





Understanding the Energy Challenge: Science, Technology, Economics and Policy

Mork Family Department of Chemical Engineering and Materials Science

University of Southern California

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My Introduction to Energy Issues

Physics of Sustainable Energy: Using Energy Efficiently and Producing It Renewably
APS Forum on Physics and Society, UC-Berkeley, March 1–2, 2008

The Energy Challenge Outline

- What is the energy challenge?
- Supply and demand in the U.S. and the world
- Some points of reference
- Some energy issue examples
- Closing comments and summary

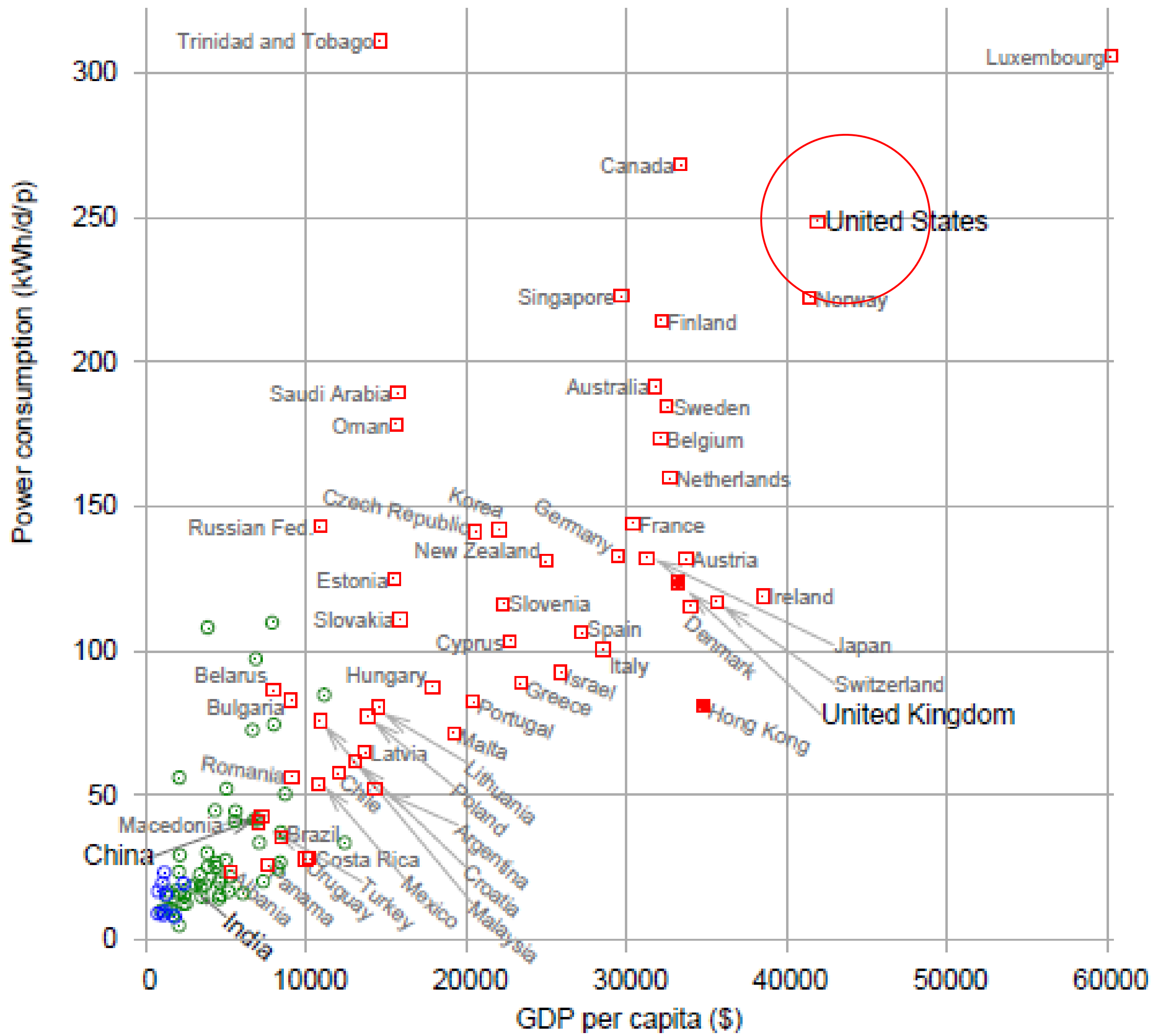
WHAT IS THE ENERY CHALLENGE?

The Energy Challenge

- Energy is crucial to modern society.
- Fossil fuels are linked to climate change.
- Our current oil supply is insecure.
- Energy demand from developing economies is increasing.
- The undeveloped world needs energy.
- World population is increasing.

Energy is crucial to modern society.

Worldwide Power Consumption per Capita vs GDP per Capita (2007)

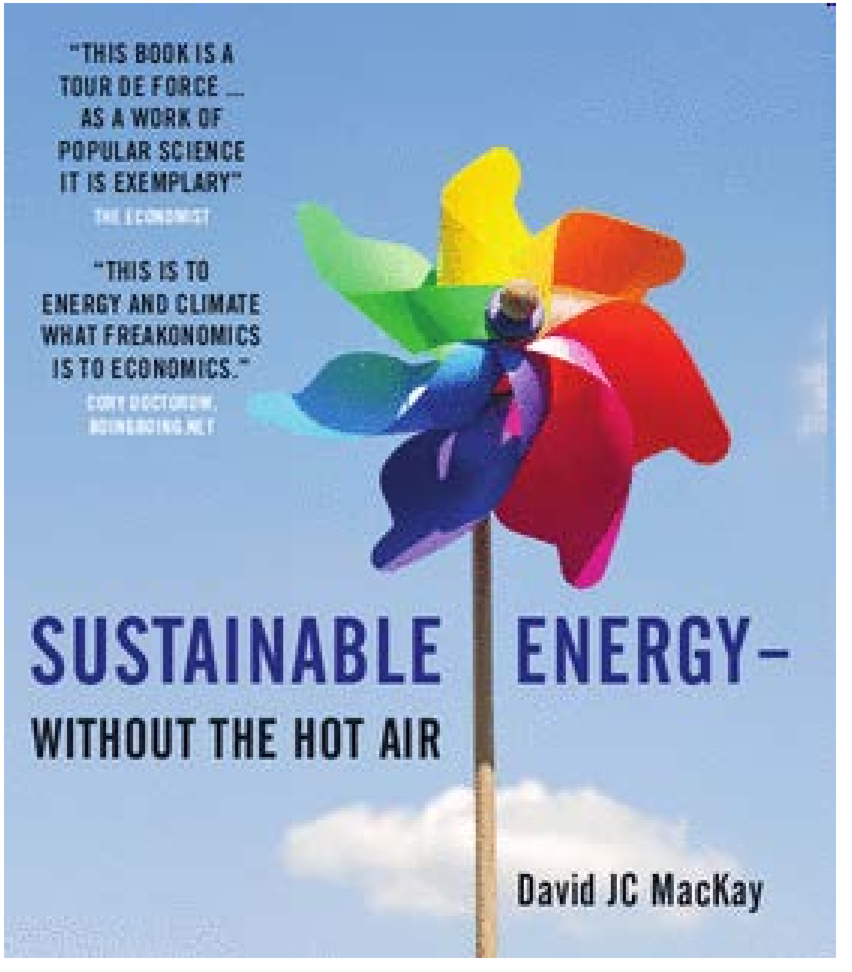


U.S.
250 kWh/d/p
GDP/p
$42,500
(2007)

CA
160 kWh/d/p
GDP/p
$47,400
(2012)

From David MacKay, Sustainable Energy without the Hot Air, Fig 18.4.

Highly Recommended

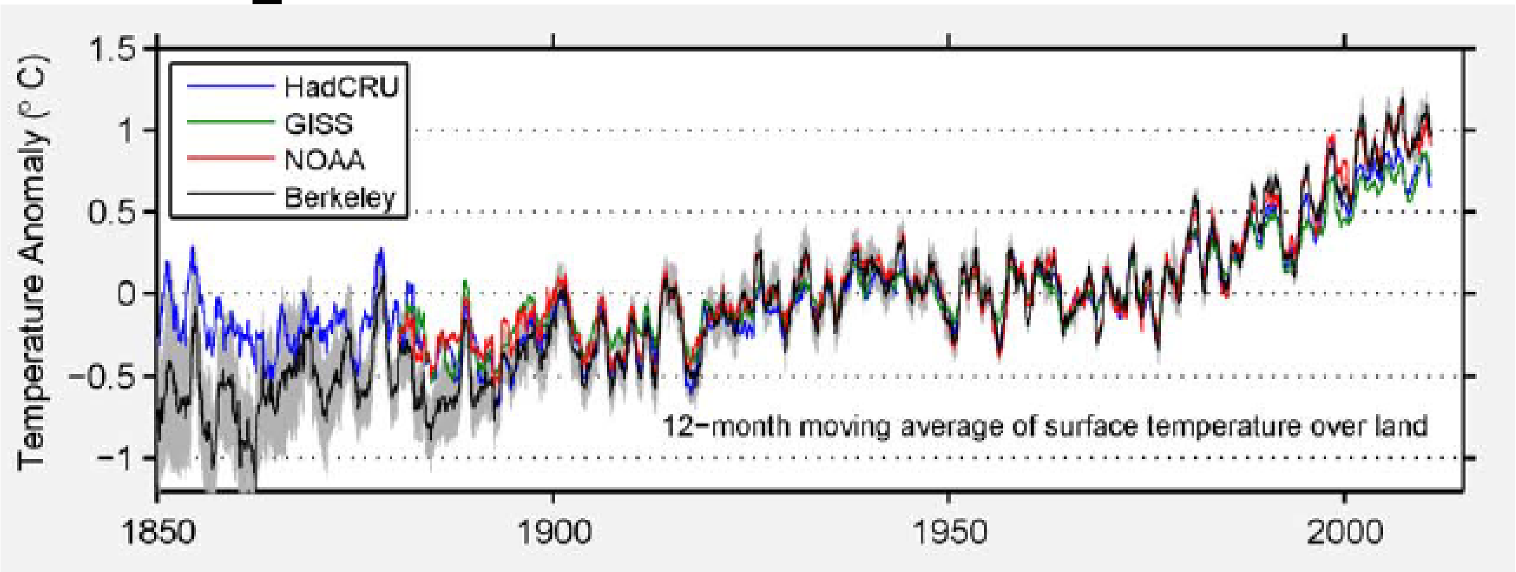


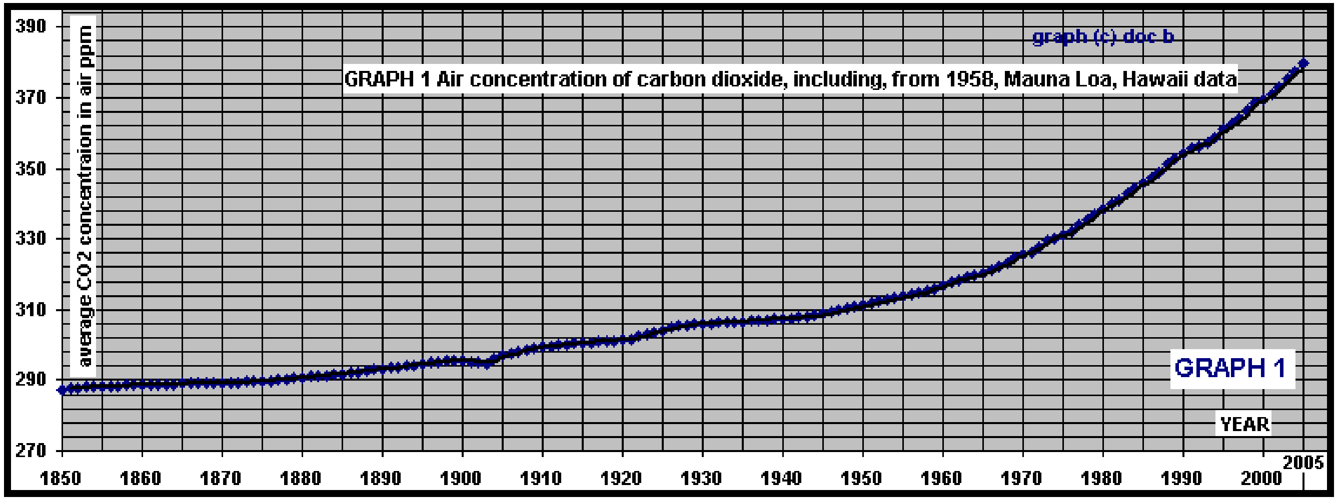
"…the aim of this book is to help you figure out the numbers and do the arithmetic so that you can evaluate policies…"

http://www.withouthotair.com/
Free pdf download - $31.55 from Amazon

Fossil fuels are linked to climate change.

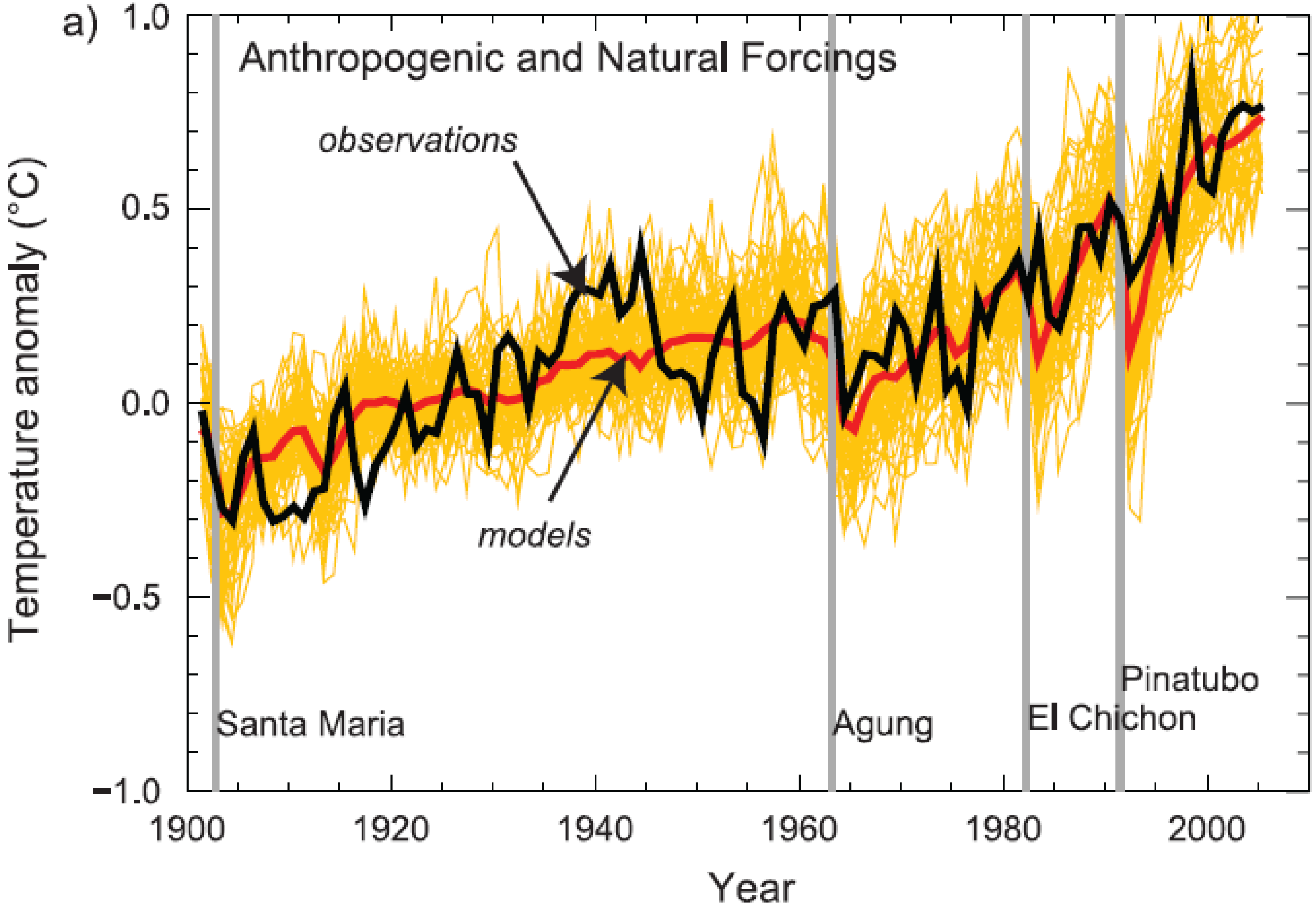
Land Surface Temperature and CO_2 Concentration Since 1850





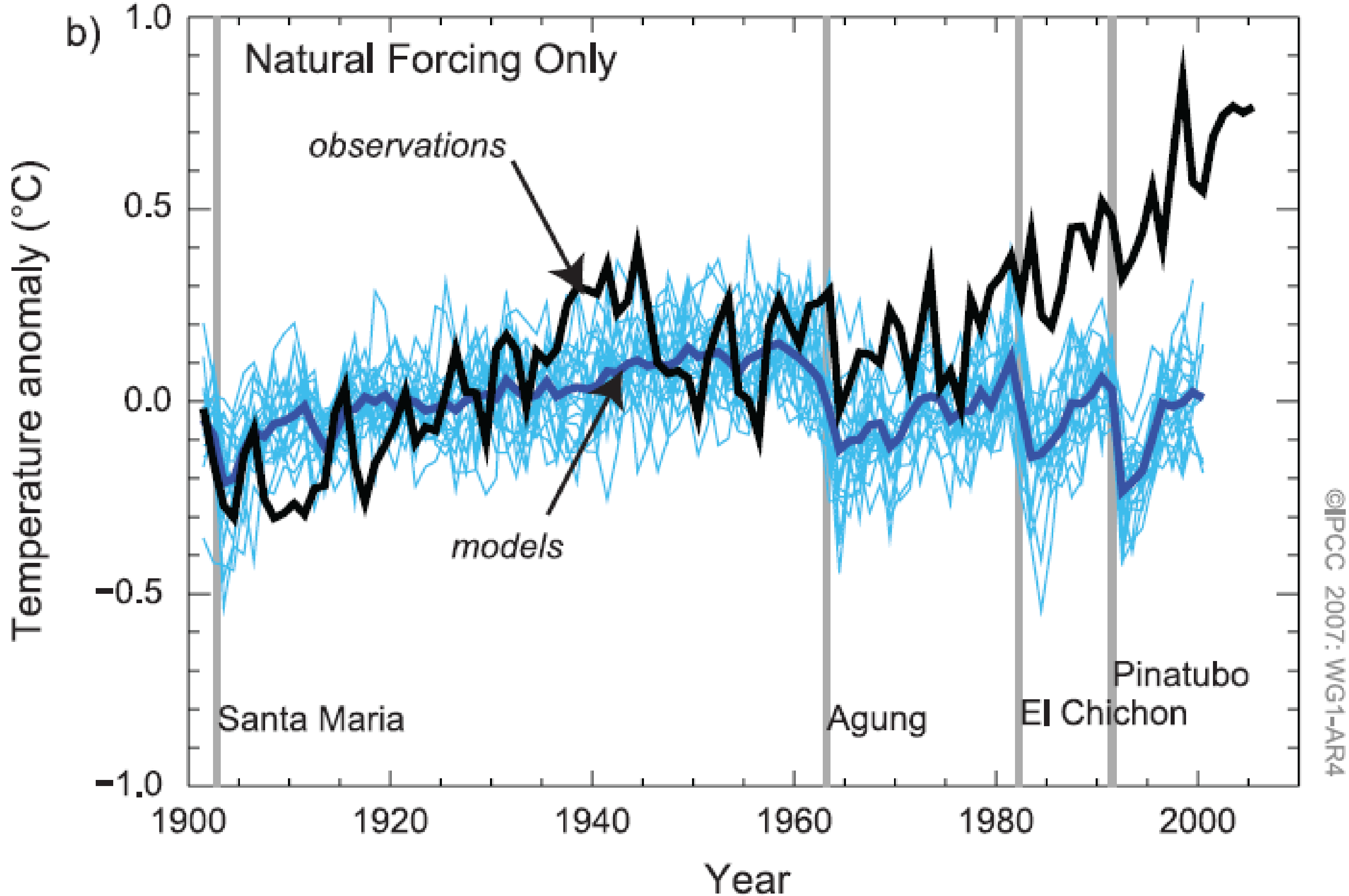
IPCC Comparison of Models:

Global Mean Surface Temperature Anomalies



IPCC Comparison of Models:

Global Mean Surface Temperature Anomalies

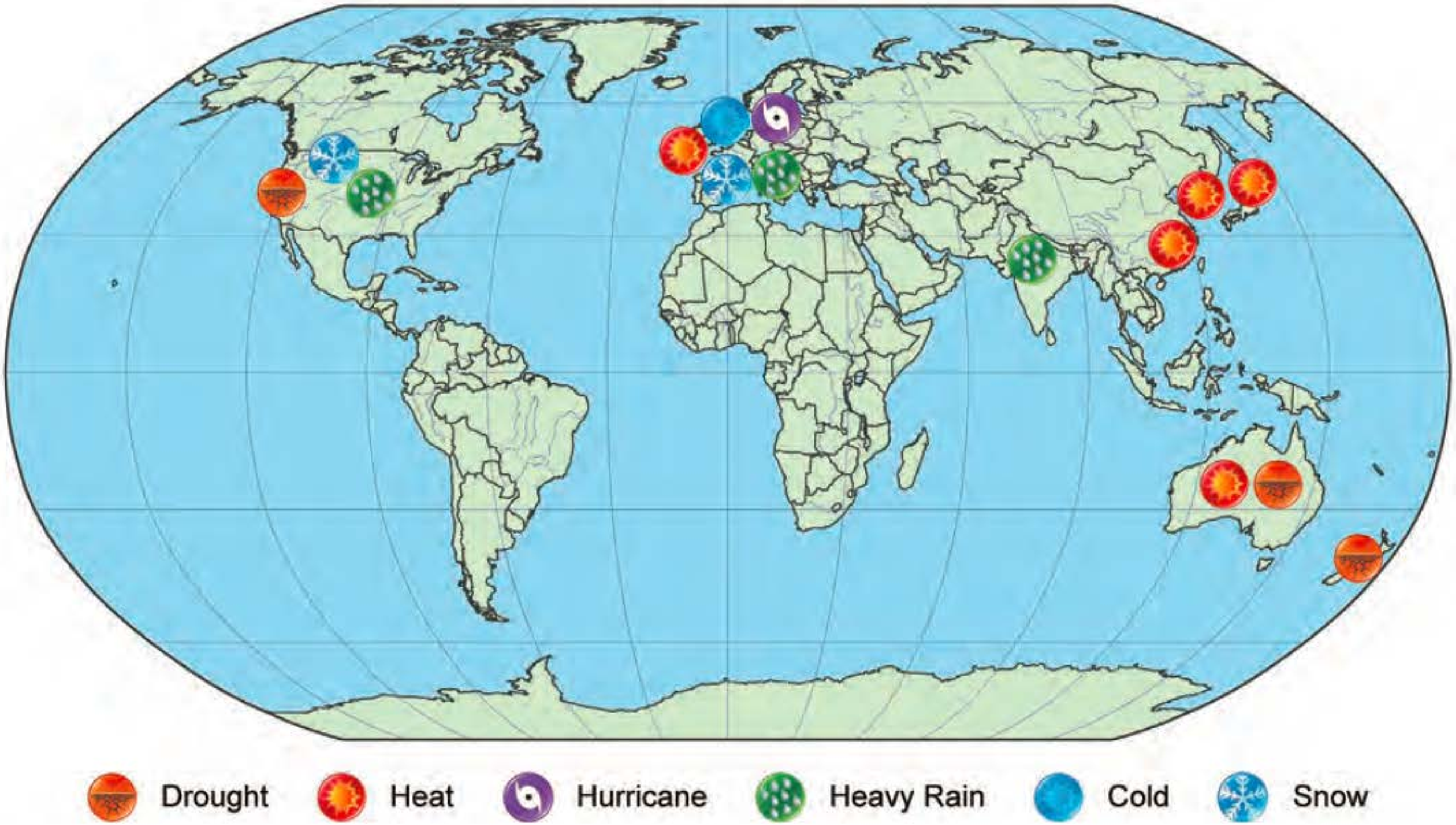


EXPLAINING EXTREME EVENTS OF 2013

From A Climate Perspective

Special Supplement to the
Bulletin of the American Meteorological Society
Vol. 95, No. 9, September 2014

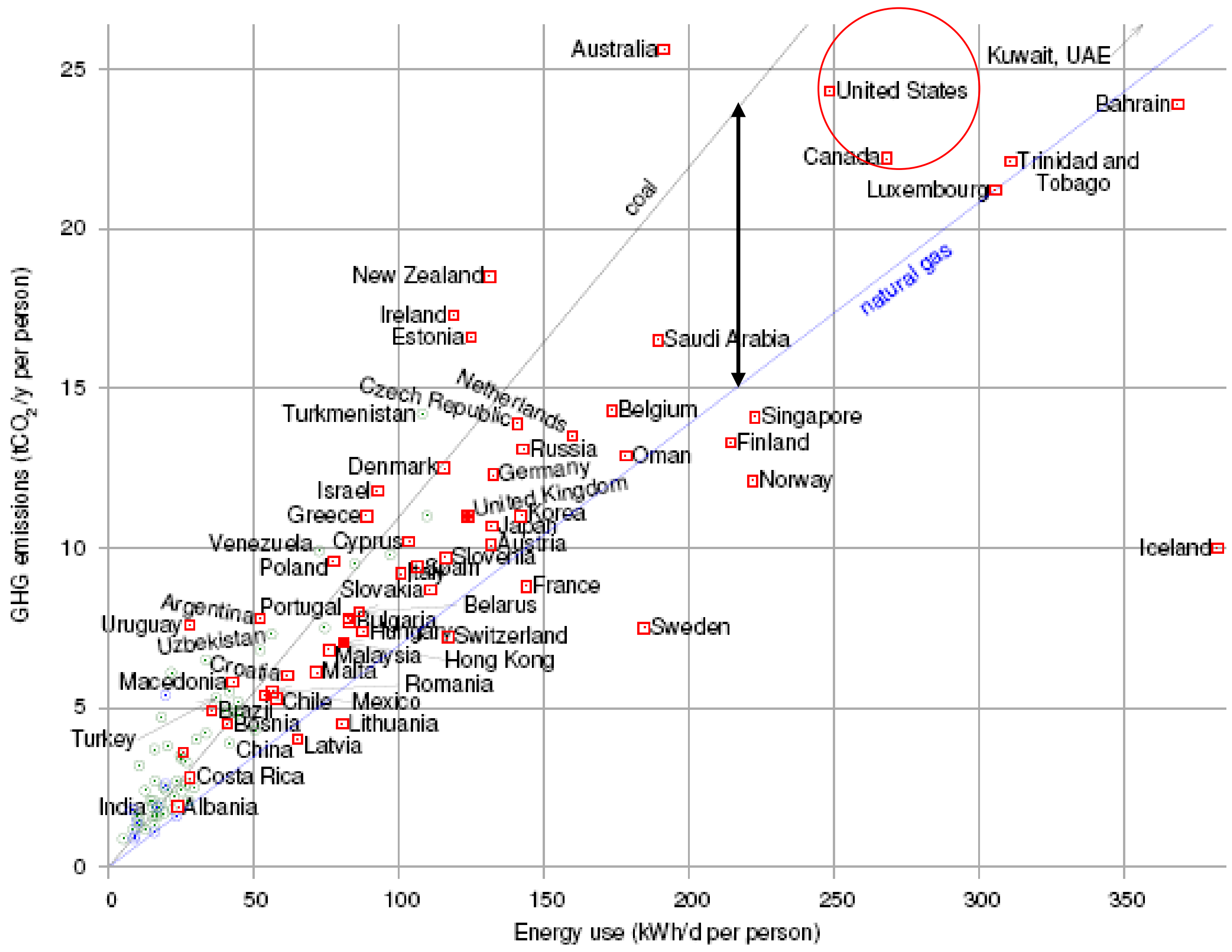
Location and Type of Extreme Events in 2013



2013 Extreme Events AGW Score Card

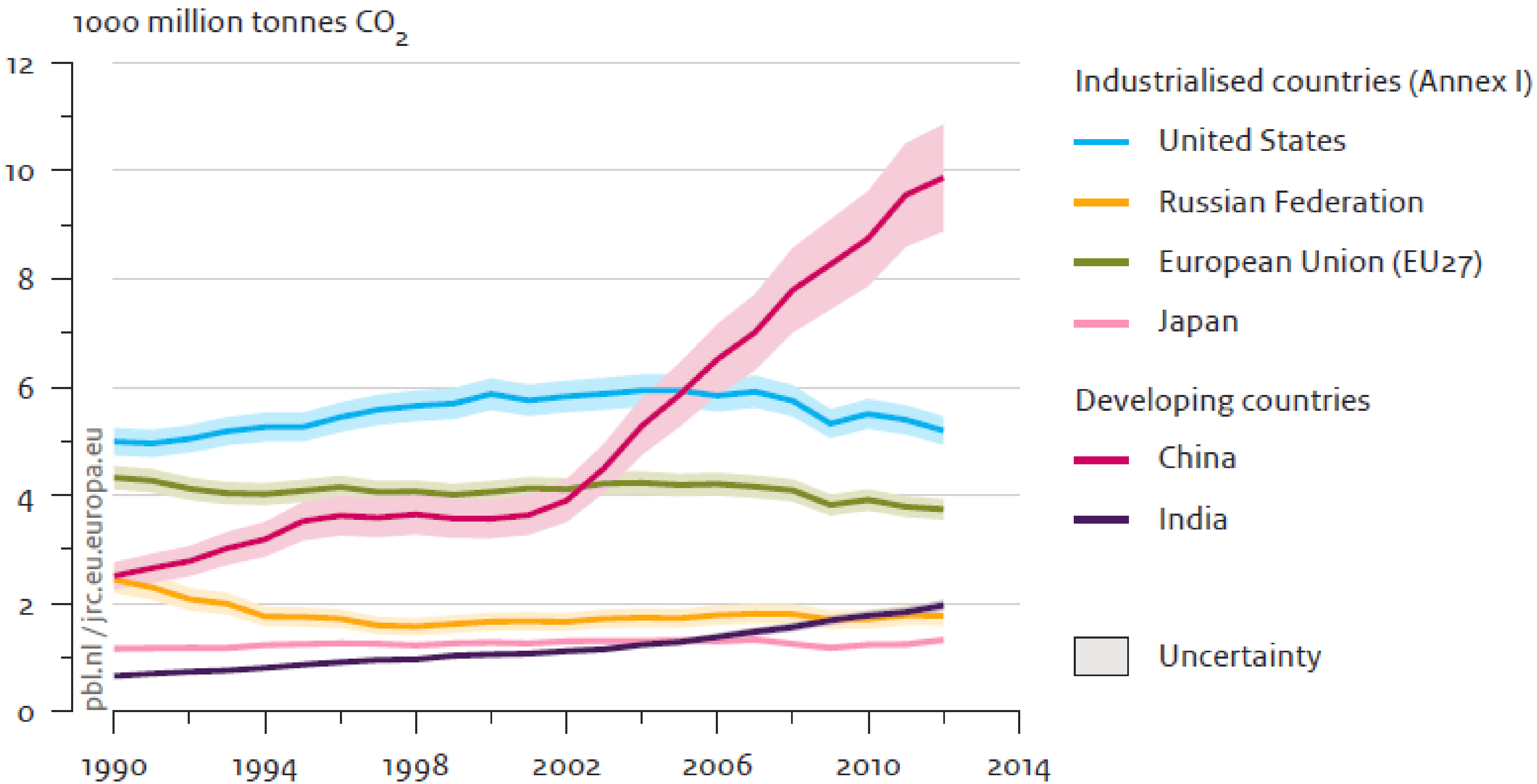
- Influenced by AGW
  - Heat waves in Australia, Europe, China, Japan, Korea
  - Drought in Australia, New Zealand
  - North India extreme precipitation
- Not influenced or uncertain influence by AGW
  - California drought (!)
  - Northern Colorado extreme precipitation
  - South Dakota blizzard
  - Danube and Elbe basins extreme precipitation

Worldwide GHG Emissions and Energy Use (2007)



From David MacKay, Sustainable Energy without the Hot Air, Fig I.12.

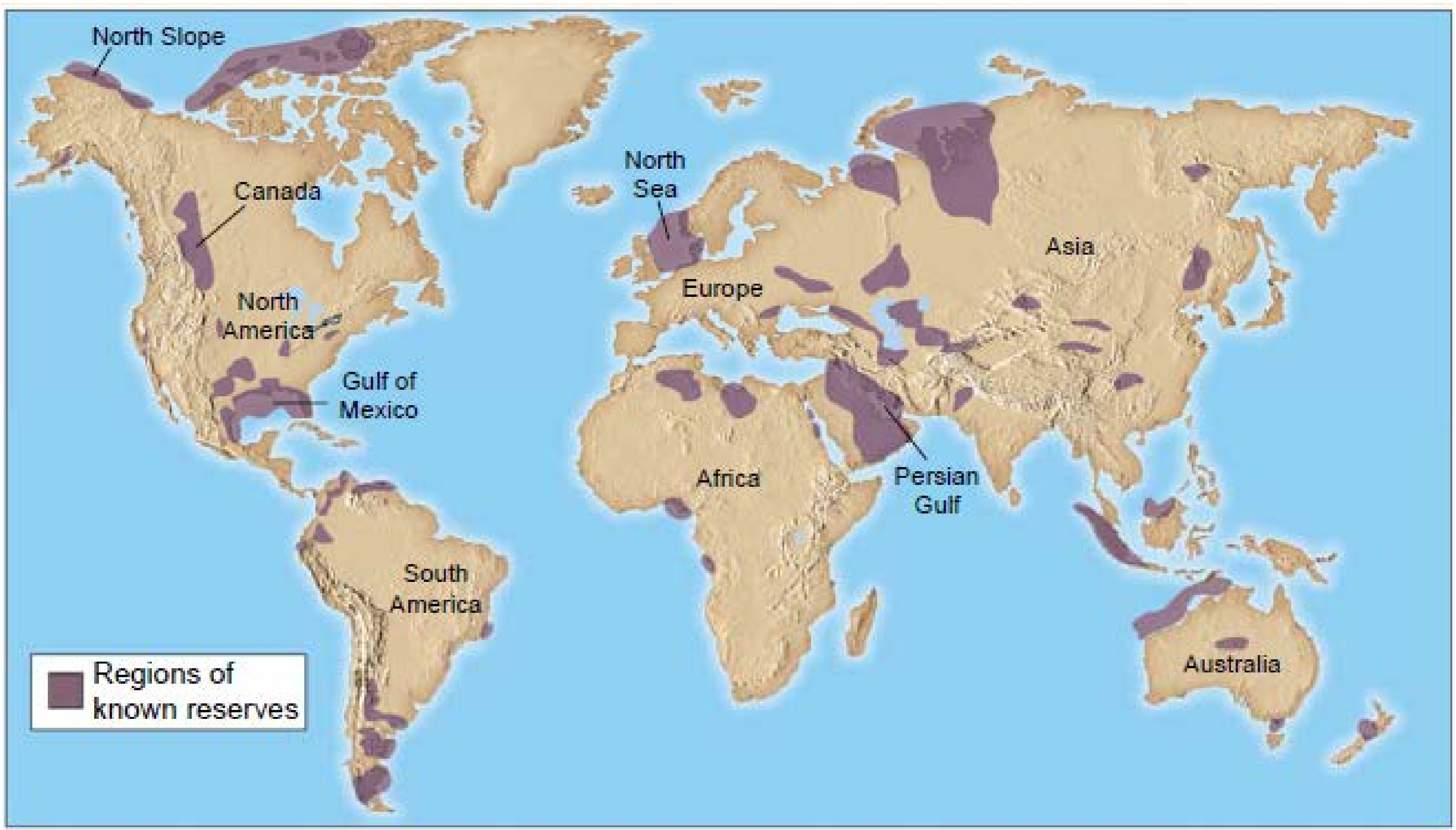
CO_2 Emissions in the Top Six Emitting Countries and the EU 1990-2013



Source: EDGAR 4.2FT2010 (JRC/PBL, 2012); BP, 2013; NBS China, 2013; USGS, 2013; WSA, 2013; NOAA, 2012

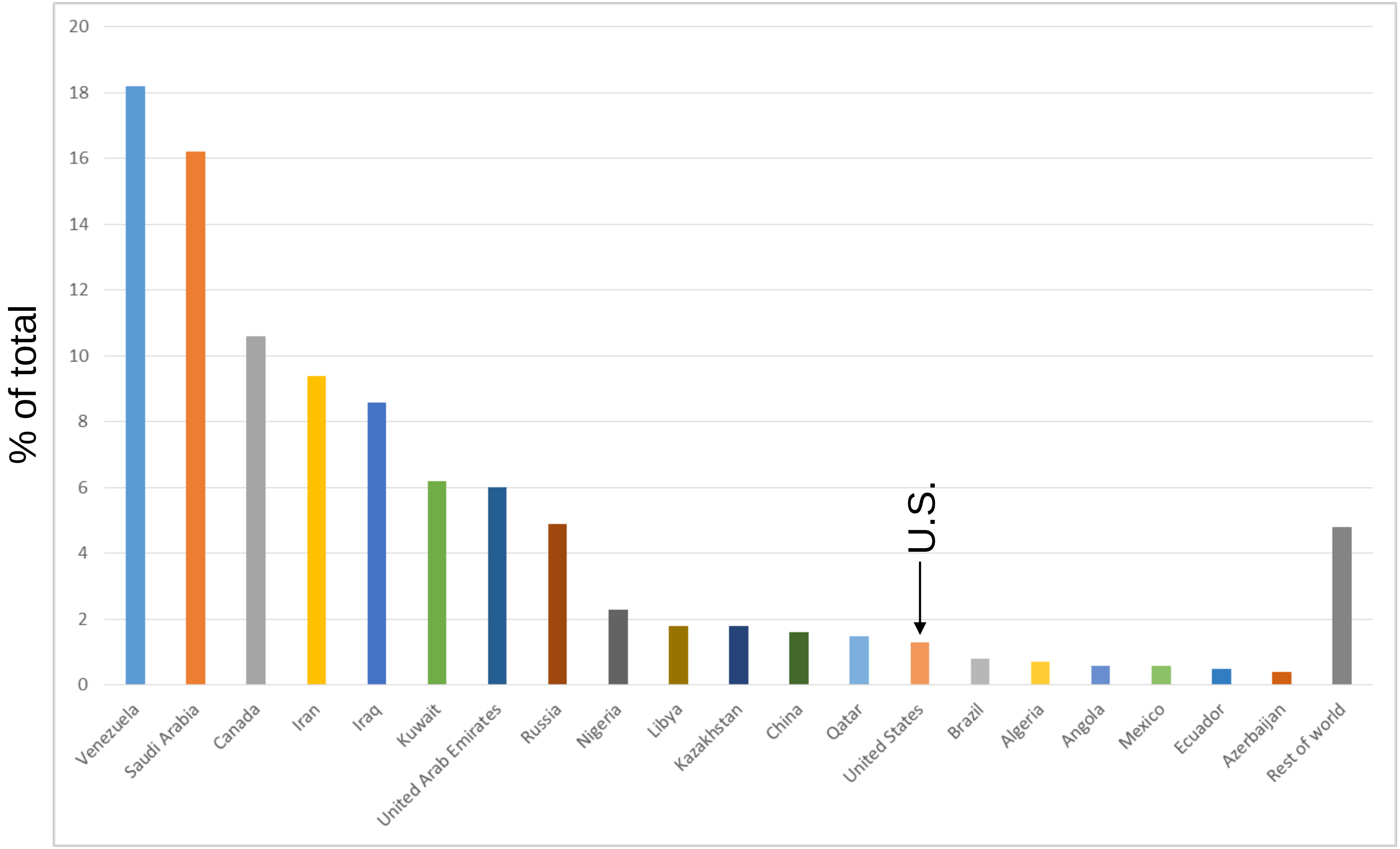
Our current oil supply is insecure.

