Networking in the Long Emergency

Barath Raghavan and Justin Ma
ICSI and UC Berkeley

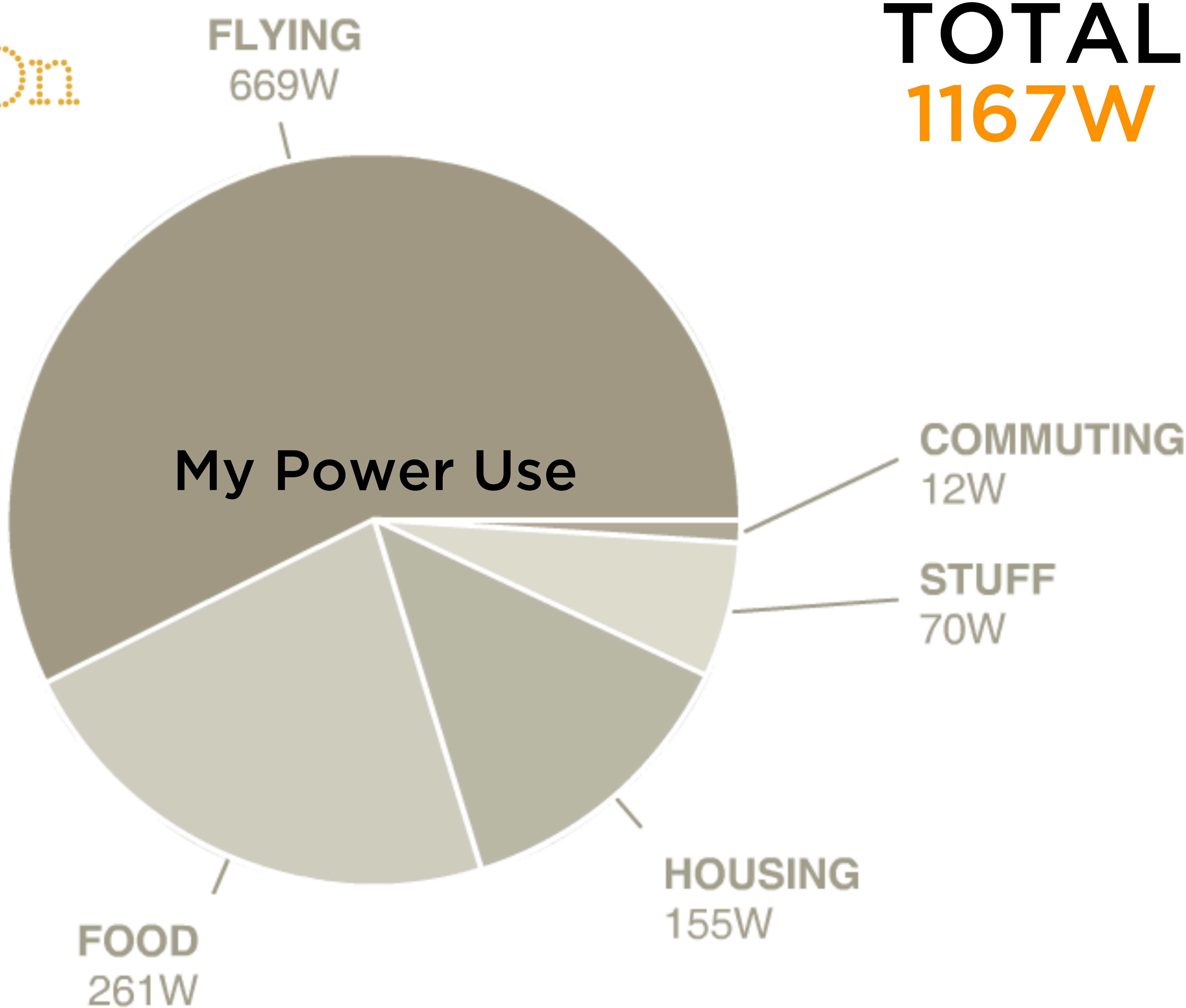
How do we use energy?

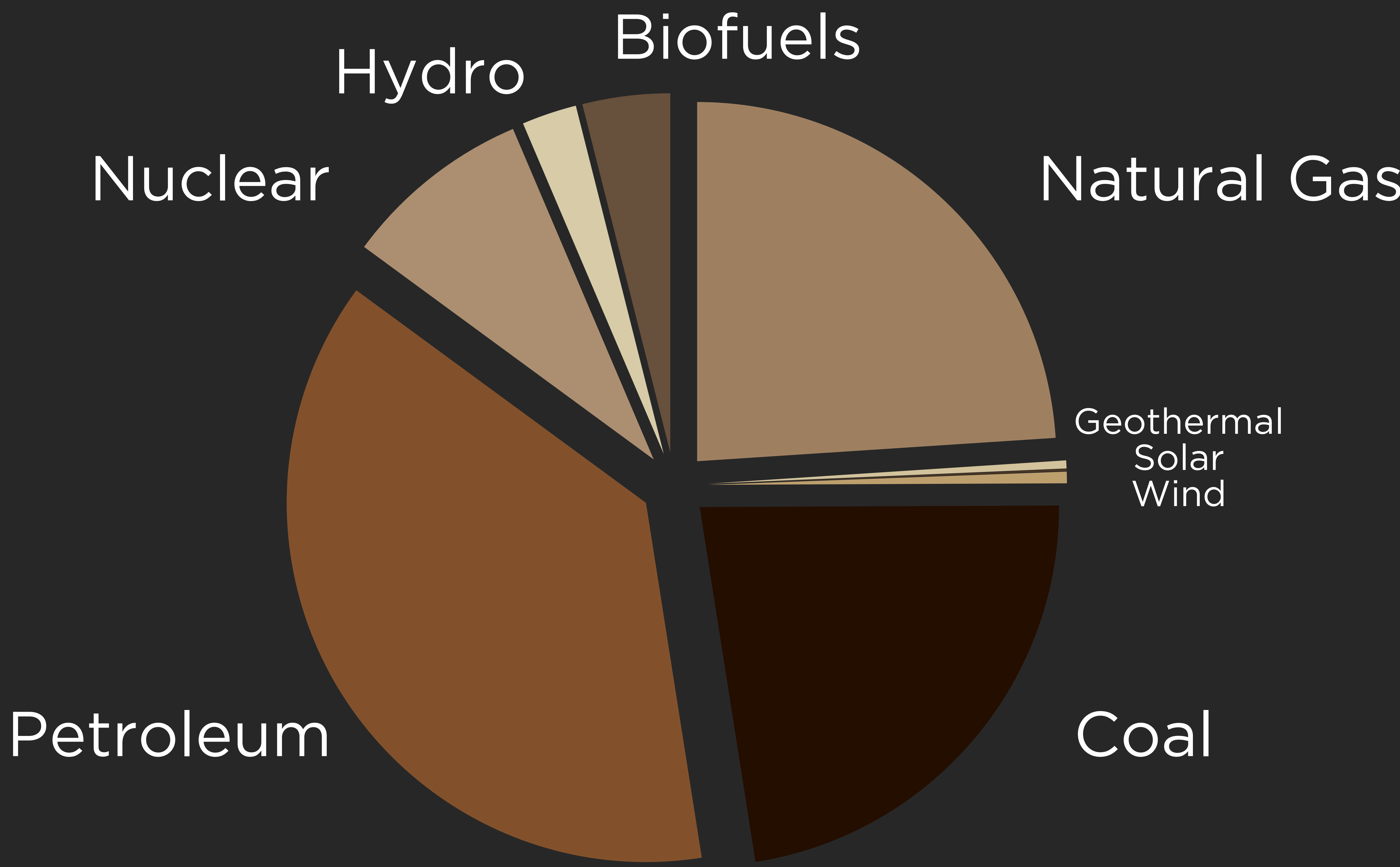
What are the consequences?

ENERGY

WattzOn

TOTAL
1167W





US Energy Sources 2008 [DOE EIA]

OIL

Why do we use oil?

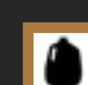
Easy to pump, transport, store

Stable at useful temperatures

Easily refined into numerous forms

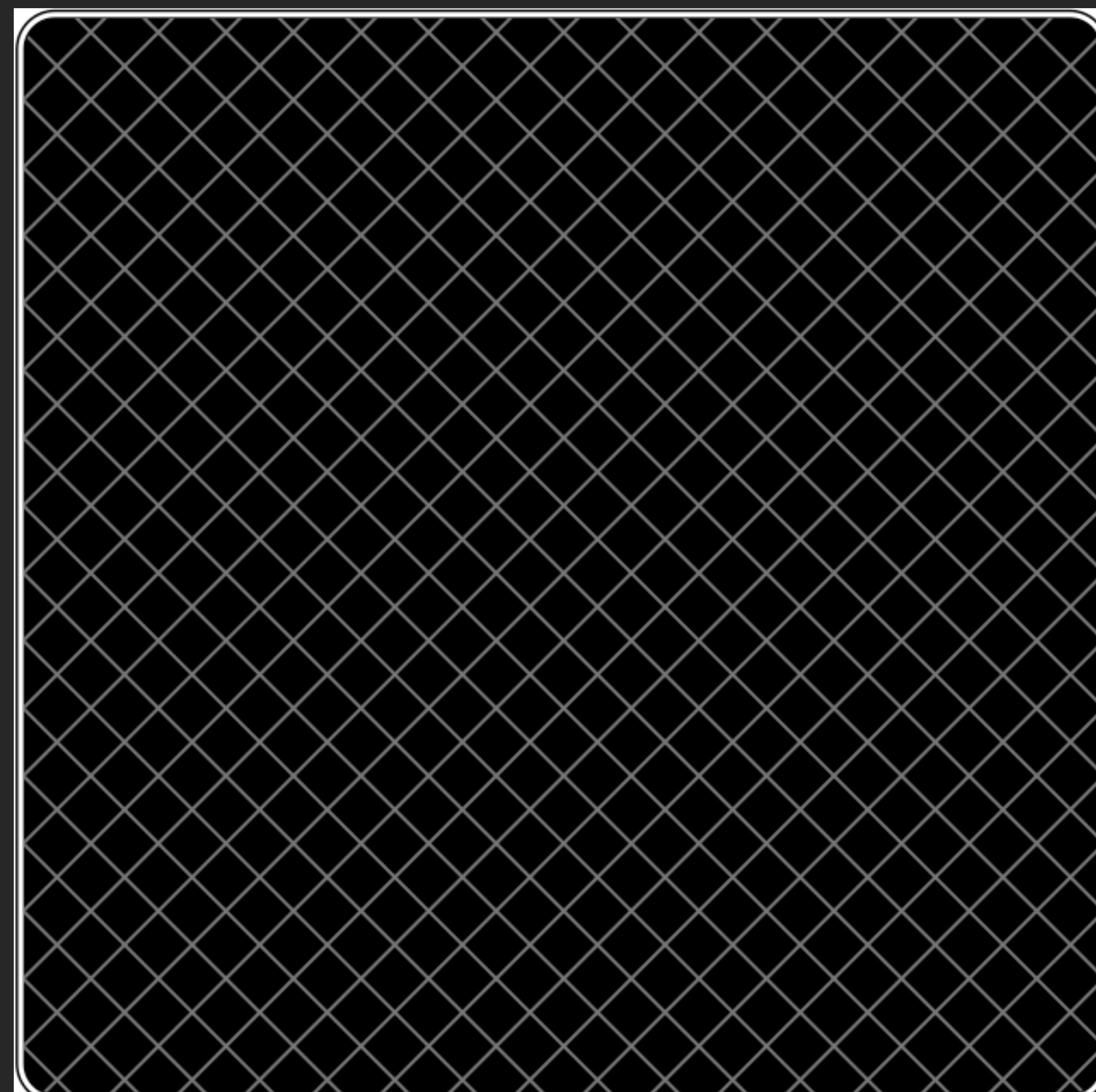
High energy density

1167W



Oil: 0.7 gallons/day

1167W



Solar PV: 418 sq. ft

(15% efficiency, good siting)

Food Production

Tilling, Planting, Irrigation, Pesticides, Harvesting, Packaging, Transportation

Transportation

Cars, Trucks, Planes, Ships, Trains, Buses

OIL

heart valves • asphalt • crayons • parachutes • phones • dishwashing liquid • IV drips • tape • pop tarts • smoke detectors • strollers • candles • chicken nuggets • antiseptics • credit cards • deodorant • tupperware • ziplock bags • panty hose • air conditioners • shower curtains • shoes • volleyballs • floor wax • lipstick • synthetic clothing • coal extraction • bubble gum • car bodies • tires • paint • pens • markers • hair dryers • ammonia • eyeglasses • contacts • insect repellent • pesticides • hair coloring • movie film • ice chests • loudspeakers • basketballs • footballs • combs/brushes • linoleum • fishing rods • rubber boots • water pipes • motorcycle helmets • fishing lures • petroleum jelly • lip balm • antihistamines • golf balls • dice • insulation • trash bags • rubber cement • cold cream • umbrellas • ink • hearing aids • CDs/DVDs • mops • bandages • artificial turf • cameras • glue • shoe polish • caulking • stereos • flooring • toilet seats • car batteries • refrigerators • carpet • pharmaceuticals • solvents • nail polish • lighters • balloons • artificial flavoring • perfumes • toothpaste • toothbrushes • plastic forks • hair curlers • plastic cups/lids • electric blankets • oil filters • light switches • guitar strings • skis • upholstery • thermoses • plastic chairs • clingwrap • rubber bands • computers • gasoline • diesel • kerosene • heating oil • motor oil • jet fuel • bunker fuel

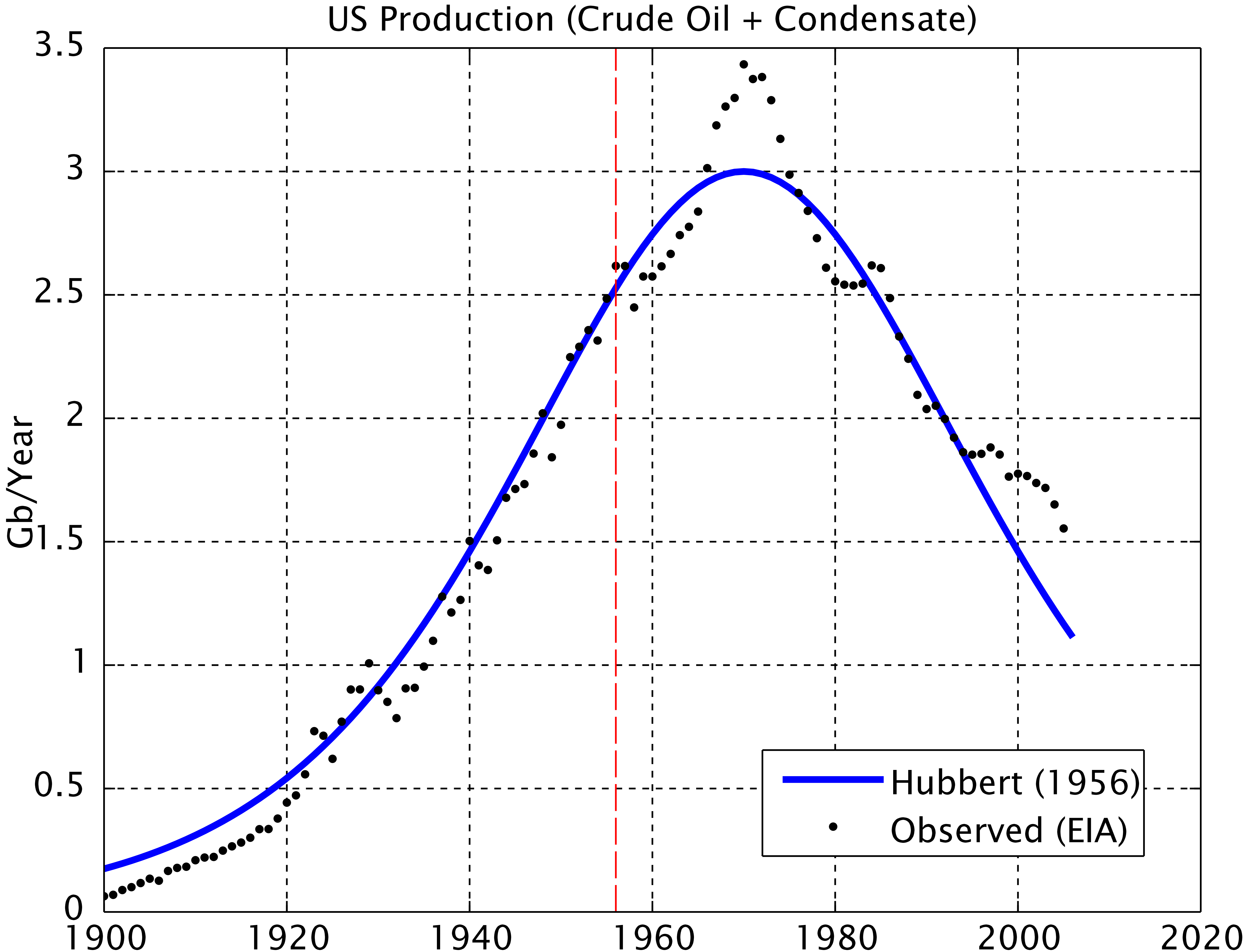
OIL DEPLETION

Oil Discovery

1. Sonar, etc. to map geological formations.
2. Drill test wells.

Oil Production

3. Build infrastructure.
4. Pump oil.
5. Production rate increases for some time.
6. Production rate declines.


US Production (Crude Oil + Condensate)
Gb/Year
3.5
3
2.5
2
1.5
1
0.5
0
1900
1920
1940
1960
1980
2000
2020
Hubbert (1956)
Observed (EIA)

“My grandfather rode a camel, my father rode a camel, I drive a Mercedes, my son drives a Land Rover, his son will drive a Land Rover, but his son will ride a camel.”

