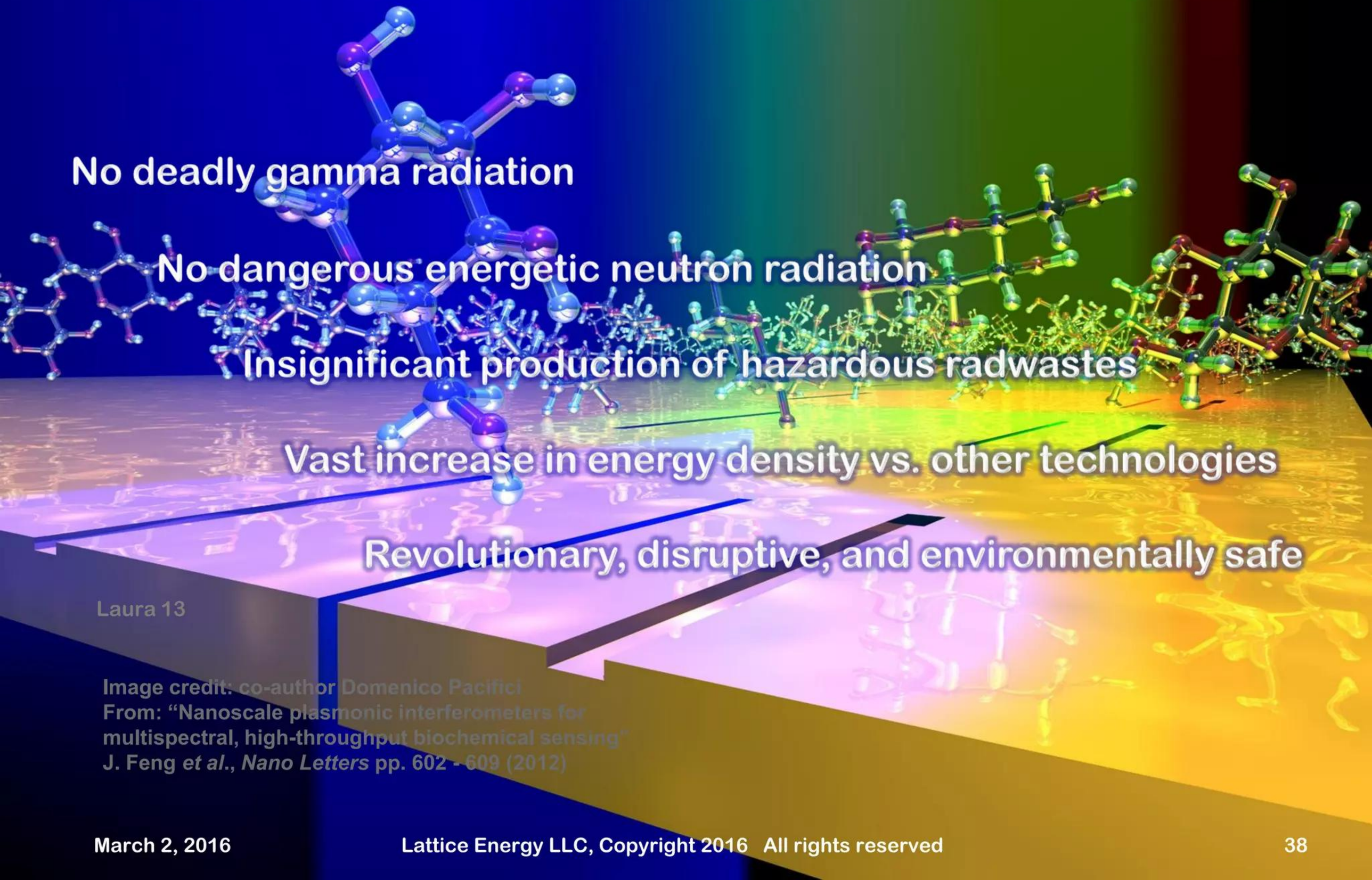


Image credit: co-author Domenico Pacifici
From: "Nanoscale plasmonic interferometers for multispectral, high-throughput biochemical sensing"
J. Feng *et al.*, *Nano Letters* pp. 602 - 609 (2012)

LENRs: radiation-free, low-cost source of nuclear energy

Should be affordable, biosafe, and highly scalable

Enables truly sustainable global economic growth

Delivers "energy miracle" sought by Bill Gates

- ✓ 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
- ✓ Ultralow 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 powerless people

Comparison of LENRs to fission and fusion power sources

Fission, fusion, and LENRs all involve controlled release of nuclear binding energy (heat) for power generation: no CO_2 emissions; scale of energy release is MeVs (nuclear regime) > 1,000,000x energy density of chemical energy power sources

Heavy element fission: involves shattering heavy nuclei to release stored nuclear binding energy; **requires massive shielding and containment structures to handle radiation; major radioactive waste clean-up issues and costs;** limited sources of fuel: today, almost entirely Uranium; Thorium-based fuel cycles now under development; **heavy element U-235 (fissile isotope fuel) + neutrons → complex array of lower-mass fission products** (some are very long-lived radioisotopes) + energetic gamma radiation + energetic neutron radiation + **heat**

