PDHonline Course C765 (8 PDH)

Sustainability for Civil Engineers

Instructor: James Newton, PE

2020

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Sustainability for Civil Engineers

University Course Material

- The following material was developed for use in University settings for Civil Engineers, however, it can be used for other purposes.
- This slideshow discusses infrastructure sustainability and introduces the Envision rating system, and other related topics.
- Some of the material is time sensitive, so updates will be needed.
- We welcome comments and suggestions. We also welcome your input concerning Sustainability material that you use in your lectures, readings, or homework.
- This material was assembled from many sources by Frank Sherkow.
- ***Contact information:***

  - fsherkow@earthlink.net (Frank Sherkow, P.E., T.E., P.S.E., ENV SP, F.ASCE), or
  - mghoseha@uno.edu (Malay Ghose Hajra, Ph.D., P.E., ENV SP)

Sustainability – University Course

By Frank Sherkow, P.E., ENV SP, F.ASCE

- Rev. 10.3.13
- Topics

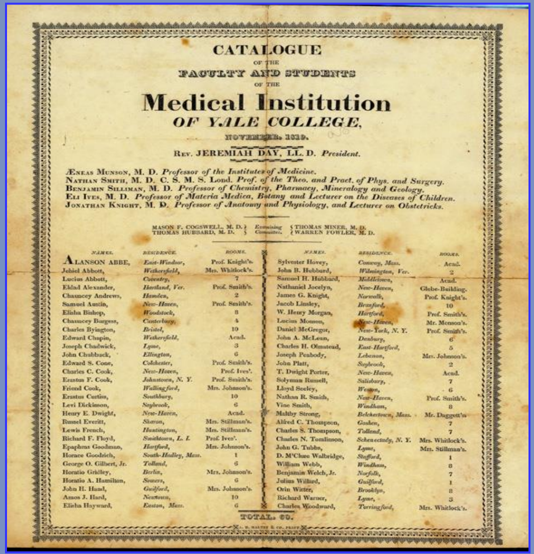
What are the issues and why study them?





Civil Engineers DO have an Important Impact on Society and Public Wellbeing

"…the greatest advances in improving human health were the development of clean drinking water and sewage systems. So, **we owe our health as much to civil engineering as we do to biology**."



CATALOGUE
OF THE
FACULTY AND STUDENTS
OF THE
Medical Institution
OF YALE COLLEGE,
NOVEMBER, 18[illegible].

REV. JEREMIAH DAY, LL. D. *President.*

ÆNEAS MUNSON, M. D. *Professor of the Institutes of Medicine.*
NATHAN SMITH, M. D. C. S. M. S. Lond. *Prof. of the Theo. and Pract. of Phys. and Surgery.*
BENJAMIN SILLIMAN, M. D. *Professor of Chemistry, Pharmacy, Mineralogy and Geology.*
ELI IVES, M. D. *Professor of Materia Medica, Botany and Lecturer on the Diseases of Children.*
JONATHAN KNIGHT, M. D. *Professor of Anatomy and Physiology, and Lecturer on Obstetricks.*

MASON F. COGSWELL, M. D. } *Examining Committee.* { THOMAS MINER, M. D.
THOMAS HUBBARD, M. D. } { WARREN FOWLER, M. D.

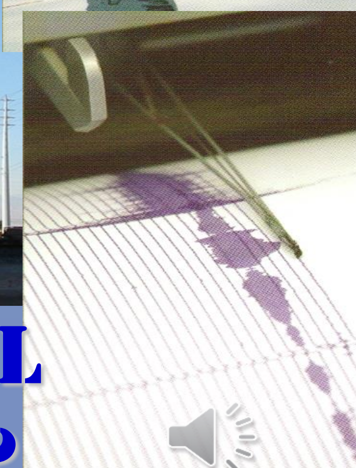
NAMES.	RESIDENCE.	ROOMS.	NAMES.	RESIDENCE.	ROOMS.
ALANSON ABBE,	*East-Windsor,*	Prof. Knight's.	Sylvester Hovey,	*Conway, Mass.*	Acad.
Jehiel Abbott,	*Wethersfield,*	Mrs. Whitlock's.	John B. Hubbard,	*Wilmington, Ver.*	2
Lucius Abbott,	*Coventry,*	7	Samuel H. Hubbard,	*Middletown,*	Acad.
Eldad Alexander,	*Hartland, Ver.*	Prof. Smith's.	Nathaniel Jocelyn,	*New-Haven,*	Glebe-Building.
Chauncey Andrews,	*Hamden,*	2	James G. Knight,	*Norwalk,*	Prof. Knight's.
Samuel Austin,	*New-Haven,*	Prof. Smith's.	Jacob Linsley,	*Branford,*	10
Elisha Bishop,	*Woodstock,*	8	W. Henry Morgan,	*Hartford,*	Prof. Smith's.
Chauncey Burgess,	*Canterbury,*	4	Lucius Monson,	*New-Haven,*	Mr. Monson's.
Charles Byington,	*Bristol,*	10	Daniel McGregor,	*New-York, N. Y.*	Prof. Smith's.
Edward Chapin,	*Wethersfield,*	Acad.	John A. McLean,	*Danbury,*	6
Joseph Chadwick,	*Lyme,*	3	Charles H. Olmstead,	*East-Hartford,*	5
John Chubbuck,	*Ellington,*	6	Joseph Peabody,	*Lebanon,*	Mrs. Johnson's.
Edward S. Cone,	*Colchester,*	Prof. Smith's.	John Platt,	*Saybrook,*	2
Charles C. Cook,	*New-Haven,*	Prof. Ives'.	T. Dwight Porter,	*New-Haven,*	Acad.
Erastus F. Cook,	*Johnstown, N. Y.*	Prof. Smith's.	Solyman Russell,	*Salisbury,*	7
Friend Cook,	*Wallingford,*	Mrs. Johnson's.	Lloyd Seeley,	*Weston,*	6
Erastus Curtiss,	*Southbury,*	10	Nathan R. Smith,	*New-Haven,*	Prof. Smith's.
Levi Dickinson,	*Saybrook,*	6	Vine Smith,	*Windham,*	8
Henry E. Dwight,	*New-Haven,*	Acad.	Maltby Strong,	*Belchertown, Mass.*	Mr. Daggett's.
Russel Everitt,	*Sharon,*	Mrs. Stillman's.	Alfred C. Thompson,	*Goshen,*	7
Lewis French,	*Huntington,*	Mrs. Stillman's.	Charles S. Thompson,	*Tolland,*	7
Richard F. Floyd,	*Smithtown, L. I.*	Prof. Ives'.	Charles N. Tomlinson,	*Schenectady, N. Y.*	Mrs. Whitlock's.
Epaphras Goodman,	*Hartford,*	Mrs. Johnson's.	John G. Tubbs,	*Lyme,*	Mrs. Stillman's.
Horace Goodrich,	*South-Hadley, Mass.*	1	D. M'Clure Walbridge,	*Stafford,*	1
George O. Gilbert, Jr.	*Tolland,*	6	William Webb,	*Windham,*	8
Horatio Gridley,	*Berlin,*	Mrs. Johnson's.	Benjamin Welch, Jr.	*Norfolk,*	7
Horatio A. Hamilton,	*Somers,*	6	Julius Willard,	*Guilford,*	1
John H. Hand,	*Guilford,*	Mrs. Johnson's.	Orin Witter,	*Brooklyn,*	8
Amos J. Hard,	*Newtown,*	10	Richard Warner,	*Lyme,*	3
Elisha Hayward,	*Easton, Mass.*	6	Charles Woodward,	*Torringford,*	Mrs. Whitlock's.

TOTAL, 60.

Dr. Lewis Thomas
(1913-1993)
Dean, Yale Medical School

Global & Environmental Issues

- Shift Even More to Urban Areas
- Require Widespread Sustainability
- Climate Change
- Transportation
- Energy Supplies
- Clean Water and Air
- Safe Waste Disposal
- Population Pressure
  - Food
  - Disease
  - Space/Density
- Terrorism/War/Unrest/Natural Events
- Other resource limitations



WHAT CAN CIVIL ENGINEERS DO?

Source: ASCE and others

Top US Social/Political Issues

1. Federal spending
2. Jobs & economy
3. Government regulations
4. National security
5. Illegal Immigration
6. Health care
7. Gun rights
8. Energy
9. Education
10. Social Security / Medicare

Poll Question: How important will each of the following issues be to you this year and next?

Fox News; Dec. 2012

National Academy of Science –
Grand Challenges of the 21st Century Engineering

Source: *The Essential Engineer*

1. Make Solar Energy Affordable
2. Provide Energy From Fusion
3. Develop Carbon Sequestration Methods
4. Manage the Nitrogen Cycle
5. Provide Access to Clean Water
6. Restore and Improve Urban Infrastructure
7. Advance Health Informatics
8. Engineer Better Medicines
9. Reverse-Engineer the Brain
10. Prevent Nuclear Terror
11. Secure Cyberspace
12. Enhance Virtual Reality
13. Advance Personalized Learning
14. Engineer the Tools for Scientific Discovery

CE/CEM Environment

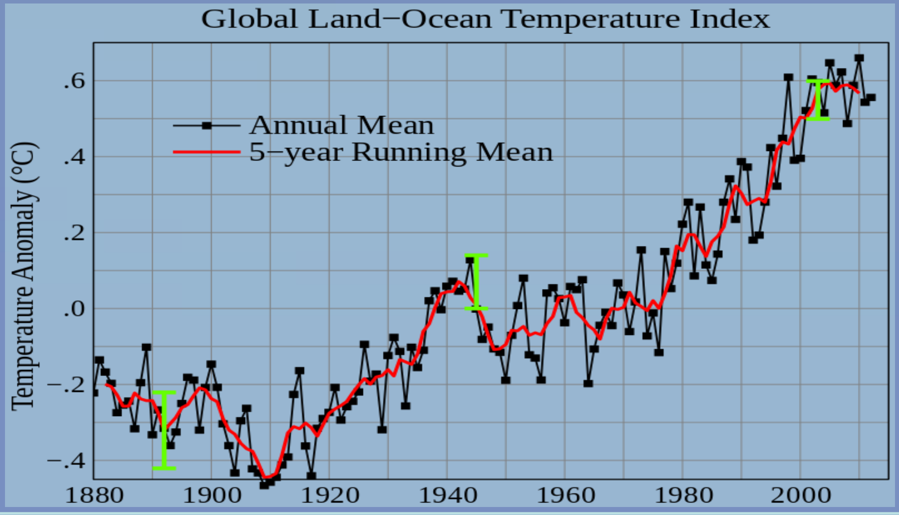
- Increased constraints on financial resources
- Major demographic changes
- Rapid globalization with increasing competition
- Rapid technology advances and fusing of engineering and science disciplines are driving changing engineering needs

Climate Change – Different Points of View?

Remember: Weather is not climate!

- **Global Warming**

  Strategies
  - Conservation
  - Make motors more efficient
  - Build 600 nuclear power plants

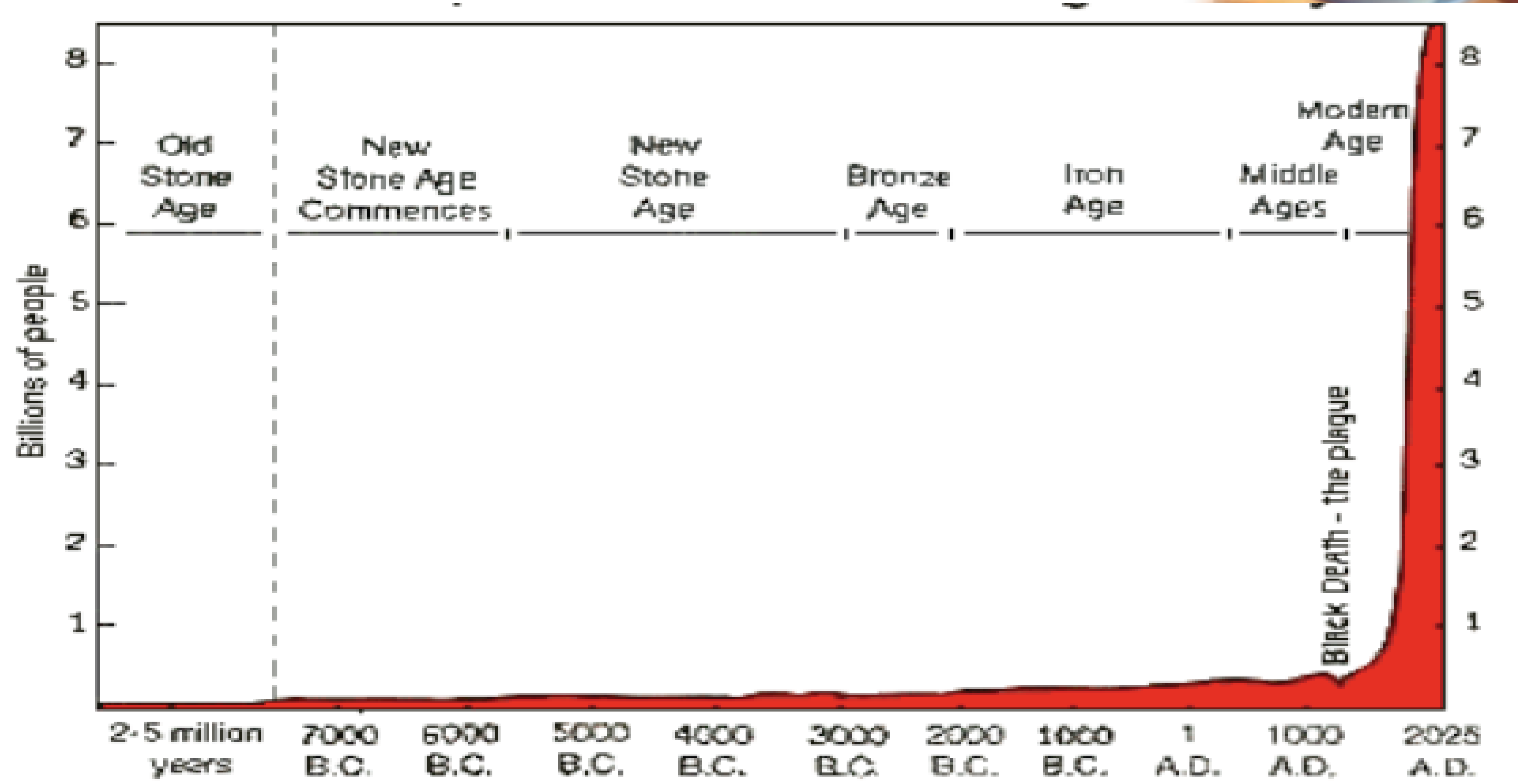


- **Global Cooling**
  - A new NASA study shows that from 1978 to 2010 the total extent of sea ice surrounding Antarctica in the Southern Ocean grew by roughly 6,600 square miles every year, an area larger than the state of Connecticut. And, previous research by the same authors indicates that this rate of increase has recently accelerated, up from an average rate of almost 4,300 square miles per year from 1978 to 2006. *NASA*

  Strategies
  - Conservation
  - Make motors more efficient
  - Build 600 nuclear power plants

People

Human Population



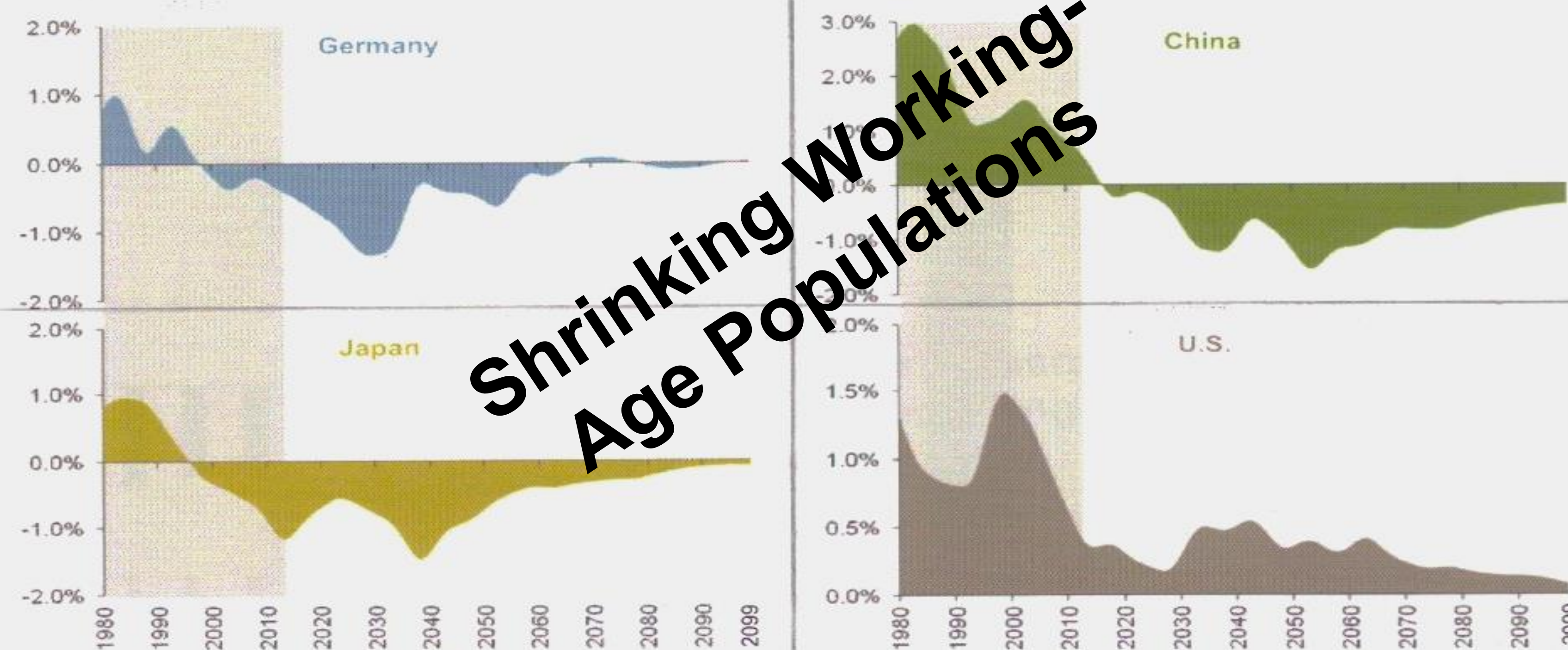
Resource Constraints *will* Intensify.


Growth in China's Urban Population
2012
572
MILLION
Urbanization
2025
922
MILLION
Source: "Preparing for China's Urban Billion," McKinsey Global Institute

Demographics Favorable Relative to Many Other Economies

The U.S. is expected to face slower growth of its working-age population—a key factor for economic growth—over the next several decades relative to its post-WWII experience, but the growth rate will remain positive. In contrast, working-age populations are already declining in Japan and Germany, and will begin to fall in China during the next several years.