-- Sheikh Rashid bin Saeed Al Maktoum
(Prime Minister, UAE 1979-1990)

When might a final production peak occur?

In 2005, the US Department of Energy commissioned a study to answer this question, and to examine its consequences.

Peaking of World Oil Production: Impacts, Mitigation, and Risk Management, known as

The Hirsch Report

Hirsch Report: Projections

2006/7 - Bakhtiari
2007-9 - Simmons
2007+ - Skrebowski
2009 - Deffeyes
2010 - Goodstein
2010 - Campbell
2010+ - World Energy Council
2010-20 - Laherrere
2015 - Oxford University
2016 - DOE EIA
2020+ - CERA
2025+ - Shell Oil

“Peaking will result in dramatically higher oil prices, which will cause protracted economic hardship in the United States and the world. However, the problems are not insoluble. Timely, aggressive mitigation initiatives addressing both the supply and the demand sides of the issue will be required.”

[Hirsch05]

Other recent reports

UK Industry Task Force on Peak Oil (peak: 2014-2015)
German military (peak: 2010)
Kuwait university (peak: 2014)
US Defense Department (peak: 2012)
Lloyds of London (peak: 2013)

Upsides

Increased Iraqi production

Downsides

Net exports vs. gross production
Geopolitical instability
Overstated reserves / capacity

So Far...

Peak year: 2005 (conventional crude)
Peak month: July 2008 (conventional crude)
Peak year: 2011-2015? (all liquids)

Mitigation approach:

Burn more coal

Process coal, heavy oil, tar sands into synthetic fuels

Try to extract more oil from old fields

CLIMATE CHANGE

RESPONSES

Change behavior

(use less)

Change sources

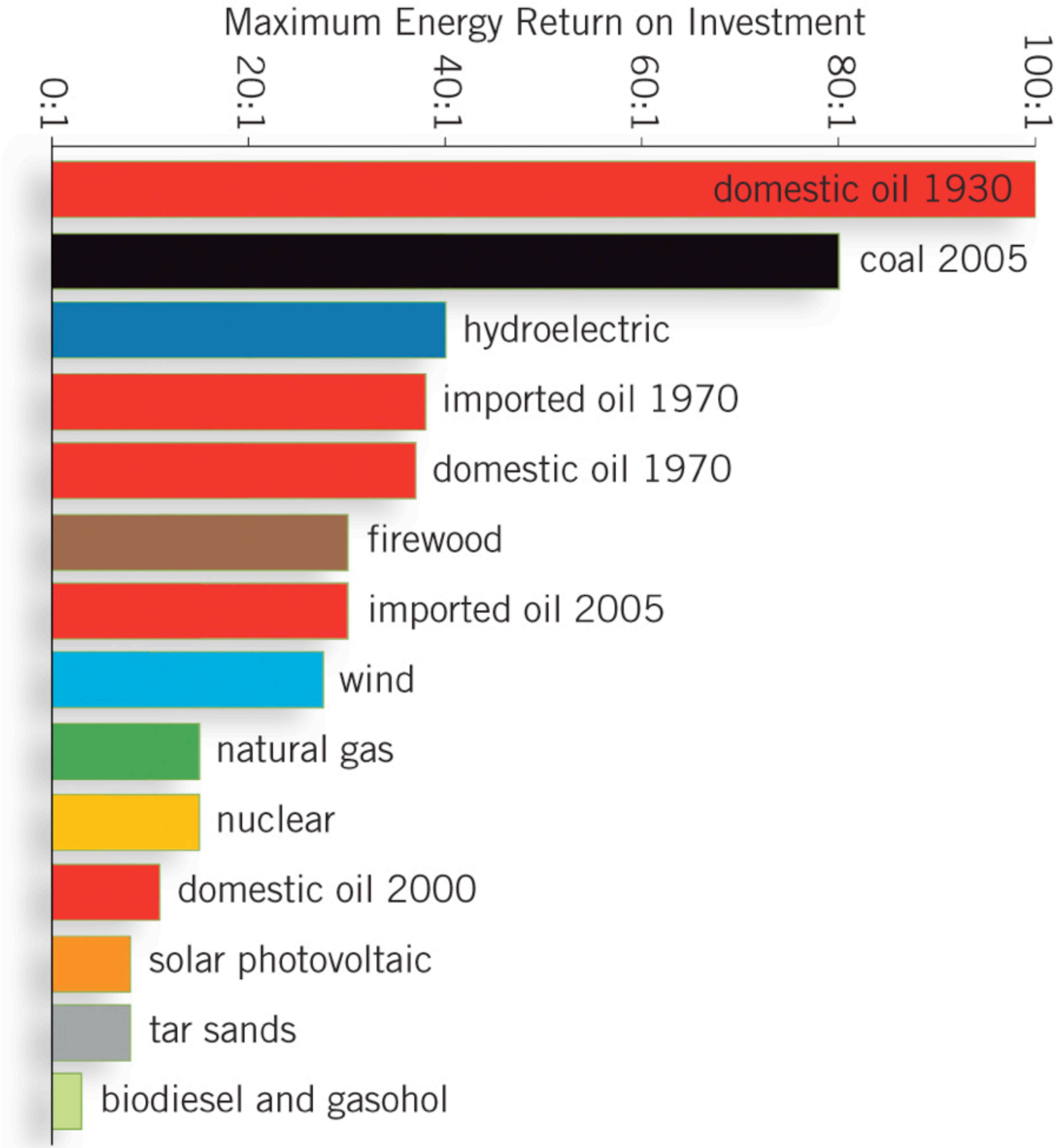
(find more)

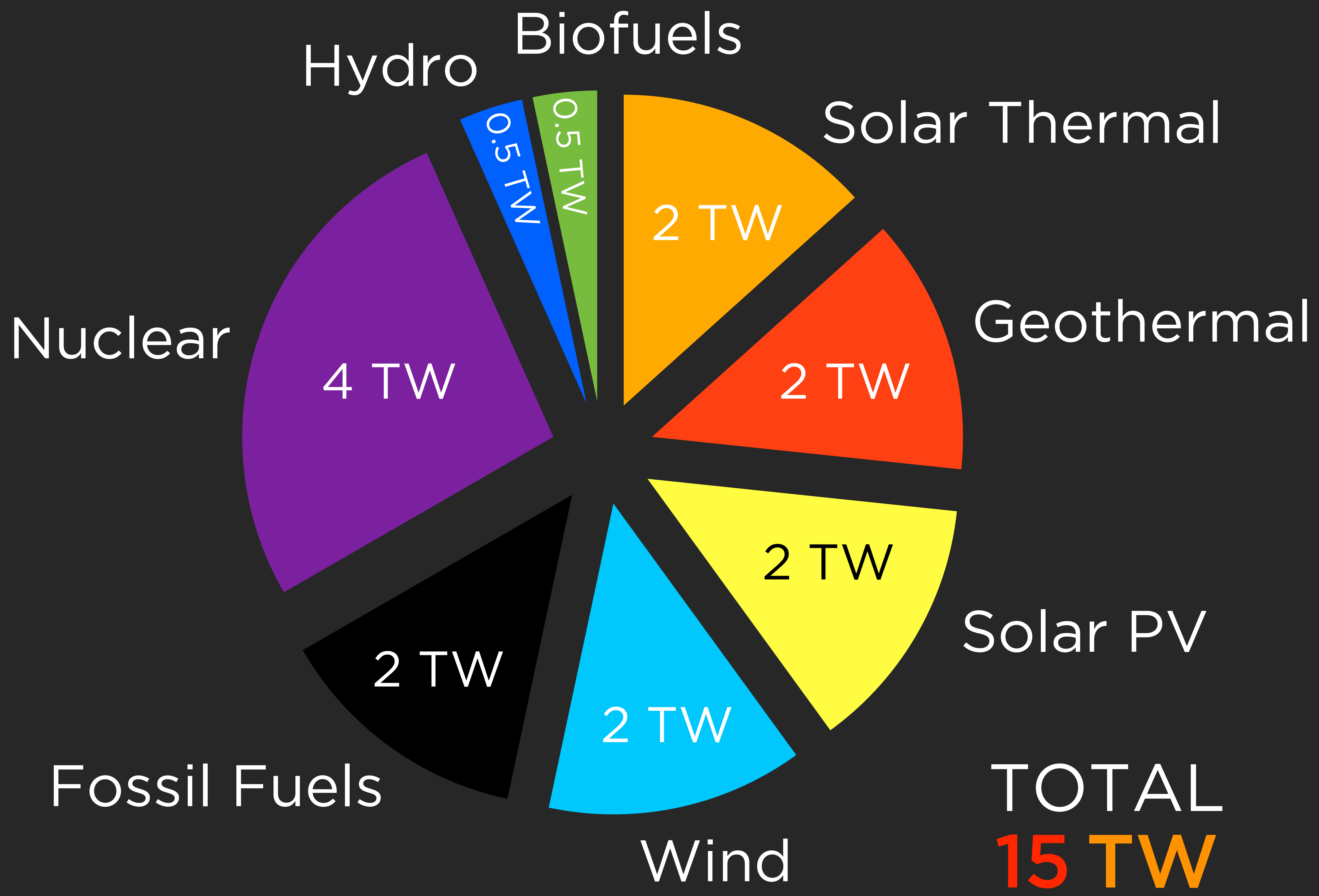
Oil depletion mitigation: move to coal and tar sands.

Climate mitigation: eliminate fossil fuel use, especially coal; move to non-carbon energy.

Both: eliminate fossil fuel use.

I was promised a Mr. Fusion


Maximum Energy Return on Investment
0:1
20:1
40:1
60:1
80:1
100:1
domestic oil 1930
coal 2005
hydroelectric
imported oil 1970
domestic oil 1970
firewood
imported oil 2005
wind
natural gas
nuclear
domestic oil 2000
solar photovoltaic
tar sands
biodiesel and gasohol



Power Profile for 2030-2035 [Griffith09]

Source (New capacity)	How Much? (New capacity in 2030-2035 mix)	How Fast? (Manufacturing rate required, sustained over 20 years)
Solar PV	2 TW	100 m^2 photovoltaic / sec
Solar Thermal	2 TW	50 m^2 mirrors / sec
Wind	2 TW	12 x 100m turbines / hour
Nuclear	3 TW	3 x 1GW plants / week
Geothermal	2 TW	3 x 100MW turbines / day
Biofuel	0.5 TW	1250 m^3 oil algae / sec

New Generating Capacity for 2030-2035 [Griffith09]

Source (New capacity)	How Fast? (Manufacturing rate required, sustained over 20 years)	Capacity (Optimistic estimate of manufacturing potential)
Solar PV	100 m^2 PV/sec	35 m^2 PV/sec
Solar Thermal	50 m^2 mirrors/sec	large?
Wind	12 x 100m turbines/hr	5 turbines/hr
Nuclear	3 x 1GW plants/wk	0.5 plants/wk
Geothermal	3 x 100MW turbines/day	3 turbines/month
Biofuel	1250 m^3 oil algae/sec	2 m^3 oil algae/sec

Energy transition: ~20 year crash program required.

Crash program: ~7 TW short by 2030s.

Oil peak: ~3 years until all-liquids peak.

CONSEQUENCES

Turning points

Peak per-capita gross energy production 1979

Peak net energy production ~1990

Peak conventional oil production 2005/2008

Peak total gross energy production 2011-2015

Turning points

Peak per-capita gross energy production 1979

Peak grain per capita ~1986

Peak wild fish catch 1989-1995

Peak net energy production ~1990

Peak fresh water availability ~2000

Peak conventional oil production 2005/2008

Peak total gross energy production 2011-2015

Peak coal ~2020s

Peak rock phosphorus ~2030s

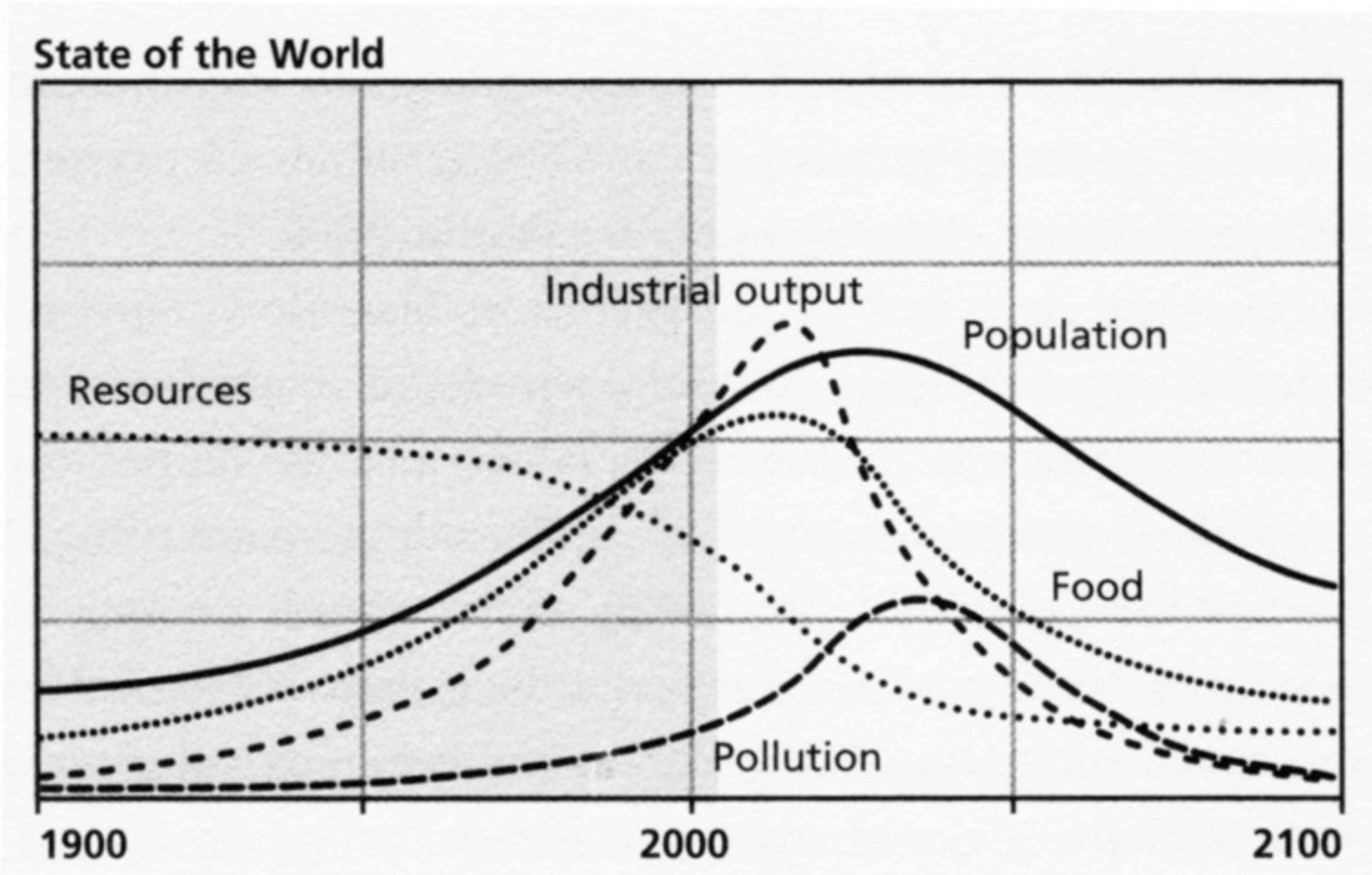
"The long-run impact of sustained, significantly increased oil prices associated with oil peaking will be severe. Virtually certain are increases in inflation and unemployment, declines in the output of goods and services, and a degradation of living standards. Without timely mitigation, the long-run impact on the developed economies will almost certainly be extremely damaging, while many developing nations will likely be even worse off."