Fusion of light nuclei: involves smashing light nuclei together to release stored nuclear binding energy; present multi-billion $ development efforts (e.g., ITER, NIF, other Tokamaks) focusing mainly on D+T fusion reaction; **requires massive shielding/containment structures to handle 14 MeV neutron radiation;** minor radioactive waste clean-up $ costs vs. fission

Two key sources of fuel: Deuterium and Tritium (both are heavy isotopes of Hydrogen)

Most likely to be developed commercial fusion reaction involves:

D + T → He-4 (helium) + neutron + heat (total energy yield 17.6 MeV; ~14.1 MeV in neutron)

Ultralow energy neutron reactions (LENRs): distinguishing feature is neutron production via electroweak reaction; neutron capture on fuel + gamma conversion to IR + decays [β , α] releases nuclear binding energy: early-stage technology; **no emission of energetic neutron or gamma radiation and no long lived rad-waste products; LENR systems do not require massive and expensive radiation shielding and containment structures → much lower $$$ cost;** many possible fuels: any element/isotope that can capture LENR neutrons; involves **neutron-catalyzed transmutations of fuels into heavier stable elements** that release **heat**

LENRs superior to fission or fusion for power generation

Why build huge D-T fusion reactors if LENRs can be commercialized?

Greenness of LENRs could enable revolutionary portable nuclear power sources

- ✓ While LENRs do use ultralow energy neutrons to trigger release of nuclear binding energy (heat) from an enormous array of stable element target fuels, they are radically different from fission reactors that require criticality to operate properly. Unlike fission, LENRs don't involve multiplicative chain reactions with fuels that in turn release multiple neutrons which explosively accelerate neutron production --- nuclear runaways are not a risk with LENRs
- ✓ D-T fusion reactors like ITER and other similar Tokamaks mainly create heat by harvesting the kinetic energy of deadly 14.1 MeV neutrons. Consequently, they require massive shielding and containment systems for safe operation and unsurprisingly have enormous costs and unavoidably huge physical size. Given that the Lithium LENR fuel cycle releases nearly 27 MeV versus a total Q-value of 17.6 MeV for the D-T fusion reaction, it is hard to imagine a sound economic argument for spending 100s of billions on commercial fusion reactors if LENR technology is successfully developed and scaled-up as we discuss herein
- ✓ Lack of hard radiation and radioactive wastes permit *downward* scalability that could enable future development of revolutionary, compact battery-like portable LENR power sources that can compete directly on $ price/kwh with chemical batteries in many applications including power tools, tablets, and smartphones

Electroweak reaction in Widom-Larsen theory is simple

Protons or deuterons react directly with electrons to make neutrons

Capture of produced neutrons by atoms induces green nuclear transmutations

electrons + protons (Hydrogen) → neutrons + neutrinos (benign photons, fly into space)

Require source(s) of input energy

Input energy creates electric fields > 2.5 x10^{11} V/m

Collective many-body quantum effects: many electrons each transfer little bits of energy to a much smaller number of electrons also bathed in the very same extremely high local electric field

Many-body collective electroweak neutron production

Heavy-mass e^{-}* electrons react directly with protons

Quantum electrodynamics (QED): smaller number of electrons that absorb energy directly from local electric field will increase their effective masses ($m = E/c^2$) above key thresholds β_0 where they can react directly with a proton (or deuteron) → neutron and neutrino

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

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

Radiation-free LENR transmutation

Neutrons + fuel elements → heavier elements + decay products

Neutrons induce nuclear transmutations that release enormous amounts of clean, CO_2-free heat

Ultralow energy neutron reactions --- its acronym is LENRs

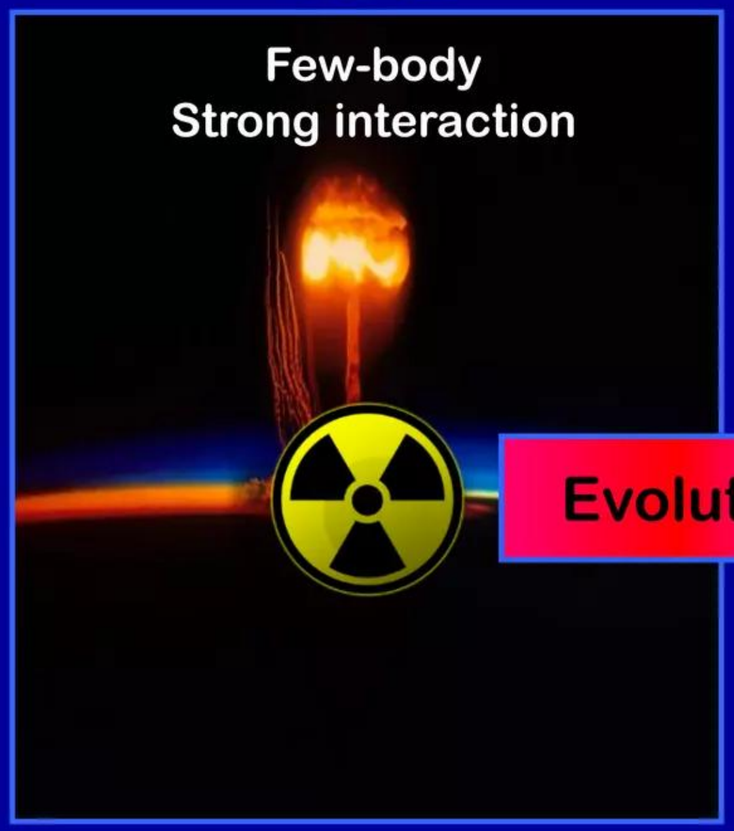
Truly green nuclear power: no deadly radiation or long-lived wastes

