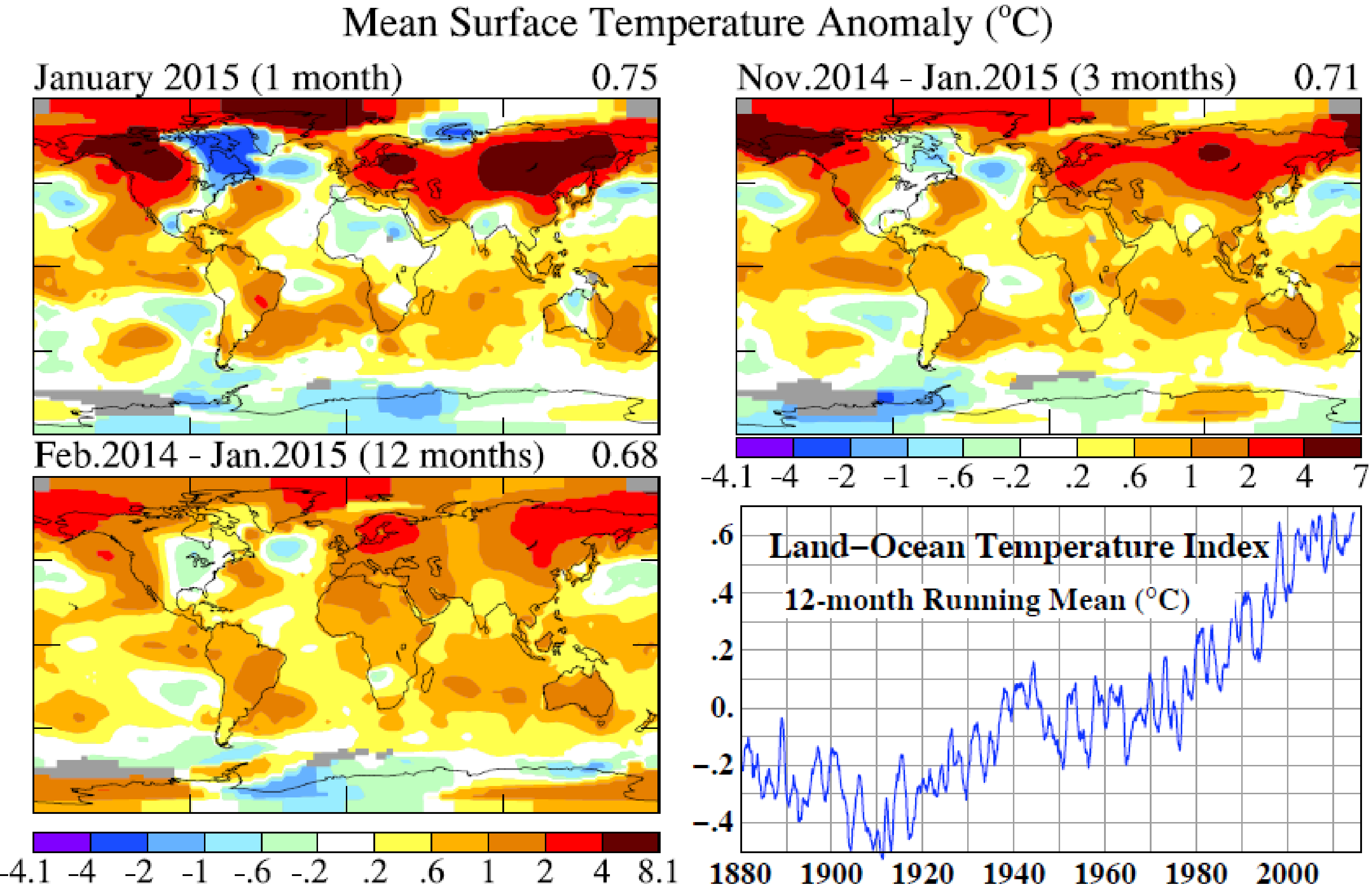
Climate Change and Energy: Problems and Opportunities

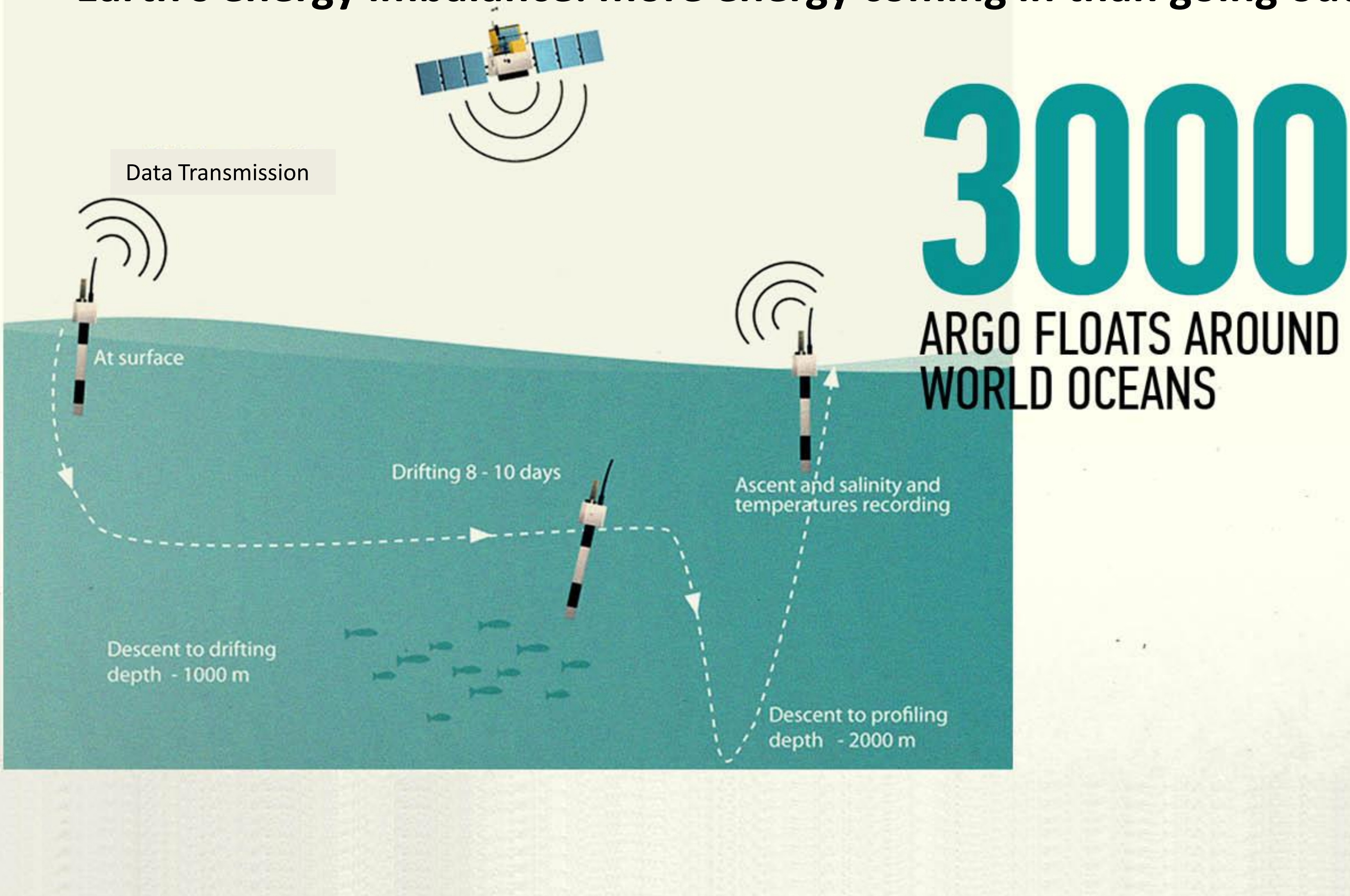
James Hansen

26 February 2015

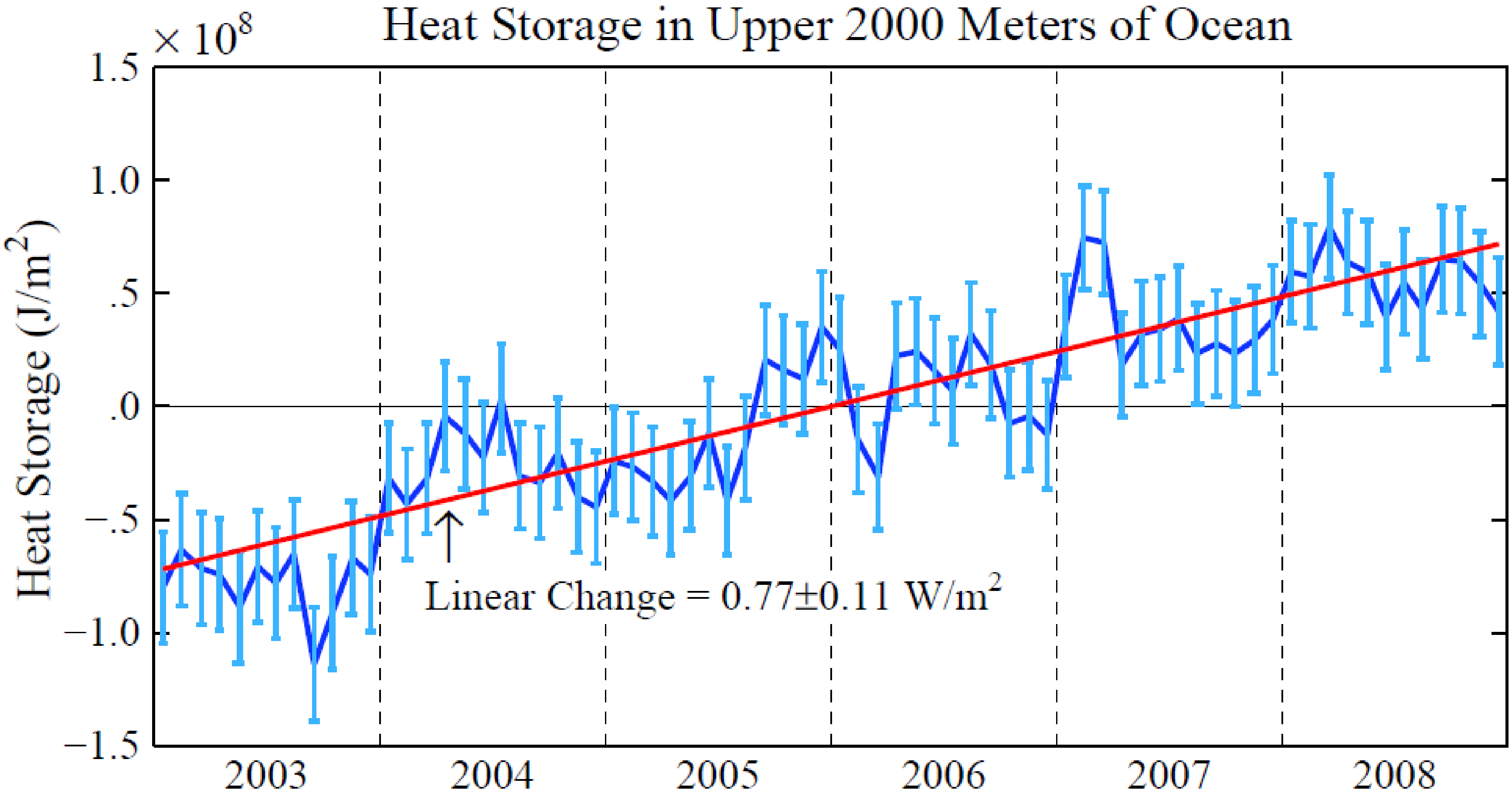
Ottawa, Canada


Mean Surface Temperature Anomaly (°C)
January 2015 (1 month) 0.75
Nov.2014 - Jan.2015 (3 months) 0.71
Feb.2014 - Jan.2015 (12 months) 0.68
-4.1 -4 -2 -1 -.6 -.2 .2 .6 1 2 4 7
-4.1 -4 -2 -1 -.6 -.2 .2 .6 1 2 4 8.1
Land−Ocean Temperature Index
12-month Running Mean (°C)
.6
.4
.2
0.
−.2
−.4
1880 1900 1920 1940 1960 1980 2000

Earth’s energy imbalance: more energy coming in than going out



ARGO floats have allowed accurate measurement of ocean heat gain since 2005. Earth is gaining energy at a rate 0.6 W/m^2, which is 20 times greater than the rate of human energy use. That energy is equivalent to exploding 400,000 Hiroshima atomic bombs per day, 365 days per year.