[Hirsch05]

“Energy scarcity will cause a recession of a new kind - one from which anything other than a temporary, partial recovery will be impossible. We humans may, if we are intelligent and deliberate, create a different kind of economy in the future, building steady-state, low-energy, sustainable societies...But the industrial-growth global economy that we are familiar with will be gone forever. The timing of this event will depend upon that of the global petroleum production peak.”

[Heinberg03]

Limits to Growth


State of the World
Industrial output
Population
Resources
Food
Pollution
1900
2000
2100

[Meadows04]

NETWORKING IN THE LONG EMERGENCY

“If I had my finger on the switch, I’d keep the juice flowing to the Internet even if I had to turn off everything else…The Net is the one solvent we can still afford; jet travel can’t be our salvation in an age of climate shock and dwindling oil, so the kind of trip you can take with the click of a mouse will have to substitute.”

[McKibben10]

A SCENARIO

Premises

Volatile descent
Economic challenges
Liquid fuel constraints
Stalling trends
Relocalization
Shrinking user bases

PRINCIPLES

P1. TARGET ABSOLUTE CONSUMPTION

P2. ACCOUNT FOR ALL INPUTS

P3. REUSE HARDWARE + SOFTWARE

P4. DESIGN RESILIENT SYSTEMS

P5. BECOME MULTIDISCIPLINARY

P6. BUILD SELF-SUSTAINING SYSTEMS

Network Structure

Reevaluation

Integration

Components & Tools

Now What?

a) We have some serious challenges ahead
b) There's a lot that needs doing, soon
c) There's a lot we can do, if we're creative

READING

RECOMMENDED

Eaarth, McKibben
The Party's Over, Heinberg
The Long Descent, Greer

ENERGY

Peaking of World Oil Production, Hirsch et al.
Sustainable Energy without the Hot Air, MacKay

CLIMATE

Climate Change 2007 (3 volumes), IPCC
Six Degrees, Lynas

RELATED

The Ecotechnic Future, Greer
The Post Carbon Reader, Heinberg et al.
What We Leave Behind, Jensen
Deep Economy, McKibben
The Omnivore's Dilemma, Pollan

CLASSICS

Overshoot, Catton
The Structure of Scientific Revolutions, Kuhn
The Limits to Growth, Meadows
Technics and Civilization / The Myth of the Machine, Mumford
The Collapse of Complex Societies, Tainter

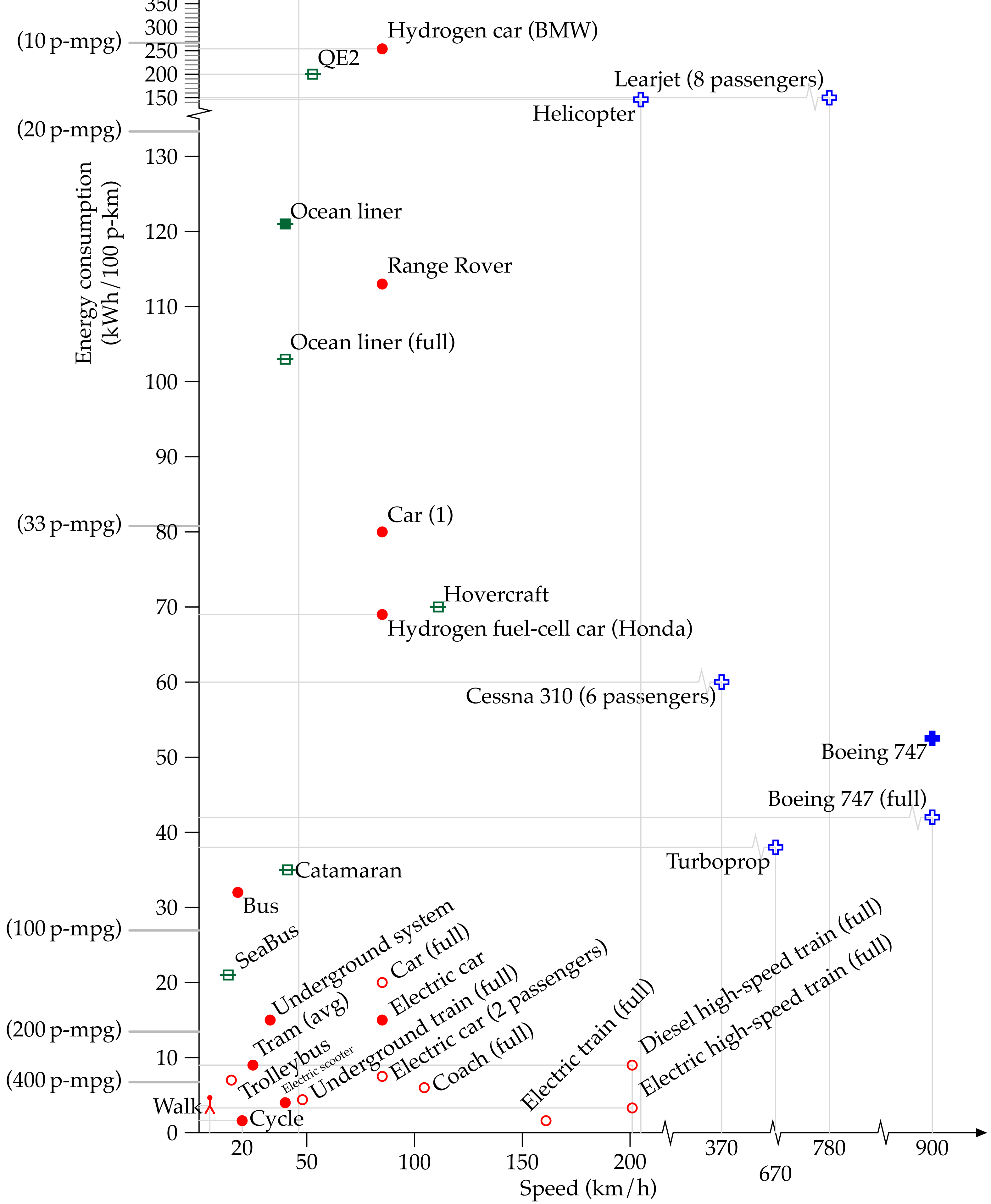
Non-Goals

a) Present an optimistic or pessimistic view

b) Address ethical or political questions

c) Predict cornucopia or apocalypse

The Pacific Electric Railway
Los Angeles, 1956



Transportation [MacKay09]

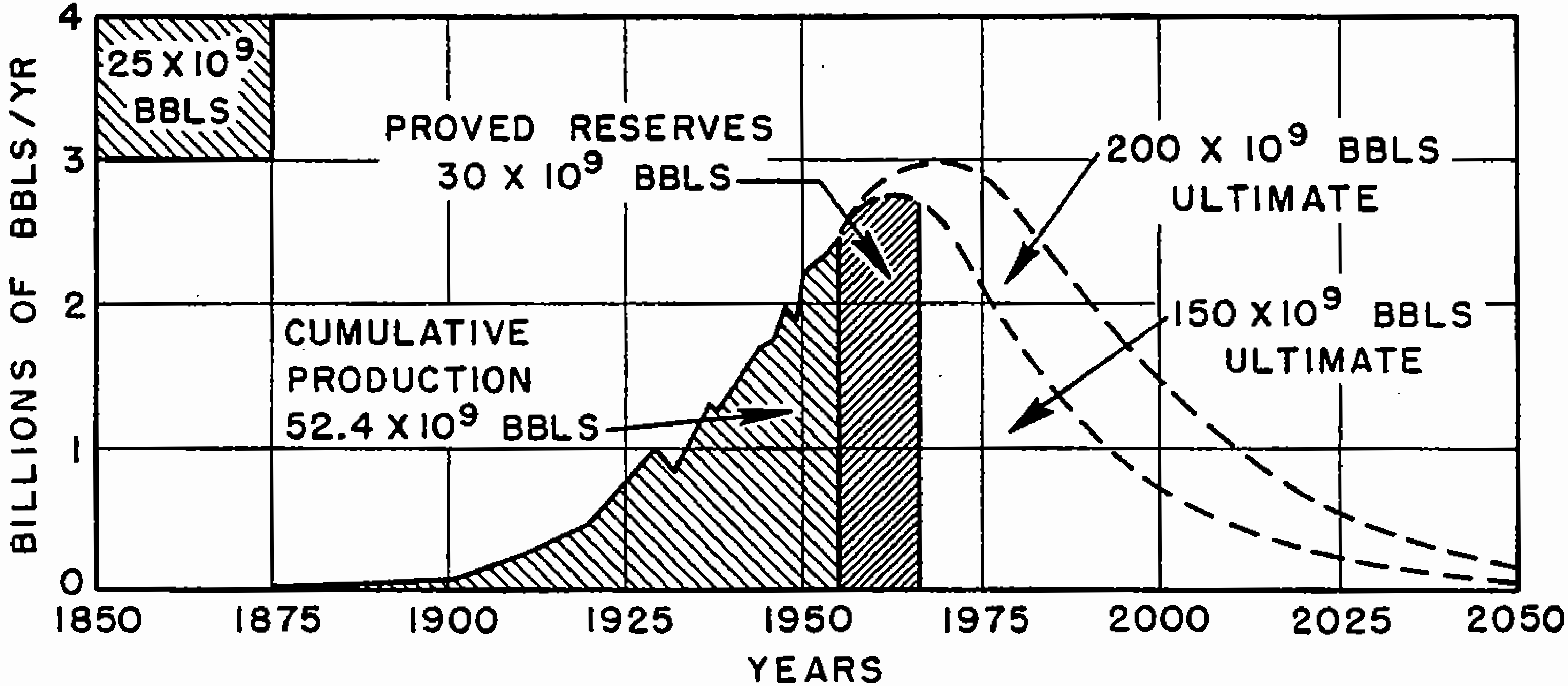


Figure 21 – Ultimate United States crude-oil production based on assumed initial reserves of 150 and 200 billion barrels.

Projection of US oil production [Hubbert56]

“It is difficult for people living now, who have become accustomed to the steady exponential growth in the consumption of energy from the fossil fuels, to realize how transitory the fossil fuel epoch will eventually prove to be when it is viewed over a longer span of human history.”

[Hubbert71]

Running the Numbers [chrisjordan.com]

The Oil Age

World Oil Production 1859 - 2050

Oil is created from the remains of plants and animals distilled over millions of years. The source of most oil found today can be traced to two brief periods of global warming some 90 and 150 million years ago, and to the shallow seas teeming with algae that covered much of the earth at the time. As generations of sea life settled to the bottom, a unique carbon-rich sedimentary rock was formed. Over time, some of the rock sank to just the right depth, where the earth's natural heat gently cooked the rock's organic fraction, transforming it into a dark liquid. Petroleum—literally "rock oil"—was born.

After its creation, oil can migrate great distances, and much of it eventually escapes to the surface. Prehistoric humans gathered thick crude from pools and smeared it on boats and dwellings to repel water. Seeps of burning crude entranced ancient man, inspiring at least one religion.[8] The Chinese and Indians made medicines from petroleum, while oil-infused "Greek fire" wreaked havoc on Medieval battlegrounds.

The Oil Age began in earnest in 1859, when Edwin Drake drilled one of the world's first commercial oil wells in Titusville, Pennsylvania. Mankind had discovered how to tap the immense stores of oil—some two trillion barrels—that lay trapped below the earth under cap rock. In the early decades of the oil age, most petroleum was refined into kerosene for illuminating the homes and businesses of a rapidly industrializing world.

Oil proved more effective than coal in running the world's navies, trains and shipping networks. The rise of the automobile propelled demand for a new type of refined oil—gasoline—that surpassed kerosene in total production by 1910. Oil revolutionized war, fueling a new generation of motorized tanks, airplanes and submarines. Oil powered the rapid suburbanization of America in the 1950s and 1960s, as millions took to the road and air travel took off.

Innumerable everyday products—from pharmaceuticals to clothing to computers—depend on oil and its refining into complex chemicals and plastics. Modern industrial farming, which feeds much of the world, would grind to a halt if it were deprived of diesel-powered tractors, oil- and gas-based fertilizers to grow and harvest crops, and the fossil fuels to process, package and ship food to supermarkets worldwide. Stoked with cheap calories, the world's population has skyrocketed—from 1.5 billion at the start of the Oil Age to more than 6 billion in 2005.