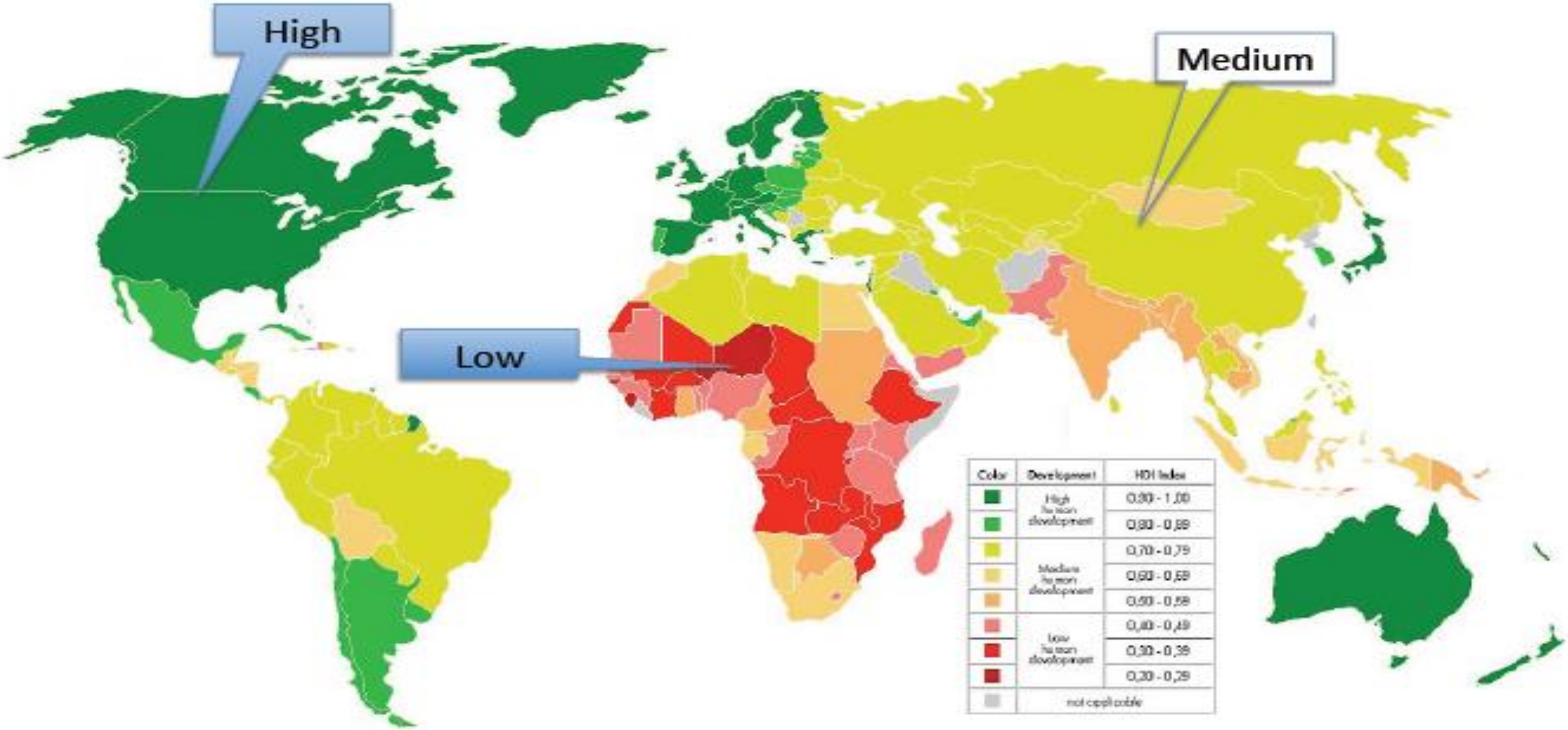
Working-Age Population Growth



LEFT: Projections through 2099. Source: United Nations, Haver Analytics, FAM (AART) through 2099. **RIGHT:** Projections through 2099. Source: United Nations, Haver Analytics, FAM (AART) through 2099

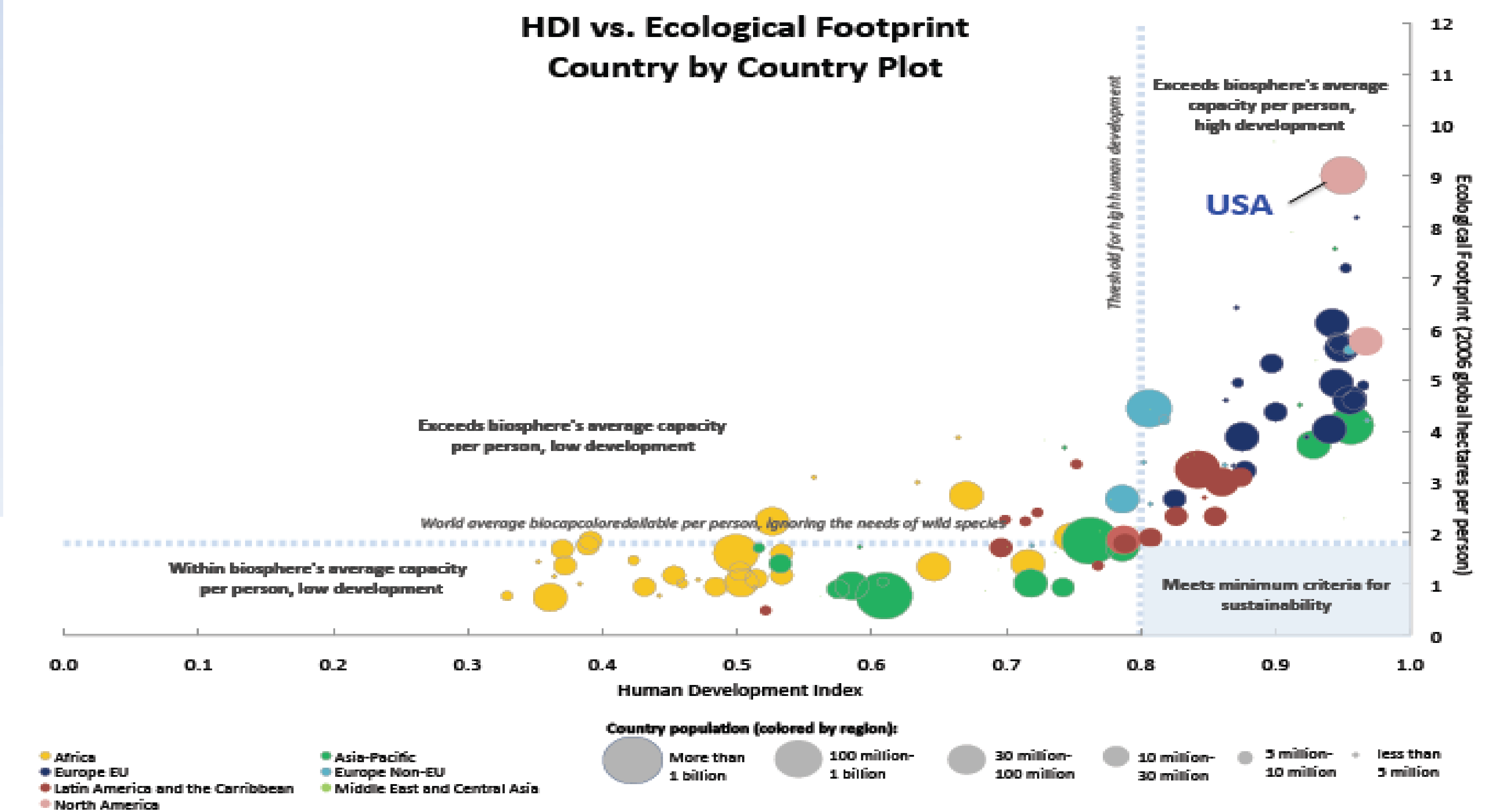
Fidelity Investments Asset Management

World map of Human Development Index (HDI)
(UN metric based on life expectancy, education, GDP)



From PPT by William A. Wallace, ASCE ILC Spring Mtg 2010

Human Development Index vs. Ecological Footprint



Source: Irene Dhong, University of Florida, ENV 6932

Technology

Technology Environment in 2020

- Rapid and accelerating pace of technological innovation
- The world will be intensely connected
- Technology in our everyday lives will be seamless, transparent, and more significant than ever
- People involved with or affected by technology will be increasingly diverse
- Social, cultural, political and economic forces will continue to shape and affect the success of technological innovation

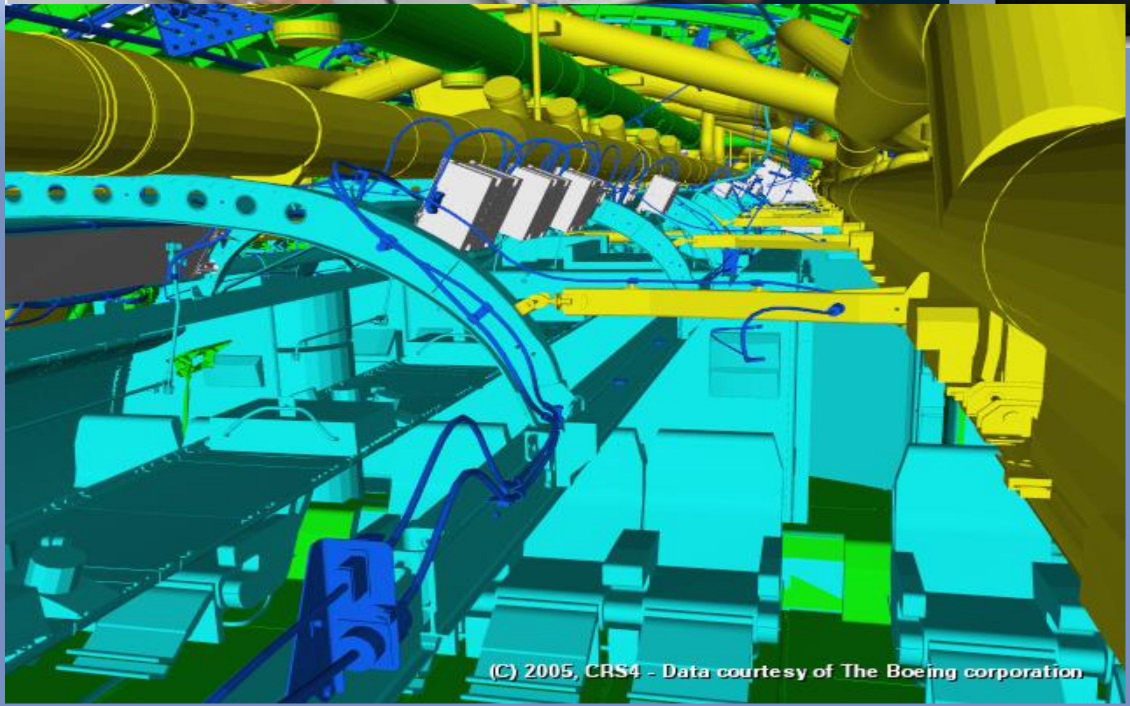
Source: “The Engineer of 2020” NAE

Boeing Engineering

WHERE BOEING PLANES GET THEIR START

Part of the Boeing Aircraft Company's engineering department made up of graduate engineers. Here new designs are initiated, all the complicated matters of stress, balance, weight, etc., are worked out and a considerable amount of research is conducted.

2005



Future???

Neuroscience Unit, Westmead
Name: Carmen Farrugia f56 pd
File: PD013EC.EEG
ID: pd013
Seg
Time
Disp Gain
set Display
Go to...
Quit

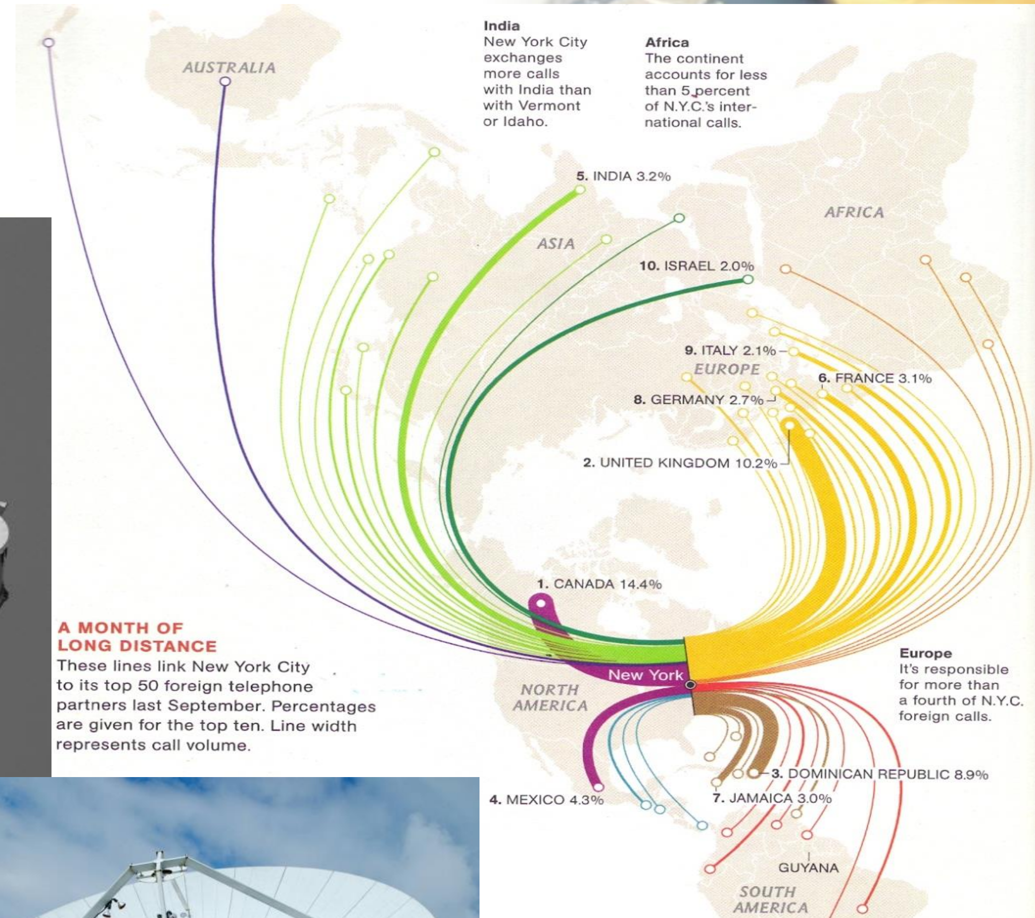
IT Future Trends

- Everything will become connected
  - Devices, systems, machines, business processes, even networks
- Digital technology is making transactions 'smarter'
  - Tiny processors see, listen, and pass messages to one another in sensor networks
- Digital technology is spawning new technical areas and creating new sub-industries
  - Molecular-level drug design, genomics – gene diagnostics and therapies

Implications: continuing culture changes

Source: W. B. Arthur, Fortune, Nov. 2003: "P. Saffo, Inst. for the Future

Connectivity

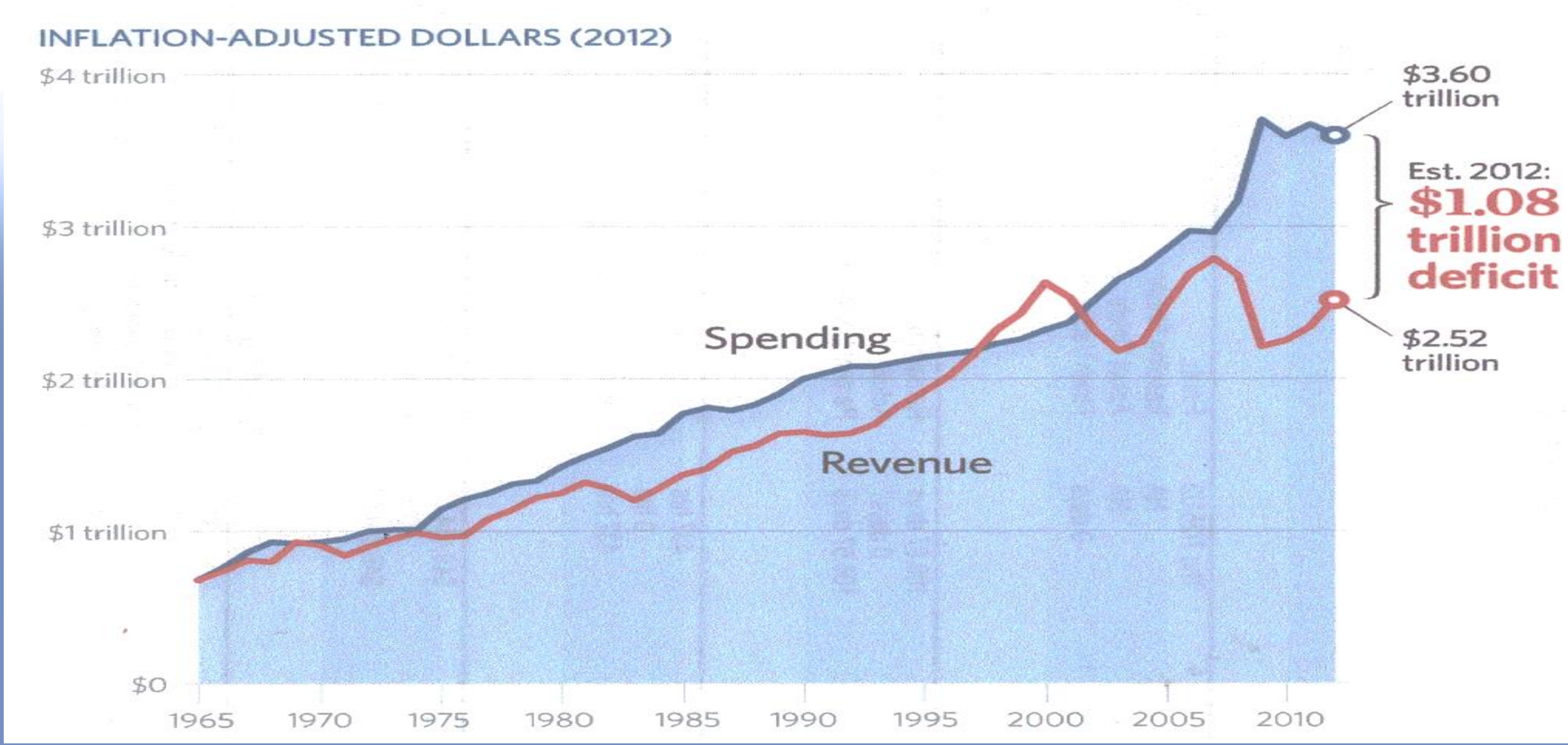


Finance

- "You can't be environmentally sustainable without having long-term financial sustainability."