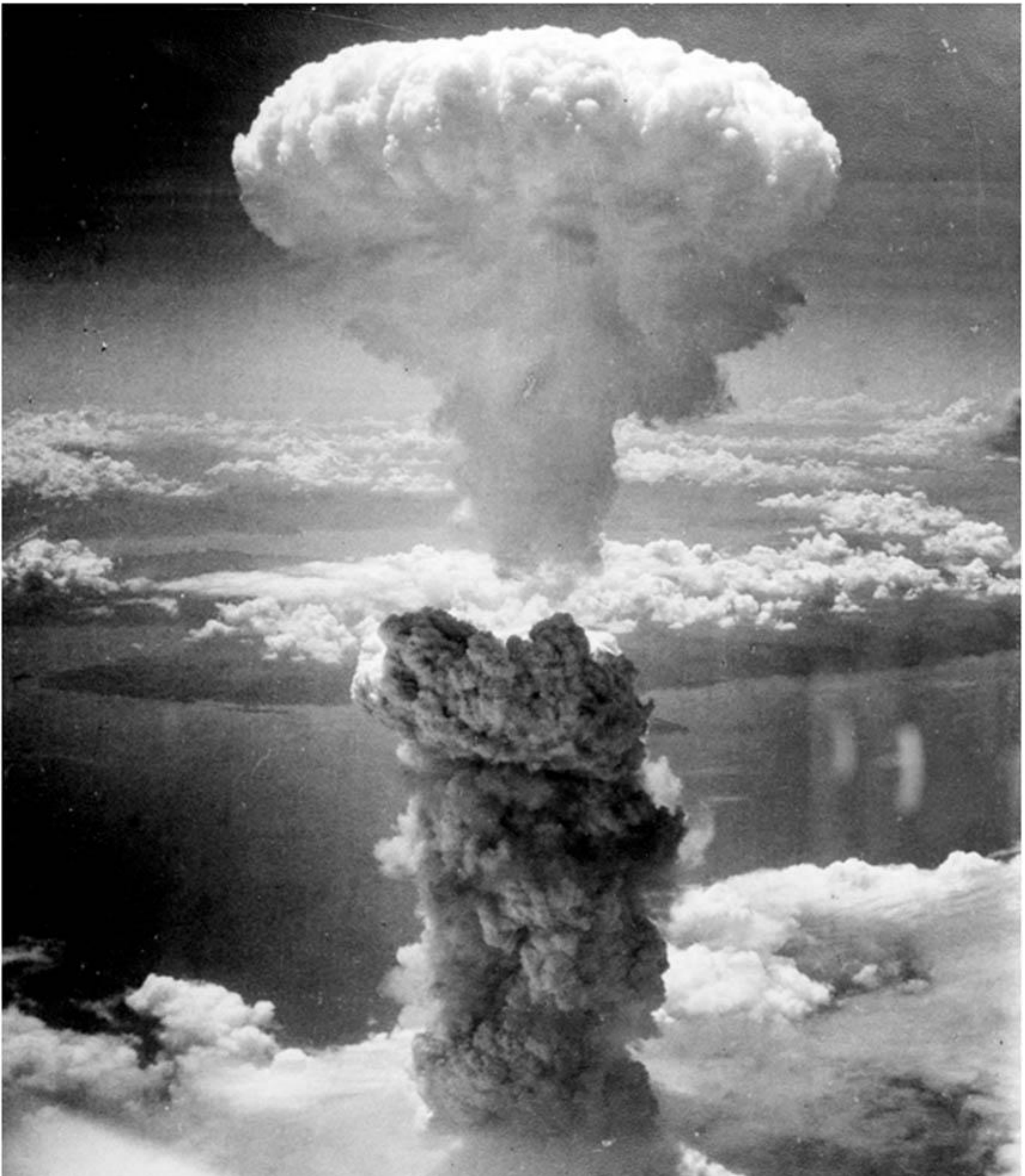
Heat storage in upper 2000 meters of ocean during 2003-2008 based on ARGO data.

Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.

This imbalance continues through the most recent (2013) data.

This imbalance assures that global warming will continue in coming decades.

Data source: von Schuckmann *et al. J. Geophys. Res.* **114**, C09007, 2009, doi:10.1029/2008JC005237.

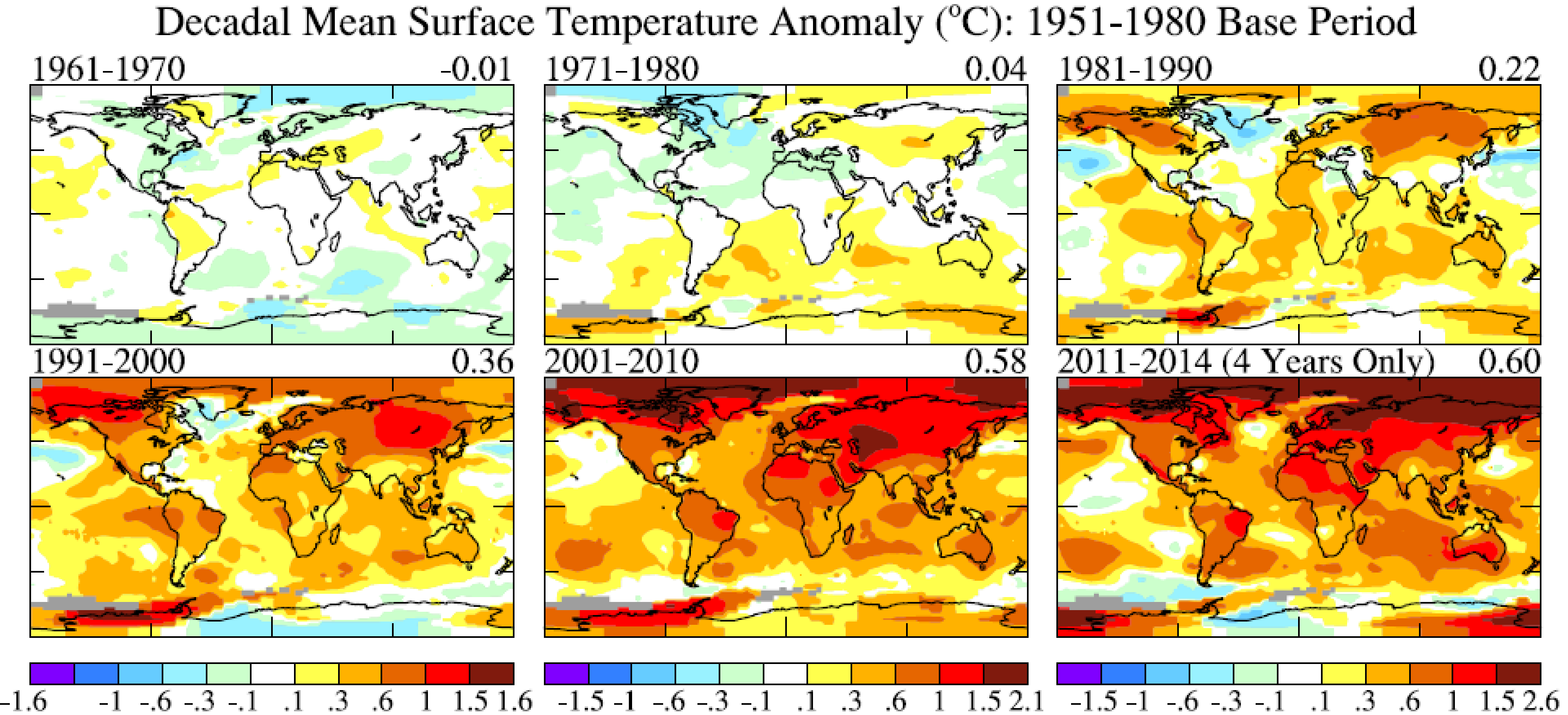


Earth's energy imbalance of 0.6 W/m^2 is equivalent to:

400,000 Hiroshima atomic bombs per day, 365 days/year

or

Every person on Earth running 44 1000-W hair dryers 24 hours/day, 365 days/year.



Decadal temperature anomalies relative to 1951-1980 mean.

Each successive decade is warmer.

First 3 years of this decade are warmer than prior decade over land, but unchanged globally.

Recent seeming slowdown is a temporary natural fluctuation of Eastern Pacific temperature.

Global Climate Situation

1. Little-Understood Global Crisis
   - Climate Inertia → Warming in Pipeline
   - Amplifying Feedbacks → Could Lose Control

2. Rapid Reduction of Forcings Needed
   - Fossil Fuel CO_2 Emissions
   - Trace Gases, Biospheric CO_2

3. Solution Makes Economic Sense
   - Not Being Pursued
   - Not Being Proposed by Any Political Party

Climate Impacts

1. Species Extermination
   - Shifting Climate Zones, Multiple Stresses, Species Interdependencies

2. Ice Sheet Disintegration & Sea Level
   - Ocean Warming → Ice Shelves Melt → Ice Streams Surge → Disintegration

3. Climate Extremes
   - Heat Waves, Drought, Fires
   - Heavier Rain, Floods, Stronger Storms

Threat of Mass Exterminations

Multiple Human-Made Stresses

Overharvesting, Land use changes, Nitrogen fertilization, Introducing exotic species, etc.