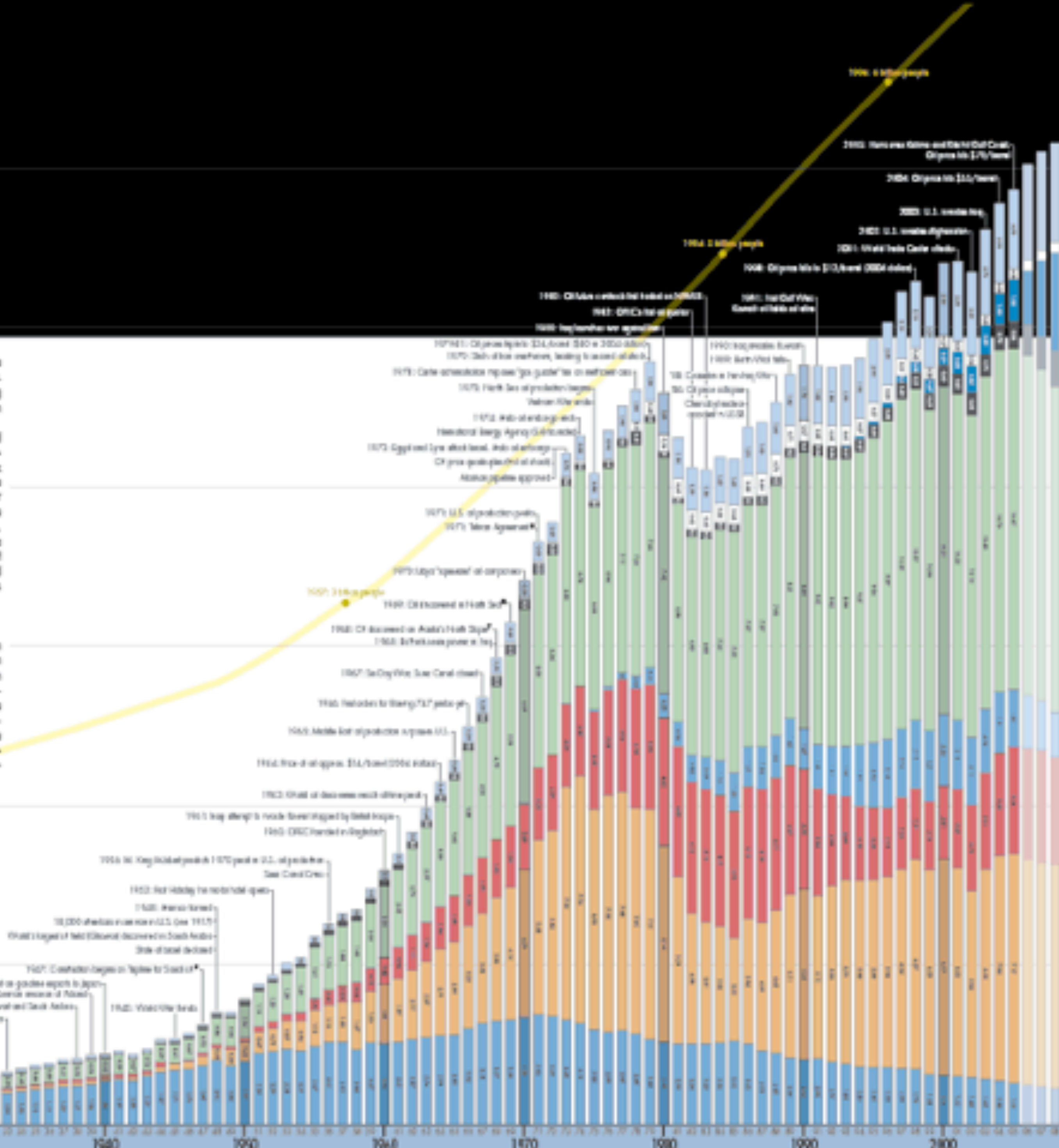
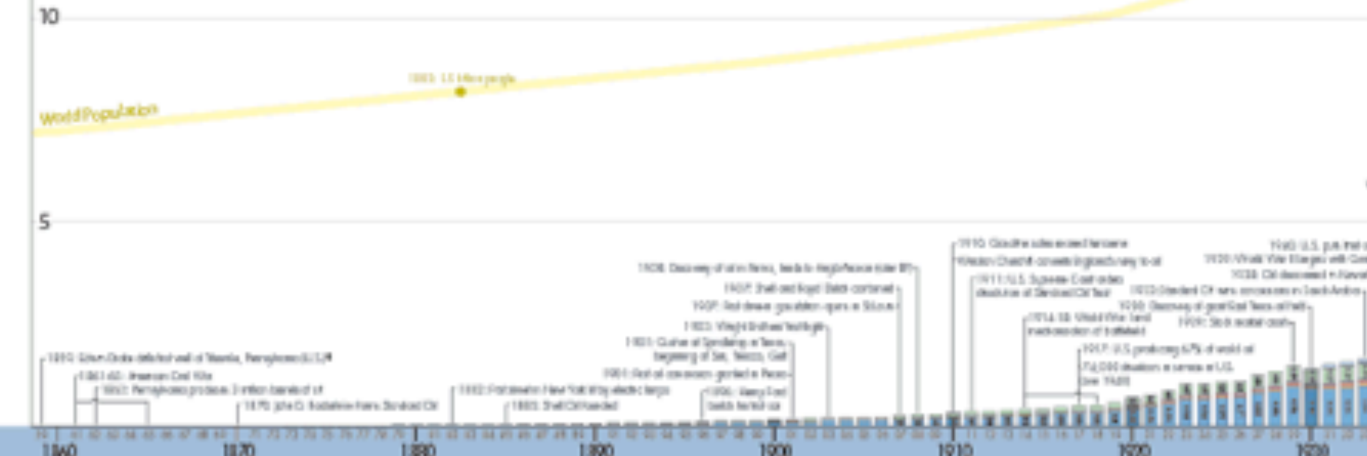
Oil is an incredibly dense energy source. A gallon of crude weighing 3.2 kilos generates as much energy as five kilos of coal, 10 kilos of wood, or the work of 50 people toiling all day. Oil supplies about 40% of the industrial world's total energy needs and 95% of the fuel used to transport people and goods. Uniquely portable, oil can be shipped anywhere in the world in tankers, trucks and trains. Interruptions in the flow of oil have led to severe disruptions in industrial societies, as witnessed during the 1973 and 1979 oil shocks.

Oil is finite and non-renewable. Of the earth's total endowment of conventional crude, we've consumed about half so far. Discovery of oil peaked in the mid-1960s and by the early 1980s we began consuming more oil than we found. Today experts say we consume about four to six barrels of oil for each one discovered, a trend that is leading the world to an inevitable turning point: the peak and then decline of global oil production.

The bell-curved phenomenon of oil production and depletion was first explored by geophysicist M. King Hubbert, who in 1956 correctly predicted the 1970–1971 peak in U.S. production. Today, about three-quarters of the world's largest oil-producing countries have reached their peak and have fallen into permanent decline.[9] Indeed, if the projections of a growing number of scientists prove correct, we are now entering the second half of the Oil Age, an era characterized by ever-dwindling supplies of man's most essential commodity. Whether substitutes can be developed soon enough to sustain modern energy-intensive societies is a question that looms larger every day.

About the Oil Depletion Model

Almost 200 years of the Oil Age are depicted in the main chart, which combines historical oil production data with projections of future output published by the Association for the Study of Peak Oil & Gas (ASPO), a network of scientists dedicated to studying the "date and impact of the peak and decline of world oil and gas production." Estimates of future oil output are based on public and private assessments of the world's ultimately recoverable oil supplies and assumptions regarding the future rate of depletion for individual countries.[a]

The Power of Oil

Transportation

Electricity and Heat

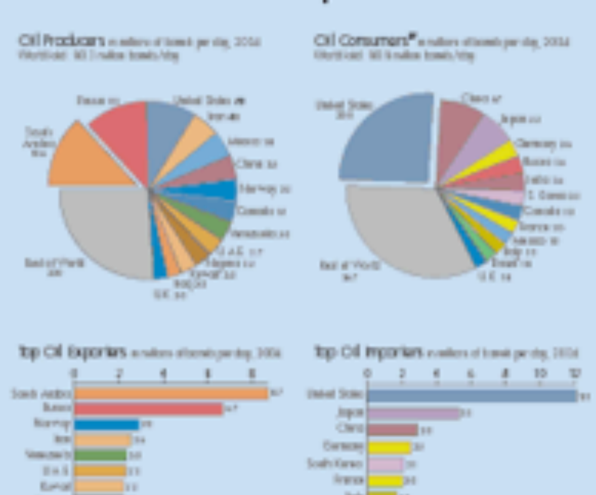
Food

Chemicals and Plastics

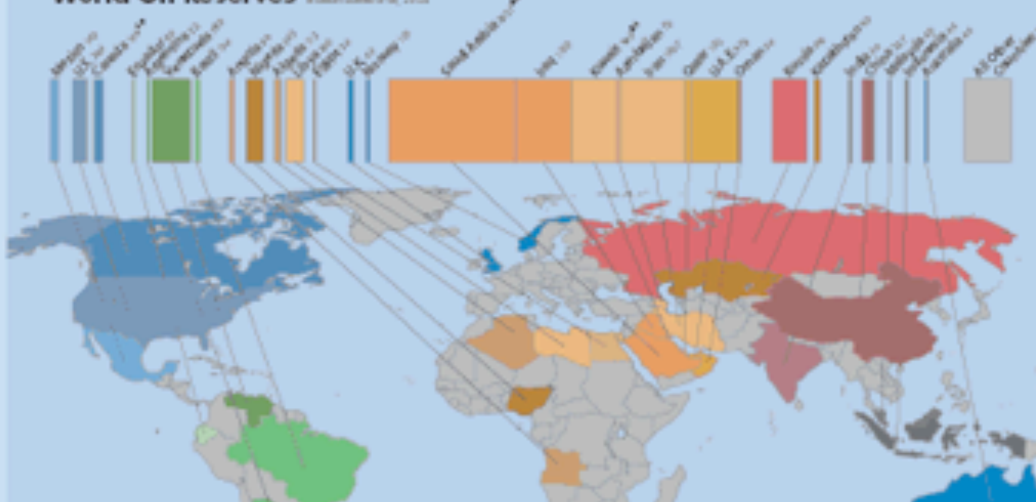
Energy Sources

Energy Profit Ratio

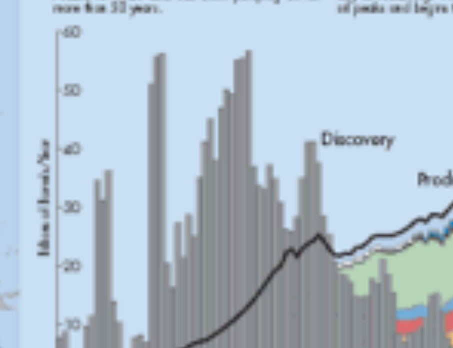
Production and Consumption*



World Oil Reserves*



The Growing Gap*



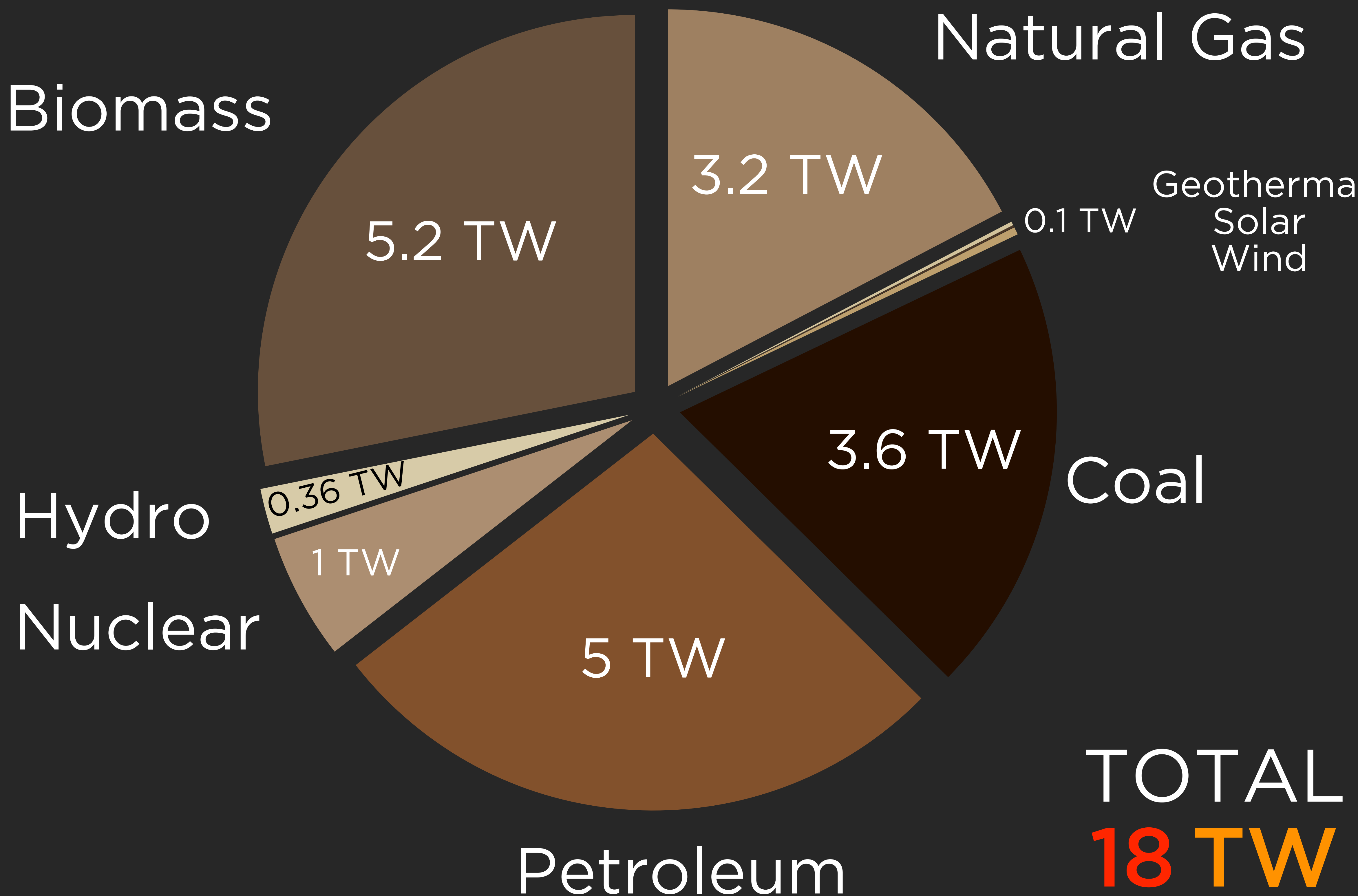
Energy consumed and what we paid for it (adjusted to 2010 dollars) for 20-year period 1989 – 2008 from latest US Department of Energy data

Year	Quads	Energy Expenditure	% Increase
1989	84.9	770,317,000,000	1.71
1990	84.7	789,162,000,000	2.45
	84.6	754,077,000,000	-4.45
	86.0	739,829,000,000	-1.89
	87.6	741,806,000,000	0.27
	89.3	742,545,000,000	0.10
1995	91.2	736,226,000,000	-0.85
	94.2	779,036,000,000	5.81
	94.8	770,844,000,000	-1.05
	95.2	703,842,000,000	-8.69
	96.8	729,094,000,000	3.59
2000	99.0	869,599,000,000	19.27
	96.3	856,094,000,000	-1.55
	97.9	803,648,000,000	-6.13
	98.1	895,448,000,000	11.42
	100.3	1,006,567,000,000	12.41
2005	100.4	1,170,194,000,000	16.26
	99.8	1,255,606,000,000	7.30
	101.5	1,299,141,000,000	3.47
2008	99.4	1,431,655,000,000	10.20
		$17,844,730,000,000	