Distribution of World Conventional Oil Reserves



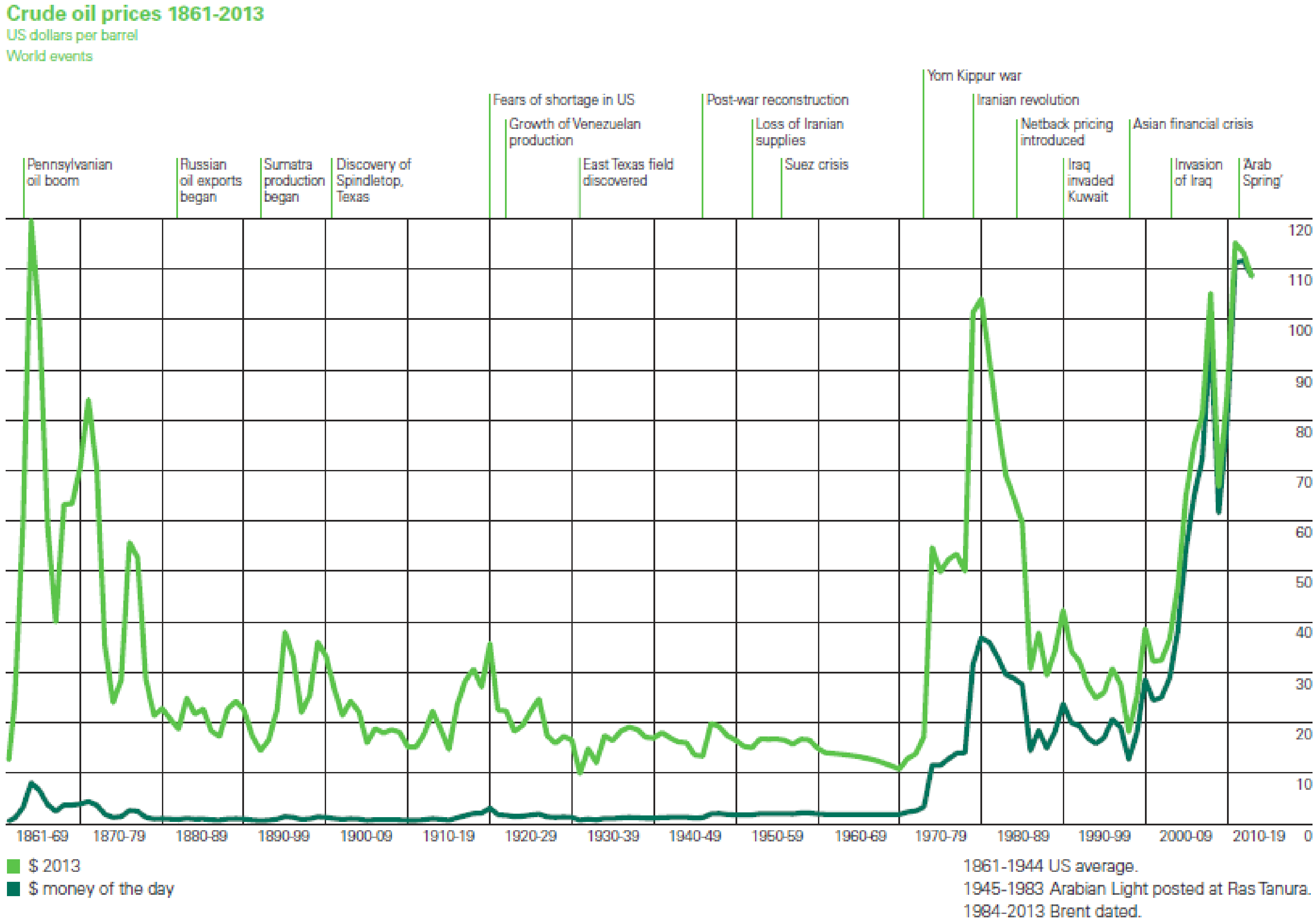
From S. Marshak, Earth: Portrait of a Planet

World Proven Oil Reserves by Country (2013)



"But with only 2 percent of the world's oil reserves, oil isn't enough. This country needs an all-out, all-of-the-above strategy that develops every available source of American energy. A strategy that's cleaner, cheaper, and full of new jobs."
President Obama, State of the Union address, January 25, 2012.

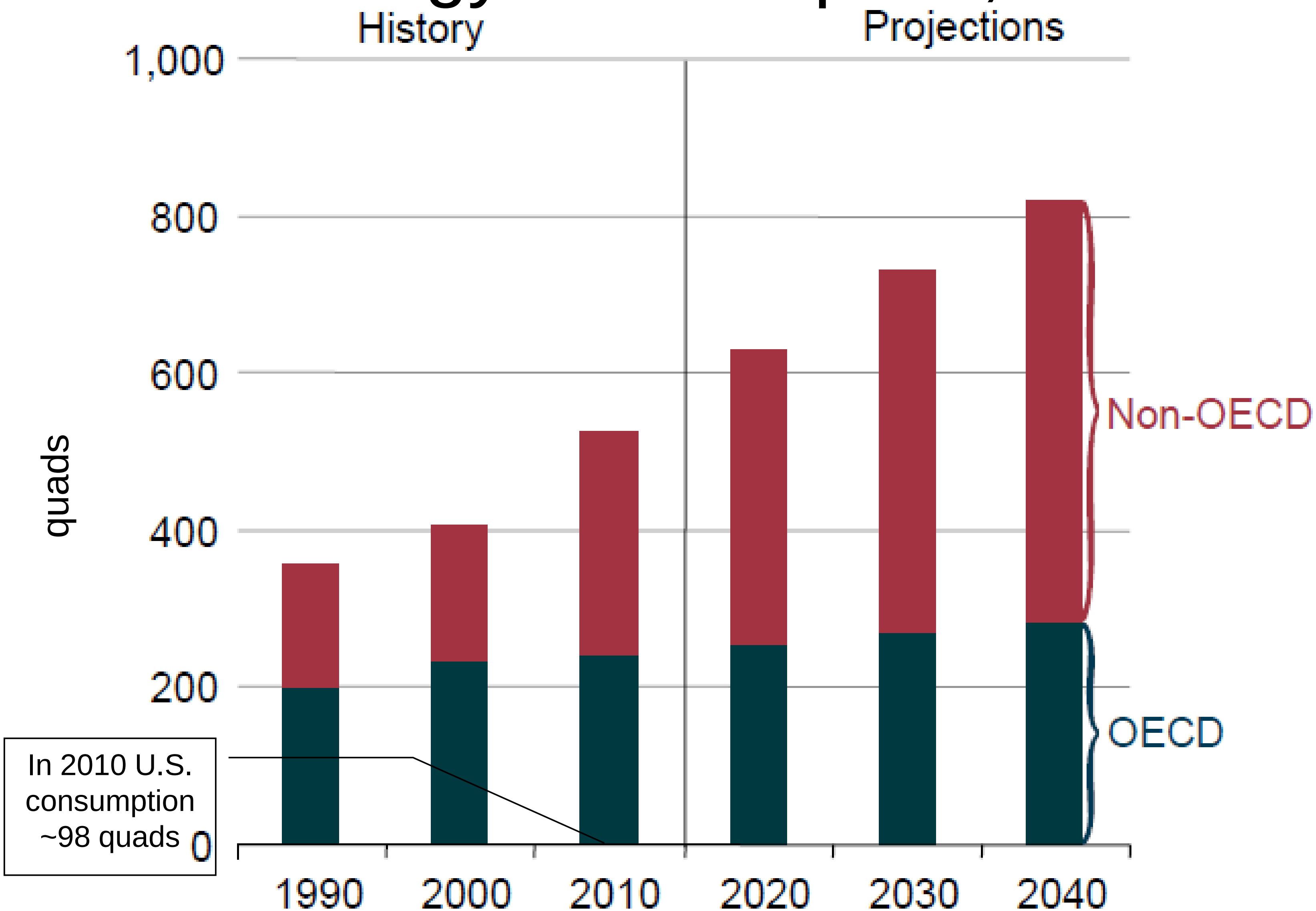
Crude Oil Prices 1861 - 2013



BP Statistical Review of World Energy (June, 2014)

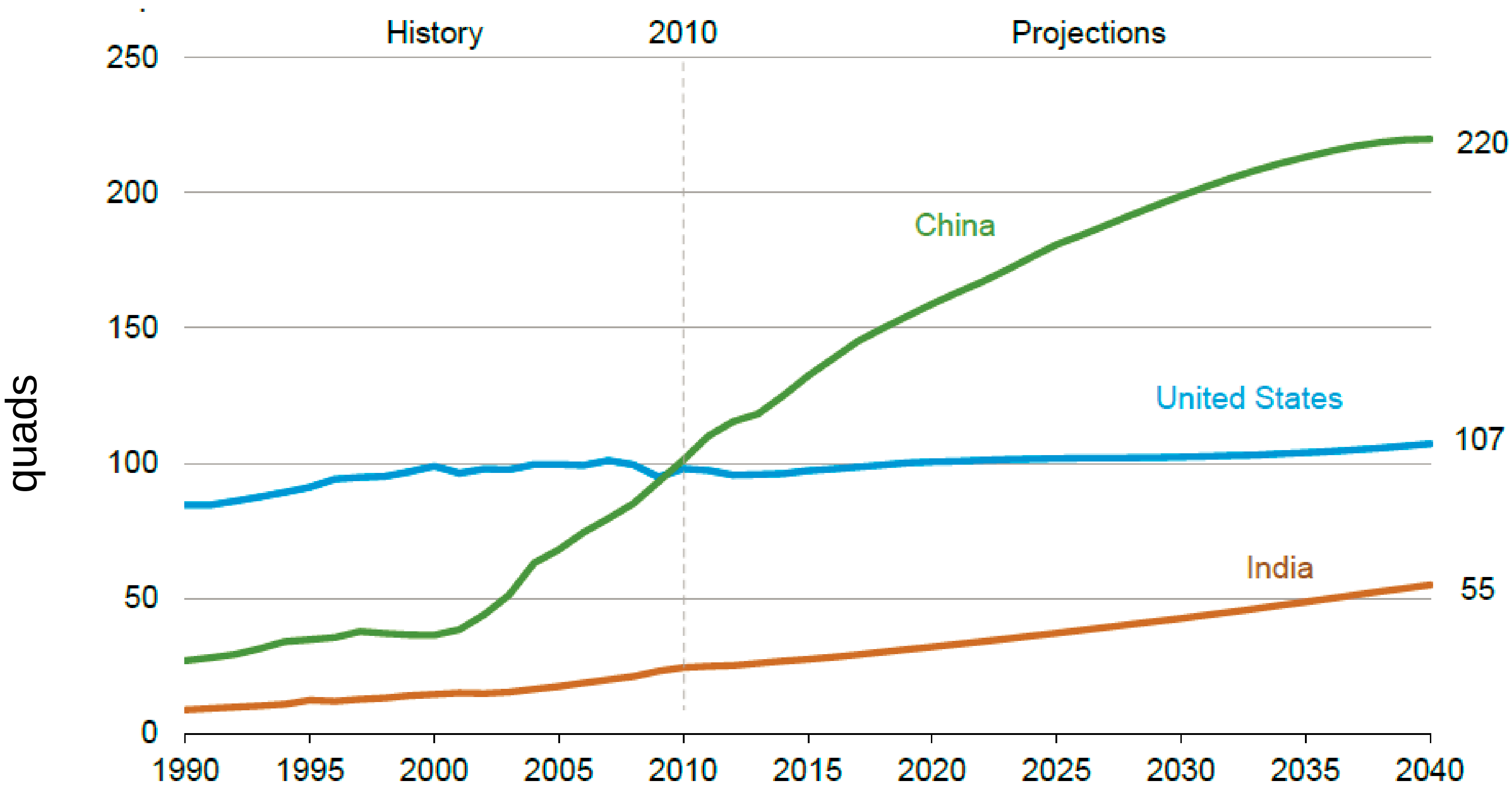
Energy demand from developing economies is increasing.

World Energy Consumption, 1990-2040



From EIA International Energy Outlook June 2013, Figure 12

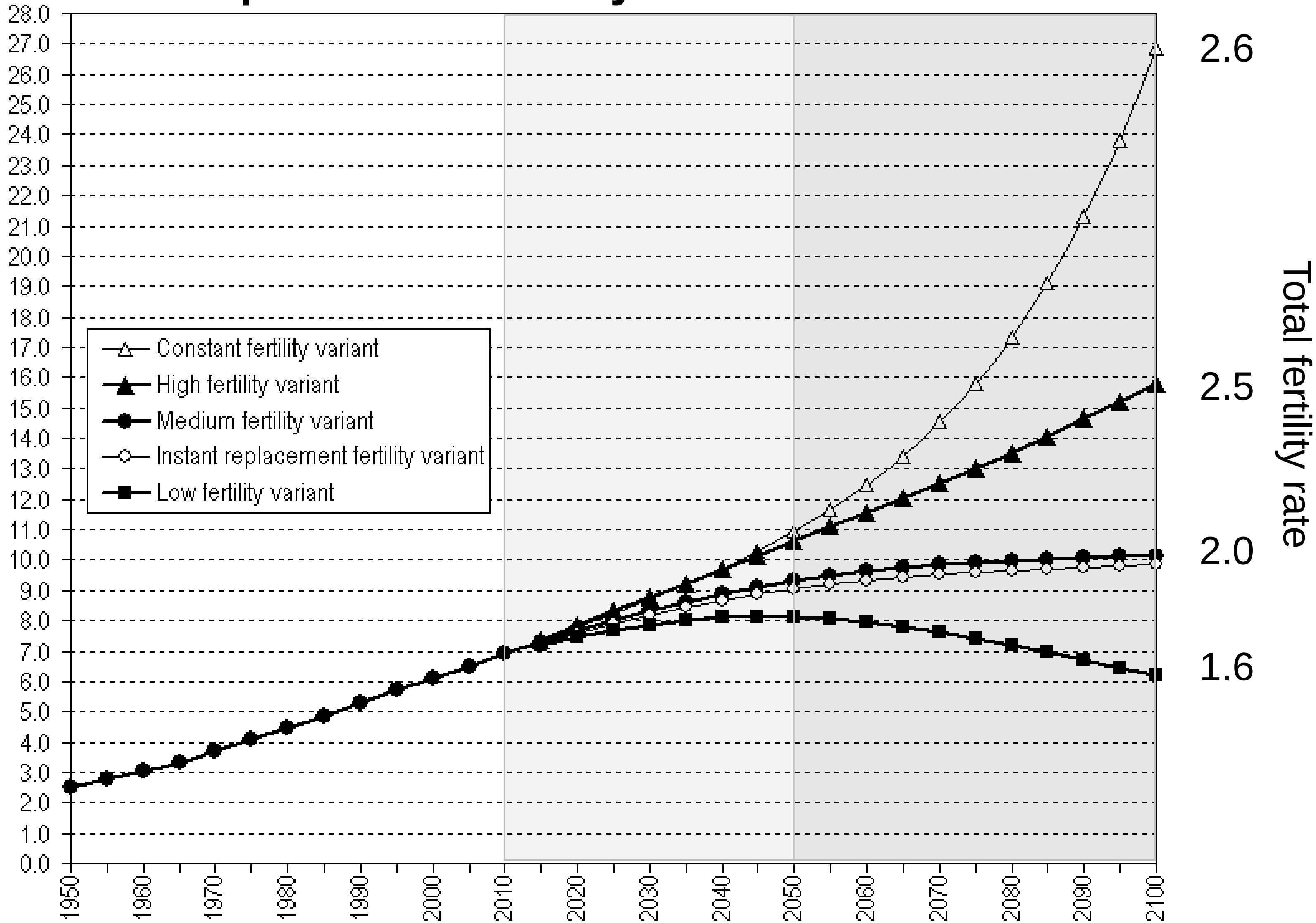
Energy Consumption in the United States, China, and India, 1990-2040



From EIA International Energy Outlook presentation June 2013, slide 5

World population is increasing.

U. N. Population Projection 2010 - 2100



Kaya Identity

Country and Regional Emissions Comparisons

Kaya Identity

$$Global\,CO_2\ emissions = Global\ population \times \frac{Gross\,world\ product}{Global\ population} \times \frac{Gross\,energy\,consumption}{Gross\,world\ product} \frac{Global\,CO_2\ emissions}{Gross\,energy\,consumption}$$

$$\frac{CO_2\ emissions}{energy\ consumption}$$

This ratio is about the fuel

$$\frac{energy\ consumption}{product}$$

This ratio is about efficiency of production

$$\frac{product}{population}$$

This ratio is about the level of development

Kaya Identity Example - World

From EIA International Energy Outlook (September, 2011) 2008 data

Global CO_2 emissions: 30.2 Gt CO_{2e}
Global energy consumption 505 quads
Global domestic product: $65.8 trillion (2008 US$)
Global population 6,731 million

$$CO_2 = \frac{CO_2}{Energy}\frac{Energy}{GDP}\frac{GDP}{capita}Population$$

$$CO_2\,emissions = \frac{59.8\,tCO_2}{10^9\ BTU}\frac{7,700\,BTU}{\$}\frac{\$9,770}{person}6,731\,million\ persons$$

CO_2 intensity of energy supply

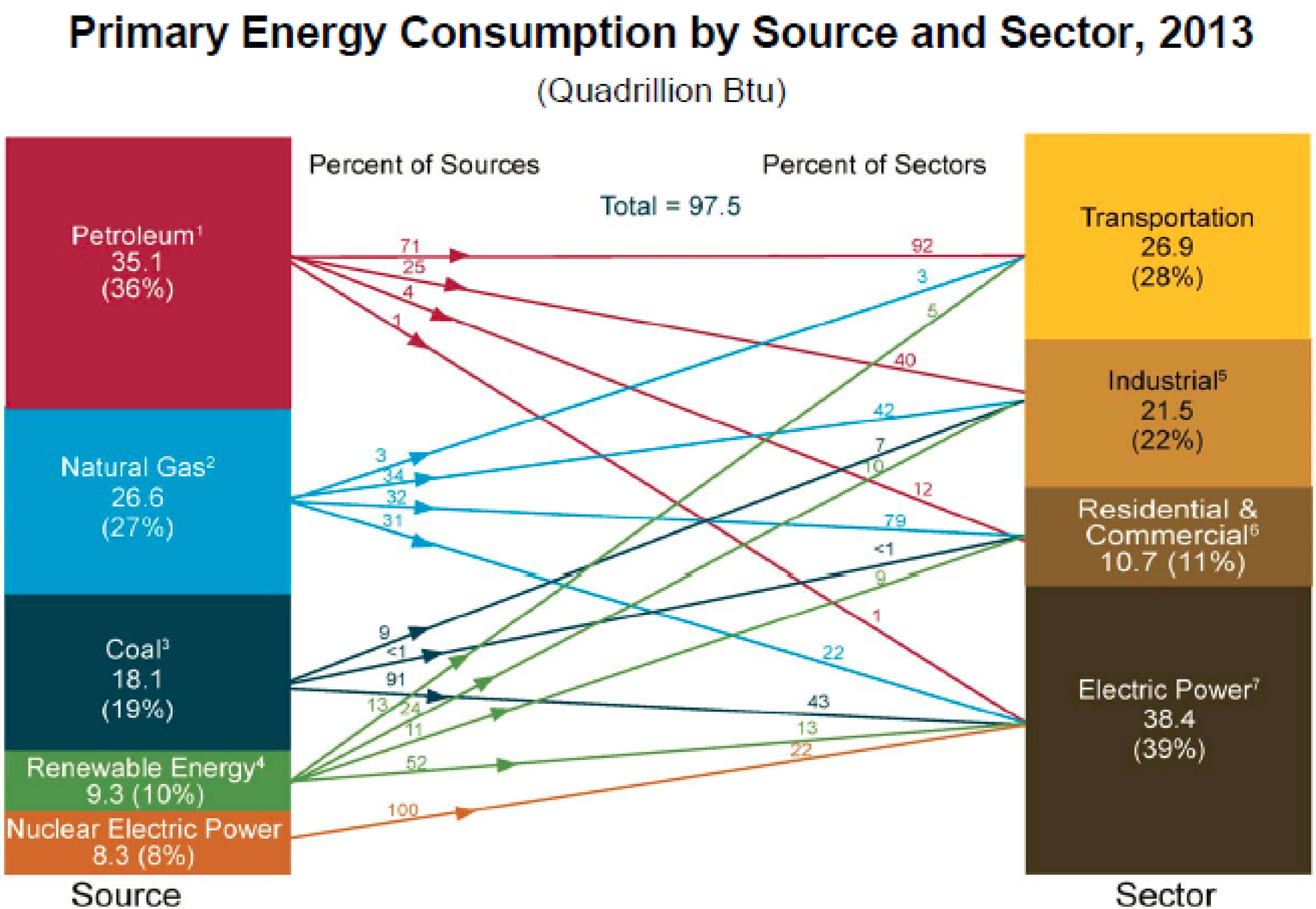
economic output per capita

energy intensity of economic output

ENERGY SUPPLY AND DEMAND

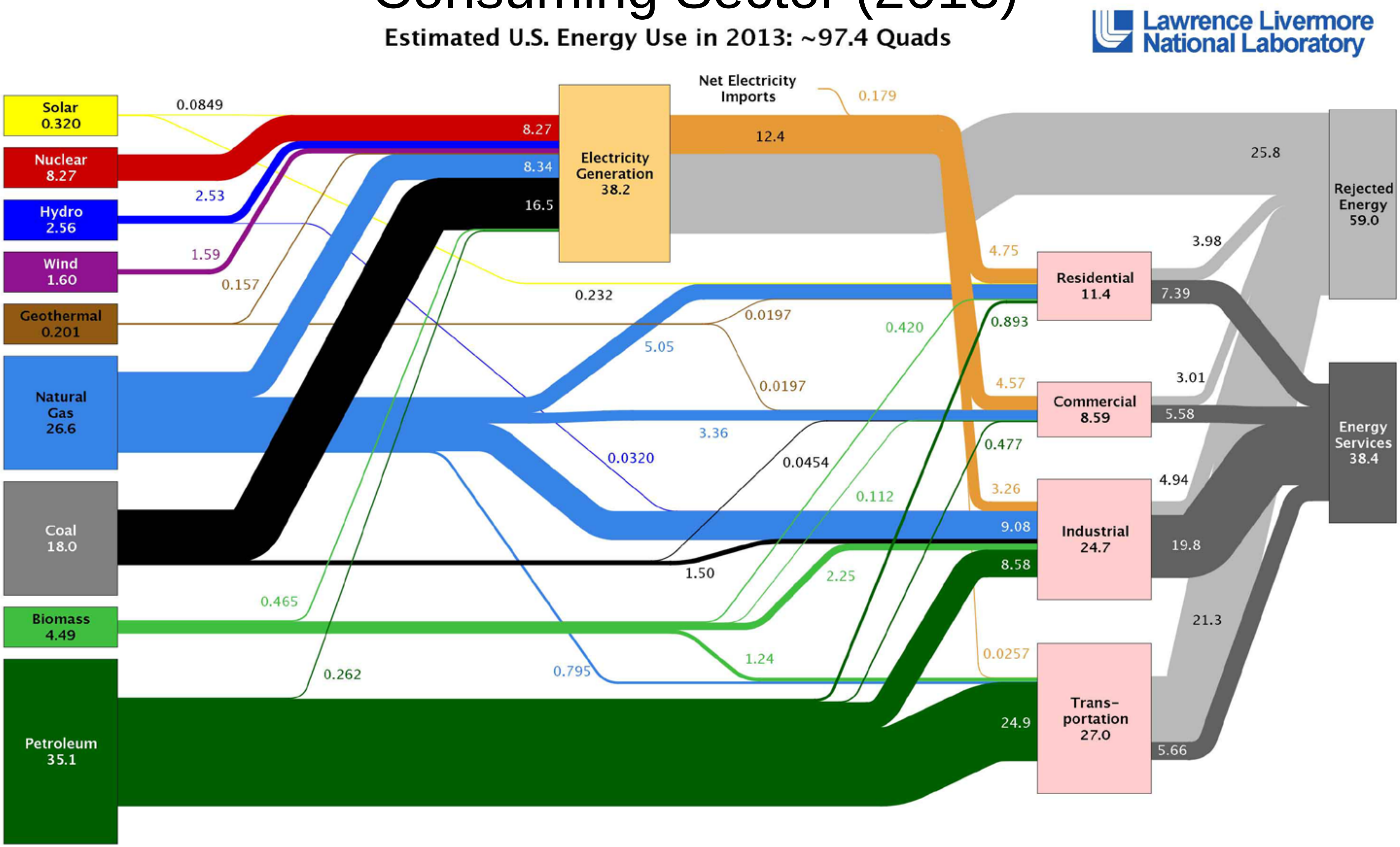
One Reason Energy Is Hard: Many Measures Are Commonly Used

- distinguish energy from power
- very large numbers
- many use the “quad” 10^{15} Btu
- oil barrels or bbl (42 U.S. gal)
- coal tons (2,000 lbs) or tonnes (1,000 kg)
- natural gas 10^{12} ft^3 or therms (10^5 Btu)
- electricity kWh



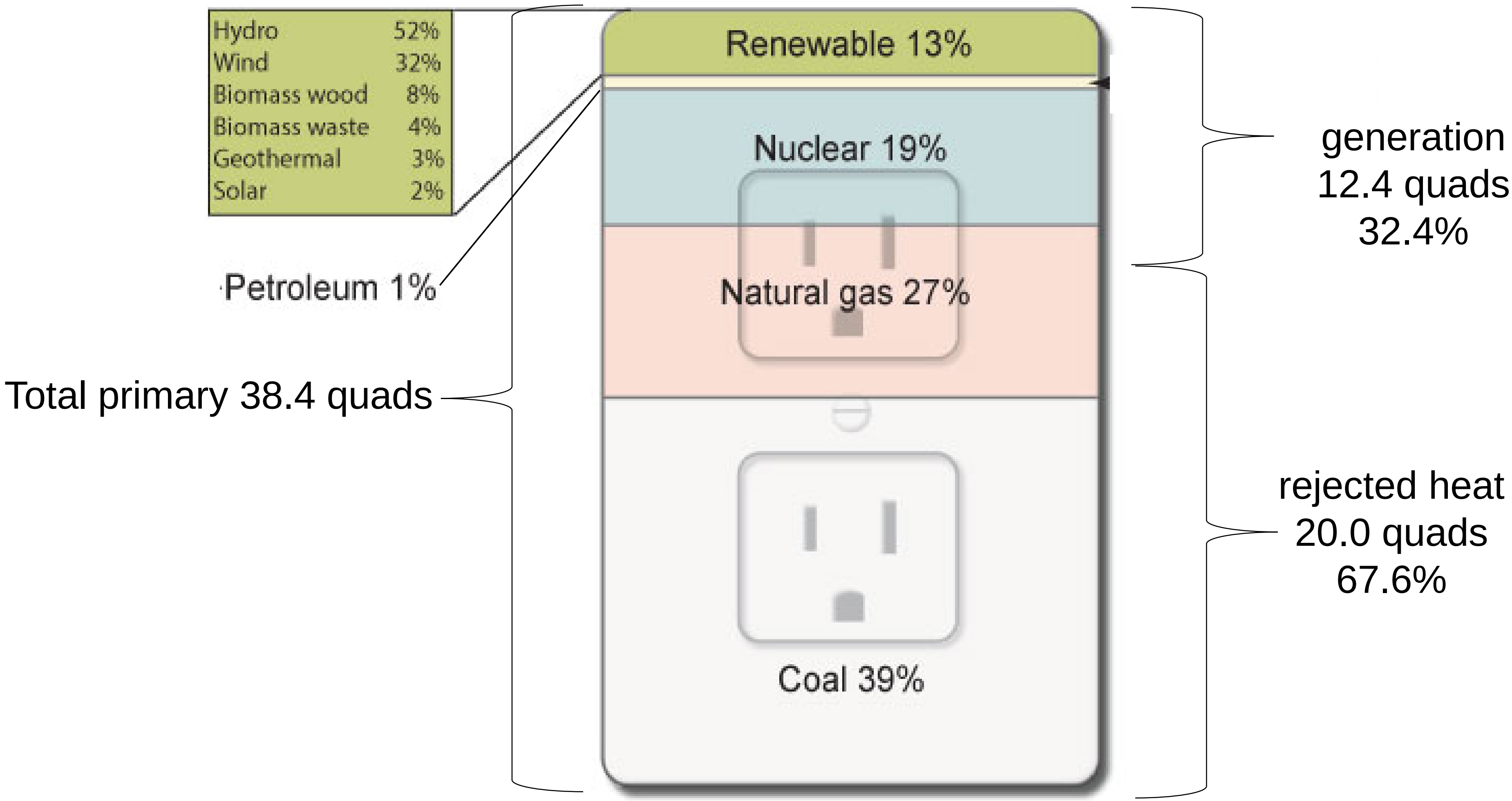
Total = 97.4 quads
82% fossil fuels

Energy Flows, by Source of Energy and Energy-Consuming Sector (2013)



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

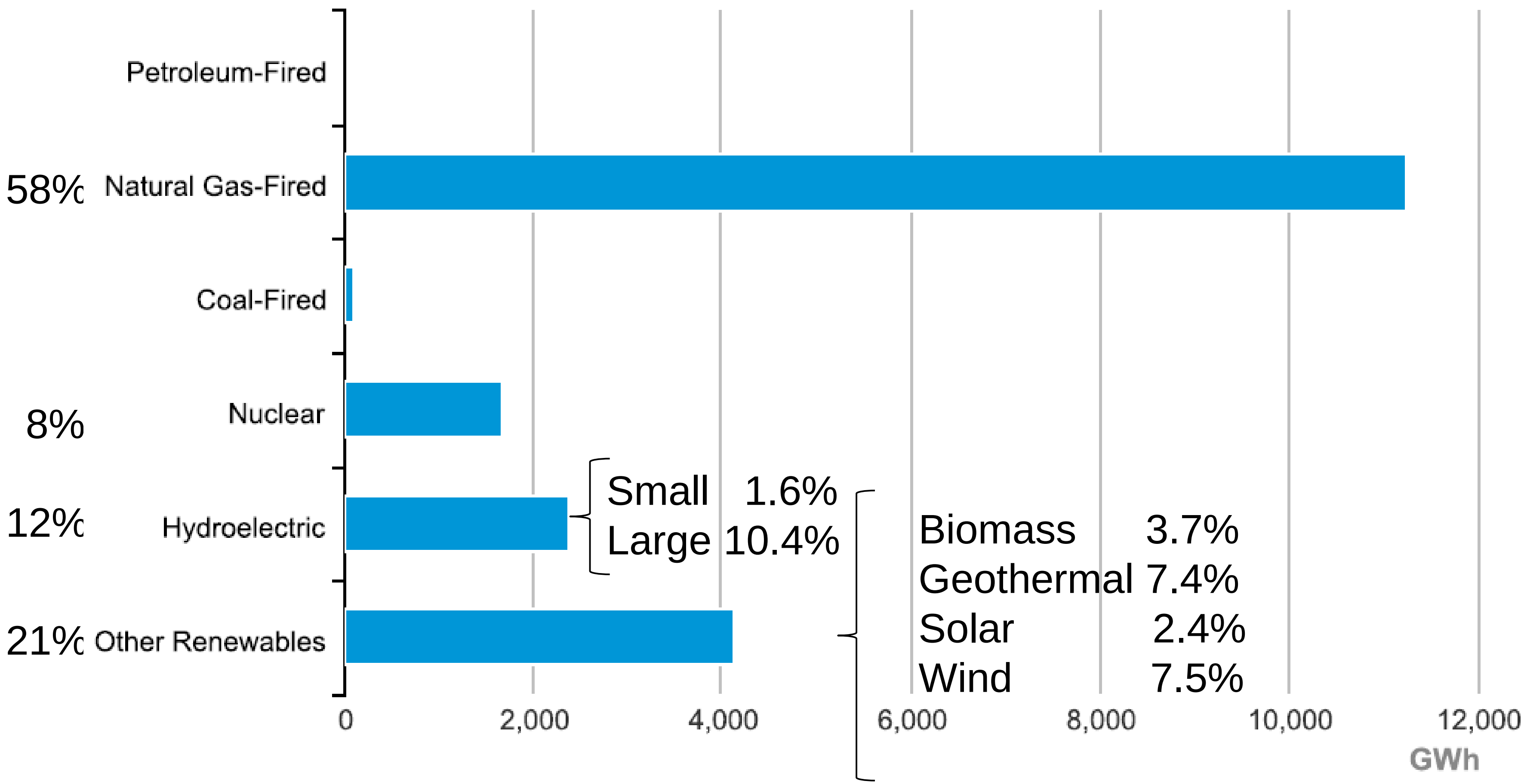
Sources of U.S. electricity generation, 2013



Source: U.S. Energy Information Administration, *Electricity Power Monthly* (February 2014). Percentages based on Table 1.1 and 1.1a; preliminary data for 2013.

Note: Sum of components may not equal 100% due to independent rounding.