in Combination with

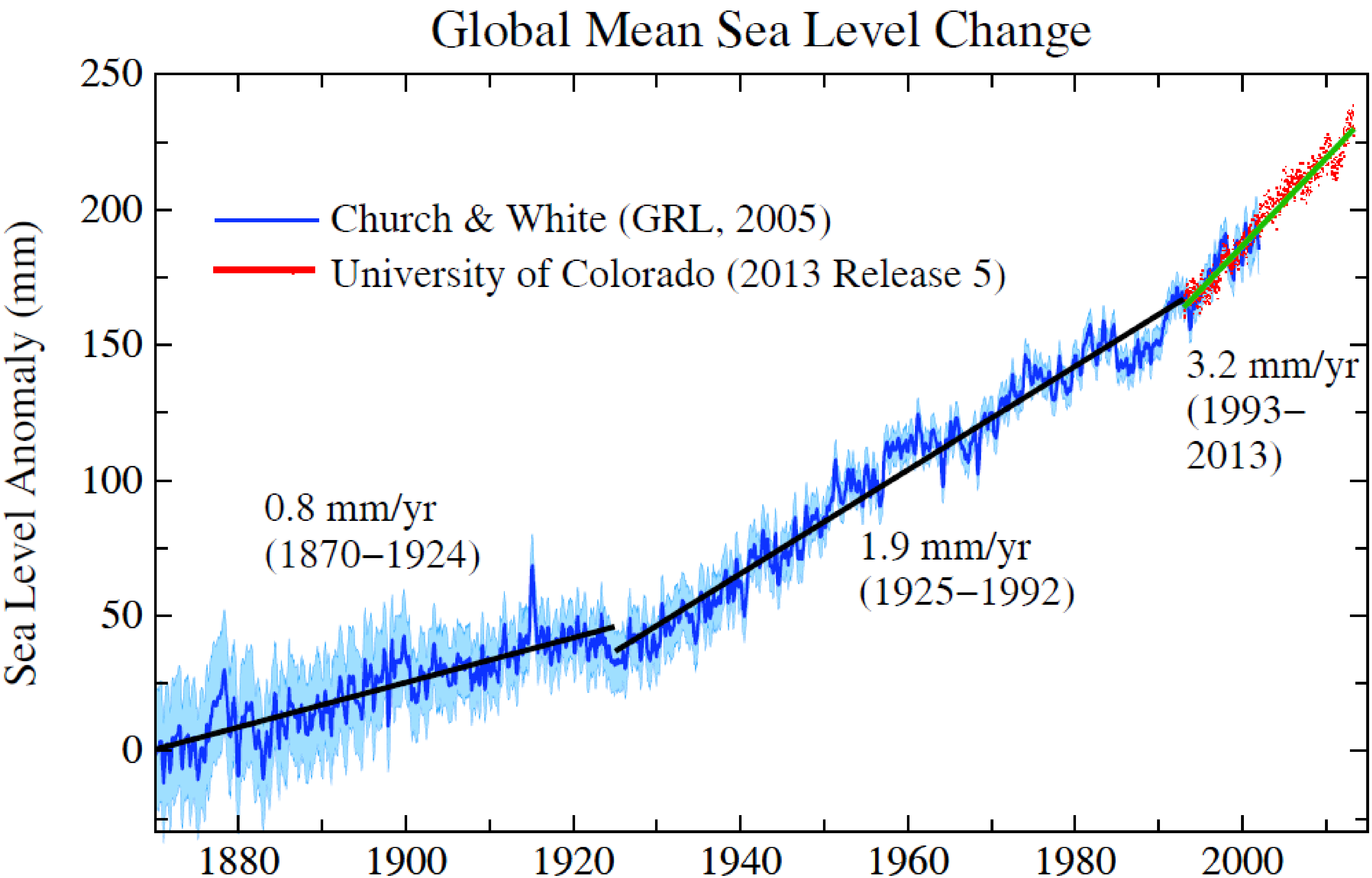
Rapid Shifting of Climate Zones

Climate Impacts

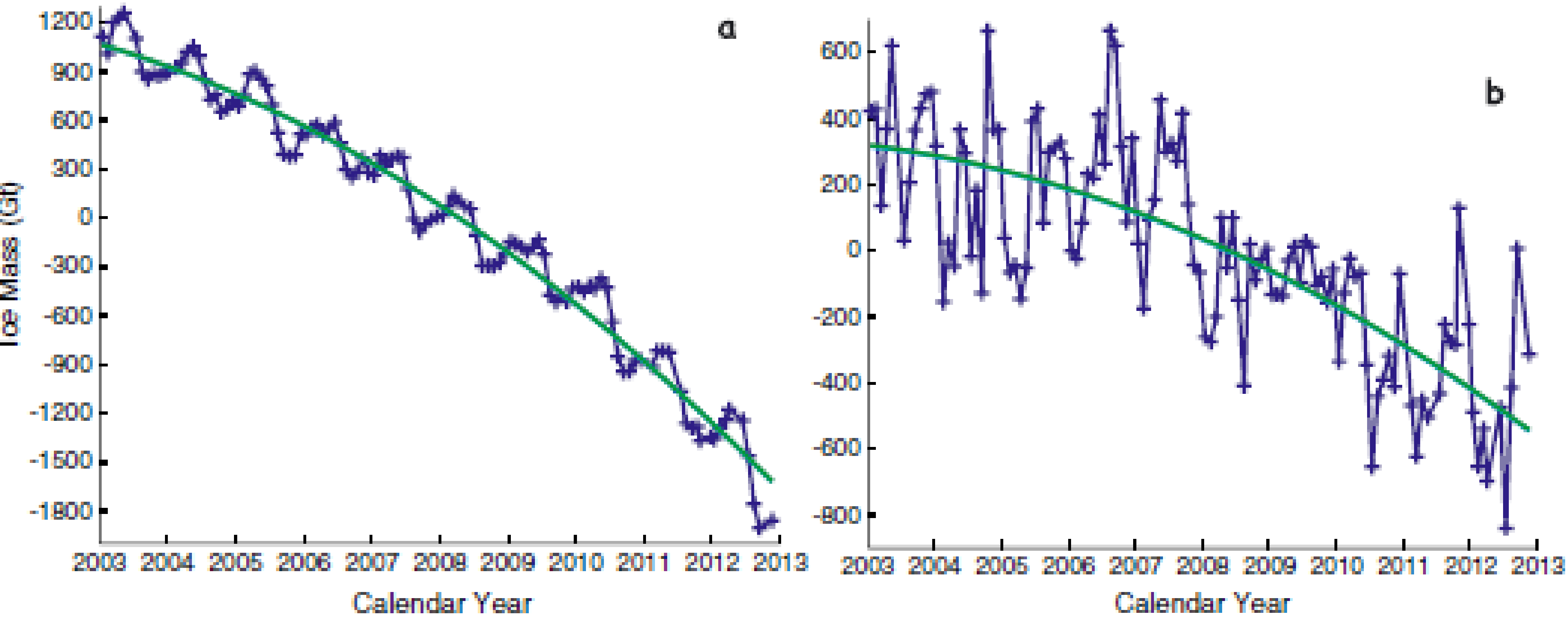
1. Species Extermination
   - Shifting Climate Zones, Multiple Stresses, Species Interdependencies

2. Ice Sheet Disintegration & Sea Level
   - Ocean Warming → Ice Shelves Melt → Ice Streams Surge → Disintegration

3. Climate Extremes
   - Heat Waves, Drought, Fires
   - Heavier Rain, Floods, Stronger Storms



Accelerating rate of sea level rise during the past century.



Ice mass change in Gigatons (1 Gt = 10^{12} kg) from GRACE data through Nov. 2012

Source: Velicogna, I. & Wahr, J., Time-variable gravity observations…, *Geophys. Res. Lett.* **40**, 3055, 2013.

Paleoclimate Guidance

Eemian sea level +5-9 meters

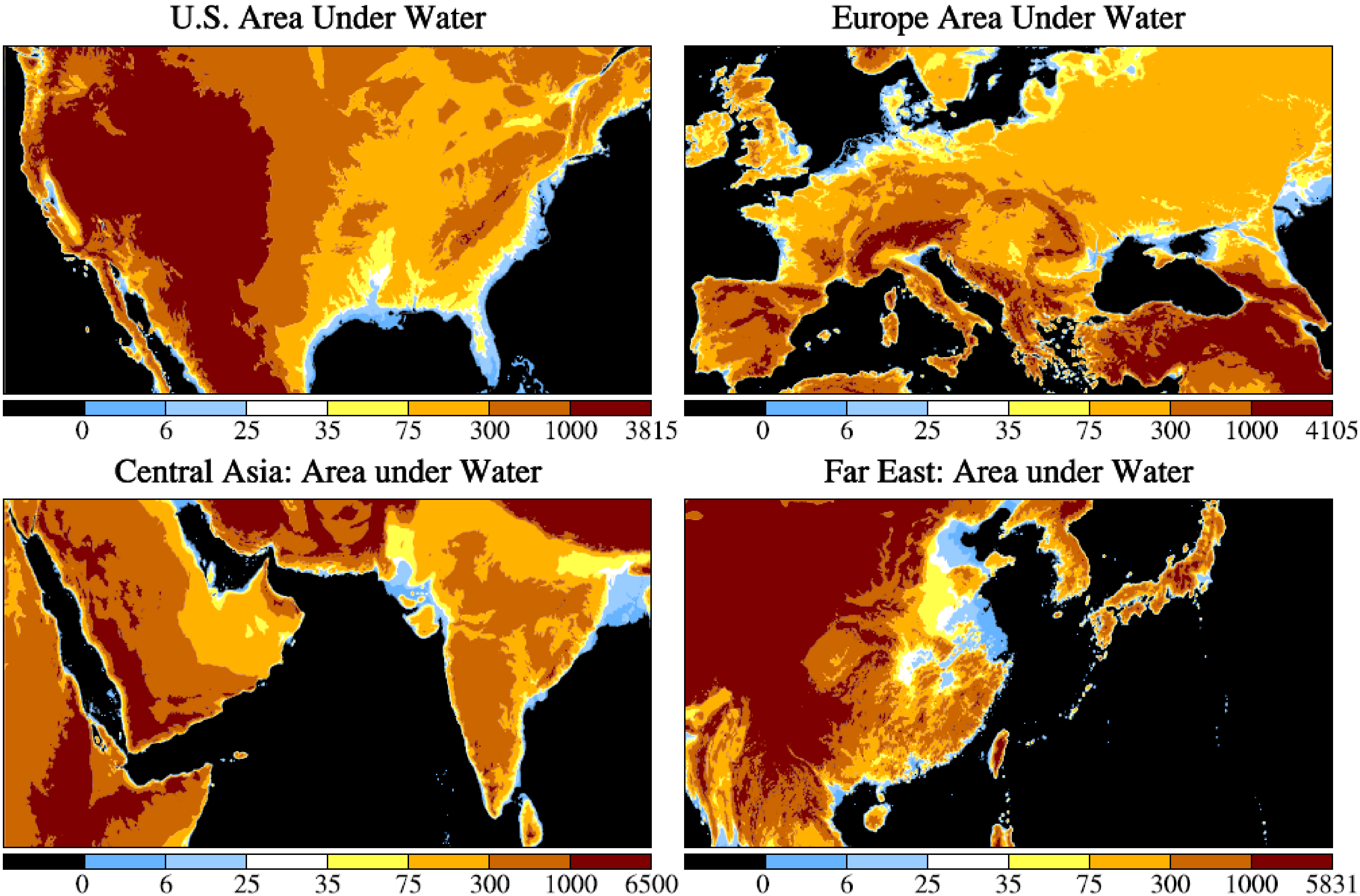
- Eemian temperature < +2°C*

Pliocene sea level up to +15-25 meters

- Pliocene temperature +3-4°C*

Ice sheet response time uncertain, but it is shorter than the lifetime of fossil fuel carbon and resulting global warming

