The Energy New Deal
Related to Subsurface Energy Options

Derek Elsworth (Pennsylvania State University)

Some Key Issues in Energy Supply
- Needs
- Constraints
- Solutions

Low Carbon Fuel Solutions
- Gas Shales
- Coalbed Methane (CBM/Coalseam gas)
- Methane Hydrates

Carbon Management Solutions
- CO_2 sequestration

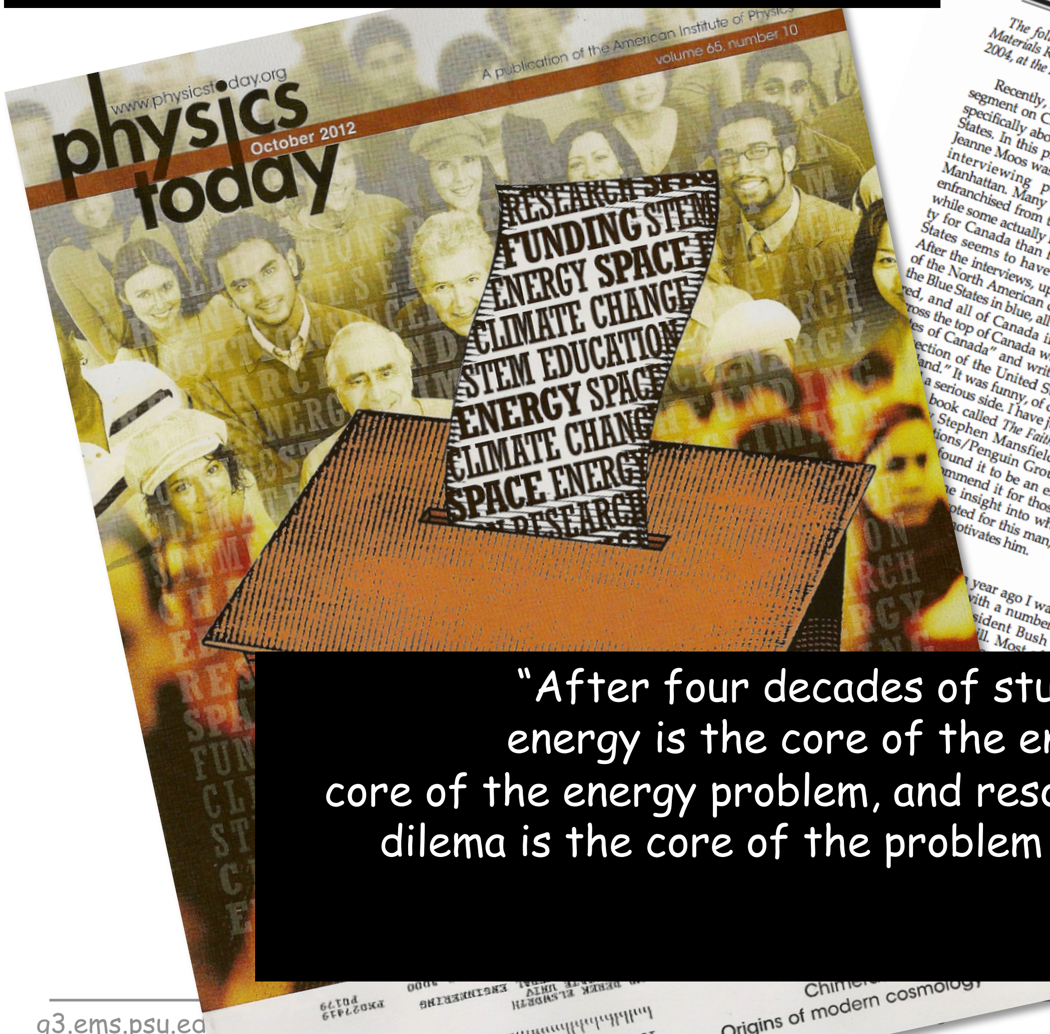
Zero Carbon Solutions
- EGS Geothermal
- Nuclear power
- Hydropower/Pumped Storage/CAES
- Wind
- Solar PV and Thermal