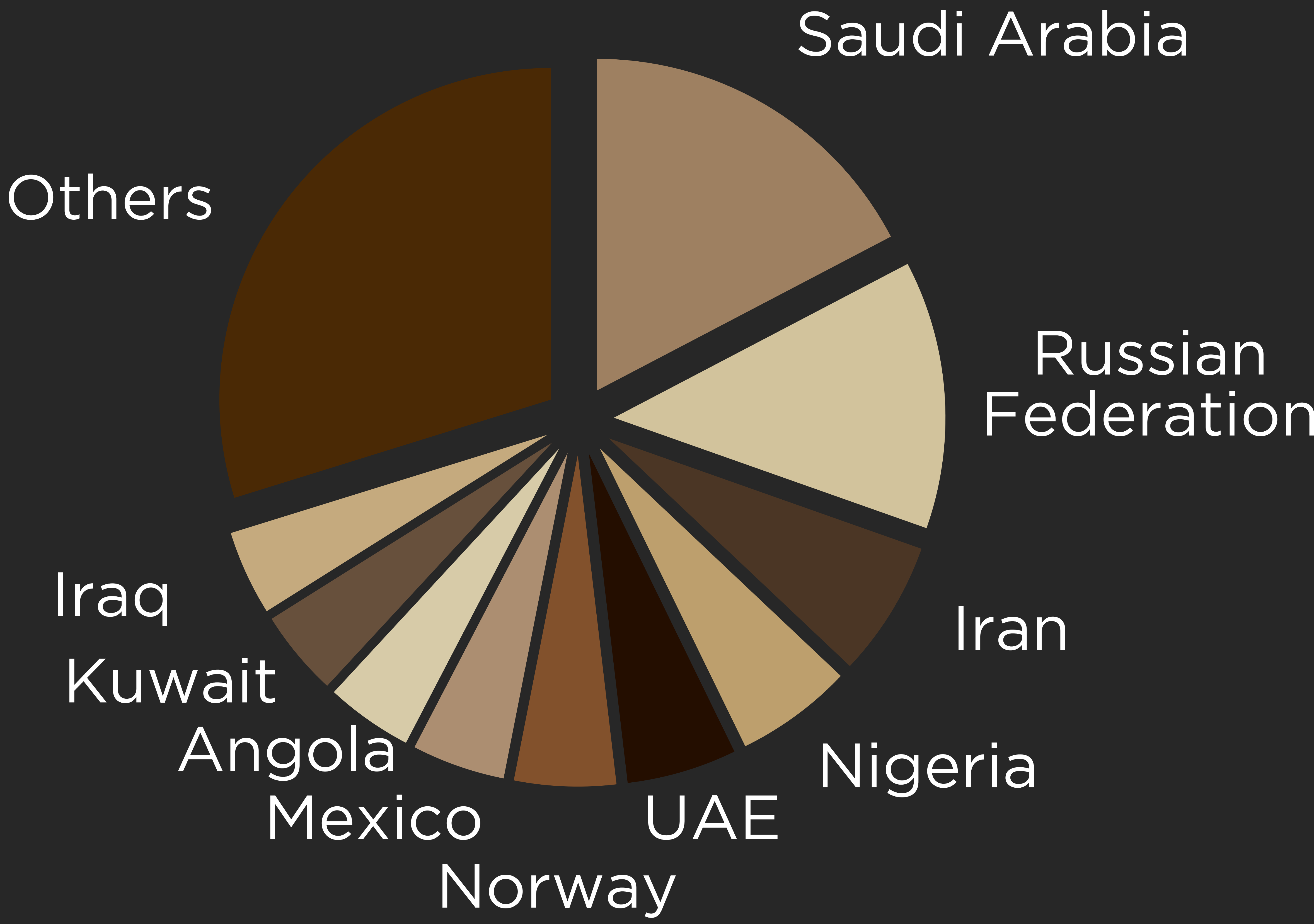
Large increase in energy: no increase in cost

Very large increase in cost of energy: no increase in quantity of energy

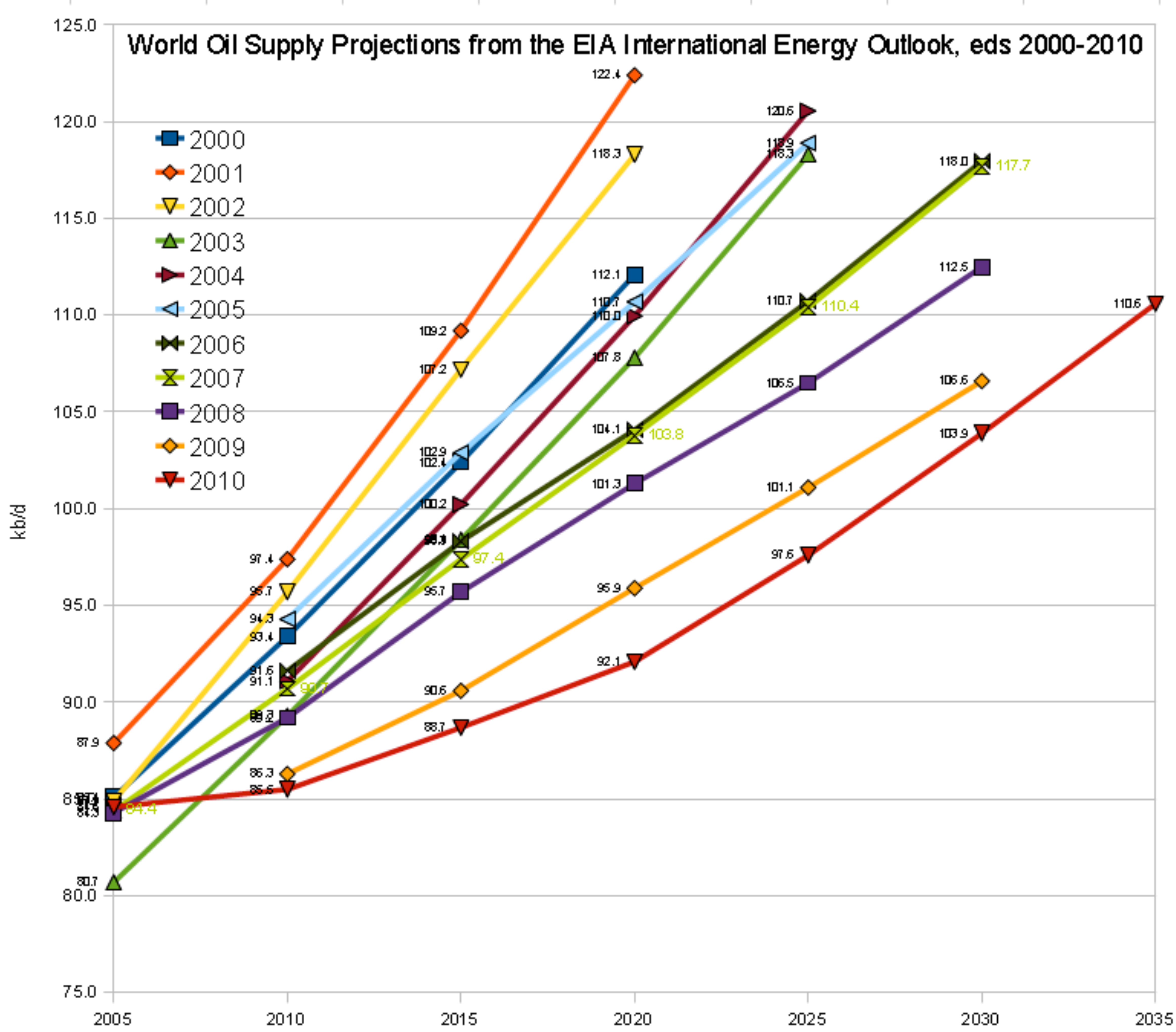
Very high rate of increase in cost of energy



World Power Production 2007 [IEA/Stanford GCEP/Griffith09]



Net Oil Exports 2007 [IEA]


World Oil Supply Projections from the EIA International Energy Outlook, eds 2000-2010
kb/d
125.0
120.0
115.0
110.0
105.0
100.0
95.0
90.0
80.0
75.0
2005
2010
2015
2020
2025
2030
2035
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

Hirsch Report: Overview

“The era of plentiful, low-cost petroleum is approaching an end. The good news is that commercially viable mitigation options are ready for implementation. The bad news is that unless mitigation is orchestrated on a timely basis, the economic damage to the world economy will be dire and long-lasting.

In the following, we describe the nature of the problem, options for mitigation, and required timing. The exact date of peaking is not known; some think it will be soon, others think a decade or more. However, the date is almost irrelevant as mitigation will take much longer than a decade to become effective, because of the enormous scale of world oil consumption.”

“Waiting until world oil production peaks before taking crash program action leaves the world with a significant liquid fuel deficit for more than two decades.”

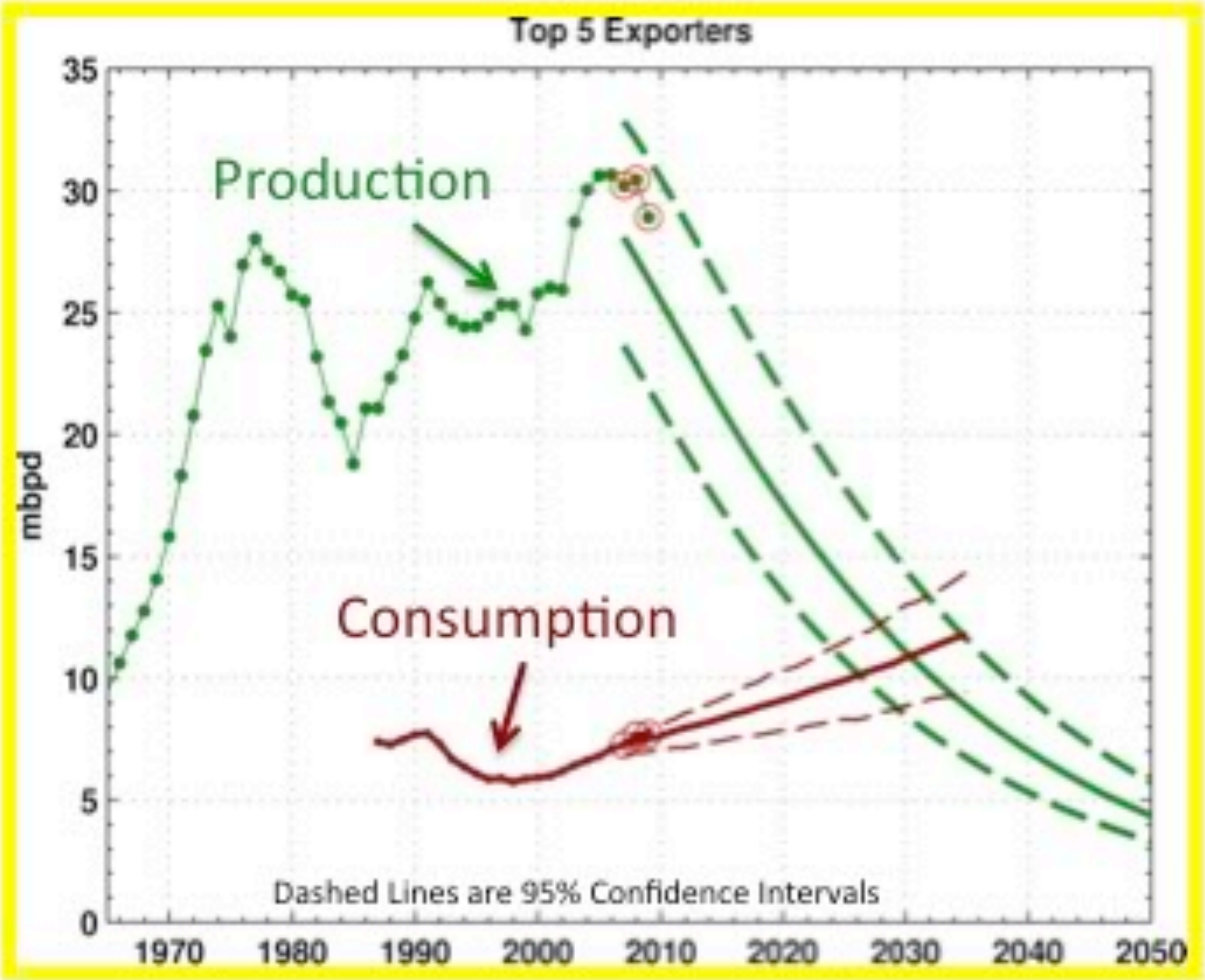
[Hirsch05]