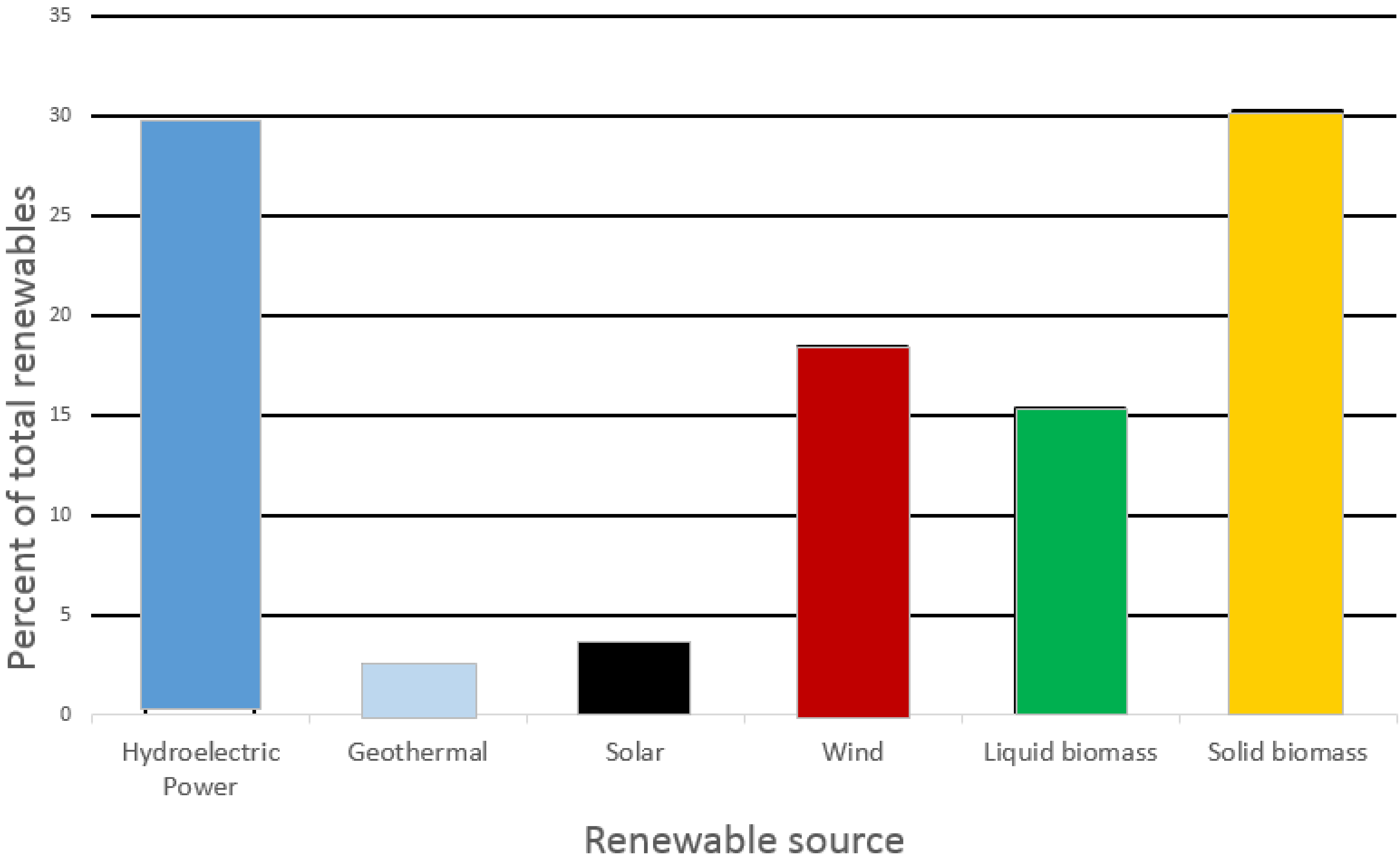
California Electricity Generation by Source July, 2014



California RPS renewables (no large hydroelectric) 23%.

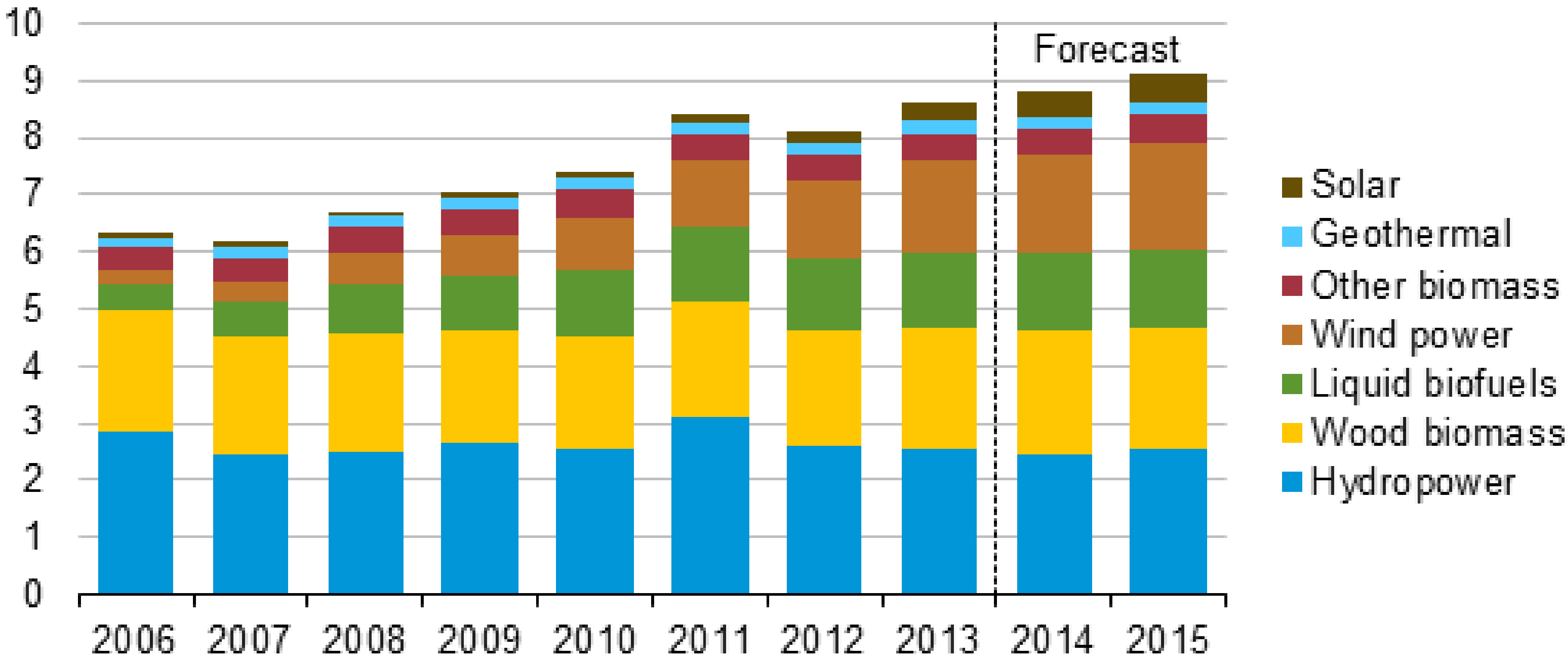
From Energy Information Agency monthly outlook, July 2014

U.S. Renewable Energy by Source (2013)
Total = 8.6 quads (9%)



U.S. Renewable Energy Supply

quadrillion British thermal units (Btu)



Note: Hydropower excludes pumped storage generation. Liquid biofuels include ethanol and biodiesel. Other biomass includes municipal waste from biogenic sources, landfill gas, and other non-wood waste.

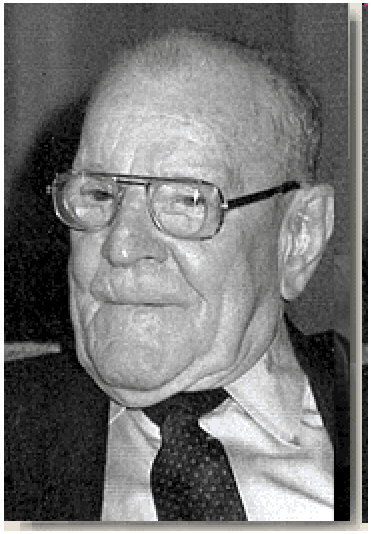
Source: Short-Term Energy Outlook, November 2014.

SOME POINTS OF REFERENCE

Reference point 1

Hubbert Model

“Peak Oil”



NUCLEAR ENERGY AND THE FOSSIL FUELS

BY

M. KING HUBBERT
CHIEF CONSULTANT (GENERAL GEOLOGY)

PUBLICATION NO. 95

SHELL DEVELOPMENT COMPANY
EXPLORATION AND PRODUCTION RESEARCH DIVISION
HOUSTON, TEXAS
JUNE 1956

To be published in
Drilling and Production Practice (1956)
American Petroleum Institute

Hubbert Data 1956

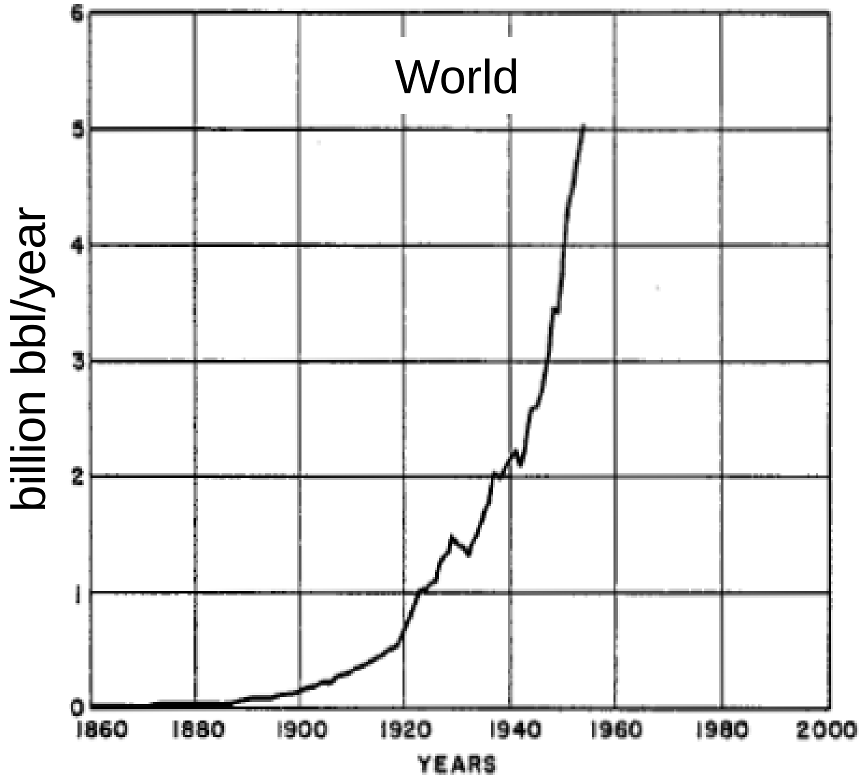


Figure 2 - World production of crude oil.

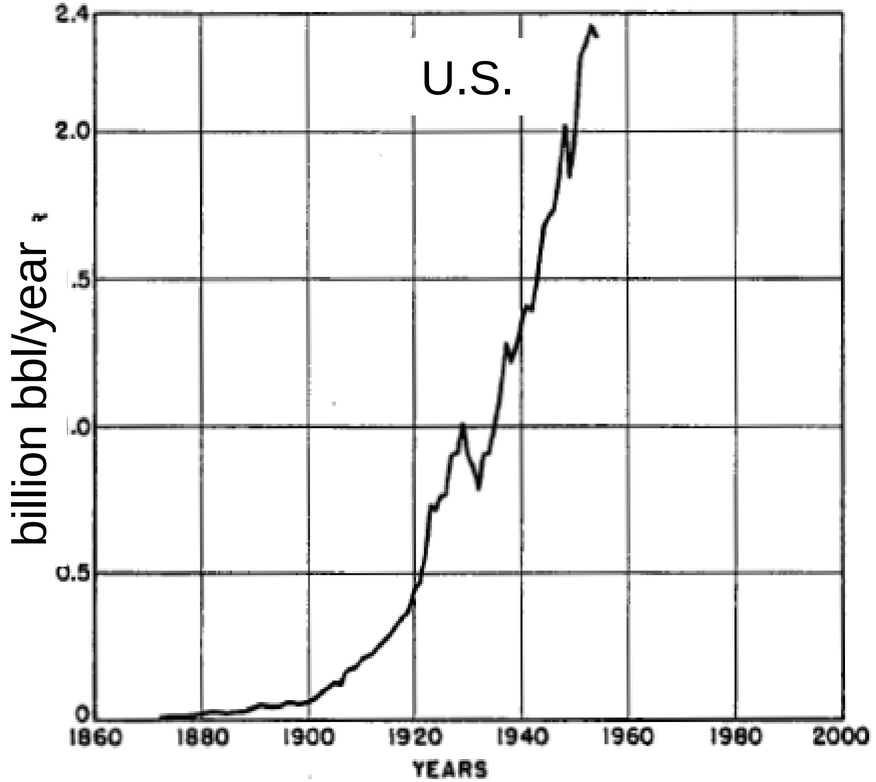


Figure 5 - United States production of crude oil.

Note: the rate of oil extraction in the world and in the U.S. is increasing.

Hubbert Data 1956

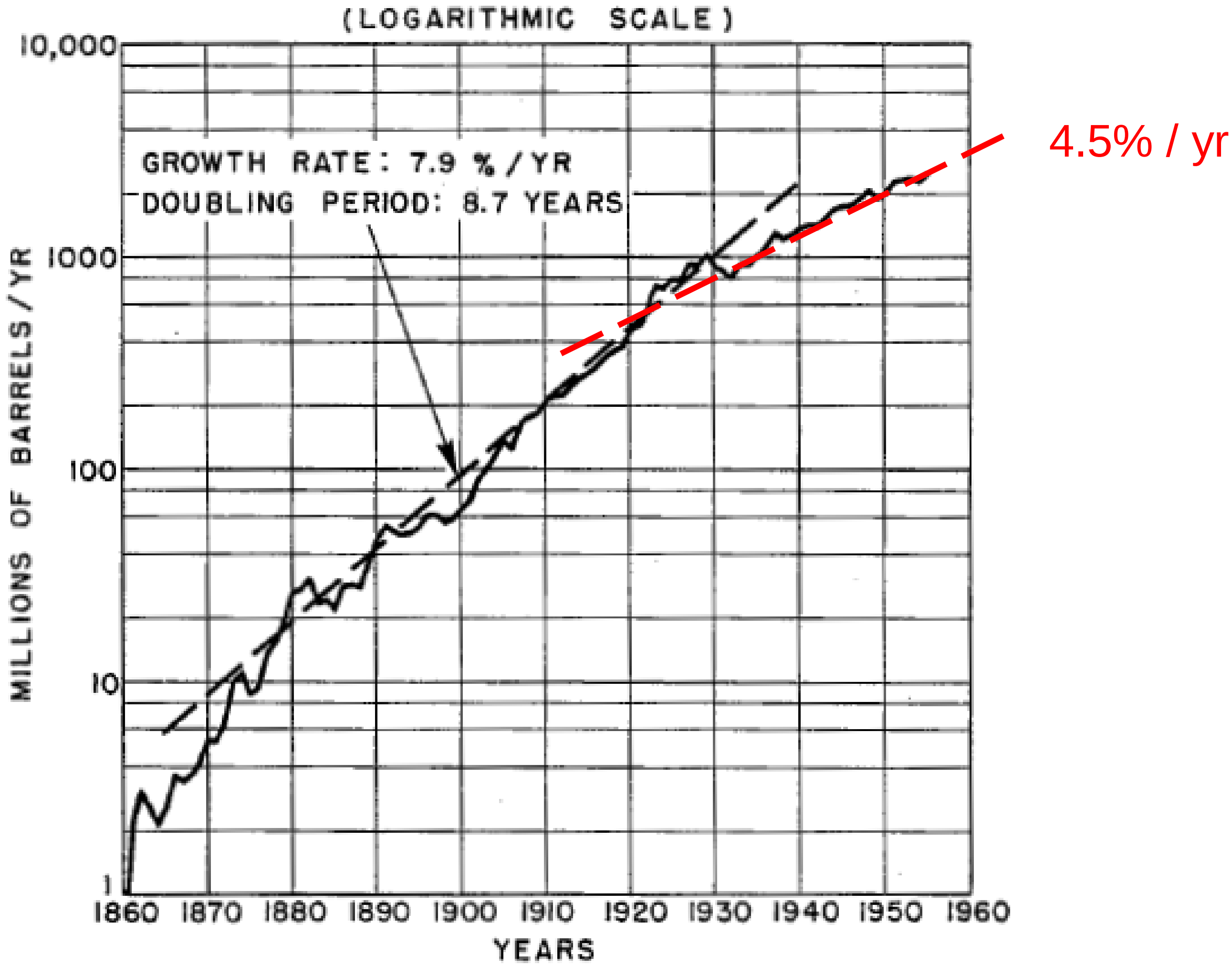


Figure 10 – Crude-oil production in the United States plotted on semilogarithmic scale.

Hubbert Prediction 1956

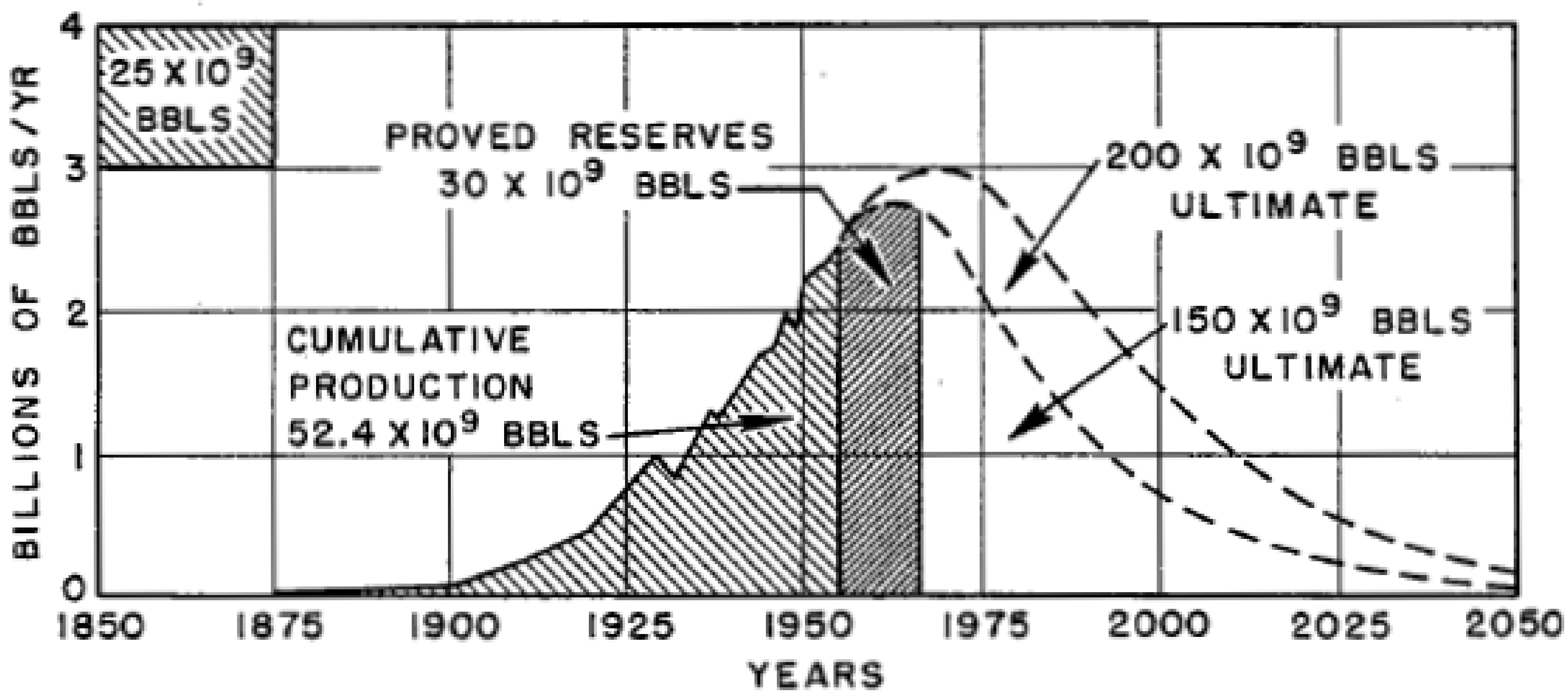
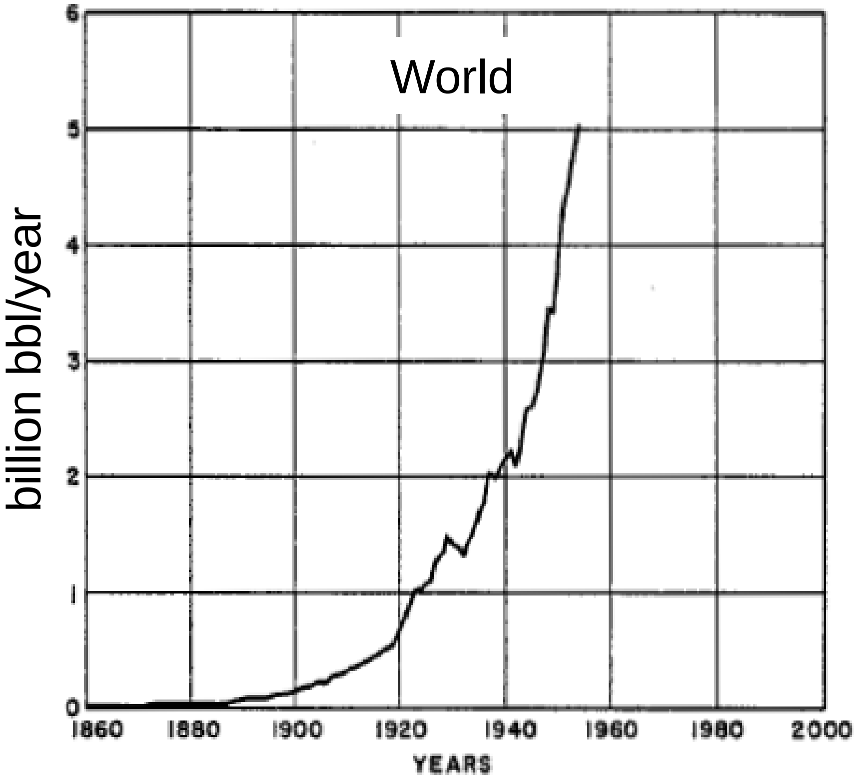


Figure 21 – Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

Peak oil prediction between 1965 -1970

Hubbert Data 1956



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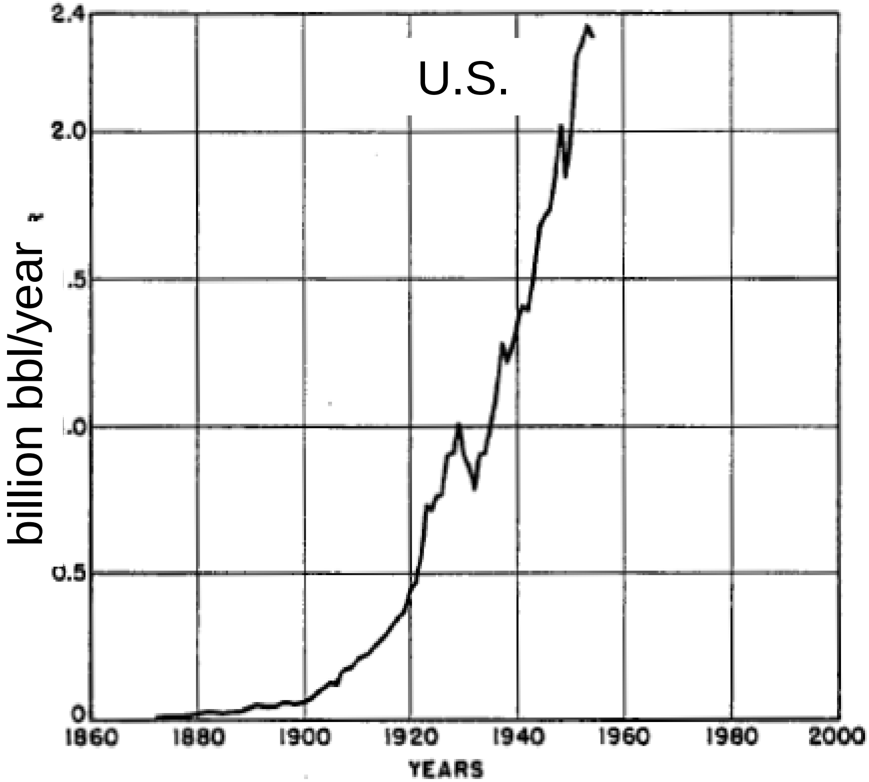
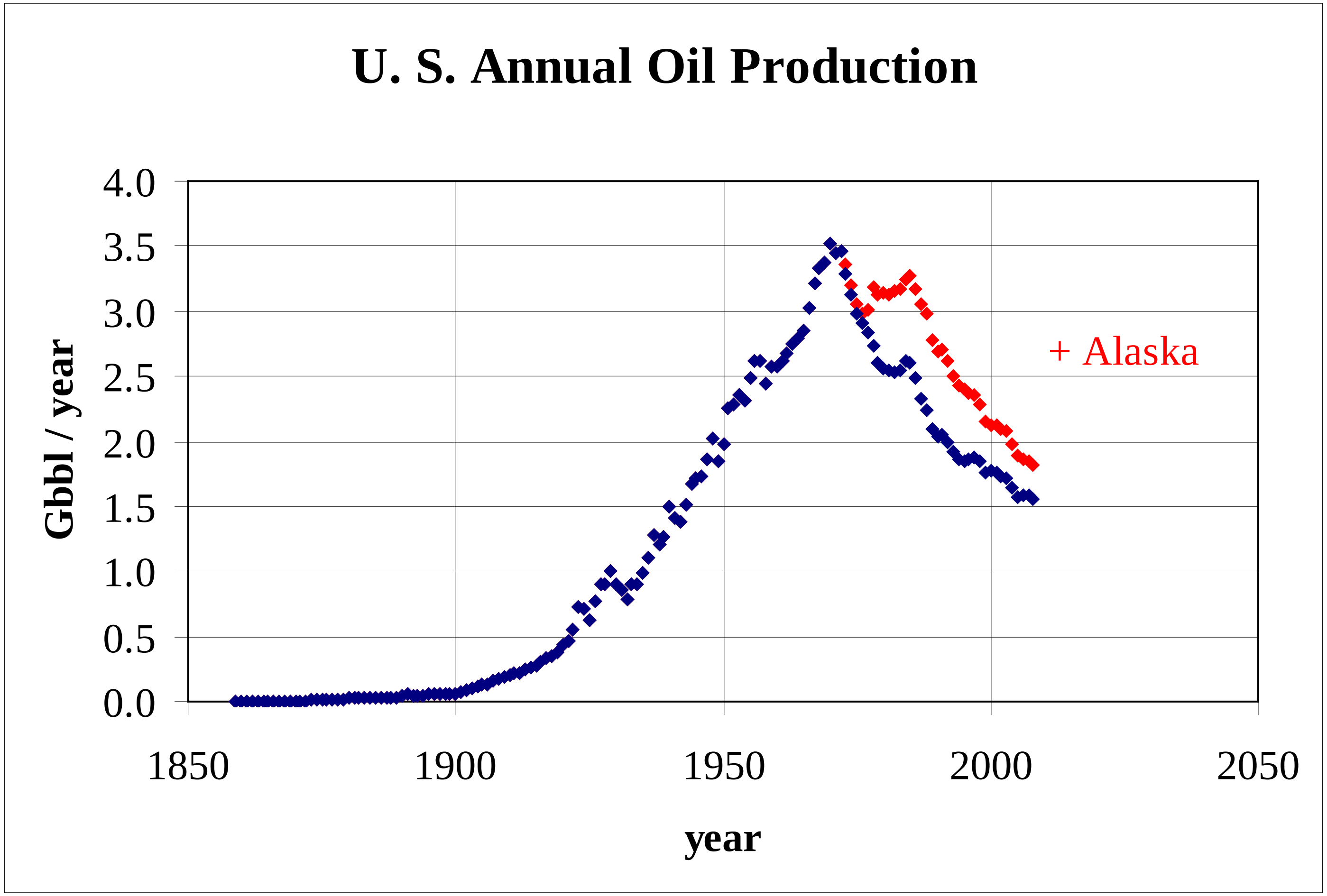


Figure 5 - United States production of crude oil.

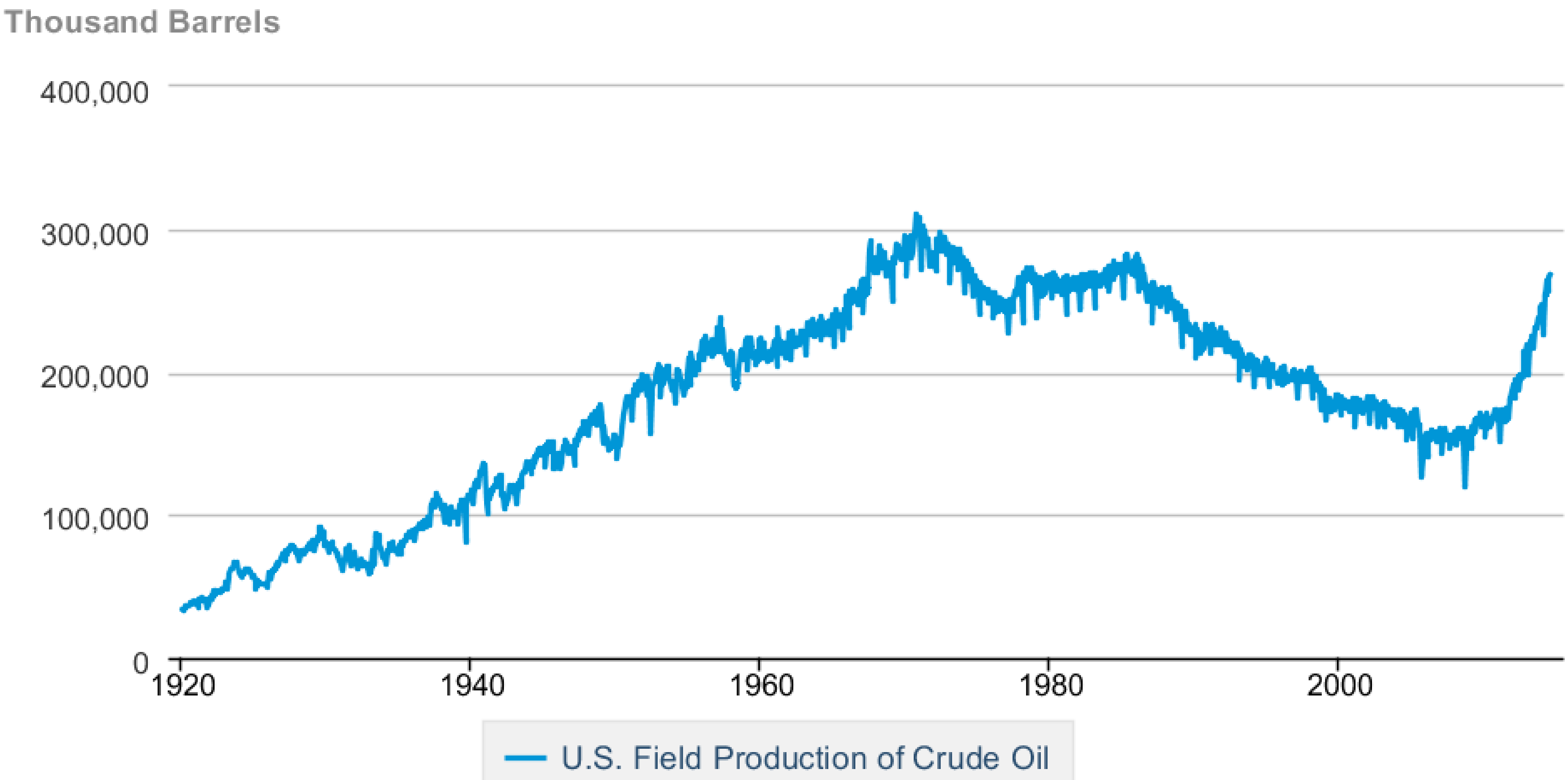
Note: the rate of oil extraction in the world and in the U.S. is increasing.

