The World Without Oil

Iskander Diyashev

PetroSkills®

SPE International

Society of Petroleum Engineers

GEEC
GORAGOVO ENERGY
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Conventional Wisdom

- Oil and gas is a limited natural resource. We are finding hydrocarbon resources in hard to reach and operate environments. That is why access to energy resources will continue to be more costly.
- Society is prepared to pay this high cost of energy because it has no real alternative.
- Alternatives that have been presented so far are too expensive, have fundamental technical limitations and will not be produced on a large enough scale to make a difference in the next 30-50 years.
- As nations like China and India continue to develop, they will replicate the same patterns of energy production and consumption as developed nations. That will continue to increase the demand for hydrocarbons for ground transportation, electricity generation and air travel.
- The oil and gas industry has unmatched intellectual, financial, political resources, and is well positioned to compete in the 21st century and will continue to prosper.

"Its hard to make predictions. Especially about the future"
– Danish proverb used by Niels Bohr

- Salt, was a "strategic resource used for centuries" and turned into an affordable commodity.
- "Great horse manure crisis" - never materialized.
- "The great promise of nuclear energy" turned out to be too expensive and too risky.
- "The limits to growth". "Hubbard's curve". "Twilight in the desert". The world did not run out of fossil fuels, we are running out of fresh air to put CO_2 into. "Peak oil" for USA has happened in the 1970's based on per capita metric.
- Holditch "resource triangle" – essentially infinite hydrocarbon resources.
- "World will continue to use more fossil energy." We see the decoupling of GDP and energy consumption in advanced economies (USA, Germany, others).

Presentation Outline

- A little bit of history. The story of salt and the great environmental crisis at the beginning of the 20th century.
- Unconventional resources, energy parity and the era of great competition.
- How do we use oil? Do we expect changes?
  - Automobiles and transportation
  - Heat and electric power generation
  - Aviation
- Where do we go from here?

Salt Story

- Today salt is a common and inexpensive substance. But, "Until about 100 years ago, when modern geology revealed its prevalence, salt was one of the world's most sought-after commodities. A substance so valuable it served as currency, salt has influenced the establishment of trade routes and cities, provoked and financed wars, secured empires and inspired revolutions."
- Salt has shaped civilizations from the very beginning. "Most Italian cities were founded proximate to saltworks, starting with Rome in the hills behind the saltworks at the mouth of the Tiber".
- Over the past several thousand years, **humans have used salt to preserve food**. The Roman army required salt for its soldiers and horses. At times soldiers were even paid in salt, hence the words *salary,* "worth his salt", soldier.
- Demand for salt established the earliest trade routes. The first of the great Roman roads, the Via Salaria, Salt Road, was built to bring this salt not only to Rome but across the interior of the peninsula.
- Salt has provoked and financed some wars, and been a strategic element in others, such as the American Revolution and the Civil War. Gandhi's salt march in 1930 began the overthrow of British rule in India.

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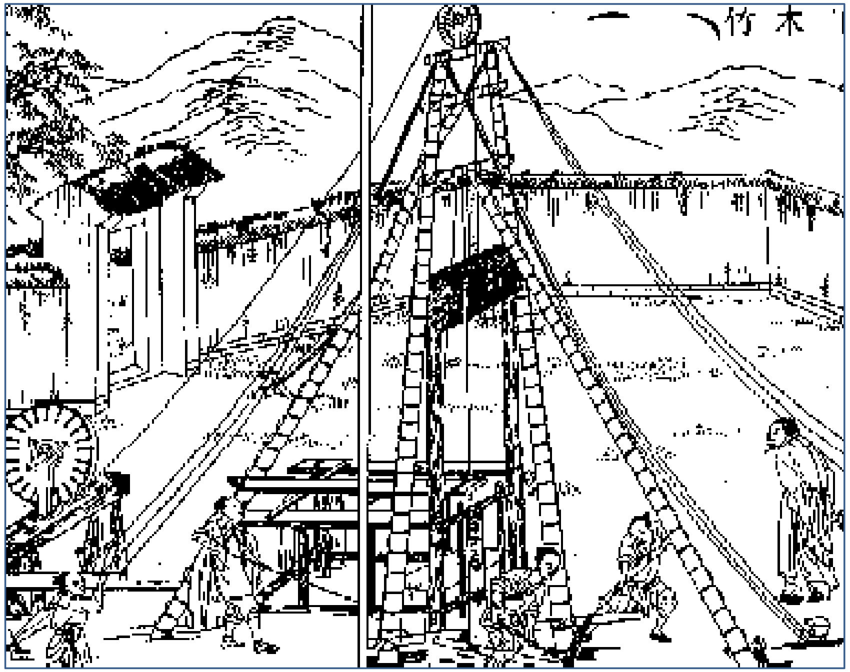
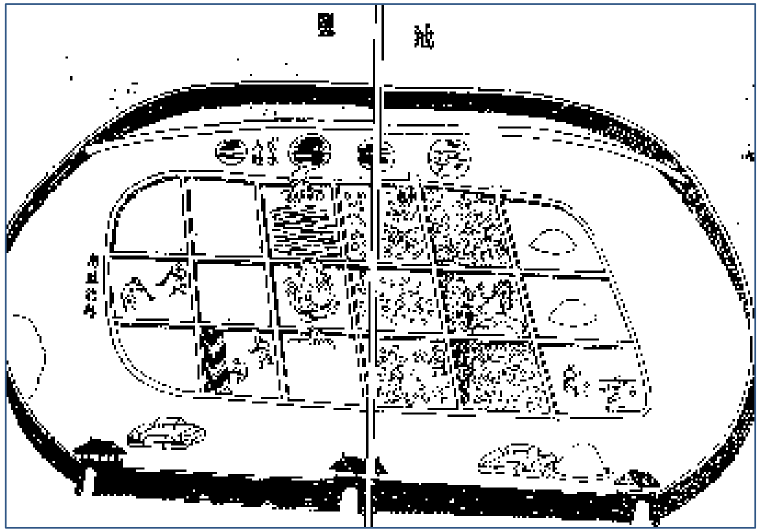
Mark Kurlansky Salt: A World History. (2002), ISBN 0-8027-1373-4

Salt Industry Inventions





The salt industry invented drilling and pumping, and had the first recorded industrial use of natural gas. “Few endeavors have inspired more ingenuity than salt making, from the natural gas furnaces of ancient China to the drilling techniques that led to the age of petroleum”.

Mark Kurlansky Salt: A World History. (2002), ISBN 0-8027-1373-4

"The Great Horse Manure Crisis"

- By the late 1800s, horse pollution became a major problem. A public health and sanitation crisis of "unimaginable dimensions" loomed. All transport of goods or people was drawn by horses. The horse had been the dominant mode of transportation for thousands of years.

- Horse population was growing faster than human city population. London (1900) had > 50,000 horses. In New York (1900) 100,000 horses produced 2.5 million pounds of horse manure per day. More horses required more land to stable and feed them.
- In 1894, the *Times* of London estimated that by 1950 every street in the city would be buried nine feet deep in horse manure. It was predicted that by 1930 the horse droppings in NYC would rise to Manhattan's third-story windows. "**Vacant lots across America were piled high with manure; in New York these sometimes rose to forty and even sixty feet".**

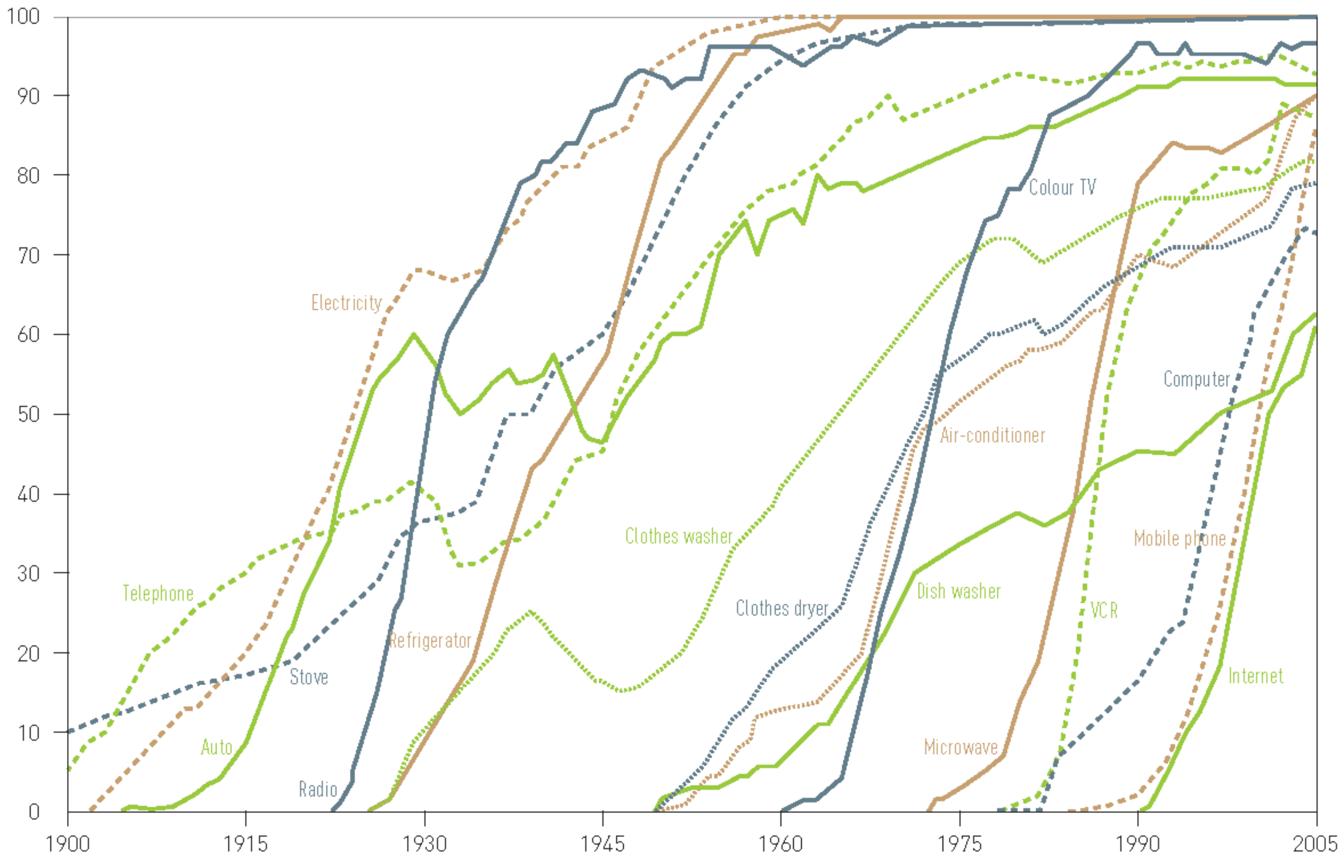
http://www.accessmagazine.org/articles/spring-2007/ **From Horse Power to Horsepower** By Eric A. Morris
Edwin G. Burrows and Mike Wallace, *Gotham: A History of New York City to 1898* New York: Oxford University Press, 1999.

What Happened? Better Technology, Better Economics

- Modern geology and drilling technology proved that salt resources are essentially infinite for practical purposes.
- The invention of refrigeration reduced the need for salt. Refrigeration is a better technology to preserve food. Also it led to increased productivity of farming and increased population of the western states.
- It took about 30 years for refrigeration to become prevalent. The timeline:
  - On February 15, 1882, the *Dunedin* sailed for London from New Zealand, what was the first commercially successful refrigerated shipping voyage, and the foundation of the refrigerated meat industry.[*]
  - By 1914, almost every location used artificial refrigeration. The big meat packers had purchased the most expensive units which they installed on train cars and in branch houses and storage facilities in the more remote distribution areas.[**]
- The great horse manure crisis vanished when millions of horses were replaced by motor vehicles.
- The price of horse-drawn transport rose steadily as the cost of keeping cities clean, feeding and housing horses increased. This created strong incentives for people to find alternatives.

* Colin Williscroft (2007). *A lasting Legacy - A 125 year history of New Zealand Farming since the first Frozen Meat Shipment*. NZ Rural Press Limited.
** Freidberg, Susanne (2010). *Fresh : a perishable history* (1st Harvard University Press pbk. ed. ed.). Cambridge, Mass.: Belknap. p. 142. ISBN 0674057228.
http://fee.org/freeman/detail/the-great-horse-manure-crisis-of-1894 09/ 01/2004 by Stephen Davies

When The Transition Starts It Takes 30 to 45 Years



Technology adoption curves for a range of modern innovations. Theoretical take-off point at 16% market penetration. (Rogers 1962)

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http://www.dtpli.vic.gov.au/__data/assets/pdf_file/0010/220402/Electric-Vehicle-trial-mid-term-report.pdf

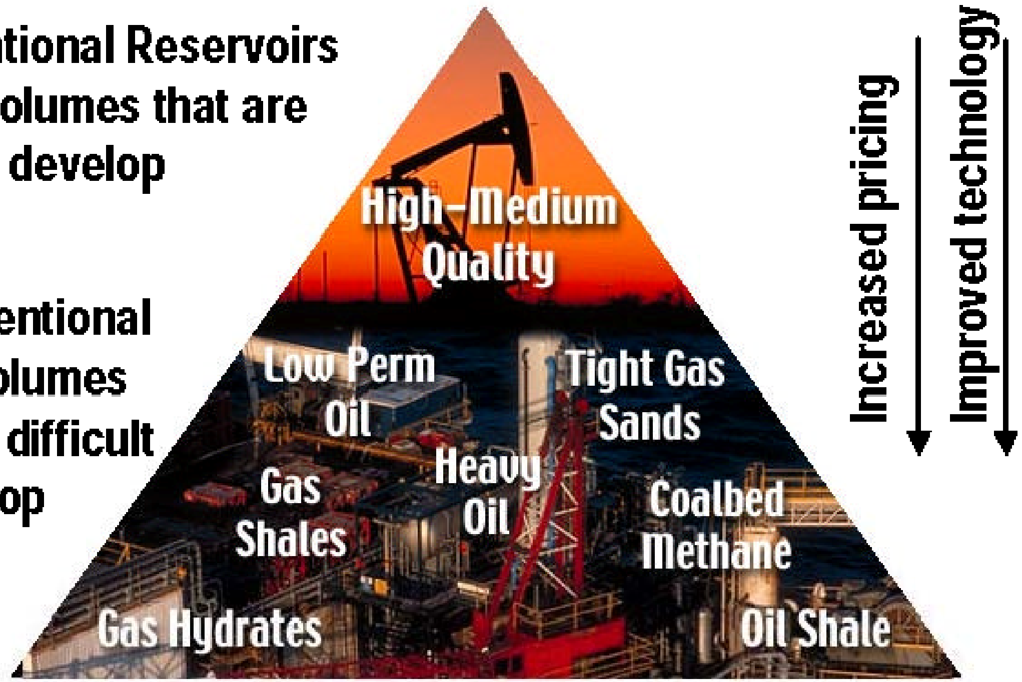
Unconventional Oil and Gas

- Estimates of conventional vs. unconventional reserves and resources for North America.
- Worldwide projections for "unconventionals" show essentially unlimited resource.
- Amazing technology advances led to drilling and completion efficiency gains.
- EUR is not very attractive for low k oil.
- What is the production activation index (PAI)? How does it translate to cost of power $/W?
- Implications.

Resource Triangle

Conventional Reservoirs
Small volumes that are easy to develop

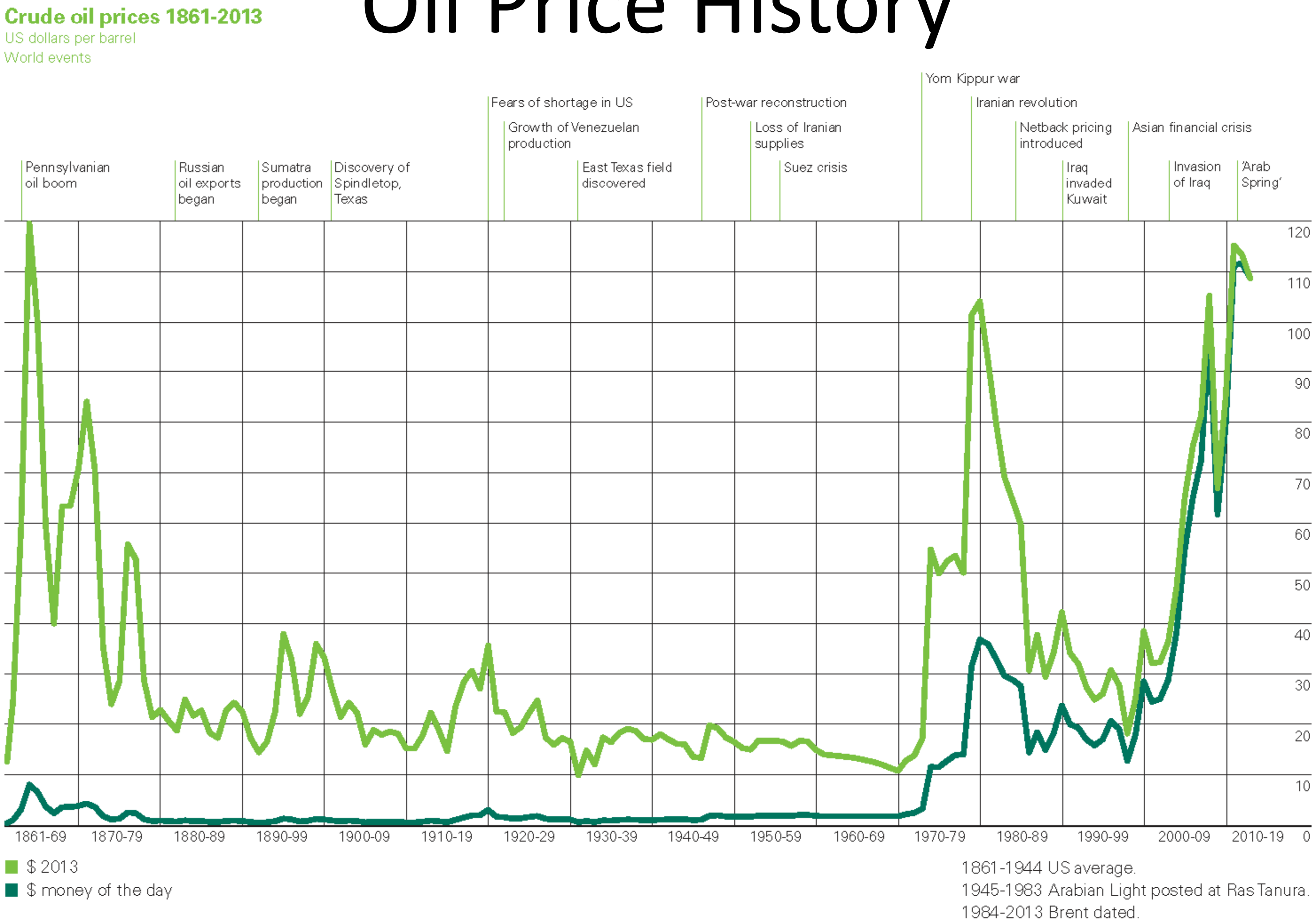
Unconventional
Large volumes that are difficult to develop



6 SPE/Holditch
4/27/2001

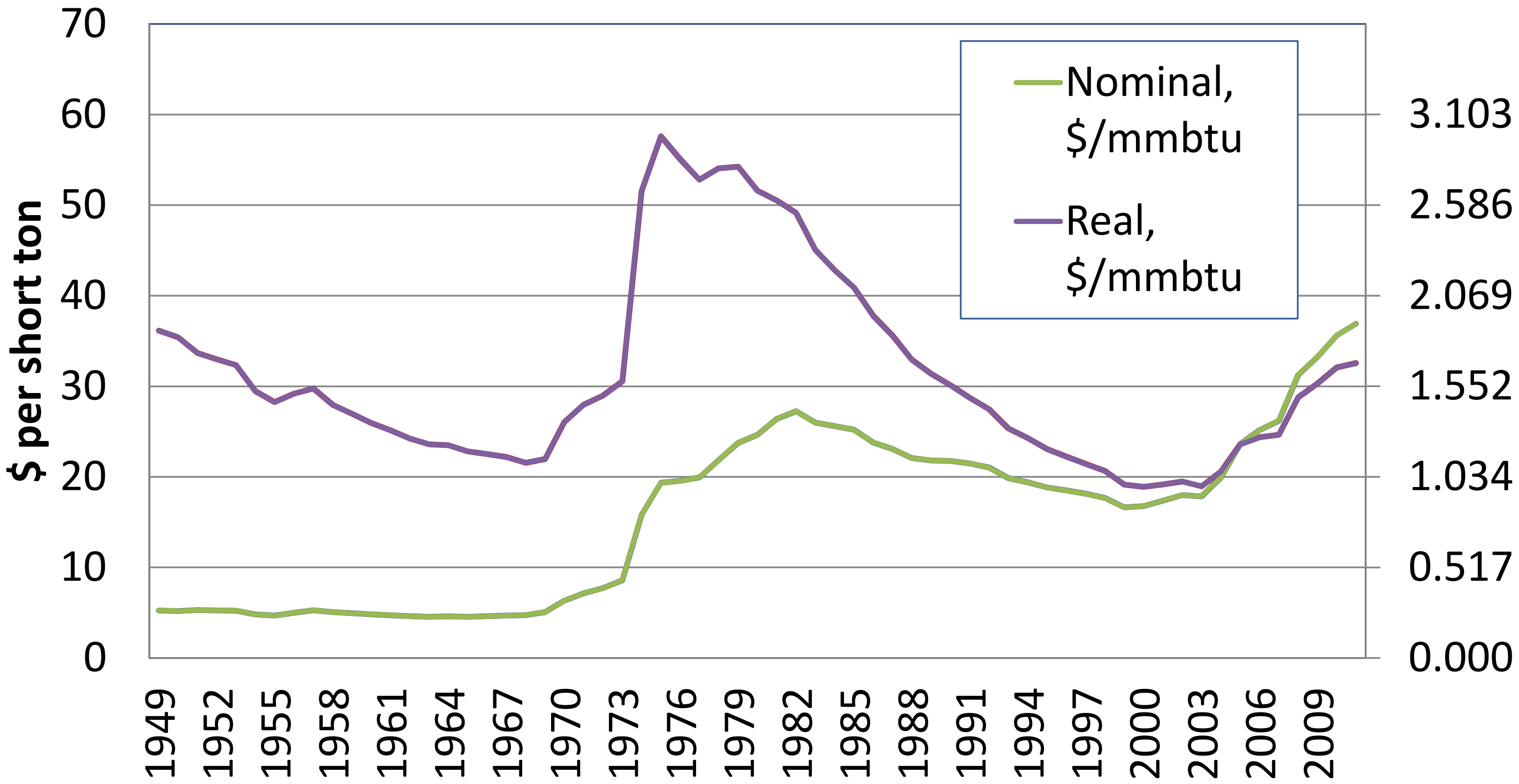
Lecture on unconventional resources by SPE President 2002 Dr. S.A.Holditch