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

2016: device physics now sufficiently understood to begin commercialization

- LENR fuels get transmuted by absorbing neutrons which releases enormous heat
- Sustainable CO_2-free transmutation of Carbon could replace combustion processes

1945



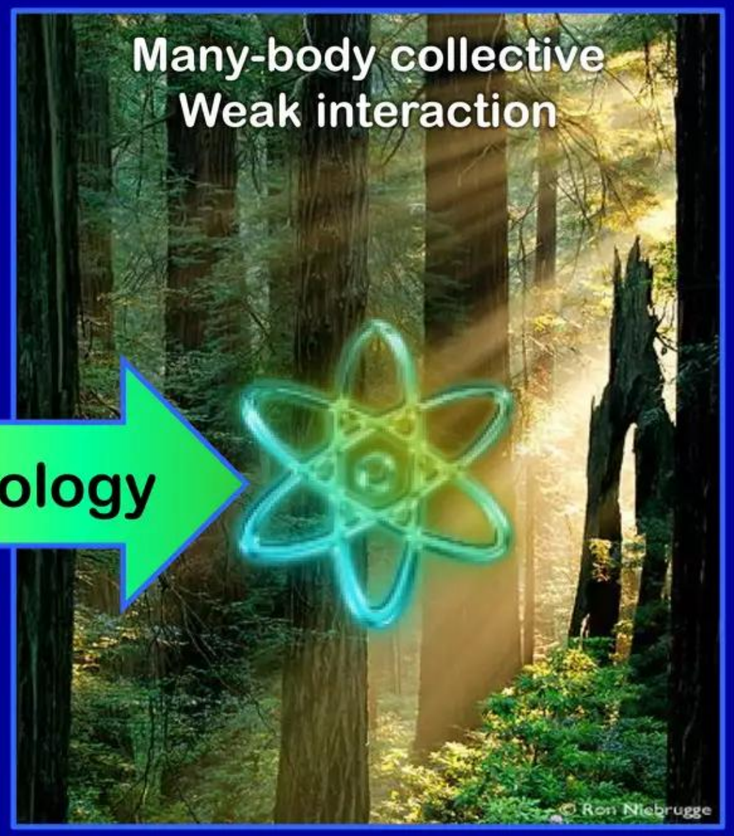
Nuclear weapons
Fission and fusion power plants

2005

Widom-Larsen theory of LENRs was developed

LENRs are biosafe and radiation-free

2016



Not good for use in weapons
Enables portable nuclear power

Evolution of green nuclear technology

LENRs are green: no energetic radiation or radwastes

Lack of hard radiation obviates need for shielding and containment

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

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

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

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

Revolution in green nuclear technology

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

LENRs have energy densities 5,000x greater vs. gasoline

Estimate of multiple based on very conservative energetic assumptions

Energy densities of LENR transmutation processes surpass chemical combustion

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)