*relative to pre-industrial times

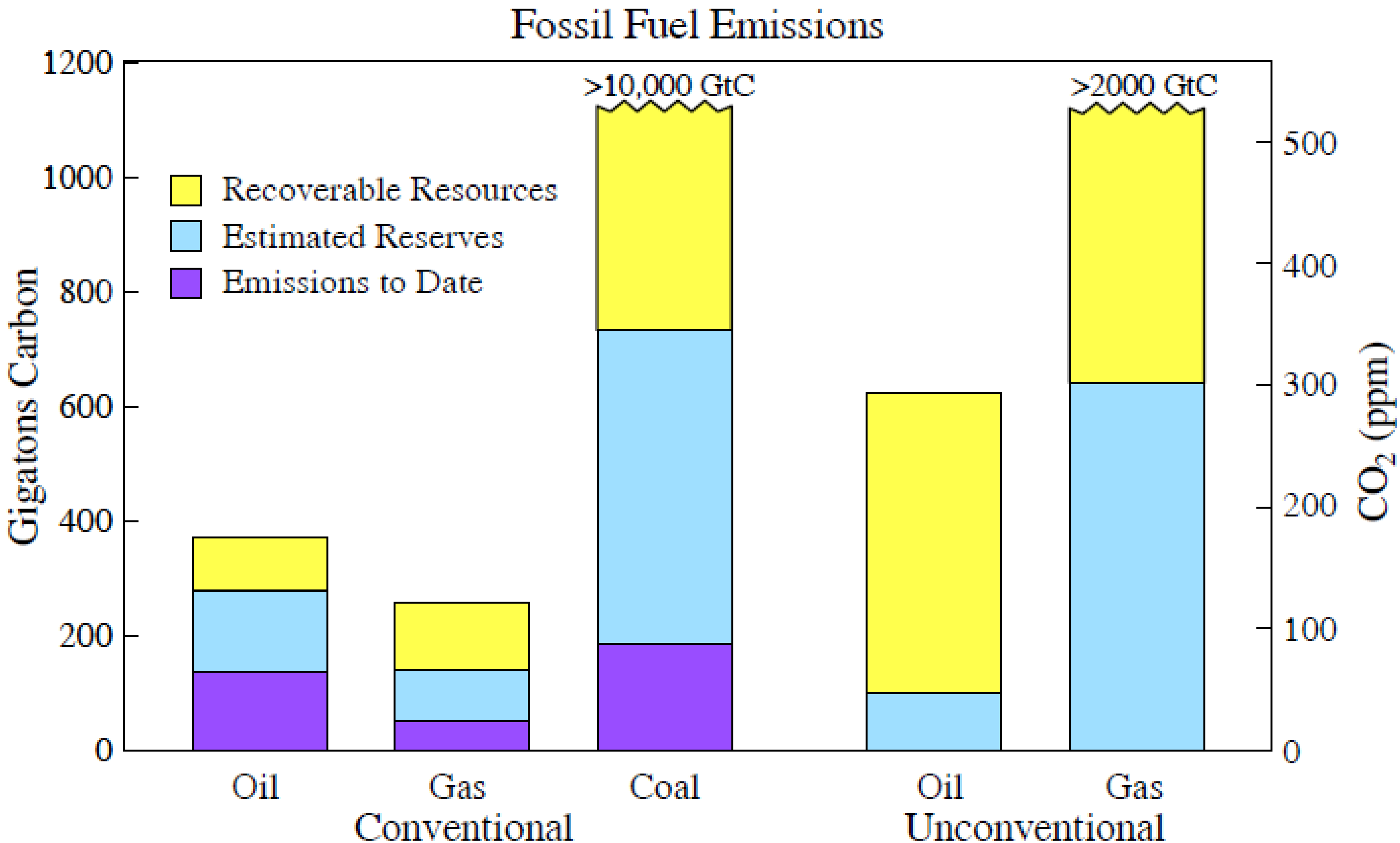

U.S. Area Under Water
0 6 25 35 75 300 1000 3815
Europe Area Under Water
0 6 25 35 75 300 1000 4105
Central Asia: Area under Water
0 6 25 35 75 300 1000 6500
Far East: Area under Water
0 6 25 35 75 300 1000 5831

Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature

James Hansen, Pushker Kharecha, Makiko Sato, Valerie Masson-Delmotte, Frank Ackerman, David J. Beerling, Paul J. Hearty, Ove Hoegh-Guldberg, Shi-Ling Hsu, Camille Parmesan, Johan Rockstrom, Eelco J. Rohling, Jeffrey Sachs, Pete Smith, Konrad Steffen, Lise Van Susteren, Karina von Schuckmann, James C. Zachos

PLOS ONE: December 03, 2013

DOI: 10.1371/journal.pone.0081648



Fossil fuel emissions; purple are emissions through 2012.