Oil Price History

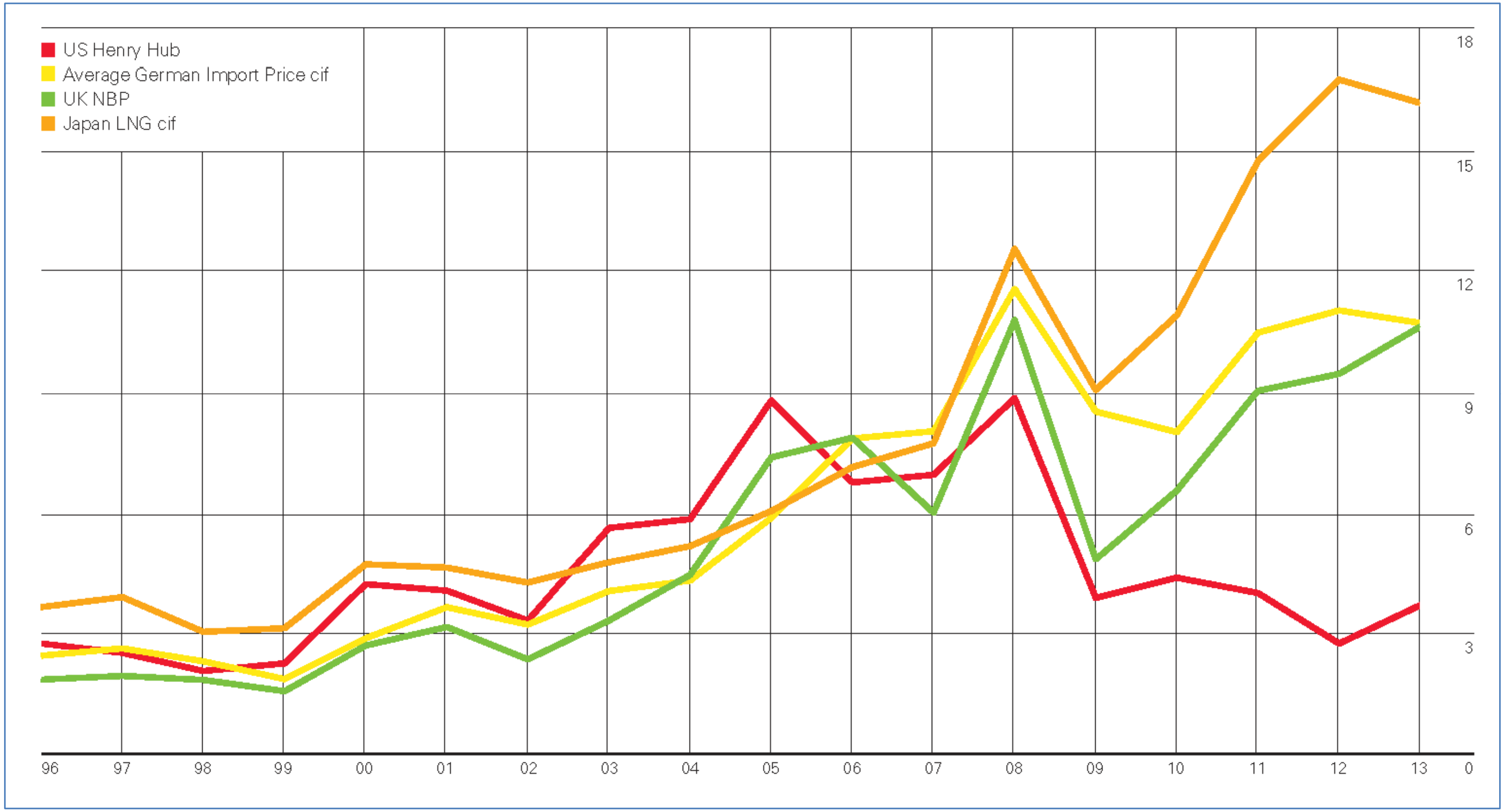


BP statistical review of world energy 2014

Coal Price History,
in $/short ton and $/MMbtu



Gas Price History, $/MMBtu



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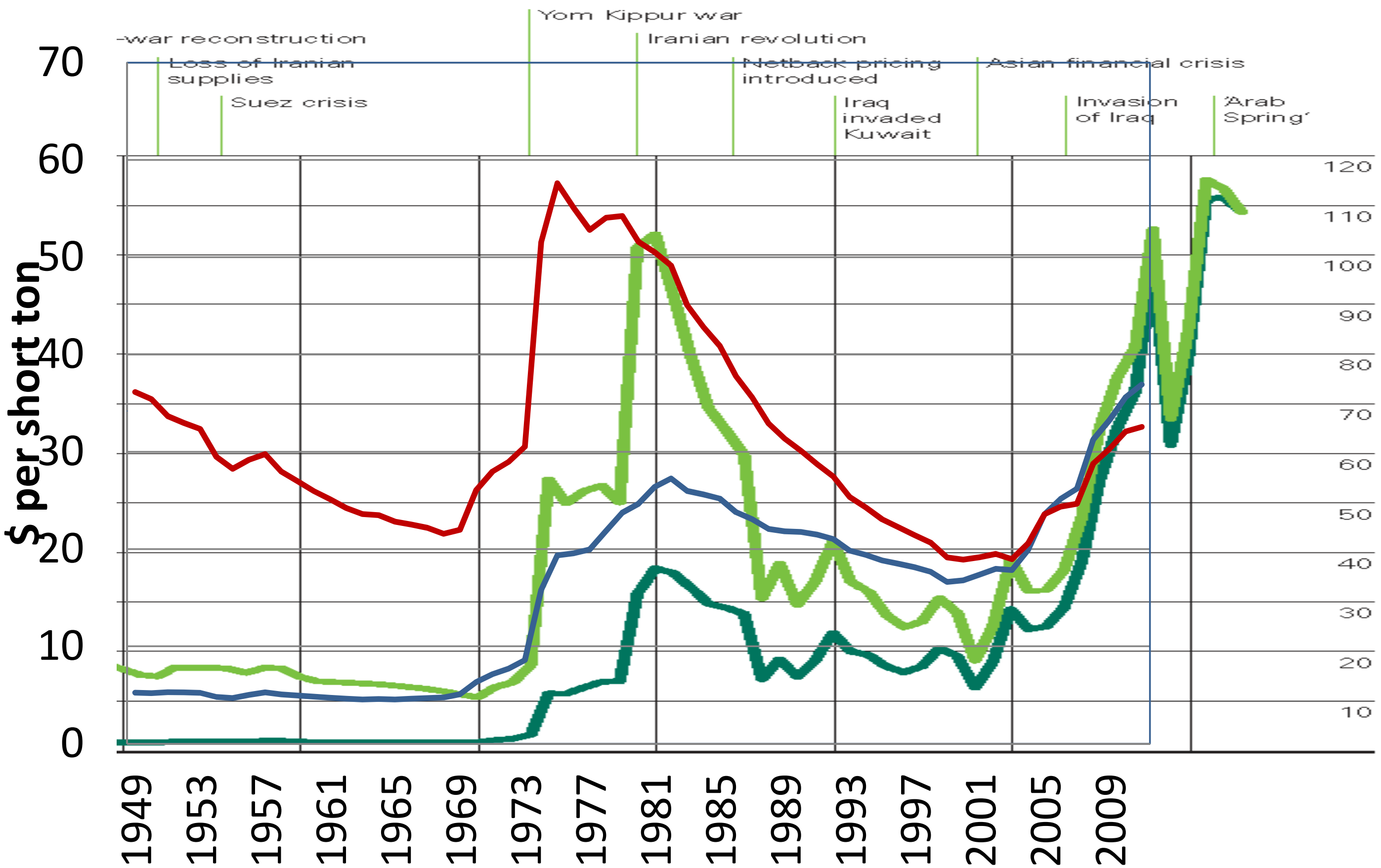
BP statistical review of world energy 2014

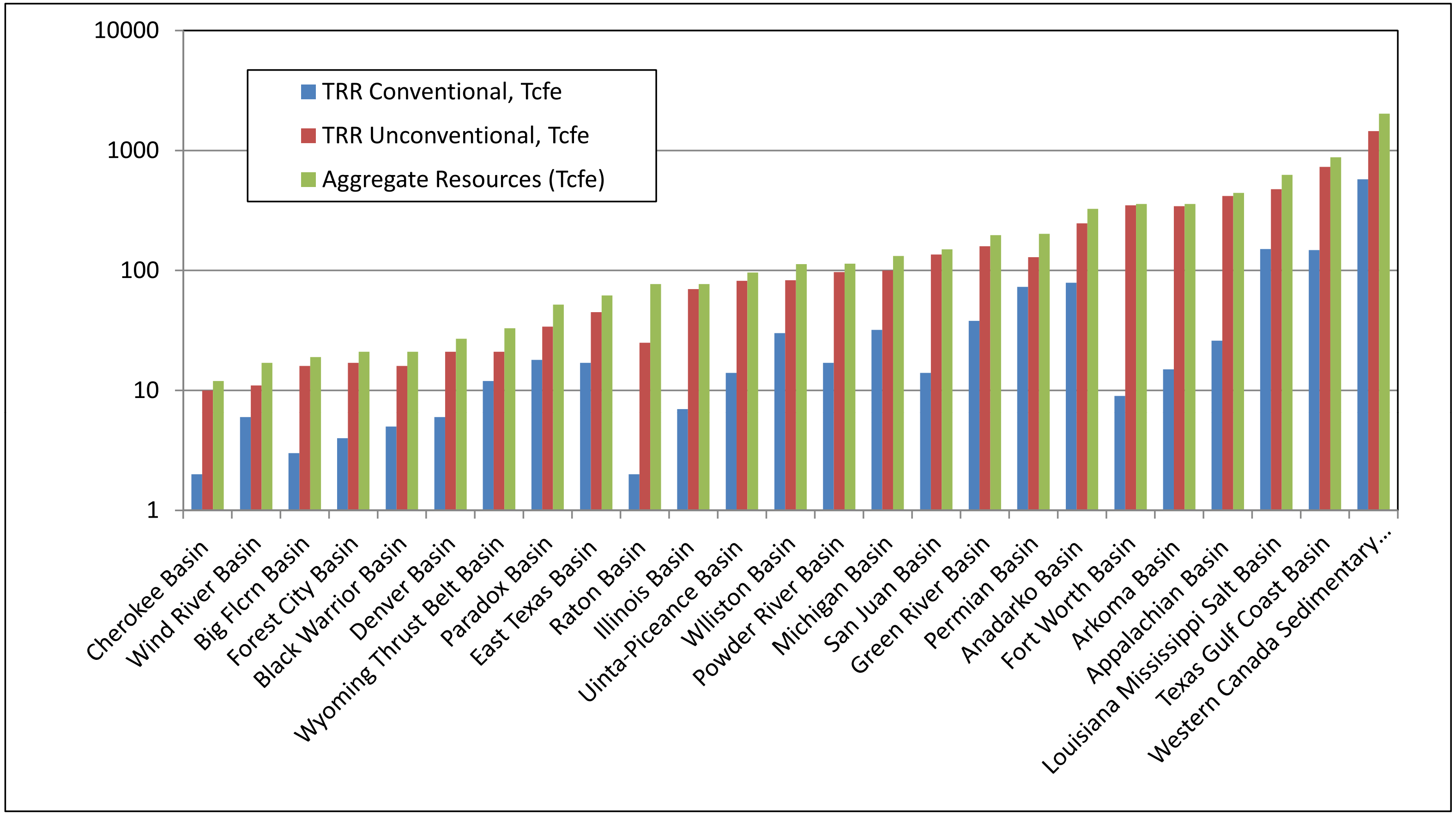
Oil Industry Continues to Enjoy a Convenience Fee

High oil price $25/MMBtu vs gas $10/MMBtu vs. coal $1.5/MMBtu (2008)



BP statistical review of world energy 2014

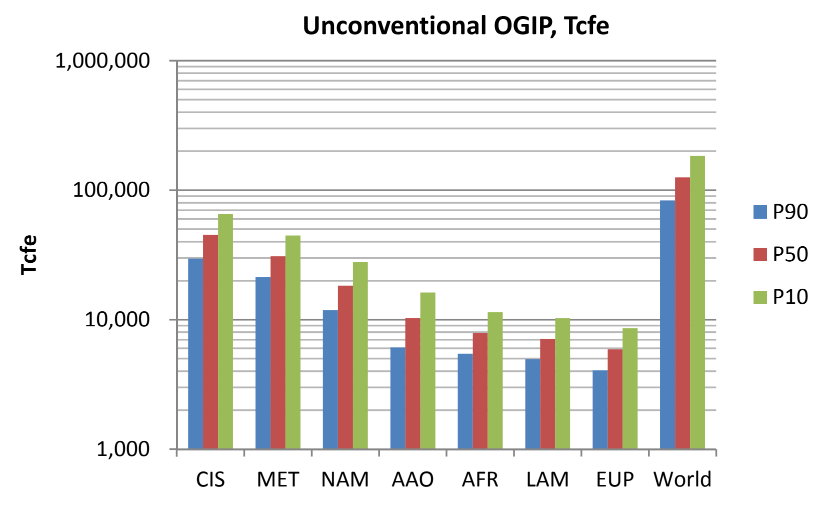
Aggregate Technically Recoverable Resources (TRR) in North America Are Sufficient for 60+ Years

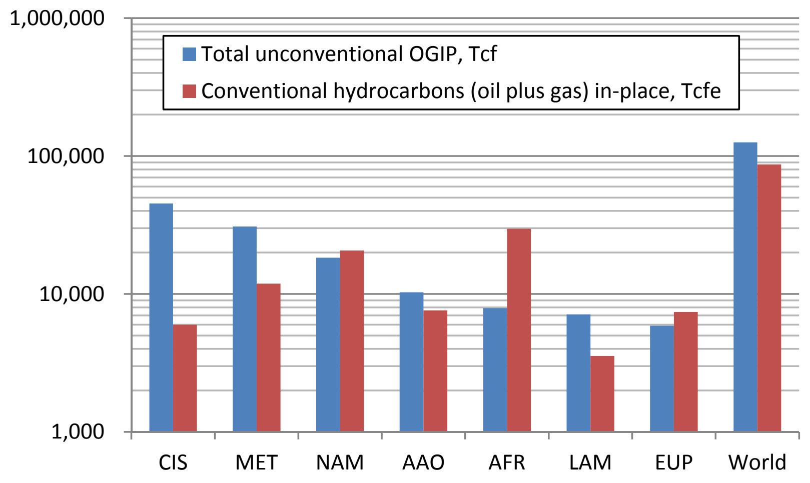


Cheng, K., Wu, W., Holditch, S. A., Ayers, W. B., & McVay, D. A. (2010, January 1). Assessment of the Distribution of Technically Recoverable Resources in North American Basins. Society of Petroleum Engineers. doi:10.2118/137599-MS

Worldwide Conventional And Unconventional Resources Are Essentially Infinite

P10/P50/P90 correspond to 377, 219 and 146 years at current consumption





"Conclusions
From using published assessments of 26 North American basins, published global assessments, and resource-triangle-based methodology presented in this paper, we have developed a global estimate of unconventional gas in place with quantifying the uncertainty and conclude the following:
1. Estimated global unconventional OGIP ranges from 83,300 Tcf(P90) to 184,200 Tcf(P10). The P50 of our global unconventional OGIP assessments (125,700 Tcf) is 4 times greater than Rogner's estimate of 32,600 Tcf."

Dong, Z., Holditch, S., McVay, D., & Ayers, W. B. (2012, October 1). Global Unconventional Gas Resource Assessment. Society of Petroleum Engineers. doi:10.2118/148365-PA

Comparing Different Sources of Energy

- Oil production rate, Qo (STB/D), Energy/time => Power => W
- Production activation index (PAI) = CAPEX/Qo => $/W
- PAI correlated to EUR => CAPEX/Energy => c/kWh

Darcy's Law for PSS Flow in oil field units

$$Q_o = \frac{0.00708 * kh * \left(\overline{p_r} - p_{wf}\right)}{\mu_o B_o \left[\ln\left(\frac{r_e}{r_w}\right) - 0.75 + s\right]}$$

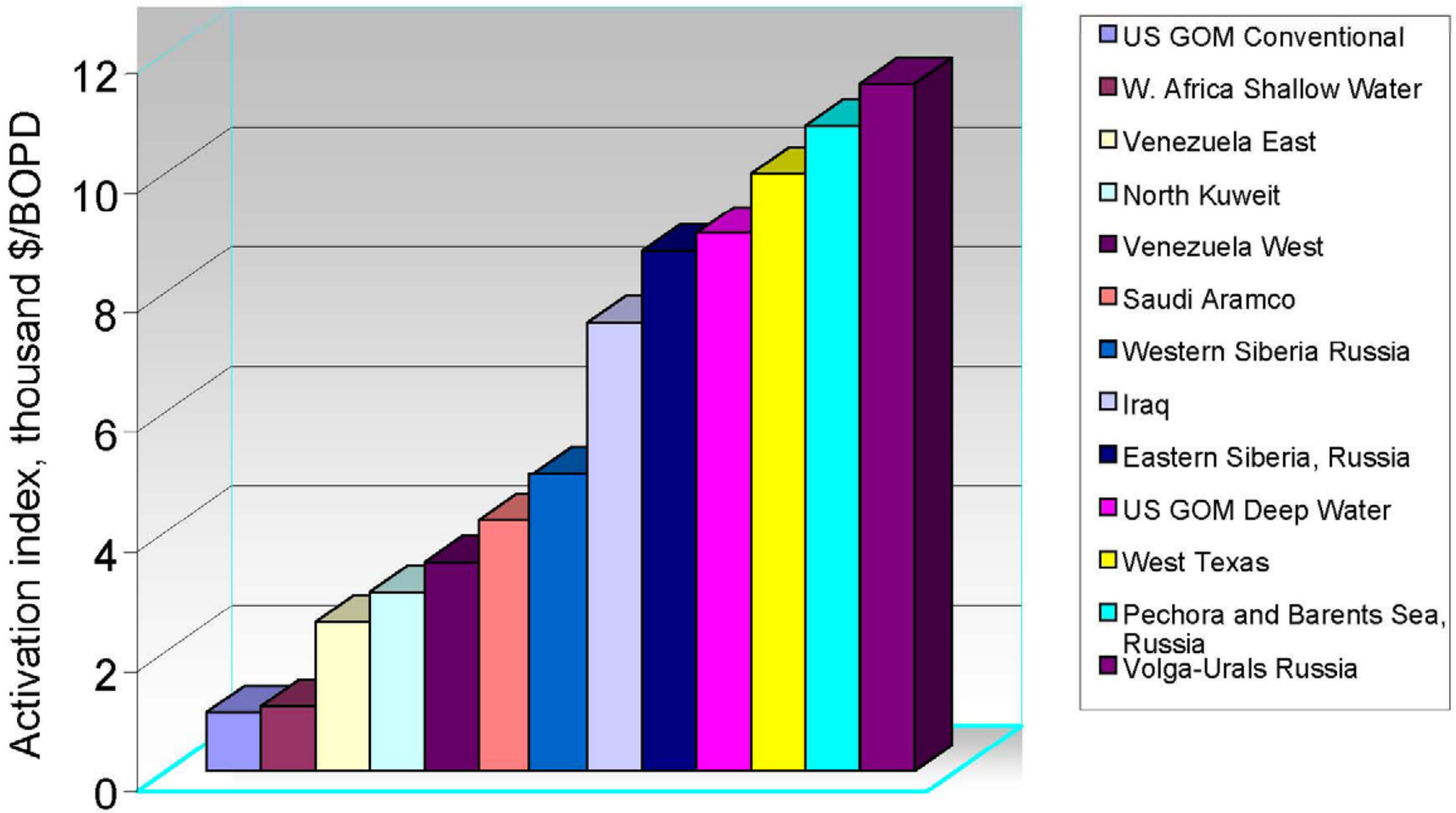
$$T = \frac{0.00708kh}{\mu_o B_o}$$

$$\Delta P = \left(\overline{p_r} - p_{wf}\right)$$

$$Q_o = T * \Delta P * J_D$$

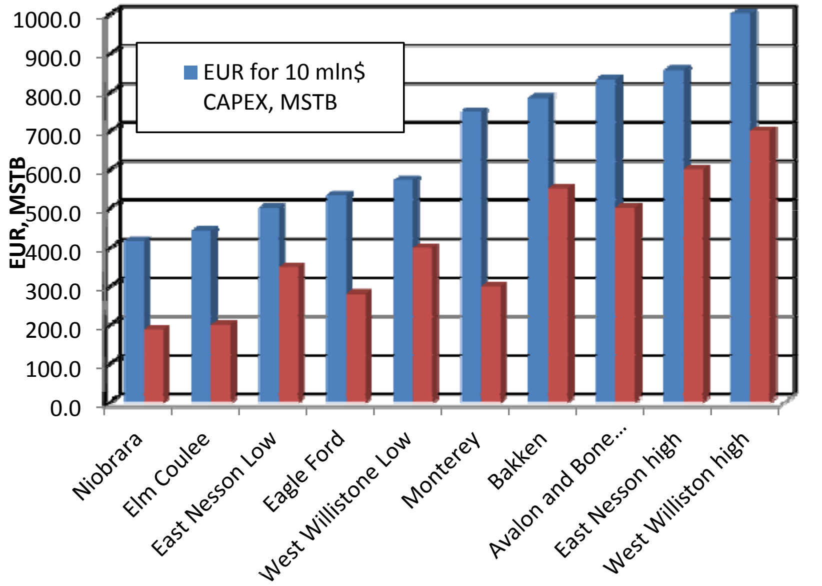
$$J_D = \frac{1}{\left[\ln\left(\frac{r_e}{r_w}\right) - 0.75 + s\right]}$$

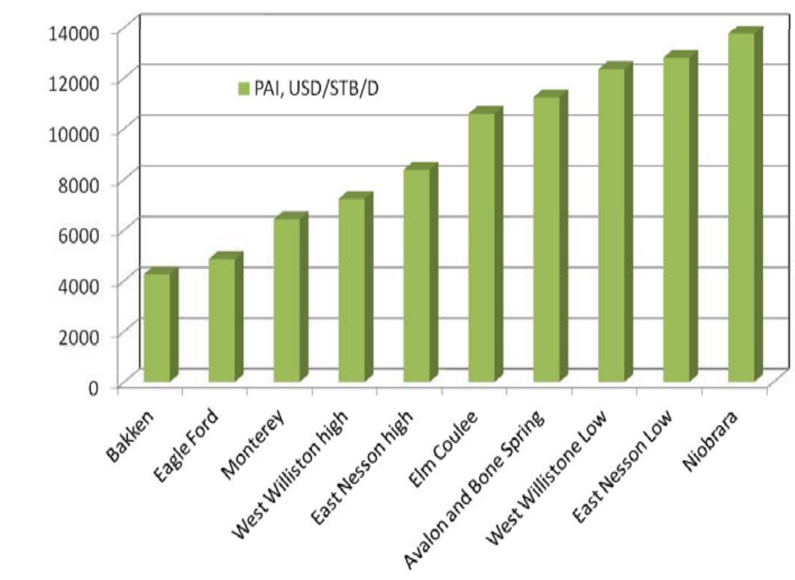
Comparison Between PAI In Different Areas



SPE 108818 Diyashev 2005

Typical EUR Per Well And PAI For Low k Oil Fields



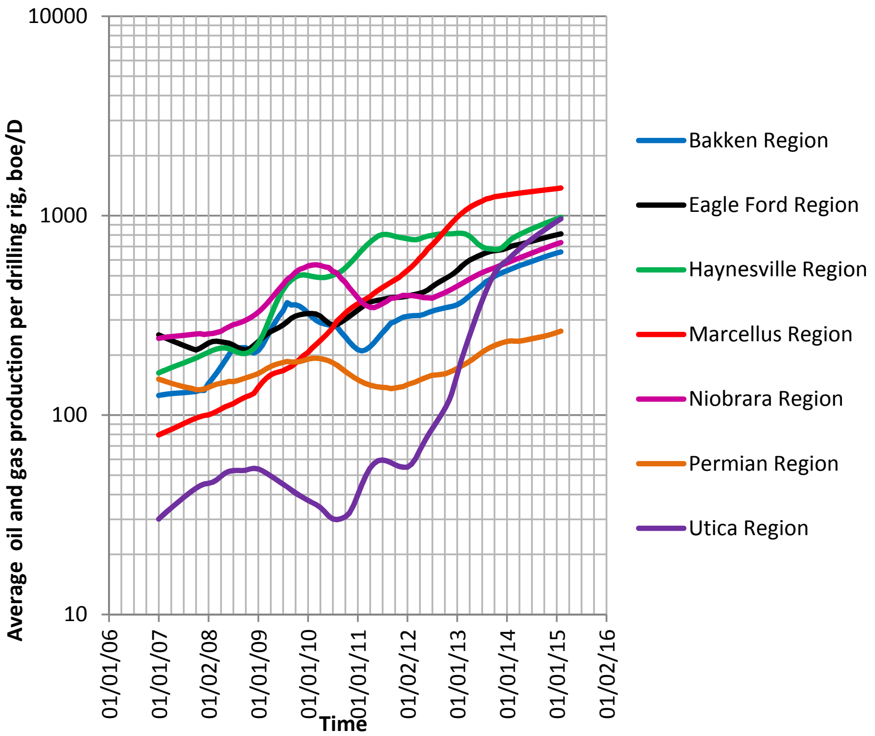


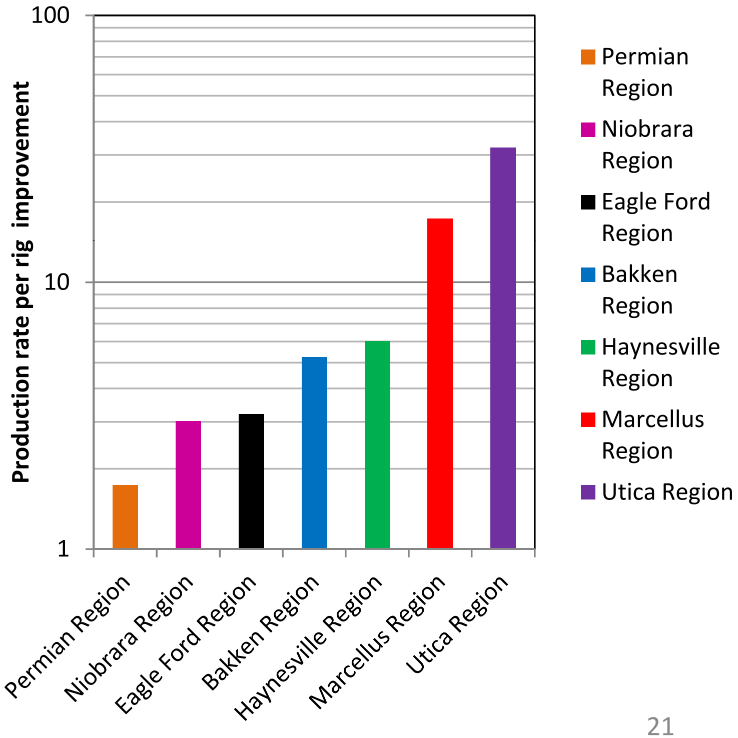
- EUR per well is from about 180 M STB to 700 M STB
- EUR per 10MMUSD CAPEX is in the range of about 400 M to 1 MM STB
- PAI, USD/STB/D is in the range from 4000 to 14000 $/STB/D

http://www.ogj.com/articles/print/vol-110/issue-12/exploration-development/evaluating-production-potential-of-mature-us-oil.html 12/3/2012 by Rafael Sandrea

Amazing Efficiency Gains

- Average oil and gas production rate per active drilling rig has improved by a factor of 3.5.
- We use more efficient drilling process, pattern drilling, better technologies, and tools.
- Horizontal drilling and better completion/stimulation increased Qo.