Oil Production Did Peak in 1973



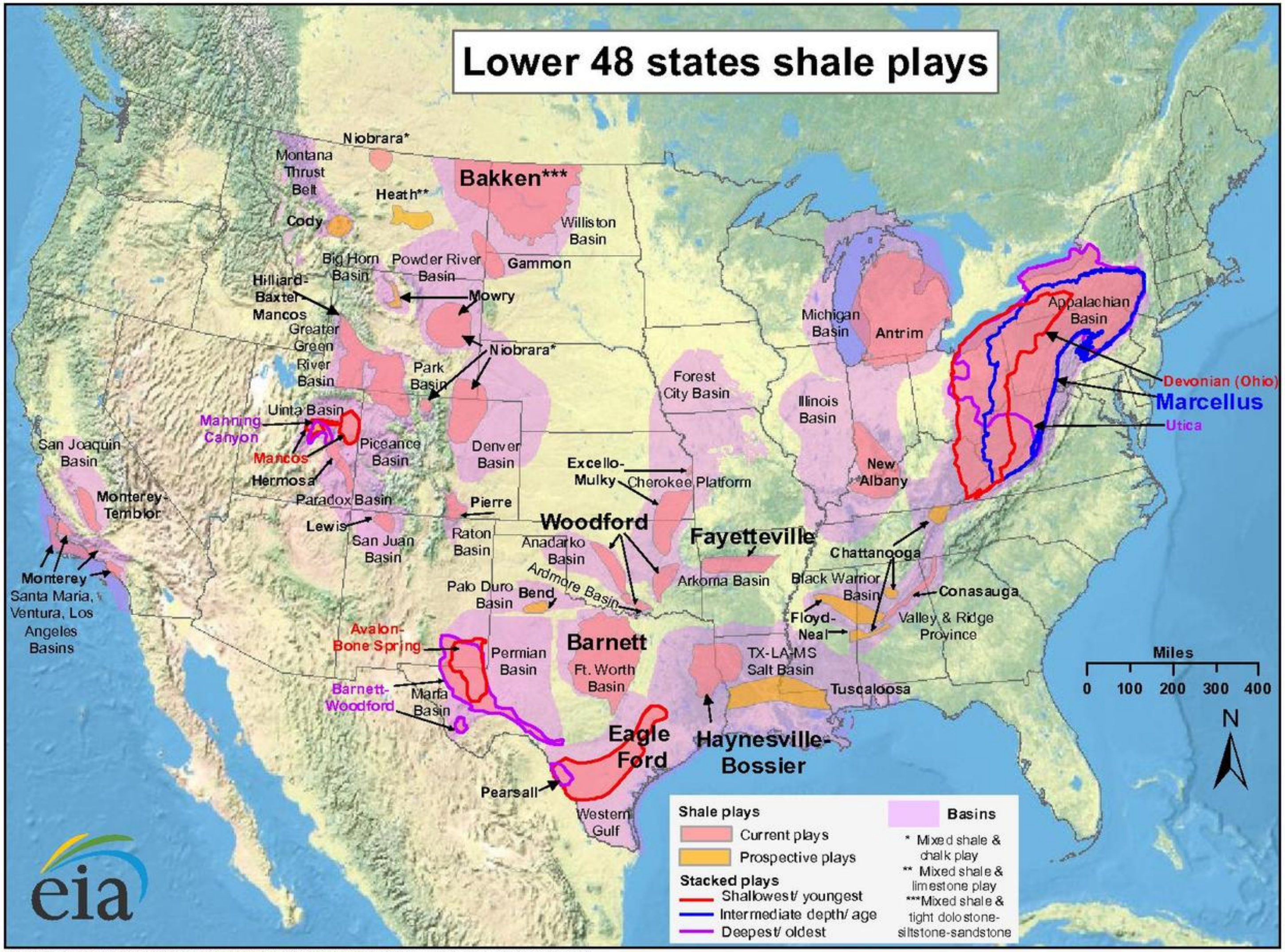
Data from Energy Information Agency Annual Energy Outlook August 2010

Monthly U.S. Oil Production through August, 2014



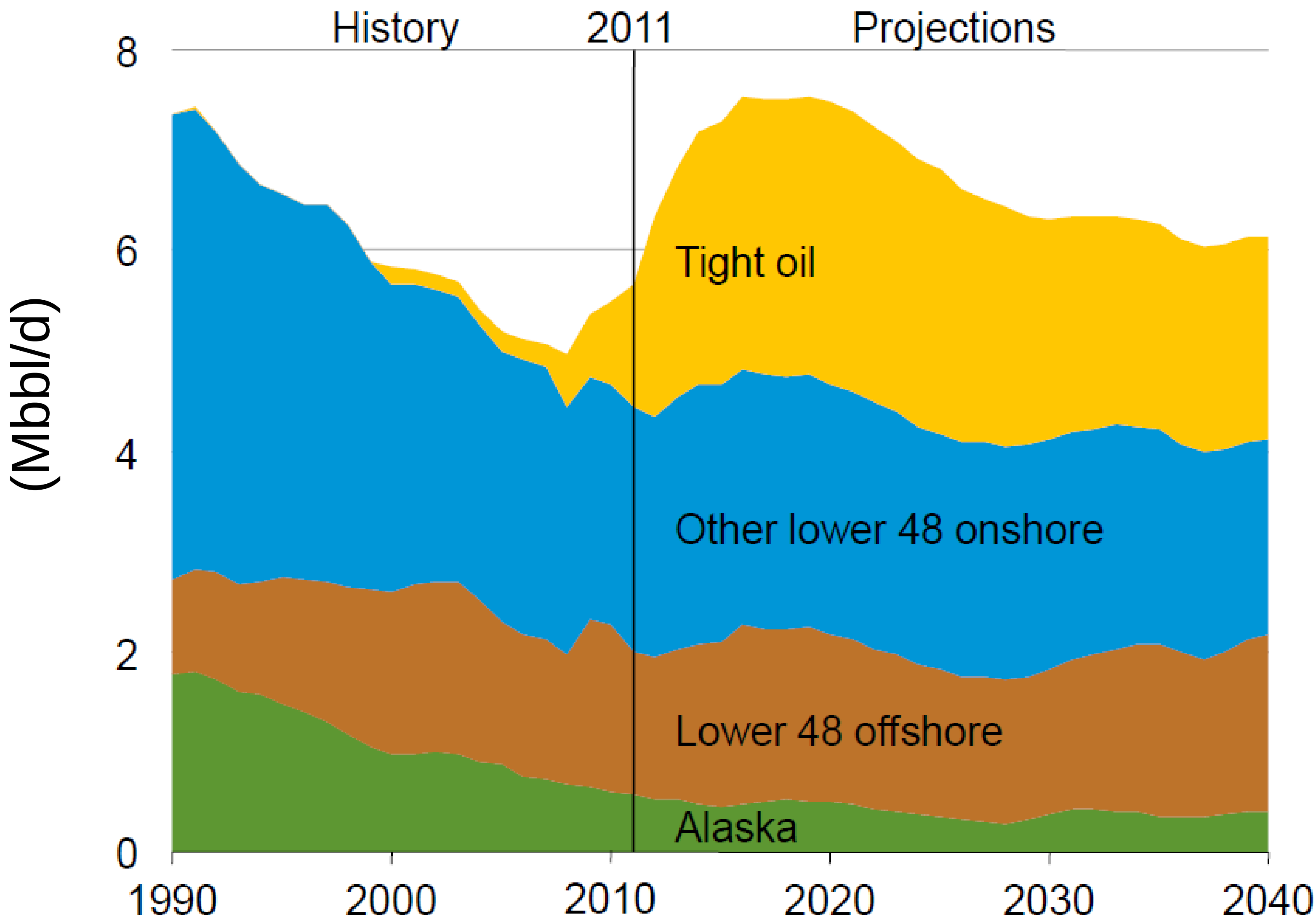
Graph from Energy Information Agency
http://www.eia.gov/dnav/pet/hist/leafhandler.ashx?n=pet&s=mcrfpus1&f=m

U.S. Shale Oil and Gas Basis Formations



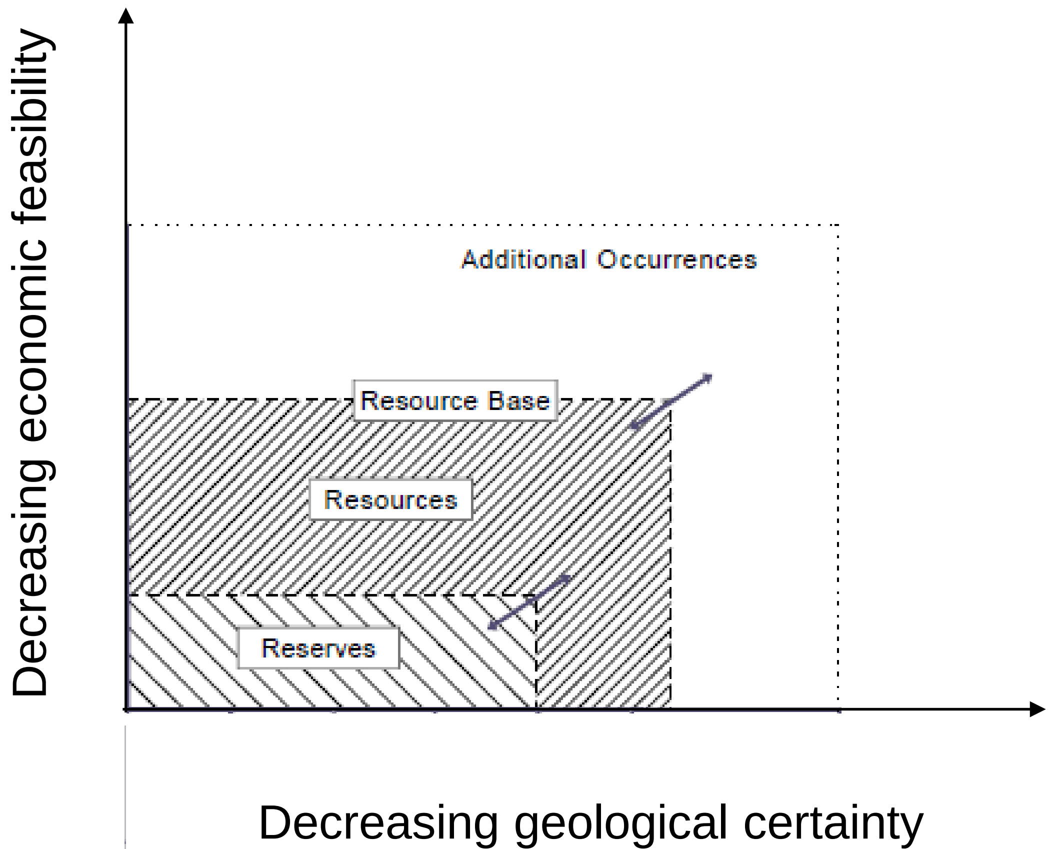
Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

U.S. Crude Oil Production



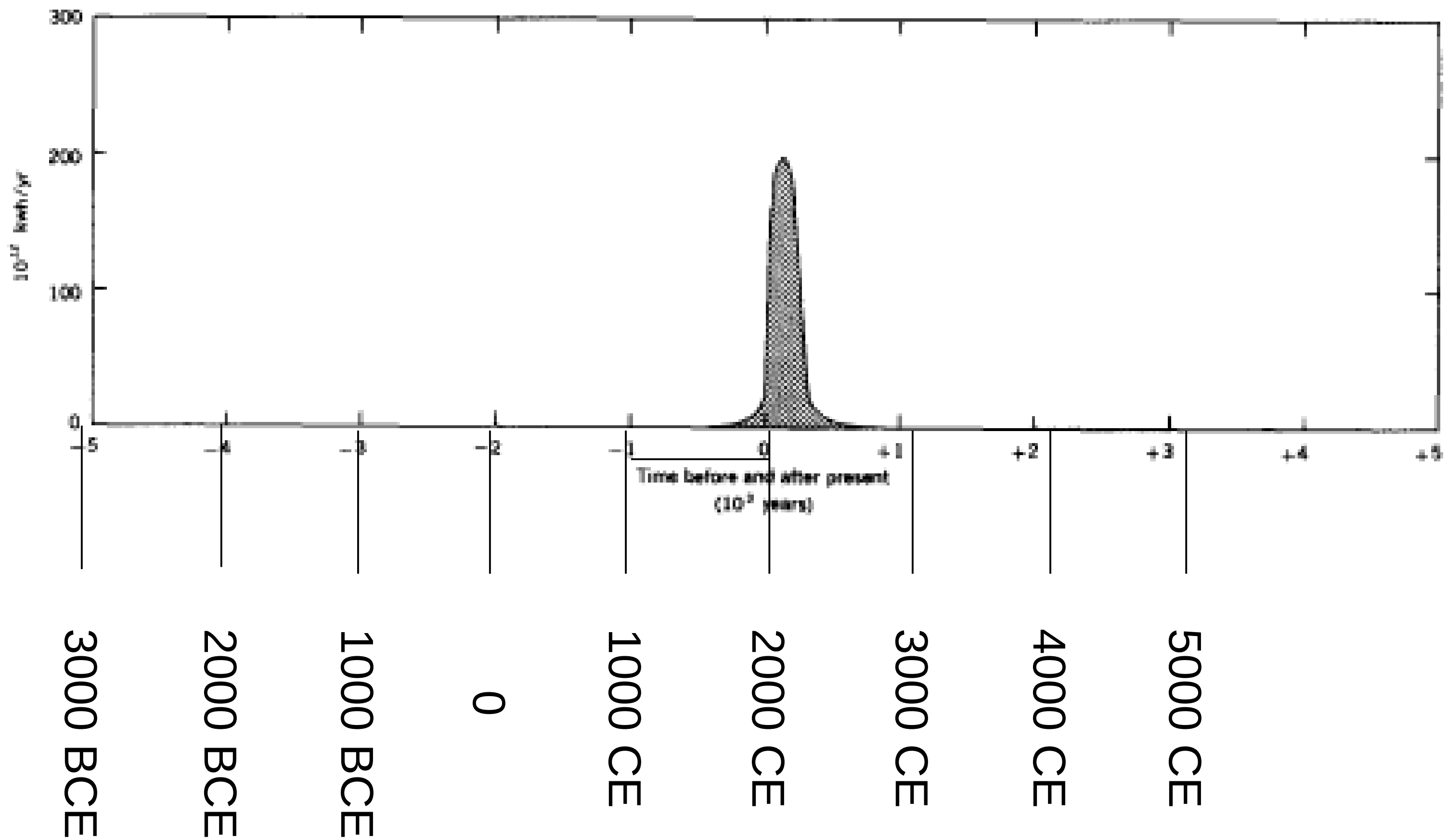
From EIA Annual Energy Outlook overview 2013, Figure 1

Reserves, Resources and Occurrences



From H-H. Rogner, “An Assessment of World Hydrocarbon Resources,” Annual Review of Energy and Environment 22(1997)217

Fossil Fuels in Human History
Hubbert Amer. J. Phys. 49(1981)1007



Reference point 2

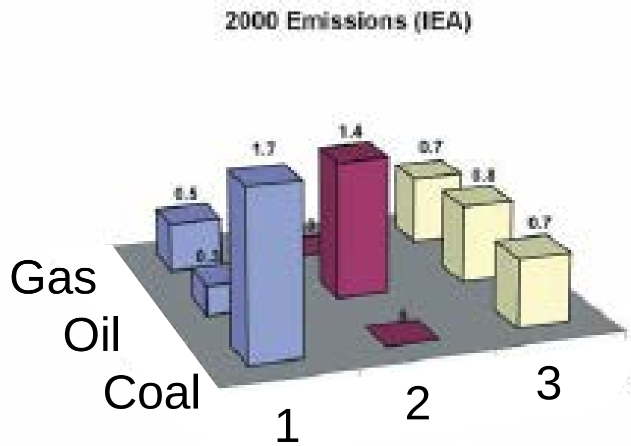
Stabilization Wedges: Solving the Climate Problem
for the Next 50 Years with Current Technologies
S. Pacala and R. Socolow

SCIENCE 305(2004)968

AUGUST 13, 2004

Present Worldwide Emissions, Business as Usual, and Flat Emission Target

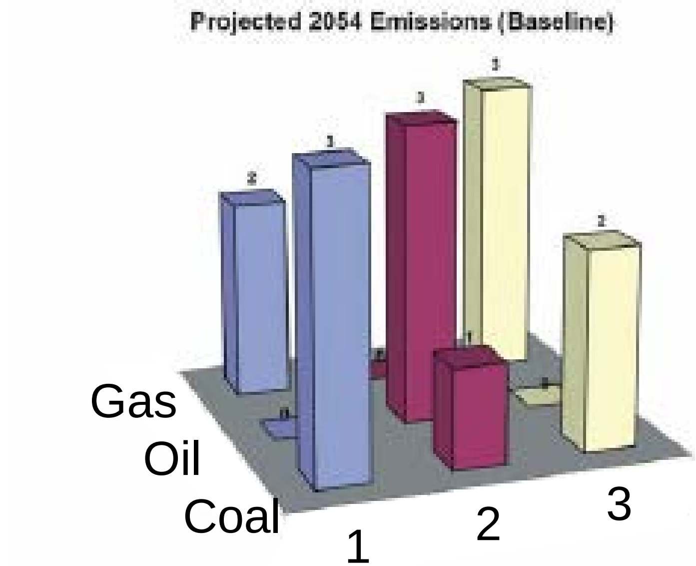
mix of fossil fuels
over three sectors
1. electricity
2. transportation
3. direct use

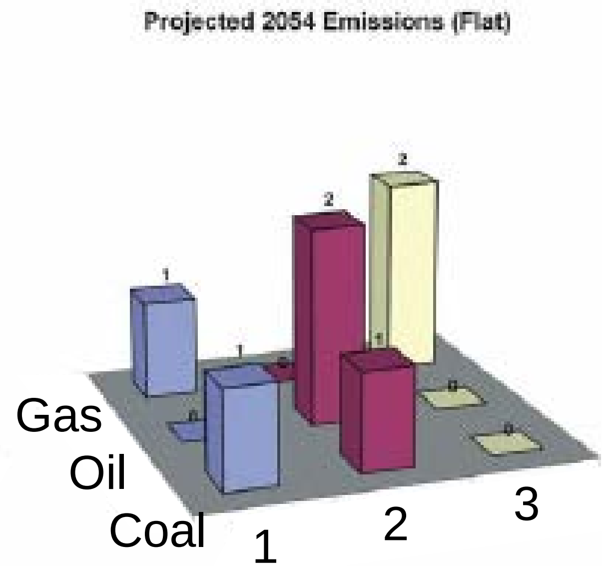


7 Gt C in 2004

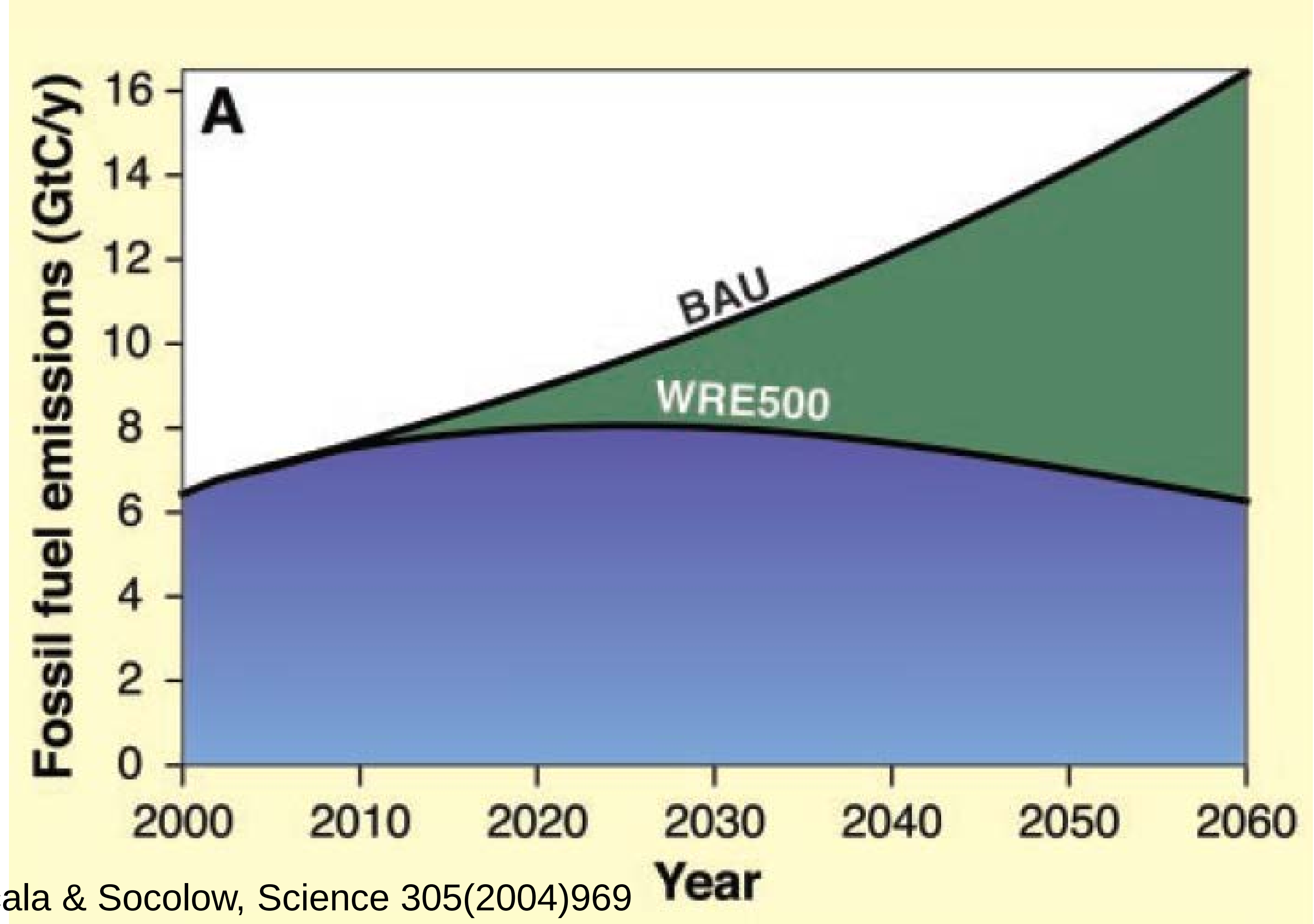
business as usual
14 Gt C in 2054

flat emissions
7 Gt C in 2054



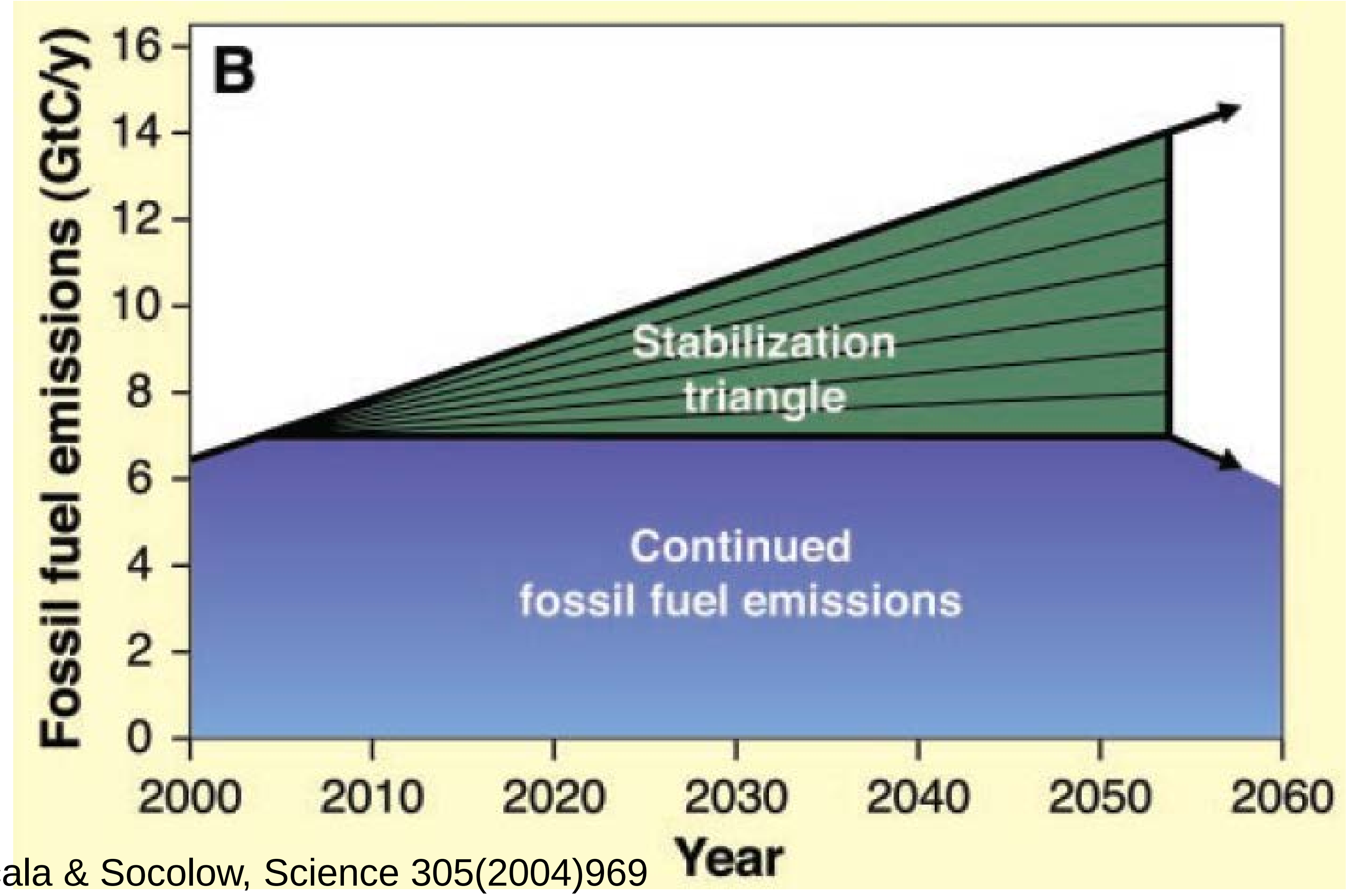


Two Emissions Projections
Business as Usual and 500 ppm CO_2 Peak



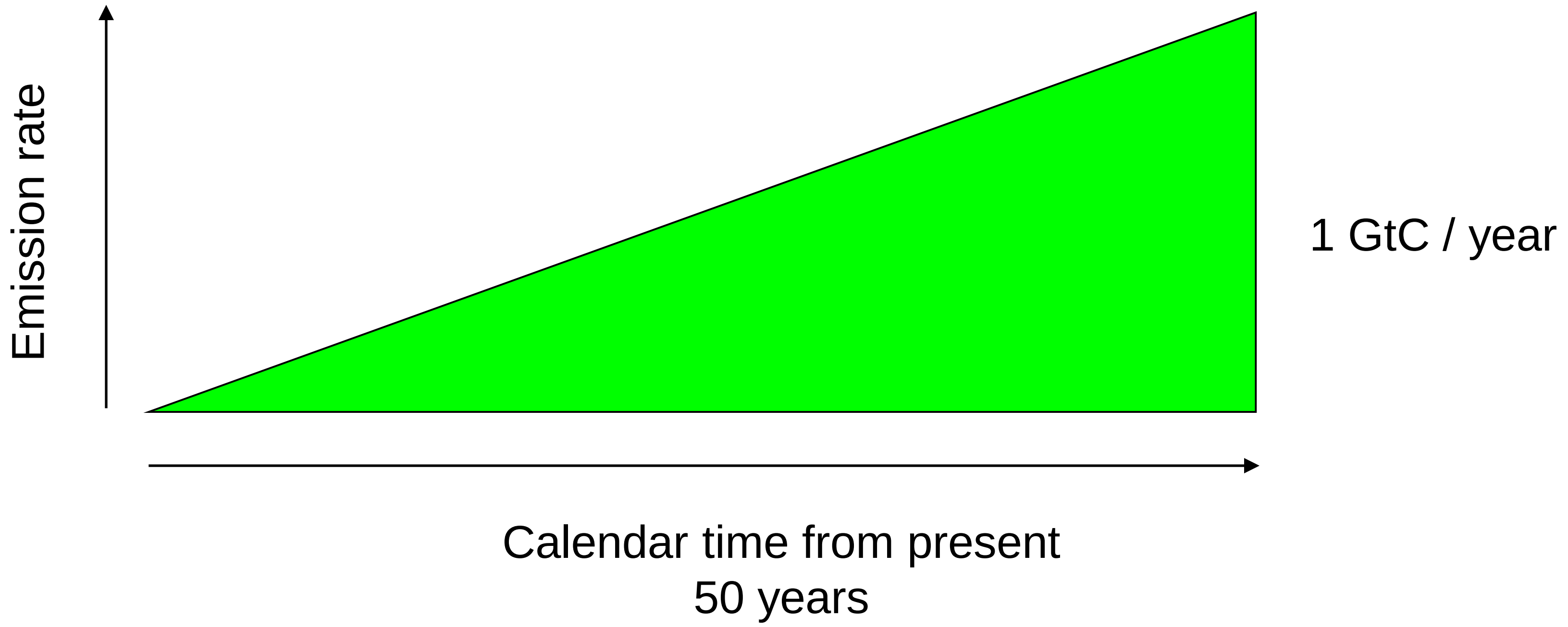
Pacala & Socolow, Science 305(2004)969

Stabilization Triangle - Wedges



Pacala & Socolow, Science 305(2004)969

What is a Wedge?



Wedge: a strategy to avoid 25 GtC of emissions
from BAU over the next 50 years.

Some Possible Stabilization Wedges Requirements by 2055

- Efficient use of fuel: 2,000,000,000 cars @ 60 mpg
- Efficient use of electricity (25% reduction overall)
- Coal plants at 60% rather than 40% efficiency
- Replace 1,400 GW of coal with natural gas (×4)
- Add CCS to 800 GW of coal plants (3,500 Sleipners)
- Wind from 1,000,000 2 MW wind turbines (×50)
- PV from 10% efficient cells on 20,000 km^2 (×700)
- Replace 700 GW coal with nuclear (×3)
- Clean ethanol from 2,500,000 km^2 (×100 Brazil)

From R. Socolow, "Policy and Technology for Living in a Greenhouse," 2007.

New York Times
November 26, 2009

Obama to Go to Copenhagen With Emissions Target

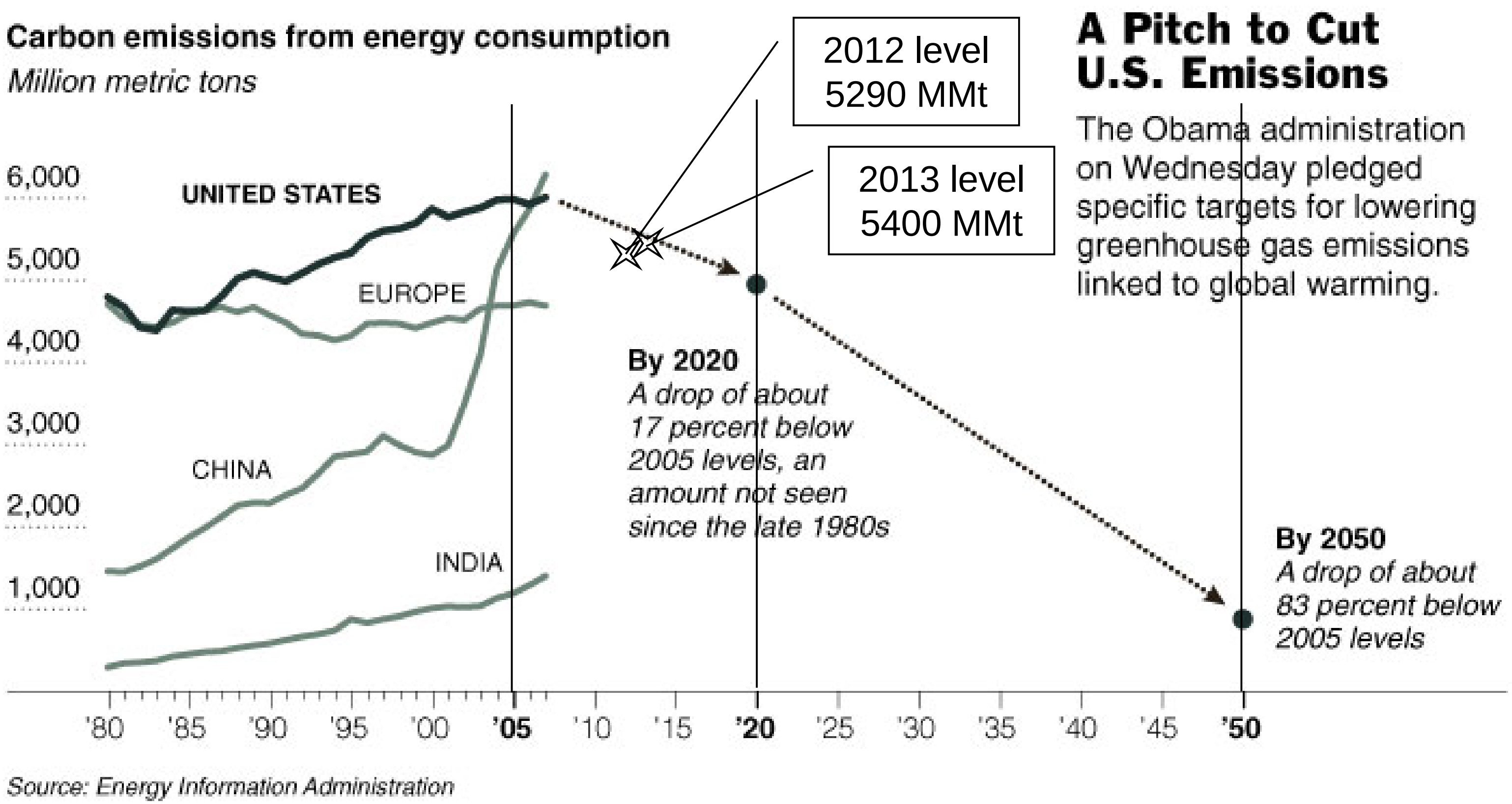
John M. Broder

…

"At the international climate meetings in Copenhagen next month, Mr. Obama will tell the delegates that the United States intends to reduce its greenhouse gas emissions 'in the range of 17 percent' below 2005 levels by 2020 and 83 percent by 2050, officials said."

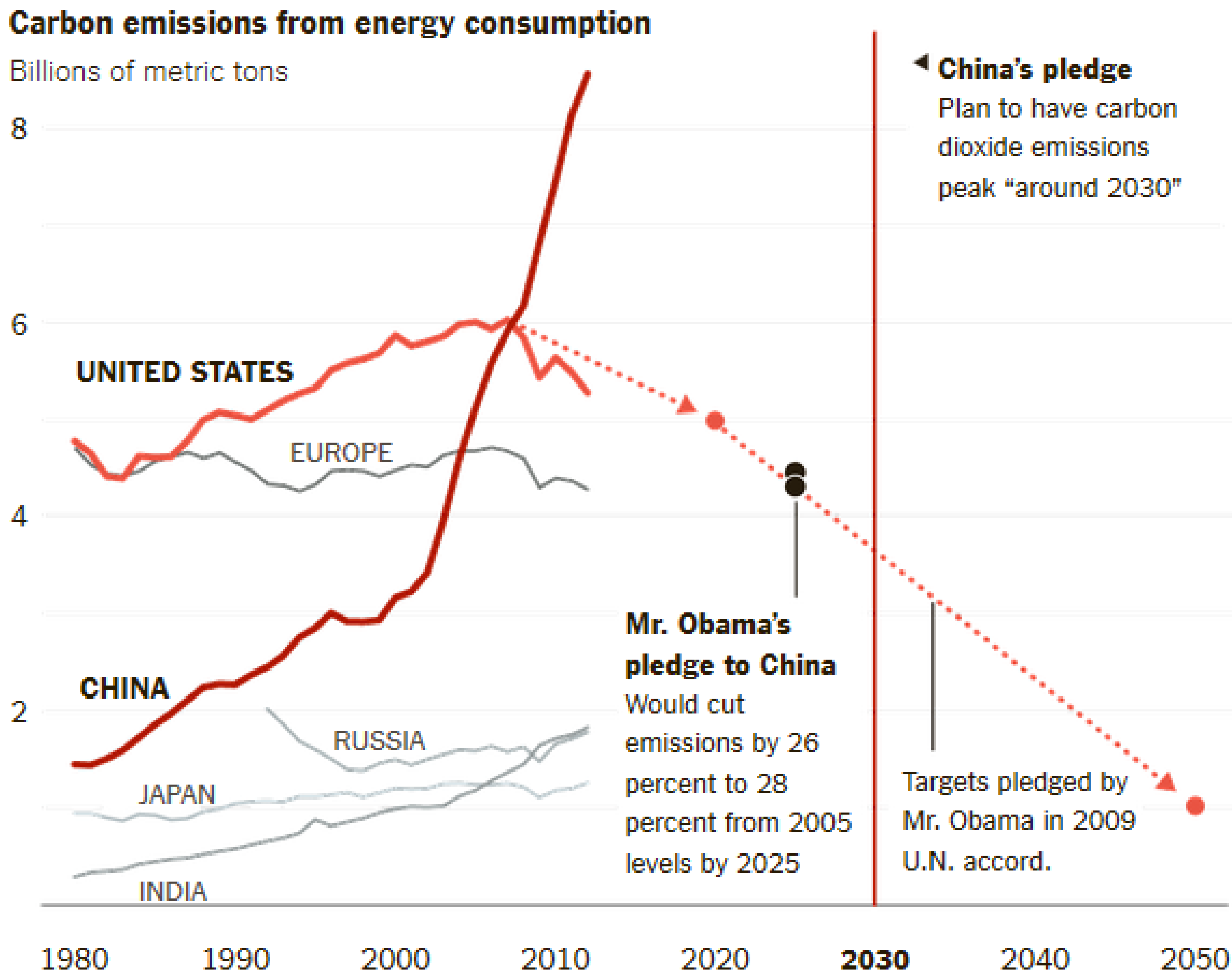
…

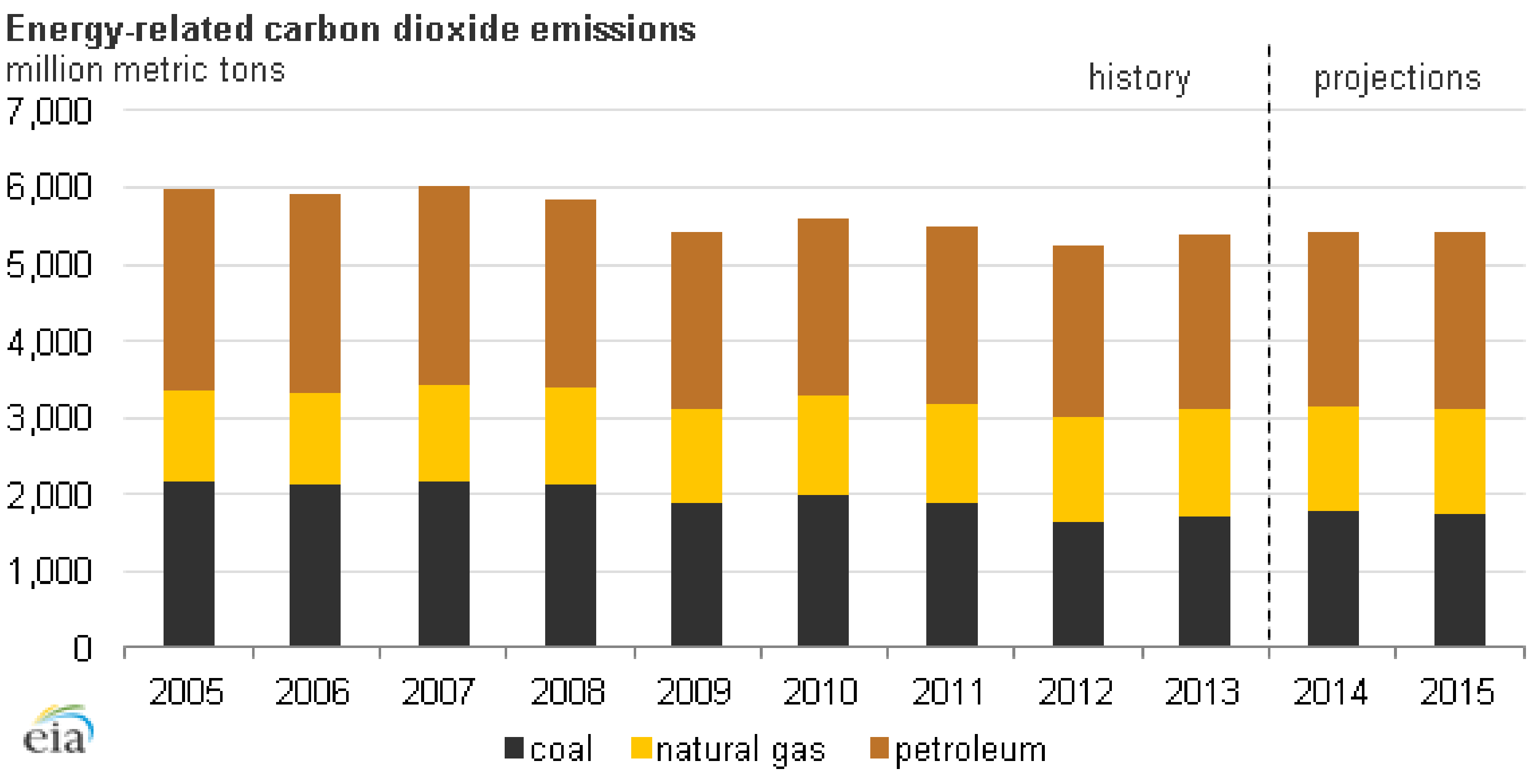
CO_2 Emissions from Energy Consumption



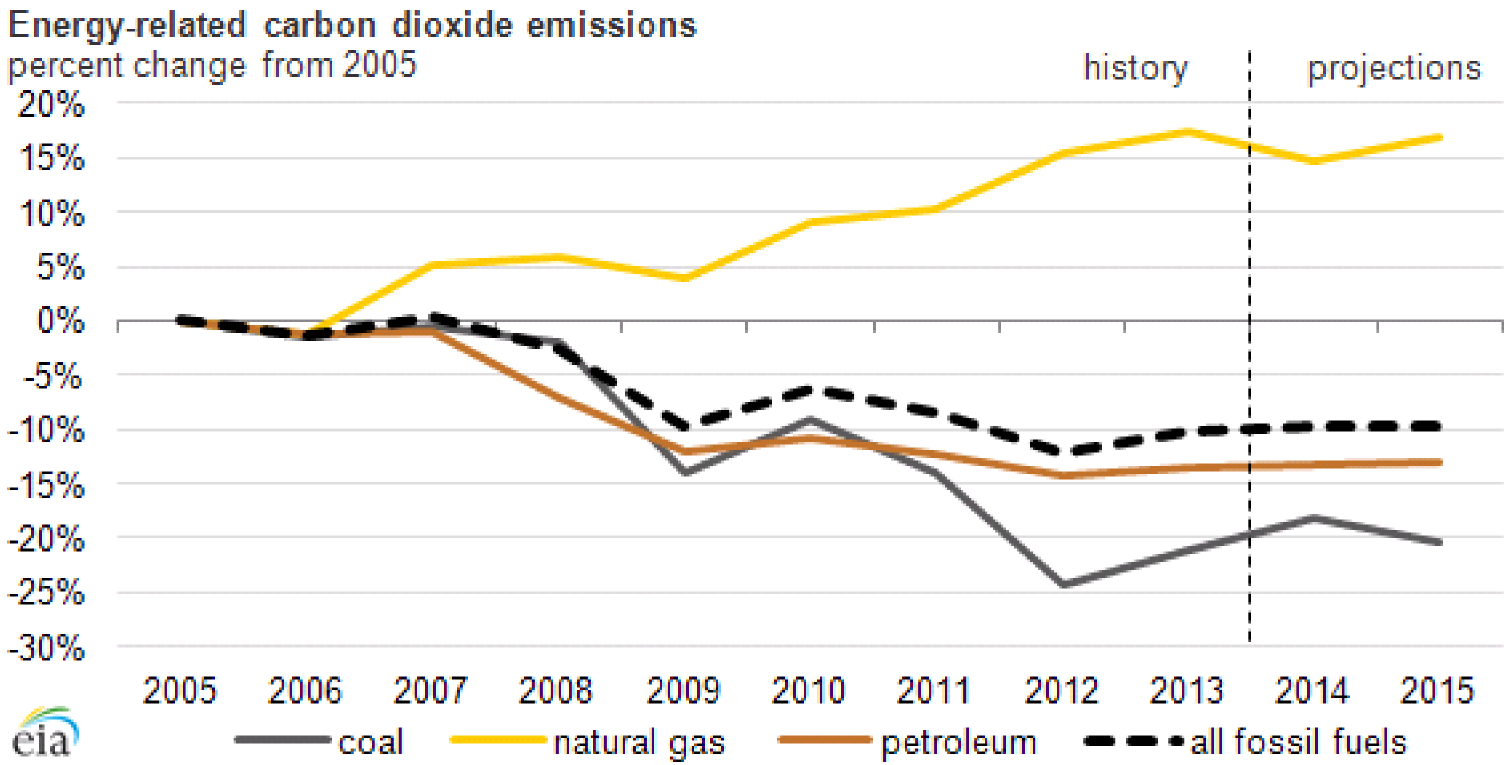
NB: CO_2 emissions plotted. U.S. pledge is 1.2 P&S wedge.
Emission reduction between 2005 and 2013 10%.