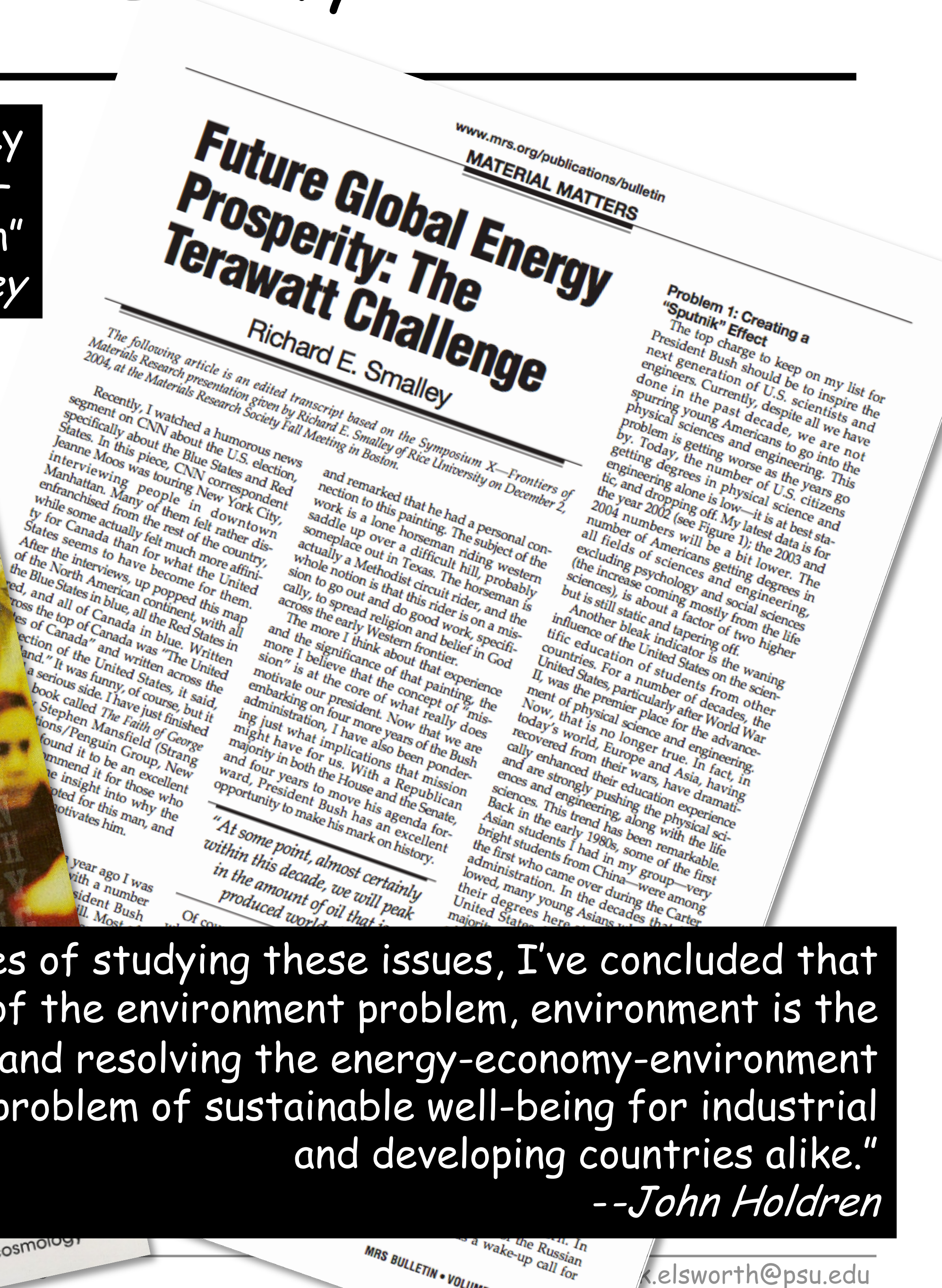
New Zealand Energy Picture

Sustainable Energy in New Zealand

Energy-Environment-Economy Nexus

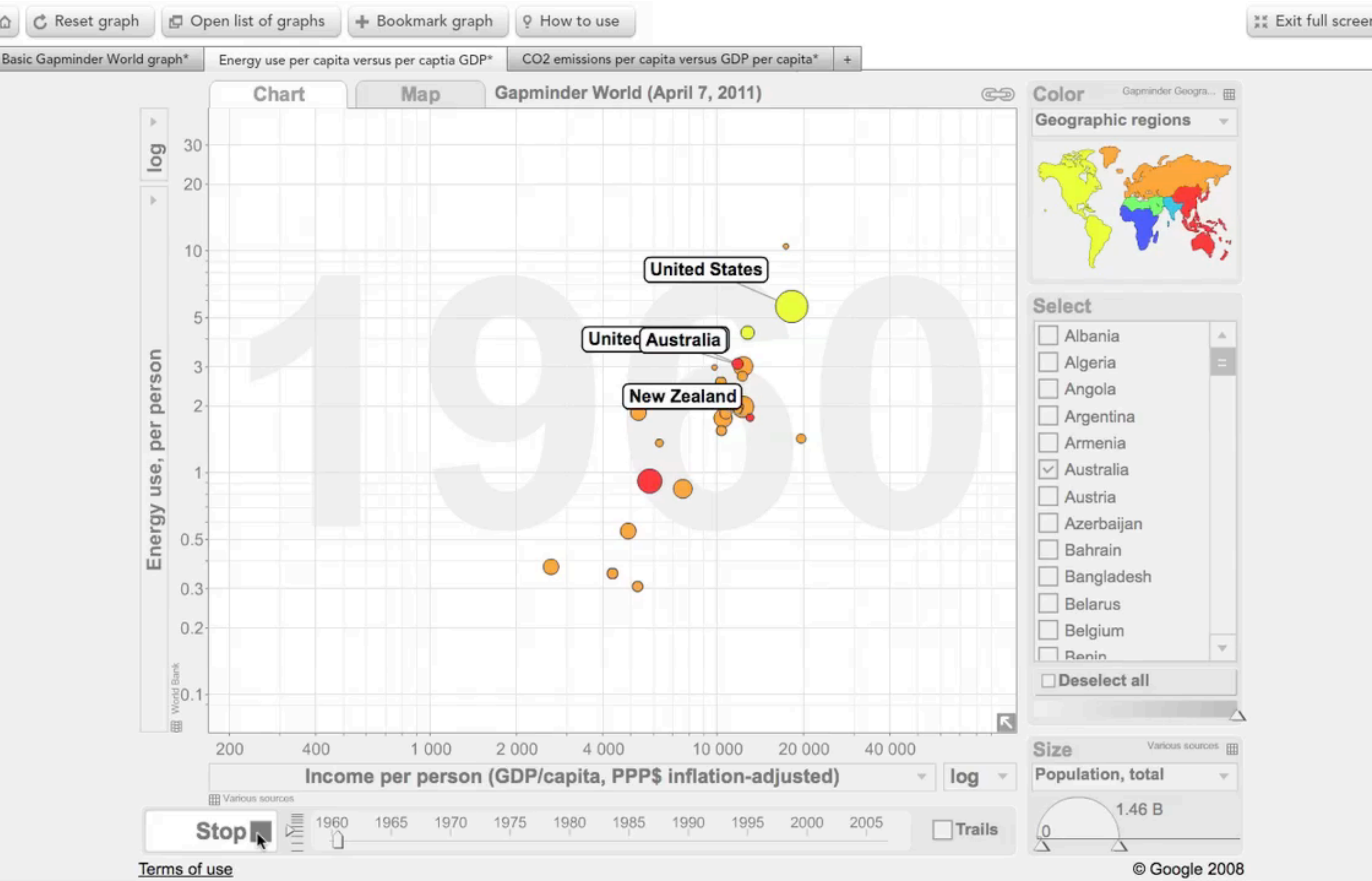
"…. we can see how energy is the key to solving all of the rest of the problems – from water to population"
--Richard E. Smalley





"After four decades of studying these issues, I've concluded that energy is the core of the environment problem, environment is the core of the energy problem, and resolving the energy-economy-environment dilema is the core of the problem of sustainable well-being for industrial and developing countries alike."
--John Holdren

Energy & Environment: Complementary Drivers?