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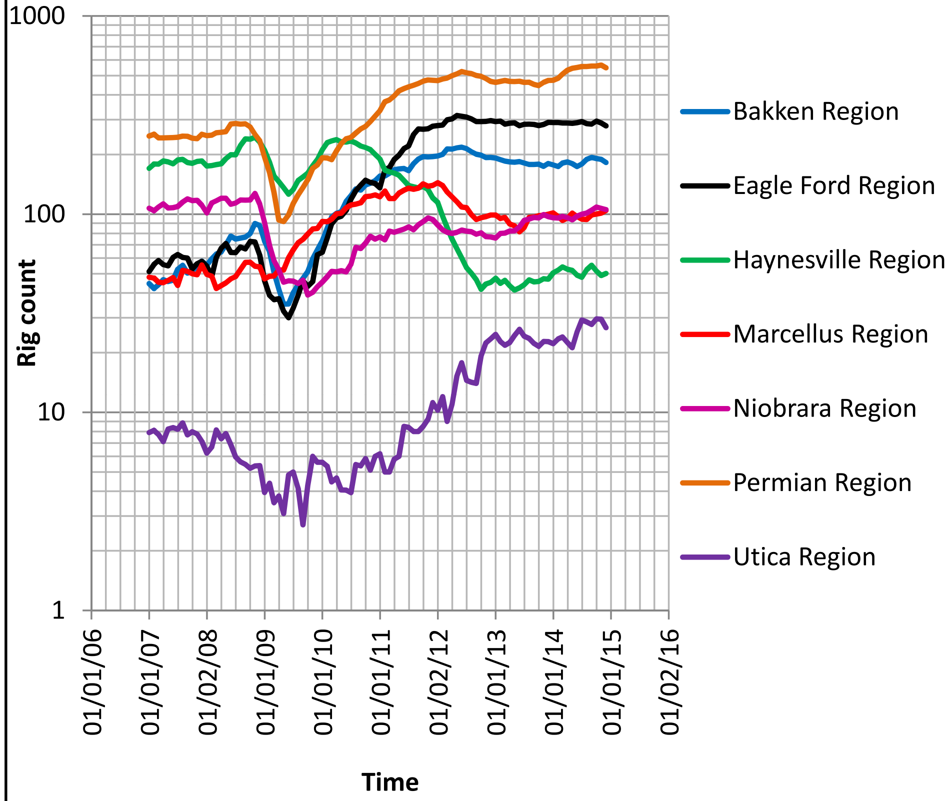
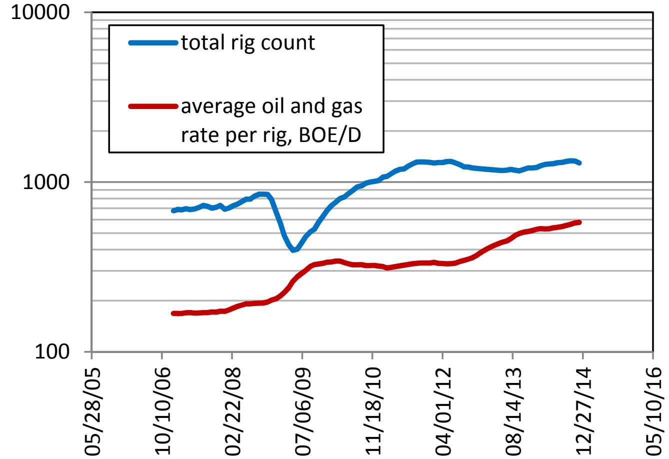
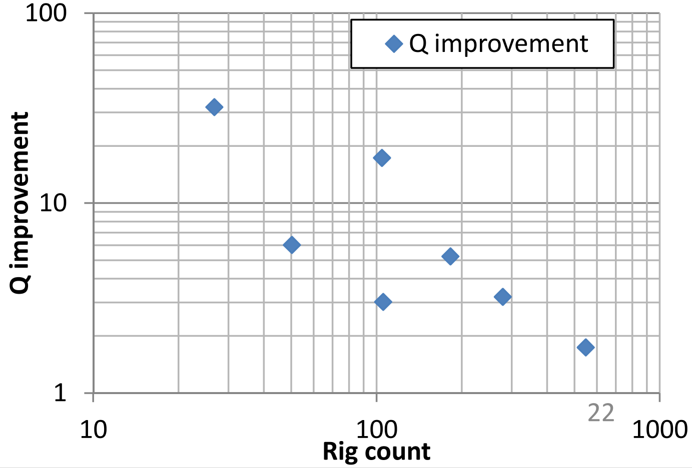
http://www.eia.gov/petroleum/drilling/ data from EIA drilling productivity report

Smaller Efficiency Gains In The Larger Basins







Data from EIA drilling productivity report

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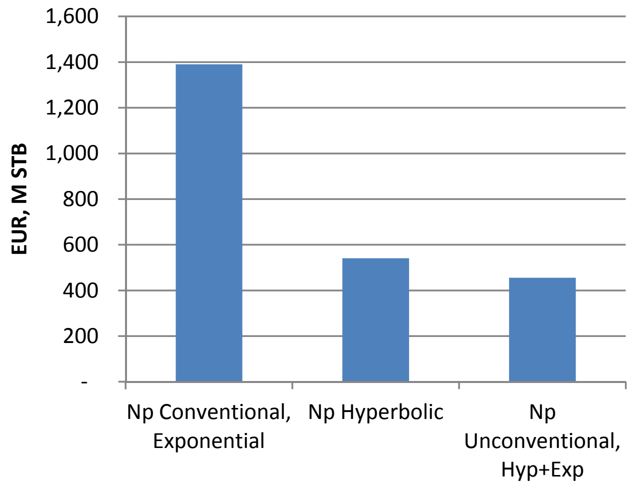
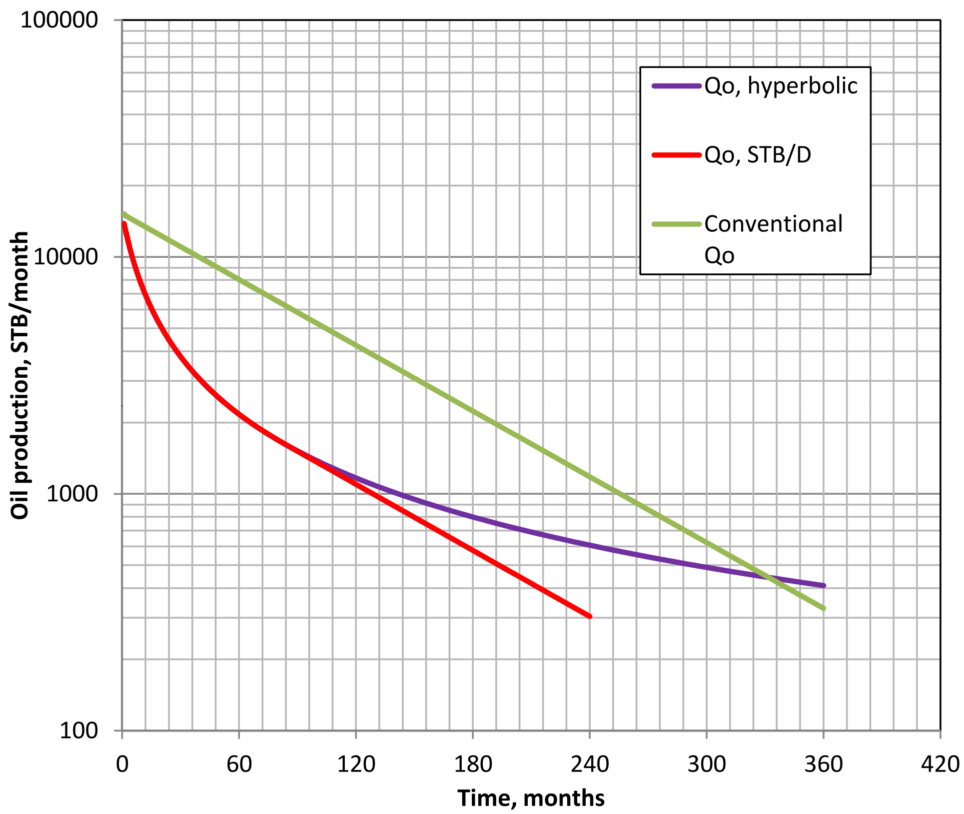
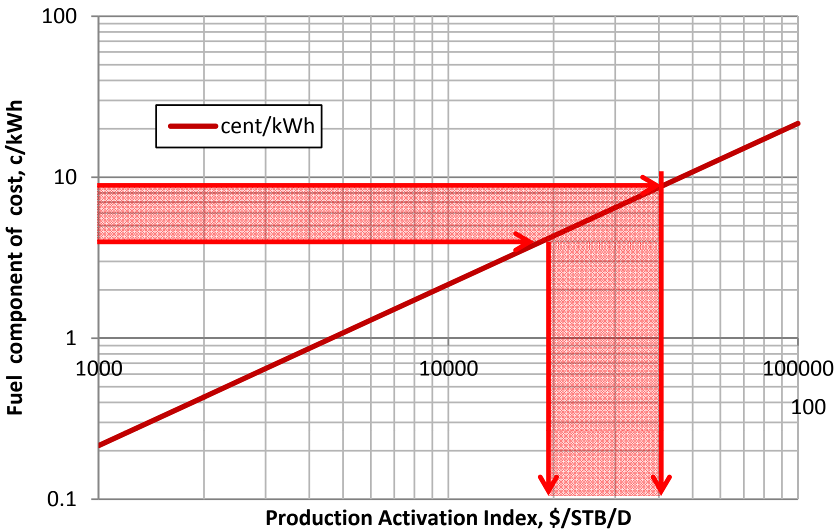
Comparison Of The Production Profile For "Conventional" And "Unconventional" Oil Well





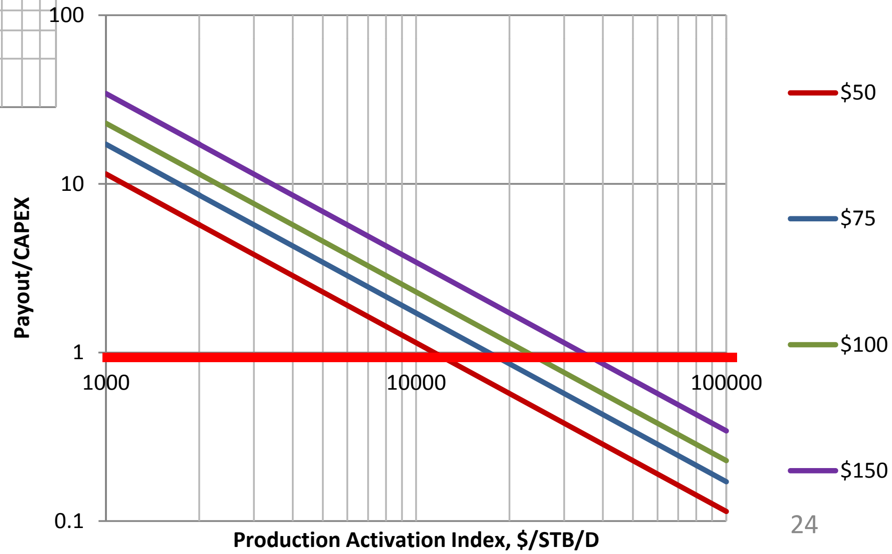
Qoi = 500 STB/D
Conventional Di =12%, 1/year
Di, 1/year= 70%
b = 1
Dmin = 12%
Economic Limit = 10 STB/D

Production Activation Index



Economic Assumptions
Unconventional oil
Combination of hyperbolic and exponential decline
CFAT = 40%
Di, year-1 = 70%
b = 1
Dmin = 12%
d (ROR) = 12%

For a given volume of investment $10 MM, for a value of PAI we can calculate EUR. Under the assumption of hyperbolic plus exponential decline PAI is related to EUR. Hence we have CAPEX/Energy => c/kWh



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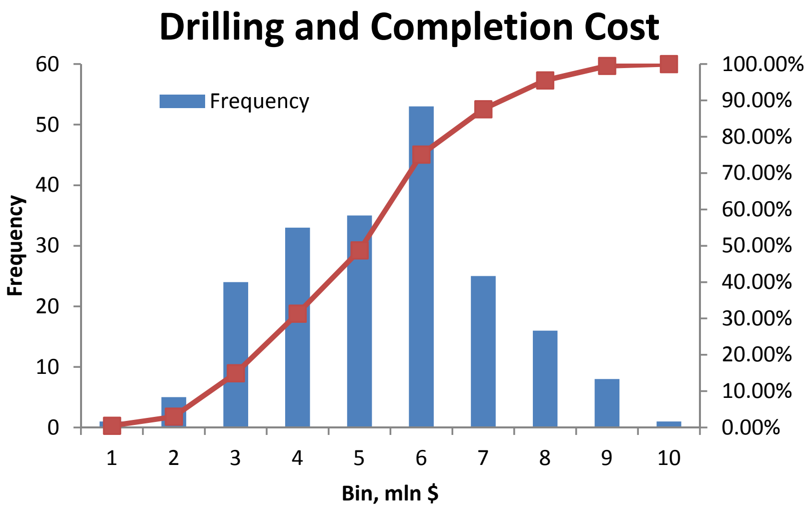
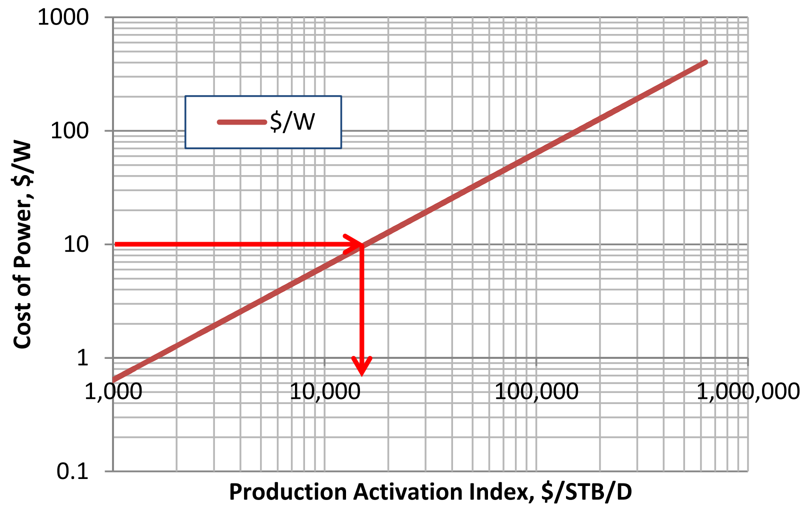
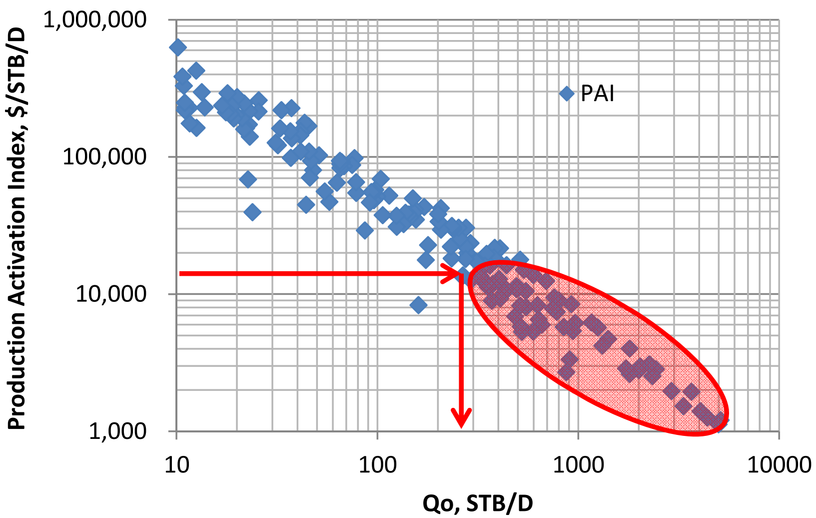
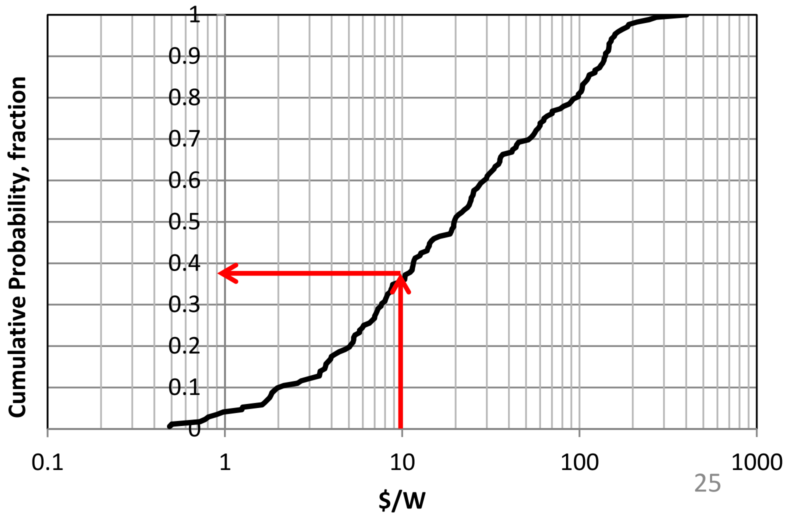
“Redlines” Existed Even If We Were Unaware Of Them

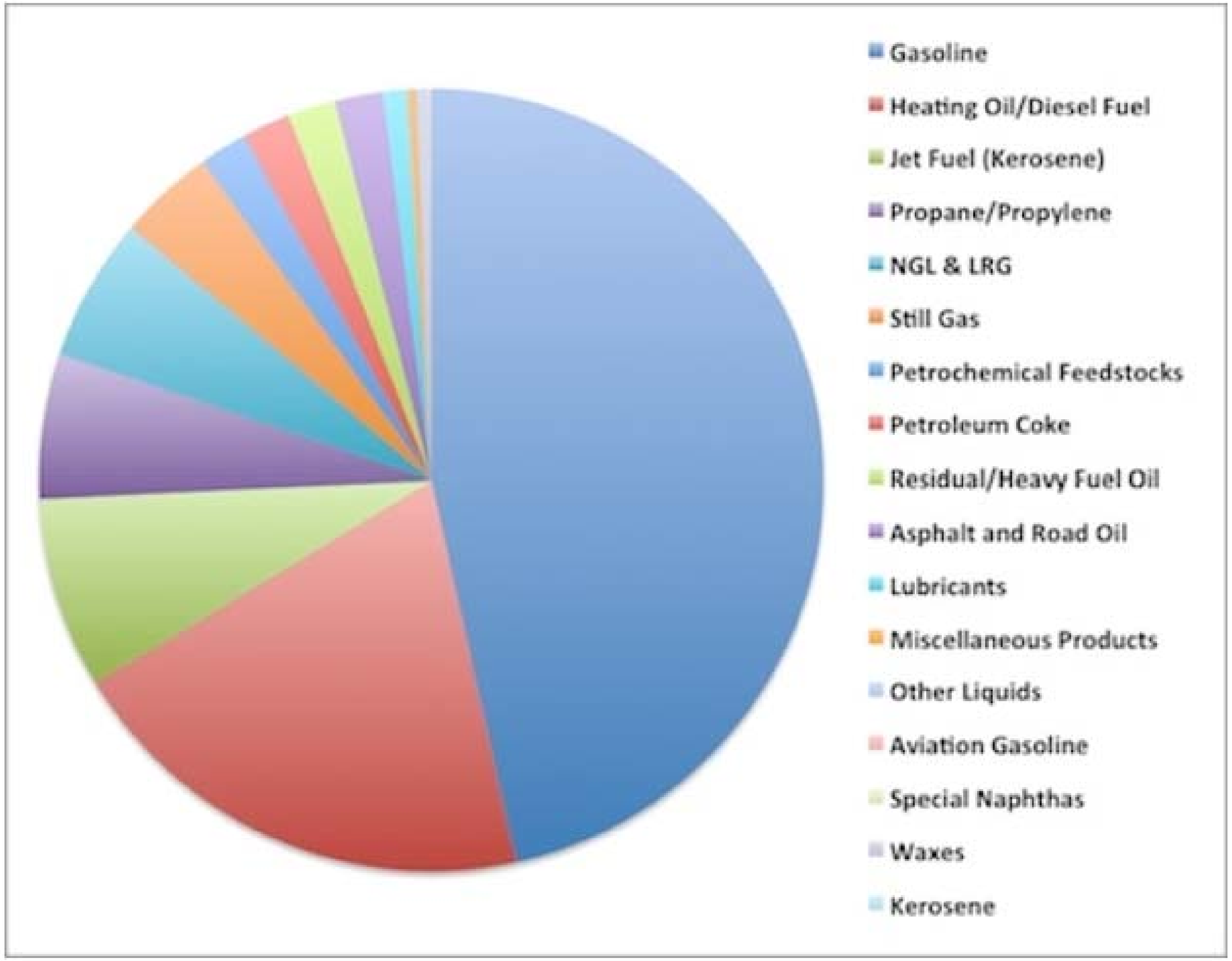








About ¾ Of All Produced Oil Is Used As Gasoline, Heating Oil And Jet Fuel



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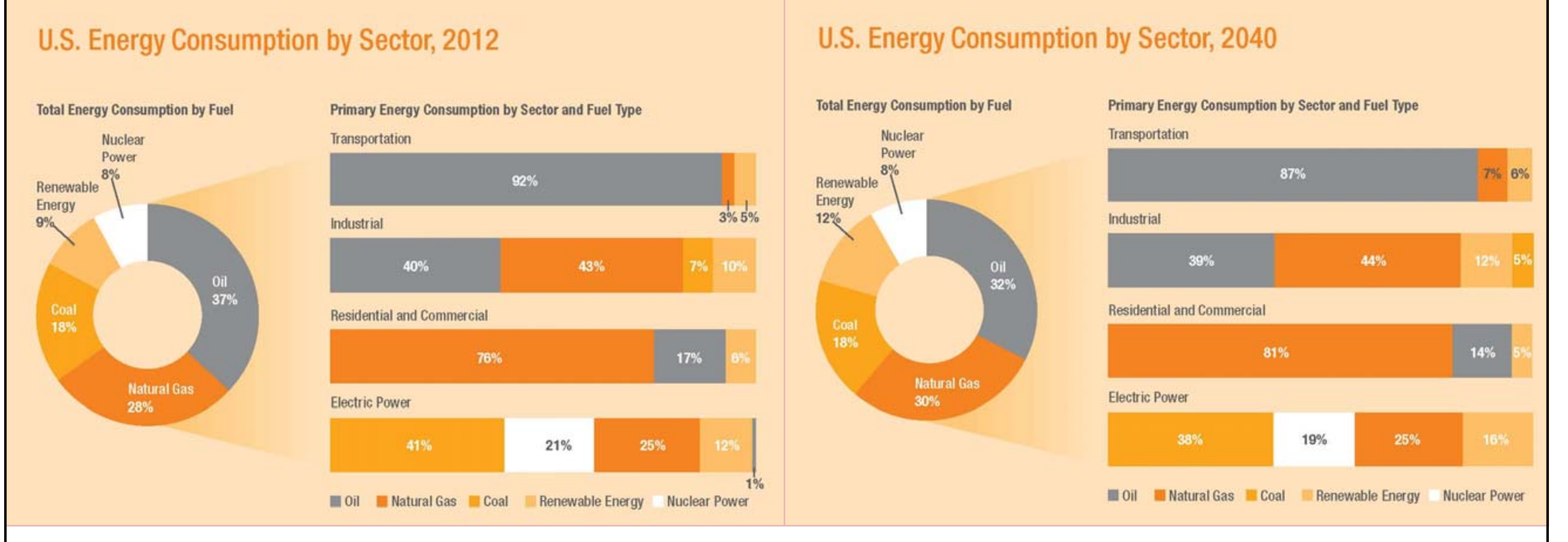
Data from http://www.eia.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_m.htm

API View “If It Ain’t Broke, Don’t Fix It.”

- Transportation solutions are primarily oil driven. Natural gas still is the major source of energy for electric power.
- The fundamental problem with this mix is its low energy efficiency. Internal combustion engines have an energy efficiency of about 20%. Jet airplanes and power stations have an efficiency of about 30-40%.



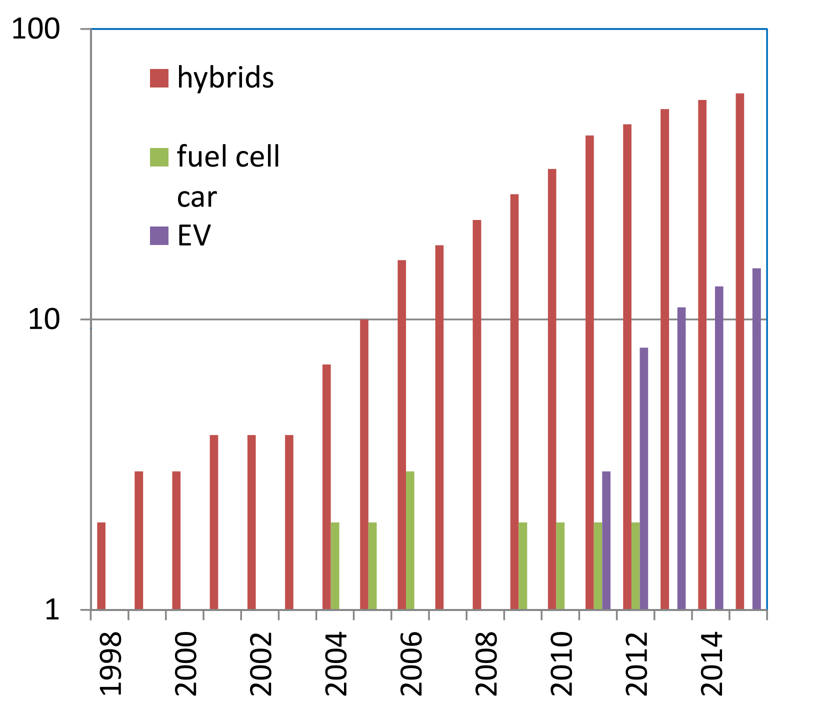
http://www.api.org/~/media/files/policy/soae-2015/api-2015-soae-report.pdf

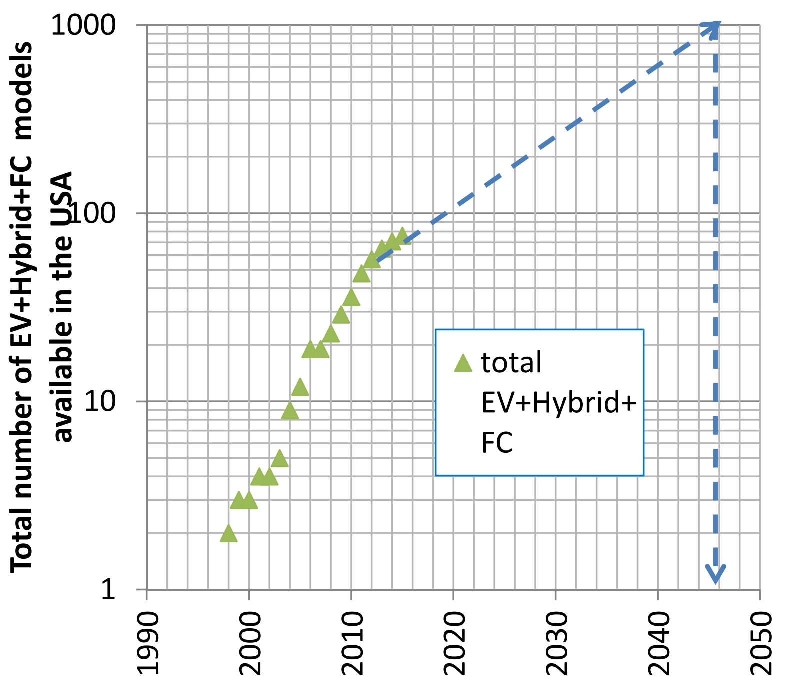
Disruptive Technologies

- Gasoline fueled cars => electric cars
- Electricity generated from fossil fuels => Solar
- How much solar power generation is needed?
- Airplanes => electric trains => magnetic levitation trains
- Efficiency and costs history and projections

Number Of Electrified Models Available In The US Market

Transportation consumes 46% of the oil in the US.