U.S. - China Announcement November 12, 2014





U.S. Energy Information Administration
Short-Term Energy Outlook, January 2014

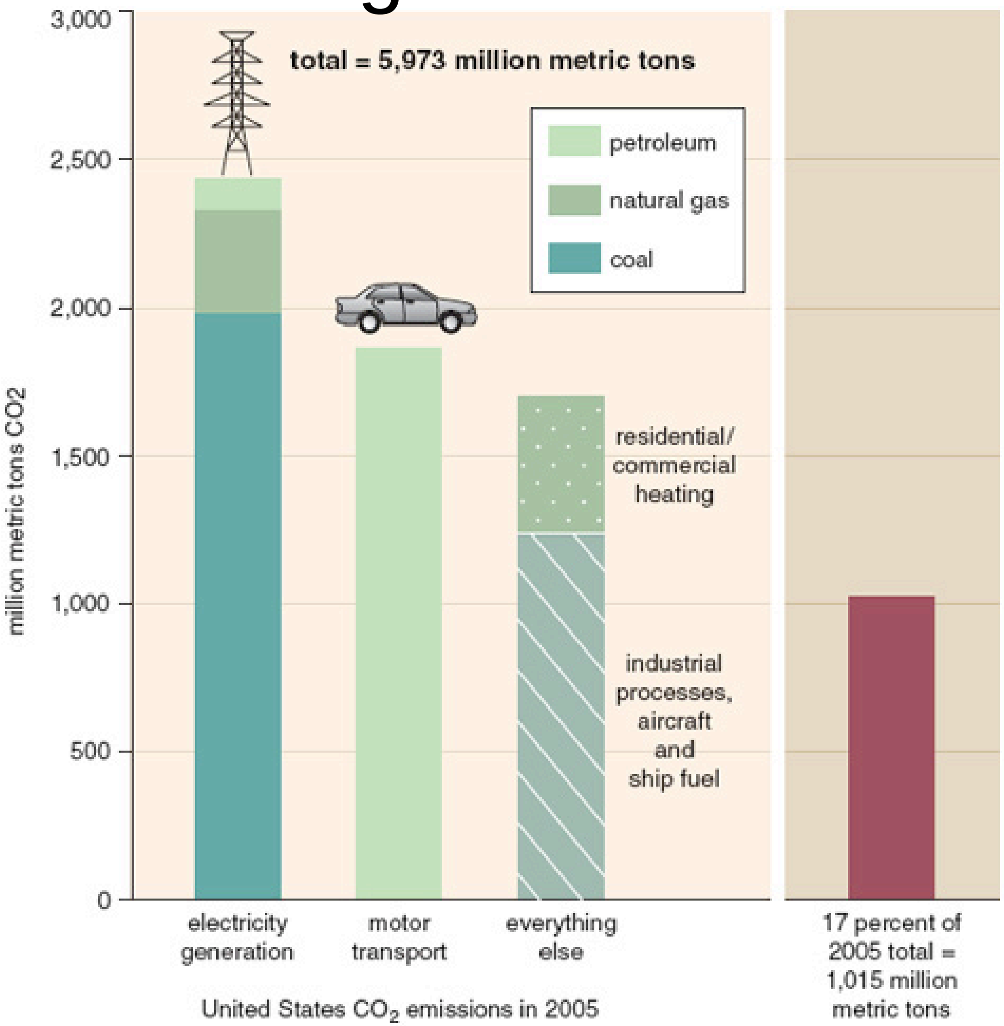


U.S. Energy Information Administration
Short-Term Energy Outlook, January 2014

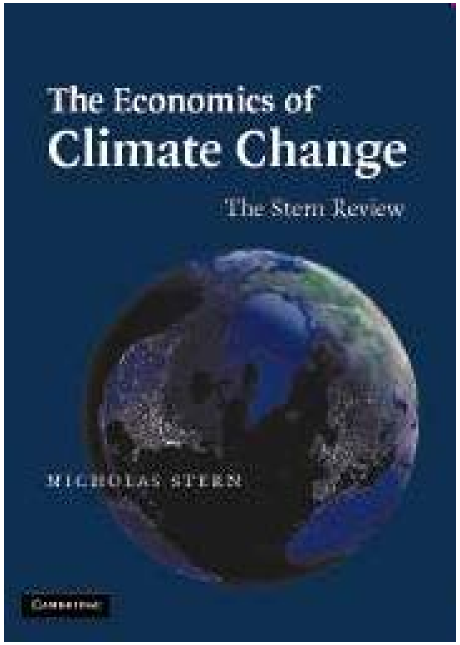
Coal and Natural Gas CO_2 Emissions Comparison

- Coal
  - Various grades differ in energy content and composition. Coal ~75% carbon.
  - $C+O_2 \rightarrow CO_2$ @ 2.88 kWh_{th}/kg CO_2
- Natural gas
  - Mostly methane and other light hydrocarbons
  - $CH_4+3O_2 \rightarrow CO_2+2H_2O$ @ 5.91 kWh_{th}/kg CO_2
- Natural gas produces half the CO_2 as coal for the same thermal energy production.

83% Reduction Goal Would Require Zero(!!!) Electricity, Transportation and Heating Emissions



From "Strategy Versus Evolution," A. Pavlak, American Scientist, Nov-Dec, 2010.



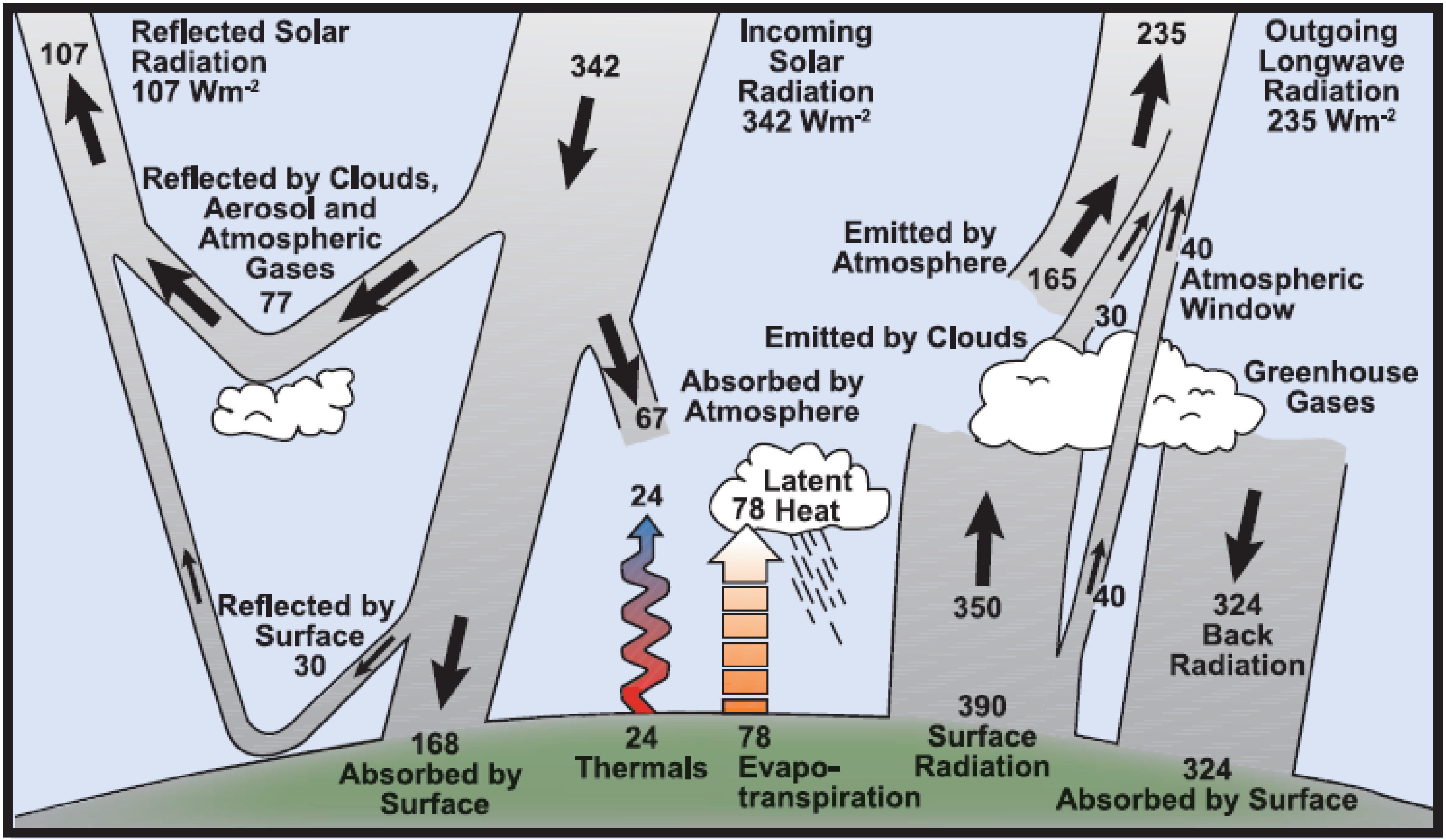
Reference point 3

The Stern Review on
The Economics of Climate Change

HM Treasury

October, 2006

The IPCC Models the Earth-Atmosphere Energy Flux Balance



FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

The Stern Review Models the Entire World Economy for the Next 100 to 200 Years!

- Uses input from climate science models
- Predicts economic impact of business as usual
- Predicts economic cost of climate change mitigation policies
- Anticipates effects of possible adaptation strategies
- Anticipates effects of possible technological change
- Analyzes effect of carbon tax, carbon trading, or carbon regulation

theguardian

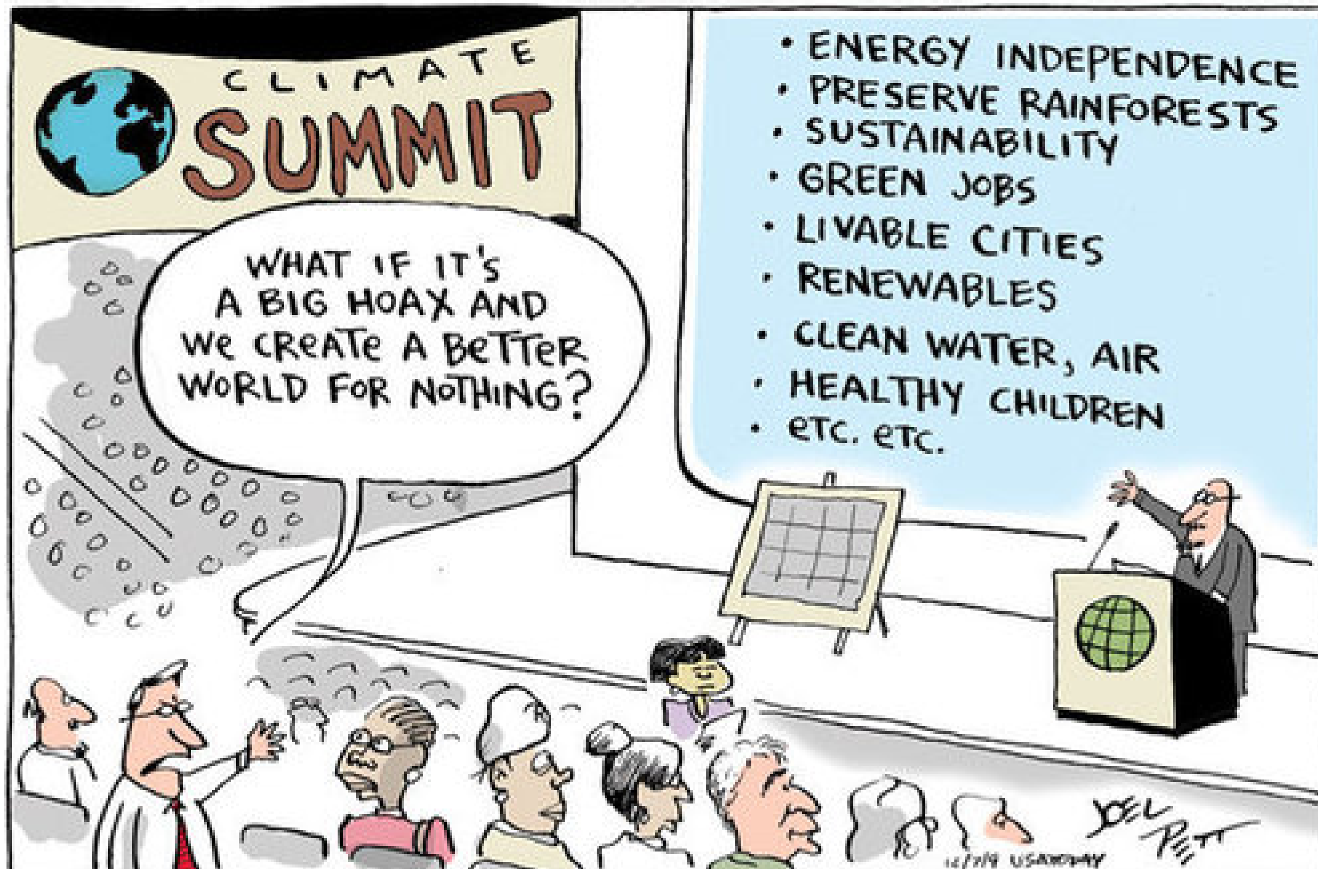
October 30, 2006
Stern report: the key points, I

- "All countries will be affected by climate change, but the poorest countries will suffer earliest and most."
- "The level [of GHG in the atmosphere] should be limited to 450-550 ppm CO_{2e}."
- "Anything higher would substantially increase risks of very harmful impacts. Anything lower would impose very high adjustment costs in the near term and might not even be feasible."

theguardian

Stern report: the key points, II

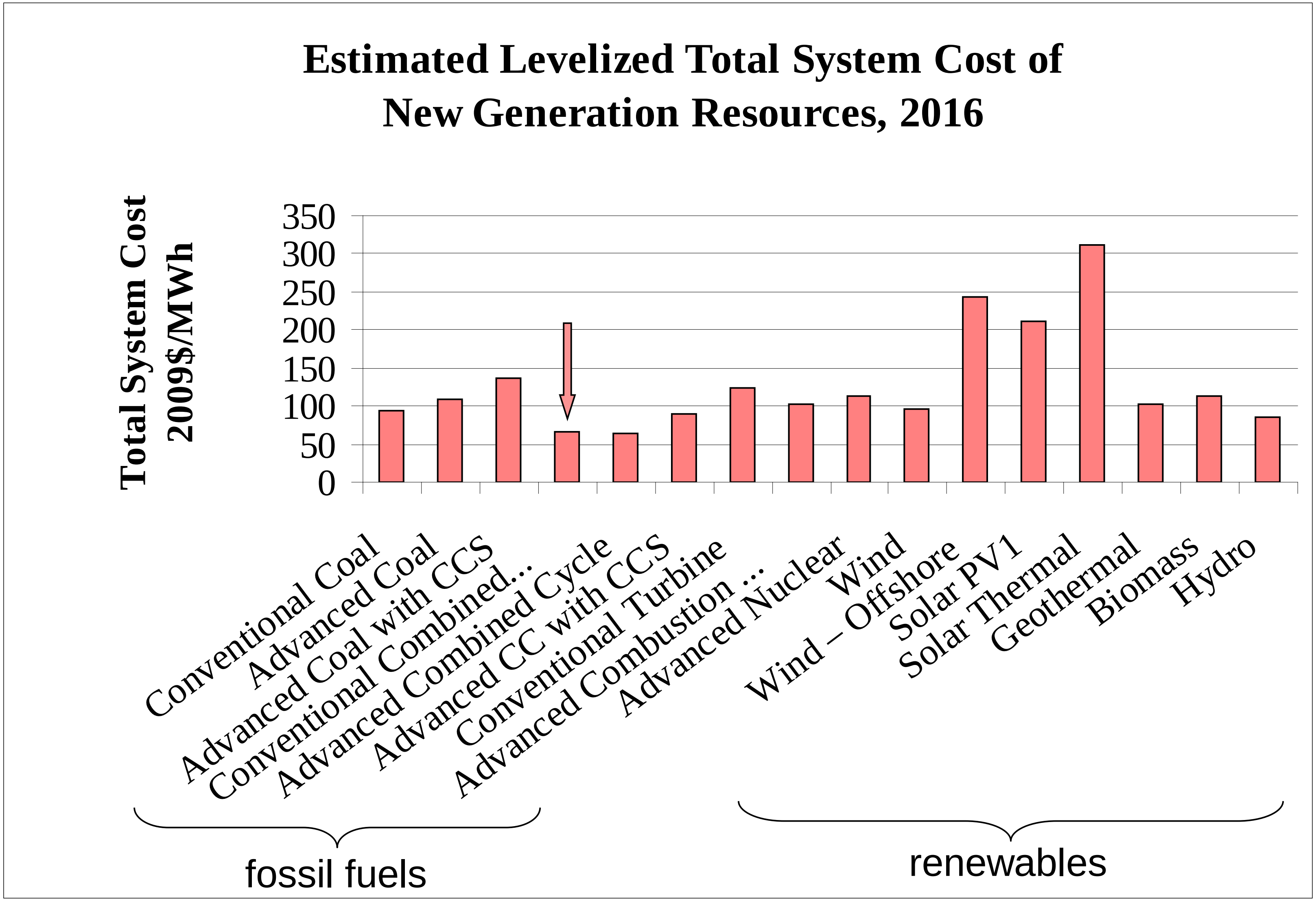
- “The benefits of strong, early action considerably outweigh the costs.”
- “Unabated climate change could cost the world at least 5% of GDP each year; if more dramatic predictions come to pass, the cost could be more than 20% of GDP.”
- “The cost of reducing emissions could be limited to around 1% of global GDP” [Stern 2012 update 2-3%]
- “What we do now can have only a limited effect on the climate over the next 40 or 50 years, but what we do in the next 10-20 years can have a profound effect on the climate in the second half of this century.”



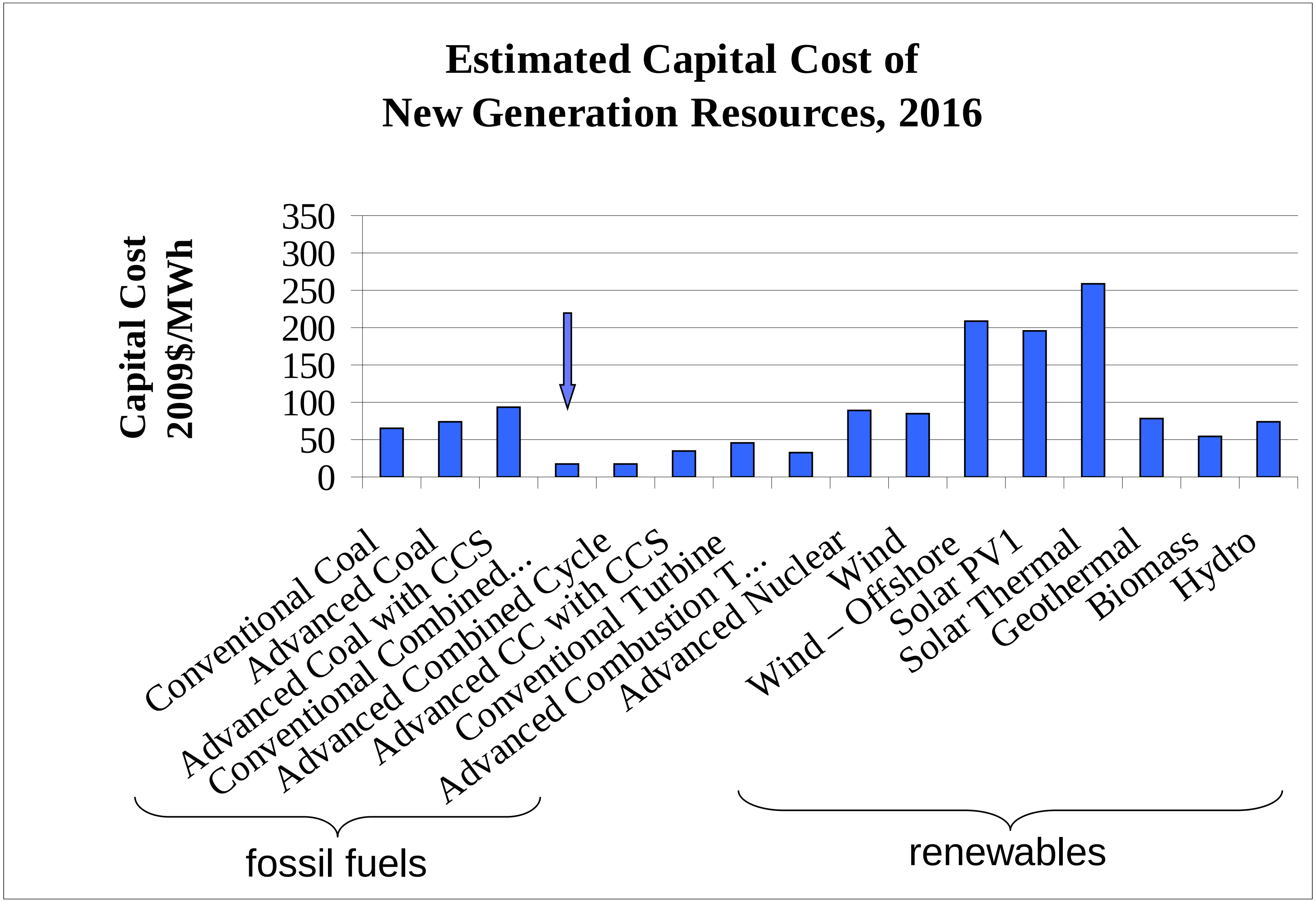
CLIMATE SUMMIT
WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• etc. etc.
JOEL PETT

ENERGY ISSUES EXAMPLES

Energy Economics



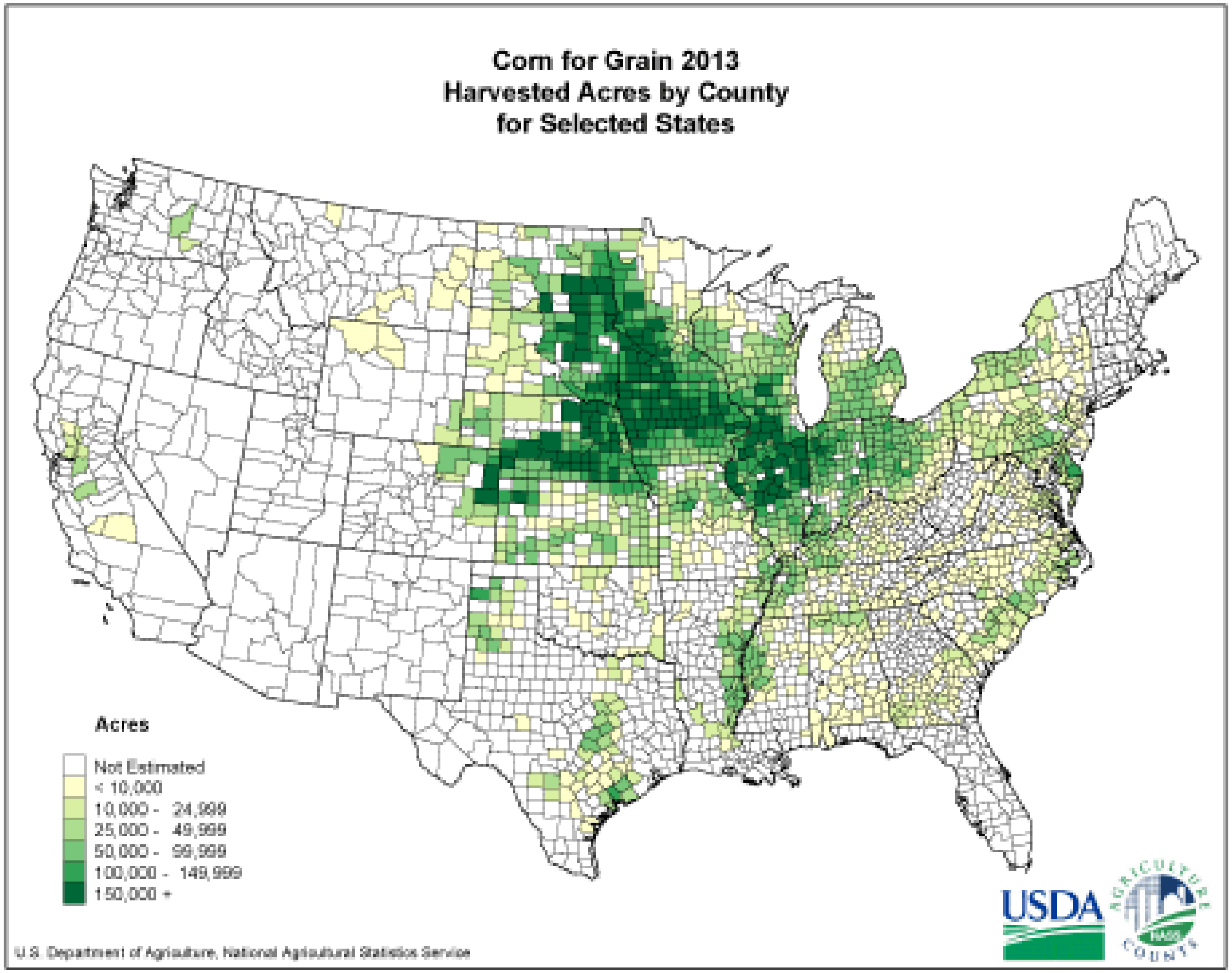
Source Energy Information Agency Annual Energy Outlook 2011



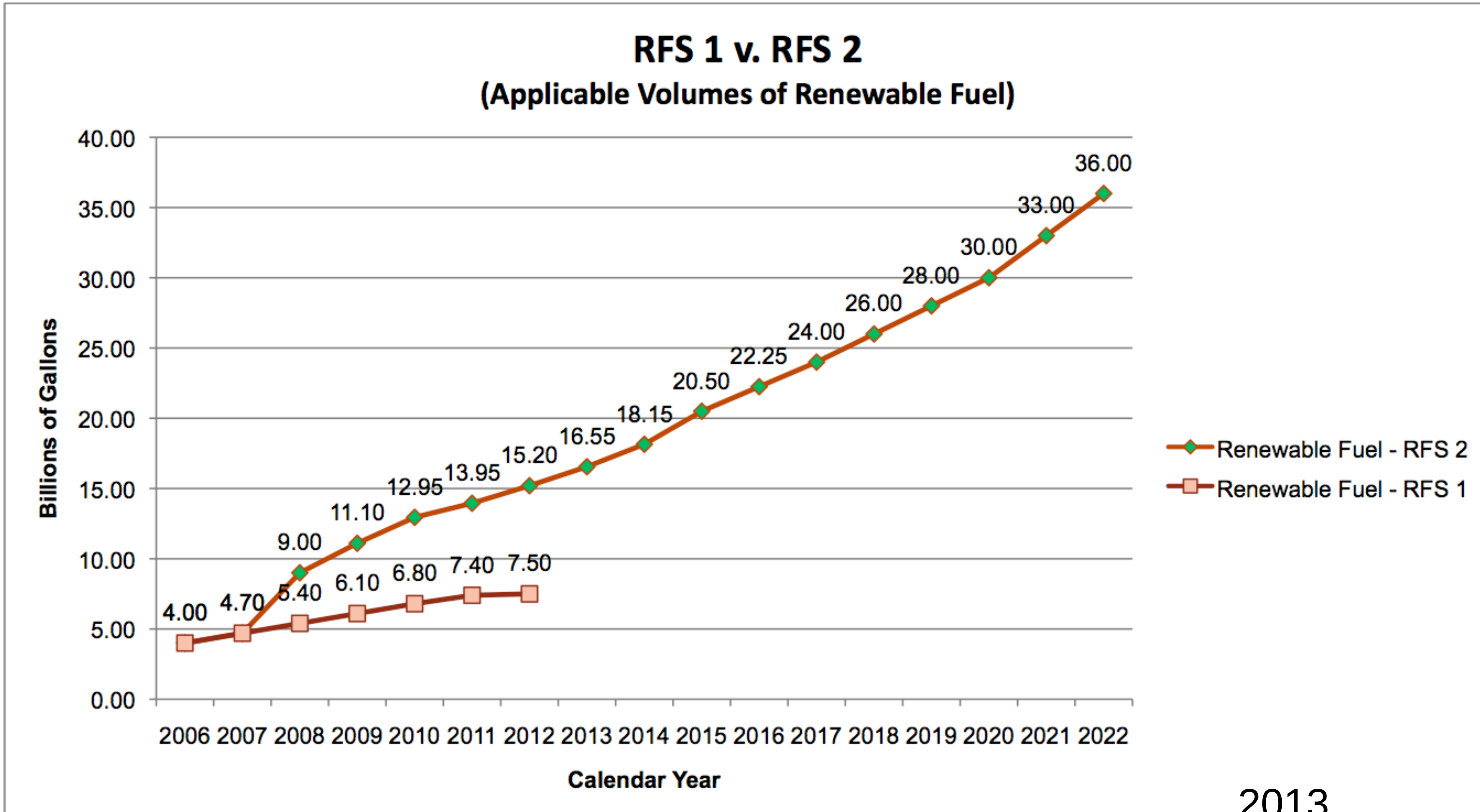
Source Energy Information Agency Annual Energy Outlook 2011

ENERGY ISSUES EXAMPLES
Ethanol

Corn Harvested Acres 2013



Federal Renewable Fuel Standards Mandate Ethanol Usage



RFS 1: Energy Policy Act of 2005
RFS 2: Energy Independence and Security Act of 2007

2013
U.S. gasoline consumption
136 billion gallons

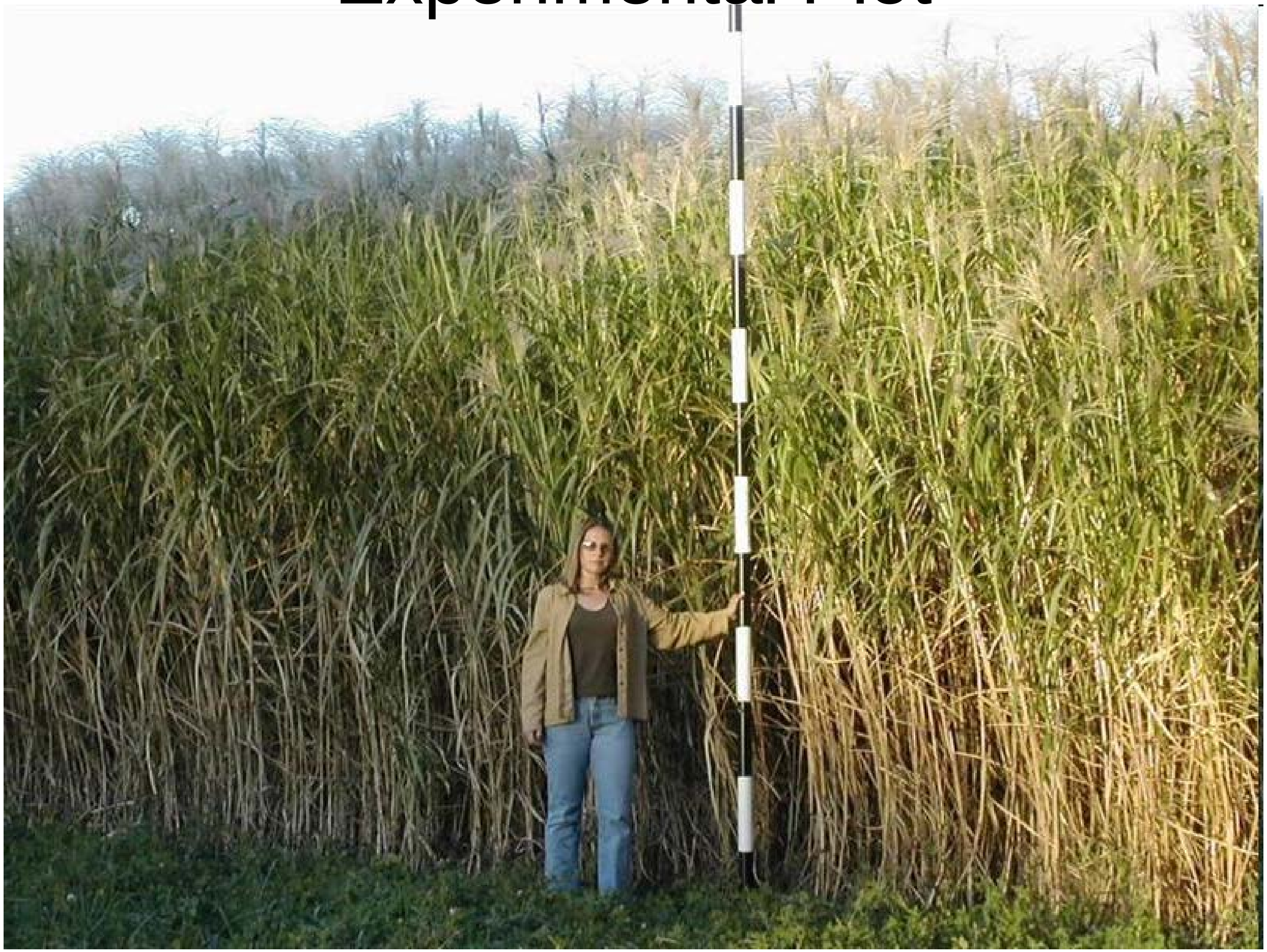
Corn Ethanol Issues

- Positive (?) energy benefit [yes]
- Reduction (?) of direct greenhouse gas emissions [yes]
- Increase of greenhouse gas emissions due to indirect land use change [LULUC]
- Food versus fuel [controversial]