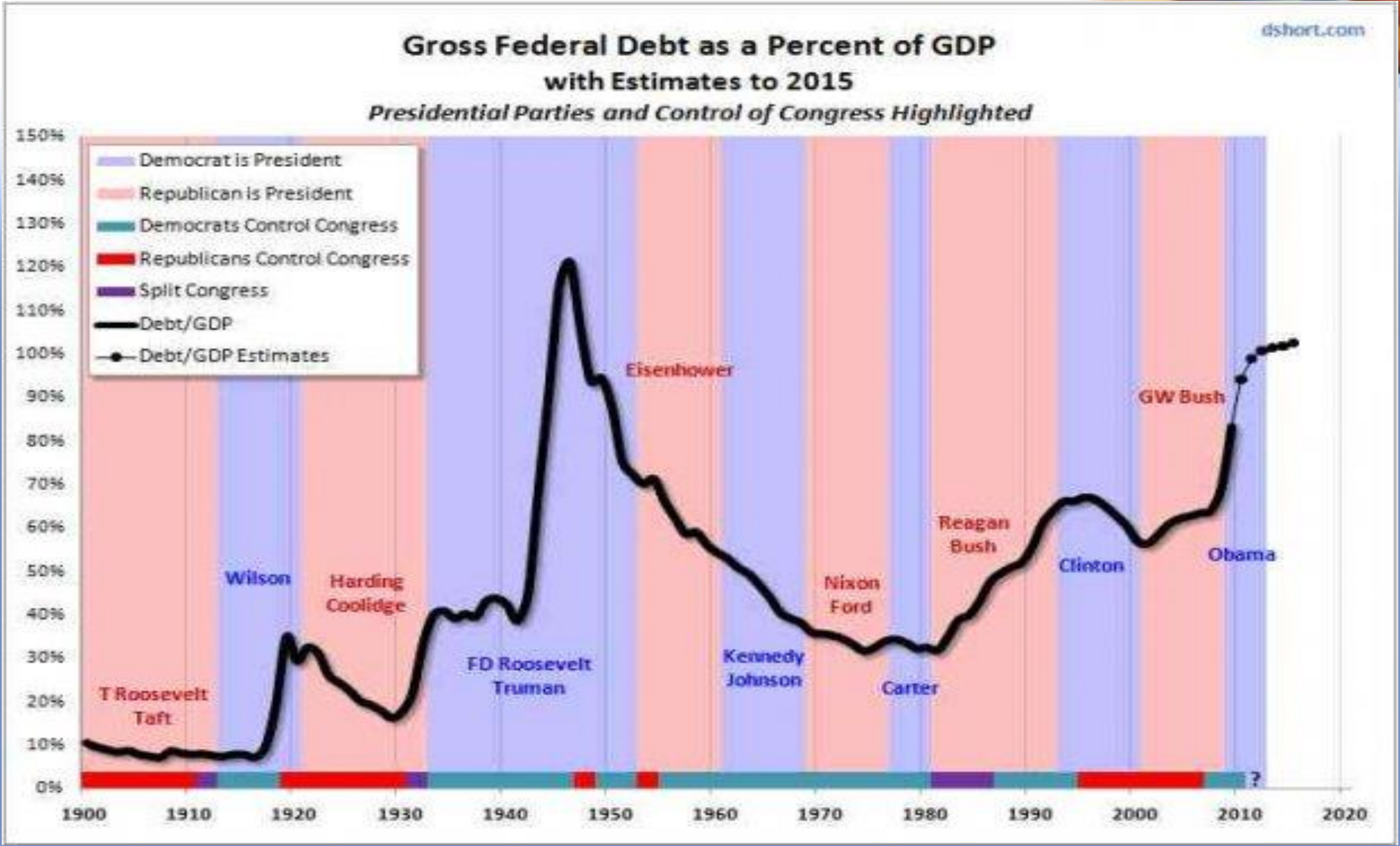
source: Frank Sherkow, P.E., F.ASCE

Federal Spending and Revenue

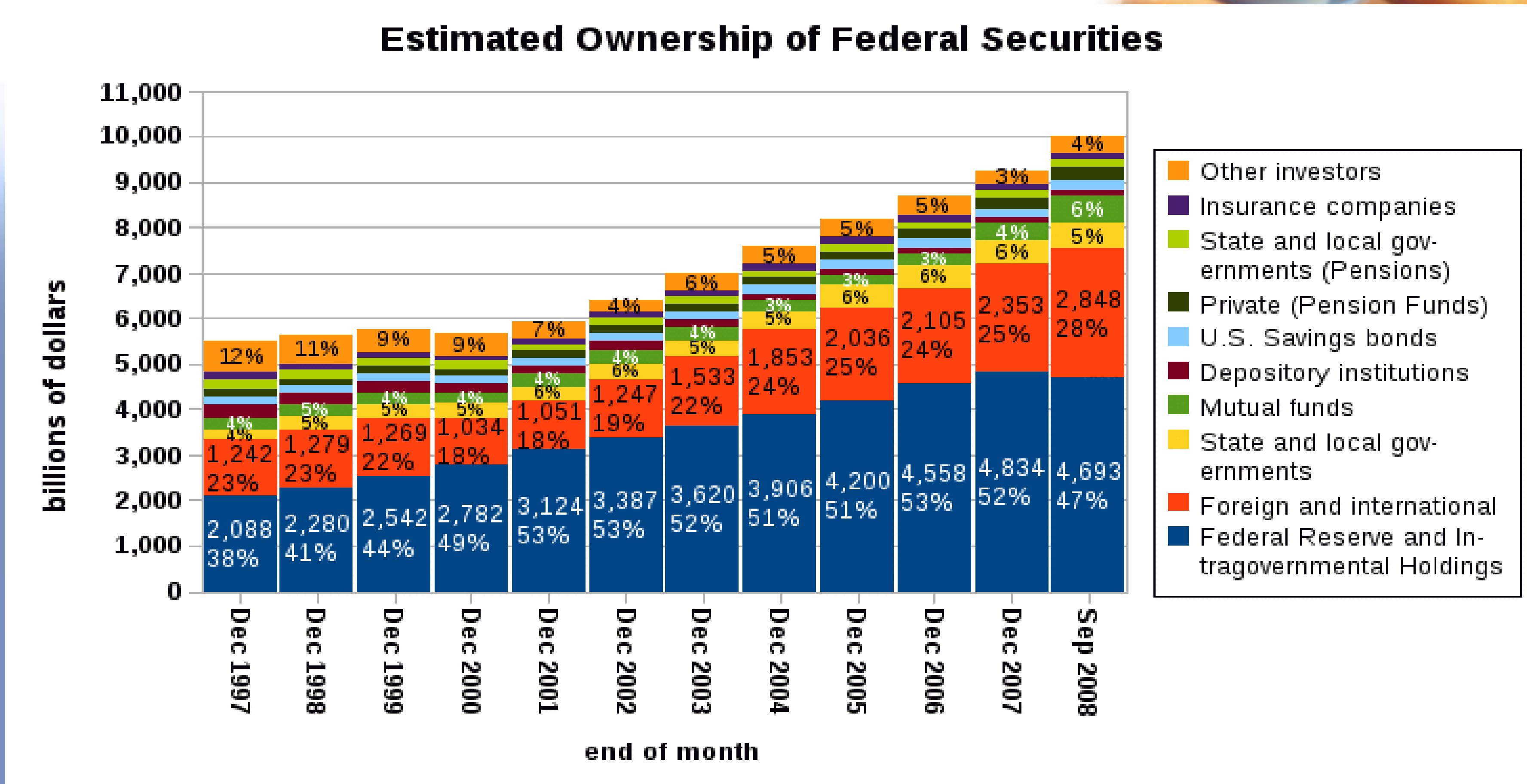


Source: **WHITE HOUSE OFFICE OF MANAGEMENT AND BUDGET.**

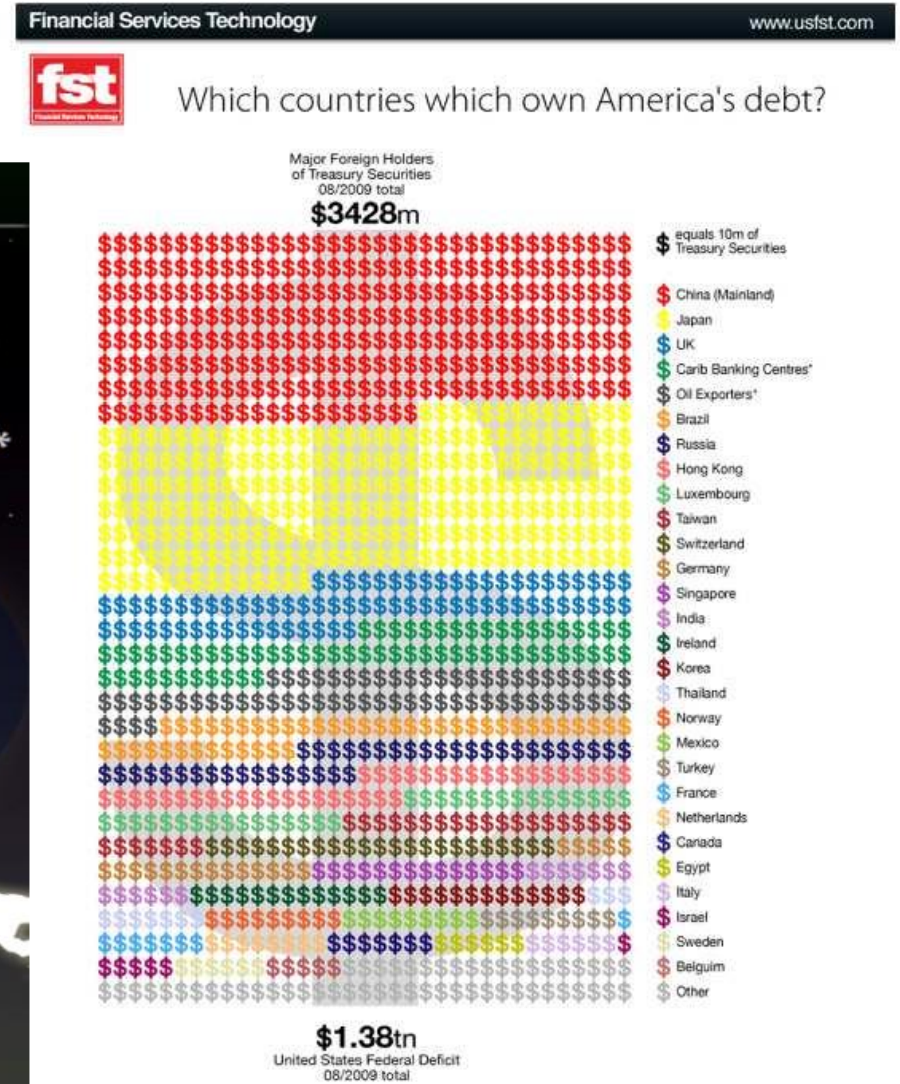
Federal Debt

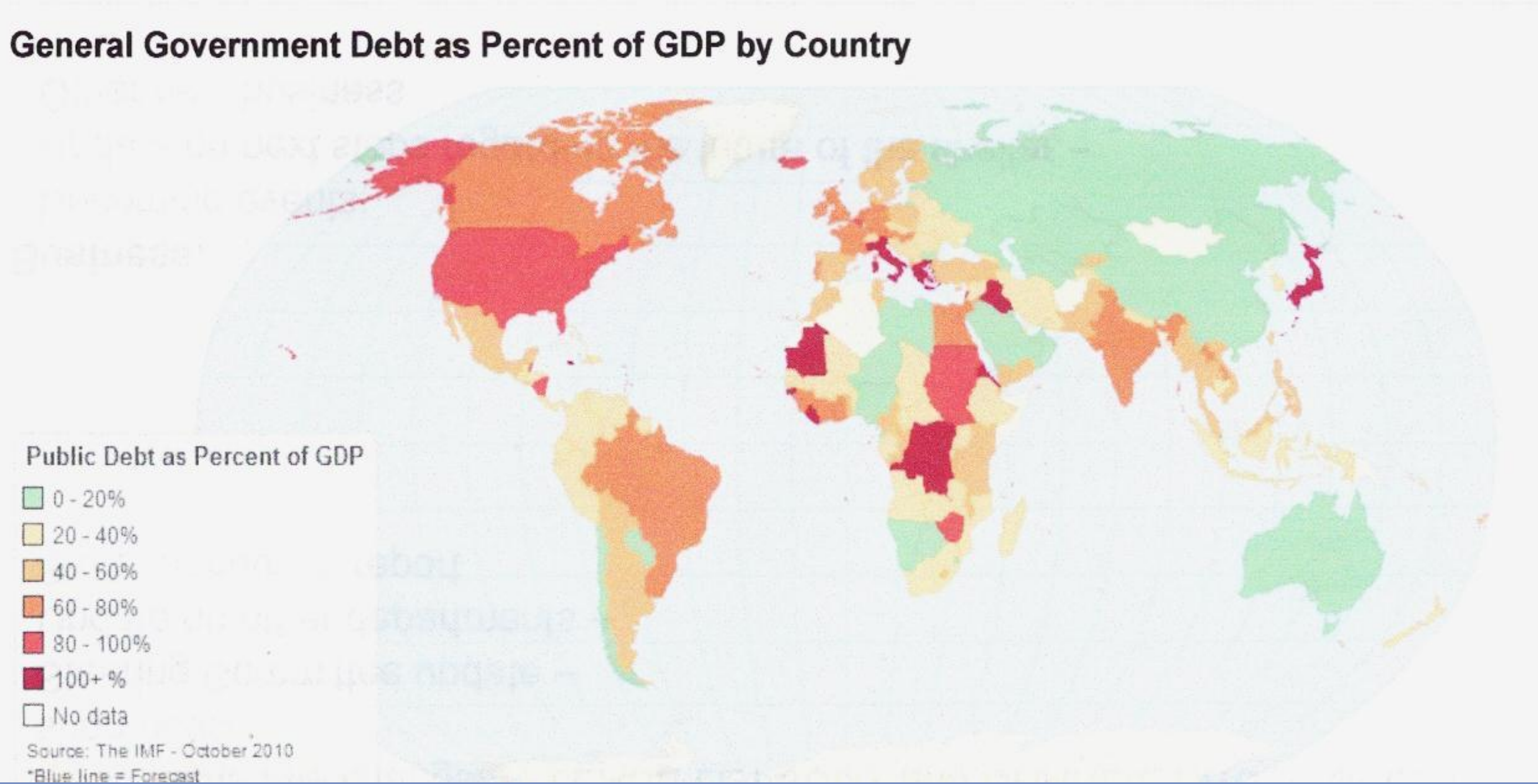


Who Owns Our Debt?



Who Owns Our Debt?

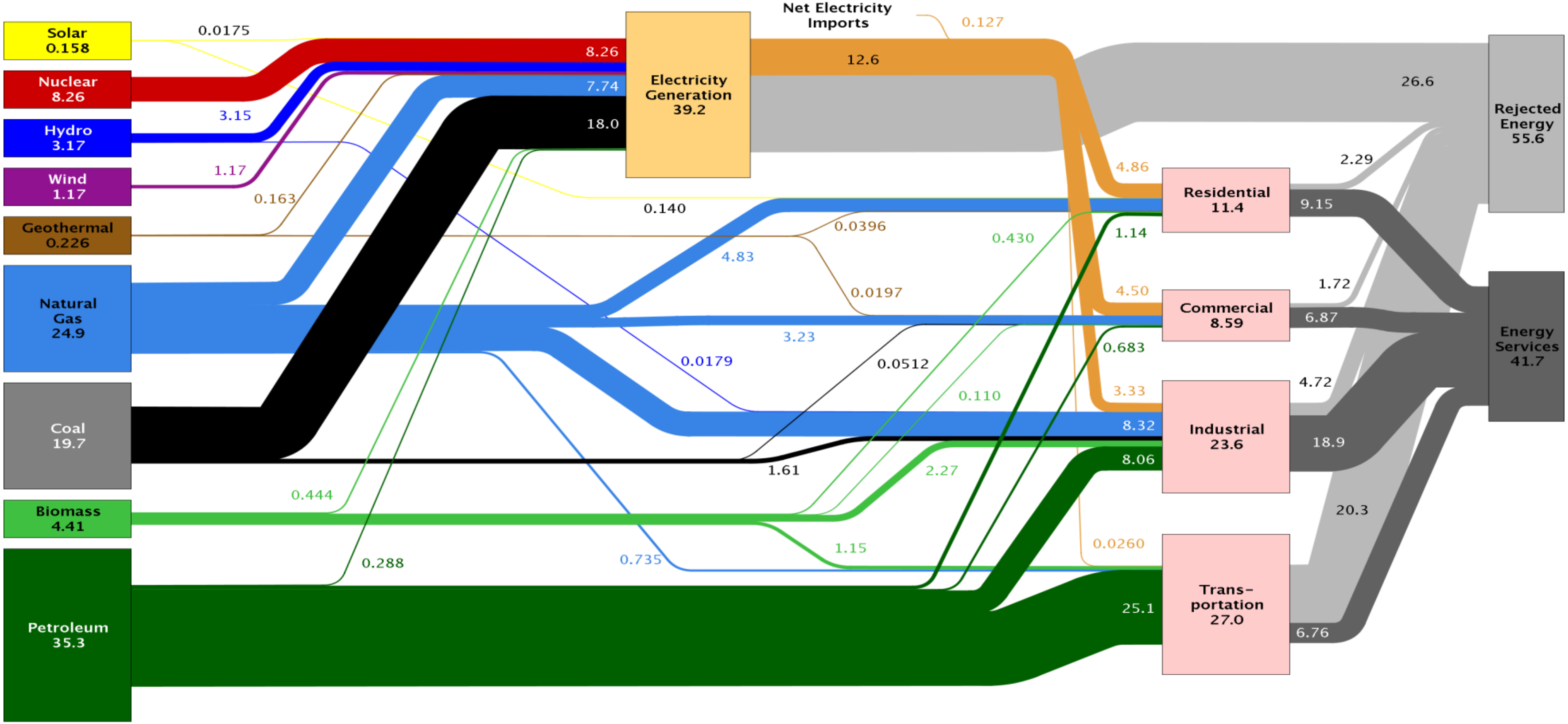




Source: Chartsbin.com; Dec. 2012

Energy and Materials

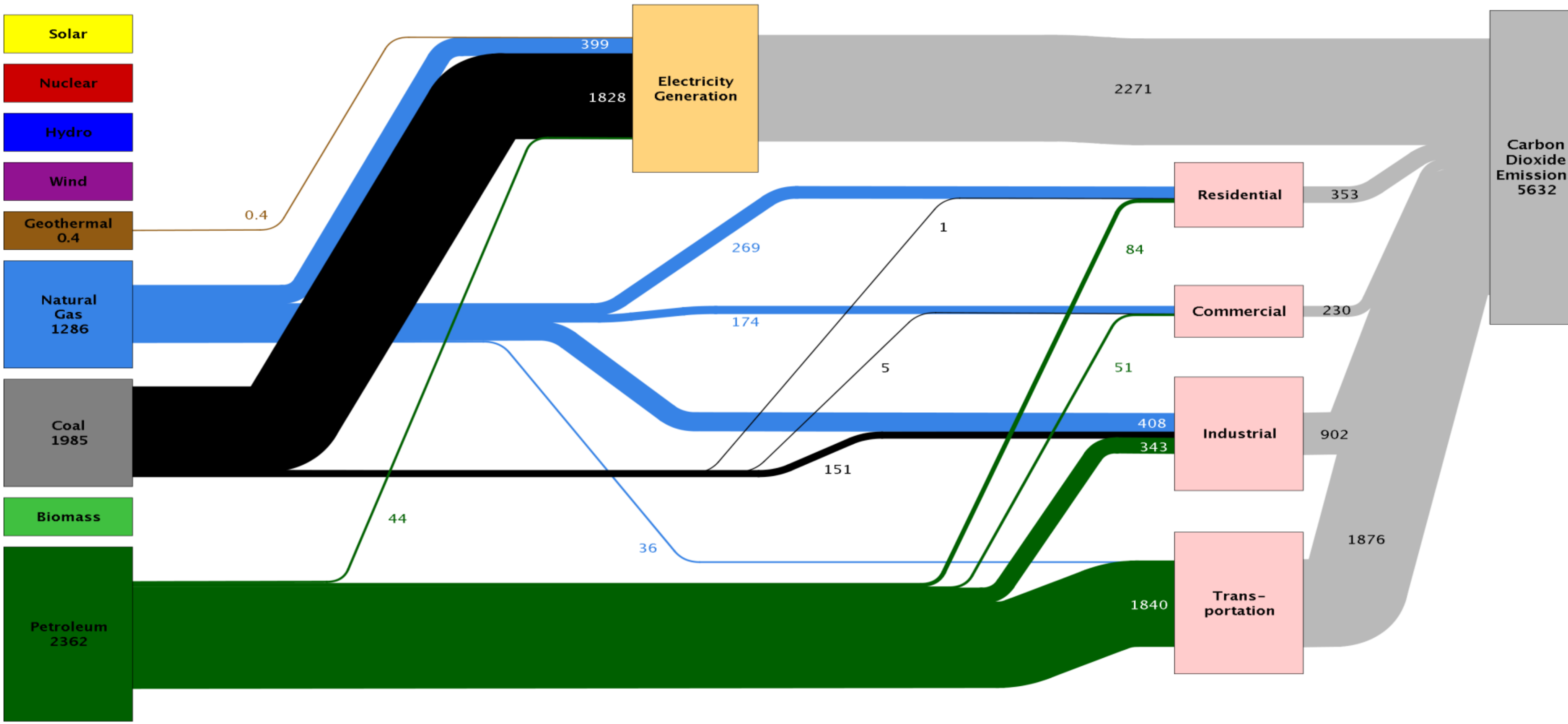
Estimated U.S. Energy Use in 2011: ~97.3 Quads