www.fueleconomy.gov data from annual fuel economy review by EPA and DOE

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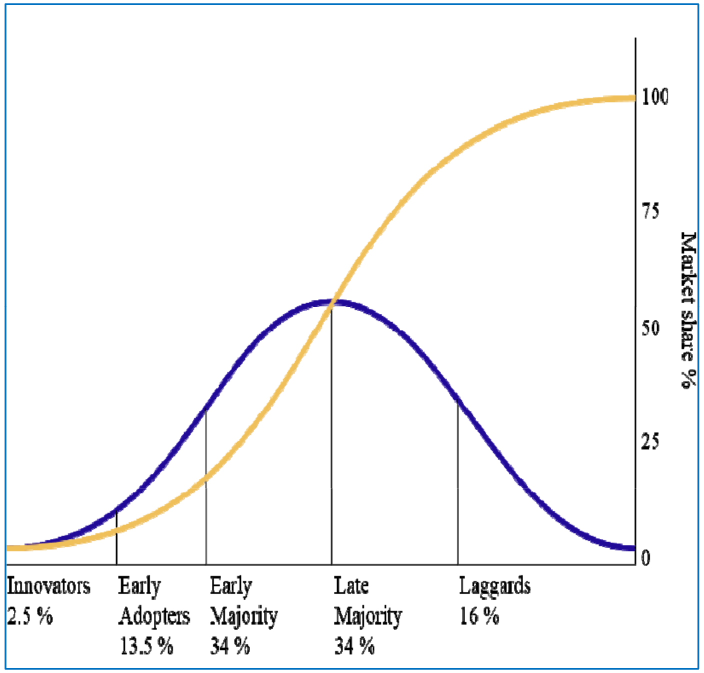
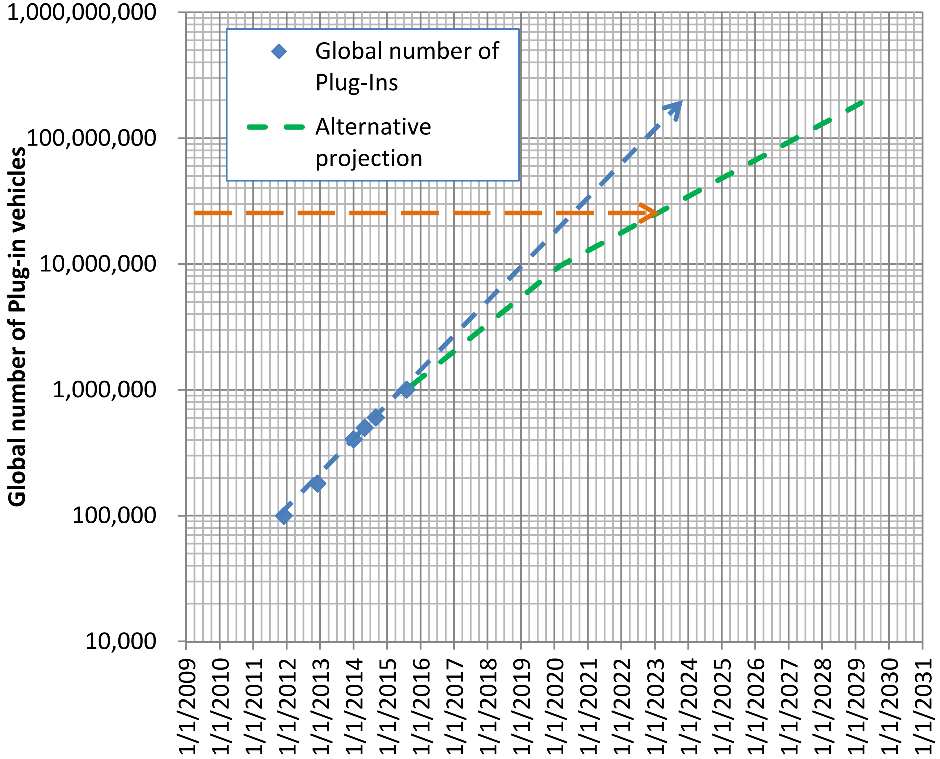
By 2023 We Should See The Trajectory Of Market Penetration by Electric Cars

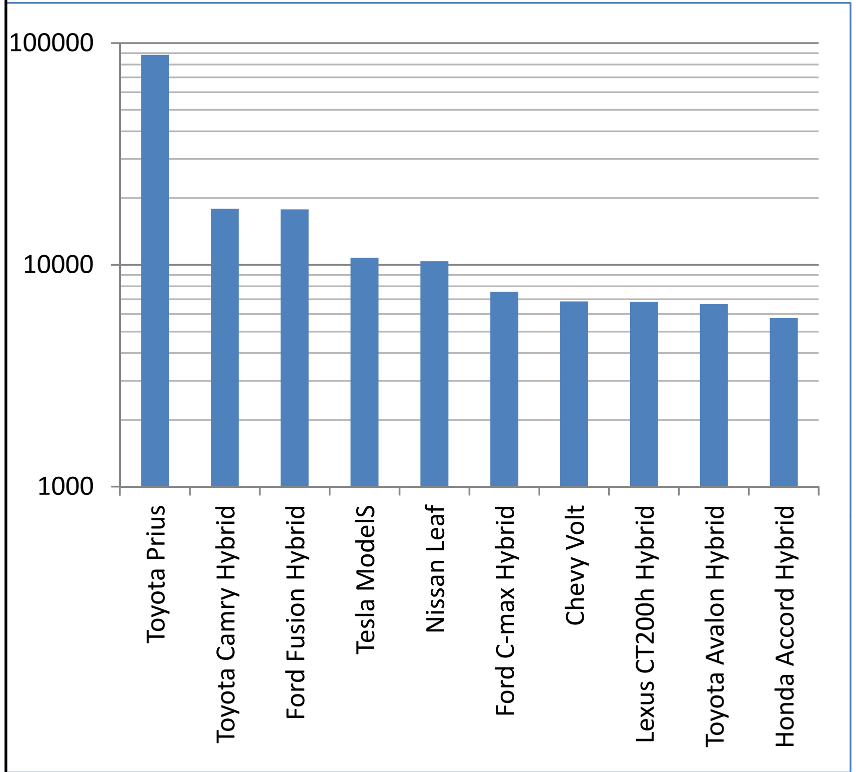
16% of total current number of automobiles is 176 million
2.5% of total number of automobiles is 27,5 million

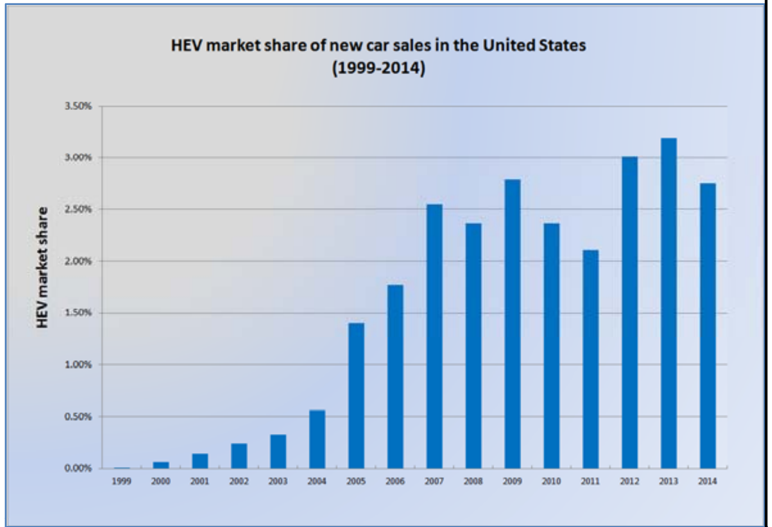


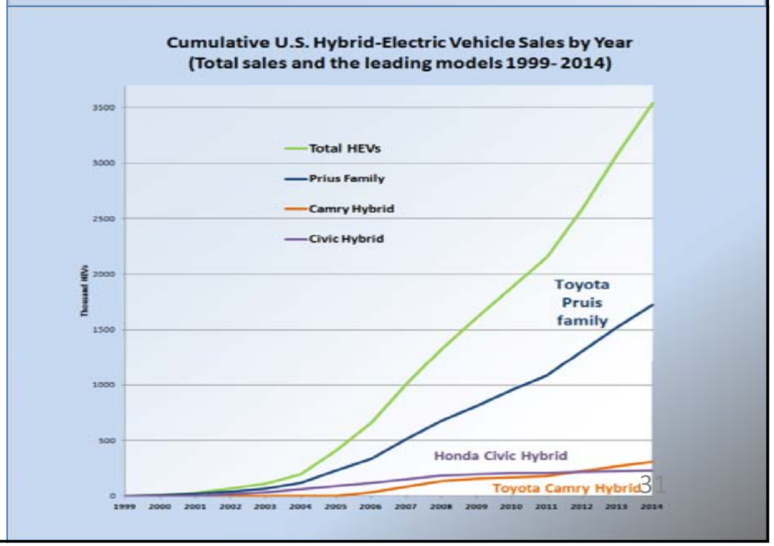


http://www.hybridcars.com/global-plug-in-car-sales-now-over-600000/ by Jeff Cobb October 22, 2014
http://cleantechnica.com/2015/09/21/1-million-evs-sold-worldwide/ by James Ayre September 21st, 2015

USA Sales Numbers Indicate A Transition From Innovators To Early Adopters



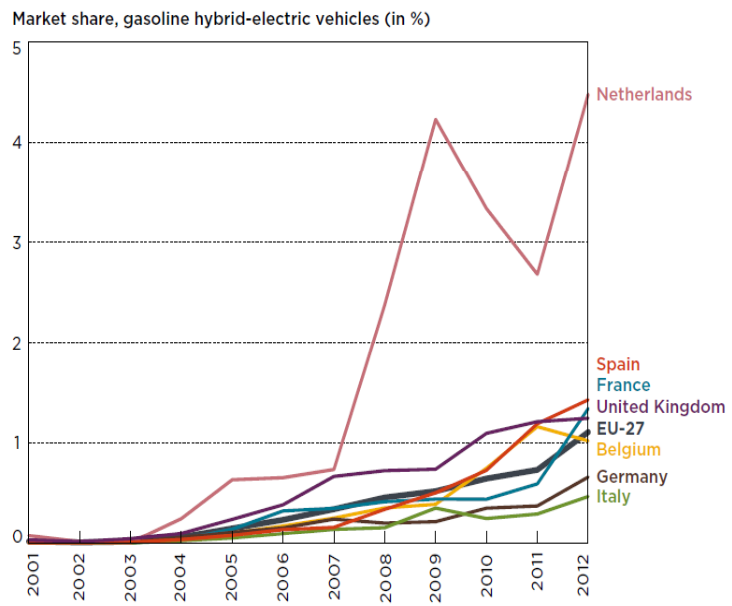




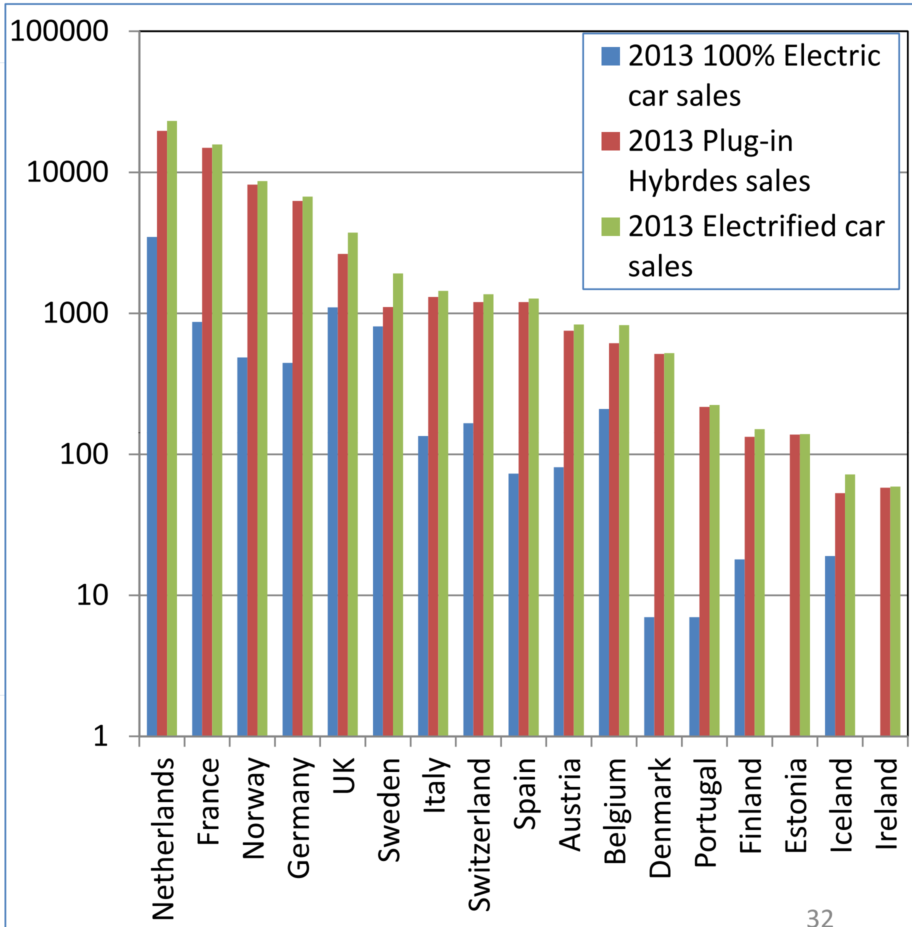
USA sales over Jan-May 2014. Estimated the year 2014 sales of 450000 units are about 2.5% of total USA sales. Today there are 1.4% of EV of the total fleet of 256 MM

Eric Schaal http://www.cheatsheet.com/automobiles/10-best-selling-electric-vehicles-and-hybrids-in-2014.html/?a=viewall
http://en.wikipedia.org/wiki/Hybrid_electric_vehicles_in_the_United_States

Electric Cars Account For 1% of Registrations In EU Member States



http://www.theicct.org/sites/default/files/publications/EU_vehiclemarket_pocketbook_2013_Web.pdf



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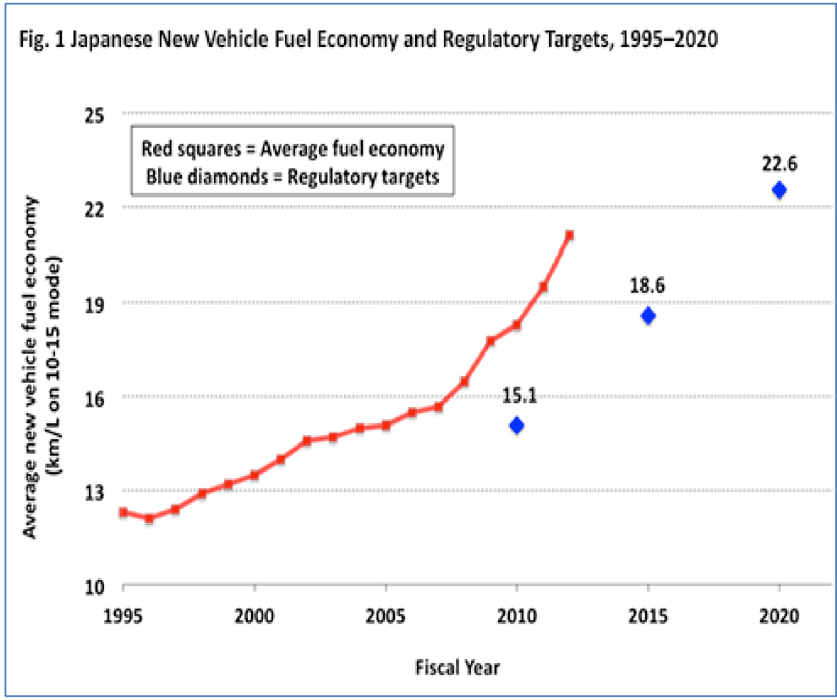
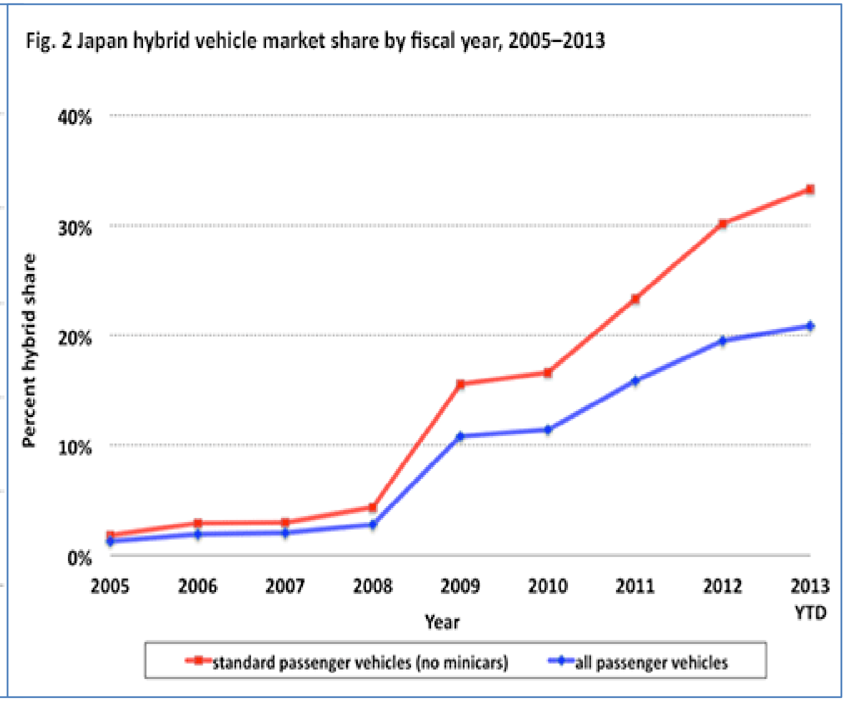
Hybrids Break Through In The Japan Auto Market



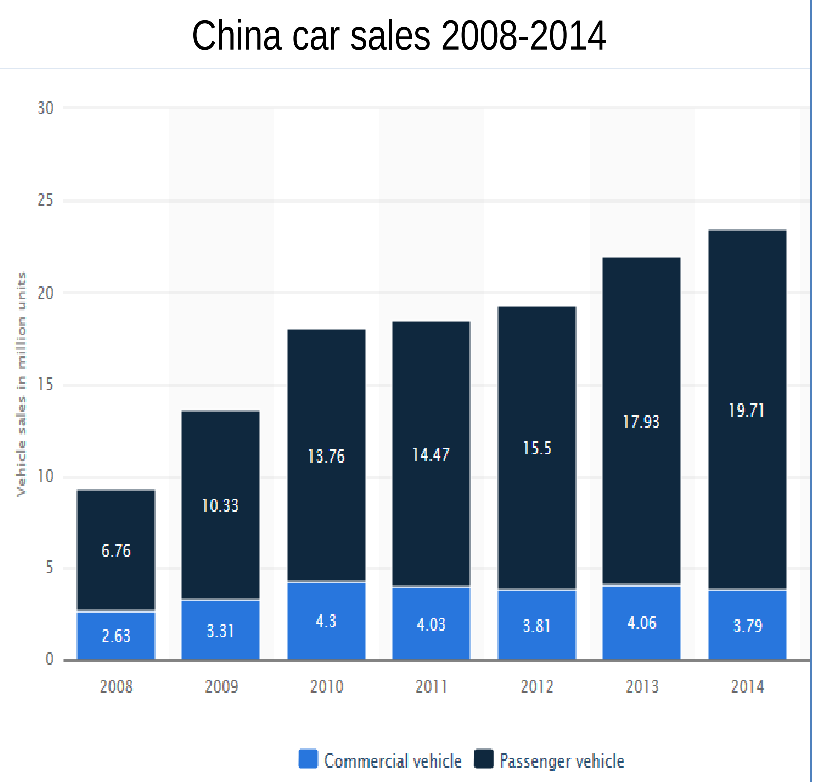


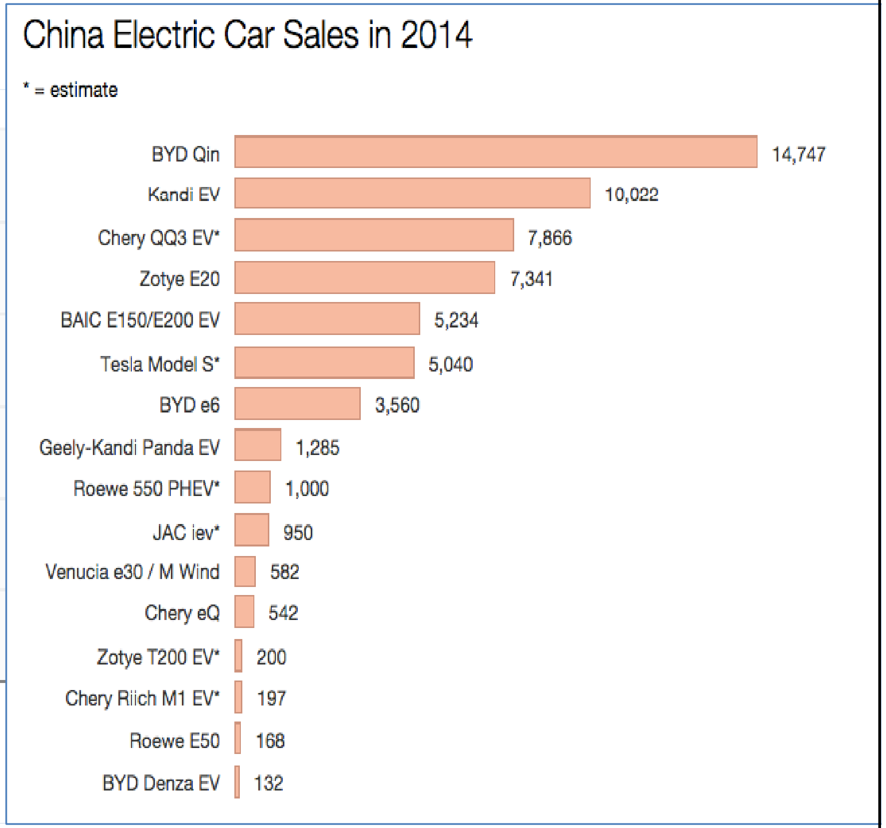
20 km/l = 47 miles/gallon

http://www.theicct.org/blogs/staff/hybrids-break-through-japan-auto-market
Published Fri, 2014.04.04 | By Dan Rutherford

China EV Story Is Amazing In Two Ways

Plug-in EV Sales in China rose 37.9% to 17,600 in 2013. Overall sales in 2014 appear to have more than tripled as compared to 2013, with total market share climbing to 0.25%. All the top selling models are Chinese made except for the Tesla model S.





http://chinaautoweb.com/2014/01/plug-in-ev-sales-in-china-rose-37-9-to-17600-in-2013/

http://evobsession.com/china-electric-car-sales-estimates-2014/ February 13th, 2015 by James Ayre

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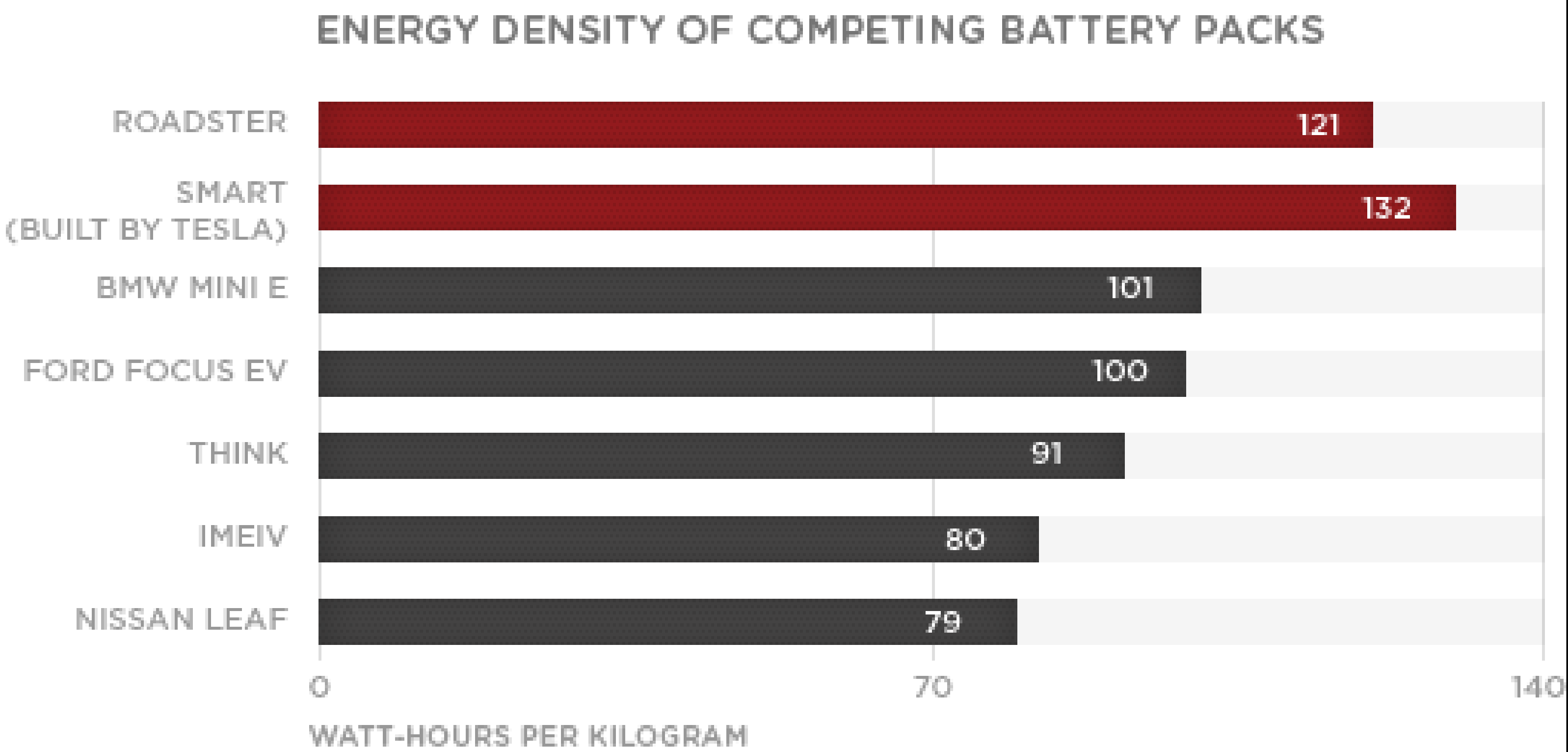
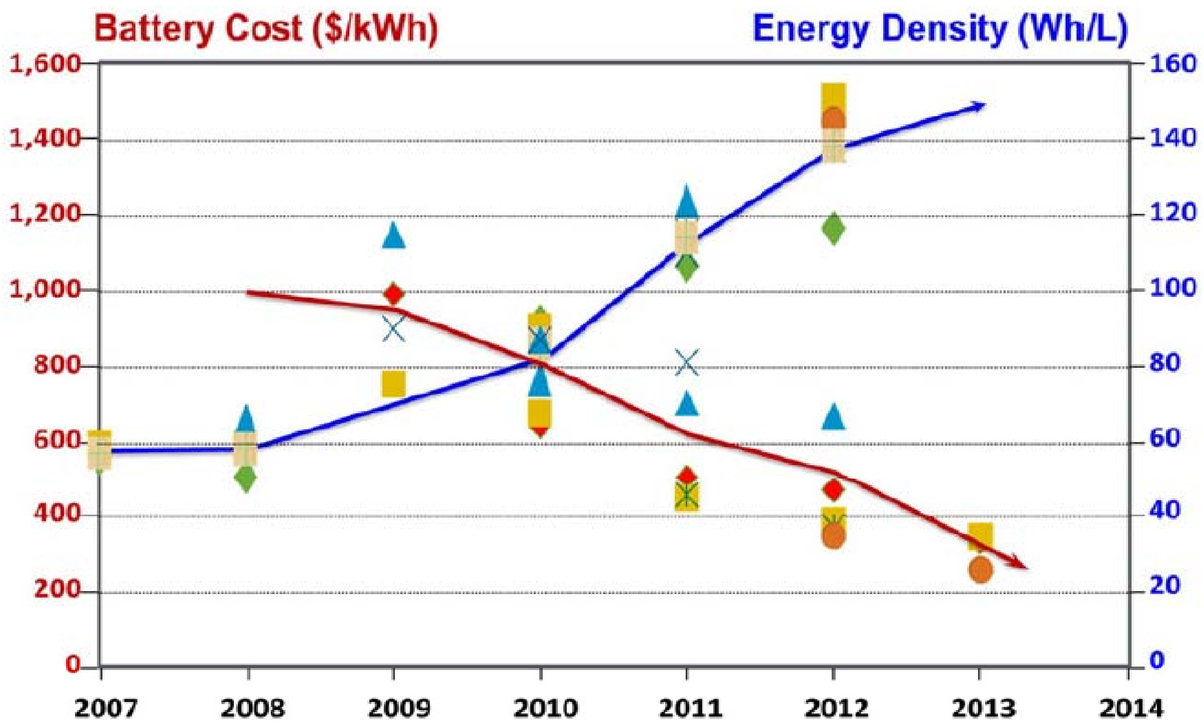
Current State Of Battery Technology