1 GtC (gigaton carbon) = 1 billion tons of carbon or ~3.7 $GtCO_2$; 1 ppm CO_2 ~2.12 GtC

Climate Stabilization is Possible, But…

Essential Requirements

1. **Quick Coal Phase-Out Necessary**

   Coal emissions halted in next few decades

2. **No Unconventional Fossil Fuels**

   Tar sands, Tar shale, Methane hydrates

3. **Don’t Pursue Last Drops of Oil**

   Polar regions, Deep ocean, Pristine land

What's Really Happening

1. Tar Sands Being Developed

   Pipelines would lock-in large emissions

2. Coal & Gas Power Plants being Built

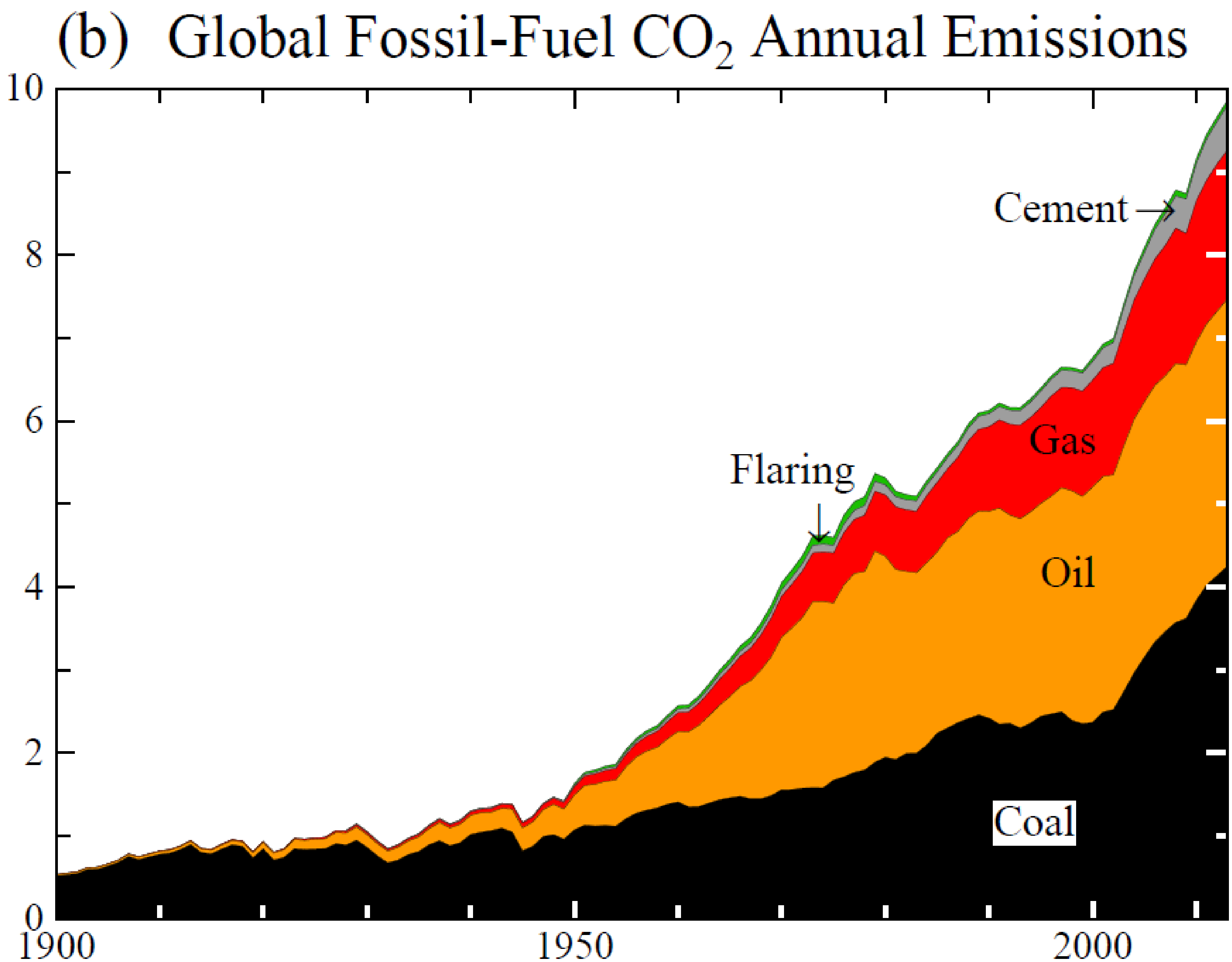
   Will lock-in large emissions

3. Mountaintop Removal, Long-Wall Mining

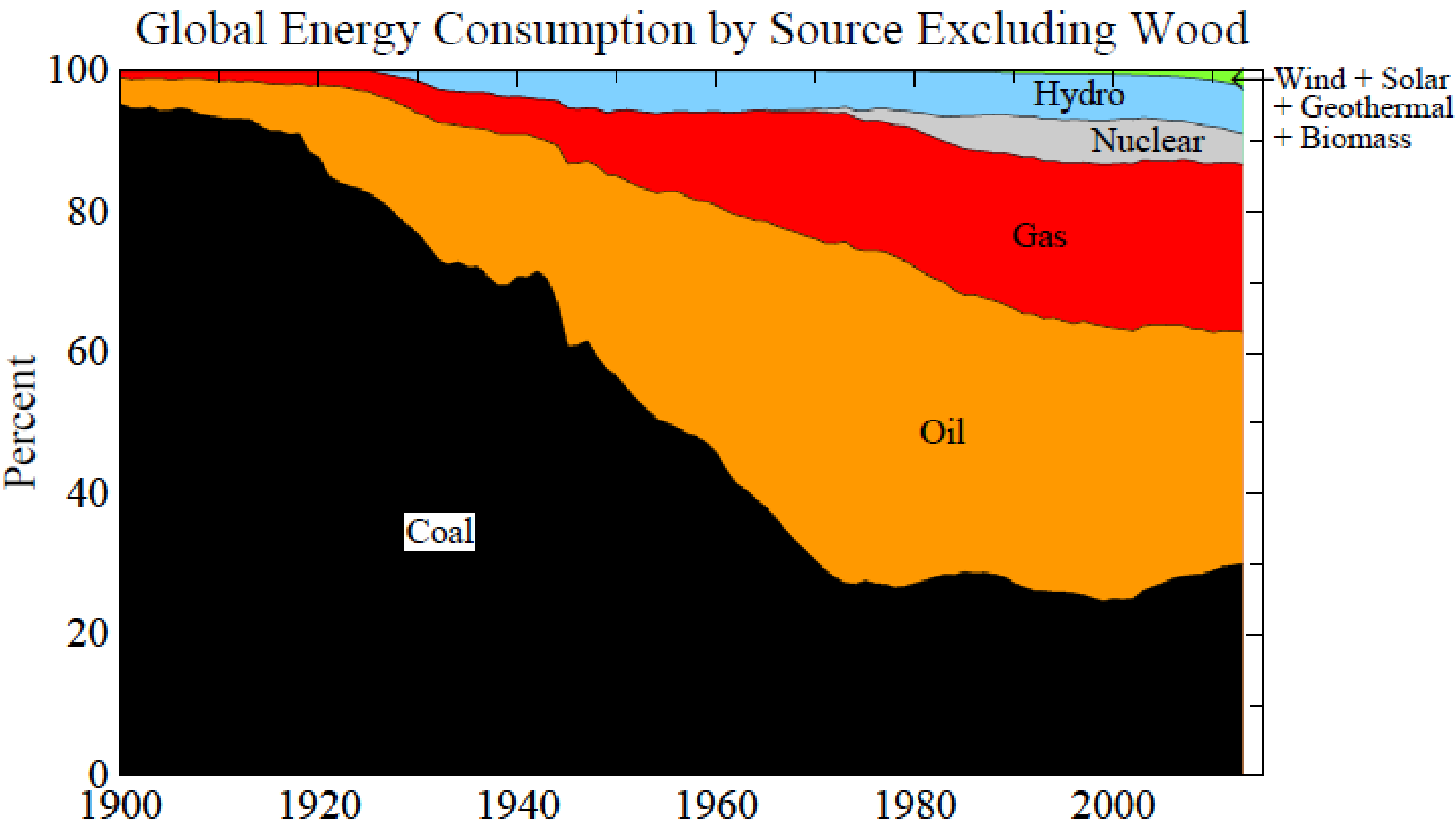
   Coal exports increase

4. Oil & Gas Extraction Expands

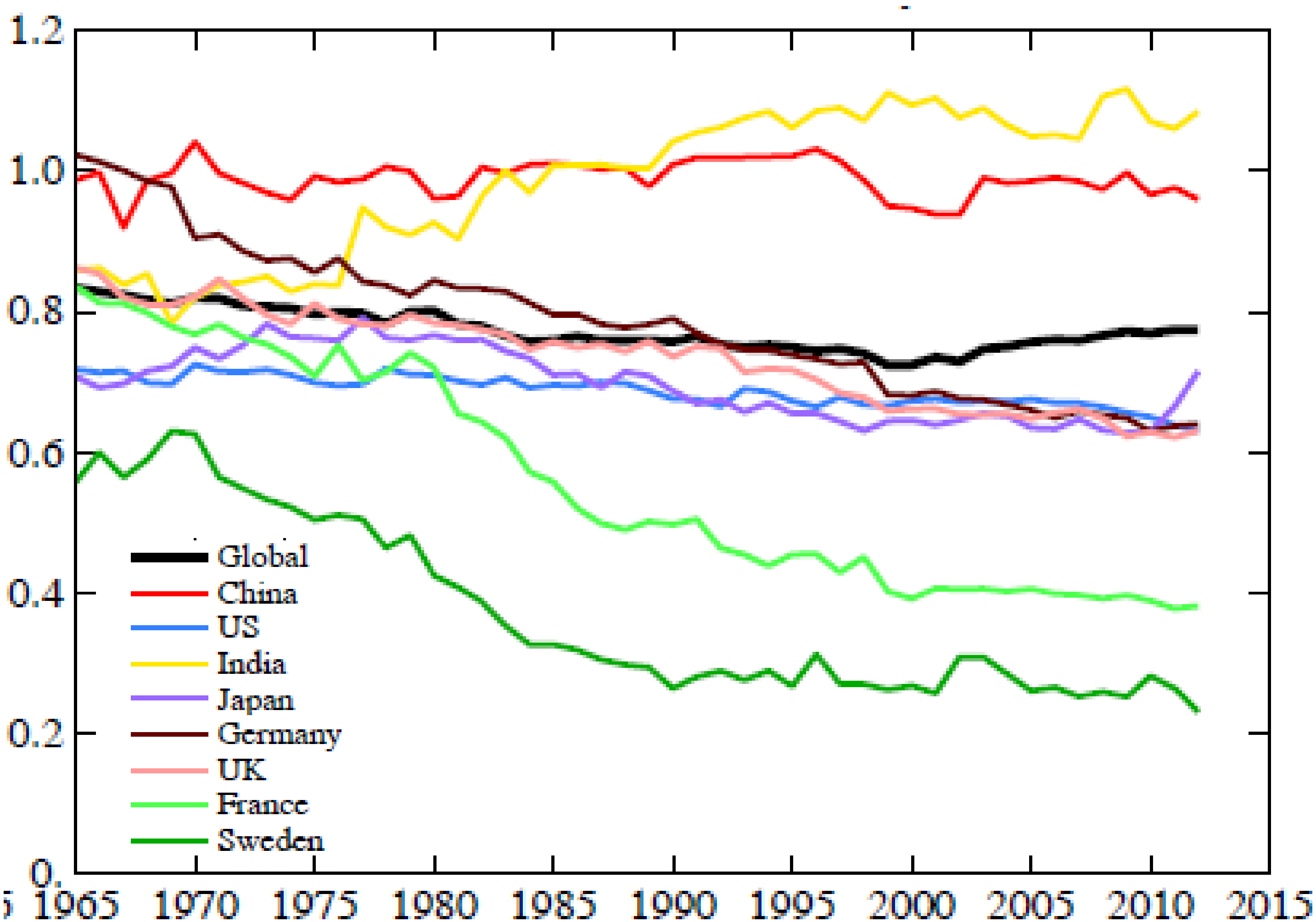
   Arctic, deep ocean, public lands



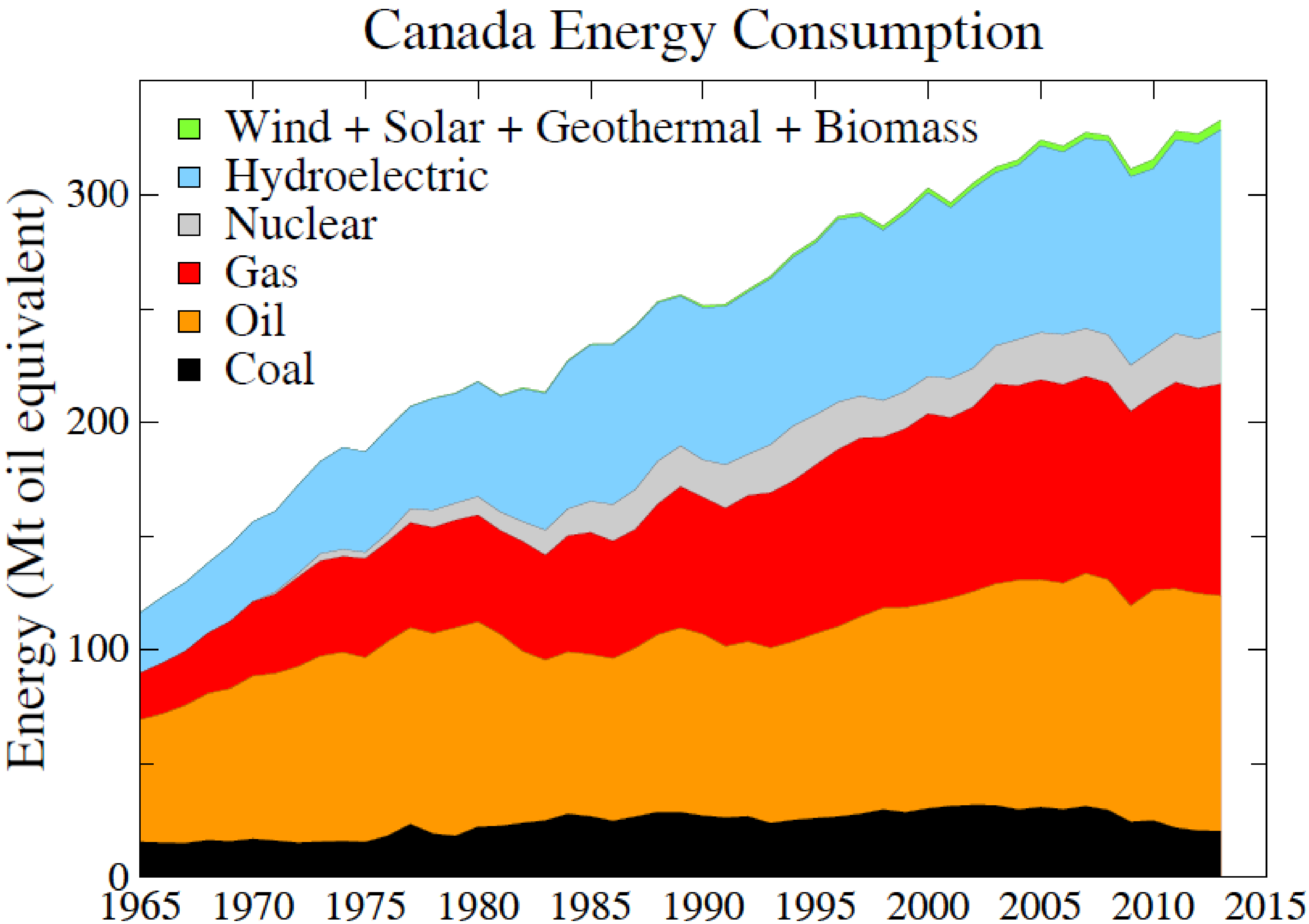
Source: Boden, TA, G Marland, and RJ Andres. 2011. Global, Regional, and National Fossil-Fuel CO2 Emissions. Carbon Dioxide Information Analysis Center, Oak Ridge Natl Lab, U.S. Department of Energy http://cdiac.ornl.gov/trends/emis/meth_reg.html#