[Hans Rosling http://www.gapminder.org/]

Close-Out Editorial on 2008-2016 US Administration

Observations:

GHG dropped/flat on 4 occasions:
1980s, 1992, 2009 (recessions)
2014 (growth)

Electricity from Gas:
21% 2008
33% 2015

Employment:
~2.2M Energy efficiency jobs
~1.1M Fossil fuel for electricity

GapMinder Linkage:
US Energy use 2.5% less in 2015 vs 2008 but economy 10% larger

[Obama, Science, 2017]

INSIGHTS

POLICY FORUM

CLIMATE AND ENERGY

The irreversible momentum of clean energy

Private-sector efforts help drive decoupling of emissions and economic growth

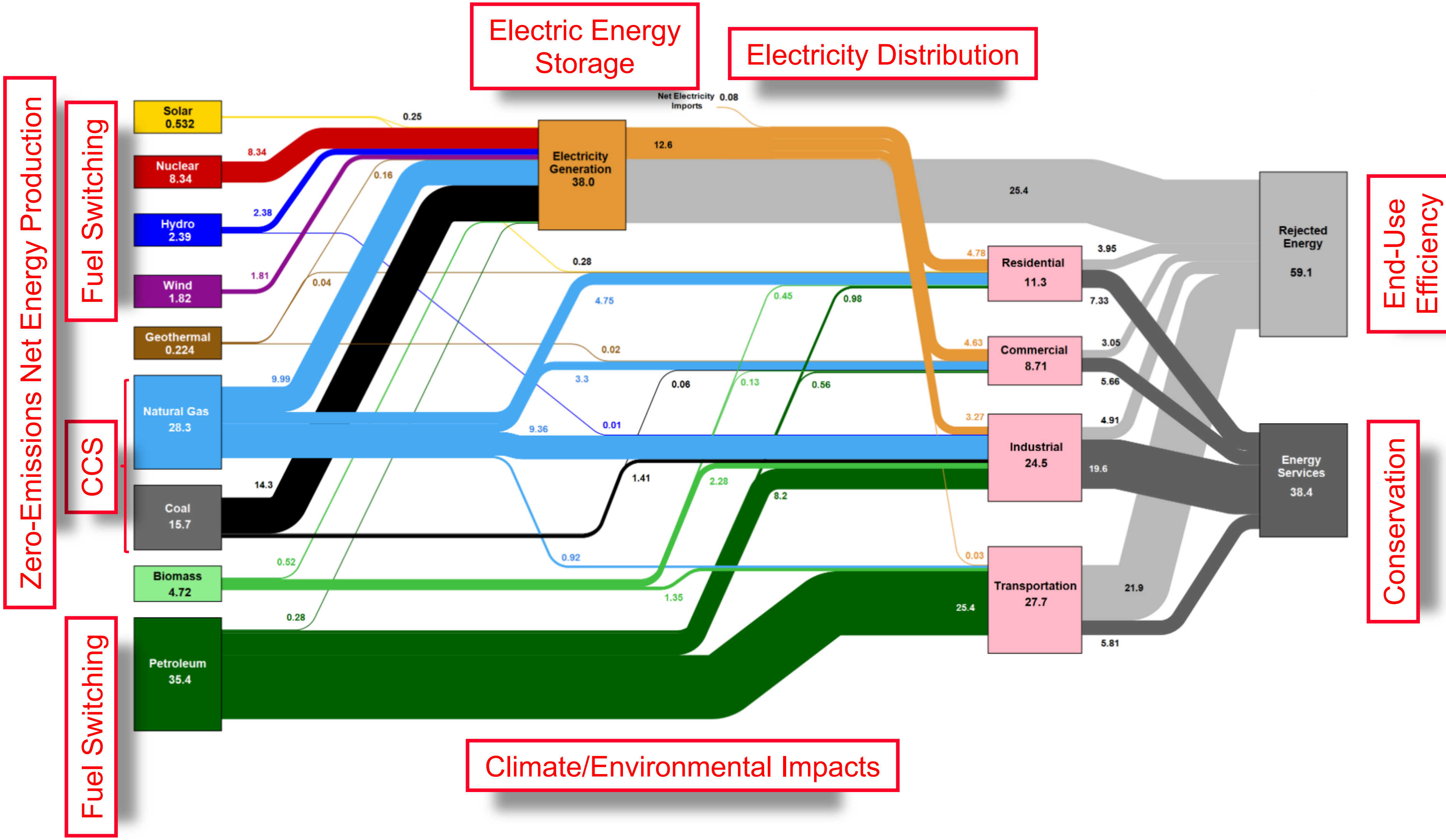
By Barack Obama

The release of carbon dioxide (CO_2) and other greenhouse gases (GHGs) due to human activity is increasing global average surface air temperatures, disrupting weather patterns, and acidifying the ocean (1). Left unchecked, the continued growth of GHG emissions could cause global average temperatures to increase by another 4°C or more by 2100 and by 1.5 to 2 times as much in many midcontinent and far northern locations (1). Although our understanding of the impacts of climate change is increasingly and disturbingly clear, there is still debate about the proper course for U.S. policy—a debate that is very much on display during the current presidential transition. But putting near-term politics aside, the mounting economic

President of the United States, Washington, DC 20500, USA. Email: press@who.eop.gov. After 20 January 2017: contact@obamaoffice44.org