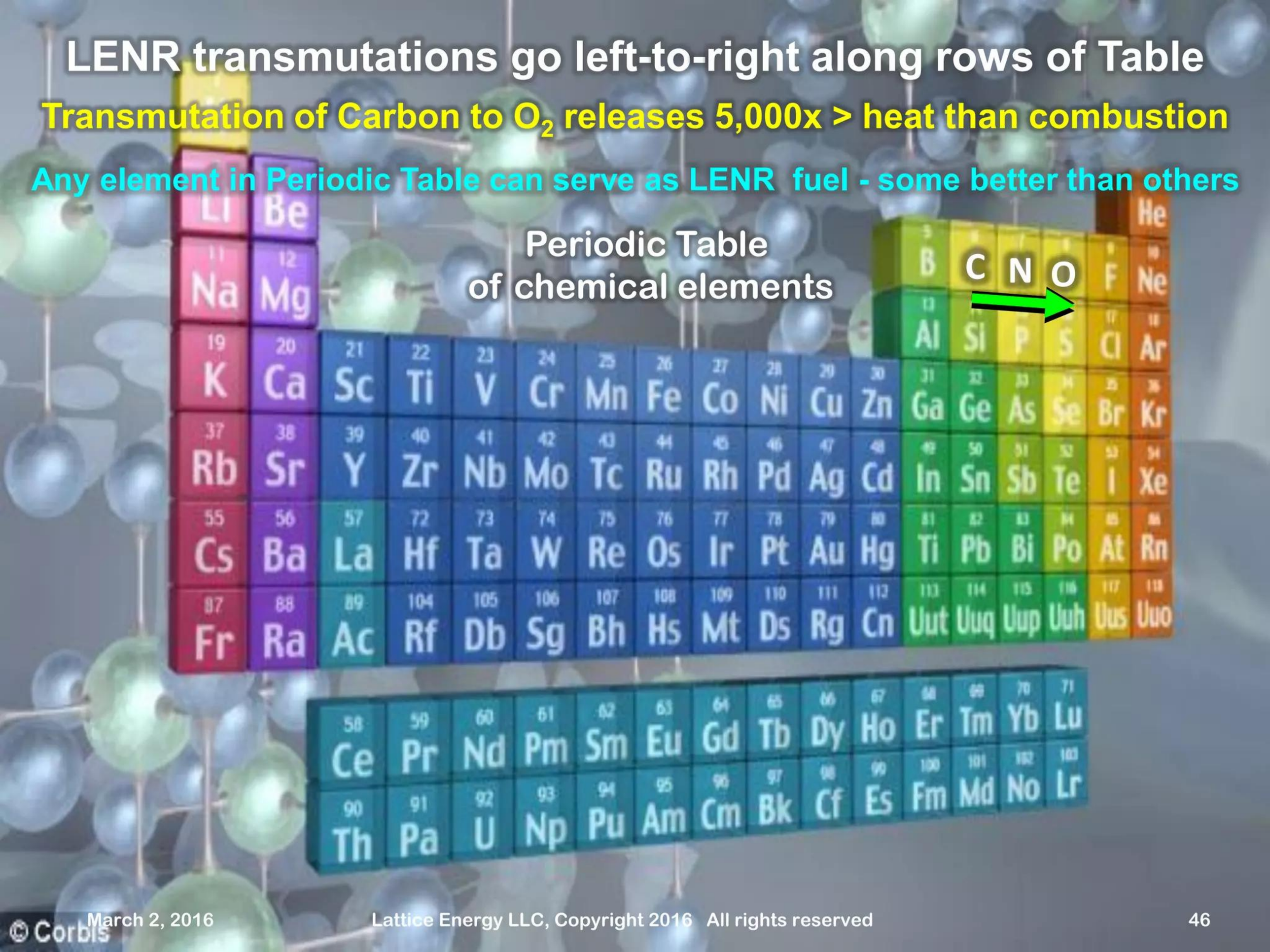
Chemical Energy Sources

LENRs

LENR transmutations go left-to-right along rows of Table

Transmutation of Carbon to O_2 releases 5,000x > heat than combustion

Any element in Periodic Table can serve as LENR fuel - some better than others



Fossil fuels could be converted into green LENR fuels

Breakthroughs in physics and nanotechnology make this possible

Bitumen, heavy oil, and coal may be much more valuable as CO_2-free LENR fuels

In 2009 Larsen discovered that aromatic molecules can potentially be extracted and processed to be converted into green LENR fuels in which there would be no hard radiation emissions, no production of any long-lived radioactive wastes or emission of gaseous CO_2 into the atmosphere; would instead release **> 5,000 times more thermal energy versus combustion of Carbon-based molecules with Oxygen**

These fossil hydrocarbons contain aromatic ring molecules on which LENRs can be triggered

Canadian natural bitumen

Heavy viscous oils found in many fields

Various grades of coal

Fossil Carbon can be transmuted rather than combusted

Heavy oil and coal could be processed to produce CO_2-free LENR fuels

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

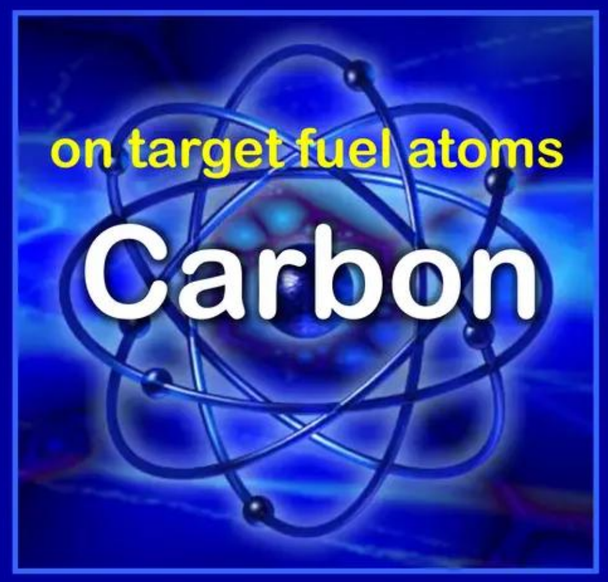
Radiation-free LENR transmutation

Neutrons + target fuel atoms → heavier elements + decay products + heat

Catalytic neutron 'match'

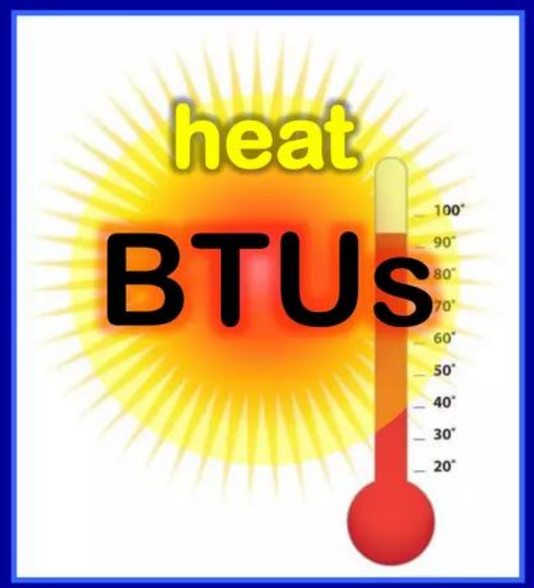
capture +

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



produces →

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



Process does not emit any deadly radiation or produce troublesome radwastes

Many moieties contain or are convertible into aromatics

LENR fuels can be created from many different types of Carbon sources

Base feedstock → Aromatic molecules → Nanoparticulate fuels

Contain aromatic molecules

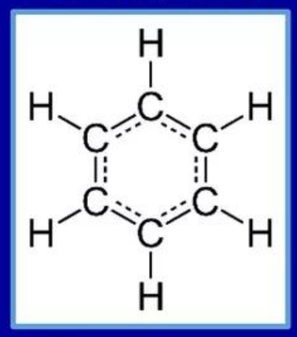
Examples:

- Heavy oils and natural bitumen — Extract
- Coal — Extract
- Lignin from renewable biomass — Digest
- CH_4 natural gas — Mo catalyst → LNG
- CO_2 → C nanofibers — Processing

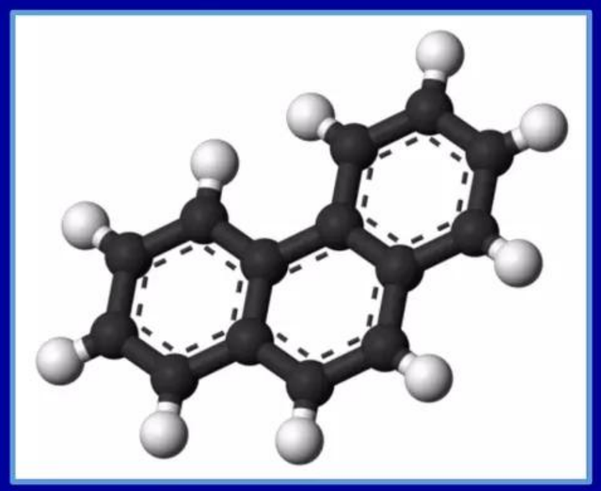
Chemical process

Variety of simple and complex aromatic molecules

Examples:



Benzene



Phenanthrene

Chemical processing

Process into

plus nanotech

Green CO_2-free LENR fuels

5,000x greater energy density

Enormous gain in energy density makes processing conversions $$$ economic

Bottom line: just about any Carbon-based moiety can be converted into aromatic ring-structure molecules using a chemical process

Transmutation of Carbon is superior to combustion

LENR technology could enable future clean energy at reasonable cost

- ✓ Successful commercialization and broad deployment of LENR Carbon transmutation in power generation applications could increase the effective economic BTU $$$ value of remaining in-ground fossil fuel resources by at least 500x by releasing thermal energy from Carbon via CO_2-emission-free transmutation rather than by continuing to rely on today's age-old chemical combustion technology
- ✓ So-called "stranded asset" fossil carbon financial risk issues would disappear
- ✓ Carbon transmutation could substantially extend the effective economic lifetime of present in-ground fossil fuel resources from an estimated <150 years per British Petroleum out to at least another 25,000 years further into the future
- ✓ LENRs are therefore vastly more synergistic rather than competitive with fossil fuels [44 slides]: http://www.slideshare.net/lewisglarsen/lattice-energy-llc-compelling-economics-of-transmutation-vs-combustion-of-carbonaceous-energy-sources-jan-14-2015
- ✓ Rather than eventually replacing fossil fuels with solar, wind, and renewable energy sources over time, LENR technology instead enables oil, gas, and coal producers to convert fossil fuels into cleaner, more valuable form of CO_2-free LENR energy --- energy producers, energy consumers, and Earth will all win

Strategy: retrofit fossil fuel plants with LENR-powered boilers

Cost of retrofitted facility could be ~74% less than new natural gas plant

"Will low natural gas prices eliminate the nuclear option in the US?"

Values in Table are from R. Graber and T. Retson (released July 2013)

Table 2: Cost Components of Levelized Costs ($/MWh) ($2012)				Lattice estimates
Cost Component ($/MWh)	**Nuclear**	**Natural Gas (No Environmental cost)**	**Natural Gas (With $25/Ton CO_2)**	**Retrofit nat. gas or coal plants**
Capital	$ 57.78	$ 12.72	$ 12.72	**$ 2.54**
O&M	$ 10.03	$ 3.46	$ 3.46	**$ 5.02**
Fuel	$ 5.55	$ 46.99	$ 46.99	**$ 1.00**
Taxes[1]	$ 9.79	$ 10.39	$ 10.39	**$ 10.39**
Decommissioning	$ 1.46	-	-	**-0-**
Waste Disposal	$ 1.00	-	-	**$ .10**
Environmental Compliance	-		$ 9.80	**-0-**
TOTAL	**$ 85.61**	**$ 73.55**	**$ 82.35**	**$ 19.05**

Graber & Retson's numbers in above Table were presented at conference and differ slightly from values at URL below

Source: http://www.energybiz.com/article/13/10/will-low-natural-gas-prices-eliminate-nuclear-option-us