Corn Solar Conversion Efficiency

- Illinois average corn production = 150 bu / a / y
- Corn to ethanol conversion = 2.77 gal / bu
- Ethanol energy content = 84,300 BTU / gal
- Gasoline energy content = 125,000 BTU / gal
- Corn solar energy conversion efficiency = $\boxed{0.31\ W / m^2}$
- Illinois average solar insolation = 195 W / m^2

Alternative Fuel Stock
Miscanthus at University of Illinois Experimental Plot



From D. MacKay Sustainable Energy without the Hot Air, Figure 6.10

INEOS BIO Vero Beach, FL
Cellulosic Ethanol Plant

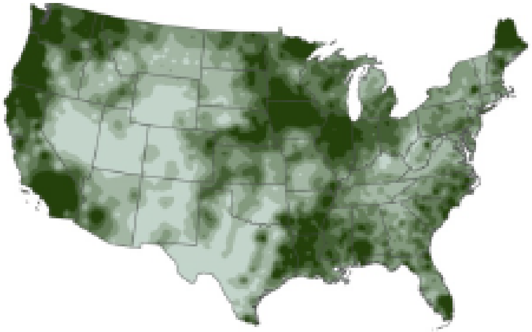
Capital cost 130M$
Design nameplate capacity 8 Mgal/y
Operation began July, 2014

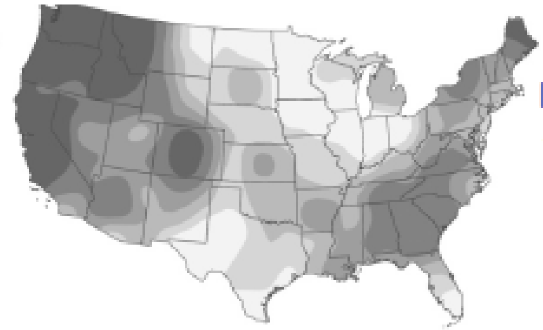
ENERGY ISSUES EXAMPLE

Renewable Energy
Wind and Others

Renewable Resources and Technologies

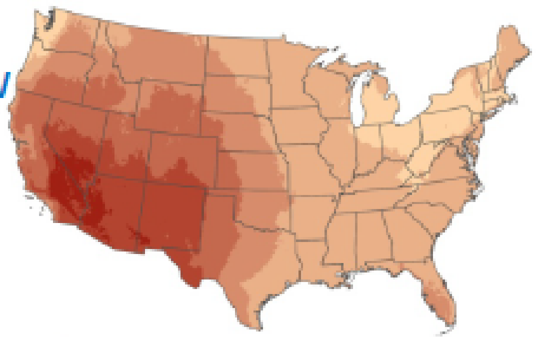
Biopower ~100 GW
- Stand-alone
- Cofired with coal

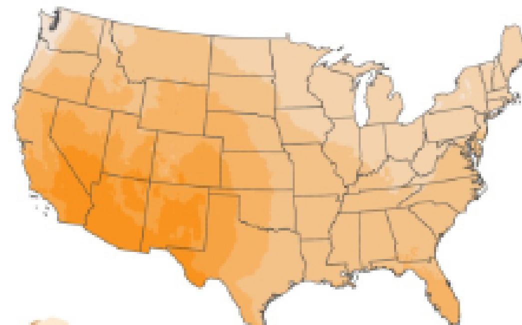




Hydropower ~200 GW
- Run-of-river

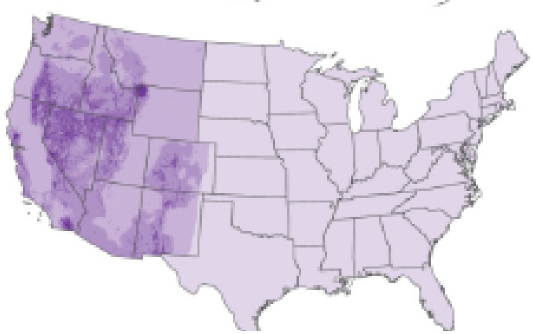
Solar CSP ~37,000 GW
- Trough ⎤ With thermal
- Tower ⎦ storage

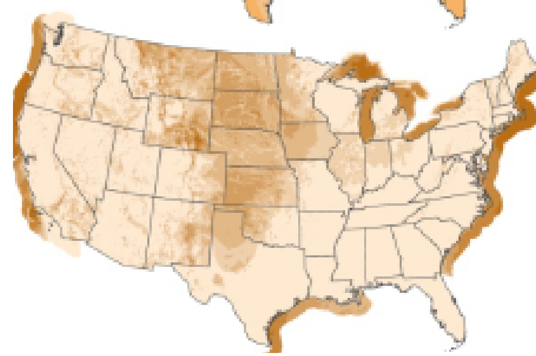




Solar PV ~80,000 GW (rooftop PV ~700 GW)
- Residential
- Commercial
- Utility-scale

Geothermal ~36 GW
- Hydrothermal

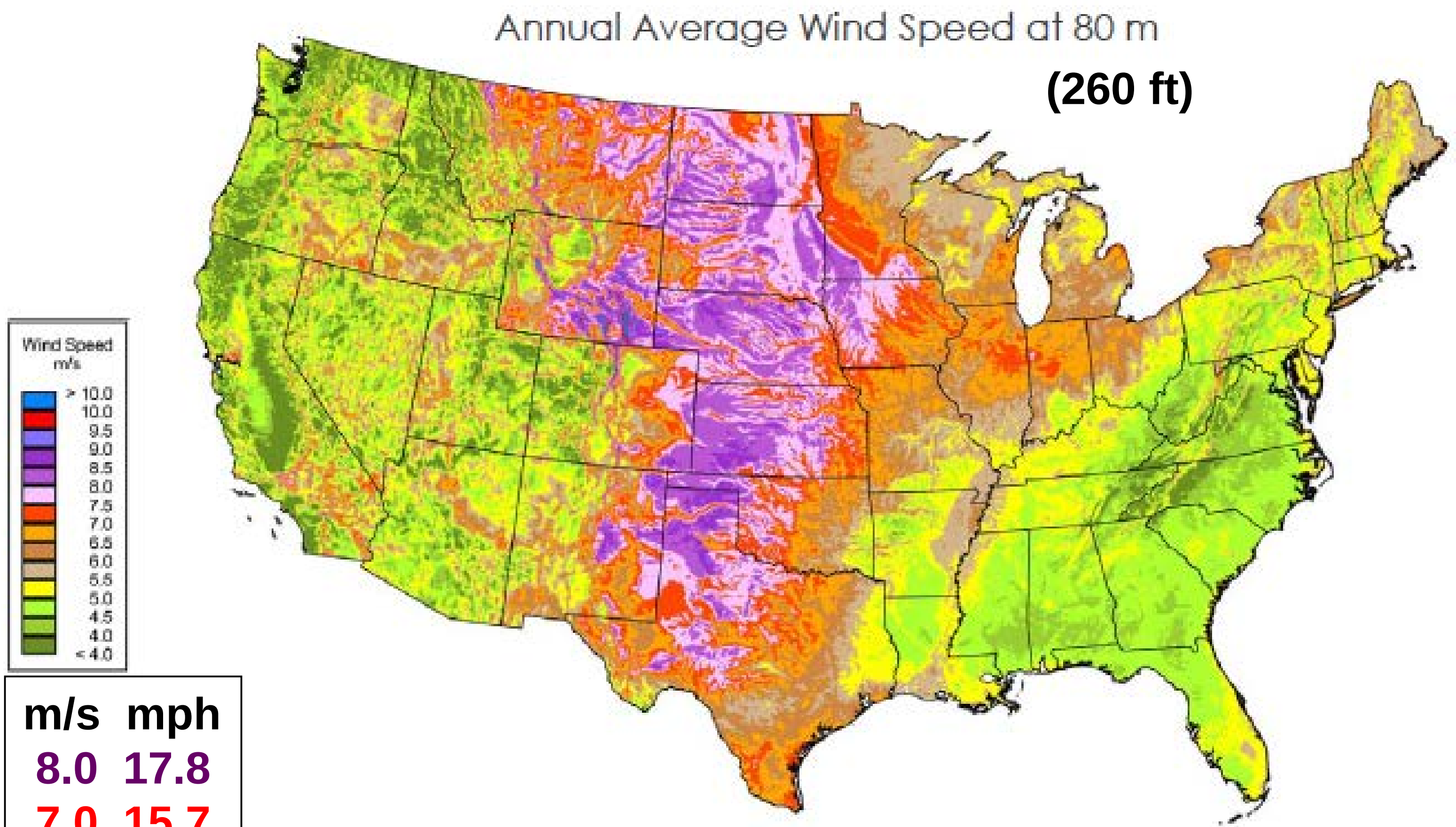




Wind ~10,000 GW
- Onshore
- Offshore fixed-bottom

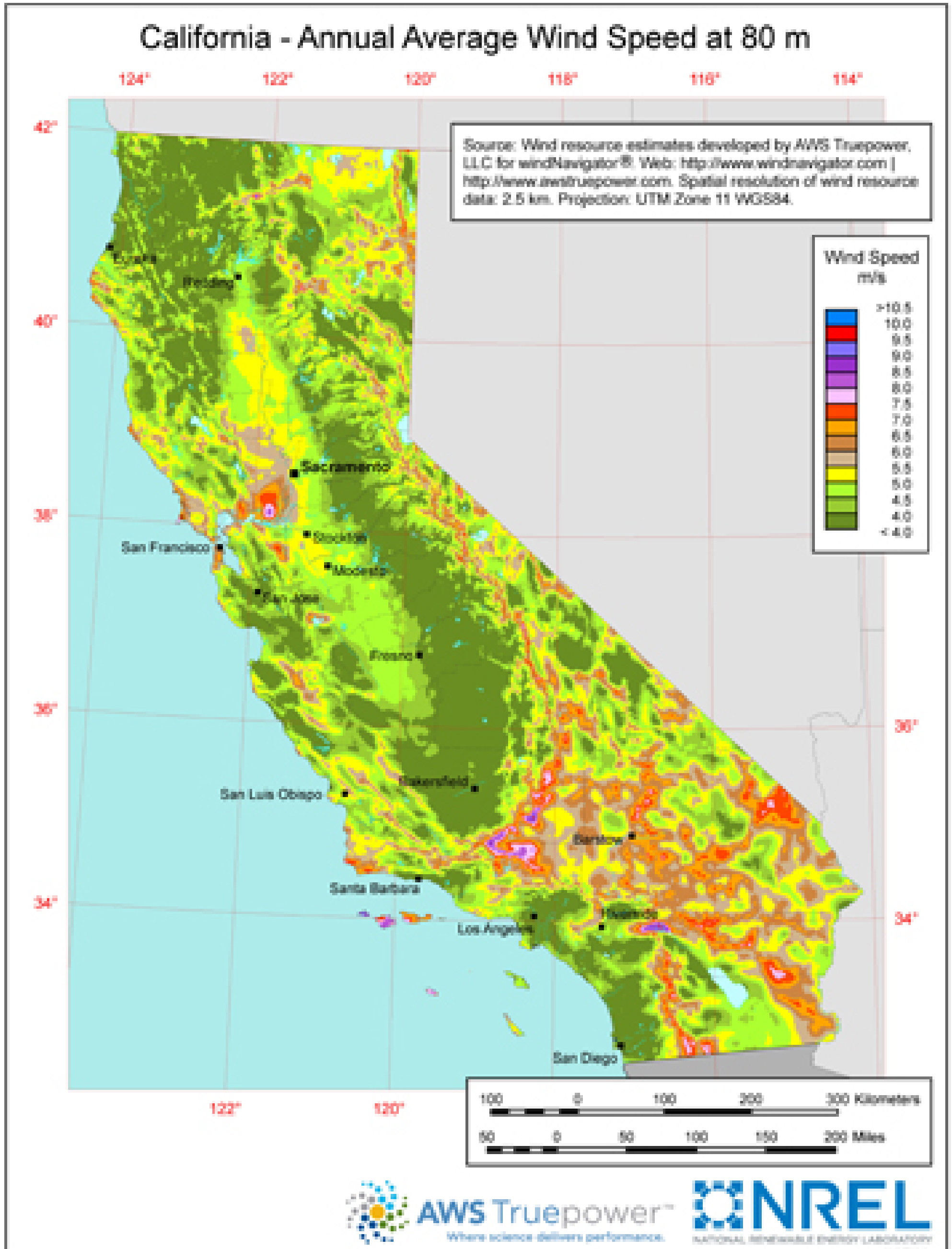
In 2013 U.S. average electrical power generation was 410 GW.

U.S. on-shore wind resource map



m/s	mph
8.0	17.8
7.0	15.7
6.0	13.4
5.0	11.2

m/s	mph
8.0	17.8
7.0	15.7
6.0	13.4
5.0	11.2



U.S. off-shore wind resource map

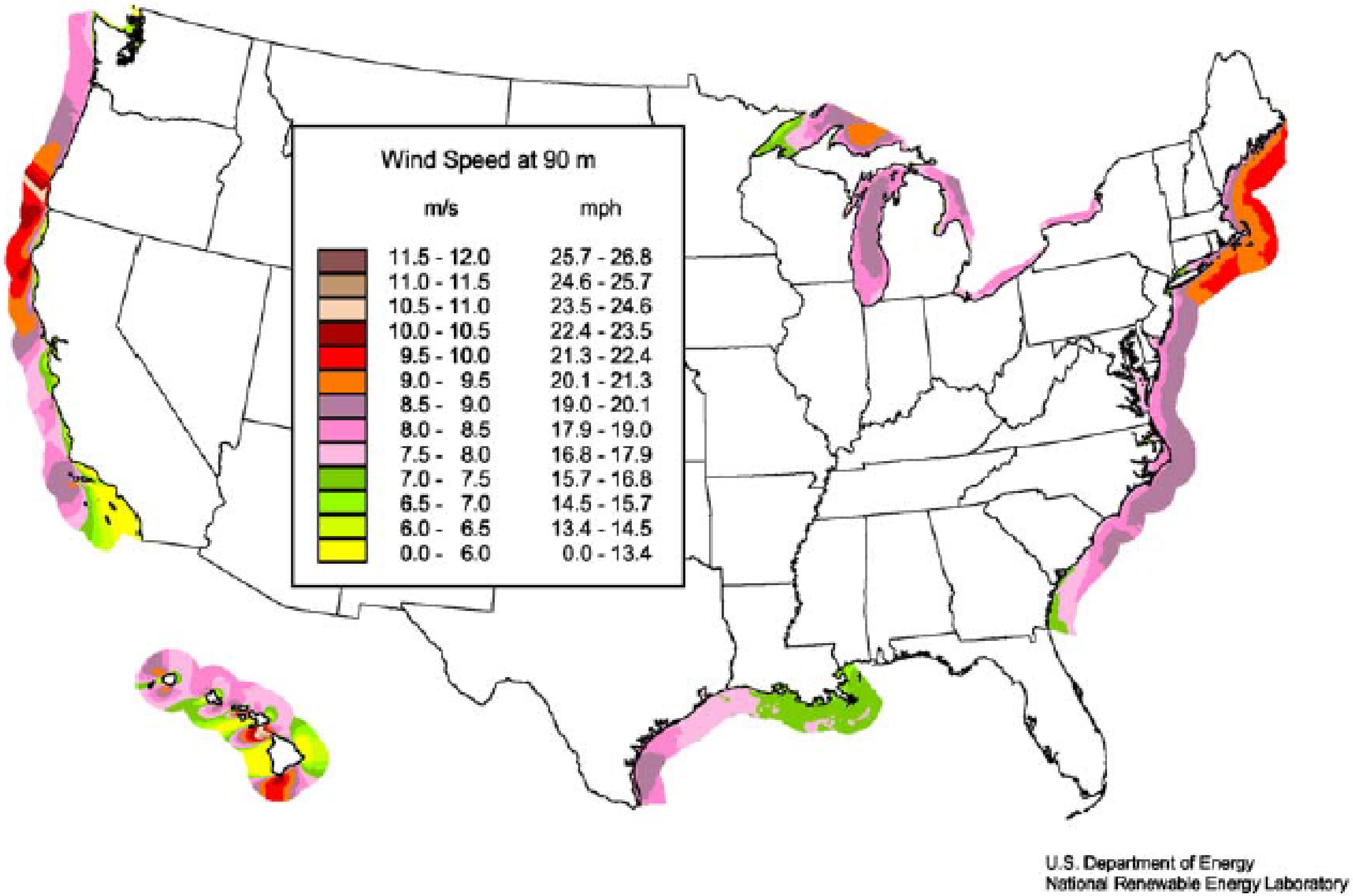
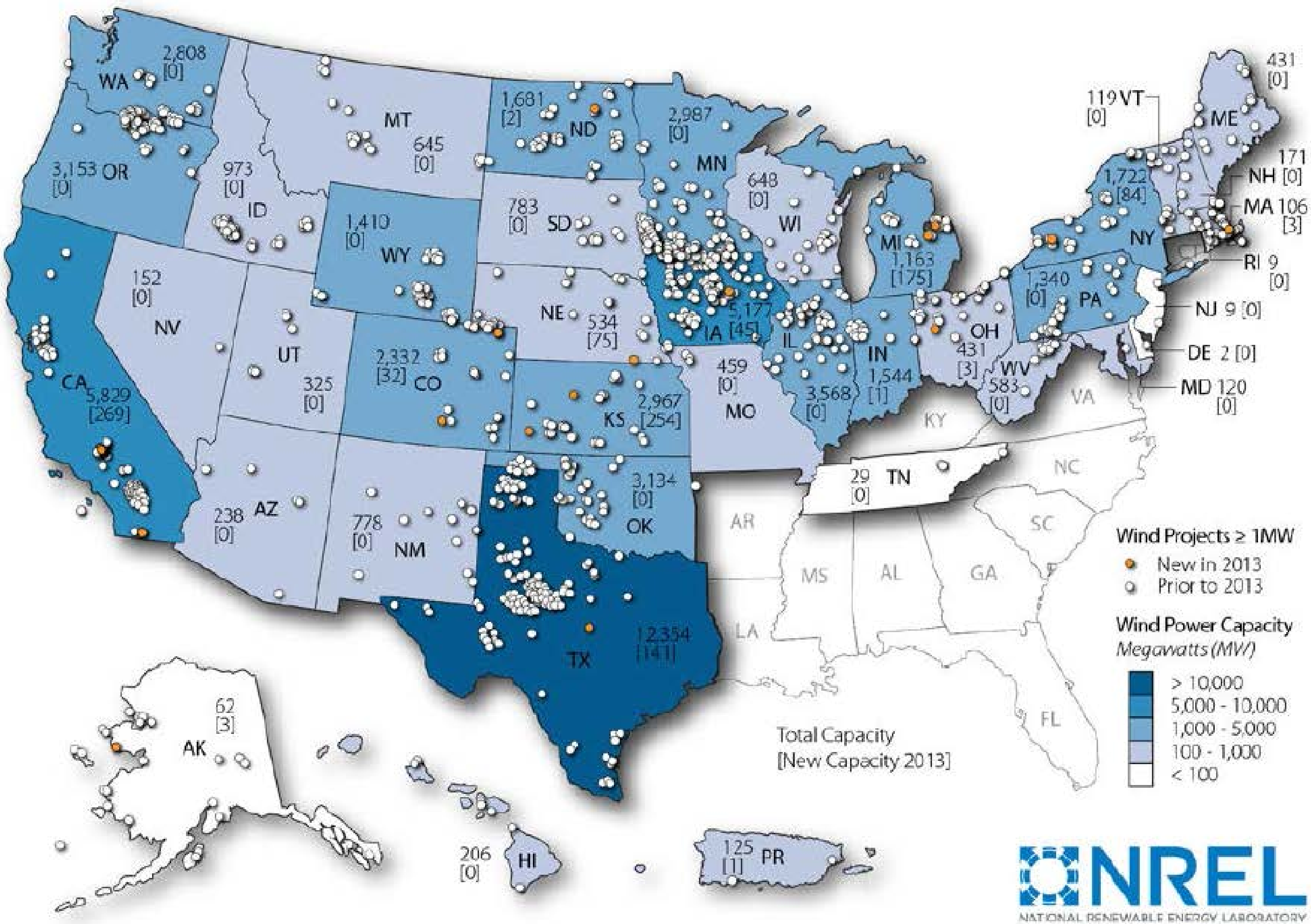


Figure 2. U.S. offshore wind speed estimates at 90-m height

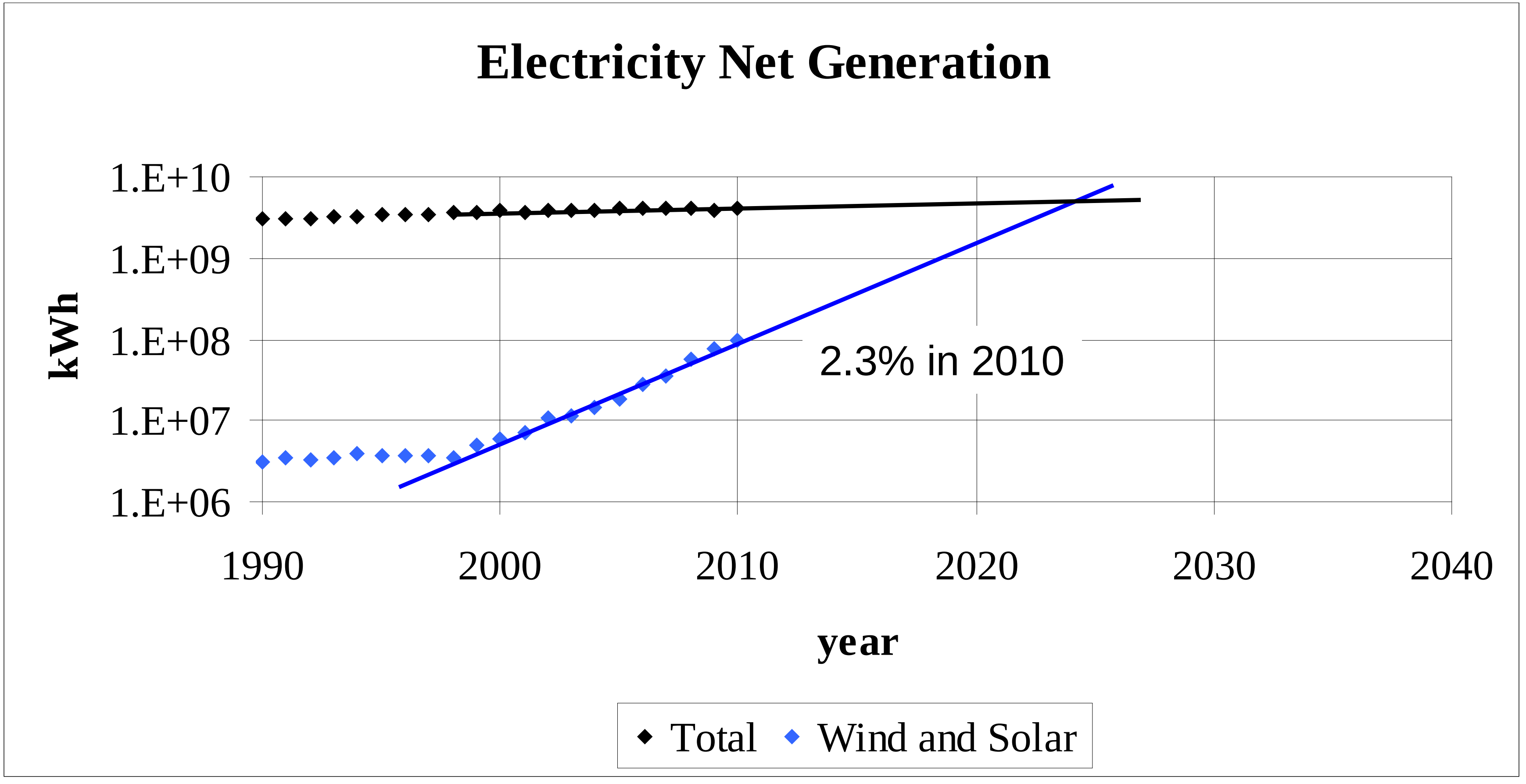
From DOE National Offshore Wind Strategy February 2011

U.S. Wind Power in 2013



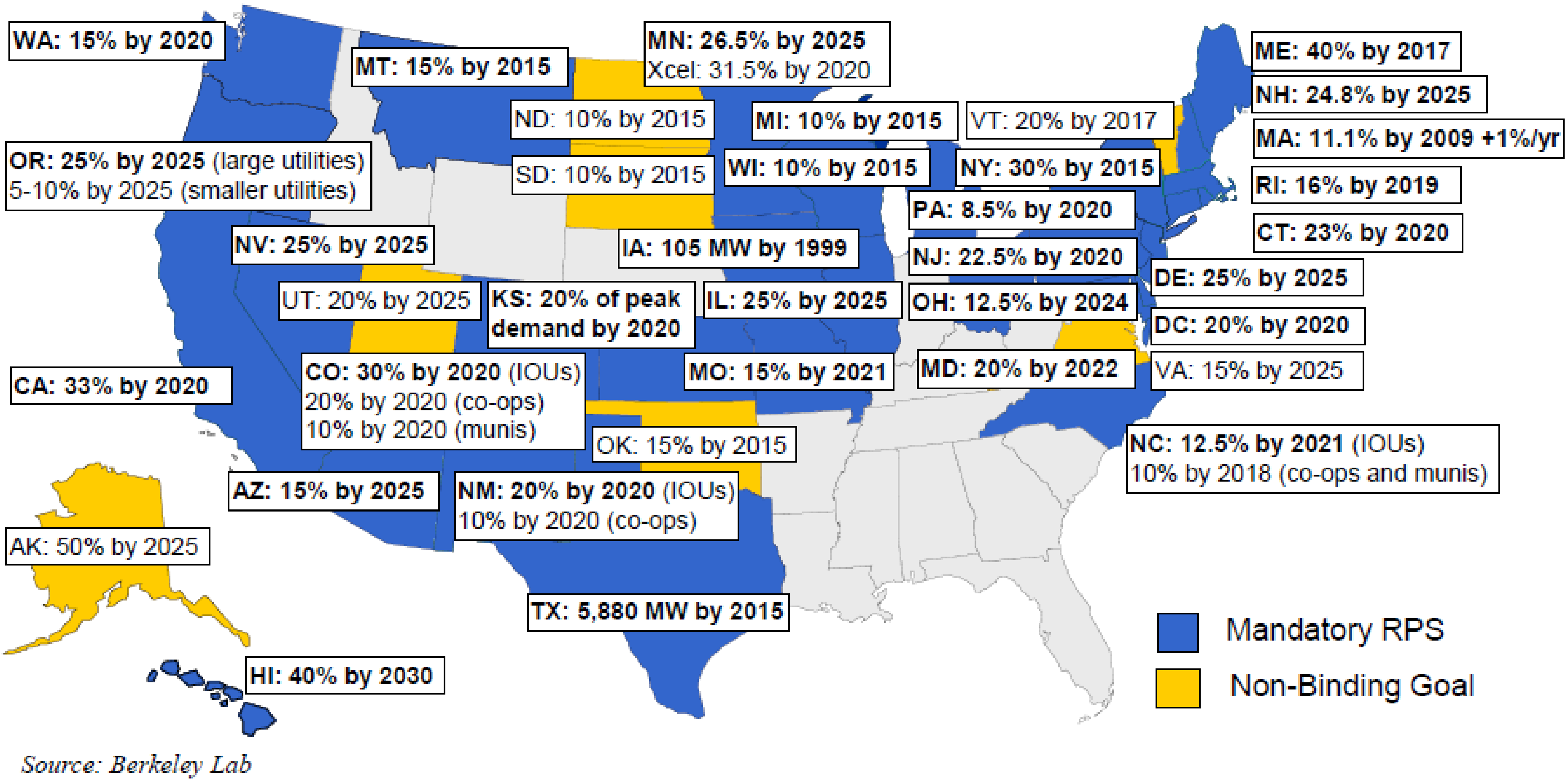
From DOE EERE 2013 Wind Technologies Market Report (August, 2014)

U.S. Source of Electric Generation 1950-2010



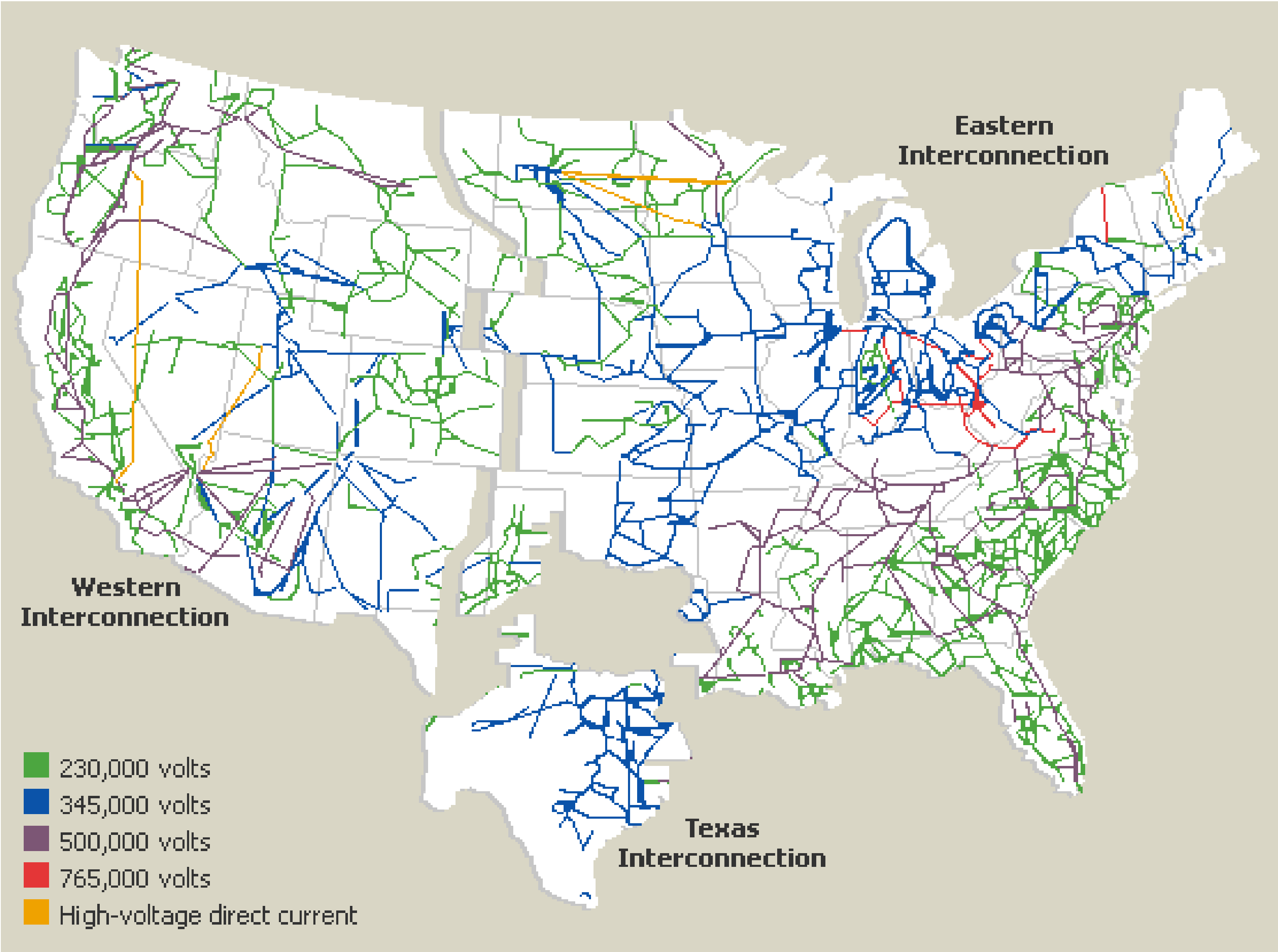
from DOE EIA Annual Energy Outlook 2011, Table 8.2a

State RPS Policies and Non-Binding Renewable Energy Goals



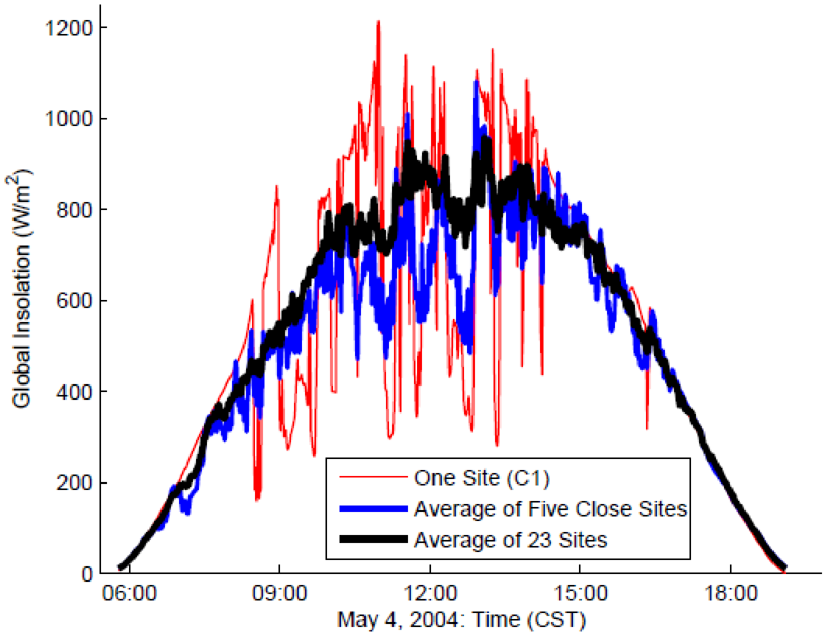
From DOE EERE 2013 Wind Technologies Market Report (August, 2014)