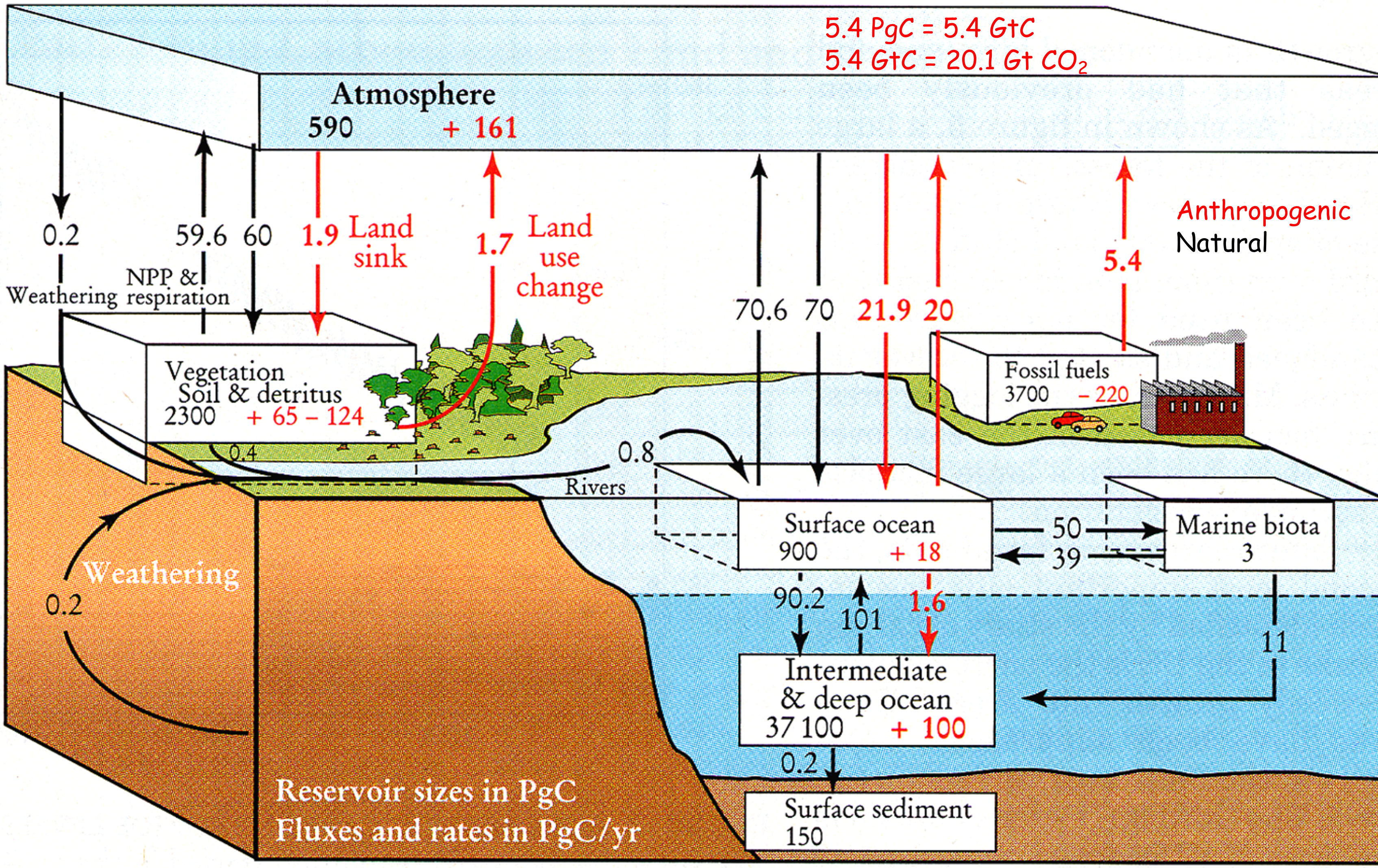
Published by AAAS

US Energy Consumption 2015 – Key R&D Strategies
~100 Quads = 100 EJ = 100 tcf CH_4 (~20% of World)



[After Pat Dehmer, US DOE, Office of Science, 2009; Sankey Diagram from LLNL]

Global Carbon Cycle



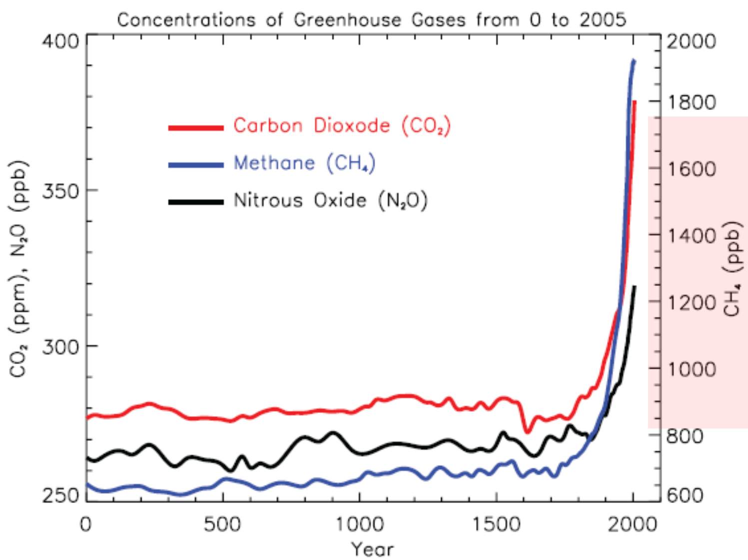
[Sarmiento and Gruber, *Physics Today*, 2002.]