Source: LLNL 2012. Data is based on DOE/EIA-0384(2011), October, 2012. 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 flows for non-thermal resources (i.e., hydro, wind and solar) 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 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

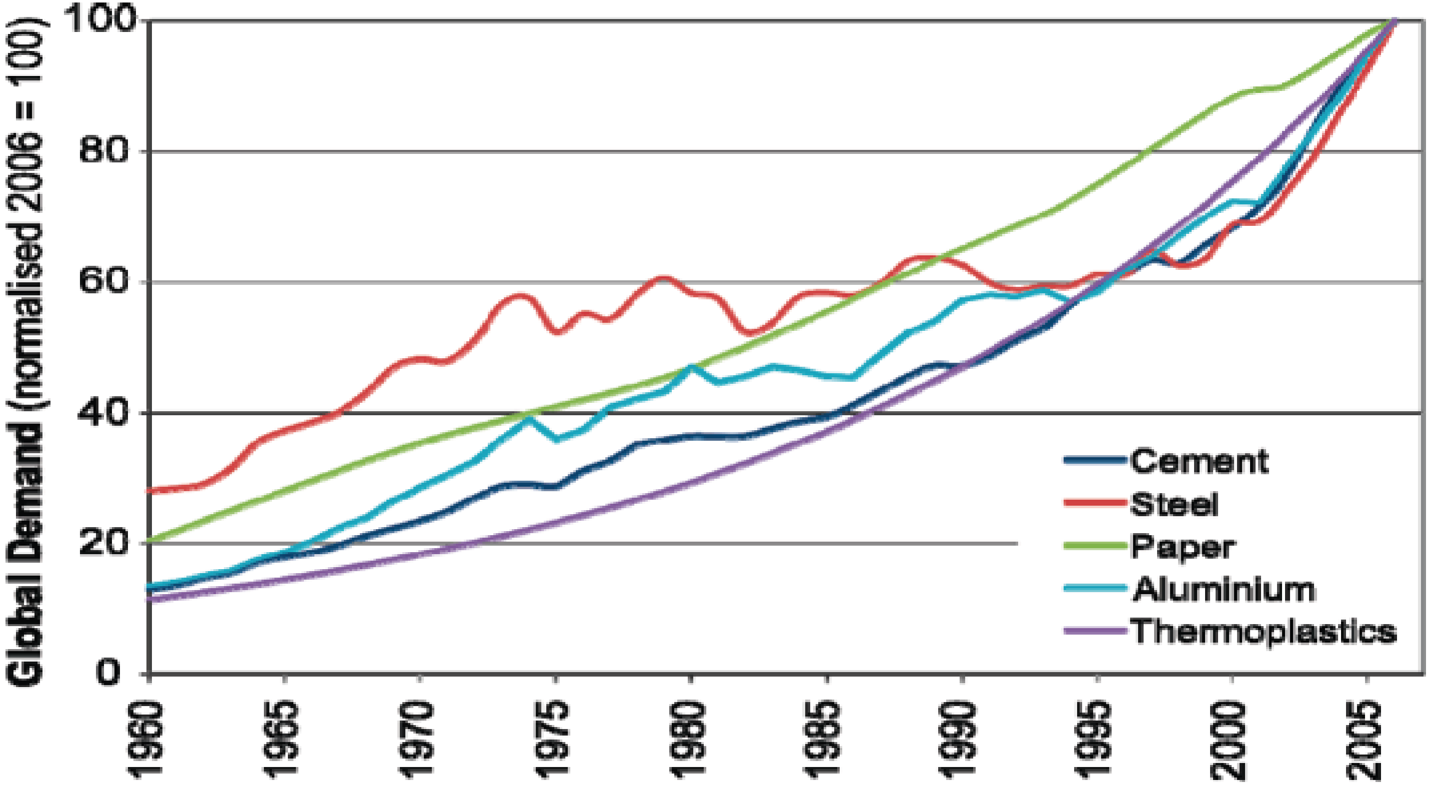
Energy-Related U.S. Carbon Dioxide Emissions in 2010: ~5632 Million Metric Tons

Lawrence Livermore National Laboratory



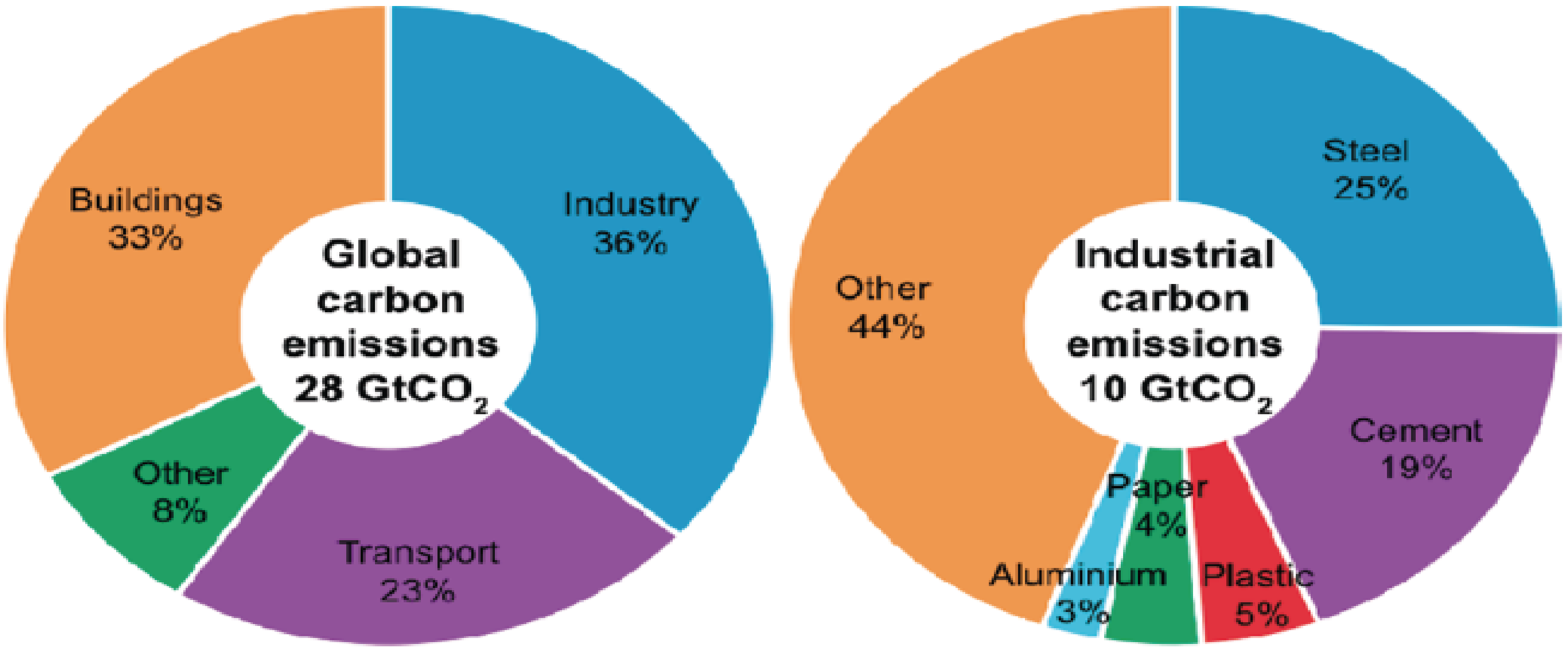
Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Non-fuel carbon and non-energy CO2 is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions – lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. Totals may not equal sum of components due to independent rounding. LLNL-MI-411167

Increasing Raw Materials Demand



Allwood, Cullen, and Milford (2010), Options for Achieving a 50% Cut in Industrial Carbon Emissions by 2050, *Environ. Sci. Technol., 44, 1888–1894.*

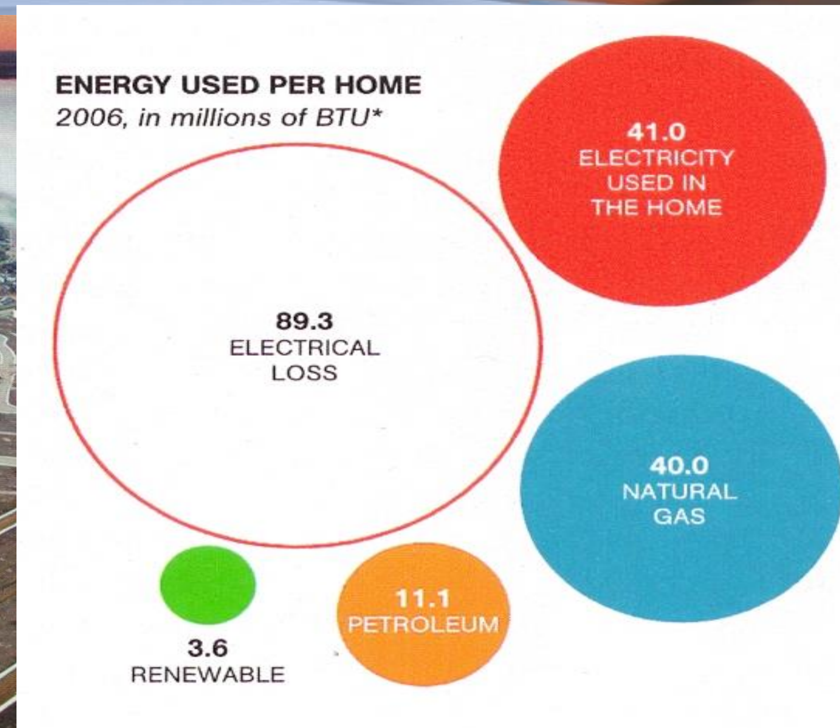
CO_2 Production



Allwood, Cullen, and Milford (2010), Options for Achieving a 50% Cut in Industrial Carbon Emissions by 2050, *Environ. Sci. Technol., 44, 1888–1894.*

1970 Earth Day Button

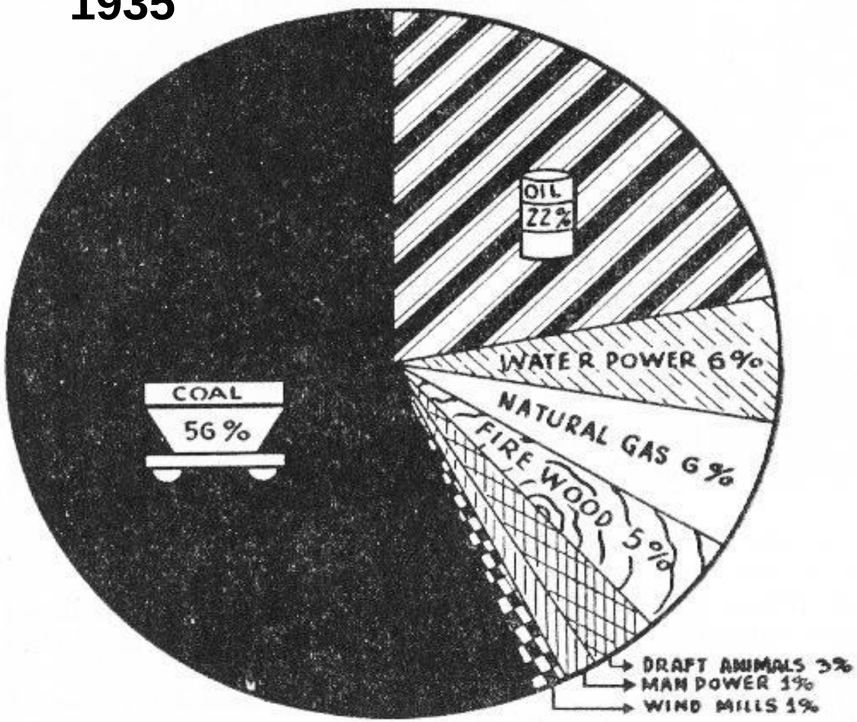
Home Energy in U.S.



Source: National Geographic, March 2009

Energy in U.S. by Source

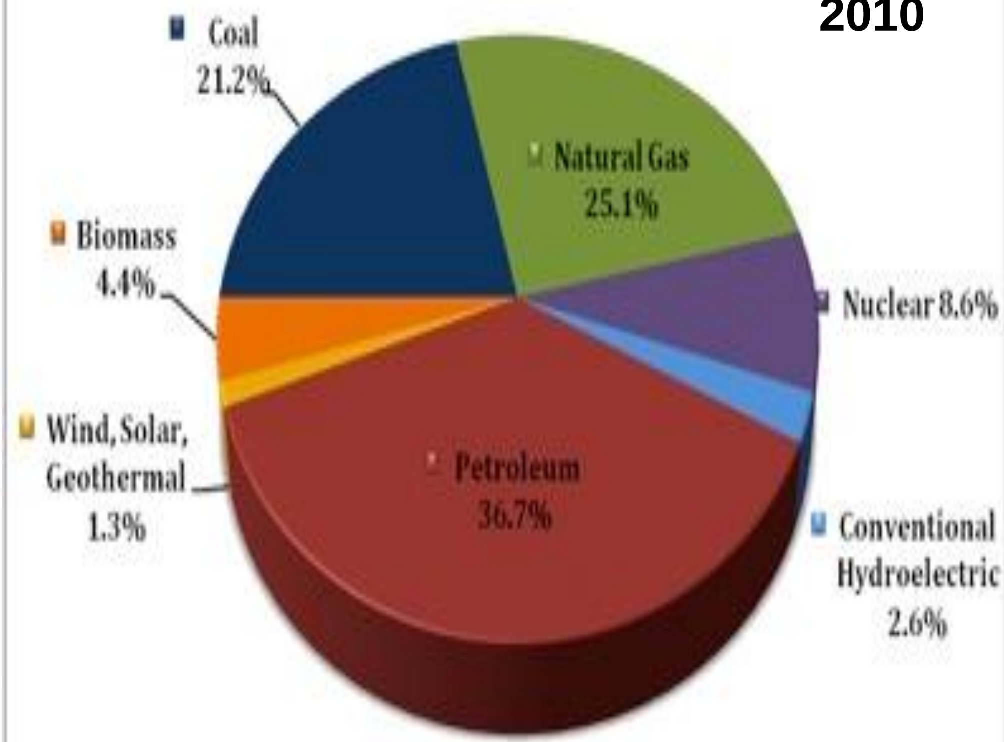
1935



Courtesy of "Building America."

This graph shows what percentage of American power is produced from each of our natural resources.

2010



Source: EIA, *Monthly Energy Review, March 2011*, Table 1.3 Primary Energy Consumption by Source (Quadrillion Btu), 7, http://www.eia.doe.gov/emeu/mer/pdf/mer.pdf.

Why Worry About Energy Efficiency in Built Environment?

- **39% of total energy use**
  - 68% of total electrical consumption
  - 38% of carbon emissions

- Most cost efficient: energy efficiency
  - Investment return usually 20-40%

Green/Ultra-Efficient Buildings

Ultra-efficient buildings optimize and include the following design features:

- Climate-specific design (construction for energy efficiency)
- Passive solar heating and cooling
- Energy-efficient appliances and lighting (daylighting?)

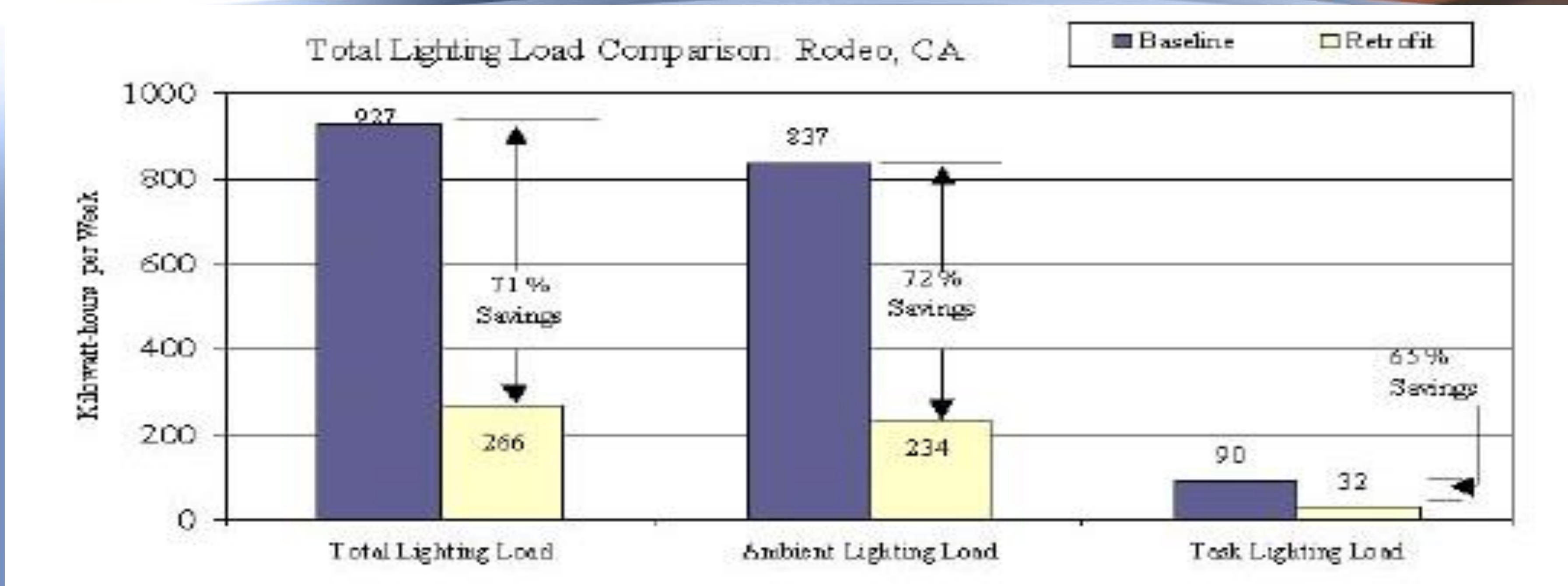
Energy-efficient homes in Lenoir City, Tennessee (left), and in Oberdorf, Switzerland.