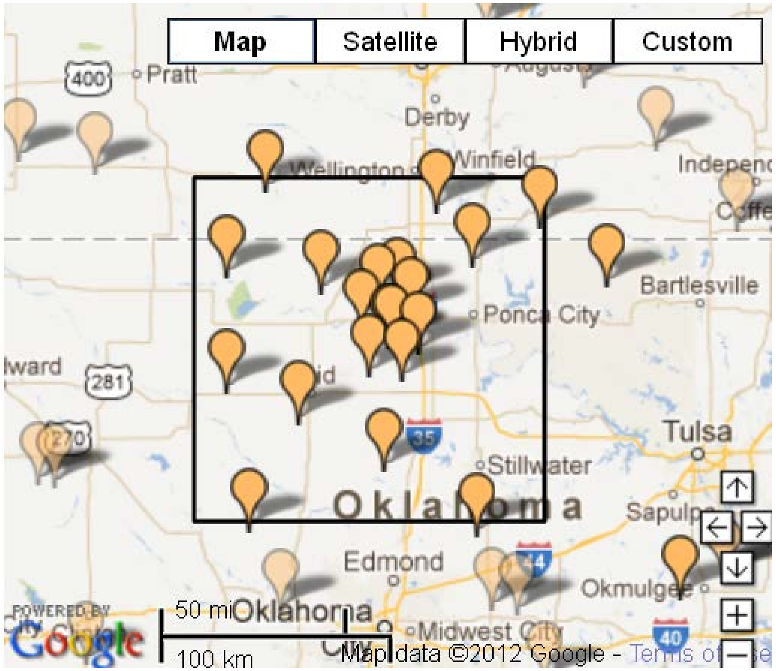
Existing High Voltage Transmission



Variability and Intermittency

Example of Solar Insolation Variability and Wide Area Aggregation

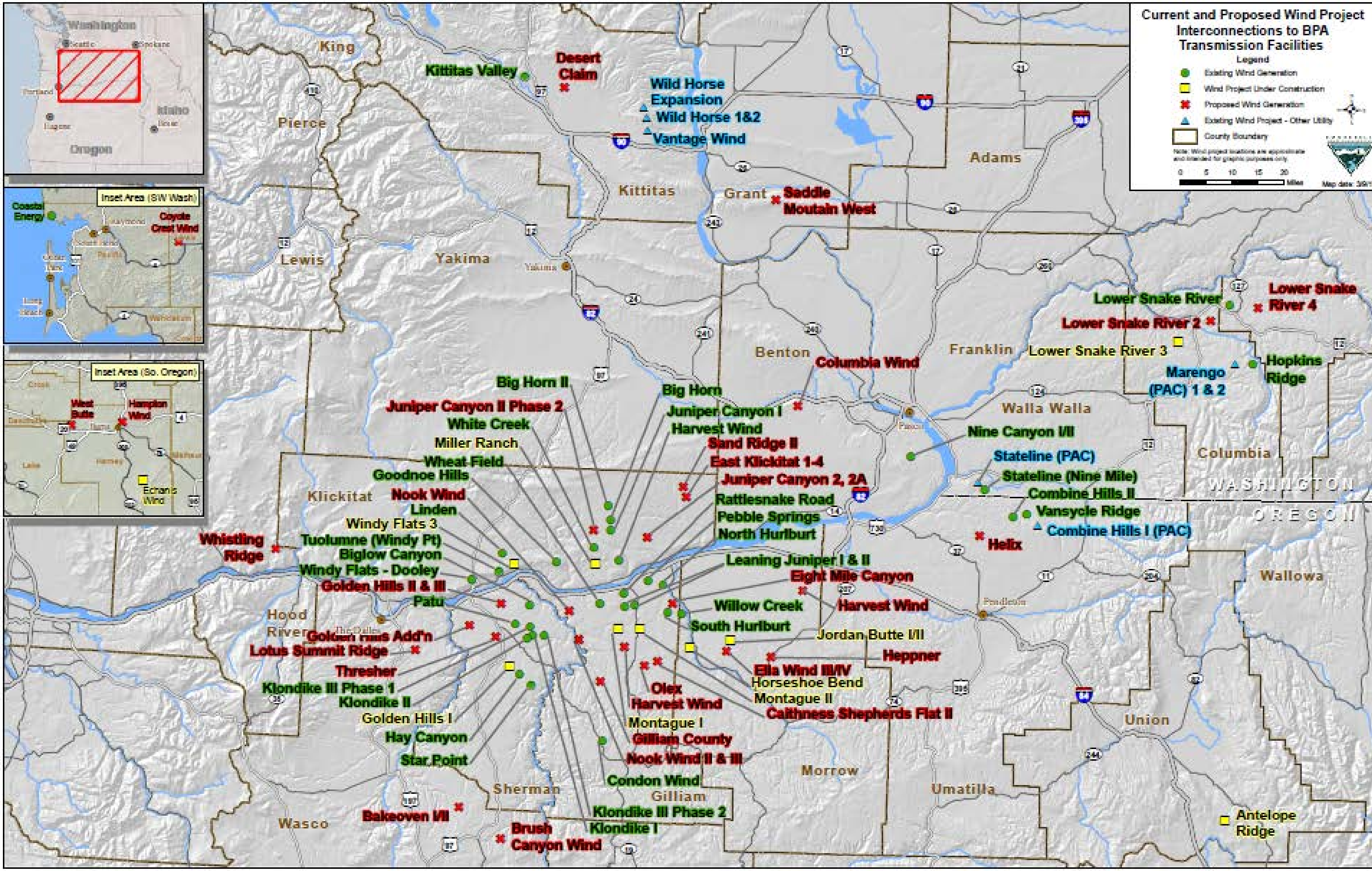


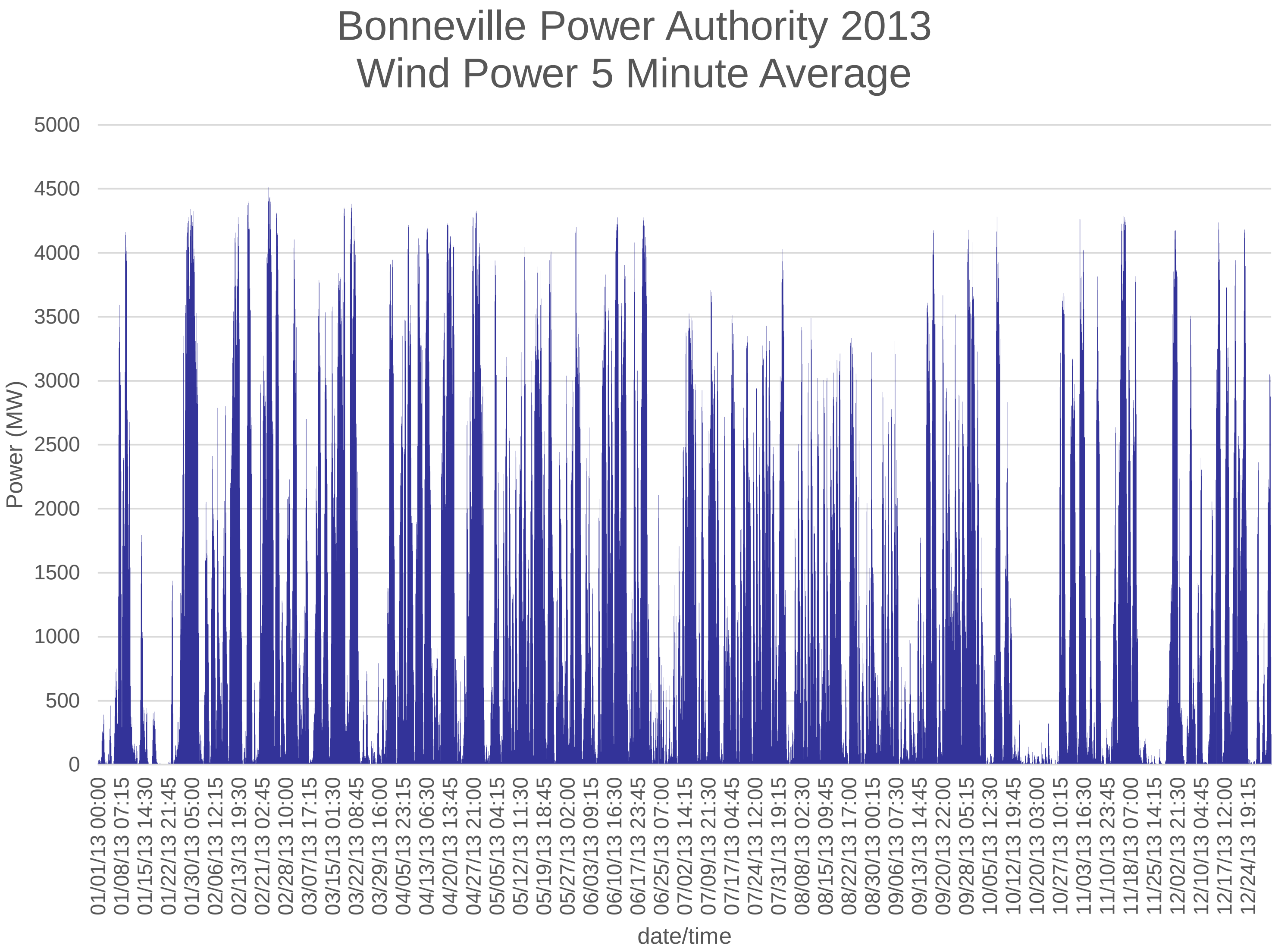


NB: No solar power before 6 AM and after 7 PM on May 4, 2004.

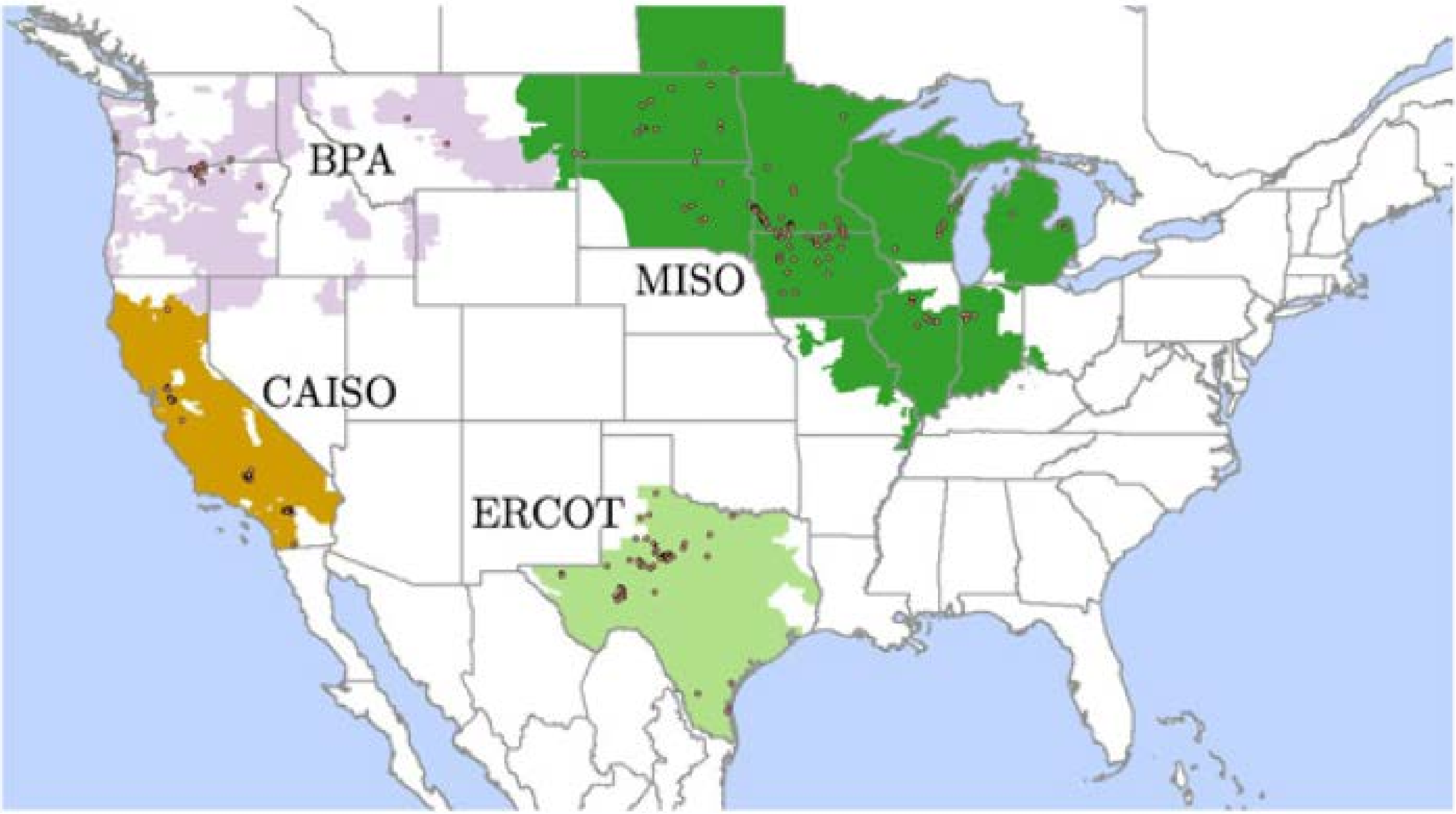
DOE Atmospheric Radiation Measurement at Southern Great Plains site

Bonneville Power Authority Wind Projects



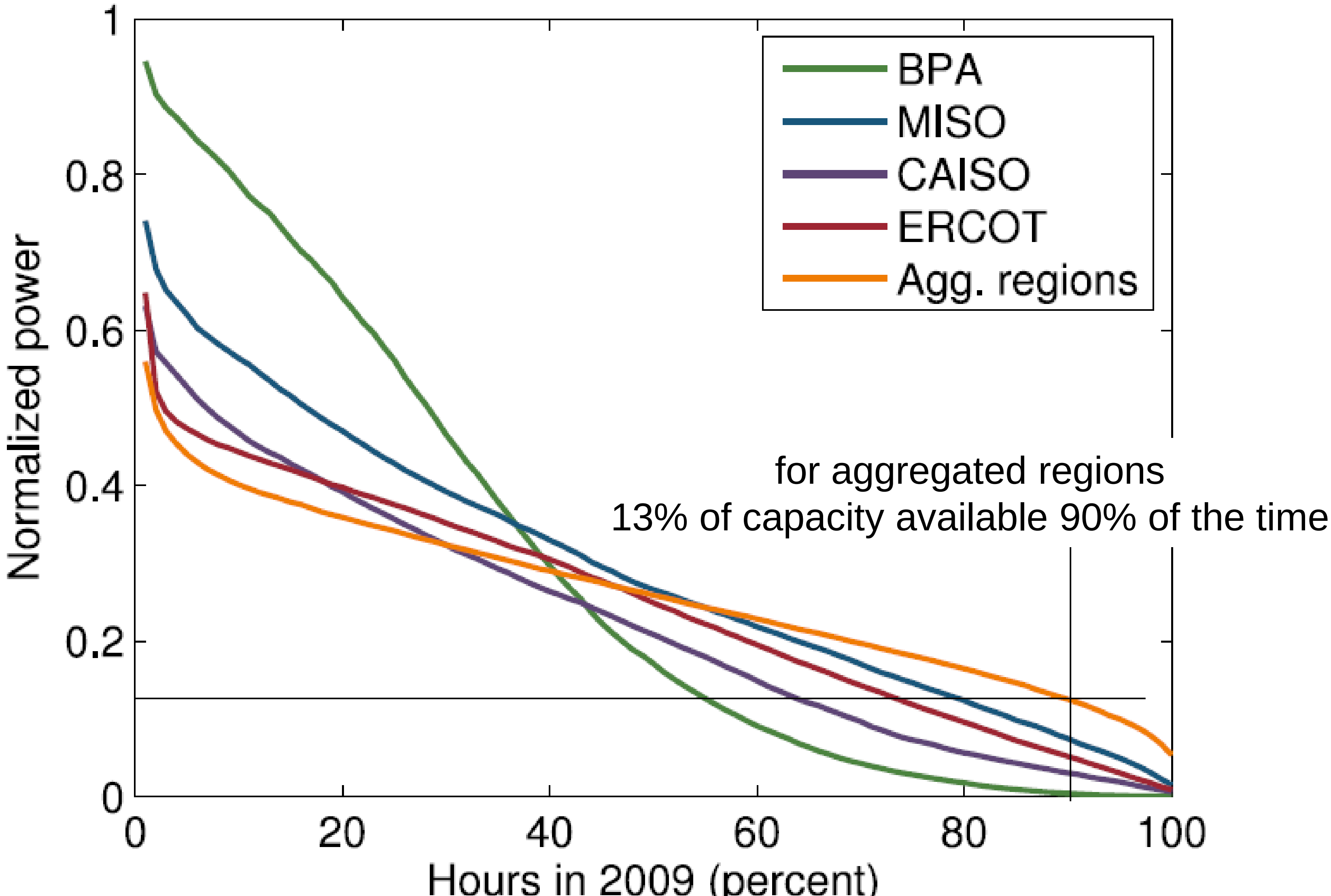

Bonneville Power Authority 2013
Wind Power 5 Minute Average
Power (MW)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
01/01/13 00:00
01/08/13 07:15
01/15/13 14:30
01/22/13 21:45
01/30/13 05:00
02/06/13 12:15
02/13/13 19:30
02/21/13 02:45
02/28/13 10:00
03/07/13 17:15
03/15/13 01:30
03/22/13 08:45
03/29/13 16:00
04/05/13 23:15
04/13/13 06:30
04/20/13 13:45
04/27/13 21:00
05/05/13 04:15
05/12/13 11:30
05/19/13 18:45
05/27/13 02:00
06/03/13 09:15
06/10/13 16:30
06/17/13 23:45
06/25/13 07:00
07/02/13 14:15
07/09/13 21:30
07/17/13 04:45
07/24/13 12:00
07/31/13 19:15
08/08/13 02:30
08/15/13 09:45
08/22/13 17:00
08/30/13 00:15
09/06/13 07:30
09/13/13 14:45
09/20/13 22:00
09/28/13 05:15
10/05/13 12:30
10/12/13 19:45
10/20/13 03:00
10/27/13 10:15
11/03/13 16:30
11/10/13 23:45
11/18/13 07:00
11/25/13 14:15
12/02/13 21:30
12/10/13 04:45
12/17/13 12:00
12/24/13 19:15
date/time

Wind Power Interconnection Regions Study



Red dots indicate existing wind farms

2009 Wind Power Duration Curve (one hour resolution)



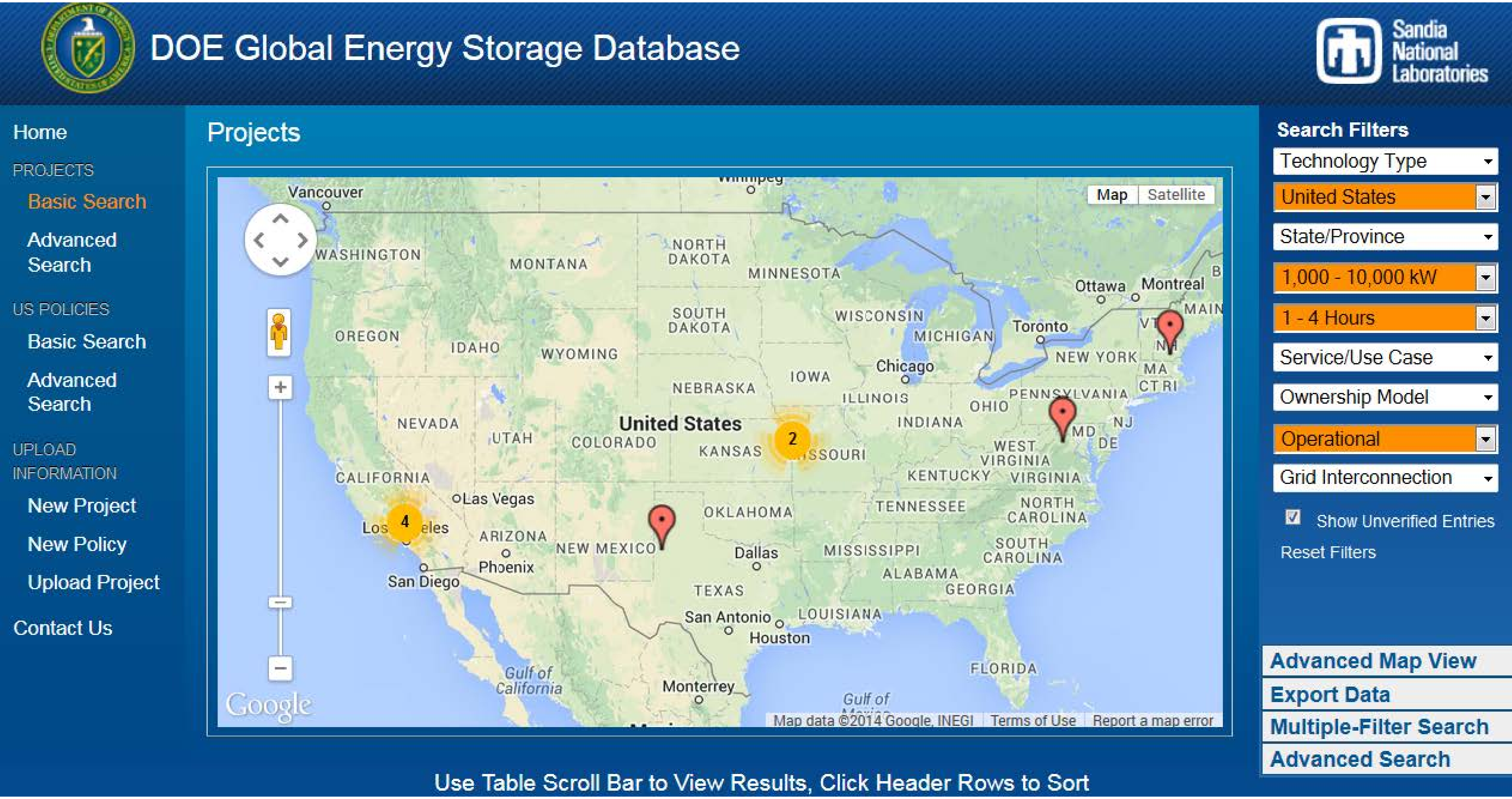
ENERGY ISSUES EXAMPLE

Energy Storage

Motivation for Energy Storage

- Energy demand varies on many time scales – daily, weekly, seasonally
- Energy supply, especially solar and wind, also varies on various time scales
- Energy storage decouples supply and demand
- Energy storage provides peak capacity without additional equipment

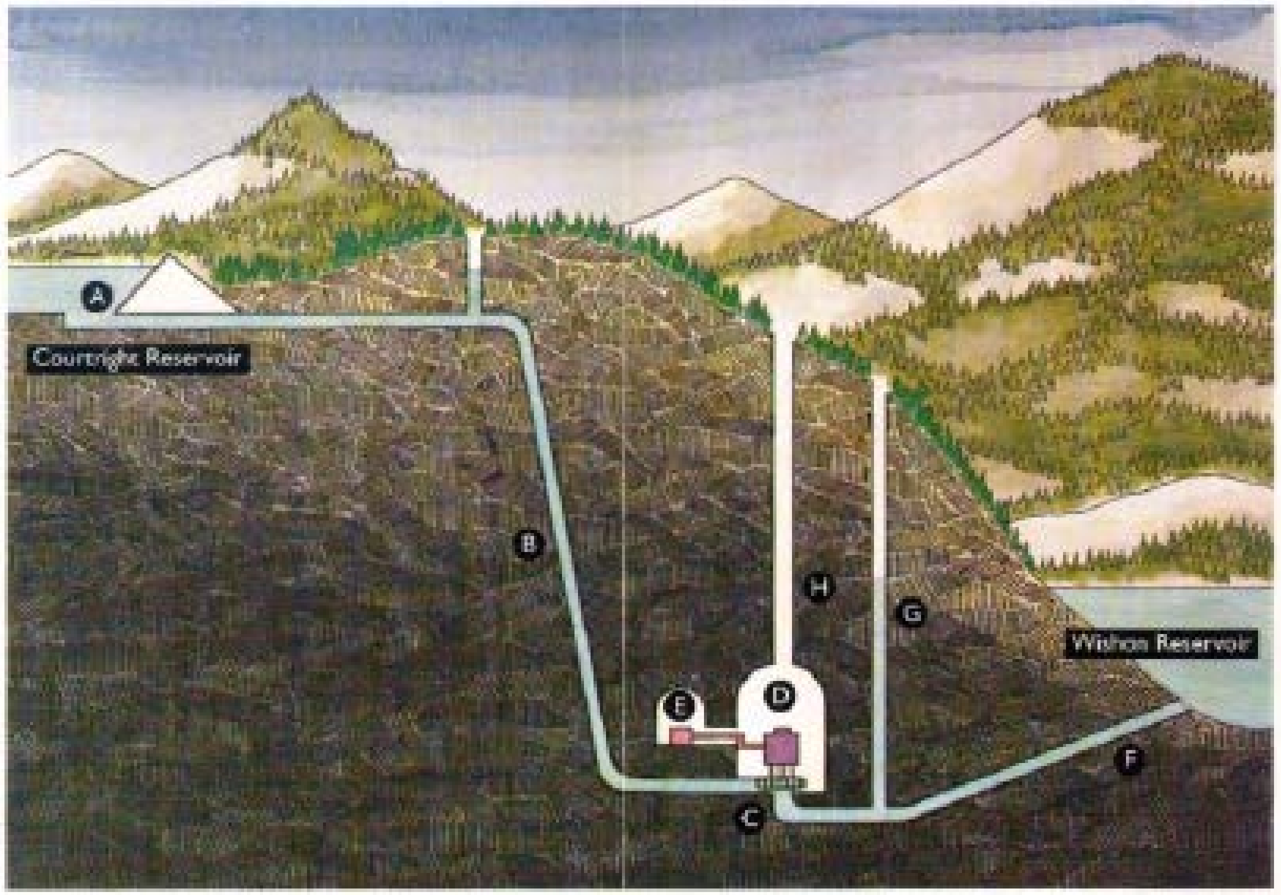
DOE Global Energy Storage Database
U.S. Operational Storage
1 – 4 Hours and 1 – 10 MW



U.S. Storage Statistics

- total storage = 28.4 GW (operational and planned)
- total generation capacity (2011) 1,051 GW
- storage / total = 2.7%
- fossil / total = 74.6%
- hydro + nuclear / total = 19.5%
- non-hydro renewables / total = 5.9 %

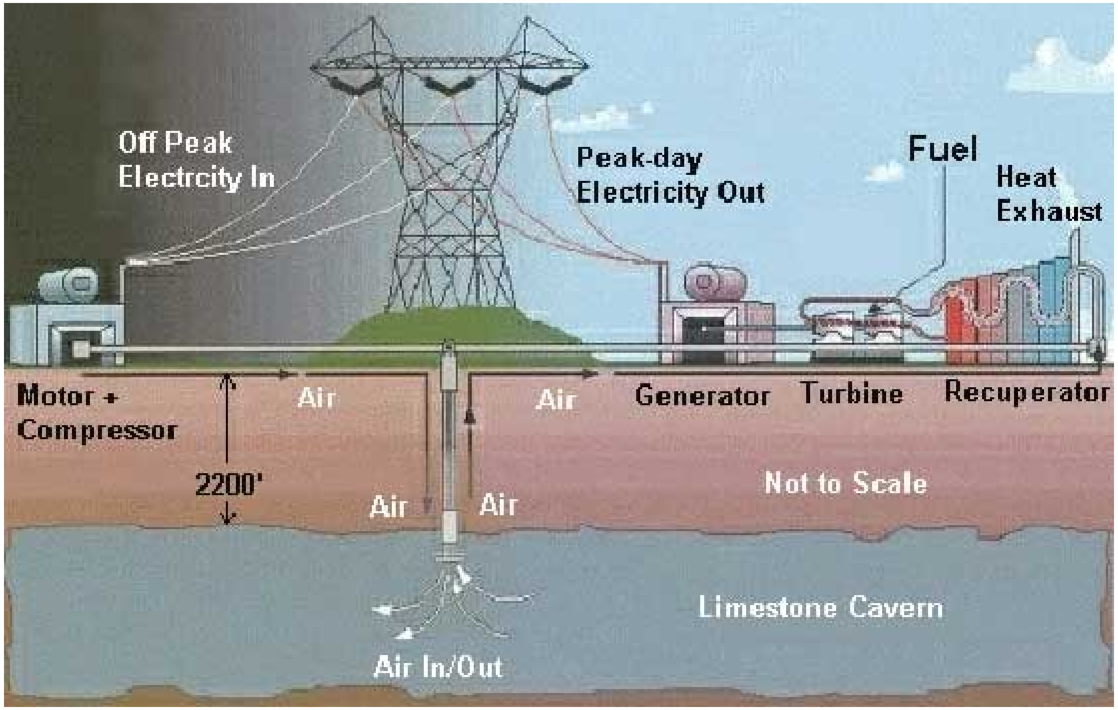
Pacific Gas and Electric Company
Helms Pumped Hydro Storage Plant



A-Courtright, B-Supply Tunnel, C-Turbine, D-Generator, E-Transformer, F-Wishon, G-Surge Chamber, H-Elevator

From Manho Yeung, Pacific Gas and Electric Company

Compressed Air Energy Storage



PowerSouth McIntosh, Alabama110 MW CAES facility.

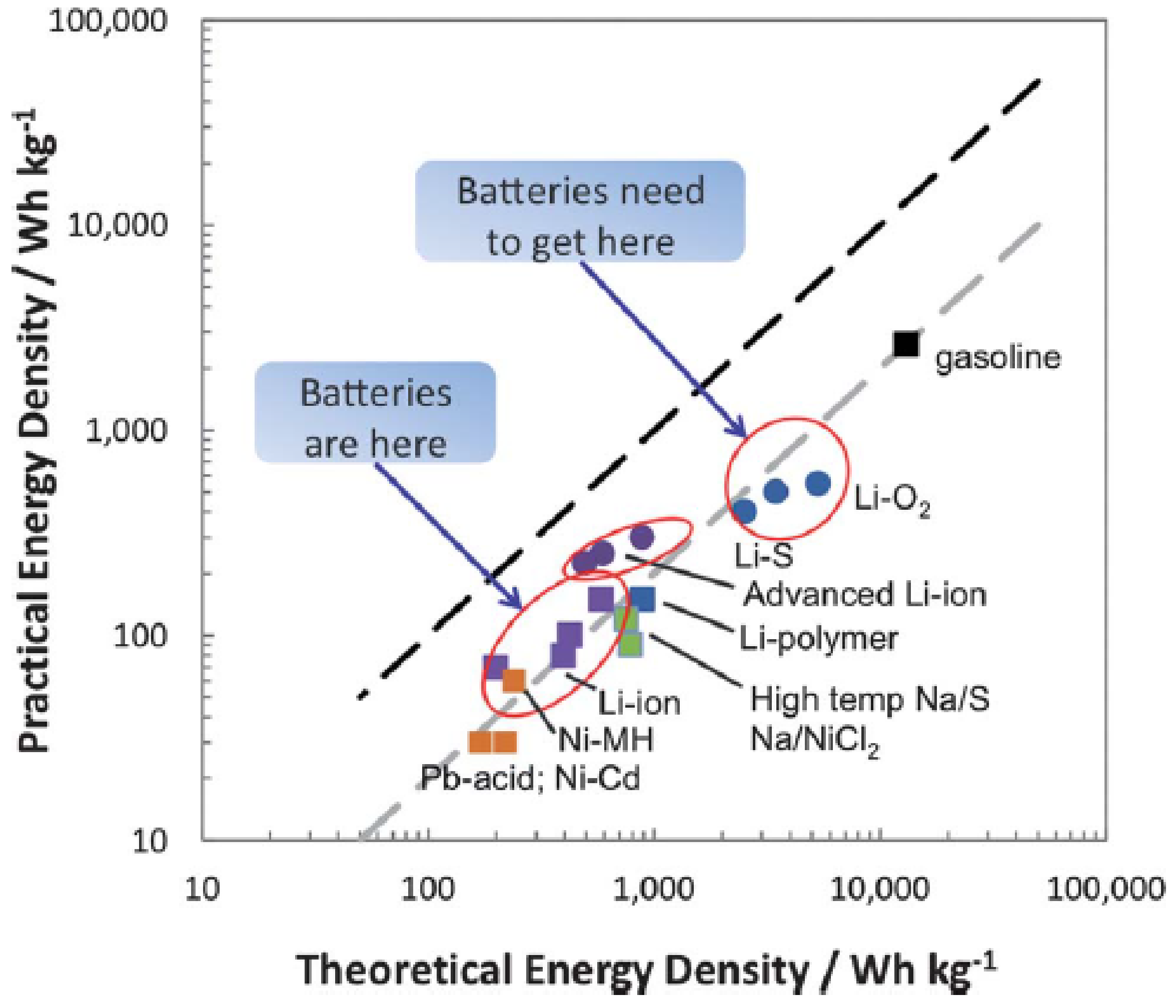
Required Storage Volume to Generate 300 MW (12 Hours Pumping, 12 Hours Generation)

0.28 million m³ of Compressed Air

7 million m³ of Water

From Dr. Chris Bullough ALSTOM Power Technology Centre

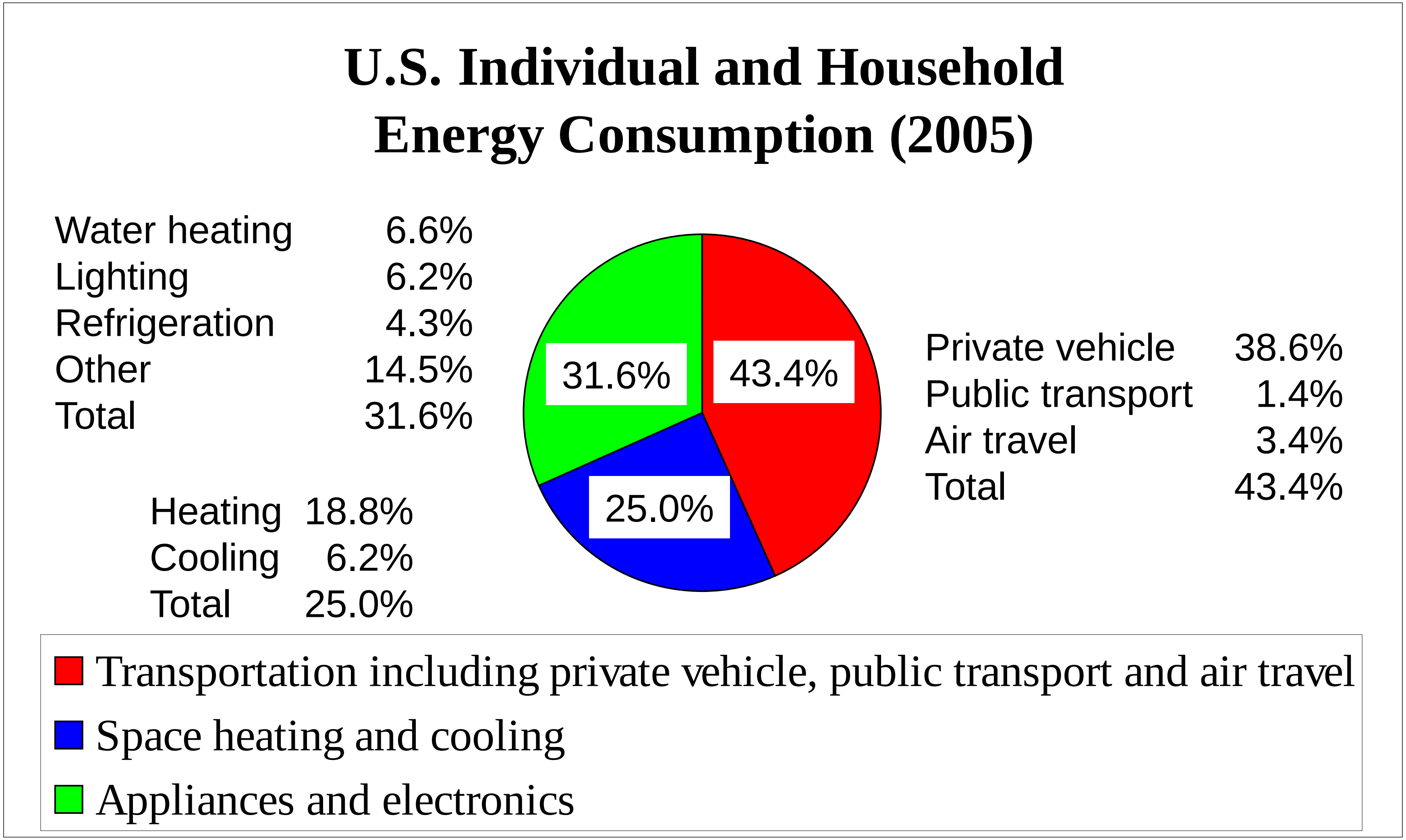
Battery Energy Density



From Thackeray et al., Energy Environ. Sci. 5(2012)7854

ENERGY ISSUES EXAMPLE

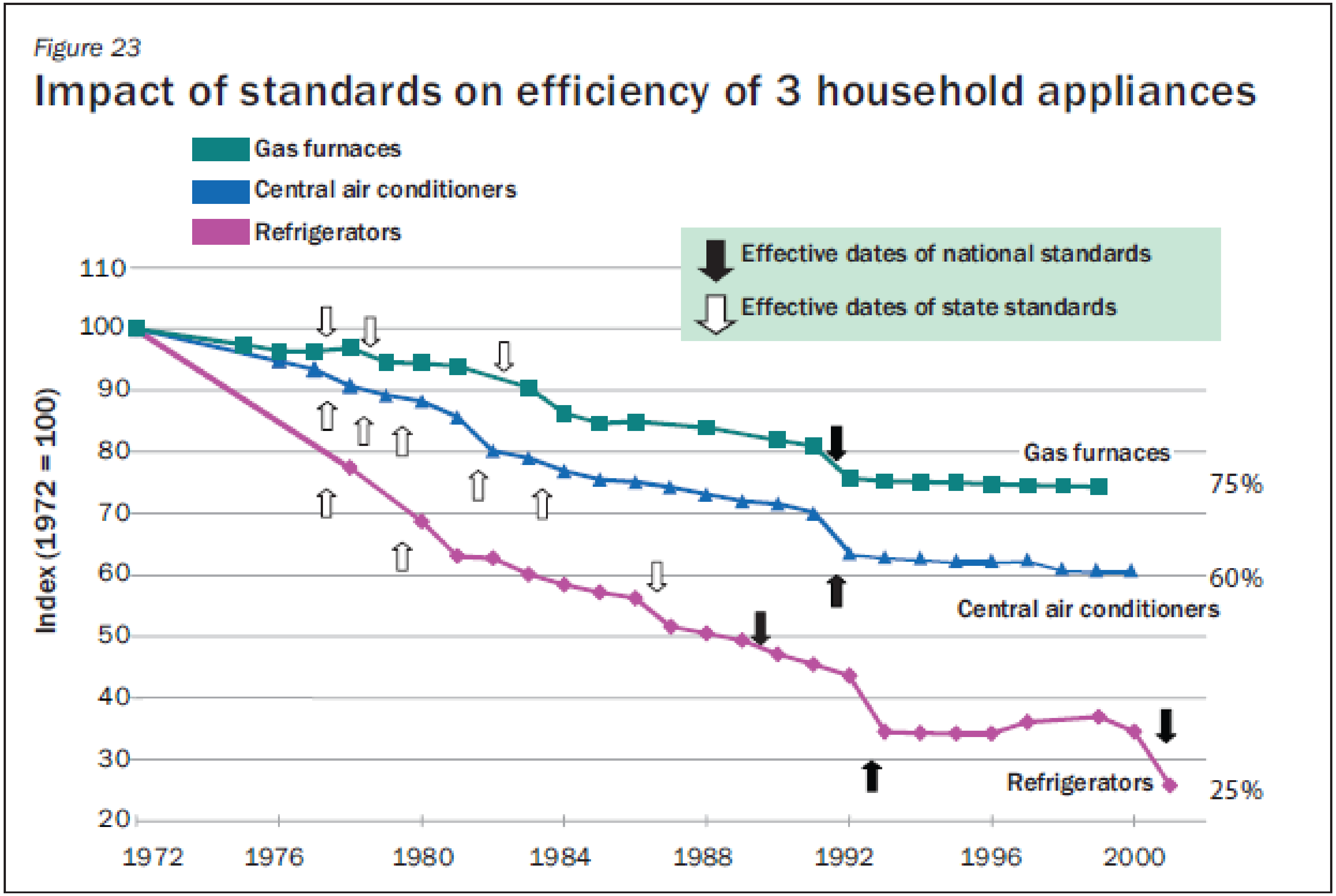
Efficiency and Conservation



Individual and household energy consumption is 38.0% of U.S. total energy consumption.