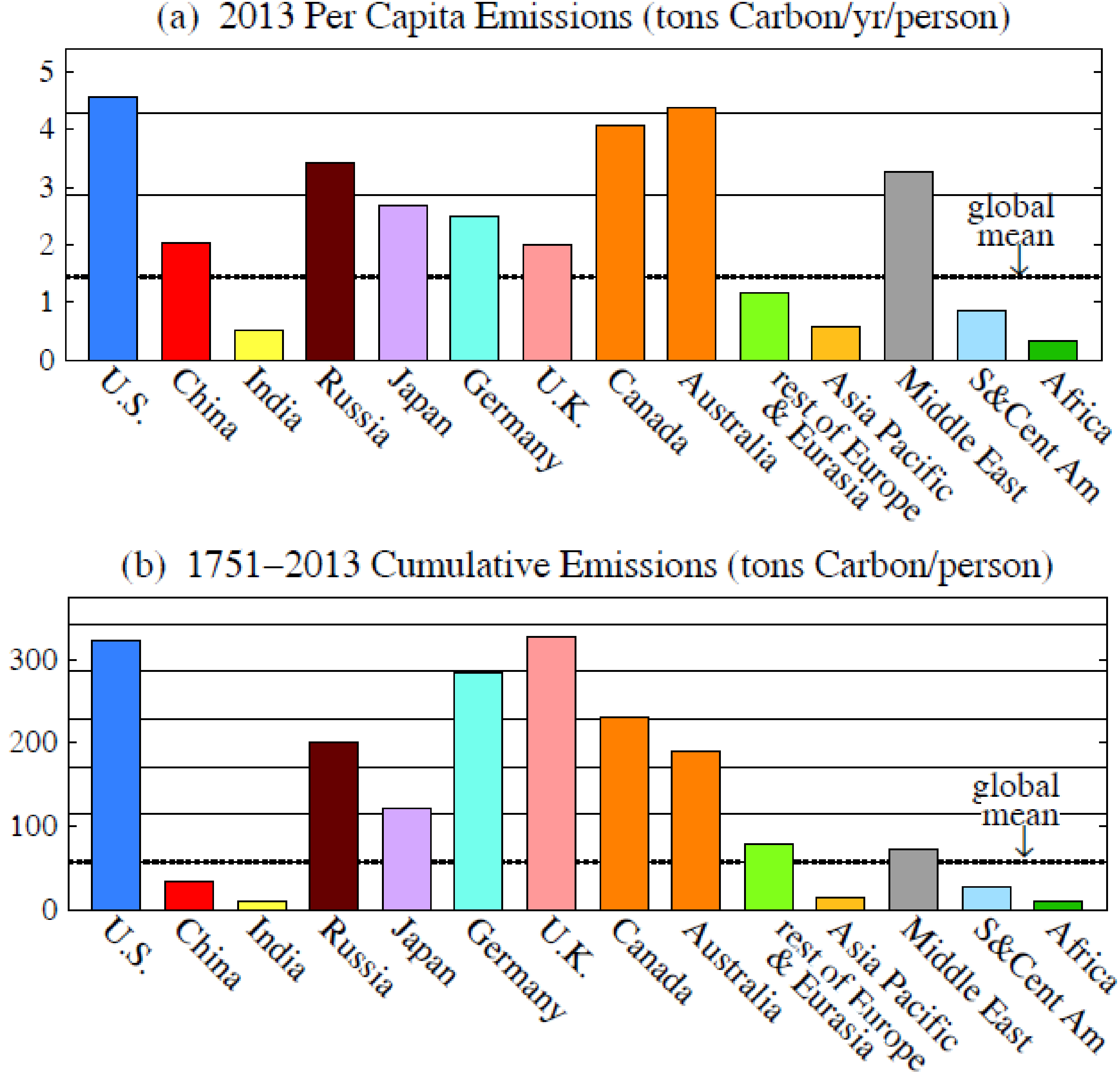


Data source: 1965-2013 [BP Statistical Reviw of World Energy 2014](#).



<u>Carbon intensity</u>, **defined as fossil fuel carbon emissions (GtC) divided by energy consumption (Gt of oil equivalent)**


Canada Energy Consumption
Wind + Solar + Geothermal + Biomass
Hydroelectric
Nuclear
Gas
Oil
Coal
Energy (Mt oil equivalent)
0
100
200
300
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015


(a) 2013 Per Capita Emissions (tons Carbon/yr/person)
0
1
2
3
4
5
global mean
U.S.
China
India
Russia
Japan
Germany
U.K.
Canada
Australia
rest of Europe & Eurasia
Asia Pacific
Middle East
S&Cent Am
Africa
(b) 1751–2013 Cumulative Emissions (tons Carbon/person)
0
100
200
300
global mean
U.S.
China
India
Russia
Japan
Germany
U.K.
Canada
Australia
rest of Europe & Eurasia
Asia Pacific
Middle East
S&Cent Am
Africa

Mackay River, Boreal Forest and Tar Sands Mine

Boreal Forests and wetlands surrounding the Tar Sands are the most carbon rich terrestrial ecosystem on Earth, with almost twice as much carbon as tropical rainforests. Referred to by the Tar Sands industry as "overburden," these forests are scraped off and the wetlands dredged, to be replaced by tar mines like the one above.

From: Canada's Tar Sands and the True Cost of Oil. Photography by Garth Lenz.

Tar Sands Mine and Truck

At the edge of a 250-foot deep mine, a massive tar sands truck is dwarfed by the surrounding landscape. The 400-ton trucks are the world's largest (25 feet high, 48 feet long, 32 feet wide). The Tar Sands were the inspiration for Avatar's Edmonton-born art director's vision of the mining operation on Pandora.

From: Canada's Tar Sands and the True Cost of Oil. Photography by Garth Lenz.

Crossroads in Alberta Tar Sands

Here a small fraction of a massive mine encroaches on the Boreal Forest. With a proposed 5-fold expansion of the Tar Sands, an area the size of Florida will be industrialized within as little as two decades.

From: Canada's Tar Sands and the True Cost of Oil. Photography by Garth Lenz.

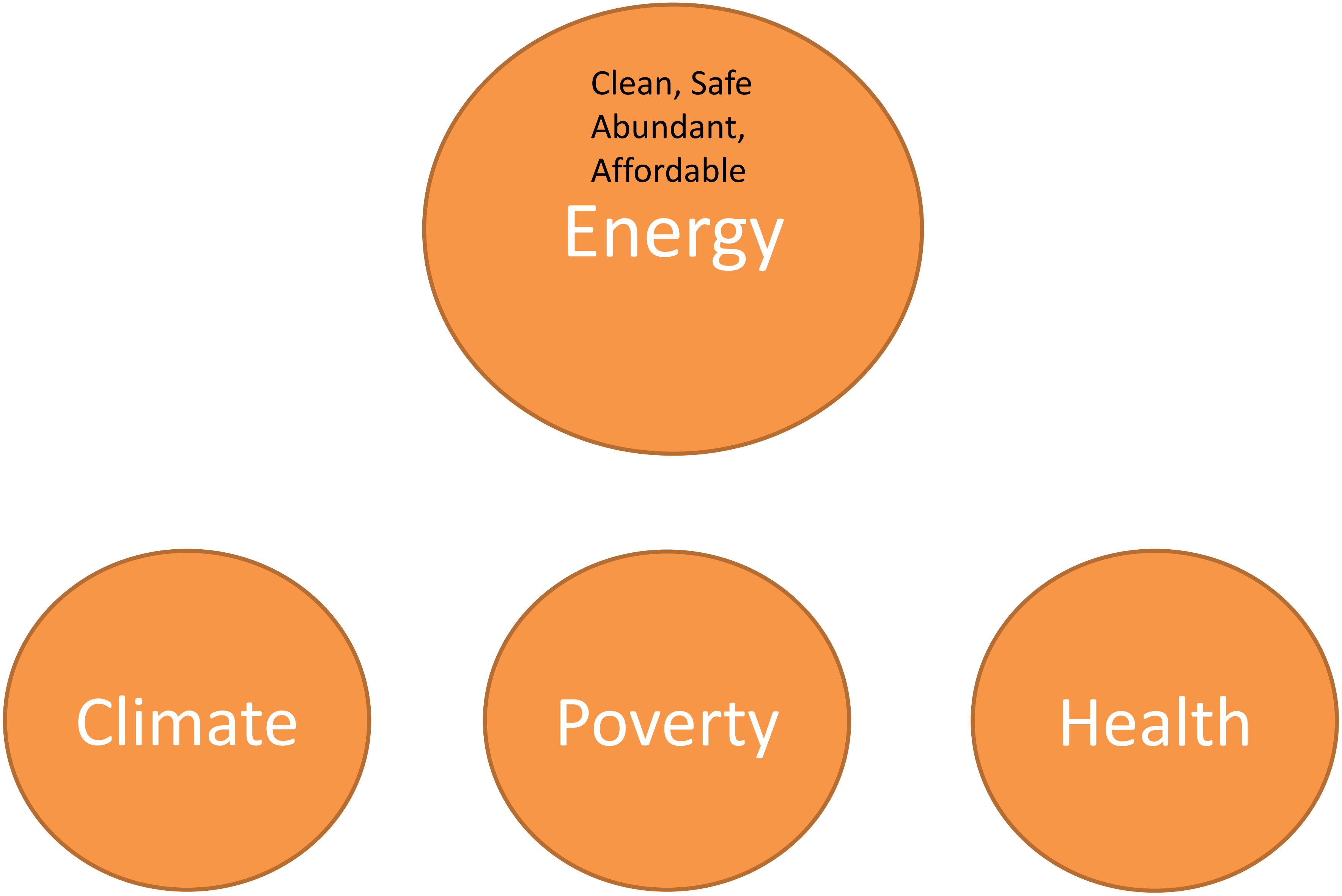
Tar Sands at Night

Twenty-four hours a day, the Tar Sands eats into the most carbon rich forest ecosystem on Earth.
The vast mines, tailings ponds, fire and pollution belching refineries resemble Tolkien’s middle-earth Mordor.
From: Canada’s Tar Sands and the True Cost of Oil. Photography by Garth Lenz.


YARHACH


GREEN

200,000 People at 1979 No Nukes Concert in New York City


Clean, Safe
Abundant,
Affordable
Energy
Climate
Poverty
Health

INTERGENERATIONAL INJUSTICE

"OUR PARENTS DID NOT KNOW THAT THEIR ACTIONS COULD HARM FUTURE GENERATIONS. WE WILL ONLY BE ABLE TO PRETEND THAT WE DID NOT KNOW."

Problem & Solution

1. Fossil Fuels are Cheapest Energy
   - Subsidized & Do Not Pay Costs
   - Solution: Rising Price on Carbon

2. Regulations also Required
   - Efficiency of Vehicles, Buildings,e.g.
   - Carbon Price Provides Enforcement

3. Technology Development Needed
   - Driven by Certainty of Carbon Price
   - Government Role Limited

Fee & Dividend

Fee: Collected at Domestic Mine/Port of Entry

Covers all Oil, Gas, Coal → No Leakage

Dividend: Equal Shares to All Legal Residents

Not One Dime to the Government.

Merits:

Transparent. Market-based. Stimulates Innovation.

Does Not Enlarge Government.

Leaves Energy Choices to Individuals & Free Competition.

A Conservative Energy & Climate Plan.

Fee & Dividend Addresses

1. Economy: Stimulates It

Puts Money in Public's Hands – A Lot

Provides Certainty to Businesses and Entrepreneurs

2. Energy: Solves Fossil Fuel Addiction

Stimulates Innovation – Fastest Route to Clean Energy

Complements Efficiency Regulations & Energy RD&D

3. Climate: Viable International Approach

Border Duties on Products from Nations without Fee

Most Coal & Unconventional Fossil Fuel left in Ground

What Can Done?

1. Citizens Climate Lobby
   - Use democratic process
   - Visit representatives, write letters, op-eds

2. 350.org
   - Demands what is needed, In the streets
   - In large numbers, Young people