Tesla 85kWh battery has stored energy equivalent to the useful energy in 11 gallons of gas.

http://my.teslamotors.com/roadster/technology/battery

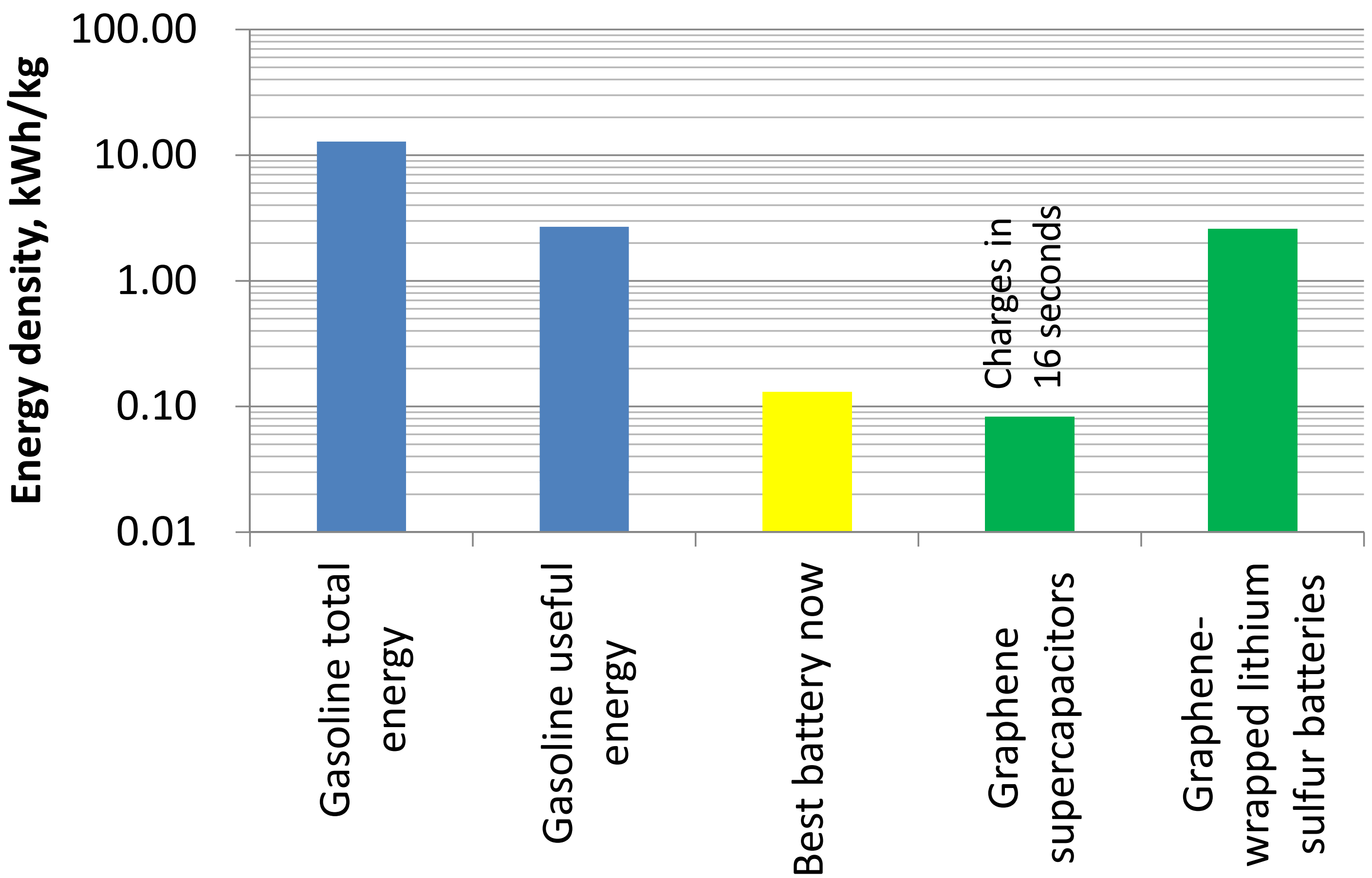
Cost And Energy Density Of EV Batteries



If battery life is 1,000 cycles, then the extra cost of storage of kWh is 20c/kWh.
If battery life is 10,000, then the extra cost is just 2c/kWh. Storage of solar energy becomes competitive.

http://energy.gov/sites/prod/files/2014/02/f8/eveverywhere_road_to_success.pdf
EV everywhere – Grand Challenge, US DOE

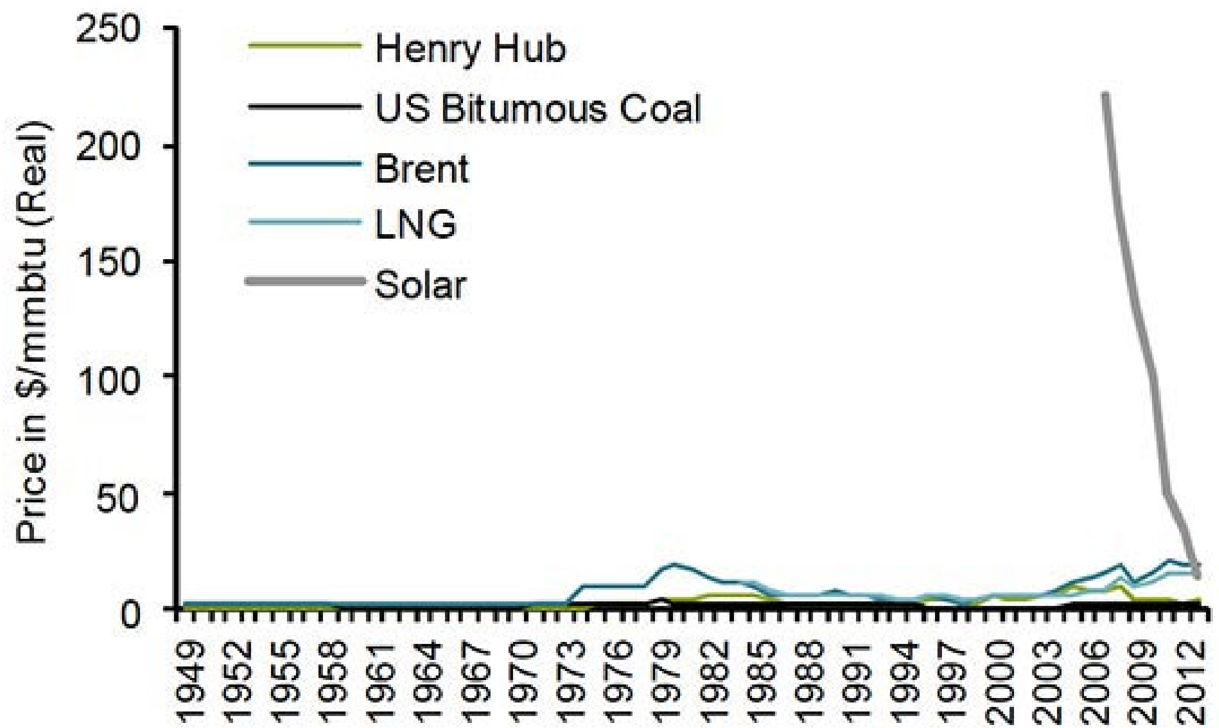
Principle Limitations Today Are Long Charging Times And Low Energy Density



5 October 2010. The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics for 2010 to Andre Geim and Konstantin Novoselov "for groundbreaking experiments regarding the two-dimensional material graphene“.
http://www.nobelprize.org/nobel_prizes/physics/laureates/2010/press.html

Bernstein said "Welcome to Terrordome"

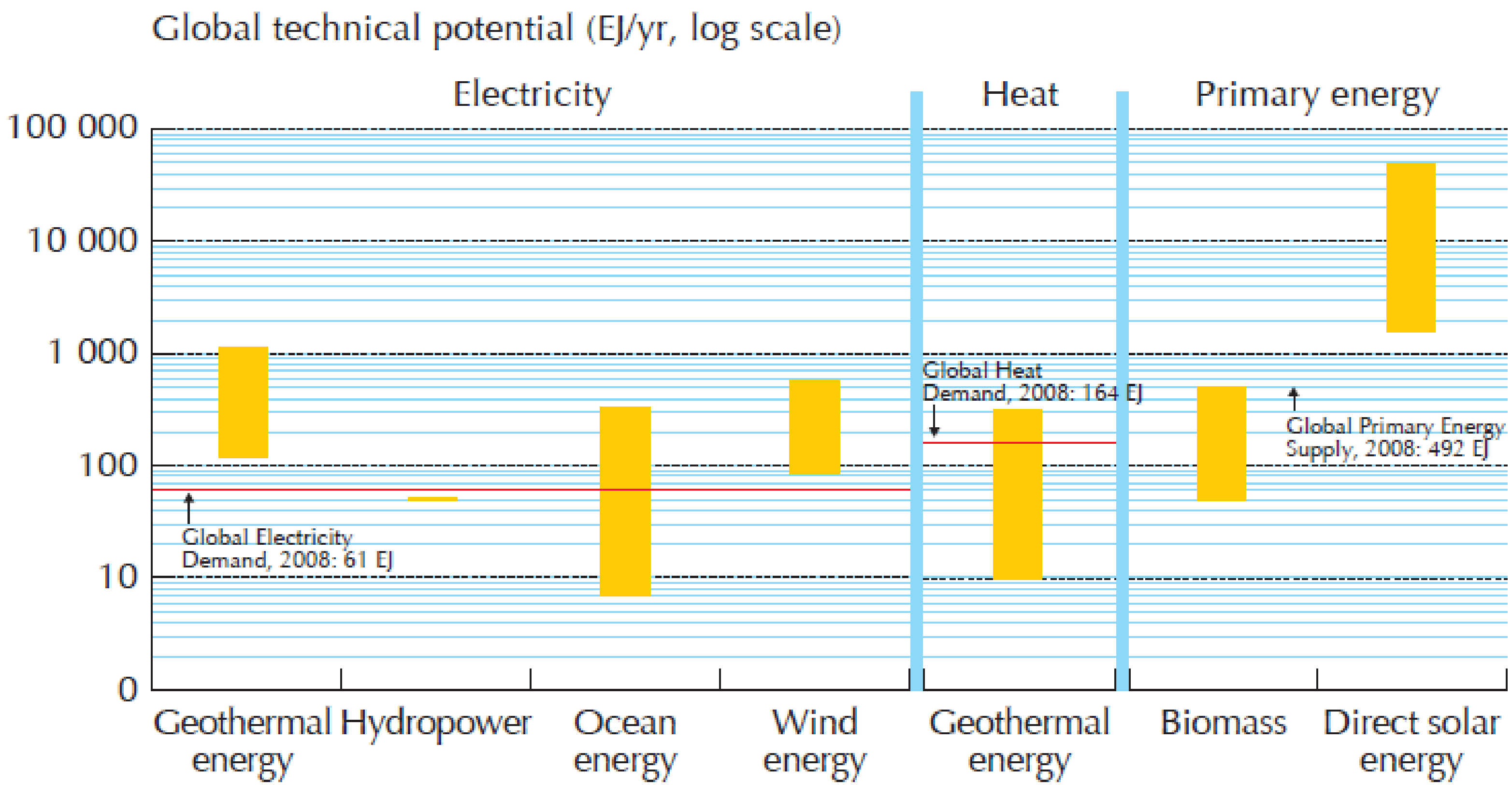
Electric power generation and heating consumes 21% of the oil in the USA.



http://reneweconomy.com.au/wp-content/uploads/2014/04/Bernstein-solar.pdf

Bernstein Energy & Power Blast: Equal and Opposite… If Solar Wins, Who Loses; By Michael Parker, Hugh Wynne, Neil Beveridge, Oswald Clint, Bob Brackett, Scott Gruber, April 4, 2014

Available Energy Resources



Technical potentials reported here represent the range of estimates for total worldwide potentials for annual RE supply and do not deduct any potential that is already being utilized. 1 exajoule (EJ) ≈ 278 terawatt hours (TWh).

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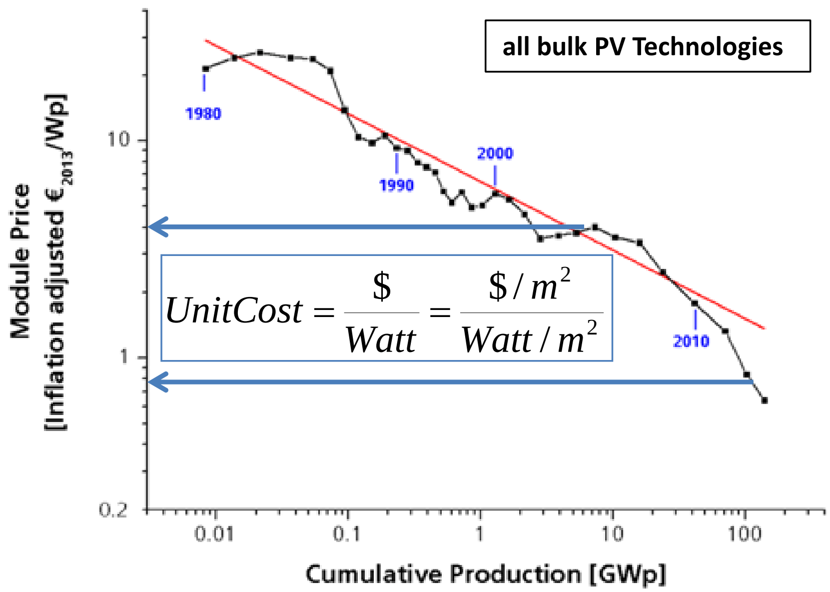
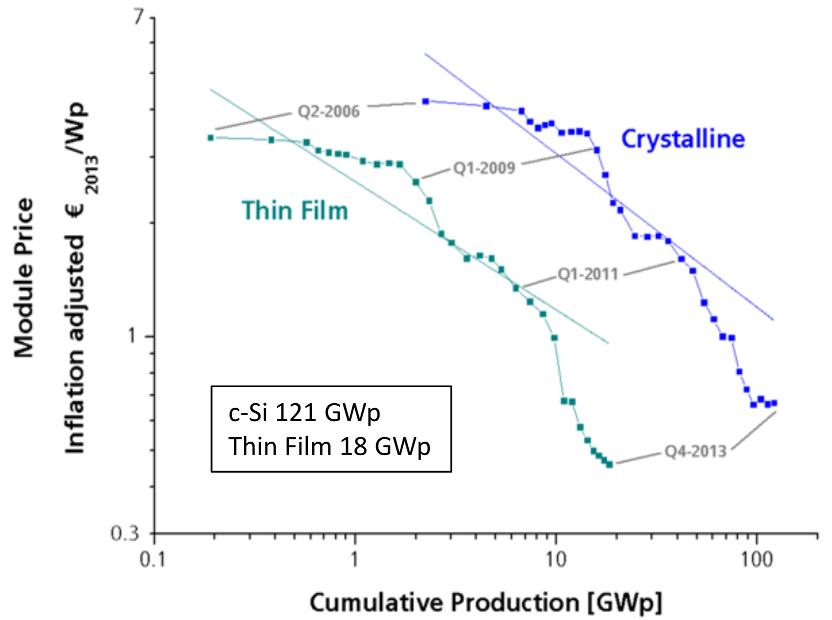
Solar Energy Perspectives © OECD/IEA, 2011

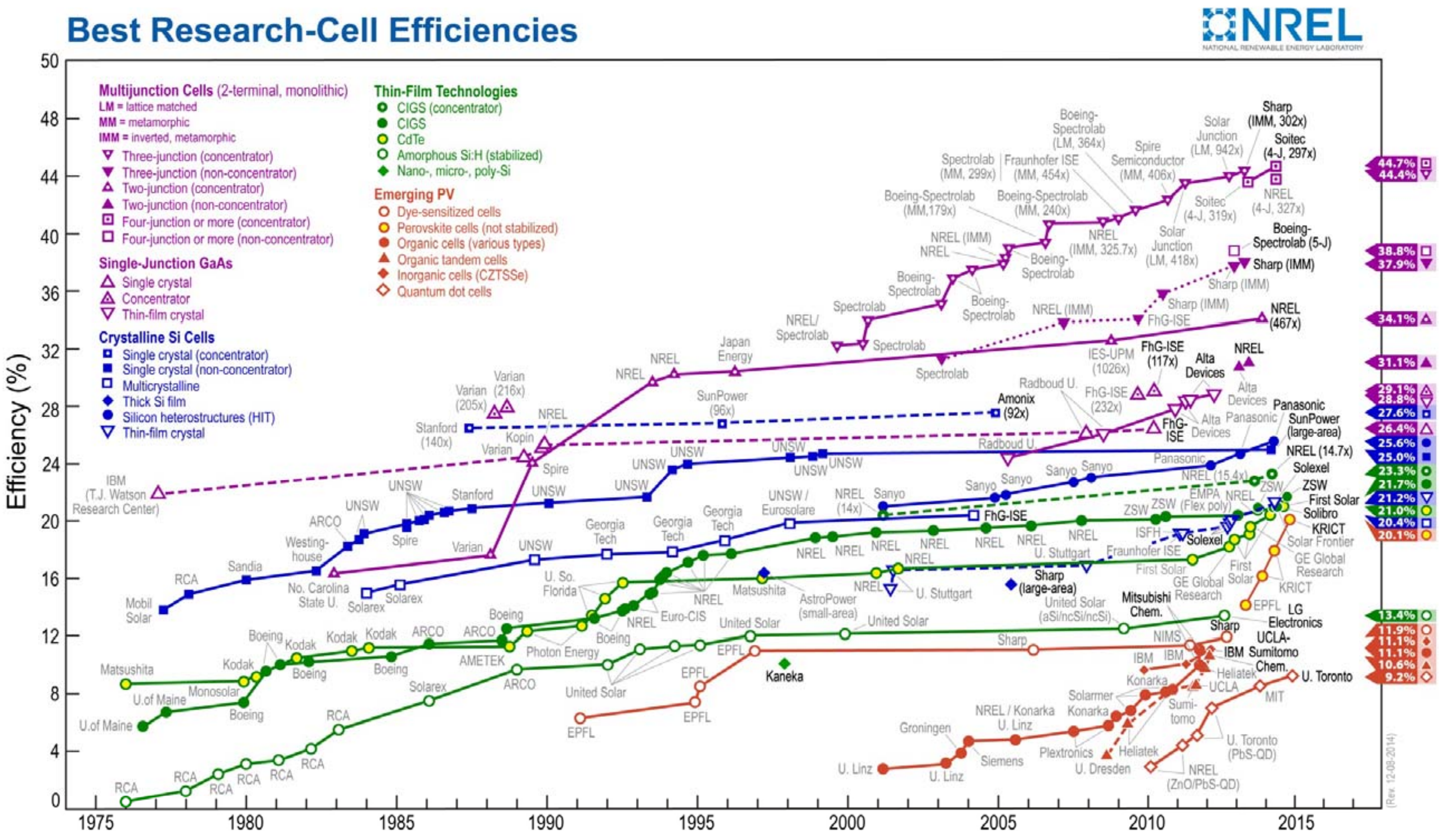
Price Learning Curve - Swanson's Law

- Learning Rate: Each time the cumulative production doubled, the price went down by 20 % for the last 33 years. Learning rate for Crystalline Technology (from Q2-2006 to Q4-2013) is **24.5 %.** Learning rate for Thin Film Technology (from Q2-2006 to Q4-2013) is **20.9 %.**
- In Germany prices for a typical 10 to 100 kWp PV rooftop-system were around 14,000 €/kWp in 1990. At the end of 2013, such systems cost about 1,350 €/kWp. This is a net-price regression of 89 % over a period of 23 years and is equivalent to an annual compound average price reduction rate of 9 %.





FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE "Photovoltaics Report". Freiburg, 24 October 2014, www.ise.fraunhofer.de 40
Dr. Simon Philipps (Fraunhofer ISE) simon.philipps@ise.fraunhofer.de and Werner Warmuth (PSE AG) warmuth@pse.de


Best Research-Cell Efficiencies
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Multijunction Cells (2-terminal, monolithic)
LM = lattice matched
MM = metamorphic
IMM = inverted, metamorphic
Three-junction (concentrator)
Three-junction (non-concentrator)
Two-junction (concentrator)
Two-junction (non-concentrator)
Four-junction or more (concentrator)
Four-junction or more (non-concentrator)
Single-Junction GaAs
Single crystal
Concentrator
Thin-film crystal
Crystalline Si Cells
Single crystal (concentrator)
Single crystal (non-concentrator)
Multicrystalline
Thick Si film
Silicon heterostructures (HIT)
Thin-film crystal
Thin-Film Technologies
CIGS (concentrator)
CIGS
CdTe
Amorphous Si:H (stabilized)
Nano-, micro-, poly-Si
Emerging PV
Dye-sensitized cells
Perovskite cells (not stabilized)
Organic cells (various types)
Organic tandem cells
Inorganic cells (CZTSSe)
Quantum dot cells
Efficiency (%)
0
4
8
12
16
20
24
28
32
36
40
44
48
50
1975
1980
1985
1990
1995
2000
2005
2010
2015
44.7%
44.4%
38.8%
37.9%
34.1%
31.1%
29.1%
28.8%
27.6%
26.4%
25.6%
25.0%
23.3%
21.7%
21.2%
21.0%
20.4%
20.1%
13.4%
11.9%
11.1%
11.1%
10.6%
9.2%
(Rev. 12-08-2014)

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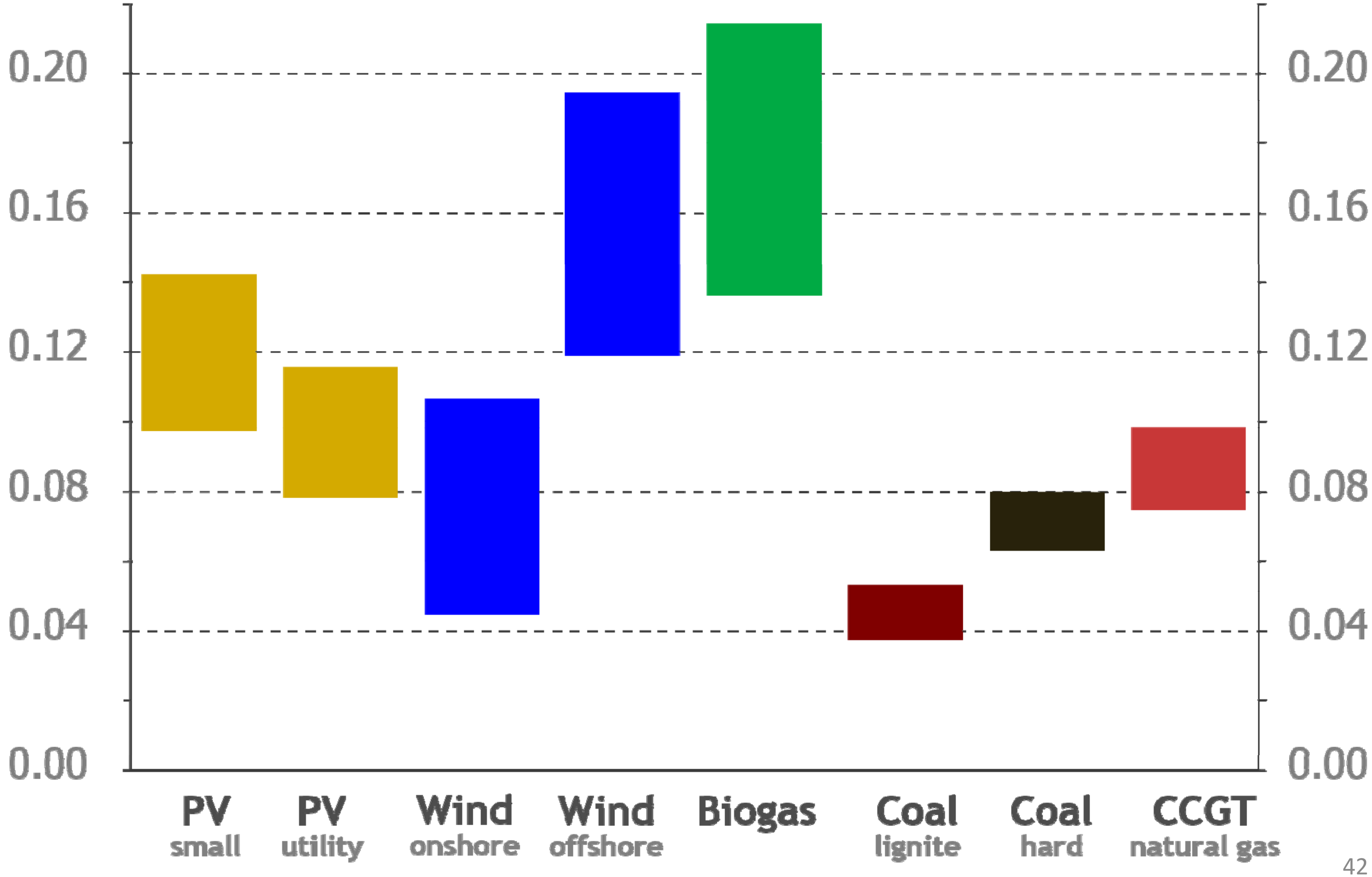
Levelized Cost of Electricity in € per kWh