Centralized grid architecture has dominated for 100 years

Climate change is making this model more vulnerable to major outages

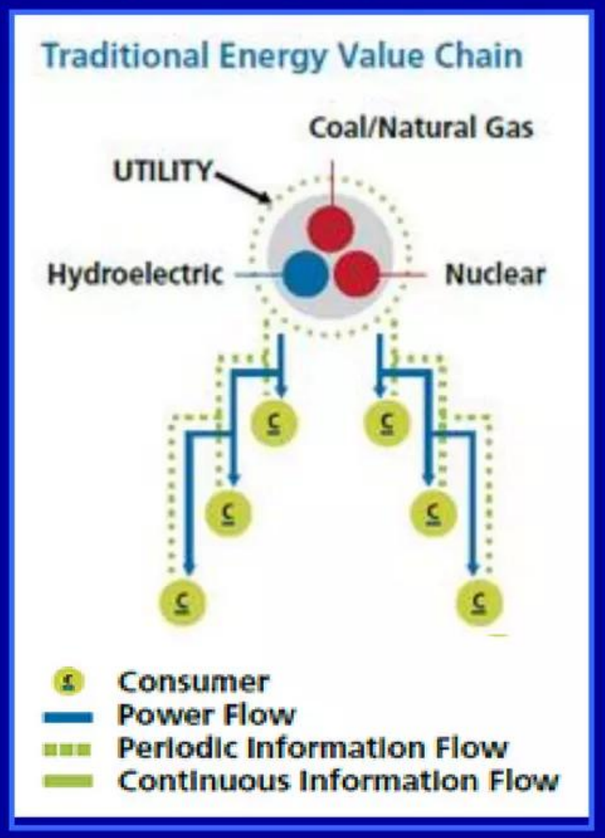
Solution is distributed generation which has dispersed network of power sources

- ✓ 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

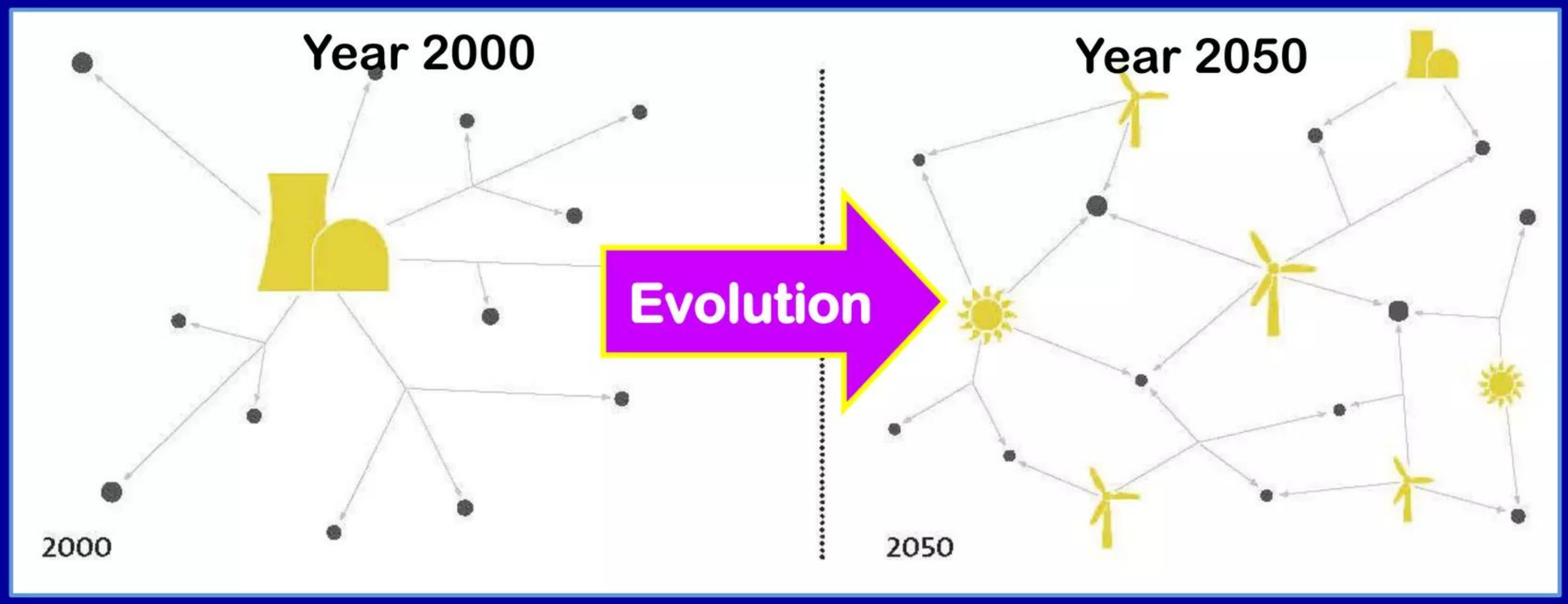


Modeling suggests decentralization of grid may be beneficial

"Solar and wind energy may stabilize the power grid"
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."

http://phys.org/news/2012-09-solar-energy-stabilise-power-grid.html



Credit: designergold, based on outlines provided by the MPI for Dynamics and Self-Organization

LENRs can enable competitive distributed power generation

Brandon Owens of GE has concluded that DG is the wave of the future

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

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.

http://www.ge.com/sites/default/files/2014%2002%20Rise%20of%20Distributed%20Power.pdf

Modular 30 kW (thermal) LENR systems ideal for homes

Distributed generation works well in urban as well as remote rural areas

Increases the stability of urban grids; enables low-cost global rural electrification