3. Our Children's Trust
   - Legal demand, science-based requirement
   - Court can require government plan

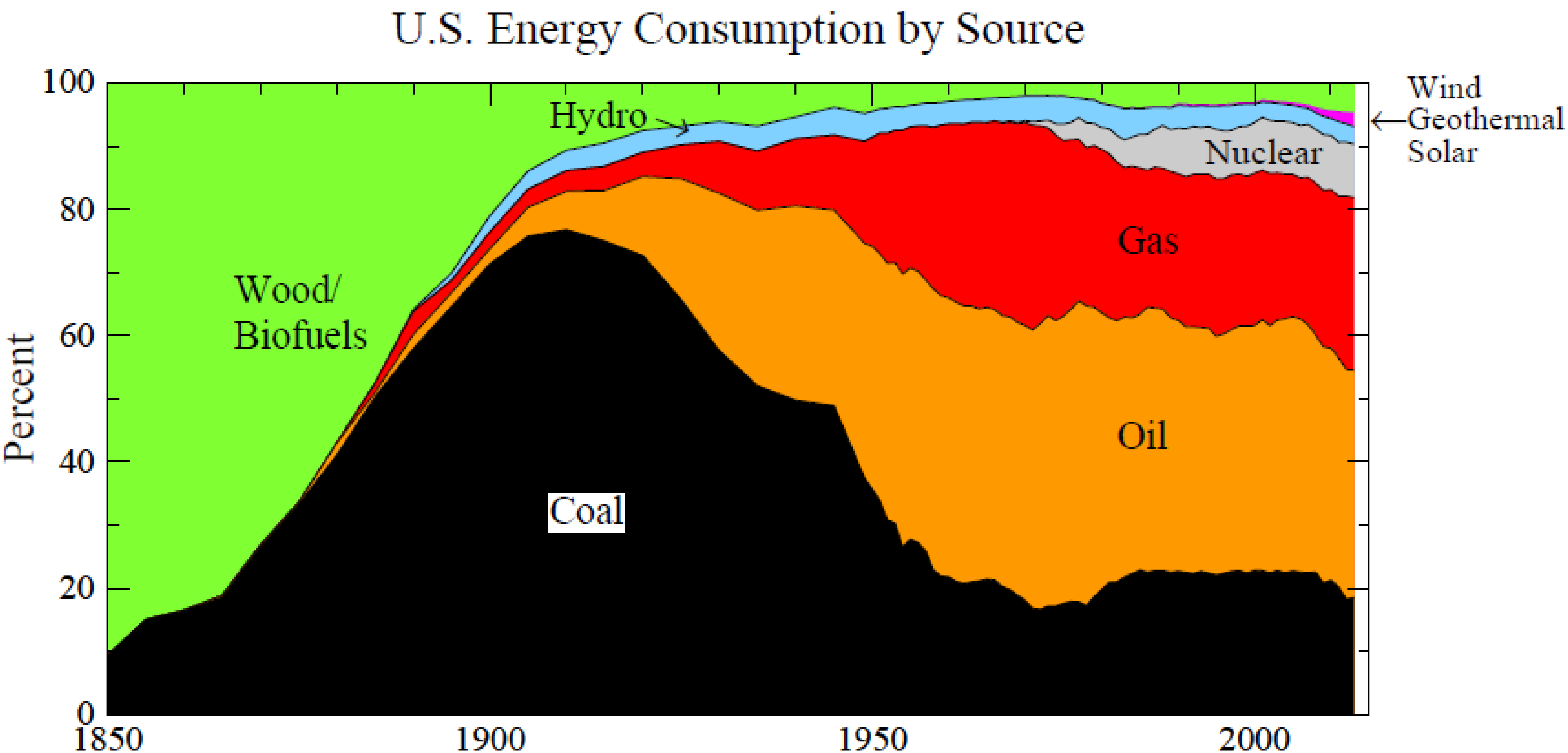
Web Sites

www.columbia.edu/~jeh1

www.CitizensClimateLobby.org

www.OurChildrensTrust.org

www.350.org



Sources: EIA Table E1 Estimated Primary Energy Consumption in the United States, 1635-1945 and EIA Table 1.3 Primary Energy Consumption Estimates by Source, 1949-2011.

Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power

Pushker A. Kharecha* and James E. Hansen
NASA Goddard Institute for Space Studies and Columbia University Earth Institute, 2880 Broadway, New York, New York 10025, United States

ABSTRACT: In the aftermath of the March 2011 accident at Japan's Fukushima Daiichi nuclear power plant, the future contribution of nuclear power to the global energy supply has become somewhat uncertain. Because nuclear power is an abundant, low-carbon source of base-load power, it could make a large contribution to mitigation of global climate change and air pollution. Using historical production data, we calculate that global nuclear power has prevented an average of 1.84 million air pollution-related deaths and 64 gigatonnes of CO_2-equivalent (GtCO_2-eq) greenhouse gas (GHG) emissions that would have resulted from fossil fuel burning. On the basis of global projection data that take into account the effects of the Fukushima accident, we find that nuclear power could additionally prevent an average of 420 000−7.04 million deaths and 80−240 GtCO_2-eq emissions due to fossil fuels by midcentury, depending on which fuel it replaces. By contrast, we assess that large-scale expansion of unconstrained natural gas use would not mitigate the climate problem and would cause far more deaths than expansion of nuclear power.

“We are eliminating programs that are no longer needed, such as nuclear power research and development.”

President William Clinton,
1993 State of the Union address

Argonne National Laboratory was ready to construct a commercial-scale reactor that:

(1) Burns >99% of nuclear fuel, compared with ~1% in existing reactors,

(2) Leaves a smaller waste pile with half-life of decades rather than millennia,

(3) Can utilize nuclear waste, depleted uranium and excess weapons material as fuel,

(4) Can shut down automatically in the event of an anomaly (e.g., earthquake),

(5) Does not require power to cool reactor in case of shut down,

(6) Does not require uranium mining for centuries; indeed, it has been demonstrated that fuel can be sieved from the ocean – the supply will last billions of years.

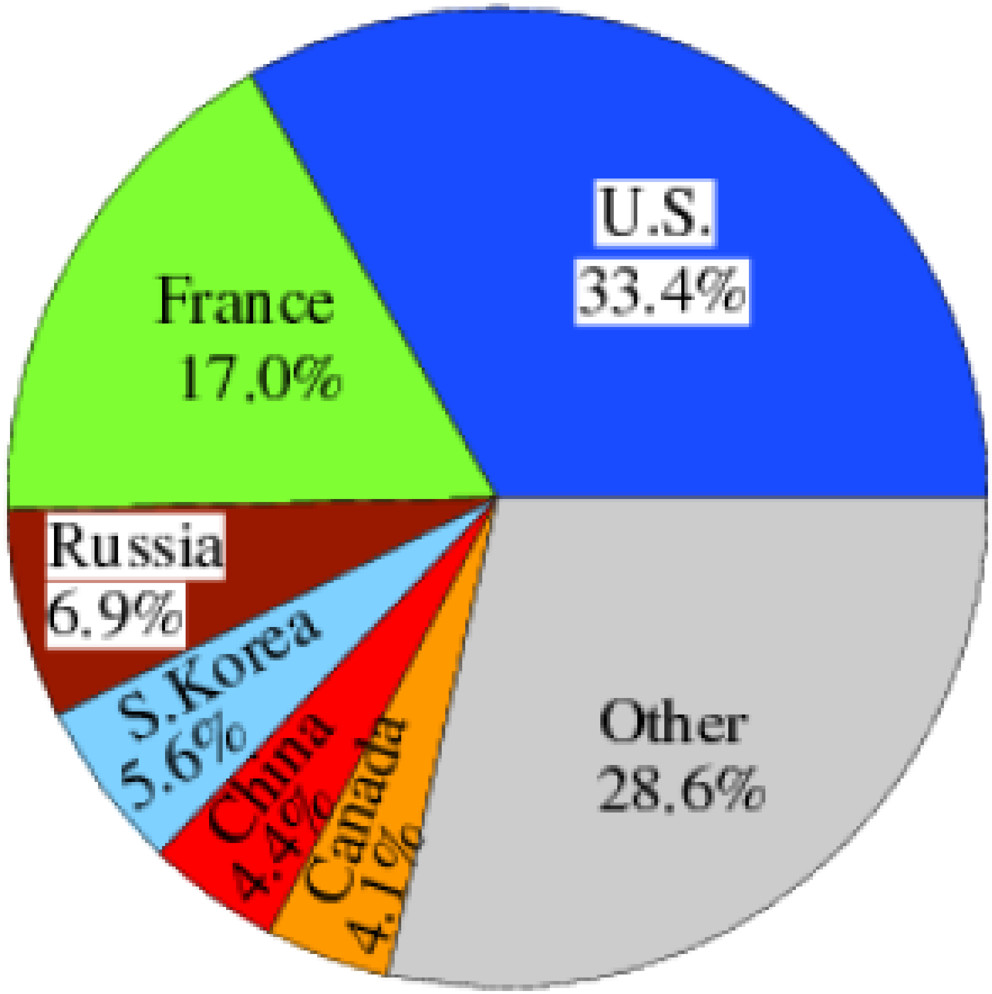
The Rise of Nuclear Fear – How We Learned to Fear the Radiation

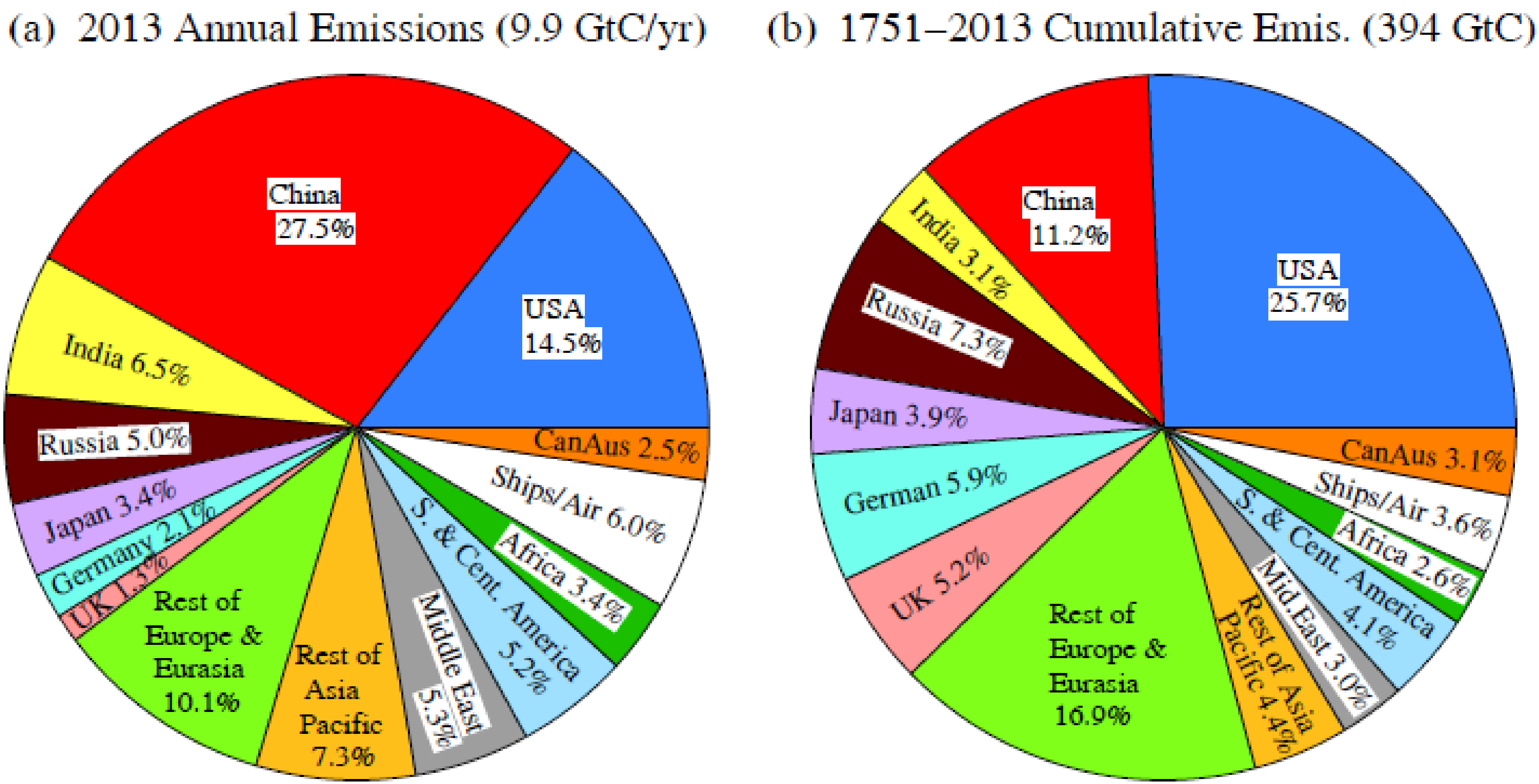
David Ropeik, 15 June 2012, Scientific American, review of Spencer Weart book