Source: Fraunhofer ISE, Germany November 2013



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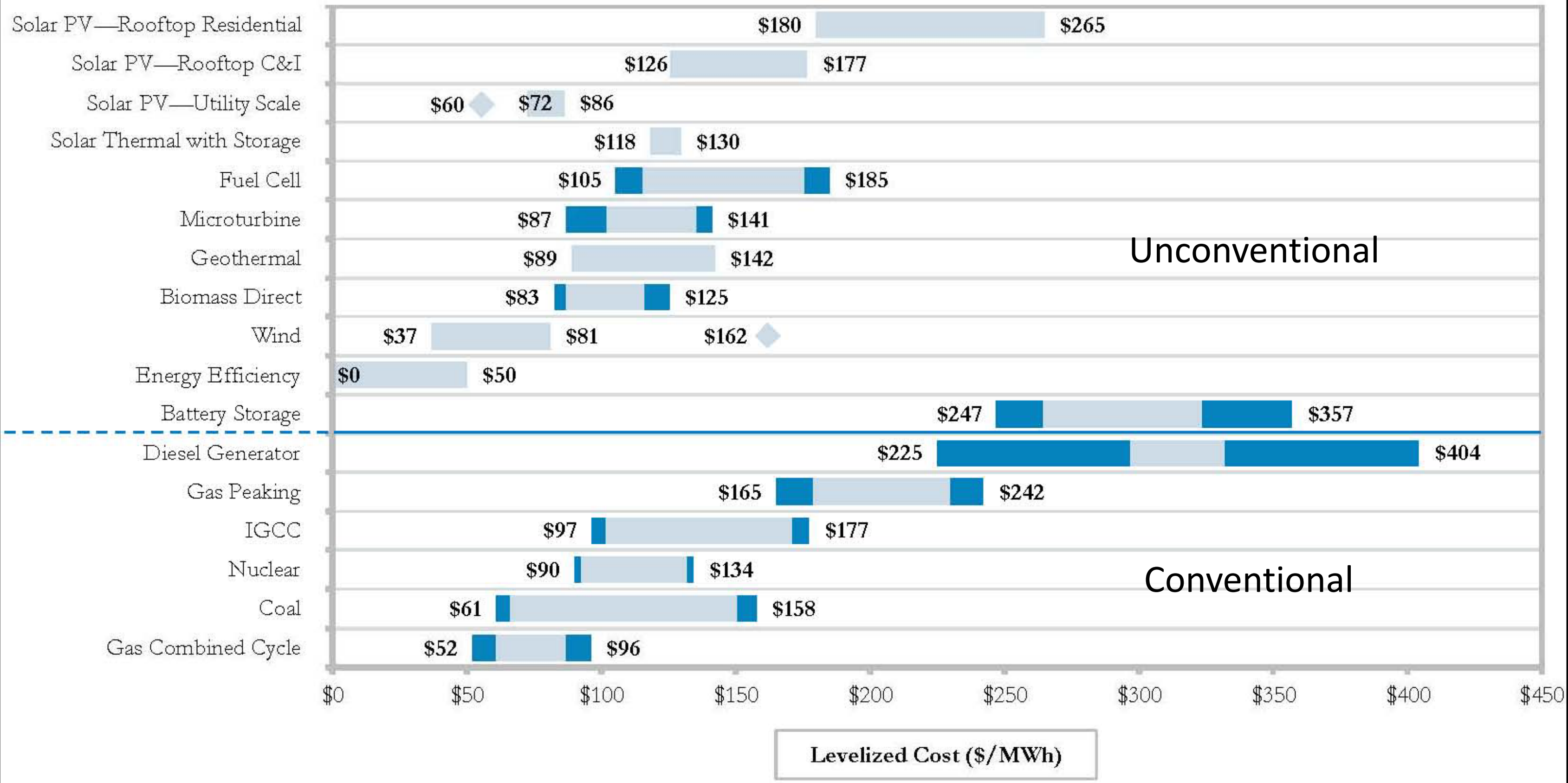
Levelized Cost Of Energy Comparison— Sensitivity to Fuel Prices

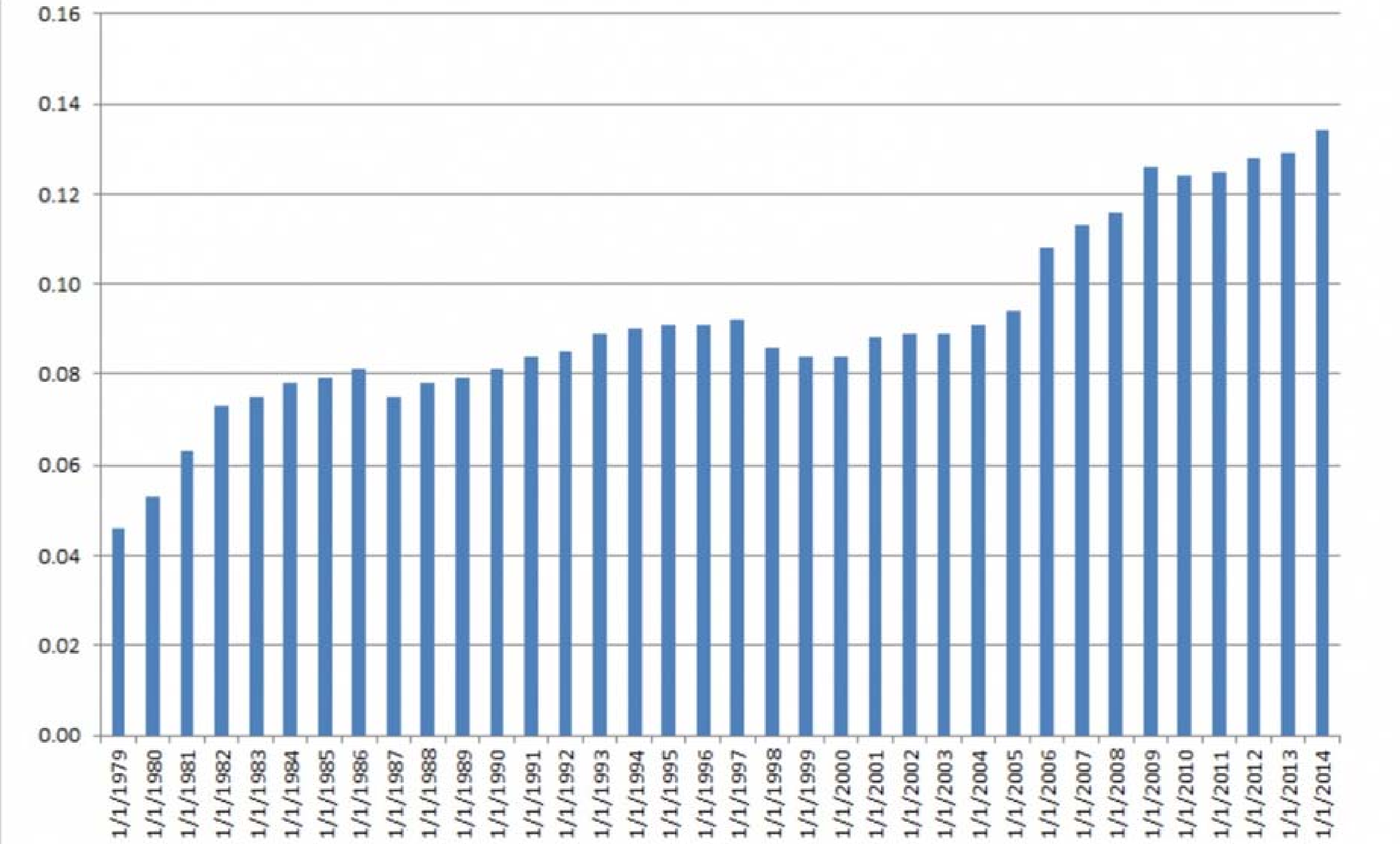


Darkened areas in horizontal bars represent low end and high end levelized cost of energy corresponding with ±25% fuel price fluctuations.

Lazard's levelized cost of energy analysis — version 8.0 September 2014

Average Price For 1 kWh In January

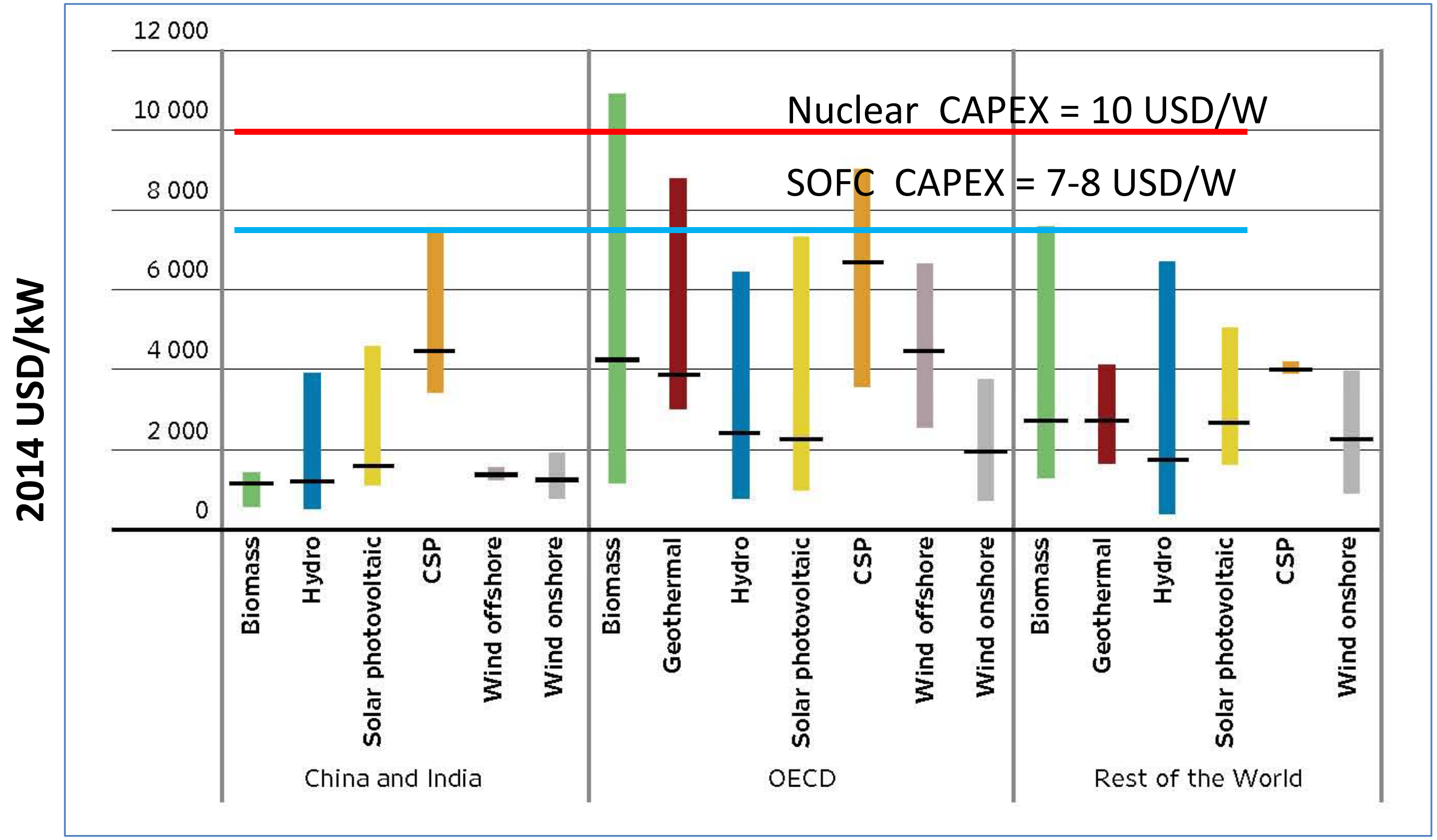
Tripled Over 35 Years



Source: Bureau of Labor Statistics

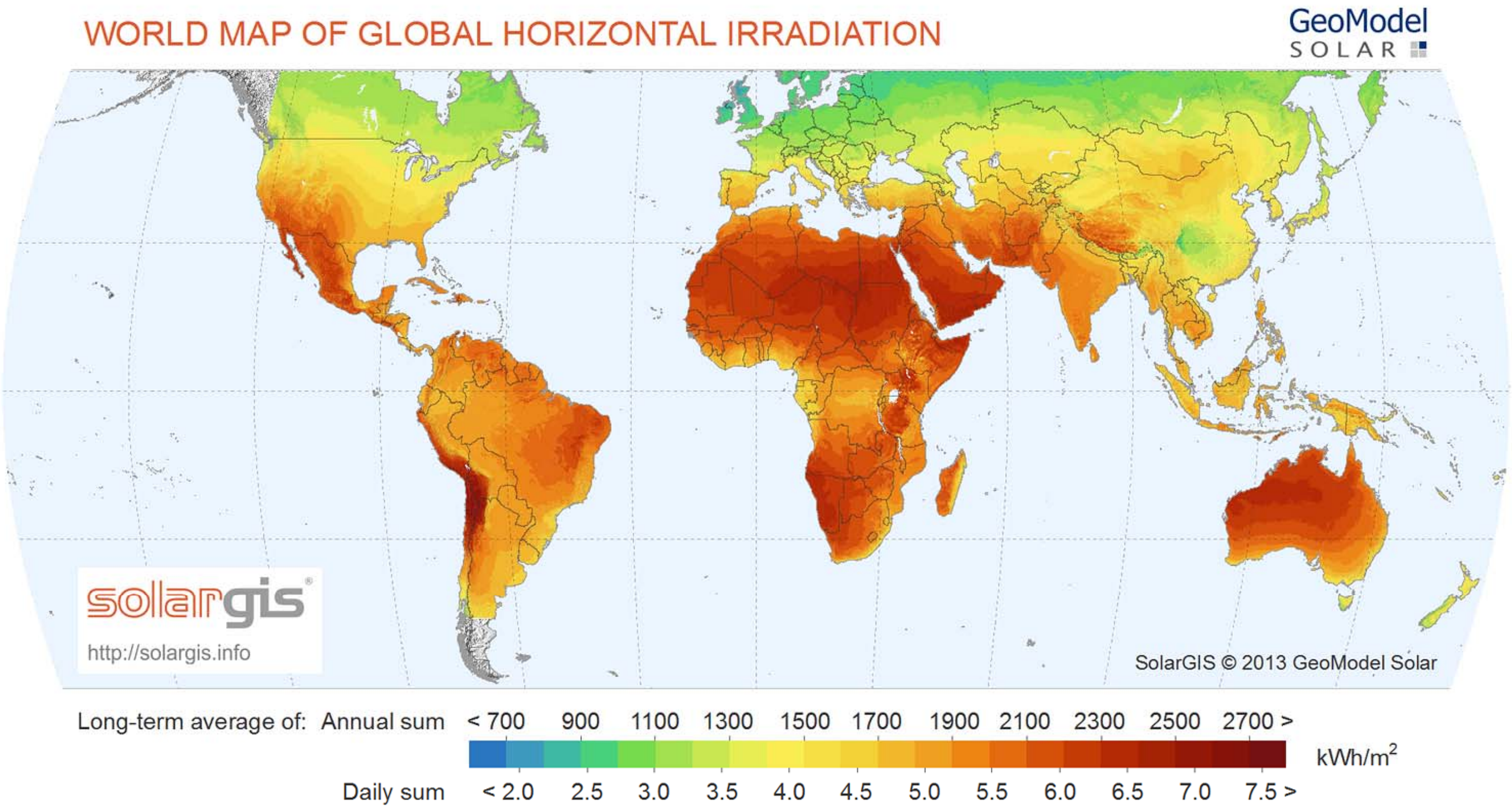
Solar Is Affordable And Competitive

Typical ranges and weighted averages for the total installed costs of utility-scale renewable power generation technologies by region, 2013/2014.

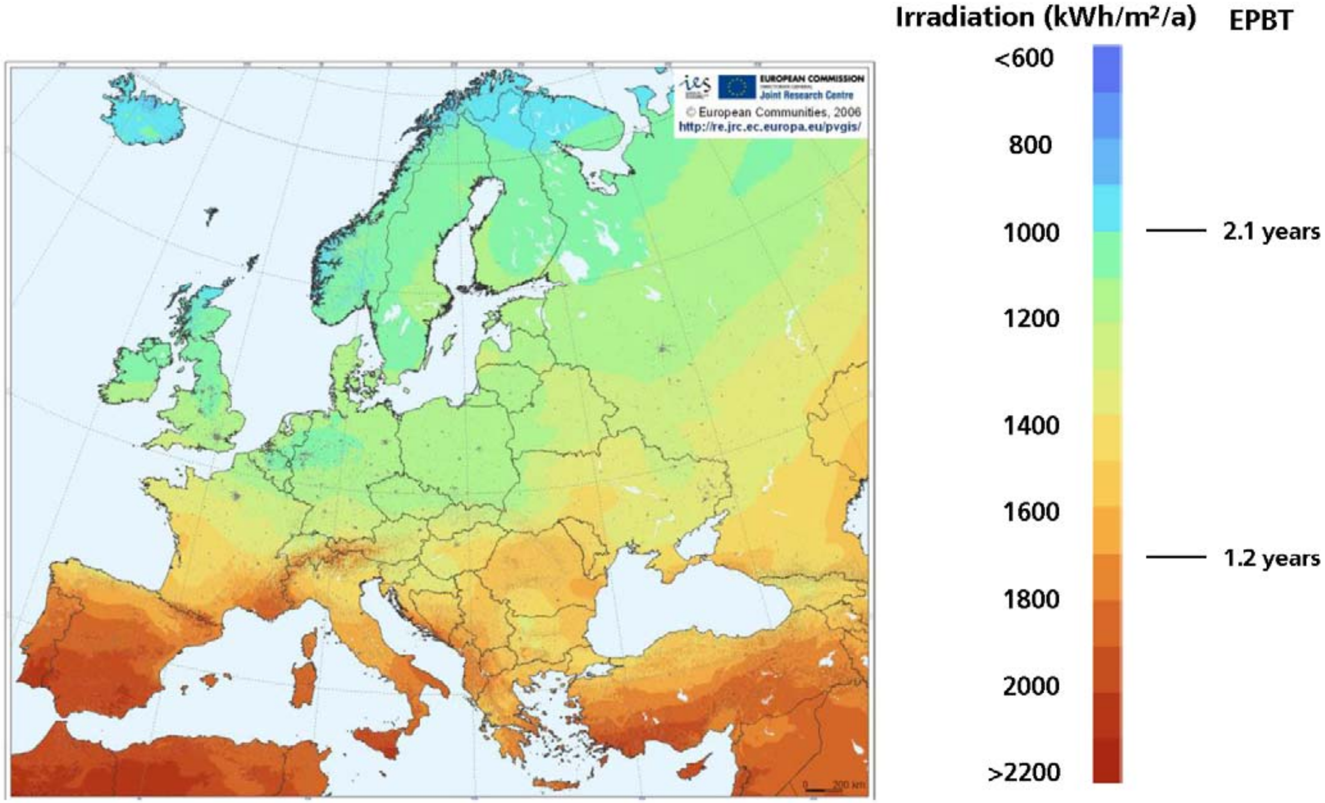


IRENA. Renewable power generation costs in 2014
http://www.irena.org/DocumentDownloads/Publications/IRENA_RE_Power_Costs_Summary.pdf

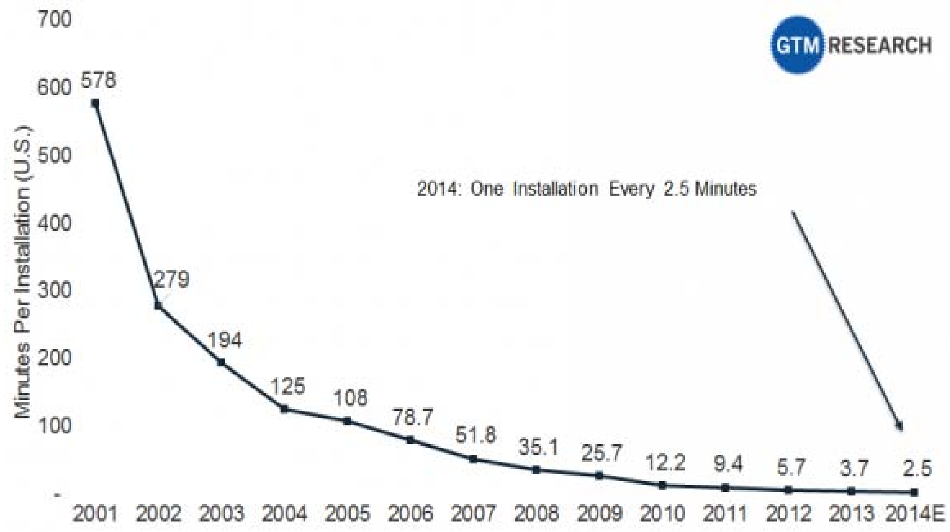
254*254 km of Solar Panels In The Sahara Can Supply The Entire World With Energy



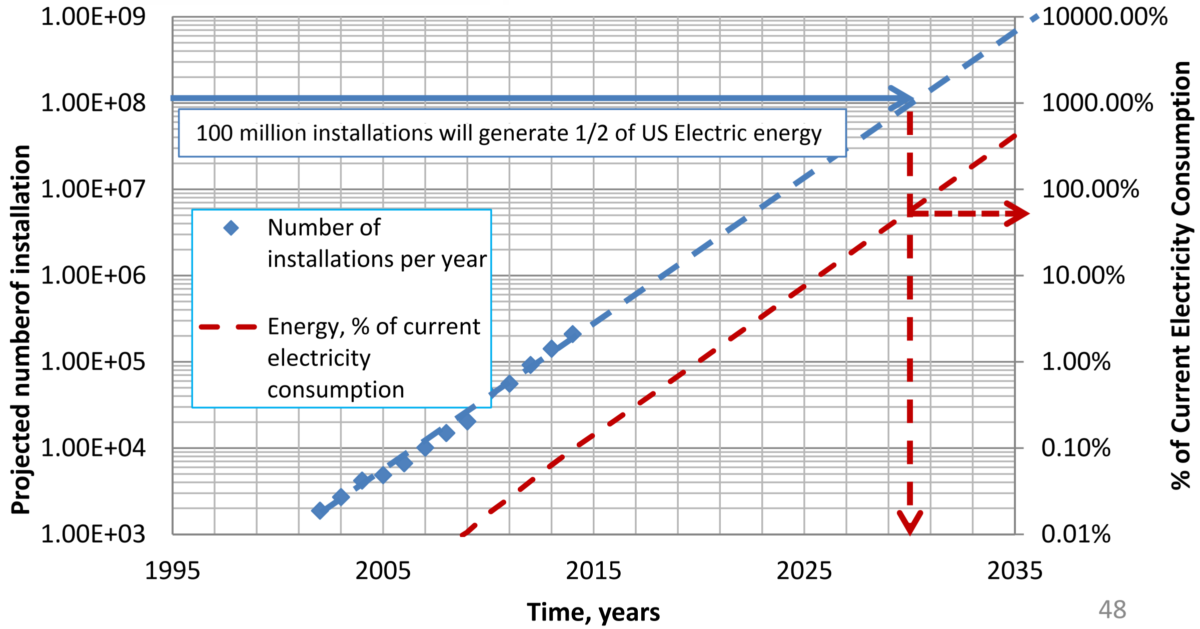
Pay Back Time for Multicrystalline Silicon PV Rooftop Systems - Geographical Comparison



Data: M.J. de Wild-Scholten 2013. Image: JRC European Commision. Graph: PSE AG 2014 (Modified scale with updated data from PSE AG and FraunhoferISE)
FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE "Photovoltaics Report". Freiburg, 24 October 2014, www.ise.fraunhofer.de
Dr. Simon Philipps (Fraunhofer ISE) simon.philipps@ise.fraunhofer.de and Werner Warmuth (PSE AG) warmuth@pse.de