Example: Energy Efficiency & Lighting

- Energy savings up to 80%
- Sources of Savings:
  - Lighting
  - Windows
  - HVAC Systems
- Efficient lighting & better windows can lead to smaller and less costly HVAC system
- Energy savings from efficient lighting:
  - Payback period can be < 2 years
  - Average investment return 50-80%

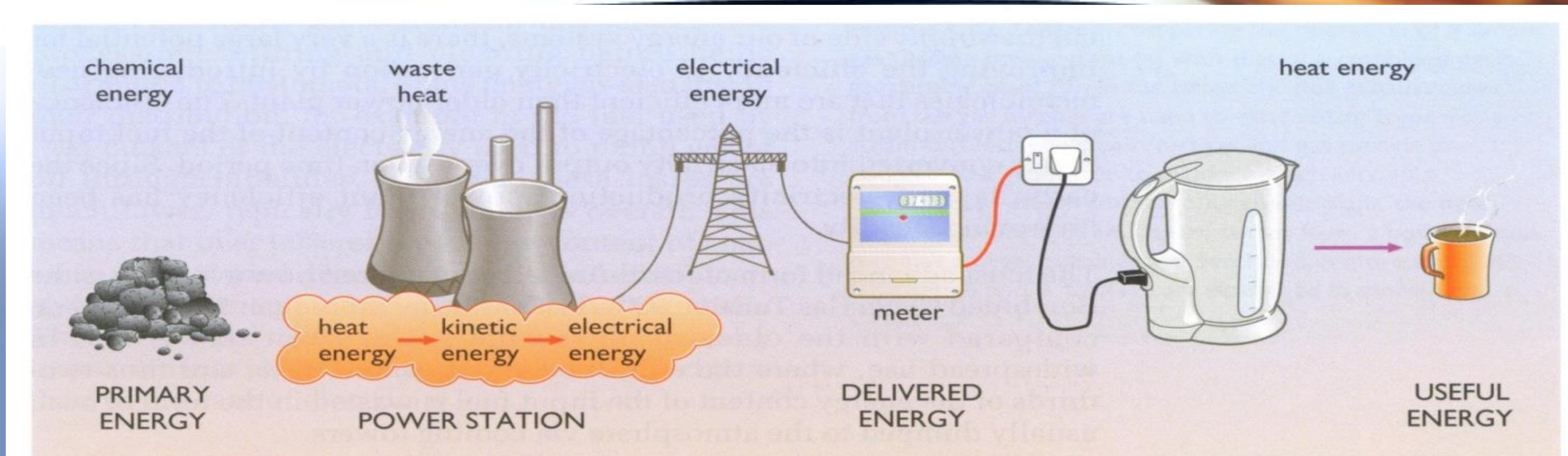
Energy Efficiency & Lighting

Case Study: Retrofit of US Postal Service, Rodeo, CA



- Total lighting load decreased 71%
- Decrease in both ambient and task lighting

Efficiency of a series of processes



From conversion chain:

combustion (& heat exchanger) → steam turbine → electric generator → distribution grid → appliance

$$\eta_{system} = \eta_{combustion} \times \eta_{turbine} \times \eta_{generator} \times \eta_{grid} \times \eta_{appliance}$$

Example: Efficiency of an

TABLE 1.2 Efficiencies of selected components and biological systems

Component	Energy Conversion Path	Efficiency (percent)
Large electric generators	m → e	98–99
Large power plant boilers	c → t	90–98
Large electric motors	e → m	90–97
Home natural gas furnaces	c → t	90–96
Drycell batteries	c → e	85–95
Waterwheels (overshot)	m → m	60–85
Small electric motors	e → m	60–75
Large steam turbines	t → m	40–45
Wood stoves	c → t	25–45
Large gas turbines	c → m	35–40
Diesel engines	c → m	30–35
Photovoltaic cells	r → e	20–30
Large steam engines	c → m	20–25
Internal combustion engines	c → m	15–25
Steam locomotives	c → m	3–6
Light Sources		
High-pressure sodium lamps	e → r	15–20
Fluorescent lights	e → r	10–12
Incandescent light bulbs	e → r	2–5
Paraffin candles	c → r	1–2
Biological Systems		
Milk production	c → c	15–20
Broiler production	c → c	10–15
Beef production	c → c	5–10
Local photosynthesis	r → c	4–5
Global photosynthesis	r → c	0.3

Energy conversion path labels: c = chemical, e = electrical, m = mechanical, r = radiant, t = thermal.

Assume grid efficiency ≈ 92%

Already includes typical Carnot term

Example: Efficiency of an incandescent lamp

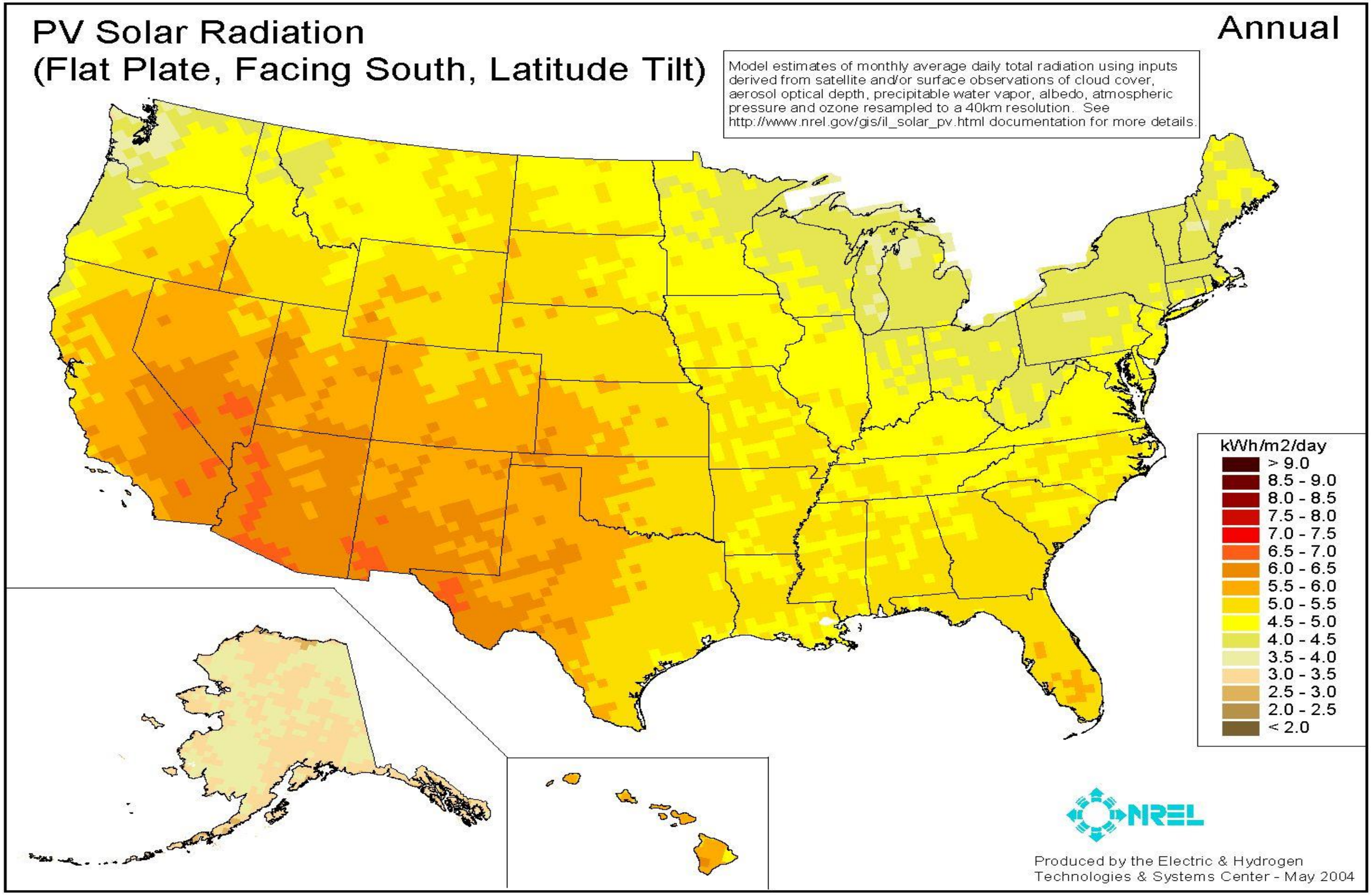
$$\eta_{system} = \eta_{combustion} \times \eta_{turbine} \times \eta_{generator} \times \eta_{grid} \times \eta_{appliance}$$

From the table and info we can get the following

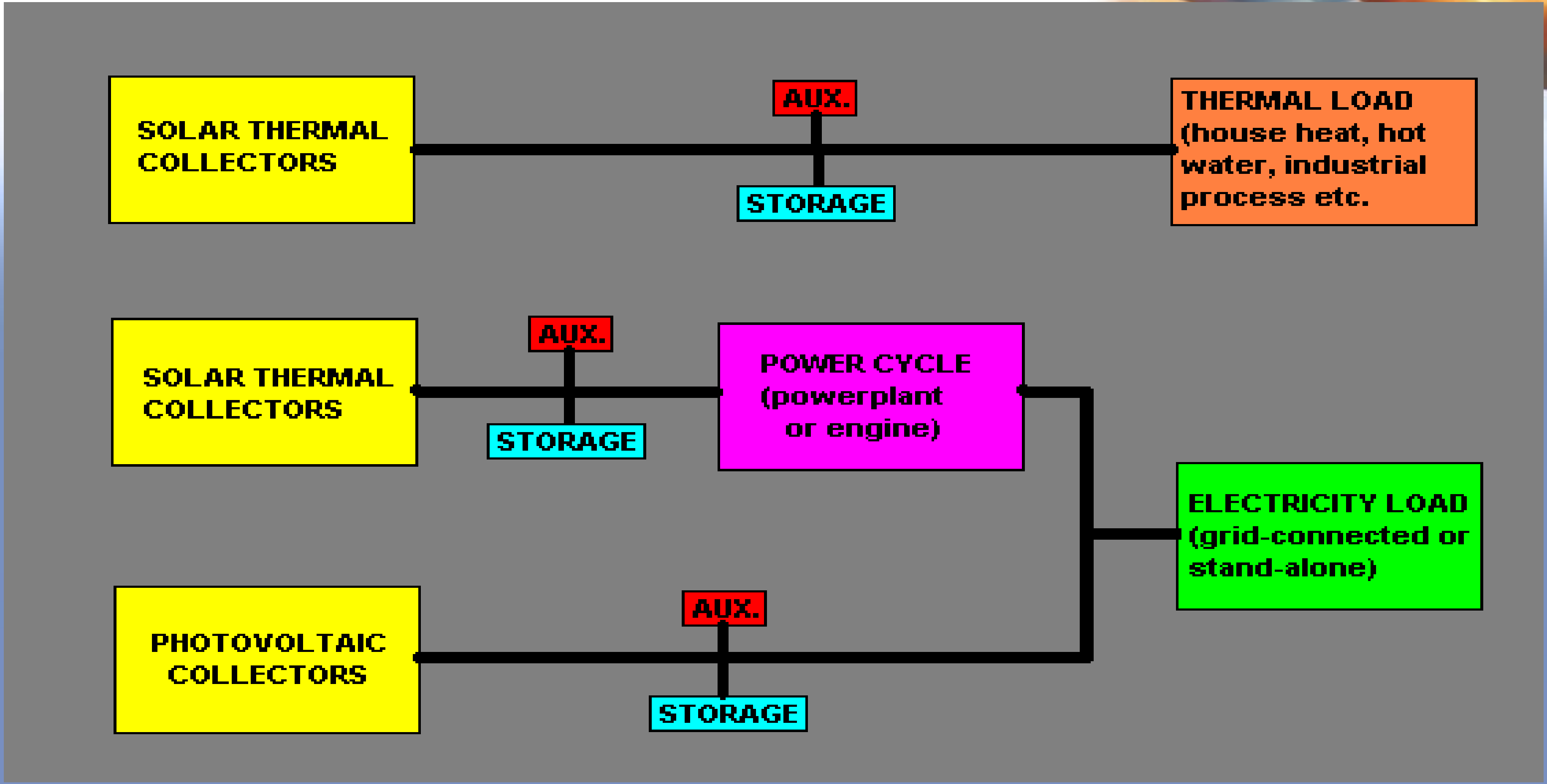
$$\eta_{system} = 94\% \times 42\% \times 98\% \times 92\% \times 4\% \quad = 1.5\%$$