- ✓ Small steam turbines (see to the right) have been developed that would be ideal for use in homes; could be integrated with boilers heated by LENRs
- ✓ Enough LENR fuel for a year of operation could probably be shipped overnight in large FedEx box
- ✓ If a 30 kW LENR thermal source were integrated with heat-to-electricity energy conversion system that was only 20% efficient, home power system could produce ~6 kWh electrical and 24 kW heat; satisfy energy demand for 95+% of homes in world
- ✓ Distributed generation helps to stabilize existing urban grids; also enables very cost-effective global rural electrification for presently powerless people

Green Turbine™ steam generator
1.2 to 15 kWh

http://www.greenturbine.eu/GT15.html

LENRs and the future of global power generation

5 -10 kwh LENR-based power systems revolutionize energy production

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

- ✓ At system power outputs of just 5 - 10 kwh, modular LENR-based distributed power generation systems providing combined heat and electricity (CHP) could potentially satisfy the requirements of a majority of urban and rural households and smaller businesses worldwide, including today's powerless
- ✓ At system power outputs of just 50 - 200 kwh, LENR-based systems could begin to power steam or electric vehicles, breaking oil's stranglehold on transportation; provide high-quality heat for many 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. Under that scenario, grid-based centralized power generation would be gradually displaced by vast numbers of smaller, lower-cost distributed power systems

Major Japanese companies are now developing LENRs

Mitsubishi Heavy Industries, Toyota, and Nissan have R&D programs

Won't admit it publicly but their goal is to replace the internal combustion engine

- ✓ Mitsubishi Heavy Industries and Toyota have been quietly funding R&D in LENRs out of their own budgets since 1989 with minimal help from their government
- ✓ Keiretsu - Japanese term that describes a loose association of different companies that share one or more common interests and work closely together to achieve mutually agreed-upon key business and technological objectives. They may or may not have some degree of mutual ownership and are tied to banks. Mitsubishi and Toyota are members of respective keiretsu; Toyota is presently considered the largest vertical conglomeration in today's Japan
- ✓ Mitsubishi Heavy Industries and Toyota have been conducting and reporting important experimental basic science results on LENR transmutation measurements for many years. Heretofore, they did not focus on trying to produce substantial amounts of excess heat to generate power. Nissan recently initiated their own basic research program on LENRs with no public fanfare
- ✓ In 2013, Toyota published a paper in the peer-reviewed *Japanese Journal of Applied Physics* which confirmed important experimental results that Mitsubishi Heavy Industries had first published back in 2002. Mitsubishi's patented Hydrogen permeation method is capable of triggering clean, radiation-free LENR nuclear transmutation reactions under relatively modest temperatures and pressures

New Energy Times reported NEDO issued RFP on LENRs

NEDO: New Energy and Industrial Technology Development Association

Arm of Government of Japan - its mission is to develop new energy technologies

Japanese Government Will Fund LENR Research Again

http://news.newenergytimes.net/2015/08/24/japanese-government-will-fund-lenr-research-again/

Selected excerpts quoted directly from Steven Krivit's August 24, 2015 news story:

For the first time in two decades, the Japanese government has issued a request for proposals [RFP] for low-energy nuclear reaction (LENR) research, according to information recently obtained by *New Energy Times*.The request for proposals was published by the New Energy and Industrial Technology Development Organization (NEDO), a national research and development agency.

The request for proposals, "Energy and the Environment New Leading Technology Program," was released in July. The line item for the LENR research is on PDF Page 16, item D4. The item translates to "Metal which becomes new energy source and analysis and control of the technology of heat reactions between metals and hydrogen."

In a response to an e-mail from *New Energy Times*, long-time LENR researcher Tadahiko Mizuno confirmed that item D4 is for LENRs. Some Japanese LENR researchers, according to Mizuno, are filing a joint application to NEDO, with the assistance of Akito Takahashi, a former professor at Osaka University.

In 1994, the Japanese government, through the Ministry of Trade and Industry [MITI], sponsored an earlier research program called the New Hydrogen Energy Agency. It ran for several years at a cost of several million dollars. It terminated after researchers reported lackluster results.