From G. T. Gardner and P. C. Stern, Environment, December 2009, Table 1.

Efficiency Successes in Appliances



Source: A. Rosenfeld, California Energy Commission; S. Nadel, ACEEE, in ECEEE 2003 Summer Study, www.eceee.org

Efficiency in Lighting

from http://www.energysavers.gov/images/lumens_education_mallposter.jpg

100 W Light Bulb Equivalent

- Incandescent – 100 W
- Halogen – 50 W
- Compact fluorescent – 26 W
- LED – 13 W

Suppose all 112 million U.S. households replaced one 100 W incandescent light bulb with an LED light bulb. At four hours per day usage, a savings of 14 TWh per year would be obtained, compared to total electricity usage of 4,100 TWh per year. One light bulb change is 0.3% effect.

Efficiency in Insulation

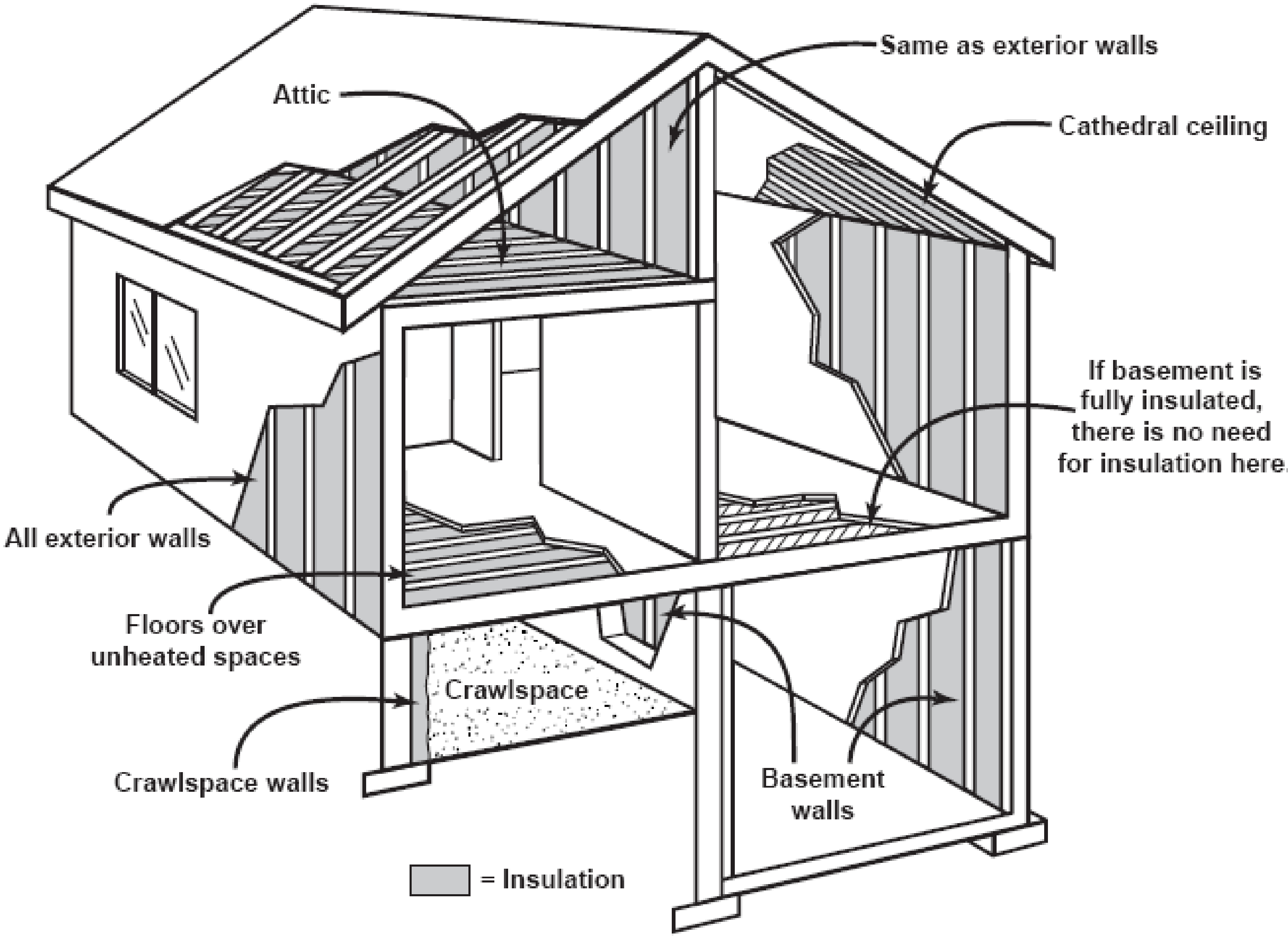


Figure 1. Places in the home where insulation should be applied

Which Little Piggy Insulated Best?

TABLE 11.1. R-Values of building materials

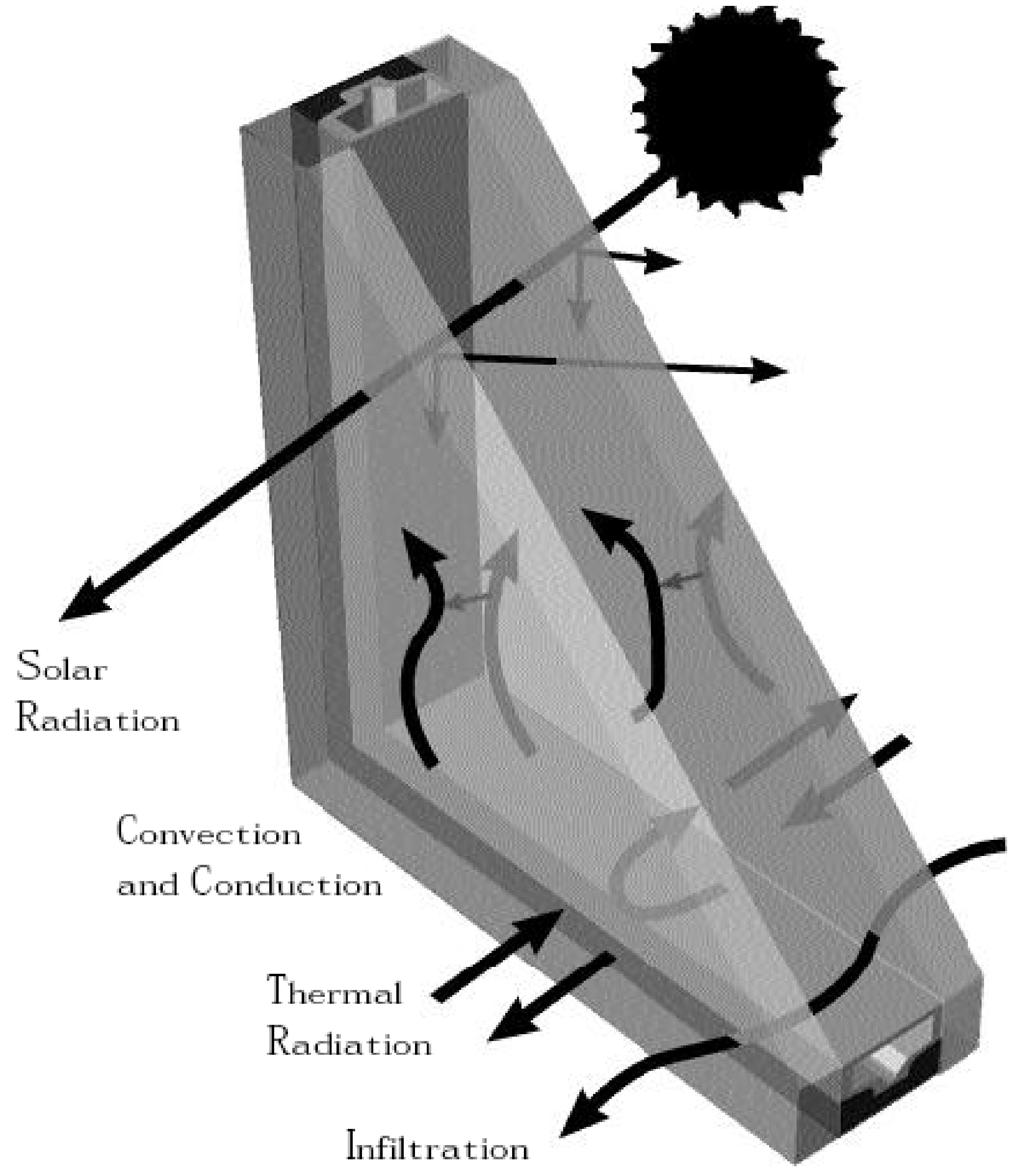
	R_{Eng}
Wood siding shingles	0.9
Stucco, 1 cm	0.1
Plywood, 1 cm	0.5
Softwood, 1 cm	0.5
Concrete block, 30 cm (12″)	1.3
Brick/cm	0.1
Gypsumboard, 1 cm	0.3
Hardwood floor, 1 cm	0.3
Carpet	0.6
Asphalt roof shingles	0.5
Wood roof shingles	1.0
Insulation, 10 cm (4″)	13
Insulation, 15 cm (6″)	19
Polystyrene, 1 cm	2.0
Polyurethane, 1 cm	2.5
Gas-filled panels, 2.5 cm (1″)	14
Gas-filled panels, 10 cm (4″)	28–56
Straw bale, 40 cm (16″)	33–50
Glass, 3 mm (0.12″)	0.03
Convection	0.2–1
Radiation	1ε

0.5 for 1 cm

0.1 for 1 cm

1.0 for 1 cm

Efficiency in Windows



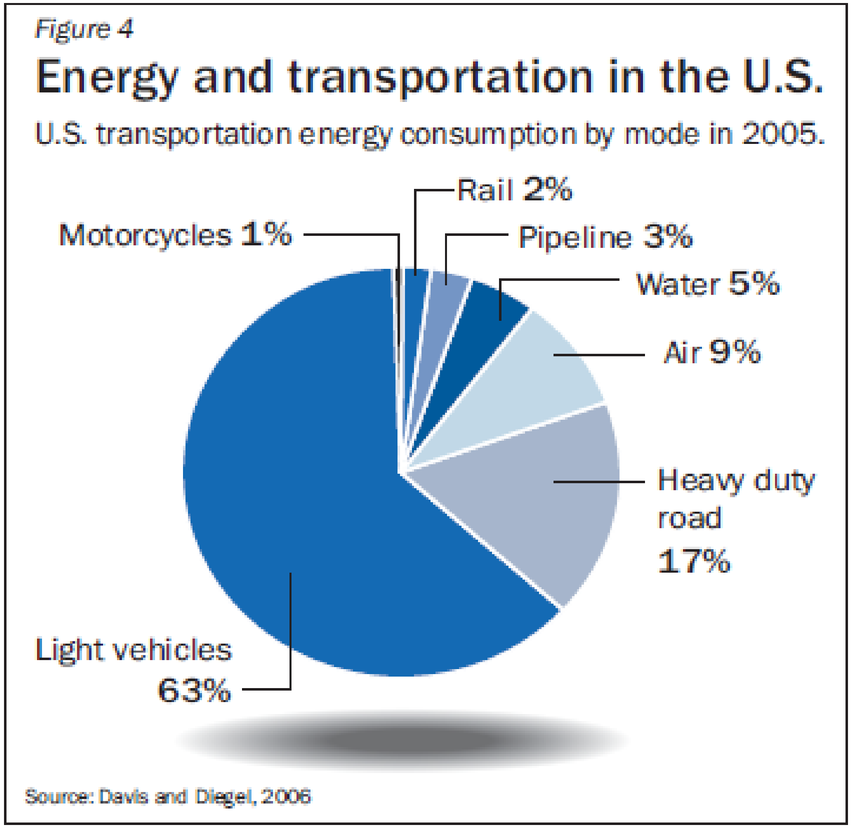
Ideal Window from Energy Efficiency Point of View

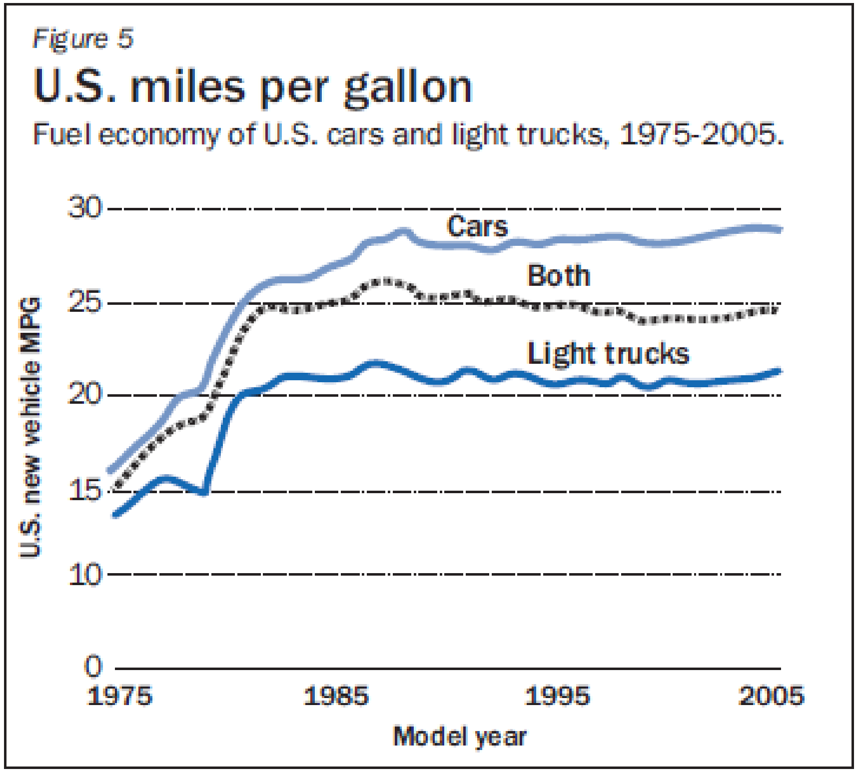
From Stephen Selkowitz APS Conference, Berkeley, March 2008

ENERGY ISSUES EXAMPLE

Transportation

U.S. Transportation Sector

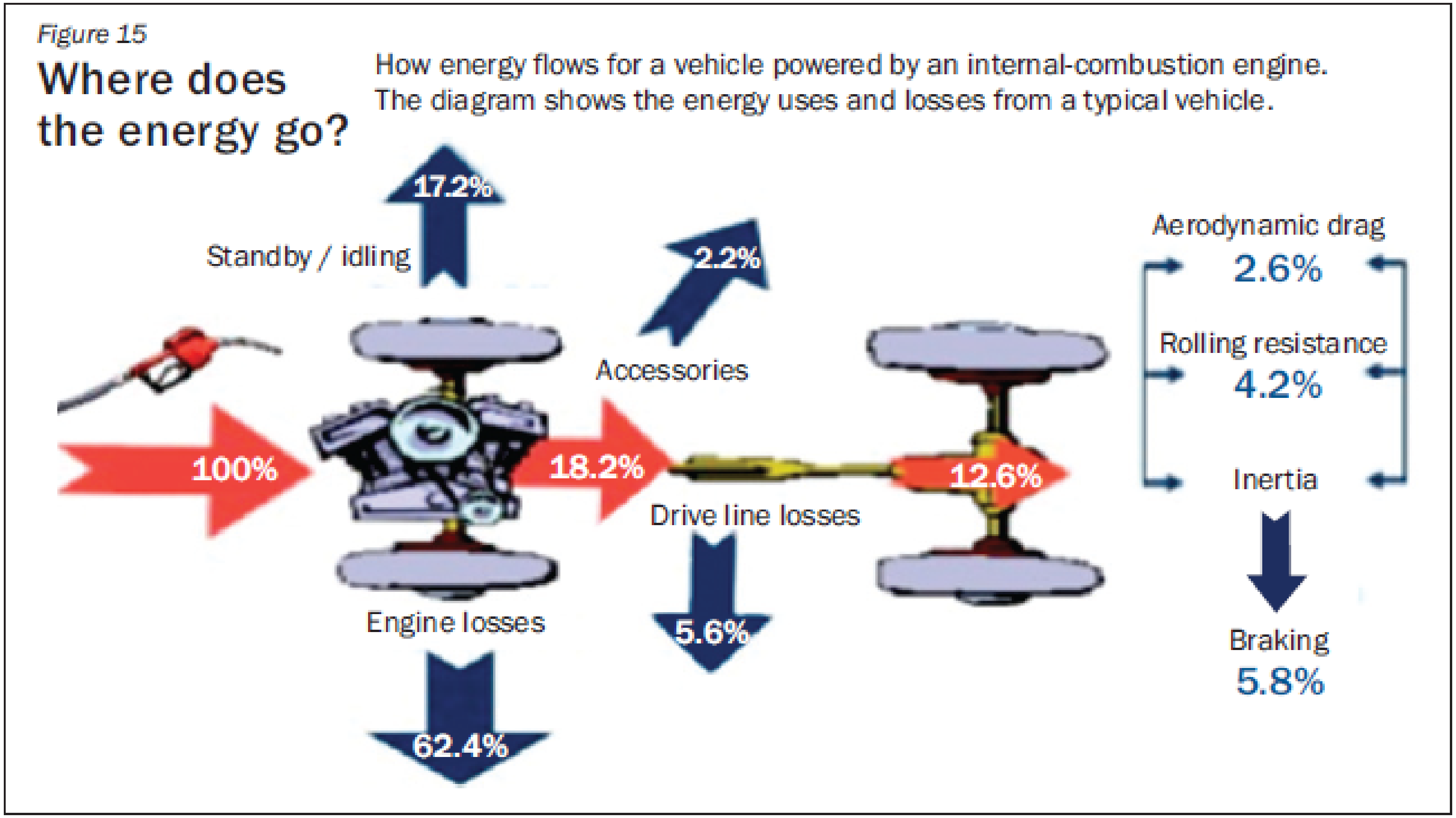




Sources: U.S. Environmental Protection Agency, National Highway Traffic Safety Administration

From APS Energy Future Think Efficiency (September, 2008)

Where Does The Energy Go?



Source: www.fueleconomy.gov

Largest losses are in the engine.

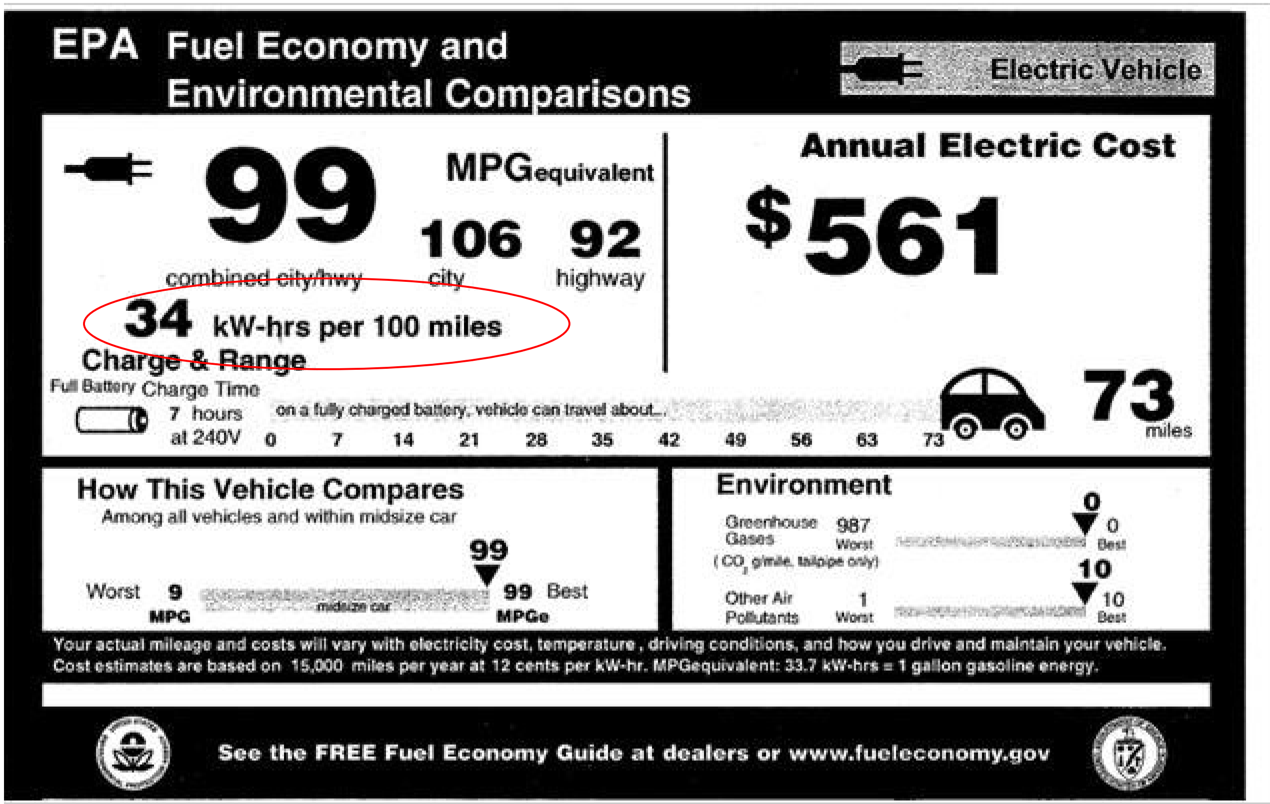
From APS Energy Future Think Efficiency (September, 2008)

Energy Storage for EV

• lead acid	0.34 MJ/l	(0.17 MJ/kg)
• NiMH	0.79 MJ/l	(0.29 MJ/kg)
• lithium ion	1.8 MJ/l	(0.80 MJ/kg)
• gasoline	36 MJ/l	(46 MJ/kg)

Nissan Leaf
Electric Vehicle (EV)

Nissan Leaf Monroney Sticker



Compare EV to CV

$$MPGe_{fuel-to-wheel} = \left[\frac{miles}{Wh}\right] \times U_{gasoline} \times \varepsilon_{electricity}$$

$$= \left(\frac{100\,miles}{34\,kWh} \times \frac{33.7\,kWh}{gal}\right) \times 0.303$$

$$= 99\,mpg \times 0.303 = 30\ mpg \quad \text{(EV)}$$

$$MPGe_{fuel-to-wheel} = MPGe_{tank-to-wheel} \times \varepsilon_{gasoline}$$

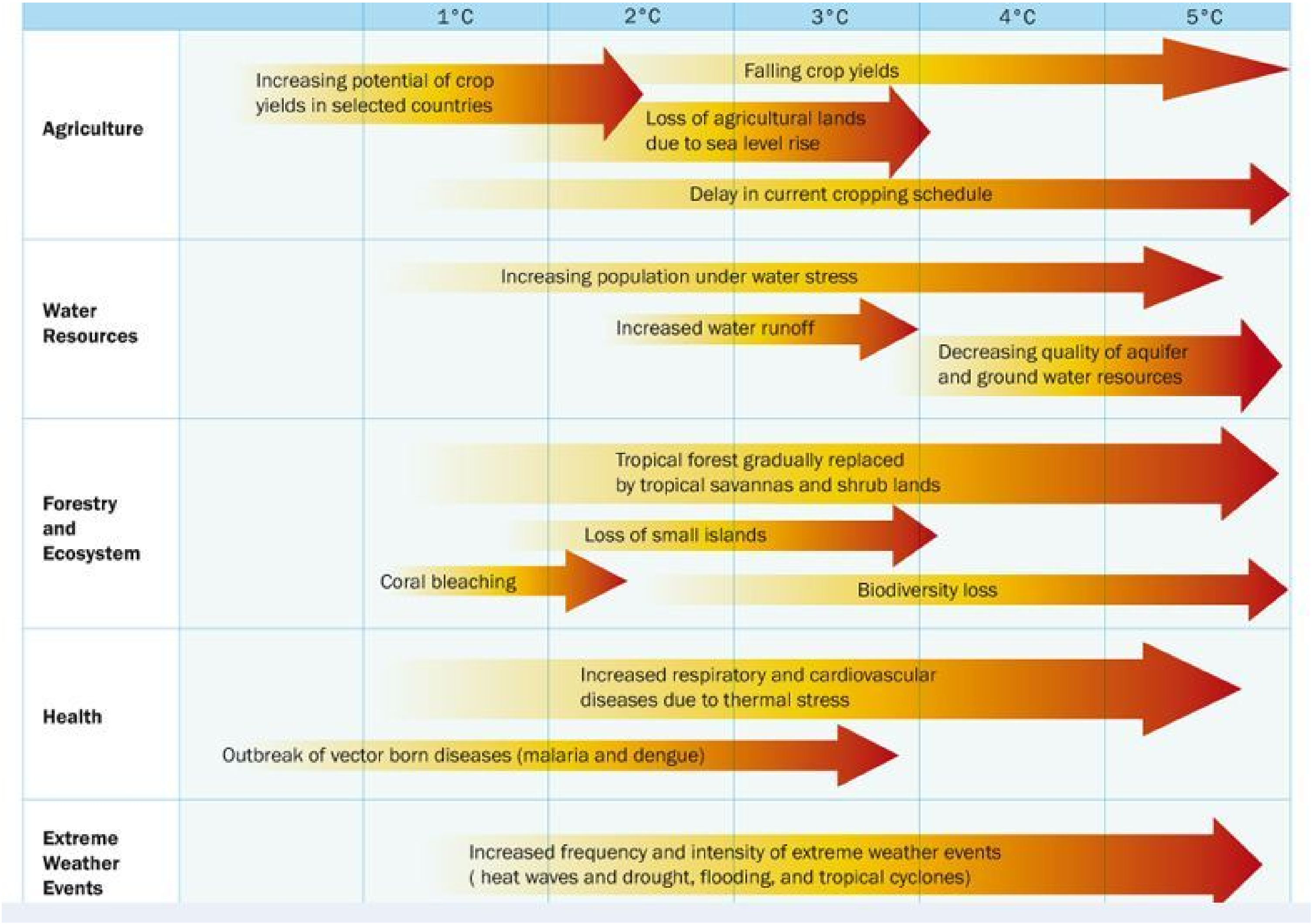
$$= 30\,mpg \times 0.830 = 25\,mpg \quad \text{(CV)}$$

ABOUT TEN TAKE-AWAY THOUGHTS FROM UNDERSTANDING THE ENERGY CHALLENGE

The gift and curse of fossil fuels can be and will be with us for many decades.

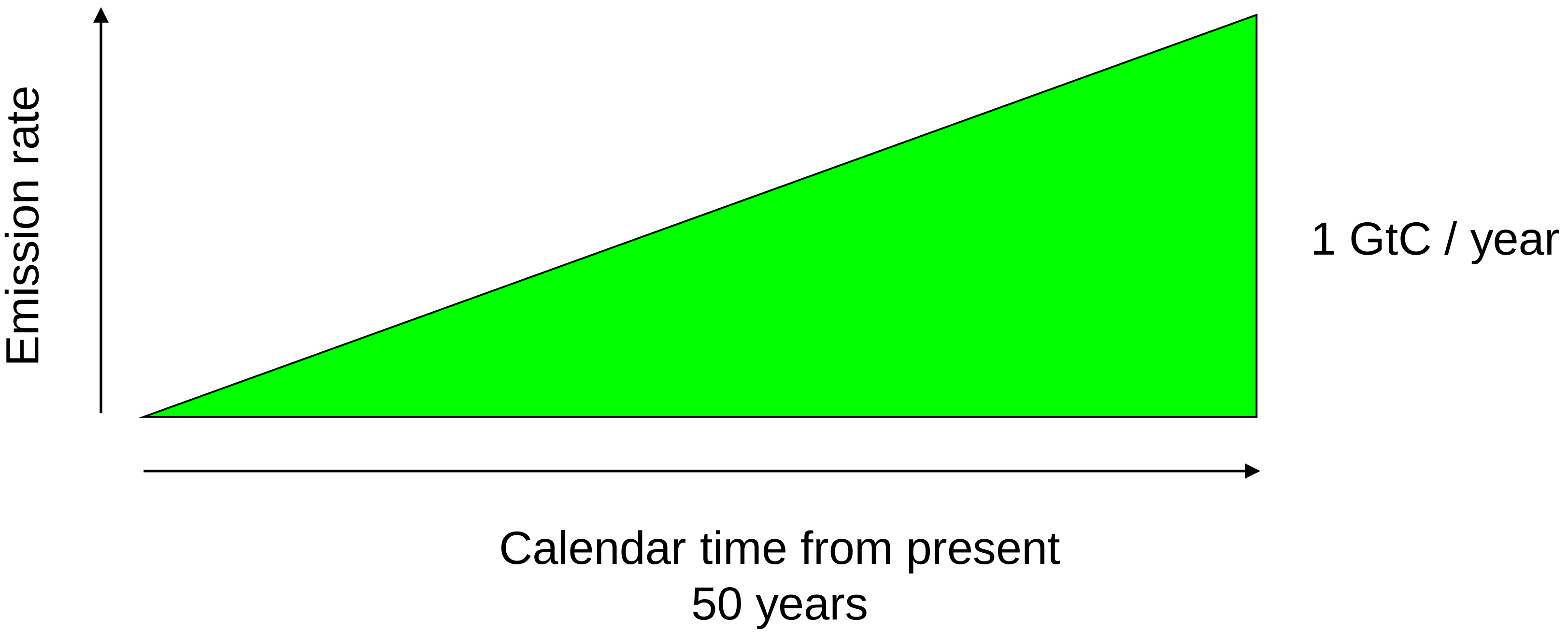
Natural gas will replace coal in electricity generation. It could replace oil in transportation. It continues the use of fossil fuels.

Climate change is happening. More climate change will happen with business as usual.



The U.S. is isolated in its opinion on climate change.

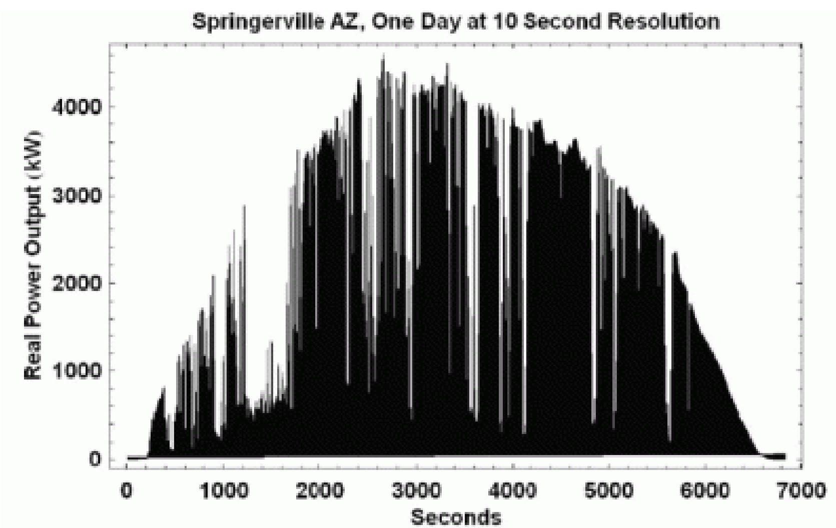
Socolow Wedge

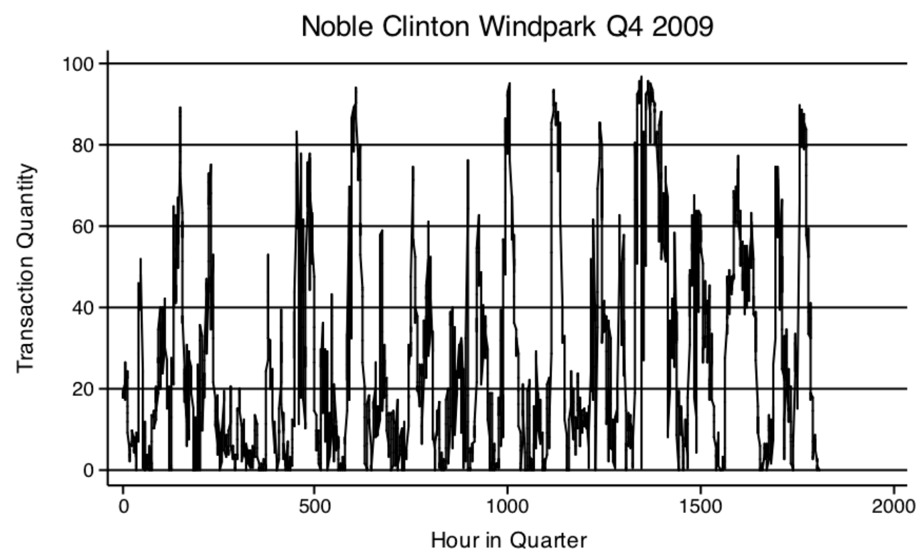


An impossible task is only very, very difficult.

Wedge: a strategy to avoid 25 GtC of emissions from BAU over the next 50 years.

Intermittency and variability of renewables must be addressed either by energy storage or baseload.





Source FERC EQR

Significant conservation and efficiency are both possible and desirable.

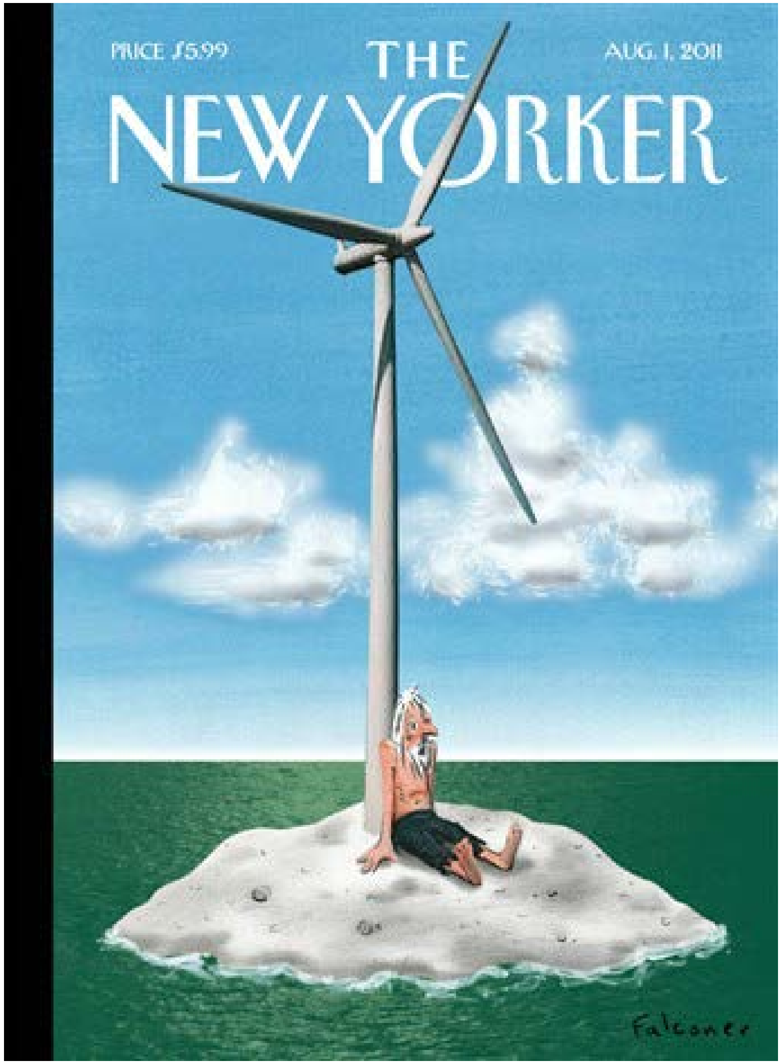
Regulation and standards often work.

Fuel efficient transportation needed to reduce oil consumption.

An incentive is needed for markets to address the energy challenge, preferably a carbon tax.

The Renaissance of nuclear power is still in the dark ages.

If not in my backyard, where?



Some new technologies may succeed.

In Sustainable Energy - without the hot air, David MacKay admonishes us that we stop saying “no” to everything, and we must start say “yes” to something.

I would admonish us that we have to start saying “yes” to enough.

“Would you tell me, please, which way I ought to go from here?” asked Alice.
“***That depends a good deal on where you want to get to***,” said the Cat.
“I don’t much care where,” said Alice.
“***Then it doesn’t matter which way you go***“, said the Cat.
“…so long as I get SOMEWHERE!” Alice added as an explanation.
“***Oh, you’re sure to do that!***…’” said the Cat.