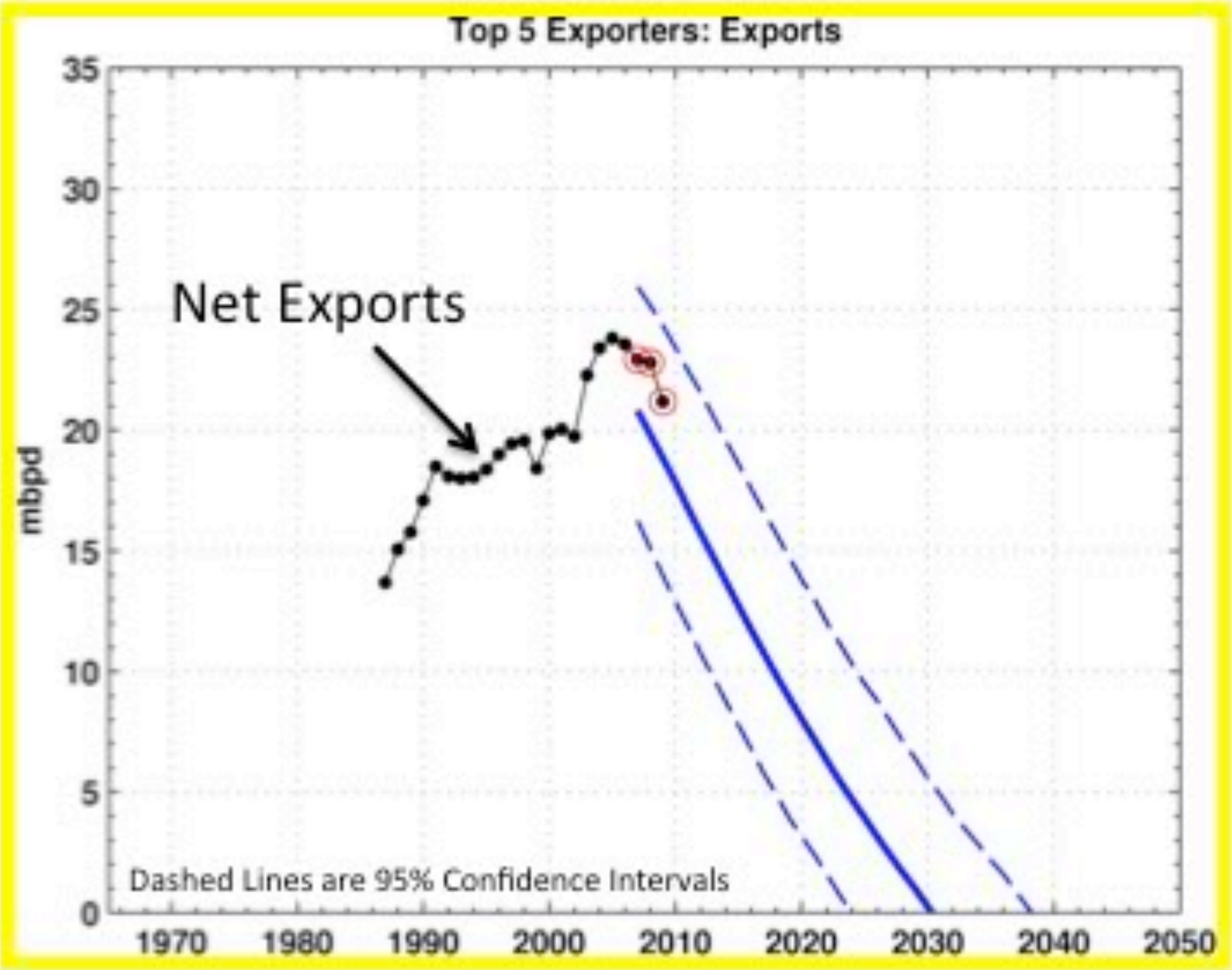
Hirsch Report: Summary

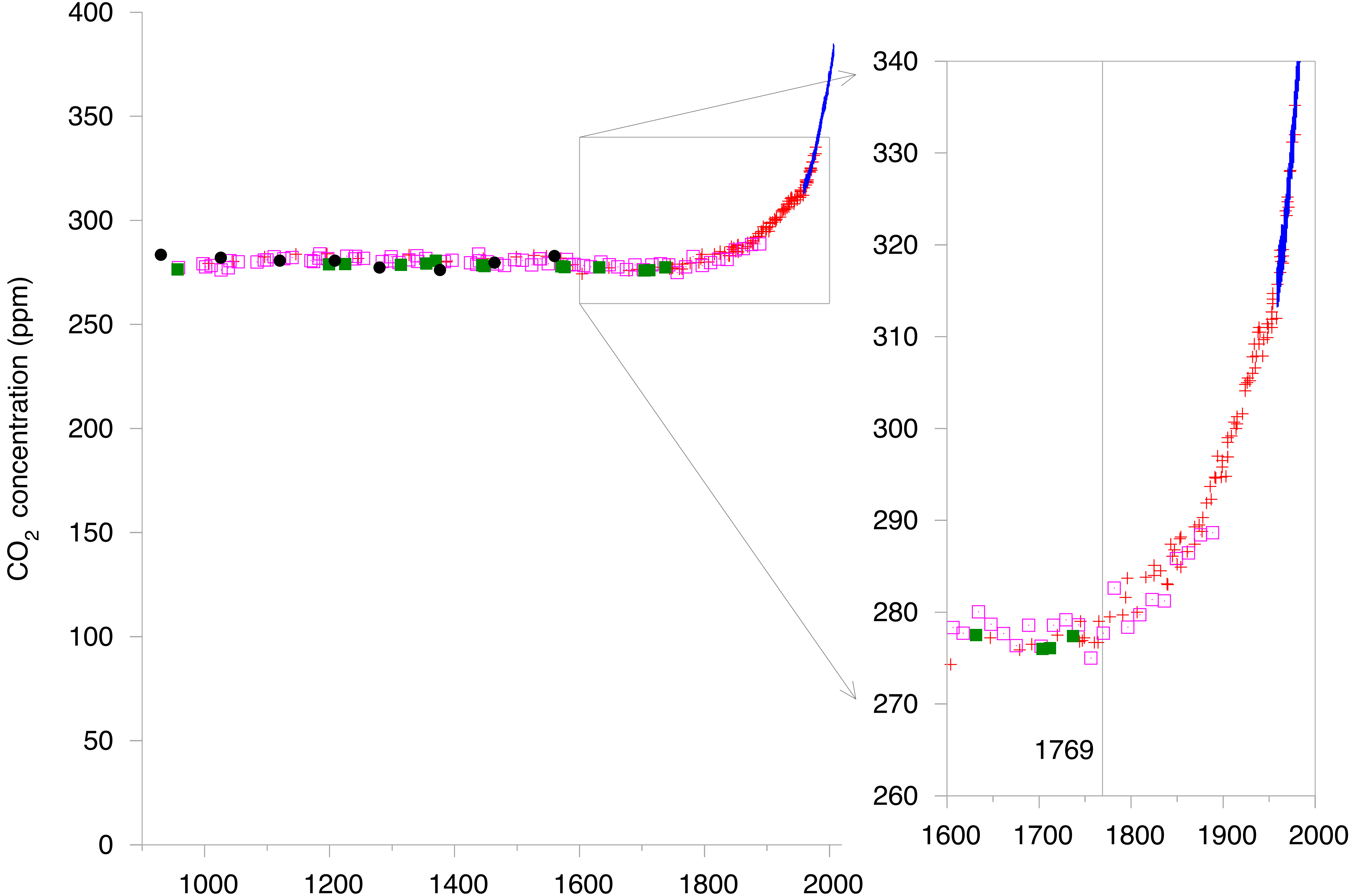
“The world has never faced a problem like this. Without massive mitigation more than a decade before the fact, the problem will be pervasive and will not be temporary. Previous energy transitions (wood to coal and coal to oil) were gradual and evolutionary; oil peaking will be abrupt and revolutionary.”

[Hirsch05]

Actual and Projected Production, Consumption, and Net Exports for (2005) Top 5 Net Exporters

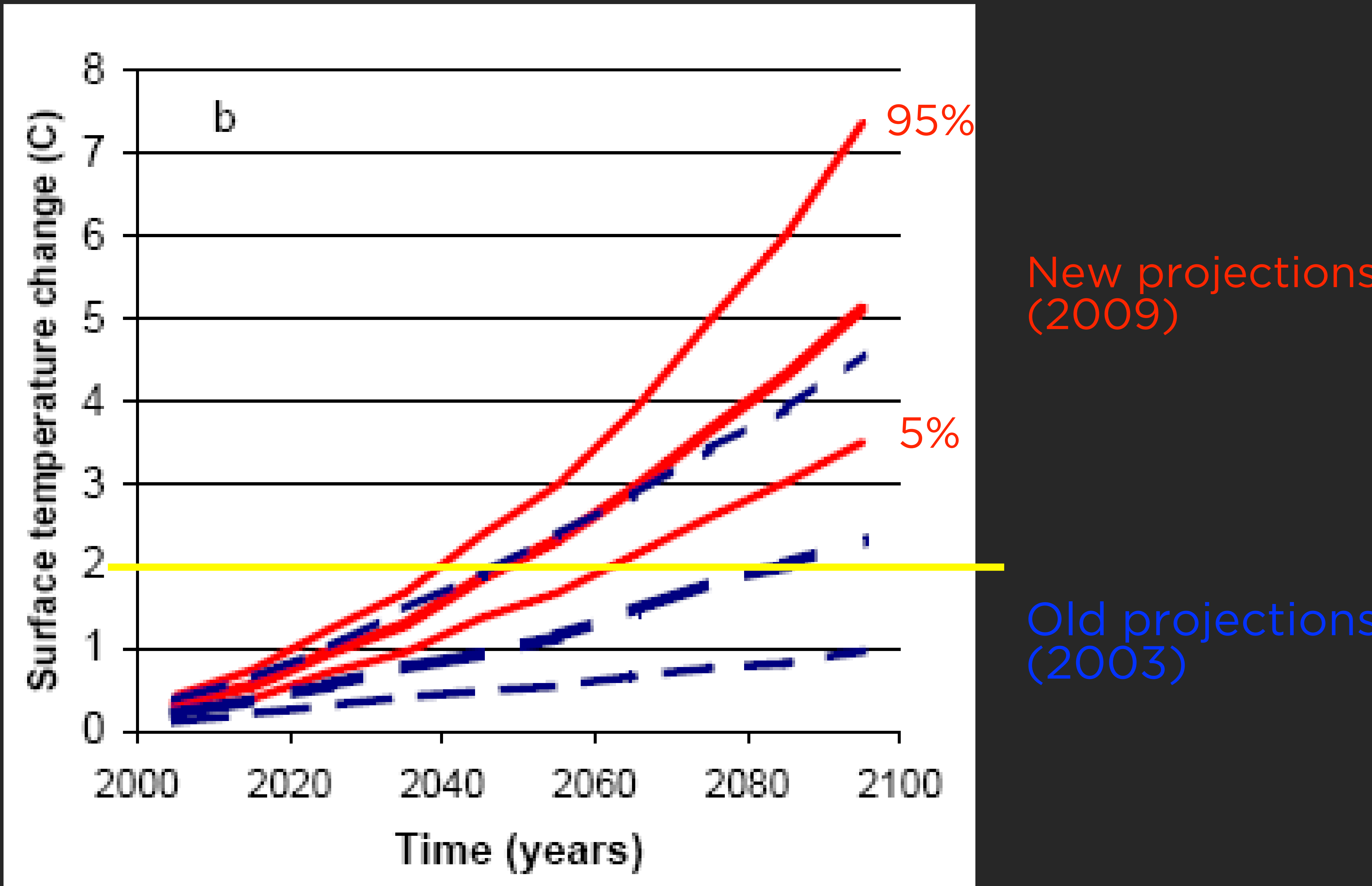






400
350
300
250
200
150
100
50
0
CO_2 concentration (ppm)
1000
1200
1400
1600
1800
2000
340
330
320
310
300
290
280
270
260
1769
1600
1700
1800
1900
2000

[MacKay09]



MIT Probabilistic Warming Projections [Sokolov et al. 09]

What Do Degrees C Mean?

1 degree Ice-free arctic summer, polar ecosystem damage; coral reef bleaching; stronger hurricanes; erratic weather

2 degrees Lots of problems; 10-15% species extinction; most coral reefs bleached; permafrost melt begins; limit of no-return

3 degrees 20-80% loss of Amazon rainforest; extinction risk for polar species, 20-30% species extinction; continued permafrost melt; 1.1-3.2 billion people with increased water stress; widespread coral loss

4 degrees Shutdown of ocean calcification; major extinctions around the globe; decrease in food production; near-total deglaciation

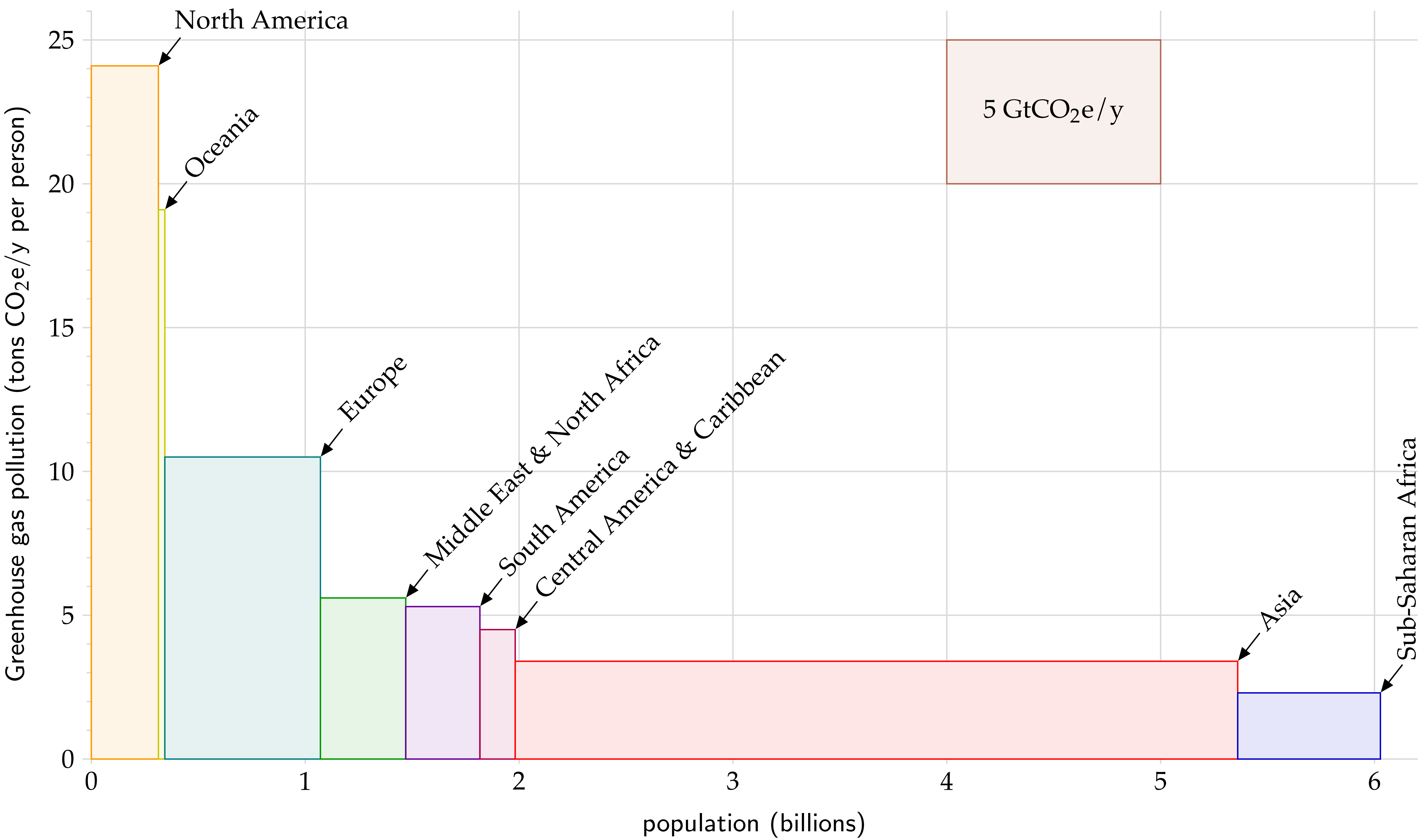
5 degrees Many unknown impacts

[IPCC07]

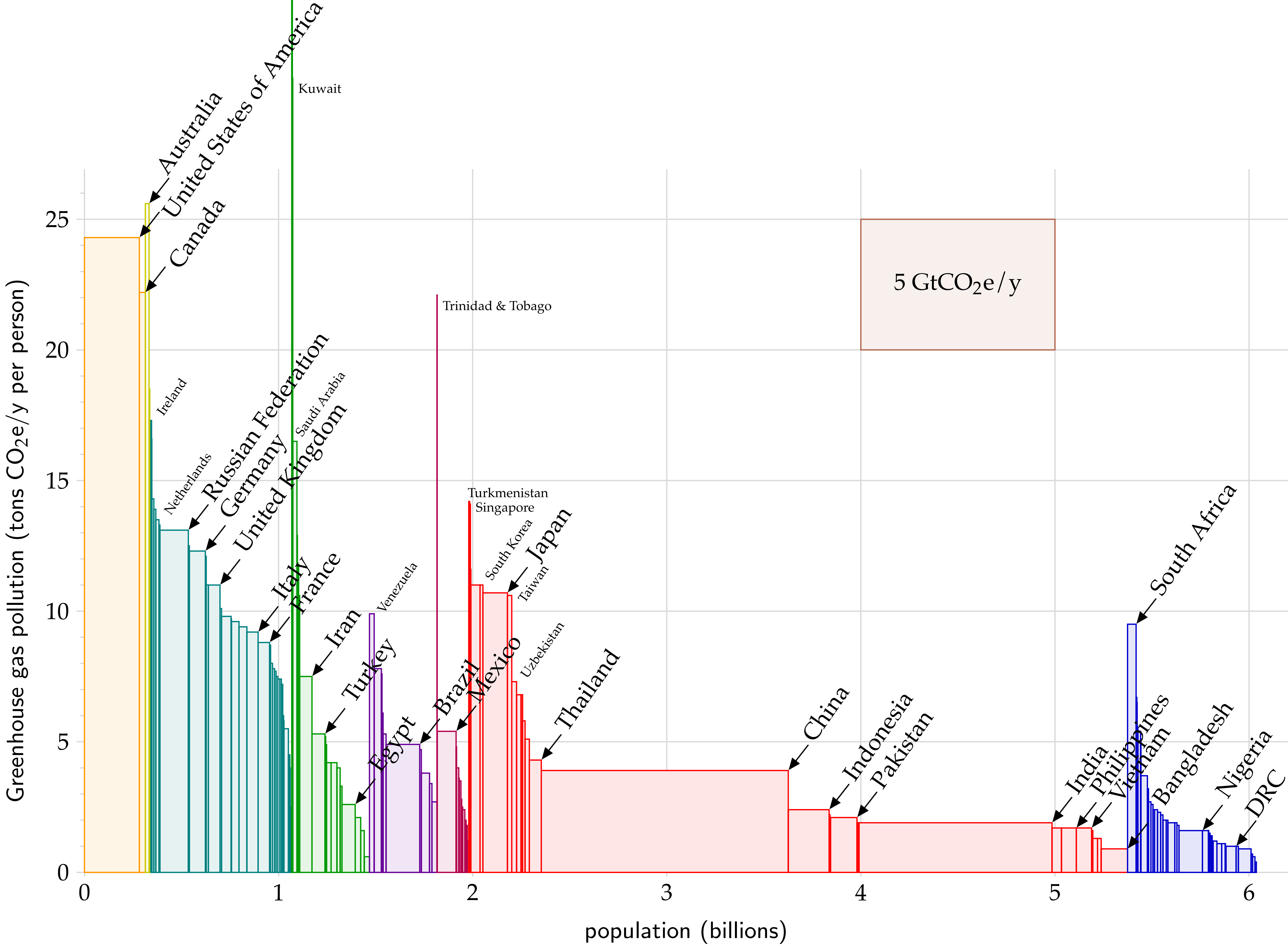
Last time the planet was 6C warmer: 55 million years ago, during the Paleocene-Eocene Thermal Maximum.