For comparison, a candle is about 1.5% efficient…

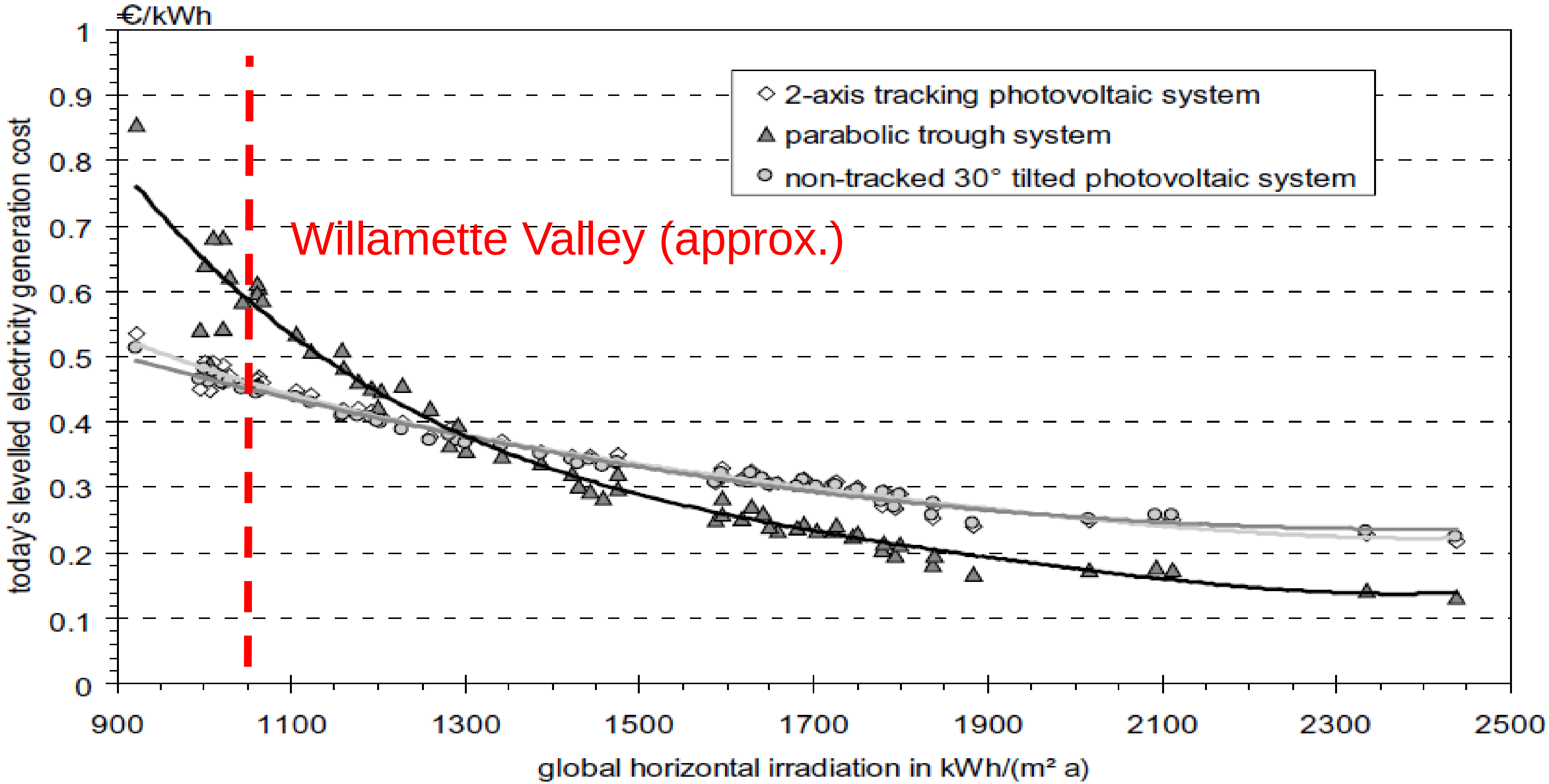
US Annual Insolation



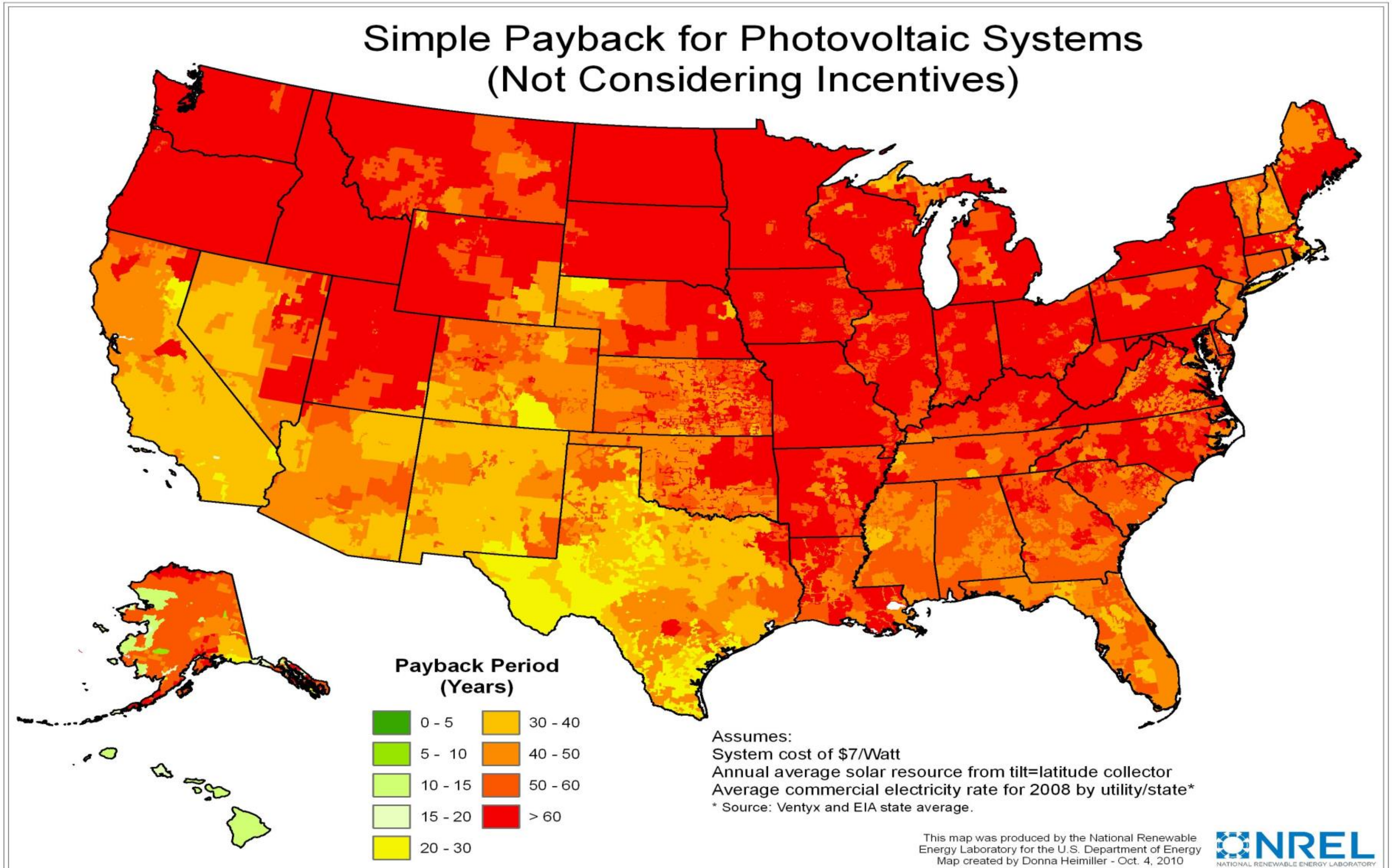
Solar Energy

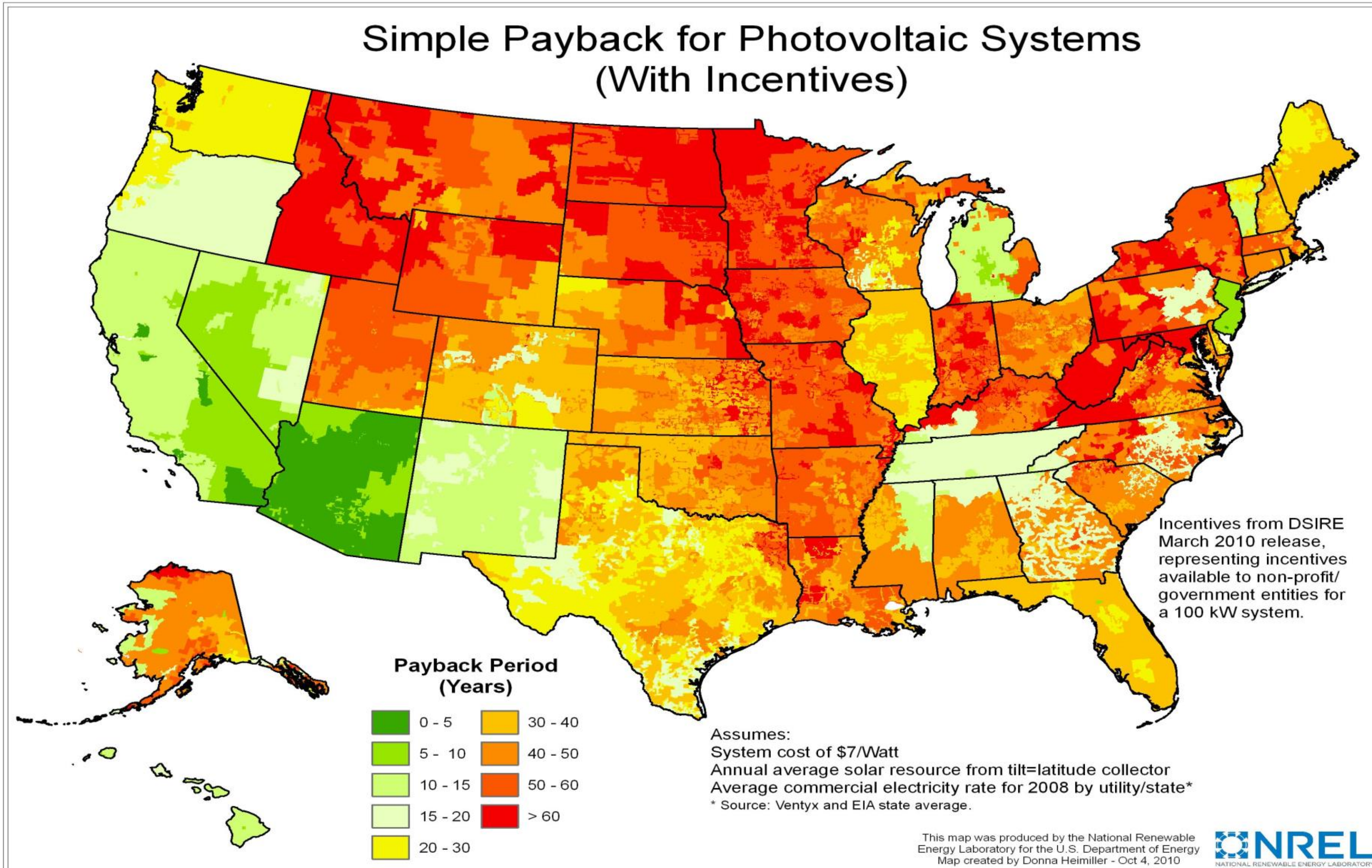


Which Solar Technology?



Break even between PV and Thermal at ca. 1300 $kW.m^{-2}.yr^{-1}$


Simple Payback for Photovoltaic Systems
(Not Considering Incentives)
Payback Period
(Years)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 50
50 - 60
> 60
Assumes:
System cost of $7/Watt
Annual average solar resource from tilt=latitude collector
Average commercial electricity rate for 2008 by utility/state*
* Source: Ventyx and EIA state average.
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct. 4, 2010
NREL
NATIONAL RENEWABLE ENERGY LABORATORY


Simple Payback for Photovoltaic Systems
(With Incentives)
Incentives from DSIRE
March 2010 release,
representing incentives
available to non-profit/
government entities for
a 100 kW system.
Payback Period
(Years)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 50
50 - 60
> 60
Assumes:
System cost of $7/Watt
Annual average solar resource from tilt=latitude collector
Average commercial electricity rate for 2008 by utility/state*
* Source: Ventyx and EIA state average.
This map was produced by the National Renewable
Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct 4, 2010
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

PEAK LOAD VS. BASE LOAD ENERGY

+

≠

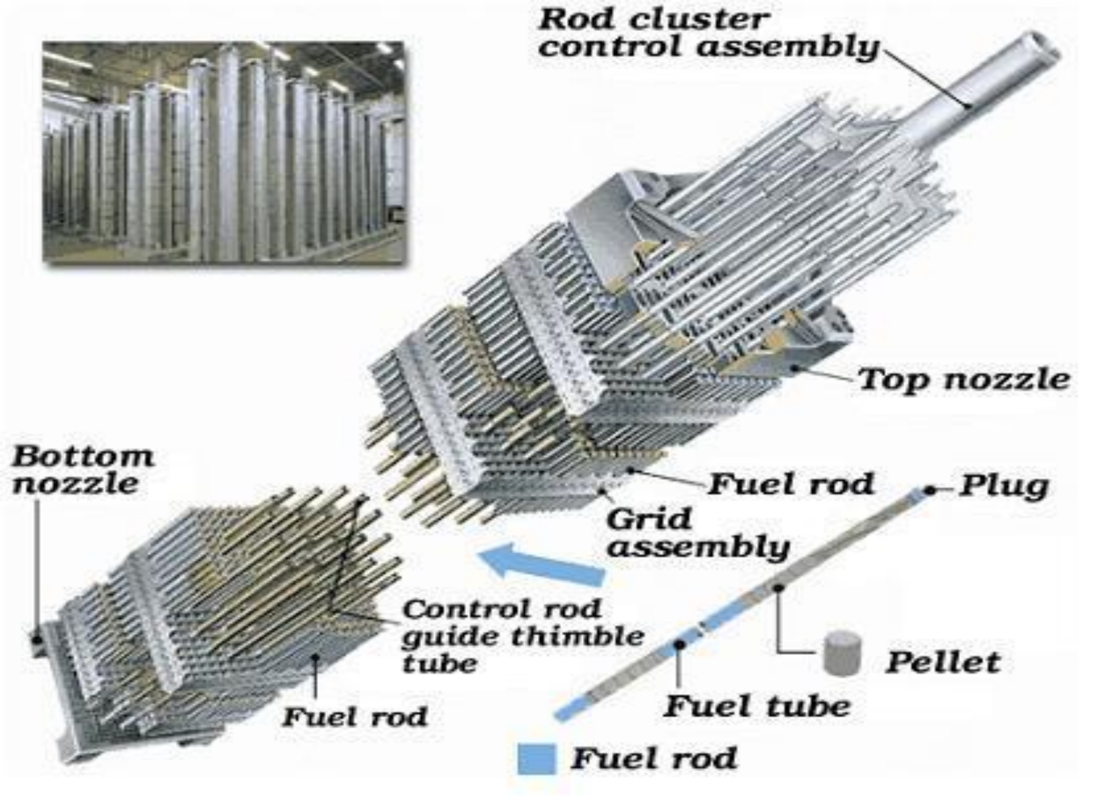
Wind and Solar are relegated to peak load because they are variable, intermittent resources

Source: Columbia Power Technologies

Nuclear Fuel Pellet

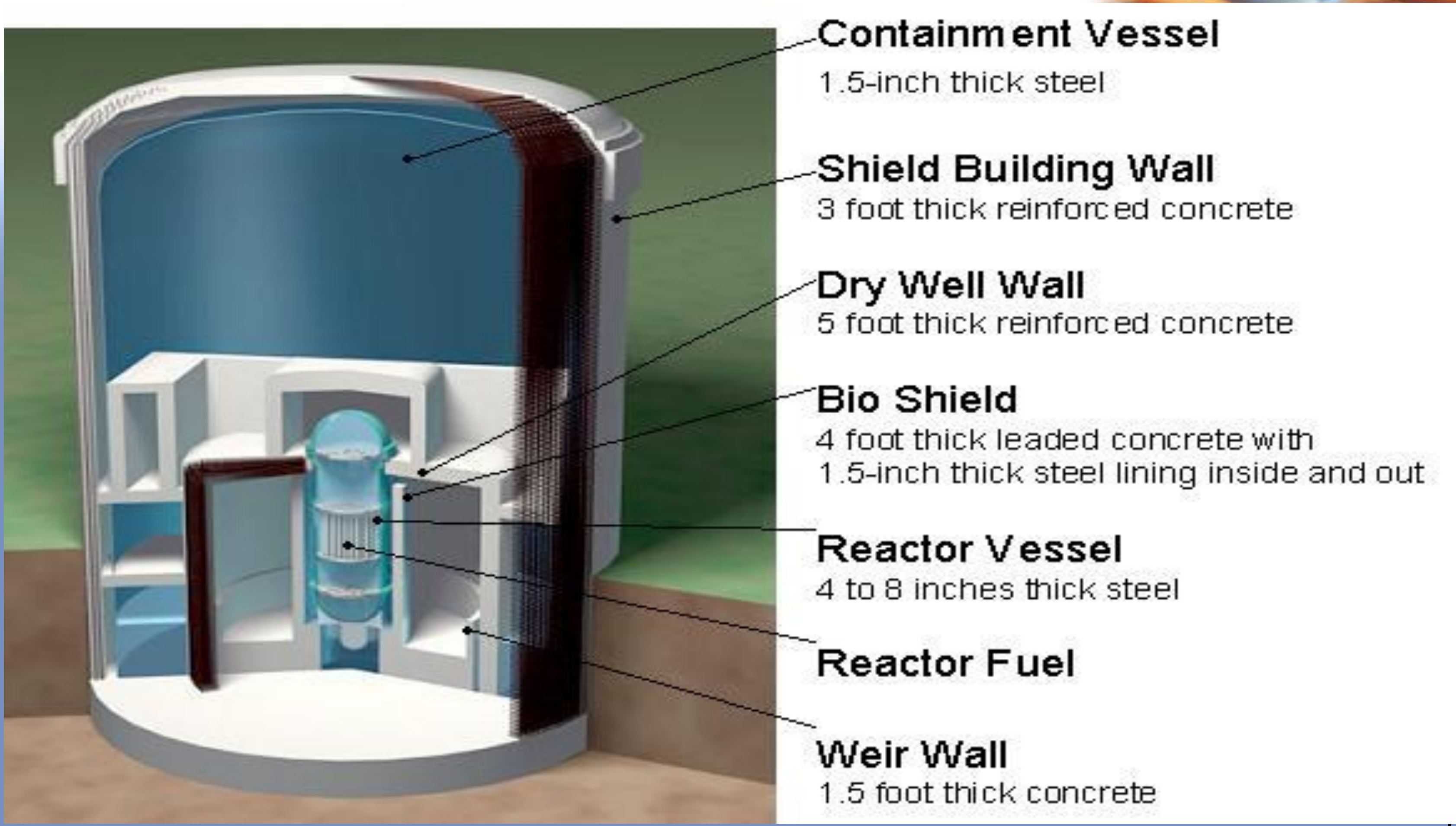
- Ceramic uranium oxide pellet the size of the tip of your little finger
- Equivalent to:
  - **1780 pounds of coal**
  - **149 gallons of oil**
  - **17,000 cu ft natural gas**

Nuclear Fuel Assembly

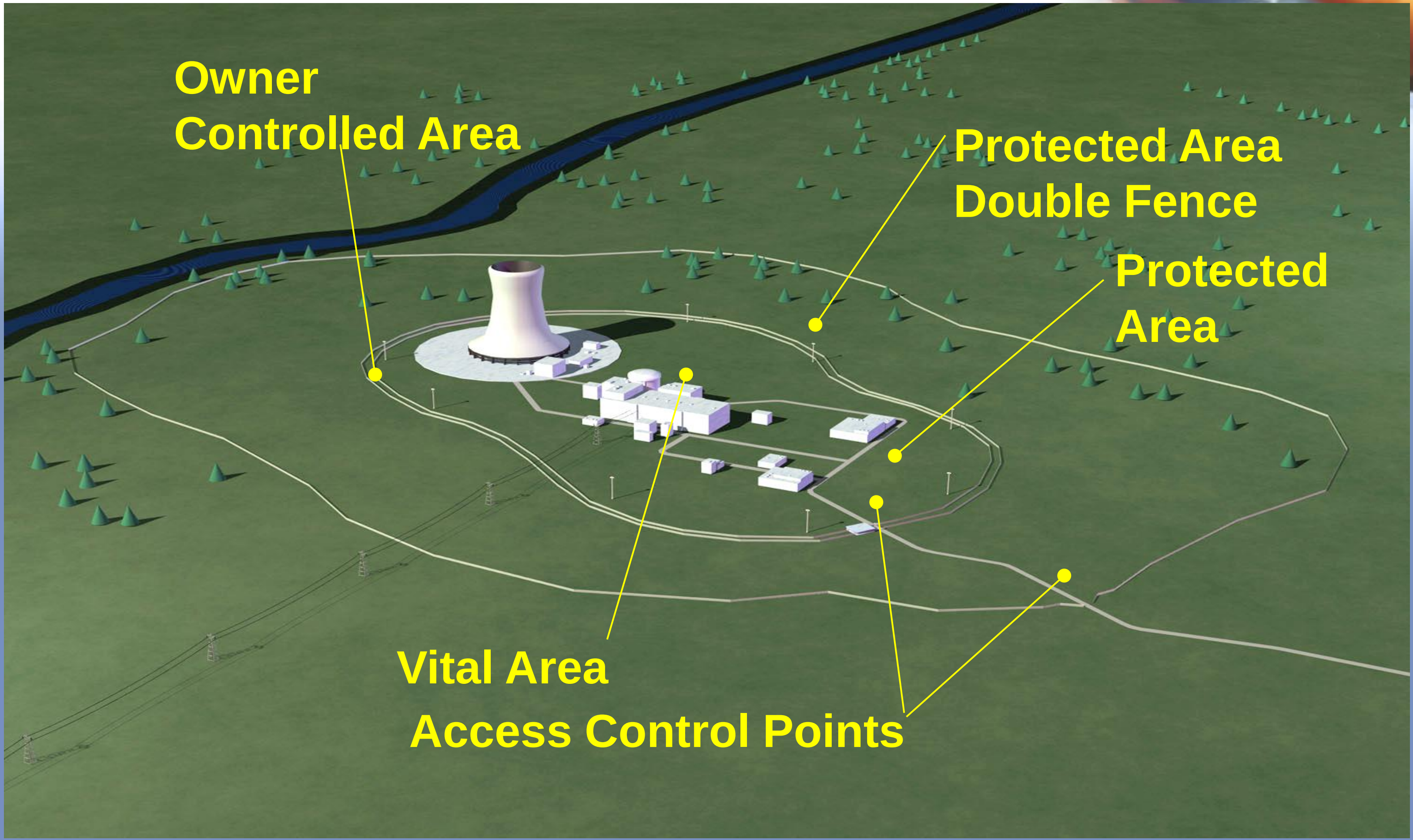


- Pellets are stacked and sealed in a Zircaloy tube to form a fuel rod
- Fuel rods are placed in a matrix to form a fuel assembly