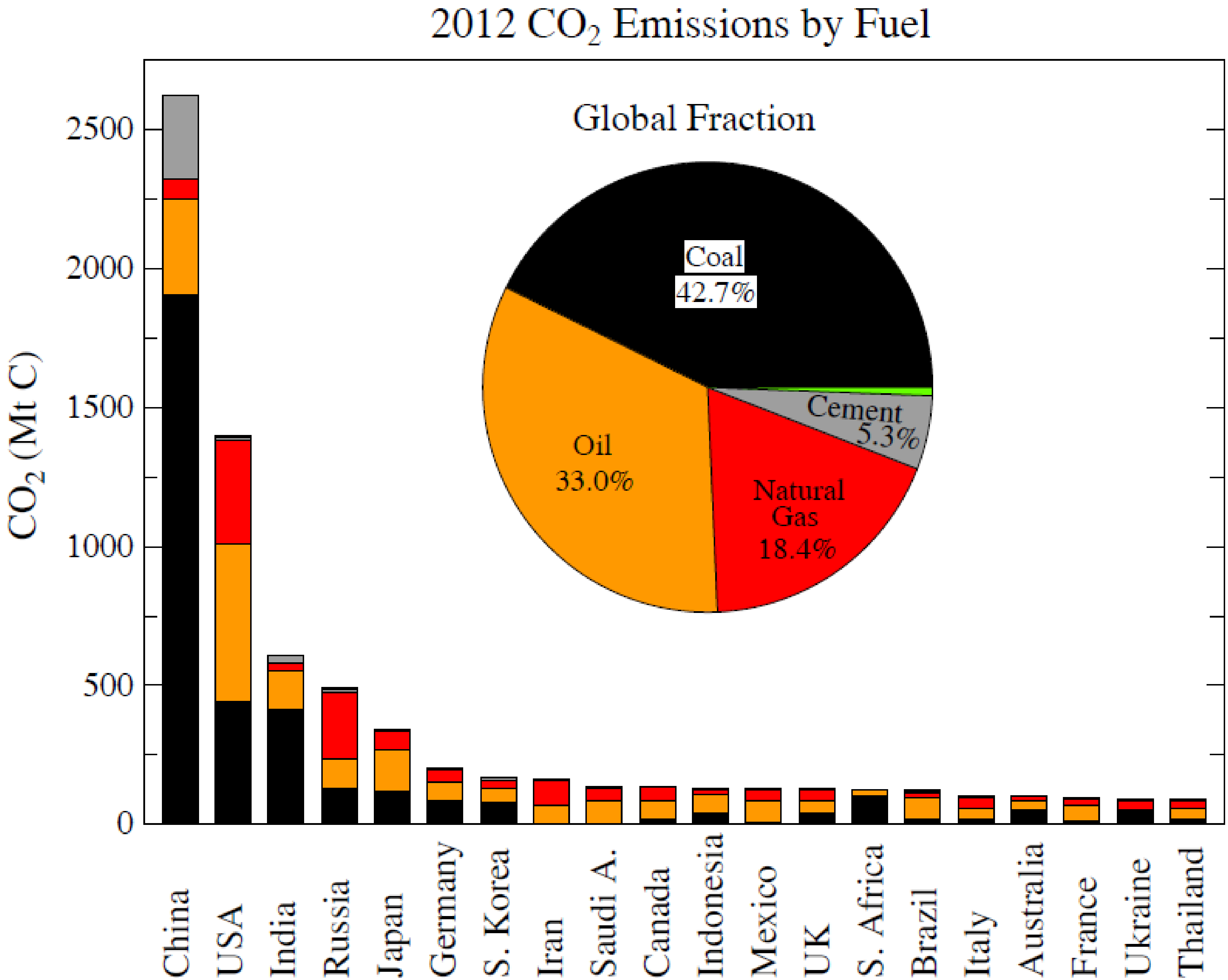
Weart caps his story with discussions about how the dissolution of the Soviet Union eased fears of nuclear war, but how disasters at Chernobyl and Fukushima have kept fear of radiation from nuclear power alive. Curiously, he devotes practically no attention to one key part of the story, the findings from the study of the atomic bomb survivors that have shown that the actual biological risk from nuclear radiation is surprisingly smaller than most people realize. The lifetime cancer death rate among those survivors went up less than one percent, and no biological effects at all have been detected among those who received lower doses (below 110 milliseiverts). No multi-generational genetic damage has been detected either. This omission is interesting, because Weart does not hesitate to argue that excessive fear of nuclear radiation is irrational and impedes development of nuclear power as one way to deal with climate change.

But it demonstrates how Weart has not written a pro-nuclear polemic. *The Rise of Nuclear Fear* is a fascinating, entertaining, insightful history, which offers an important lesson that reaches far beyond the nuclear issue itself. By illuminating the roots of our nuclear fears, and describing the vast impacts those fears have had, Weart offers an dramatic illustration of the affective/emotional/instinctive nature of risk perception in general, and a sobering lesson about how powerfully fear shapes the course of events.

Nuclear Energy Consumption
2013 Share of Total




(a) 2013 Annual Emissions (9.9 GtC/yr)
China 27.5%
USA 14.5%
India 6.5%
Russia 5.0%
Japan 3.4%
Germany 2.1%
UK 1.3%
Rest of Europe & Eurasia 10.1%
Rest of Asia Pacific 7.3%
Middle East 5.3%
S. & Cent. America 5.2%
Africa 3.4%
Ships/Air 6.0%
CanAus 2.5%
(b) 1751–2013 Cumulative Emis. (394 GtC)
USA 25.7%
China 11.2%
India 3.1%
Russia 7.3%
Japan 3.9%
German 5.9%
UK 5.2%
Rest of Europe & Eurasia 16.9%
Rest of Asia Pacific 4.4%
Mid East 3.0%
S. & Cent. America 4.1%
Africa 2.6%
Ships/Air 3.6%
CanAus 3.1%


2012 CO_2 Emissions by Fuel
Global Fraction
Coal 42.7%
Oil 33.0%
Natural Gas 18.4%
Cement 5.3%
CO_2 (Mt C)
0
500
1000
1500
2000
2500
China
USA
India
Russia
Japan
Germany
S. Korea
Iran
Saudi A.
Canada
Indonesia
Mexico
UK
S. Africa
Brazil
Italy
Australia
France
Ukraine
Thailand

Web Sites

www.columbia.edu/~jeh1

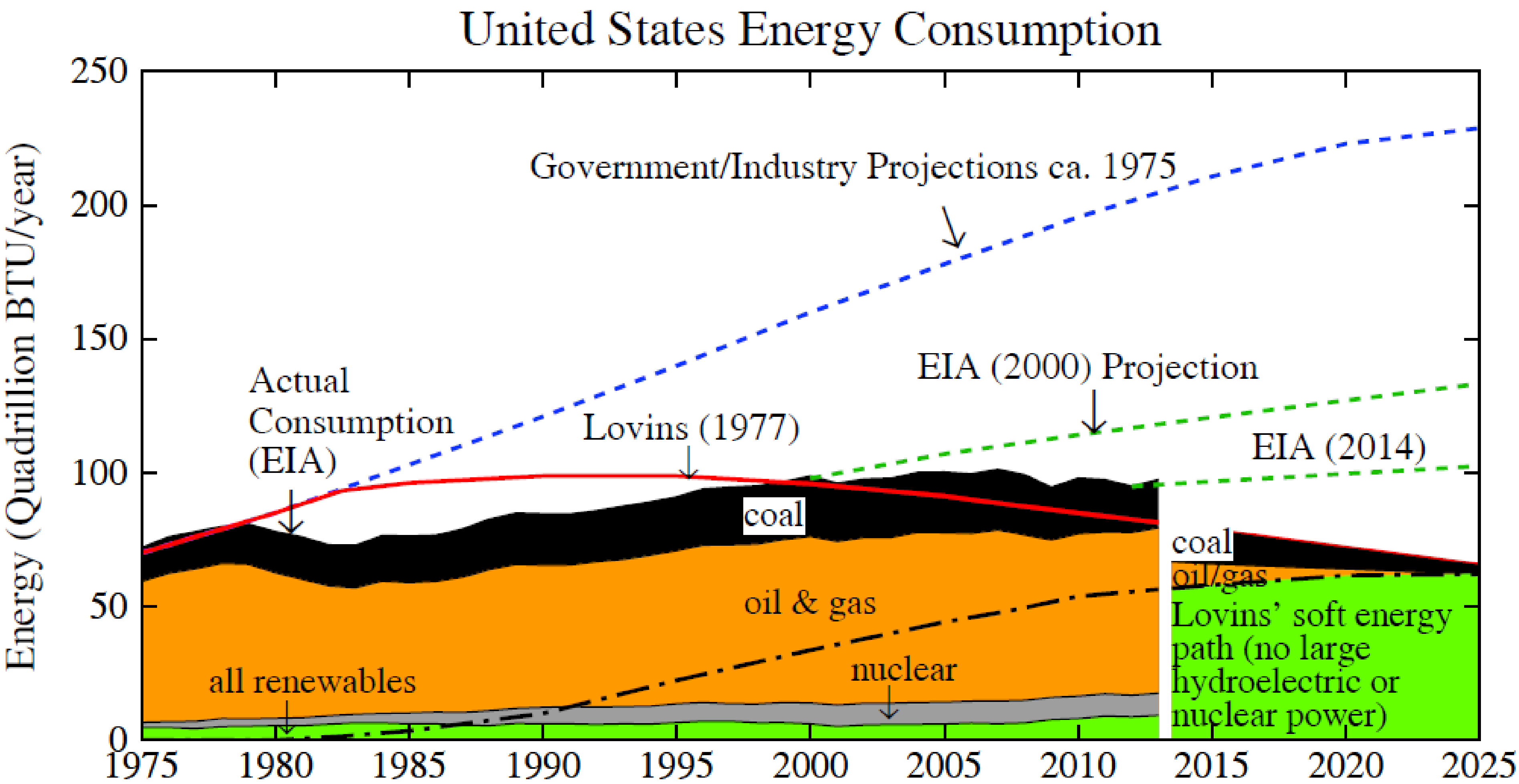
www.CitizensClimateLobby.org

www.OurChildrensTrust.org

Energy Source	Mortality Rate (deaths/trillionkWhr)	
Coal – global average	170,000	(50% global electricity)
Coal – China	280,000	(75% China's electricity)
Coal – U.S.	15,000	(44% U.S. electricity)
Oil	36,000	(36% energy, 8% electricity)
Natural Gas	4,000	(20% global electricity)
Biofuel/Biomass	24,000	(21% global energy)
Solar (rooftop)	440	(< 1% global electricity)
Wind	150	(~ 1% global electricity)
Hydro – global average	1,400	(15% global electricity)
Nuclear – global average	90	(17% global electricity)

Source: http://nextbigfuture.com/2008/03/deaths-per-twh-for-all-energy-sources.html
Some sources listed there were not functional, thus data and assumptions are questionable.

Figure-9: Mounting the fifth panel. The hoisting jig can be seen at the top of the roof and the rope used to pull the panels up onto the rails is currently not in use behind me.



Update of Fig. 2 of *Storms of My Grandchildren* (Hansen, 2009)
Data from U.S. Energy Information Administration