During this time, the planet was ice free, and crocodiles lived in the arctic. The warming happened over 20,000 years; our 6C of warming would happen in 1/200th the time.

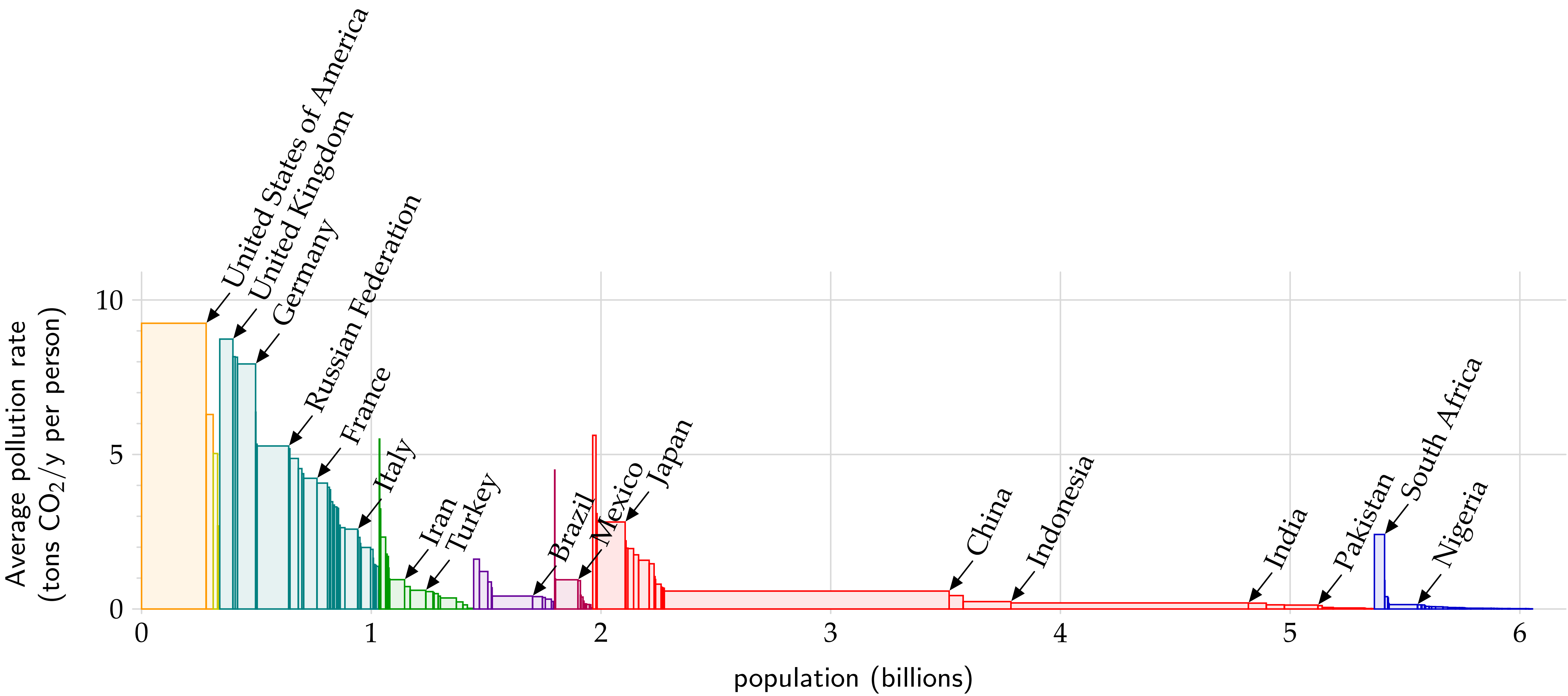
Where do the emissions come from?



Year 2000 emissions [MacKay09]



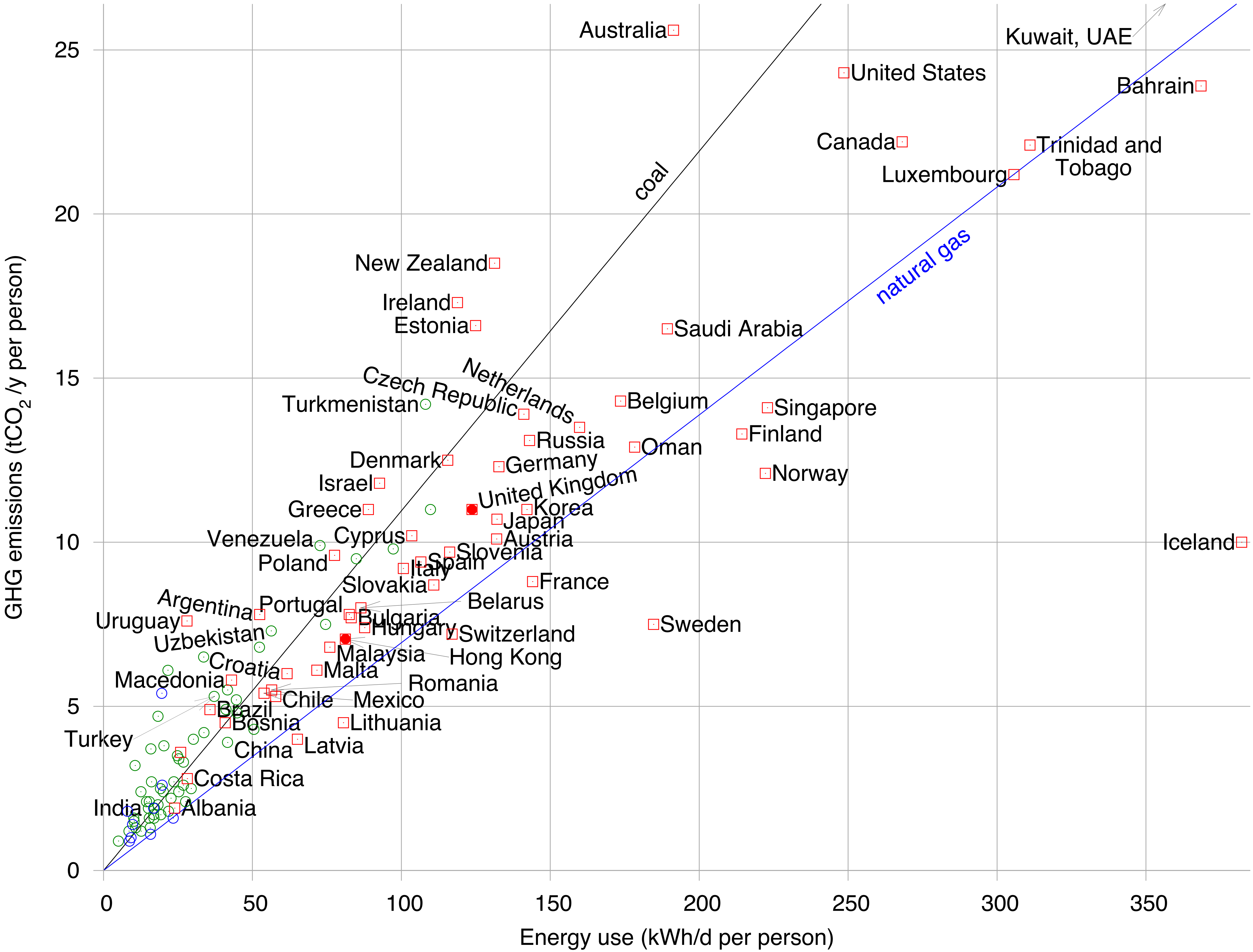
Year 2000 emissions [MacKay09]



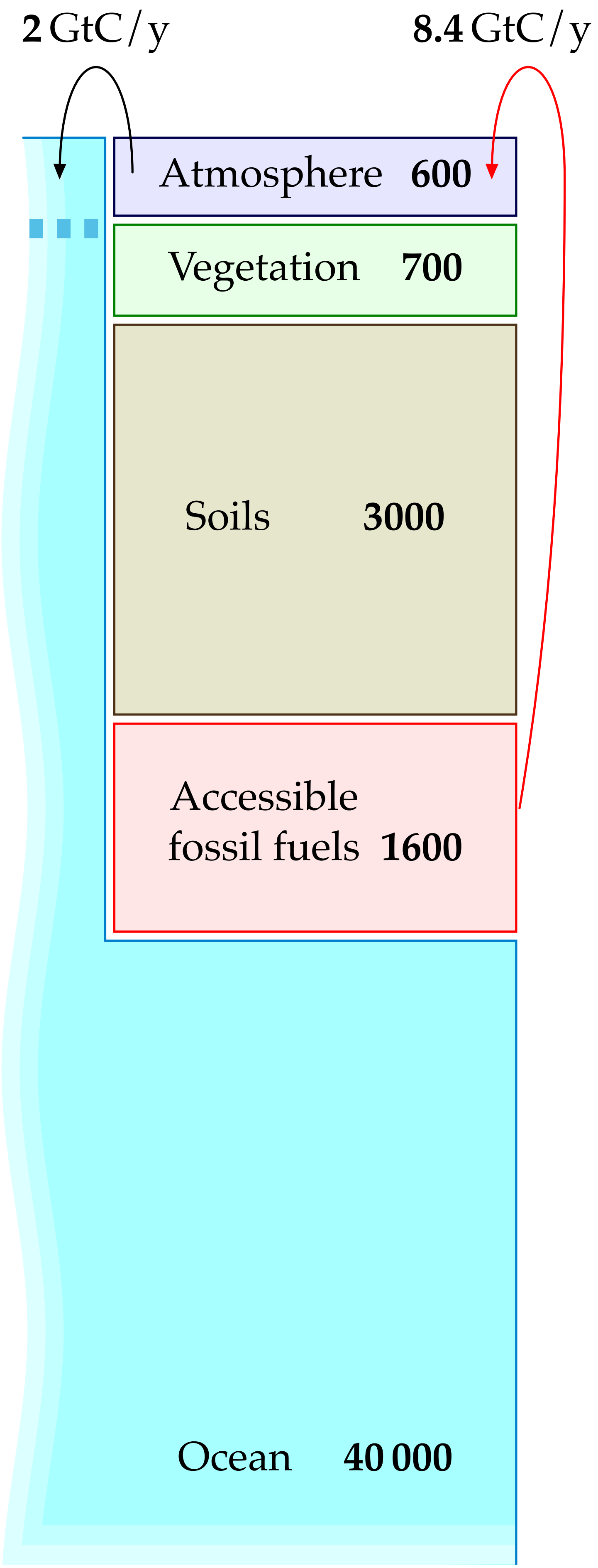
1880-2004 emissions [MacKay09]

We respond strongest to threats that are:	Climate Change and Oil Depletion are:
Visible	Invisible
With historical precedent	Unprecedented
Immediate	Drawn out
With simple causality	With complex causality
Caused by others	Caused by all of us
Have direct personal impact	Unpredictable and indirect

[Miller09]



Carbon vs. energy [MacKay09]



Carbon flows (2006) [MacKay09]

Goal: Contain warming to 2C

Business As Usual: 850+ ppm CO_2 (likely > 5C)

Copenhagen: 725 ppm (even chance > 5C)

EU target: 550 ppm (slim chance < 2C; even chance > 3C)

This talk target: 450 ppm (maybe < 2C)

Today: 390 ppm

James Hansen, NASA: 350 ppm (very likely < 2C)

Pre-Oil (1900): 290 ppm

[IPCC07]

Non-Carbon* Options

Photovoltaic
Solar Thermal
Wind
Geothermal
Hydroelectric
Tidal
Algae Fuel
Nuclear