Safety is Part of Reactor Designs



Nuclear Plant Security Zones



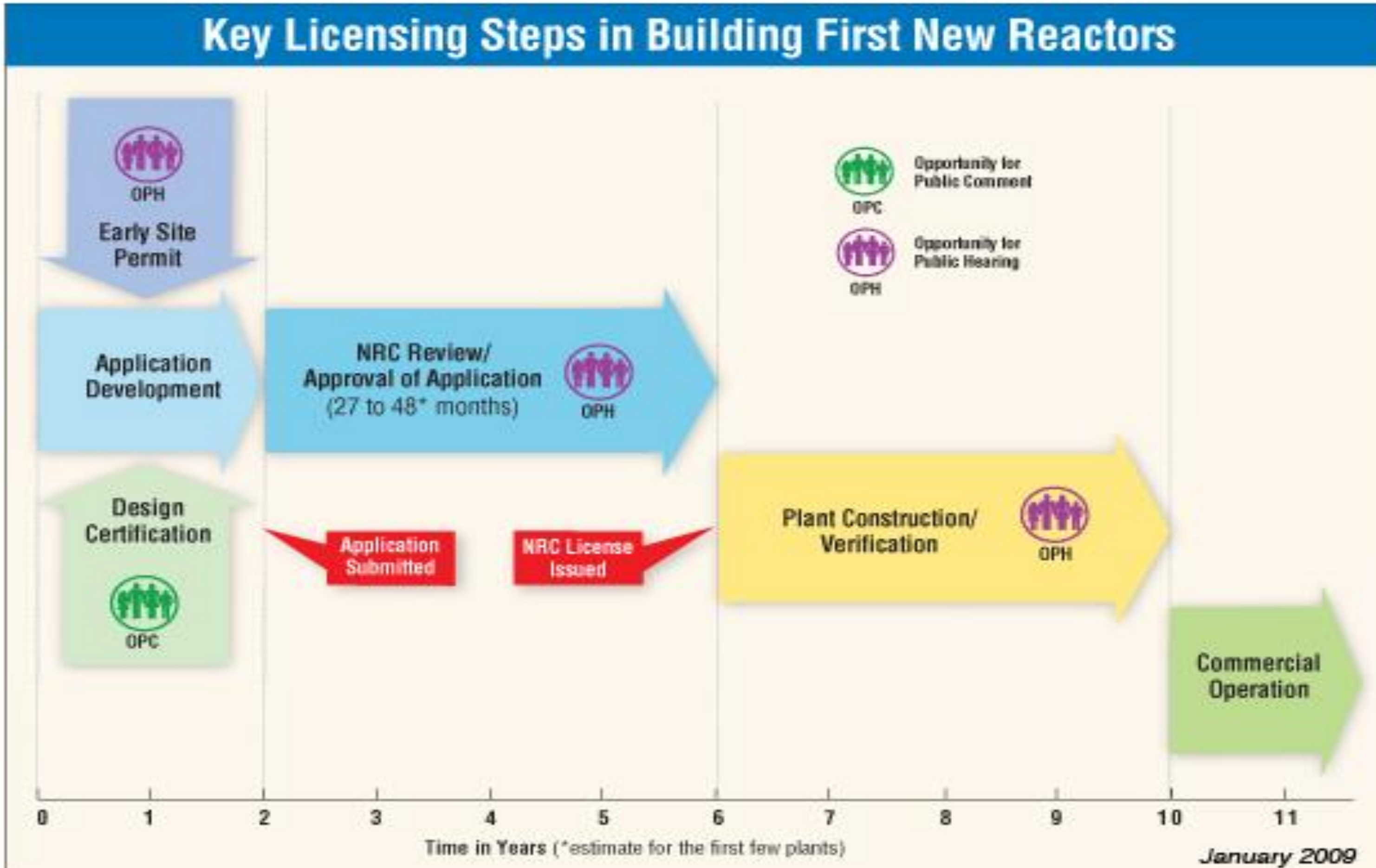
U.S. Capacity Factors by Fuel Type

2007

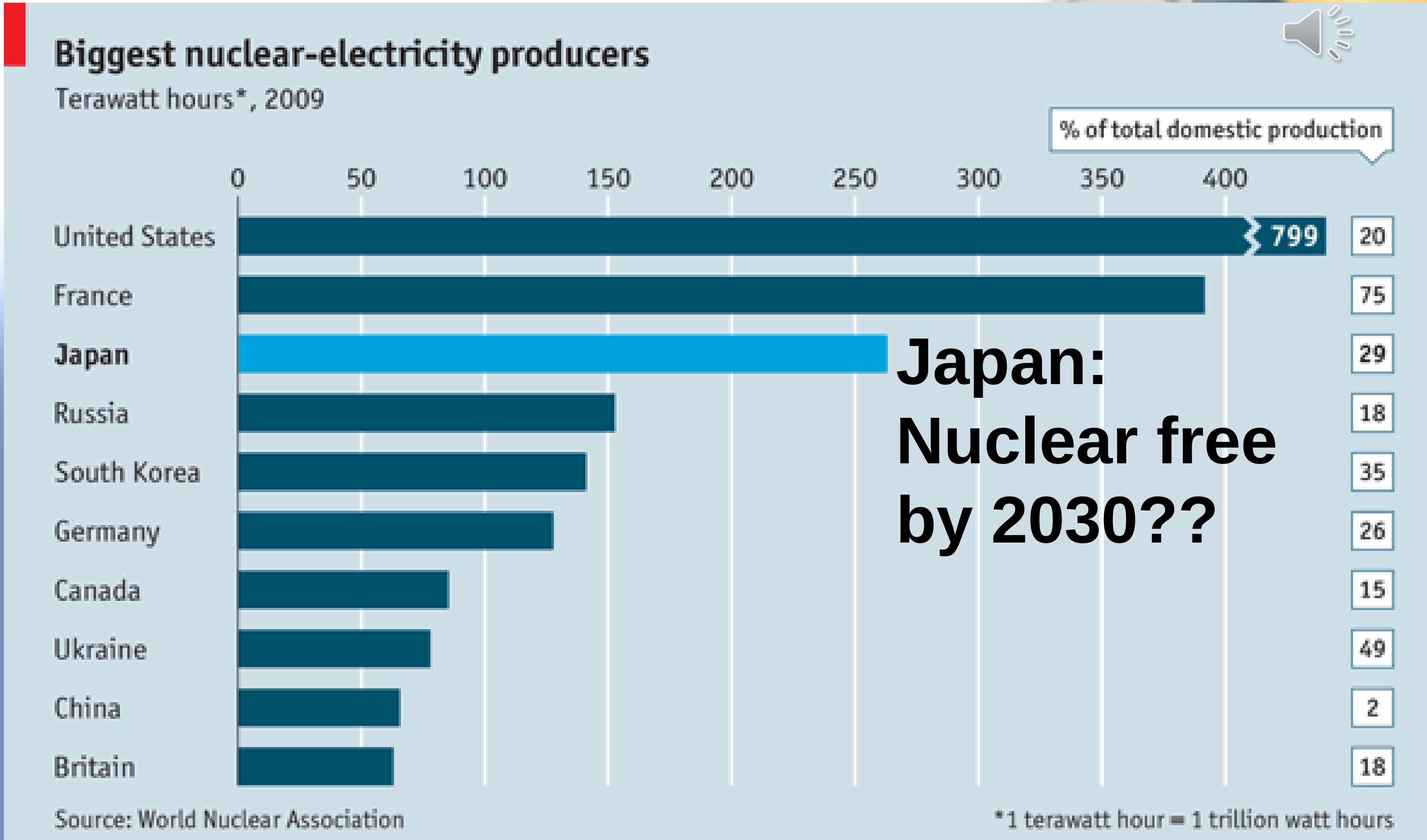
Fuel Type	Average Capacity Factors (%)*
Nuclear	91.8
Coal (Steam Turbine)	71.8
Gas (Combined Cycle)	43.3
Gas (Steam Turbine)	16.0
Oil (Steam Turbine)	19.6
Hydro	27.8
Wind	30.4
Solar	19.8

* Preliminary
Source: Global Energy Decisions / Energy Information Administration
Updated: 4/08

Streamlined NRC Regulatory Processes?

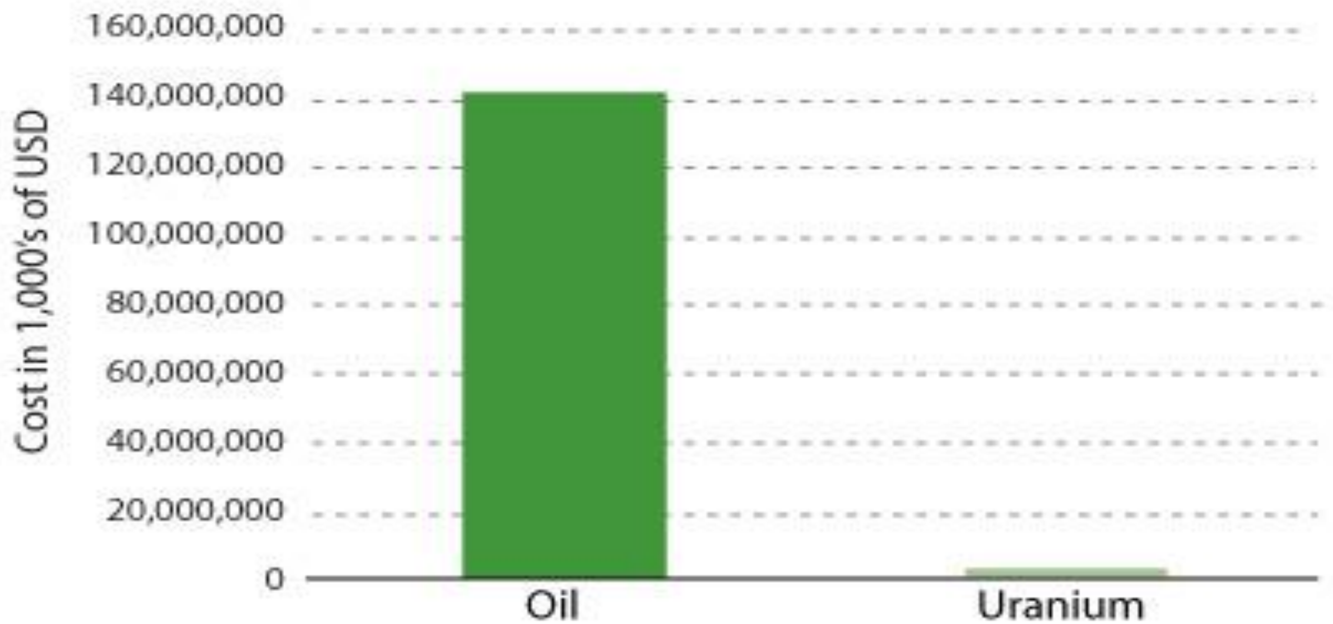


The NRC's new licensing process offers multiple opportunities for public input.



Japan: Nuclear free by 2030??

Easy Math: A Year's Worth of Energy at a Fraction of the Price...

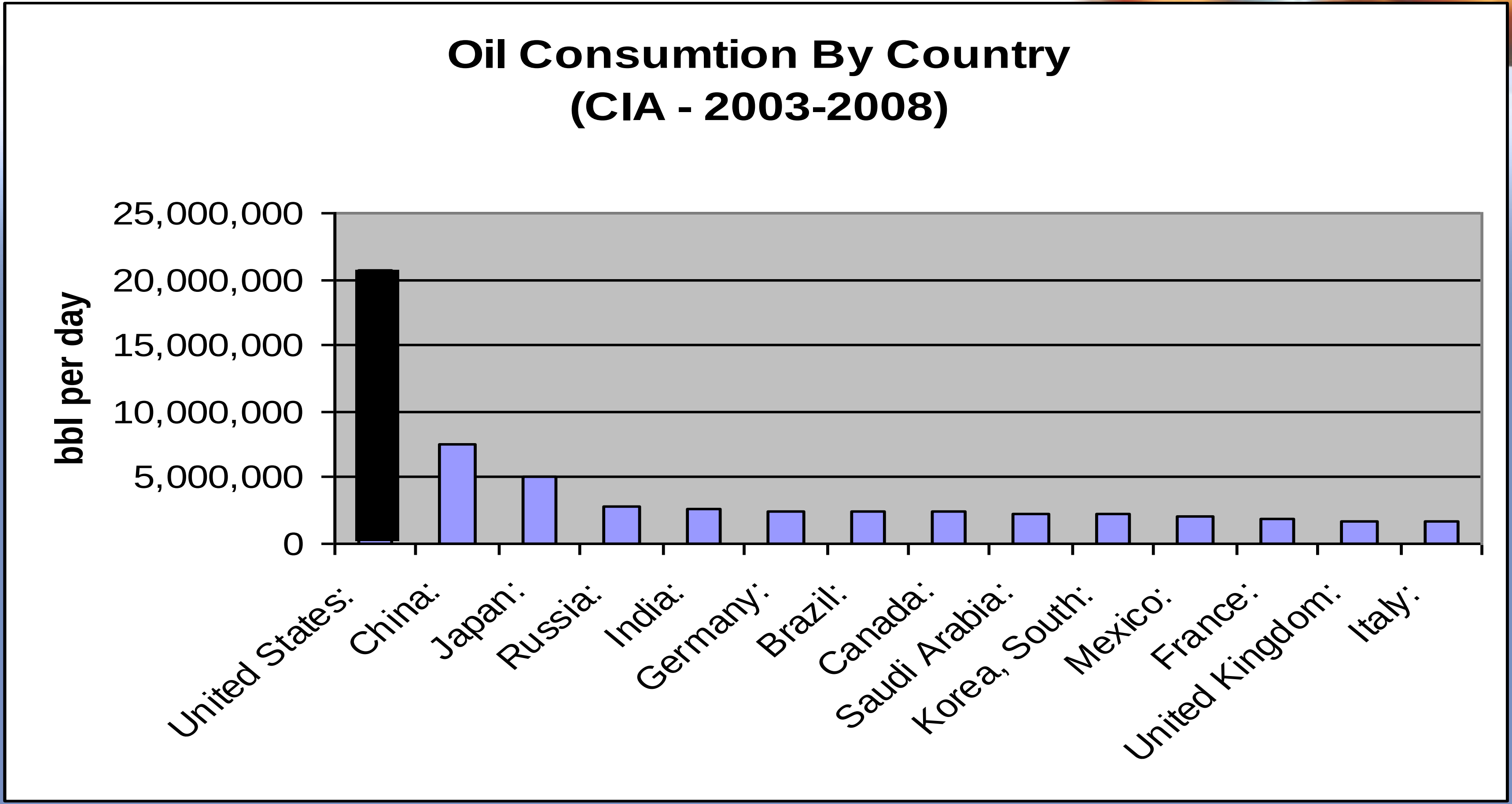


For what it costs China to run for just <u>two days</u> on oil, they could run a <u>whole year</u> on uranium!

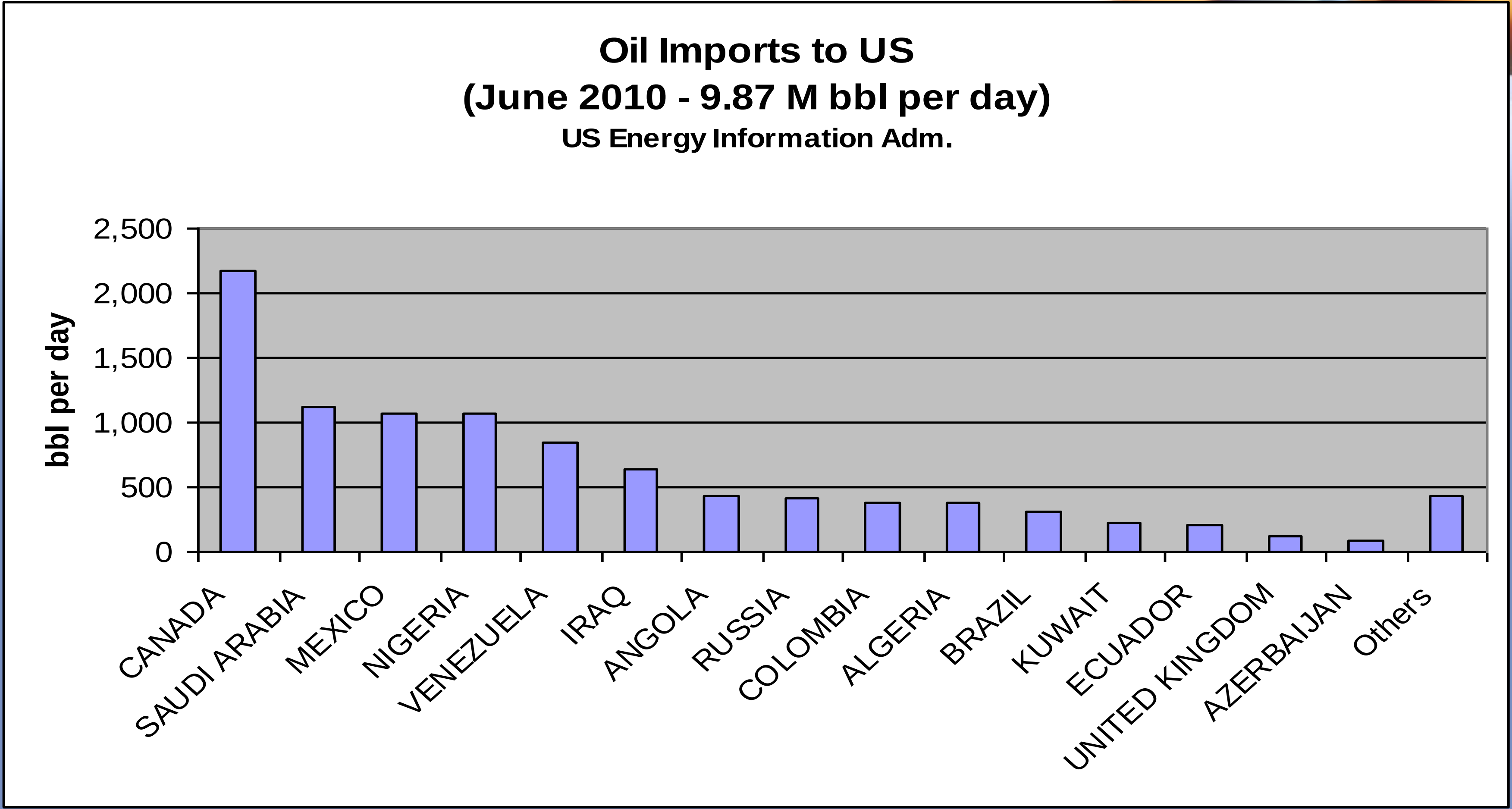
China's Energy Dilemma

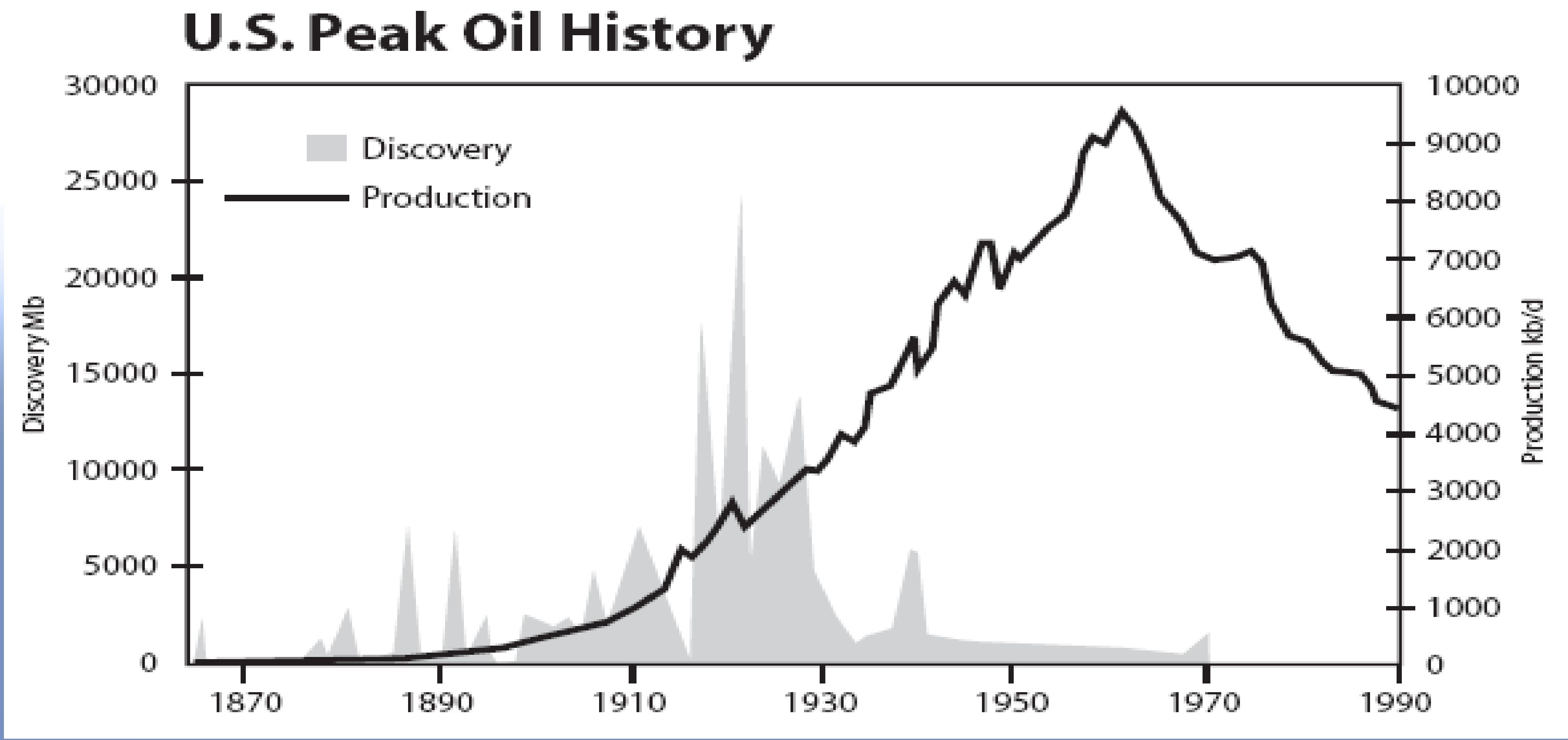
- 80% of its energy from Coal for >1 Billion People
- So, ramp up nuclear! (currently 11 reactors)
- Building 17 more now
- Wants to build ~100 more over the next several years
- China now uses 769 tons of uranium
- They could need ***20,000 tons*** in the future!
- **Global:** 436 reactors running, 50 being built, 137 in blueprint stage, and 295 more on the table for approval
- ***Nuclear energy has the power to light a city in a lump of uranium the size of a soda can***
- ***Who has uranium? Australia, US, Canada, France, Argentina, Brazil, and India*** *(and some in South Africa, Nigeria, Algeria, and Gabon)*
- **What happens to the price of uranium??**

How Much Oil Do We Use?



Where Does US **Import** Oil Come From?