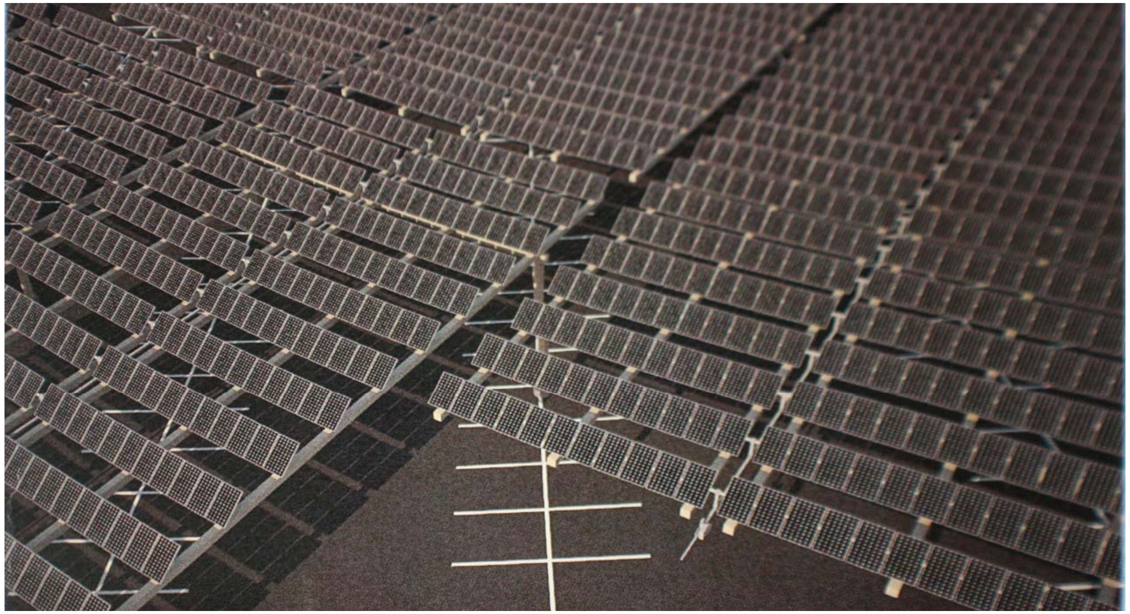


50% of US electricity may come from residential solar in our life time



Transforming Parking Lots Into Power Plants

Bakersfield College



Number of Parking spots in the USA	800,000,000
Area (8.5*21 ft)	16.58
Share of parking spots under the sun	50%
Total area that can be harvested, m2	6,633,277,056
Annual Global Horizontal Irradiation, kW*h/m2 (Average in USA)	1600
Conversion efficiency, %	20
Annual energy generation potential, kW*h	2.1E+12
Electric power consumption (kWh) in the United States	4.1E+12
Share of electric power consumption	51%

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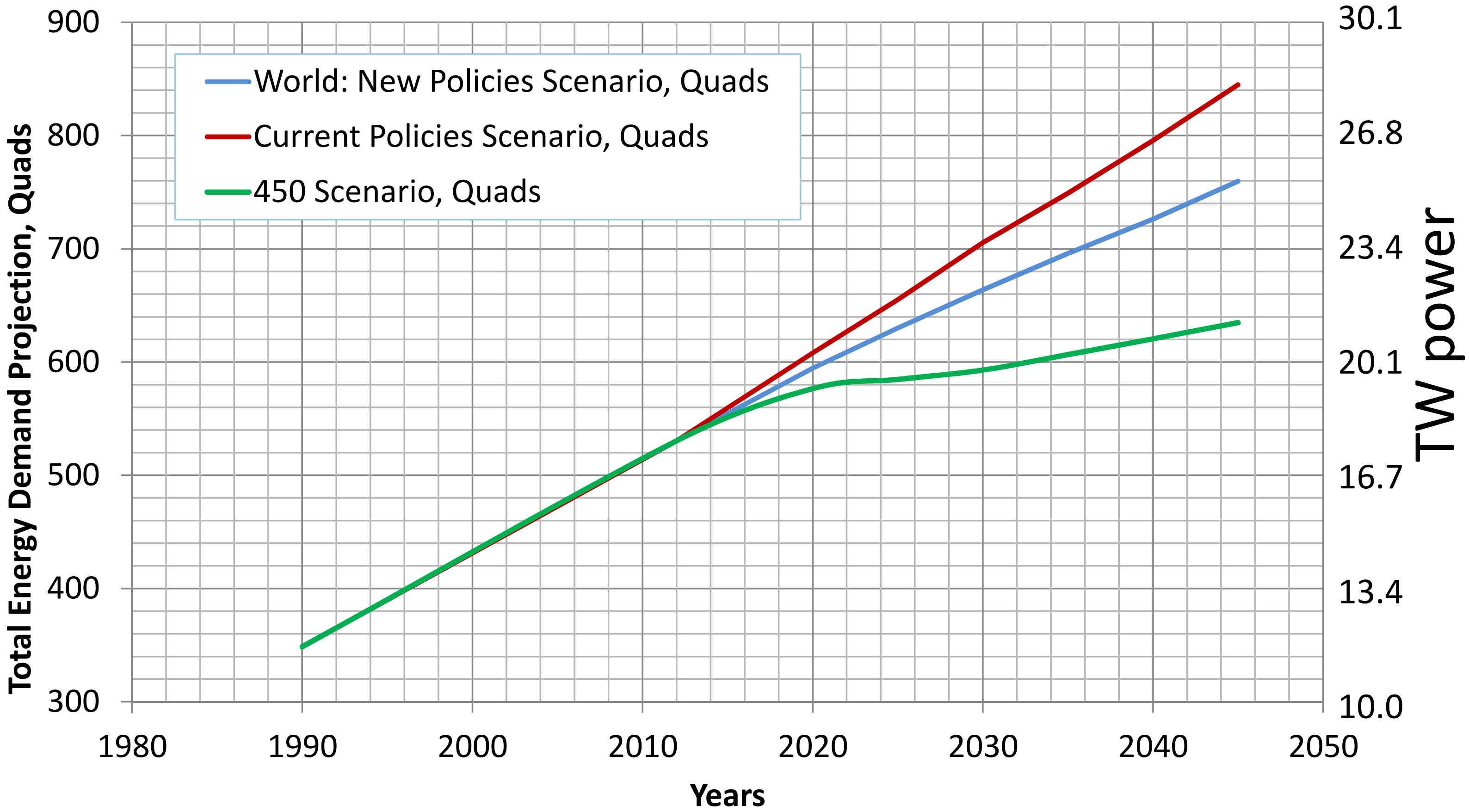
Photo credit http://solairegeneration.com/

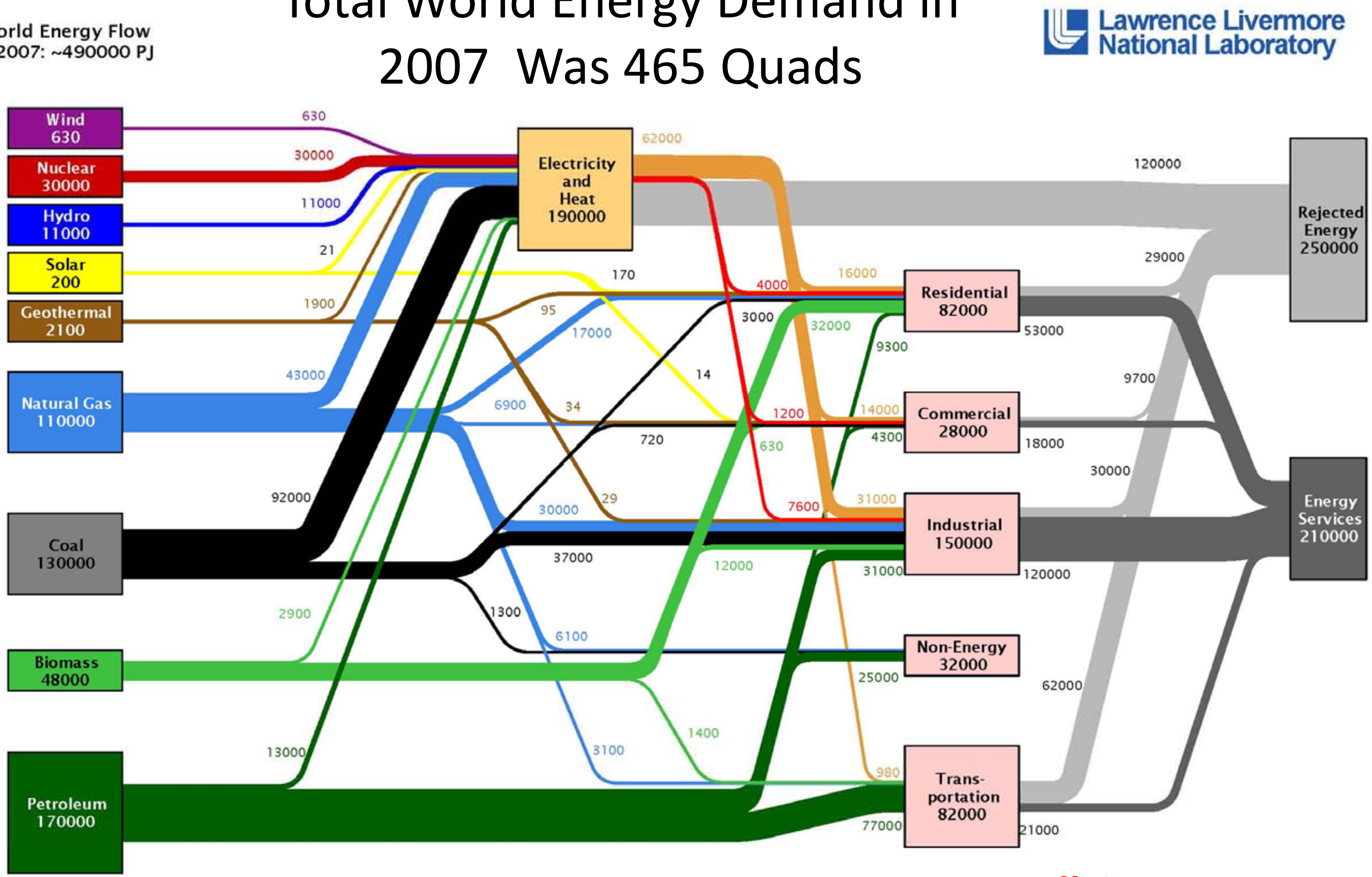
World Total Energy Demand Projection



Source: World Energy Outlook 2014

Total World Energy Demand in 2007 Was 465 Quads

World Energy Flow in 2007: ~490000 PJ



Most energy is wasted in electricity generation 63.2% and transportation 75.6%

Energy efficiency = 45.65%

Source: LLNL 2011. Data is based on IEA's Extended World Energy Balances. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the U.S. Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 PJ are not included. Totals may not equal sum of flows due to statistical differences. Domestic supply includes changes in stocks. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov. LLNL-TR-473098.

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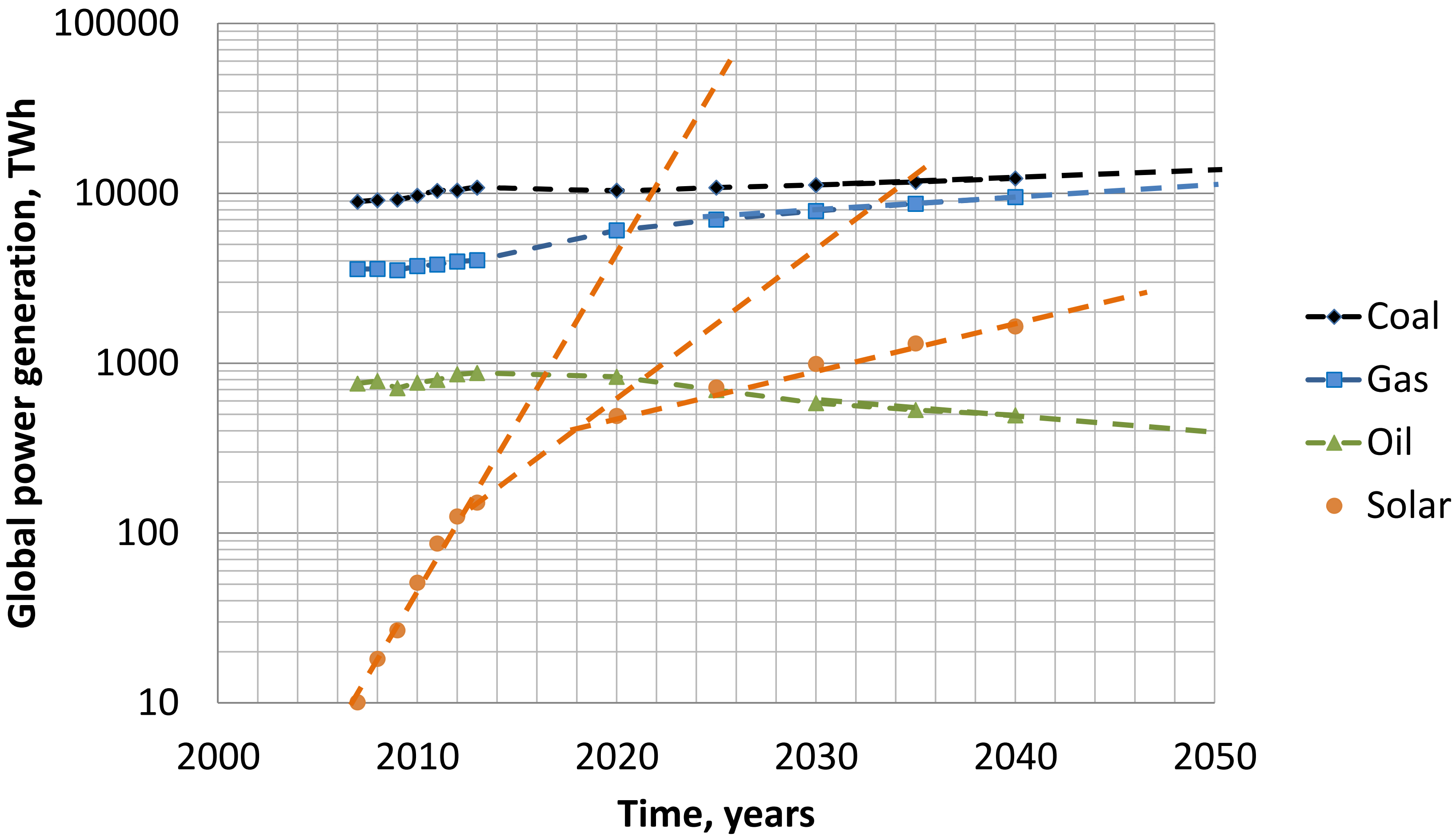
Solar Will Probably Overtake Fossil Fuels In Power Generation In Our Life Time

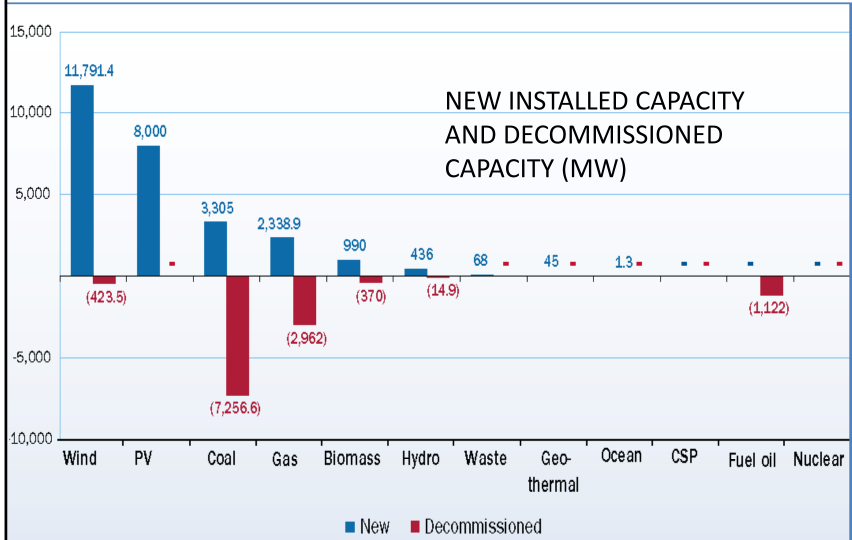


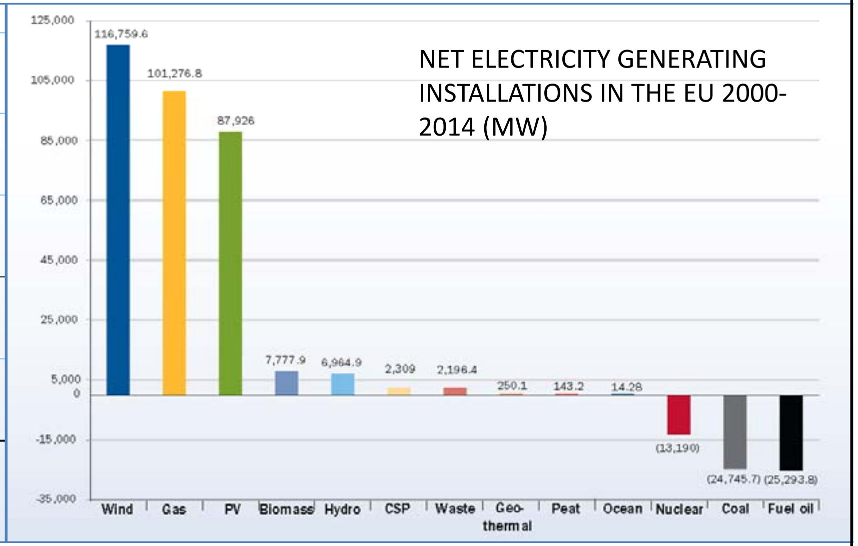
Source: World Energy Outlook 2014 New Policies Scenario
Historical data by Hanergy Research Team, Bloomberg New Energy Finance

The Transition In Electric Energy Generation In Europe Is Happening Now

Europe's fossil fuel capacity declined in 2014

It is a part of the long term trend

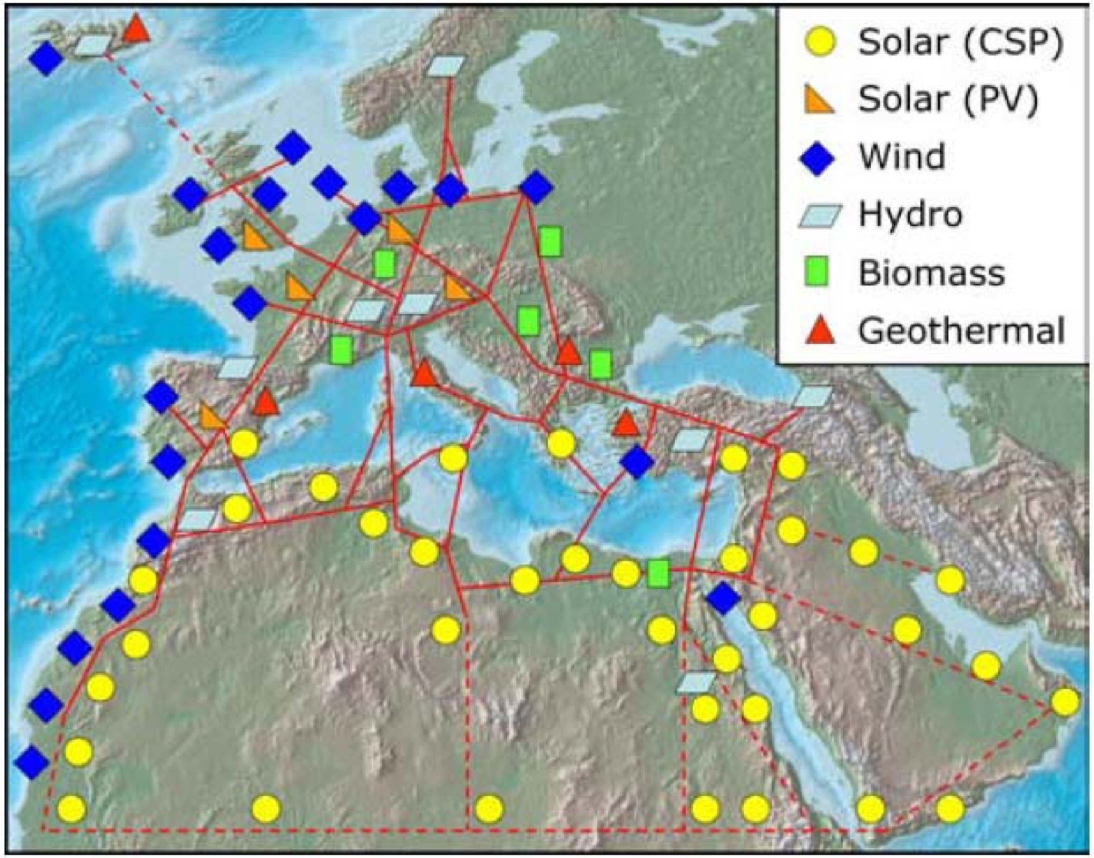




http://www.energymatters.com.au/renewable-news/wind-power-eu-em4684/

A Vision Of A Future Euro-Mediterranean Grid

Interconnecting sites with large renewable electricity sources and sites with high demand for clean energy .



http://www.menarec.org/resources/Trieb_EUMENA_Whitebook_02.pdf
Sustainable electricity and water for Europe Middle East and North Africa By Franz Trieb and Hans Müller-Steinhagen

DCHV Transmission Is a Key

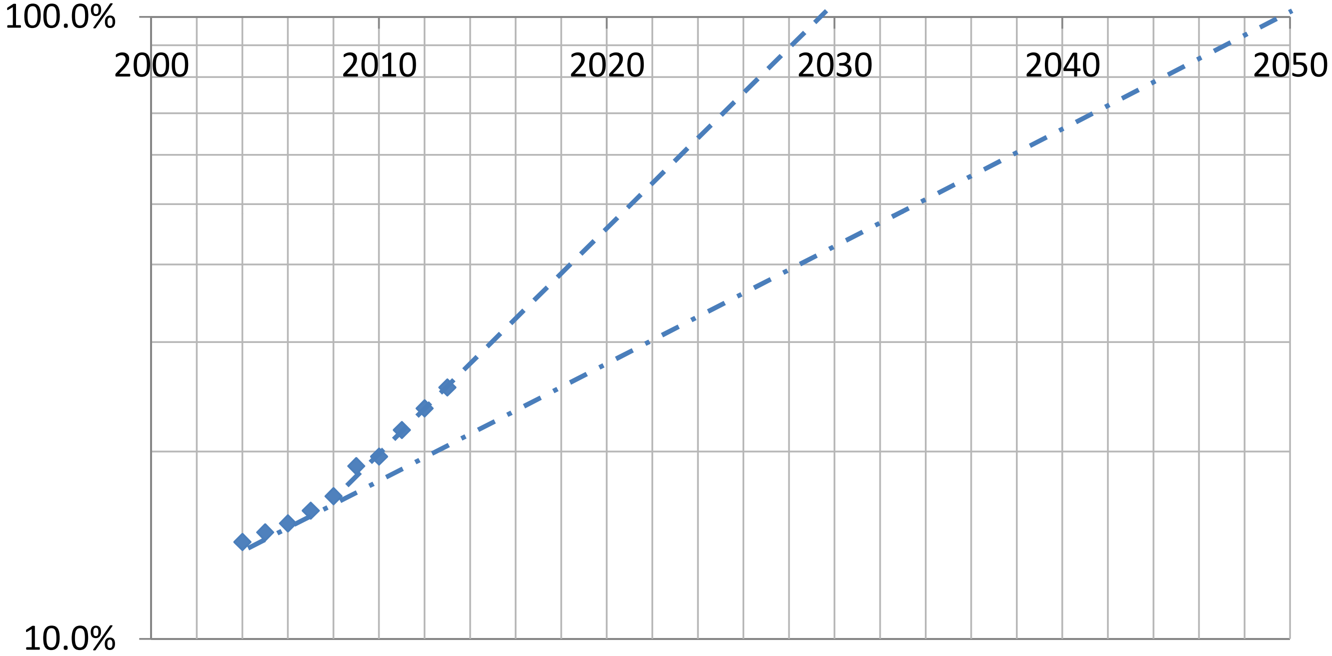
- "War of Currents" competition (end of 19^{th} century) between the direct current (DC) system of Thomas Edison and the AC system of George Westinghouse. AC transmission became the de facto standard.
- Technology mainly developed in Sweden and Germany in the 1930's. One of the first large scale trials in USSR in 1950.
- Now the longest HVDC link in the world is currently the Xiangjiaba–Shanghai 2,071 km (1,287 mi), ±800 kV, 6400 MW link connecting the Xiangjiaba Dam to Shanghai in China.
- This is roughly equivalent to 24" gas transmission pipeline operating at 250 bars (about 3700 psia) of pressure.
- HVDC link Ekibastuz – Tambov (USSR, Kaz-Rus) 2414 km line 750 kV 6000 MW was abandoned around 1990 due to the collapse of the USSR.
- The principle advantage of DCHV is minimal energy losses of about 3% at 1000 km in transmission of vast quantities of energy at large distances.

http://new.abb.com/systems/hvdc/references/xiangjiaba---shanghai
http://en.wikipedia.org/wiki/List_of_HVDC_projects

In Europe Transition Seems To Be Accelerating

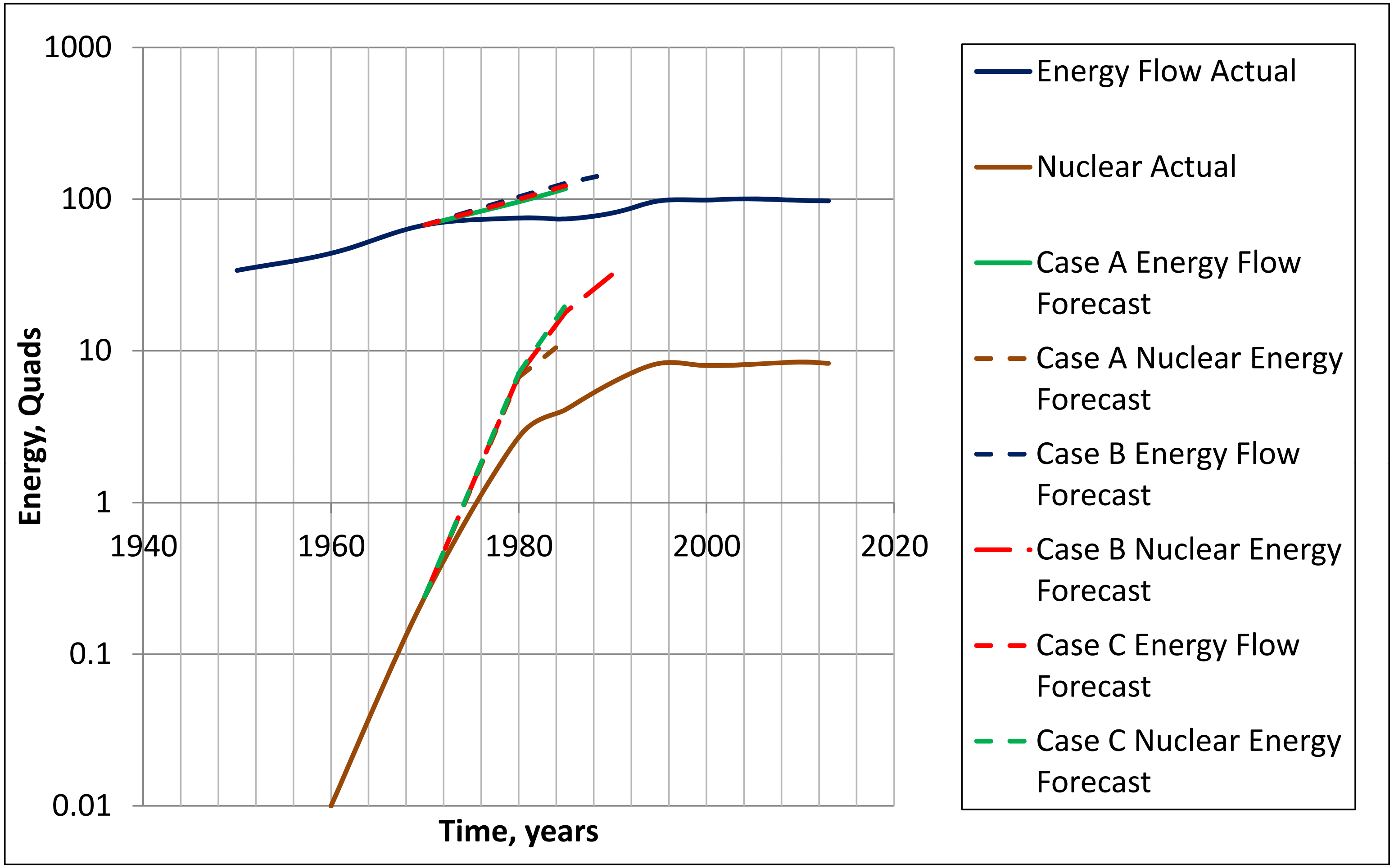
What are the reasons? Prices? Environmental concerns? Politics?