Japanese government presently funding R&D in LENRs

Orchestrates key relationships between academia and private industry

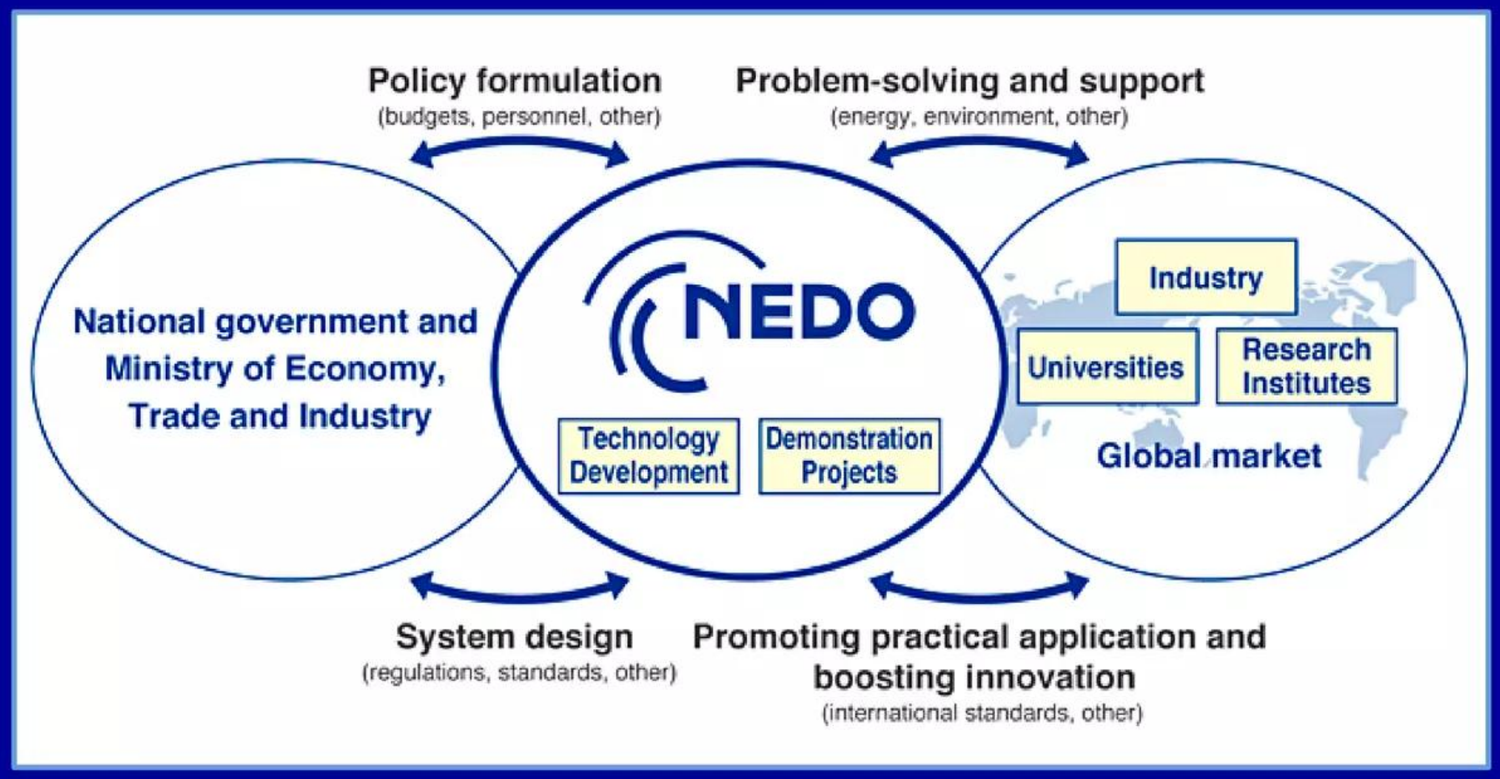
NEDO New Energy and Industrial Technology Development Organization

Combining the efforts of industry, government and academia and leveraging established international research networks, NEDO is committed to contributing to the resolution of energy and global environmental problems and further enhancing Japan's industrial competitiveness

http://www.nedo.go.jp/english/

Mode of operation – graphic is copied from home page of NEDO website

経済産業省 Ministry of Economy, Trade and Industry



MITSUBISHI

TOYOTA

NISSAN

Lattice Energy LLC

Commercializing a next-generation source of safe CO_2-free nuclear energy

H.E. Sheikh Ahmed Zaki Yamani
أحمد زكي يماني; **formerly**
Oil Minister of Saudi Arabia

Stated during a media interview (2000)

Further in-depth reading for those who wish to learn more

Incredible opportunity to develop green renewable nuclear power

LENR fuels derived from biomass: an inexhaustible green energy source

"LENR transmutation of Carbon is superior energy strategy - slashes CO_2 emissions for vehicles as well as electric power generation"
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenr-transmutation-of-carbon-better-energy-strategy-than-obama-clean-power-plan-aug-3-2015

"Scalability of LENR power generation systems"
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-scalability-of-lenr-power-generation-systems-nov-29-2015

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

"LENRs dramatically expand financing opportunities for oil & gas industry"
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-lenrs-dramatically-expand-financing-opportunities-for-oil-and-gas-industry-october-8-2015

"Index and user guide to the Widom-Larsen theory and ultralow energy neutron reactions (LENRs)"
http://www.slideshare.net/lewisglarsen/lattice-energy-llc-hyperlinked-index-to-documents-re-widomlarsen-theory-and-lenrs-september-7-2015

Strategic partnering and consulting

Deep expertise in LENRs and future ramifications of this technology

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

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

- ✓ Lattice welcomes inquiries from large, established organizations that have an interest in seriously discussing the possibility of becoming a strategic capital and/or technology development partner in the near- or long-term time frames
- ✓ Lewis Larsen also selectively engages in fee-based third-party consulting. This work covers topics in the context of micron-scale, many-body collective quantum effects in condensed matter systems (including photosynthesis), safety issues arising from field failures causing Li-ion battery thermal runaways, nuclear waste remediation, chemical catalysis, and ultra-high-temperature superconductors, among others. Additional areas of expertise include long-term strategic implications of LENRs on high cap-ex long term investments in power generation and petroleum-related assets, as well as long-term price outlooks for and investments in precious metals and real price of energy. Will consult on such subjects as long as it does not involve my disclosing sensitive proprietary engineering details applicable to LENR power generation systems