Climate Change – Equivocal –versus- Unequivocal

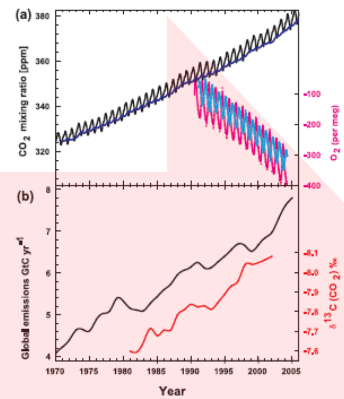
CO2 versus historic time – IPCC

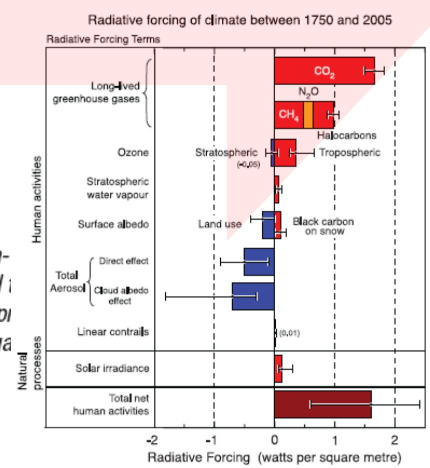
Parsing Filter

Global Mean Temperatures

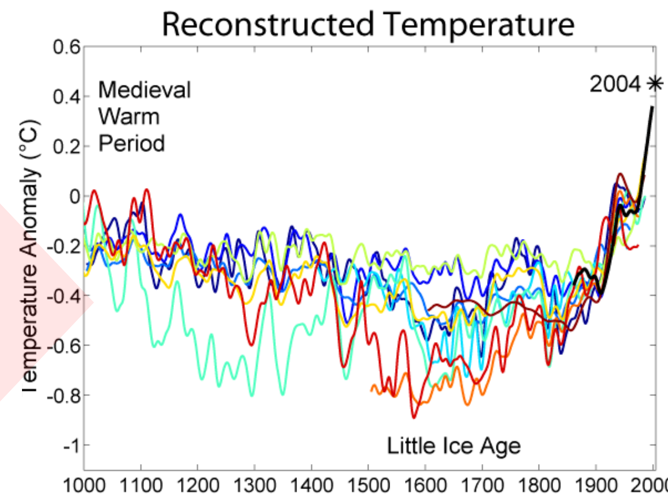


FAQ 2.1, Figure 1. *Atmospheric concentrations of important long-lived green-house gases over the last 2,000 years. Increases since about 1750 are attributed t human activities in the industrial era. Concentration units are parts per million (ppi or parts per billion (ppb), indicating the number of molecules of the greenhouse ga per million or billion air molecules, respectively, in an atmospheric sample. (Data combined and simplified from Chapters 6 and 2 of this report.)*



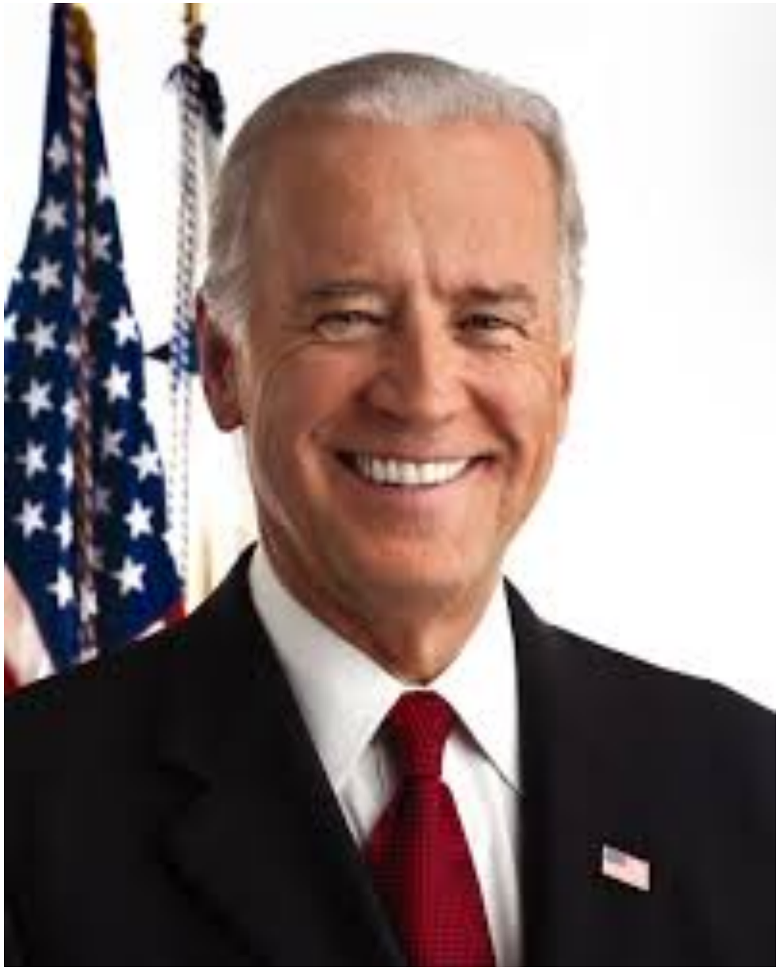


FAQ 2.1, Figure 2. *Summary of the principal components of the radiative forcing of climate change. All these radiative forcings result from one or more factors that affect climate and are associated with human activities or natural processes as discussed in the text. The values represent the forcings in 2005 relative to the start of the industrial era (about 1750). Human activities cause significant changes in long-lived gases, ozone, water vapour, surface albedo, aerosols and contrails. The only increase in natural forcing of any significance between 1750 and 2005 occurred in solar irradiance. Positive forcings lead to warming of climate and negative forcings lead to a cooling. The thin black line attached to each coloured bar represents the range of uncertainty for the respective value. (Figure adapted from Figure 2.20 of this report.)*