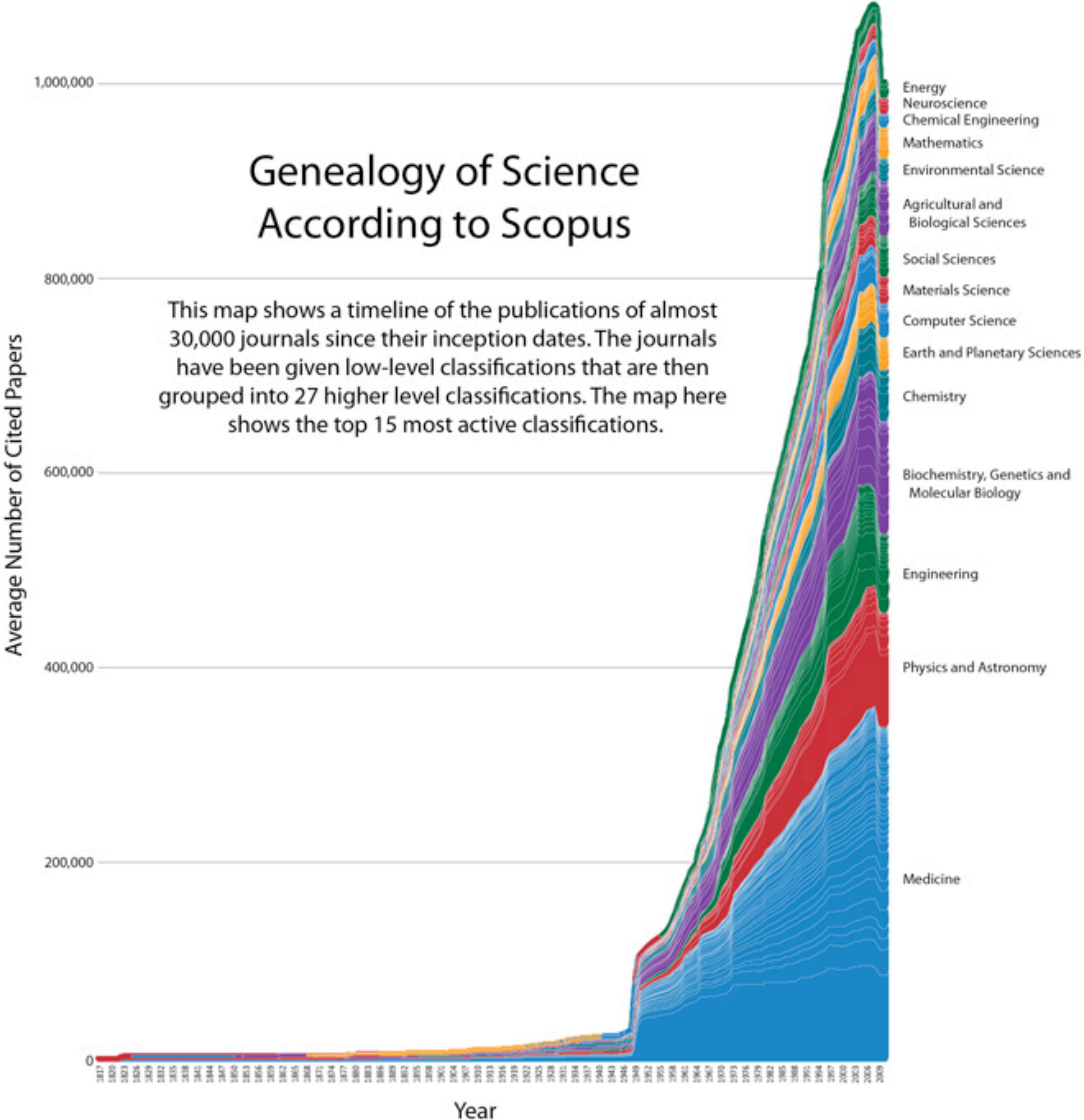
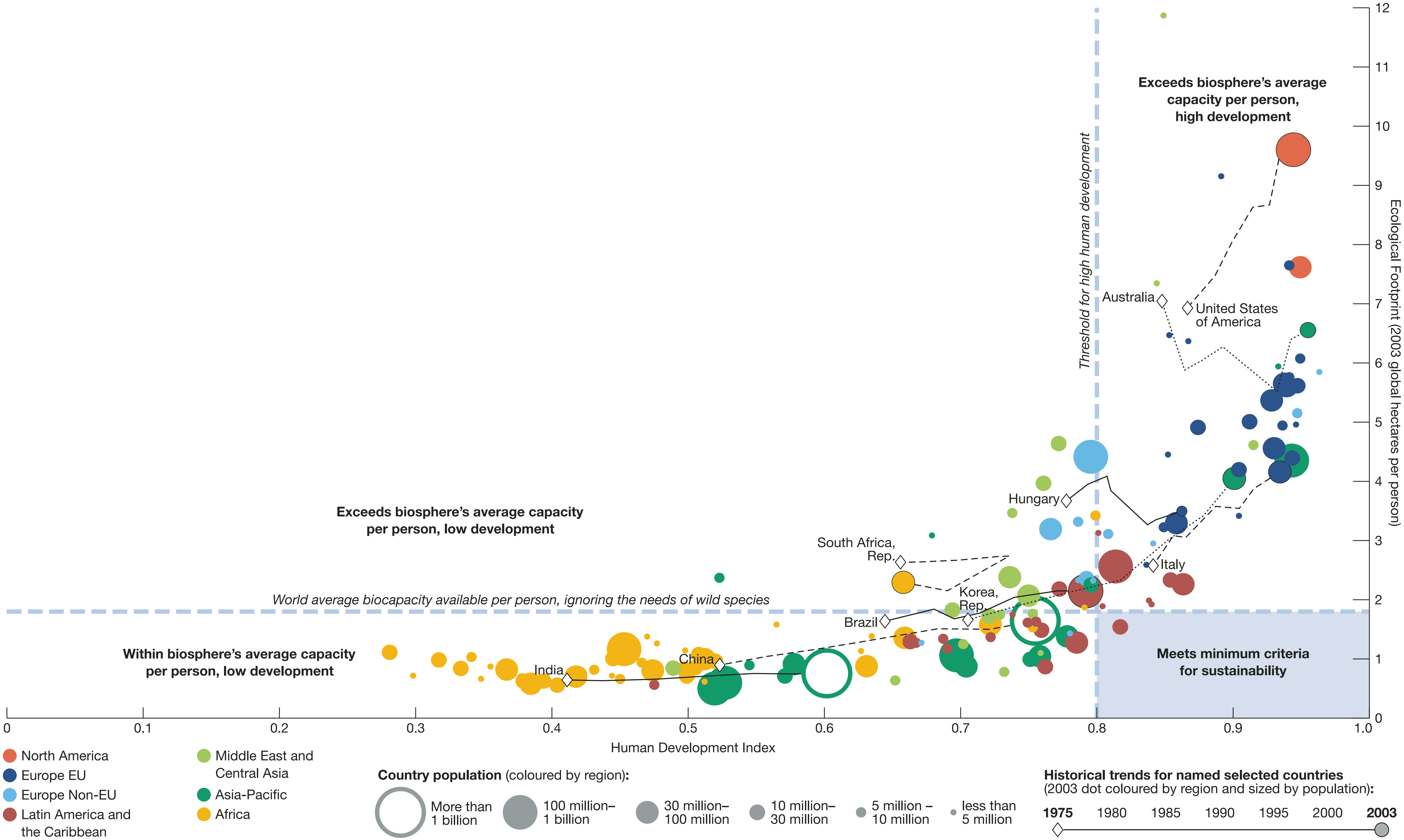
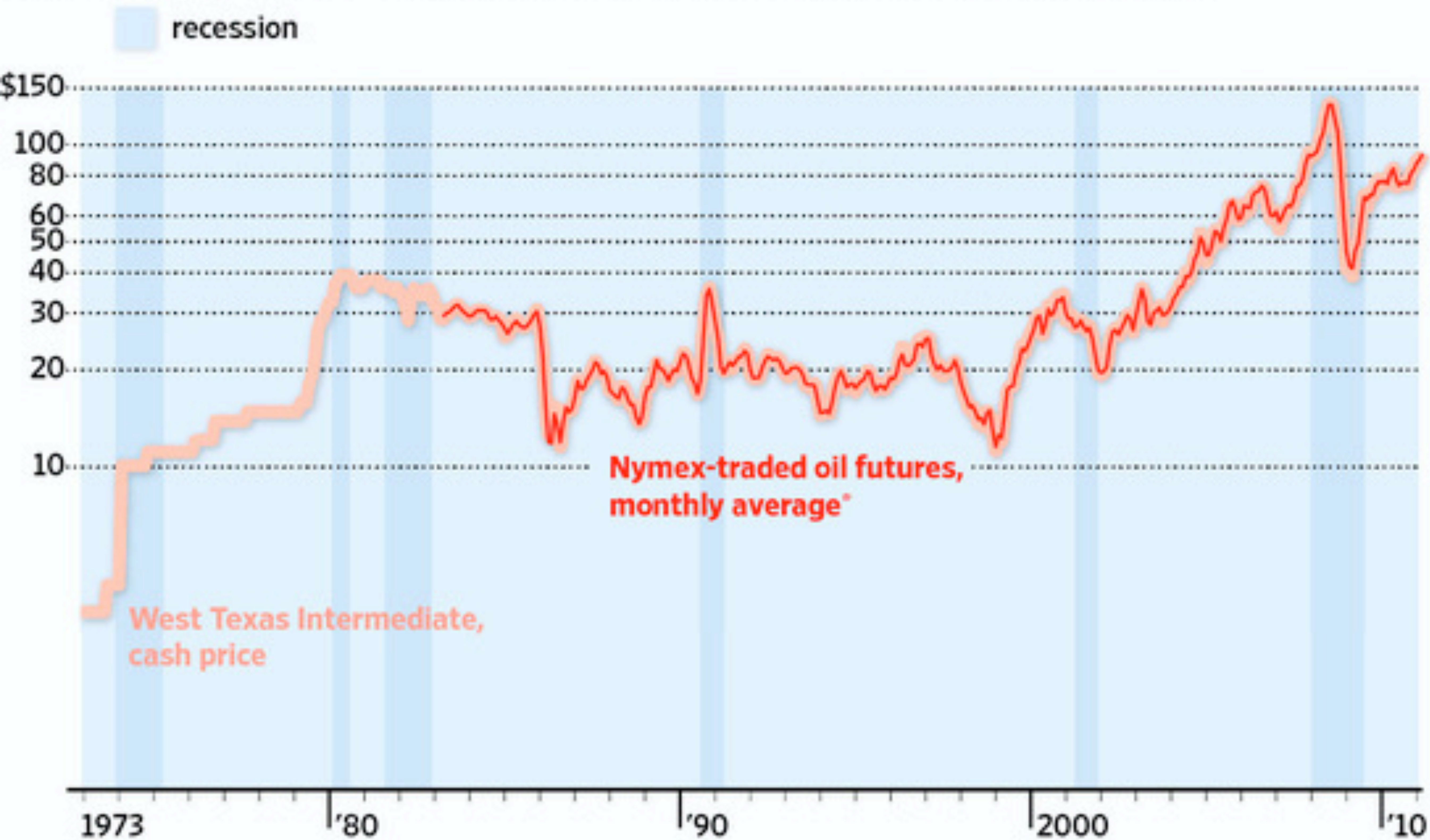

Genealogy of Science
According to Scopus
This map shows a timeline of the publications of almost 30,000 journals since their inception dates. The journals have been given low-level classifications that are then grouped into 27 higher level classifications. The map here shows the top 15 most active classifications.
1,000,000
800,000
600,000
400,000
200,000
0
Average Number of Cited Papers
Year
Energy
Neuroscience
Chemical Engineering
Mathematics
Environmental Science
Agricultural and Biological Sciences
Social Sciences
Materials Science
Computer Science
Earth and Planetary Sciences
Chemistry
Biochemistry, Genetics and Molecular Biology
Engineering
Physics and Astronomy
Medicine

Fig. 22: **HUMAN DEVELOPMENT AND ECOLOGICAL FOOTPRINTS,** 2003



Past Price Hikes Fed Recessions

Climbing oil prices have often led the way into recession. Monthly prices in dollars per barrel.



*Trading started in March 1983 Note: Logarithmic scale is labeled in dollars but increments are adjusted to express percentage changes in prices

Sources: Dow Jones Energy Service via The Federal Reserve Bank of St. Louis; Thomson Reuters

“We are grossly wasting our energy resources and other precious raw materials as though their supply was infinite. We must even face the prospect of changing our basic ways of living. This change will either be made on our own initiative in a planned and rational way, or forced on us with chaos and suffering by the inexorable laws of nature.”

[Carter74]

RESEARCH AGENDA

Network Structure

Reevaluation

Integration

Components & Tools

NETWORK STRUCTURE

Q1: What do standards look like post-peak? What role do standards bodies such as IANA and IETF play?

Q2: What cost sharing mechanisms can be feasibly deployed to offload a substantial portion of the true cost of a network service onto its user?

Q3: What does the programming model for a fully-distributed datacenter-less cloud look like?

Q4: What are the necessary security / reputation / replication mechanisms to create a fully-distributed social network platform?

Q5: As networks become more localized, the cost and latency of communicating with far away nodes will be higher than it is today. How will we cope with this?

Q6: How might we carefully guide this structural transition (transferring management from the core to the edges), instead of allowing it to descend haphazardly?

REEVALUATION

Q7: Can we develop a common methodology for calculating the emergy of a network device?

Q8: Can we measure which existing projects in energy-efficient networking are well-suited to the post-peak world and which are “greenwashed”?

Q9: When do free network services become infeasible due to energy costs?

Q10: How can network protocols be best redesigned to cope with post-peak volatility?

Q11: How can existing software implementations of network protocols be repurposed without modification?

Q12: When is it the case that software upgrades, while using old hardware, are preferable to upgrading to a more resource-efficient hardware platform?

INTEGRATION

Q13: Given increased transportation costs, can we encourage more video conferencing adoption by incorporating computer vision techniques into video streaming protocols to augment the video?

Q14: Can computer network protocols and algorithms be applied to transportation networks (or vice versa) so as to improve their overall efficiency?

Q15: Using today's architecture, how can we enable and promote a systematic way of leveraging cross-layer and network-internal knowledge at end points?

Q16: What are the economic incentive models for a demand / congestion-pricing system for a post-peak Internet?

Q17: How will the economics of network misbehavior (spam, DoS, etc.) change post-peak?

Q18: How can a secure, peer-to-peer localized microlending system be built?

COMPONENTS AND TOOLS

Q19: How can network switches and routers be built to passively (not actively) perform forwarding?

Q20: How might technology costs and energy trends change with respect to in-network storage, and when will it become unviable?

Q21: How can a long-term network-attached data archival service be designed to provide persistence and proof of storage?

Q22: Can we develop a “currency” for local network bandwidth sharing?

Nine Challenges of Alternative Energy

1. Scalability and Timing
2. Commercialization
3. Substitutability
4. Material Input Requirements
5. Intermittency
6. Energy Density
7. Water
8. The Law of Receding Horizons
9. Energy Return on Investment

[Fridley10]

Catton's Modes of Adaptation

Adaptation	Circumstance Carrying capacity exceeded	Consequence Reorganize within finite limits	Name
Recognition of major changes	Accepted	Accepted	Realism
Faith in technological progress	Accepted	Disregarded	Cargoism
Mitigation is enough	Disregarded	Partially Accepted	Cosmeticism
No problems or solutions	Disregarded	Disregarded	Cynicism
No limits	Denied	Denied	Ostrichism

[Catton80]

Peak Oil matters because of Flows

Consumers need delivery flows
Reserves are only useful as flows
Peak oil is when flows can't meet the demand
The oil industry is slow moving and predictable

Flows can be geologically constrained (North Sea)
Flows can be politically constrained (Russia, Saudi Arabia)
Flows can be physically constrained (Nigeria)
Flows can be skills constrained (old engineers)
Flows can be capital or access constrained (Mexico, Venezuela)

Many talk of reserves and ignore flows

Others talk about access and ignore flows

[Skrebowski11]

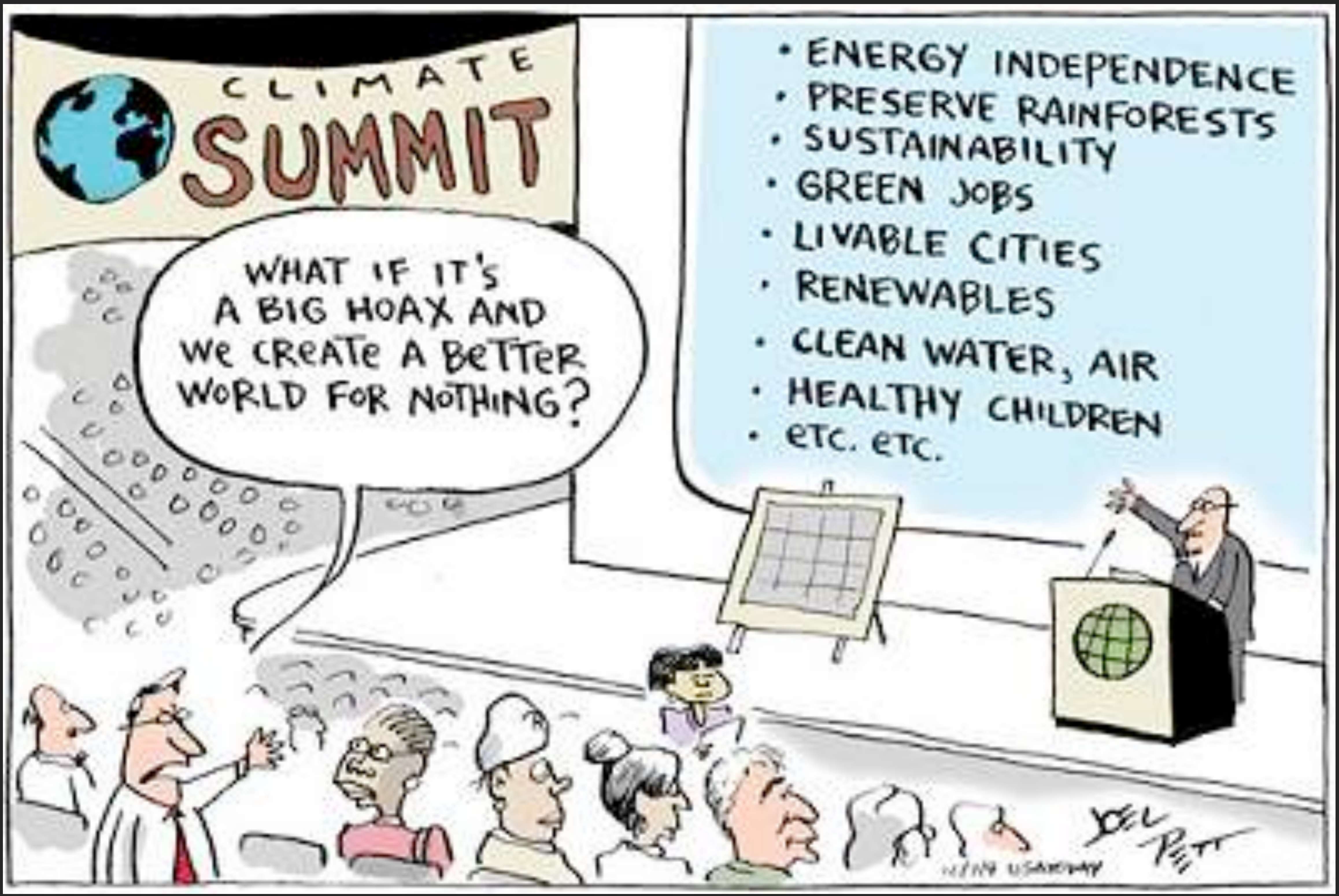
5/10/20 years post-peak

(~2019/~2024/~2034)

Transportation (cost): 3-5x / 5-15x / 10-25x

Electricity (cost): 2-4x / 2-10x / 5-20x

Grid reliability (%): 98-99% / 95-99% / 75-98%



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