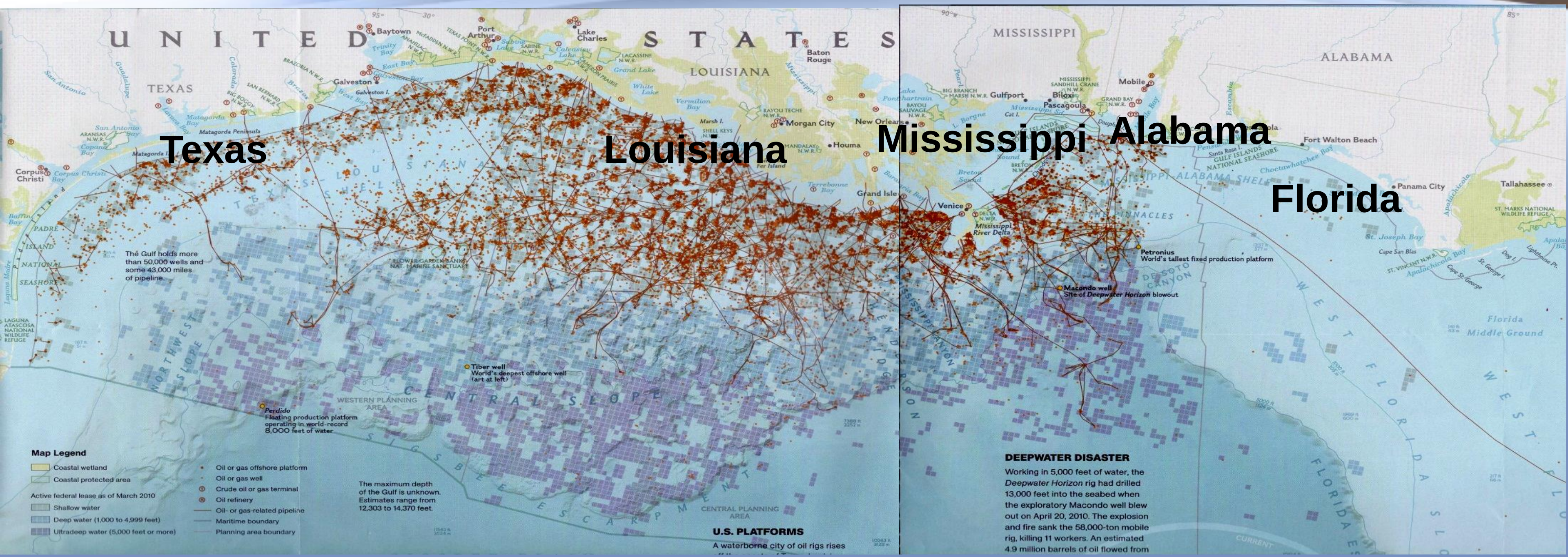


Is there nothing left to discover?? Or, did we stop looking?

- New technology and new locations

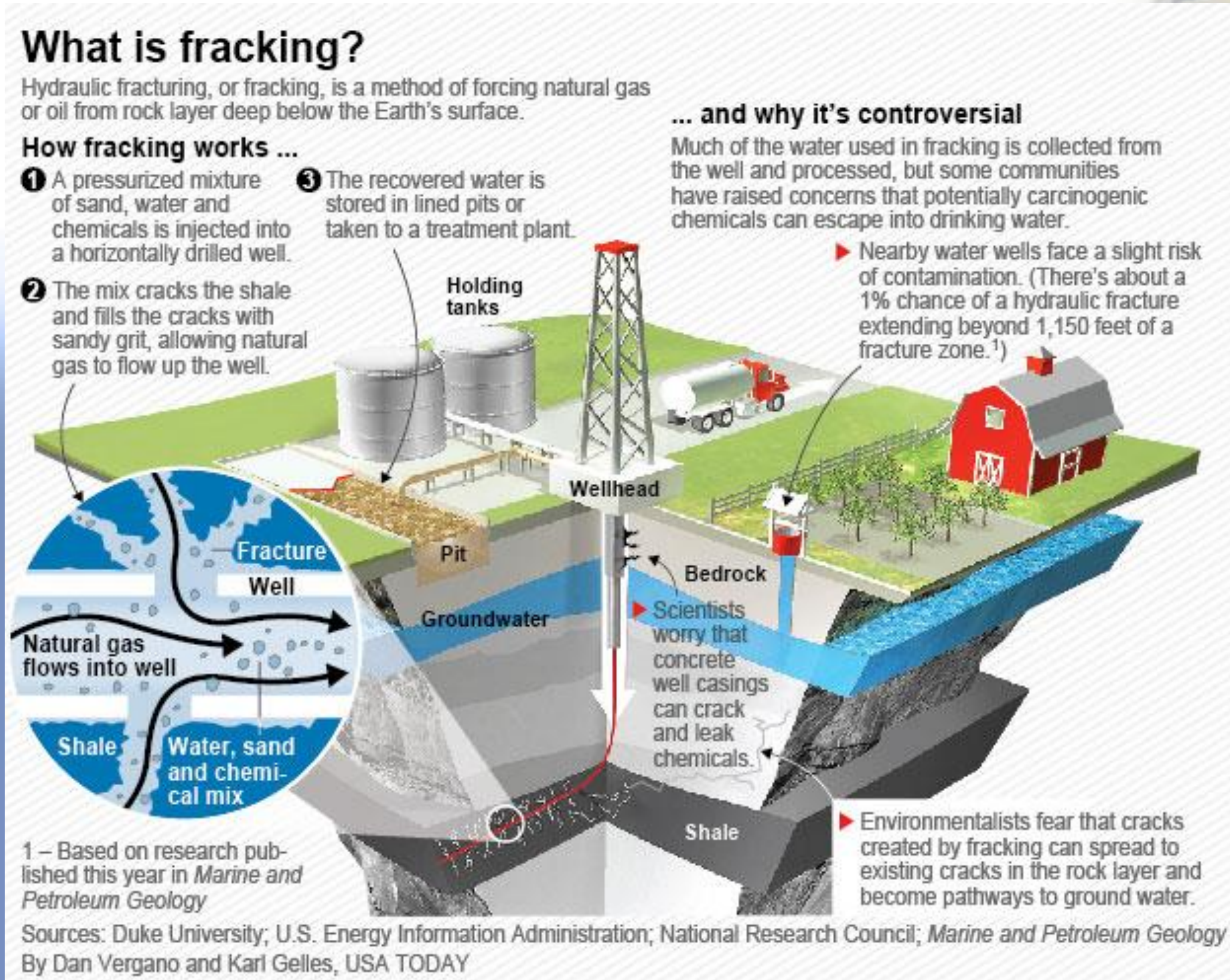
Gulf of Mexico –

Oil Drilling and Leases



Many Here

None Here



Fracking – New Technology

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.
Updated: May 9, 2011

Shale Basins –

New Locations

U.S. Natural Gas Prices

Source: Short-Term Energy Outlook, August 2010; Reuters News Service

U.S. Energy Information Administration

American Gas Association

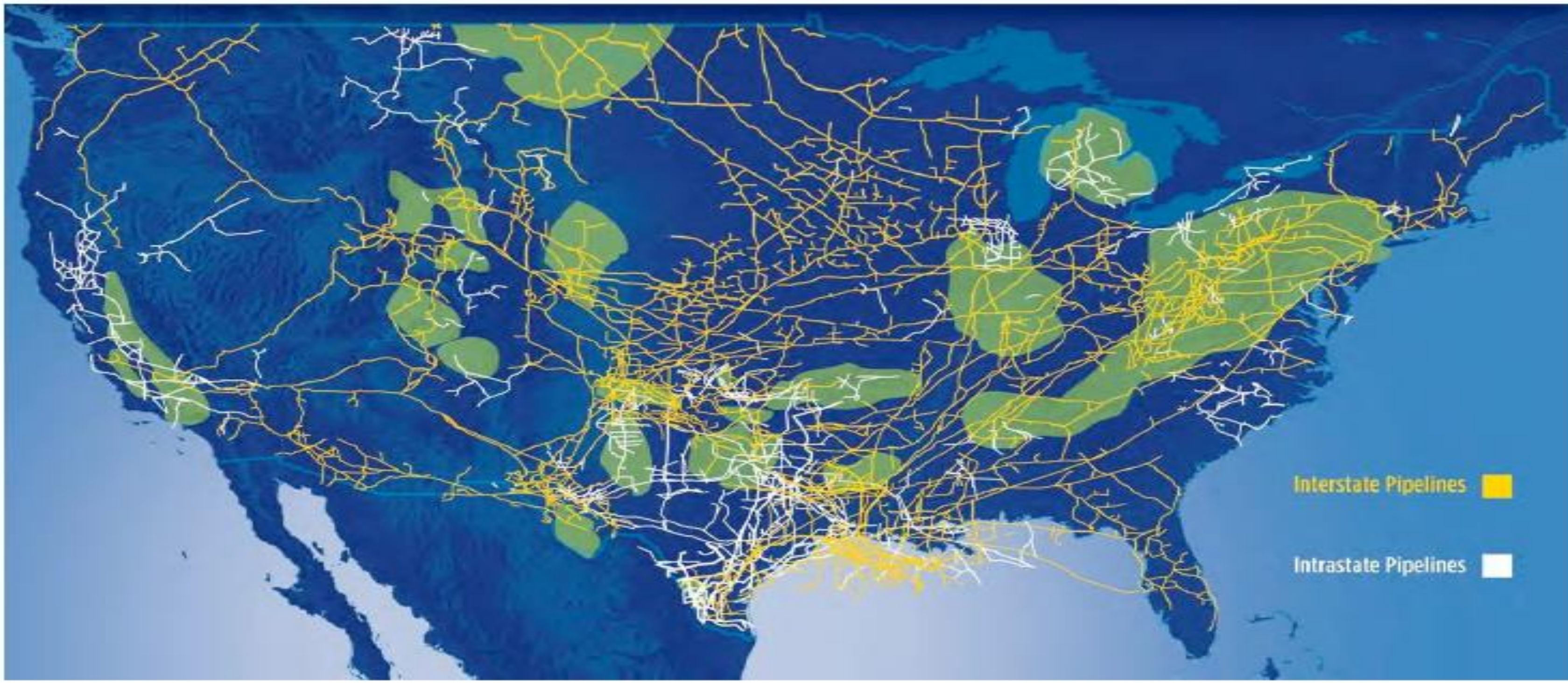
Natural Gas

Natural Gas Resource Assessment of the Potential Gas Committee, 2008 (mean values)

Traditional Resources	1,673.4 TCF
Coalbed Gas Resources	163.0 TCF
Total U.S. Resources	**1,836.4 TCF**
Proved Reserves (EIA)	237.7 TCF
Future Gas Supply	**2,074.1 TCF**

Pipeline Grid

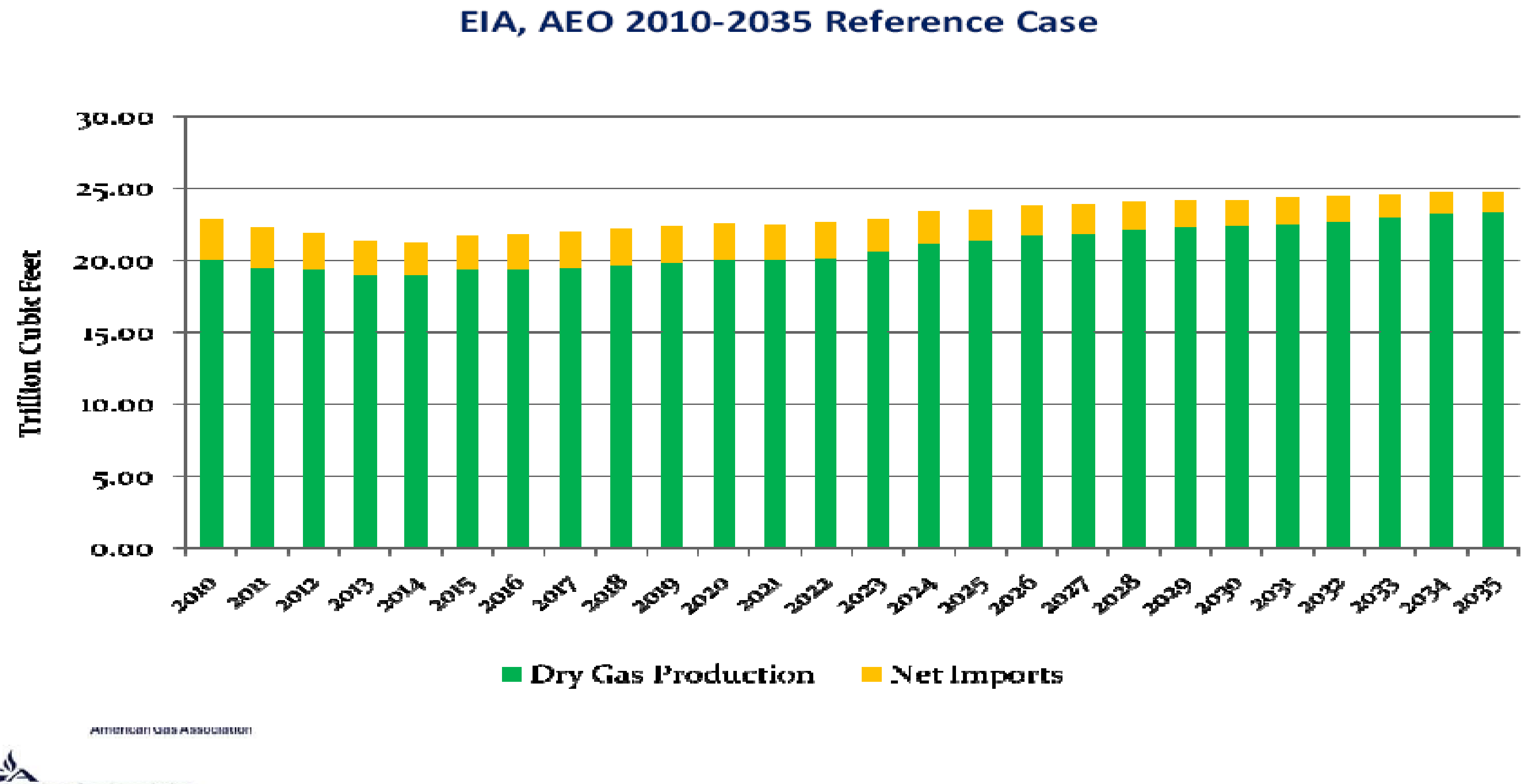
Shale Basins and the U.S. Pipeline Grid



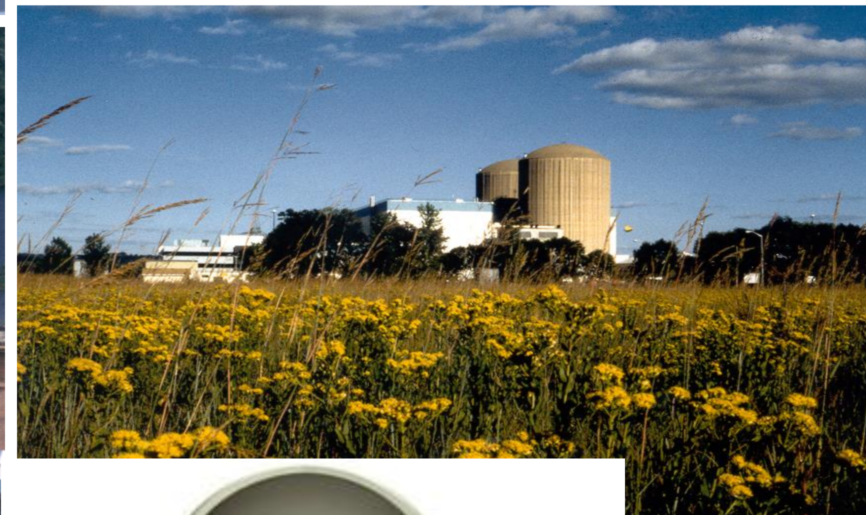
Source: American Clean Skies Foundation.

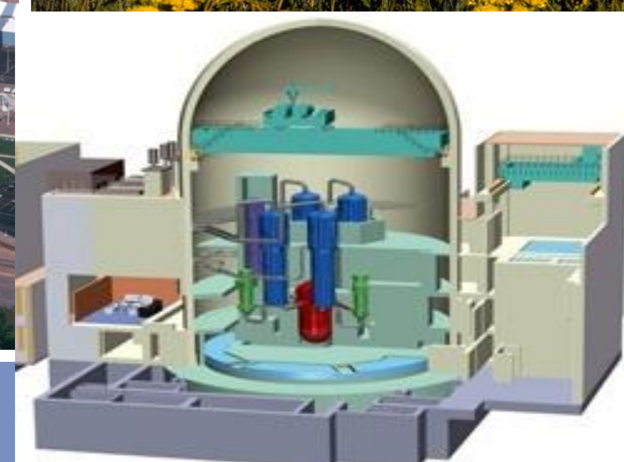
AGA American Gas Association

U.S. Natural Gas Supply



What Happens to Future Nuclear Plants if the Supply of NG is Very High and Price is Very Low?



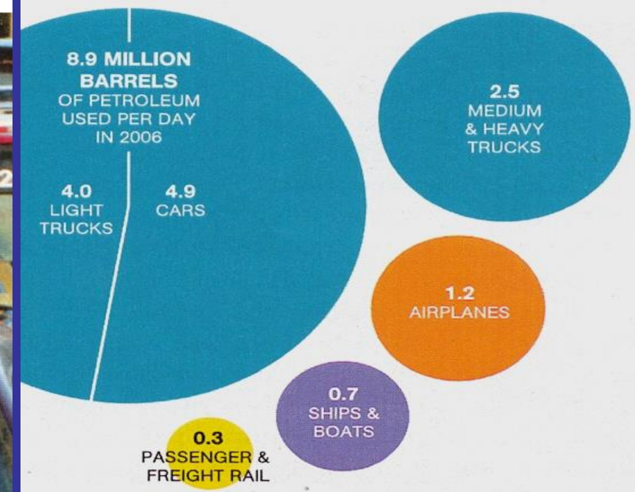


U.S. Transportation

Source: National Geographic, March 2009

TRANSPORTATION TOLLS

Cars and light trucks consume the lion's share of petroleum used for transportation in the U.S. Modest changes in efficiency and driving habits could add up to significant fuel savings.



If we drove our cars 20 fewer miles each week, we could reduce their CO_2 emissions by **107 million tons** each year, a 9 percent decrease.

If we improved our cars' gas mileage by 5 miles a gallon, we could cut their CO_2 emissions by **239 million tons** each year, a 20 percent decrease.

Sustainability

National Academy of Science – **Grand Challenges of the 21st Century Engineering**

Themes that are Essential for Humanity to Flourish:

1. **Sustainability**
2. **Health**
3. **Reducing Vulnerability**
4. **Joy of Living**

Source: *The Essential Engineer*

Many definitions…but consistent core principles

Definitions

- Brundtland Commission, 1983 World Commission on Environment & Development
- Ceres Principles
- Equator Principles
- 1992 Rio Declaration on Environment and Development
- Bellagio Principles
- Hannover Principles
- Natural Step
- One Planet Living
- Company-Specific
- and more

Core Principles

- Finite Resources
- Interdependence
- Social and Personal Well-being
- Legacy and Responsibility

The World's View of Sustainable Development

The **Brundtland Commission**, formally the **World Commission on Environment and Development** (WCED), convened by the United Nations in 1983 and defined sustainable development as:

"…. development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Universal Core Sustainability Principles

Finite Resources

- **Fresh water** – finite quantities of fresh water and water rights
- **Natural Resources** – limited global supply of carbon-based fuels, metals, and native materials
- **Clean air** – urban air quality is getting worse and air-related health issues are increasing
- **Agricultural land** – more land is taken up by development each year, or lost to desertification
- **Fisheries** – fish stocks around the world are in decline

Interdependence

- **Population increase** – world population continues to increase with increased demand for food and consumer goods
- **Ecological cycles** – Consequences of human intervention in
- **Economic health** – is dependent on health of natural world
- **Increases in impervious surfaces** – changing local and regional hydrology
- **Greenhouse gas (GHG) emissions and climate change** – affect planet's atmosphere, biosphere and human infrastructure

Principles, cont'd

Social And Personal Well-being

- Health and safety
- Disparities in wealth/income
- Culture and history
- Recreation
- Various freedoms

Legacy And Responsibility

Debts and conditions conveyed to future generations:

- Livable cities
- Adequate farmland and forests
- Abandoned mines
- Landfill reclamation
- Brownfield redevelopment
- Pollution prevention