Share of energy from renewable sources for electricity

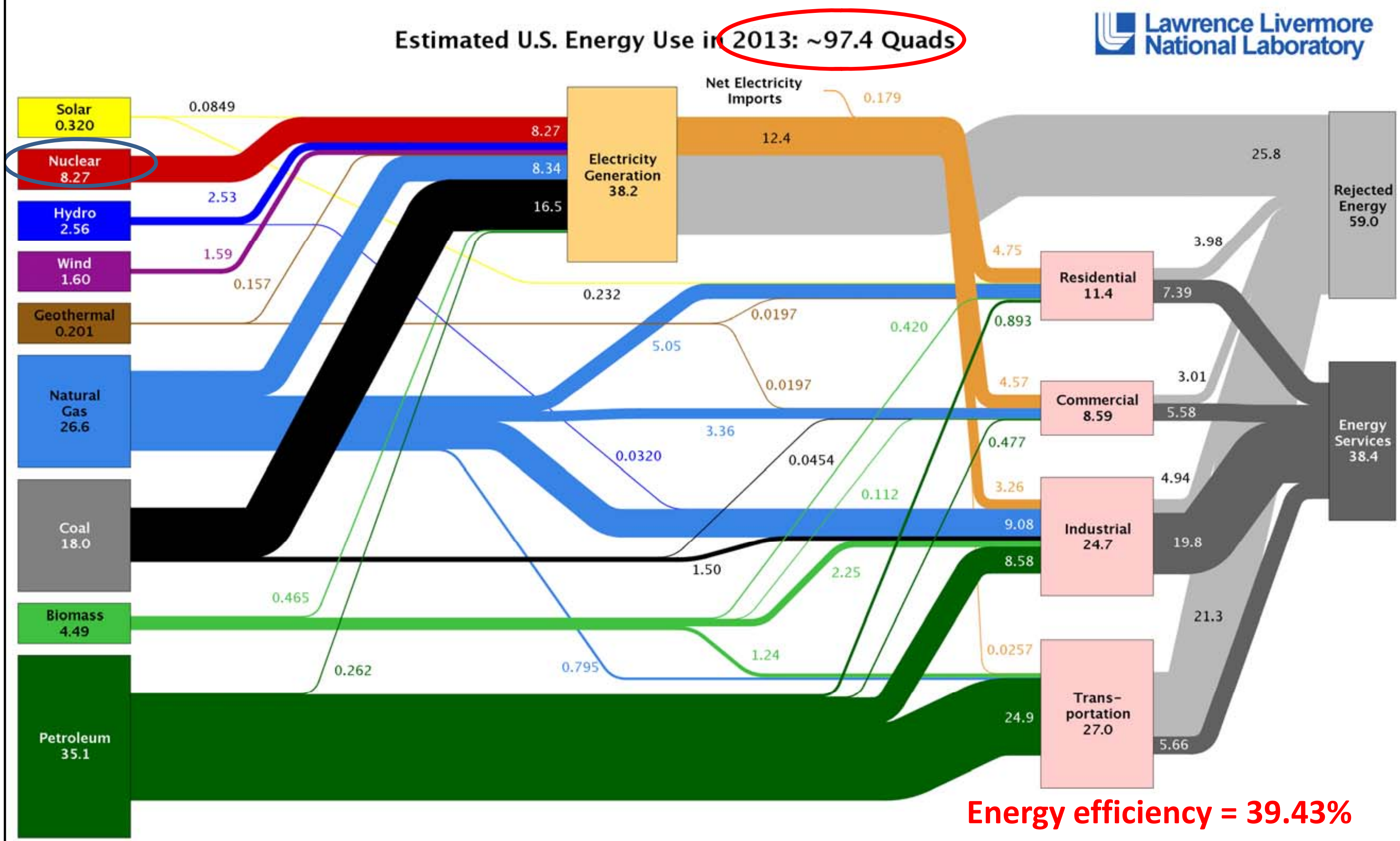


Data from http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_from_renewable_sources

USA Energy Flow 1970 Forecast vs. Actual

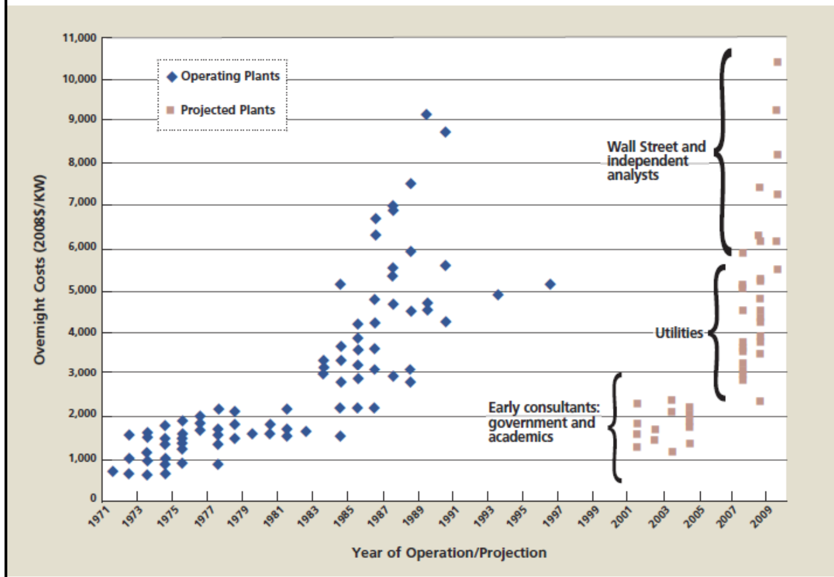


http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/USA--Nuclear-Power/
https://flowcharts.llnl.gov/archive.html#energy_archive

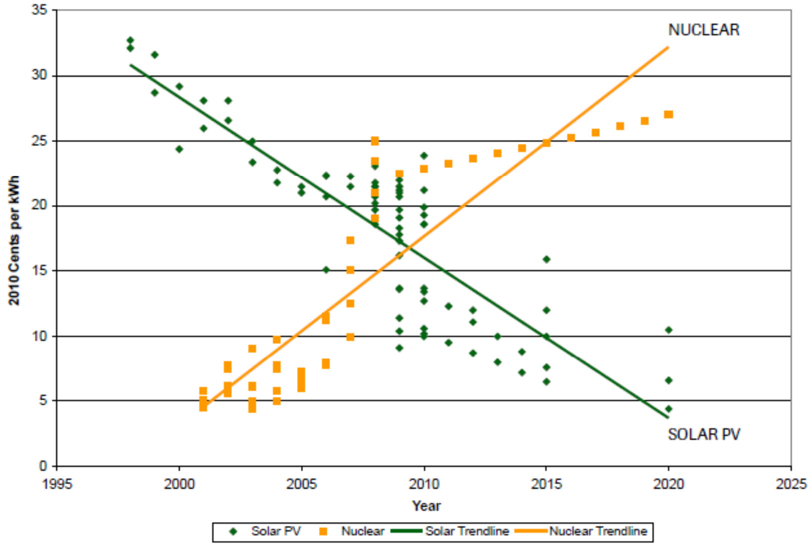


Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Nuclear Is NOT The Solution, And Perhaps Should Not Be A Part Of The Solution



The Historic Crossover



Solar and Nuclear Costs — The Historic Crossover: *Solar Energy is Now the Better Buy*
By John O. Blackburn and Sam Cunningham. July 2010. Prepared for NC WARN: Waste Awareness & Reduction Network, PO Box 61051, Durham, NC 27715-1051 • 919-416-5077, www.ncwarn.org

http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nuclear_power/nuclear-economics-fact-sheet.pdf by Union of Concerned Scientists August 2009 **Nuclear Power: A Resurgence We Can' t Afford**
http://npolicy.org/article_file/New_Nuclear-The_Economics_Say_No.pdf New Nuclear – The Economics Say No
Pan-Europe **Utilities (Citi) by Peter Atherton, Andrew M Simms, Sofia Savvantidou, Stephen B Hunt**

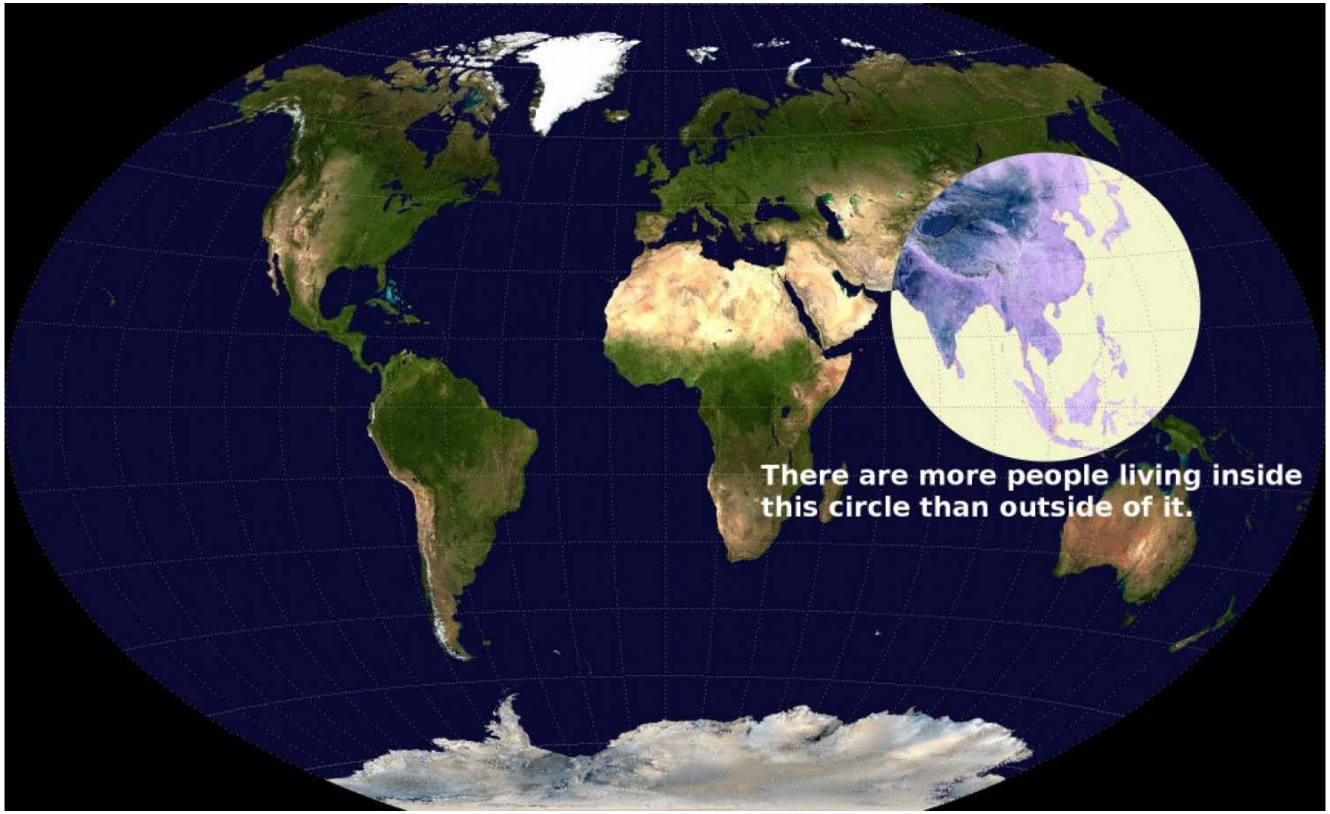
Nuclear Is NOT The Solution, And Perhaps Should Not Be A Part Of The Solution

- Safety record is not very good. To date, there have been around 440 reactors constructed. The following 9 have melted down to some degree:
  3 reactors at Fukushima
  1 reactor at Chernobyl
  1 reactor at 3-Mile Island
  1 reactor in Saint-Laurent, France, 1969
  1 reactor at Lucens, Switzerland, 1969
  1 reactor KS 150 in Czech Republic Feb. 22, 1977
  1 reactor NRX Ontario Canada in 1952
- Gap of 15 TW will require to build 15000 nuclear reactors of 1GW each over next 30 years. Potentially dozens of major accidents, nuclear terrorism danger, unsolved and (potentially unsolvable) nuclear waste problem and about 150 trillion USD in CAPEX.

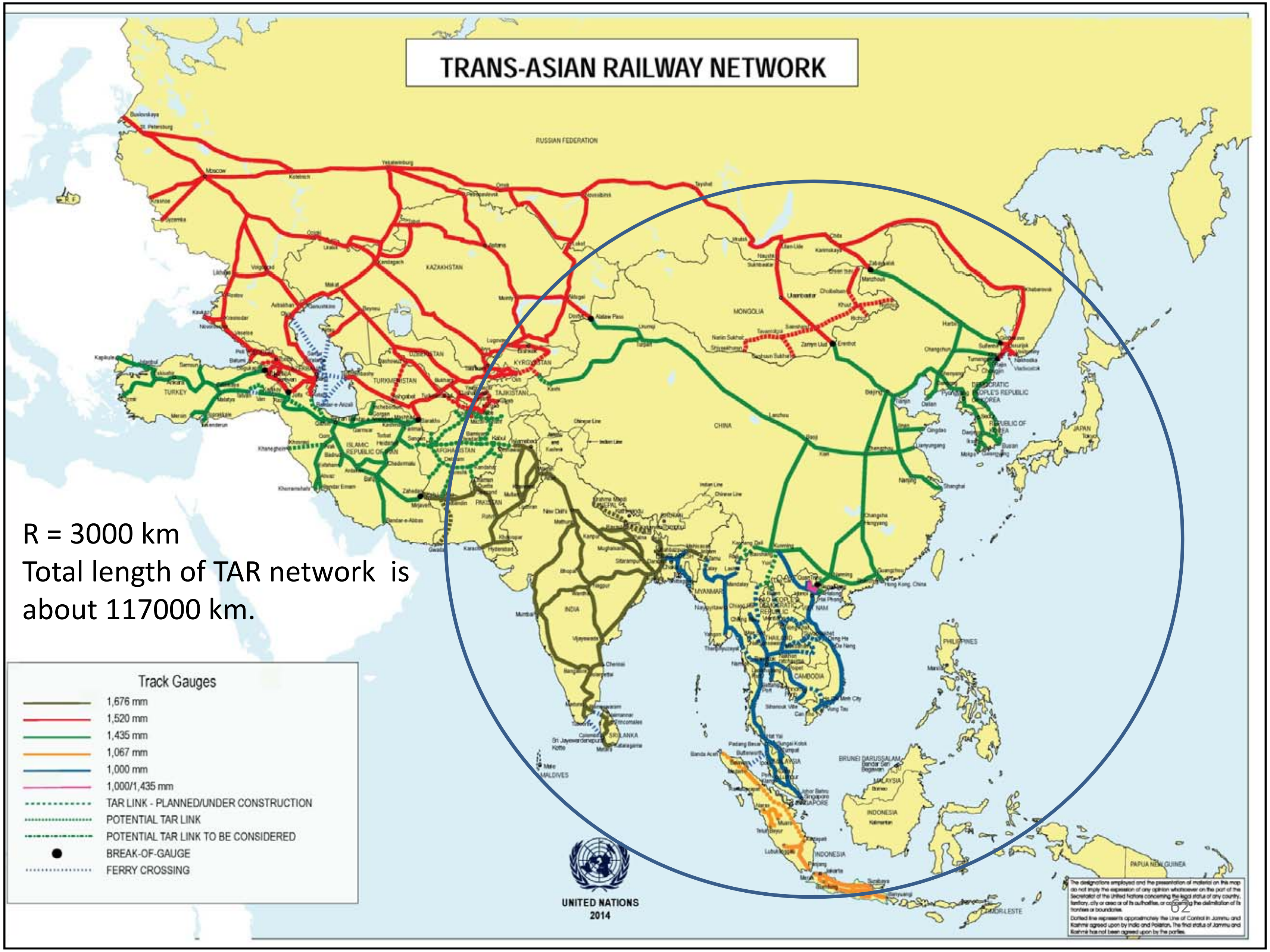
Prof. Mark Jacobson, Stanford University

Will There Be More Air Travel and More Demand For Jet Fuel As China and India Develop?

Jet fuel accounts for 8% of US oil consumption.



Radius of this circle is about 3000 km.



R = 3000 km
Total length of TAR network is about 117000 km.

"Rail map of China" by Howchou
http://commons.wikimedia.org/wiki/File:Rail_map_of_China.svg#/media/File:Rail_map_of_China.svg

63

Proven Concept, Technology And Available Capital

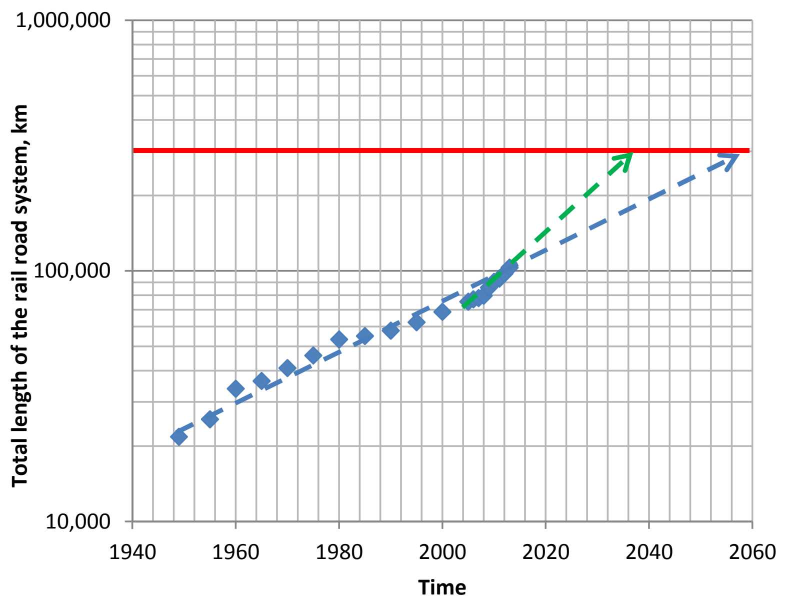
- "Just five years after China's high-speed rail system opened, it is carrying nearly twice as many passengers each month as the country's domestic airline industry. With traffic growing 28 percent a year for the last several years, China's high-speed rail network will handle more passengers by early next year than the 54 million people a month who board domestic flights in the United States". (NY Times)
- The Mid-to-Long Term Railway Network Plan adopted in 2004, and updated in 2008, laid out such a railway development plan through 2020, including the connection of all provincial capitals and cities above 500,000 people to a rapid rail network of 45,000 km, including about 16,000 km of dedicated high speed rail lines. This program was subsequently accelerated to achieve most of these objectives by 2015.
- Asian Infrastructure Investment Bank established for major infrastructure projects. All of the important Asian and European economic powers have joined this effort.

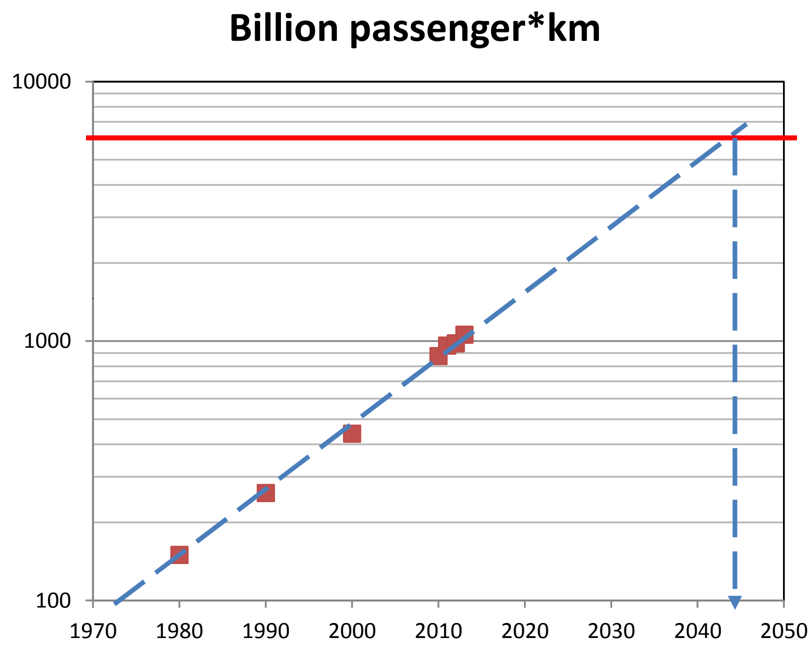
http://qz.com/116190/high-speed-rail-is-at-the-foundation-of-chinas-growth-strategy/

http://www.nytimes.com/2013/09/24/business/global/high-speed-train-system-is-huge-success-for-china.html?_r=0

We Will Probably See This Change In Our Lifetime

- In the USA in 2014 4500 passenger*km flown per capita, that translates for China to 6E12 passenger*km.
- 300,000 km network will connect every major city of more than 500,000 people in Asia



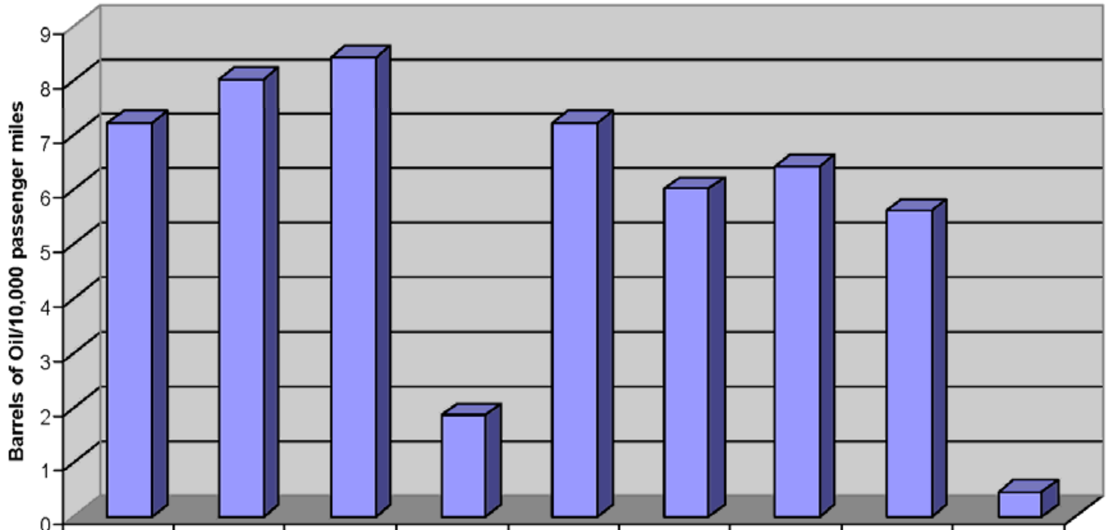


Data from High-Speed Railways in China: A Look at Traffic By Gerald Ollivier, Richard Bullock, Ying Jin and Nanyan Zhou. World Bank Office, Beijing

Energy Efficiency by Transport Mode

In Barrels of Oil or Oil Equivalent Per 10,000 Passenger*Miles

Oil fueled autos, trucks, & airplanes dominated 20th century transport. Electrically powered automobiles and MagLev will dominate 21st century transport.



	60 mph Autos	60 mph SUVs&Lt Trucks	30 mph Transit Bus	60mph Intercity Bus	500 mph Air	80 mph Intercity Rail	60 mph Commuter Rail	40 mph Transit Rail	300 mph Maglev
Series1	7.2	8	8.4	1.86	7.2	6	6.4	5.6	0.46

Energy Efficiency and Economics of Maglev Transport By James Powell and Gordon Danby
http://www.aertc.org/conference/AEC_Sessions%5CCopy%20of%20Session%201%5CTrack%20E-%20Innovation%5CIntelligent%20Advanced%20Transport%5C3.%20Dr.%20James%20Powell%5CJames%20Powell%20presentation.pdf

Conclusions

- Our industry during the "unconventional revolution" had the same rate of improvement as high tech industries. Is this rate of innovation sustainable for the petroleum industry?
- Innovations in material sciences challenge the high energy density advantage of our product.
- Competitive technologies are likely to erode the "convenience premium" for oil. Electric cars will be just as convenient as gasoline powered cars. Electric powered trains may be more convenient then airplanes.
- For the first time in history we are in direct competition with industries (transportation and power generation) that used to be our customers.

So what do we have to do now?

- Production activation index of 20000 USD/STB/D or more is a sign of great danger to the prosperous existence of our industry.
- We must keep innovating and improving drilling efficiency. We must continue to focus on recovery efficiency in developed basins. High capital cost projects like Arctic offshore may never be developed.
- Innovate, develop new products and materials based on natural gas and petroleum chemistry.
- We should embrace fuel cell technology for distributed power generation.
- We should embrace every type of technology where solar energy storage is in chemical bonds.
- Young petroleum engineers must be trained to be much more adaptable to changing business environment. We should be more like energy engineers rather than just petroleum engineers.