Science is Parsed through a Legislative Filter

Science is Parsed through a Legislative Filter



Administration's Energy Plan

- Within 10 years save more oil than we currently import from the Middle East and Venezuela combined.
- Put 1 million plug-in hybrid cars – cars that can get up to 150 miles per gallon – on the road by 2015.
- Generate 10 percent of our electricity from renewable sources by 2012, and 25 percent by 2025.
- Implement an economy-wide, cap-and-trade program to reduce greenhouse gas emissions 80% by 2050.

Pat Dehmer, DOE Office of Science, March 2009

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Sub-Surface Baseload Energy

Demand-Side Reduction

Stationary Sources and CCS

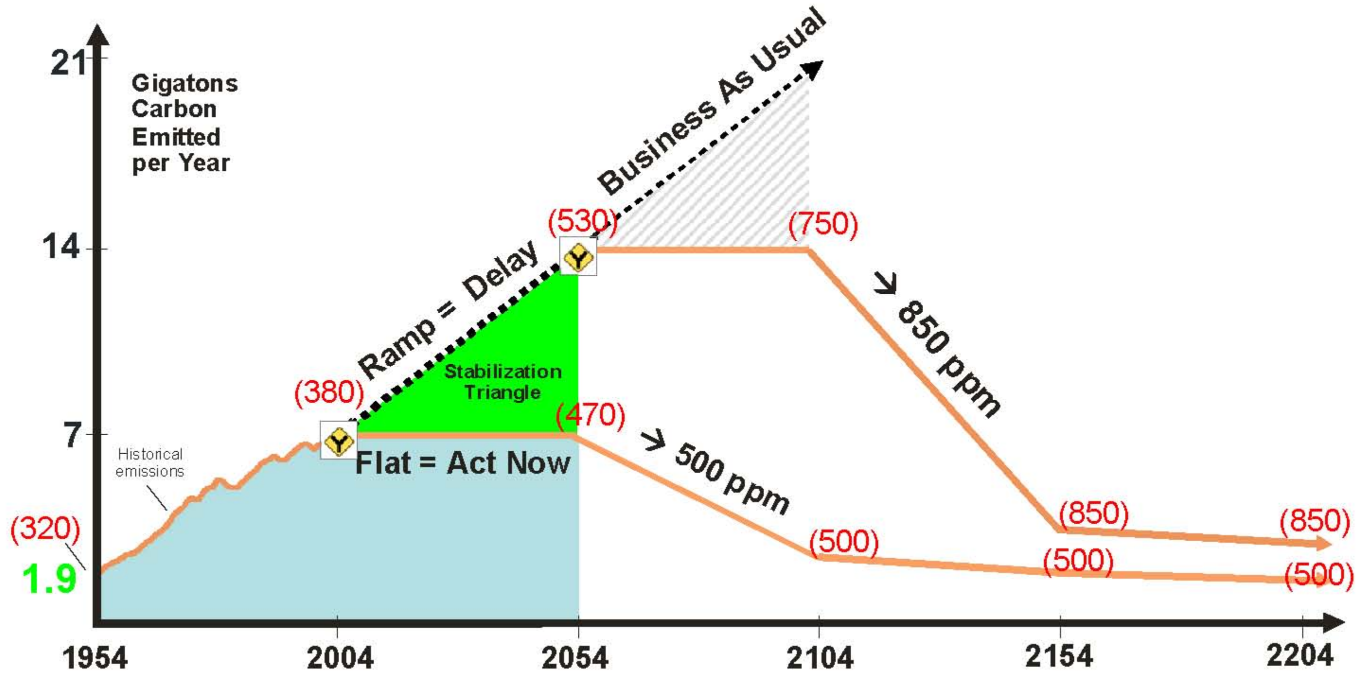
Geothermal and Other Sources

Fuel Switching to low(er) Carbon fuels and Carbon Capture & Storage

Pat Dehmer, DOE Office of Science, March 2009

Capacity Needs – Socolow Wedges

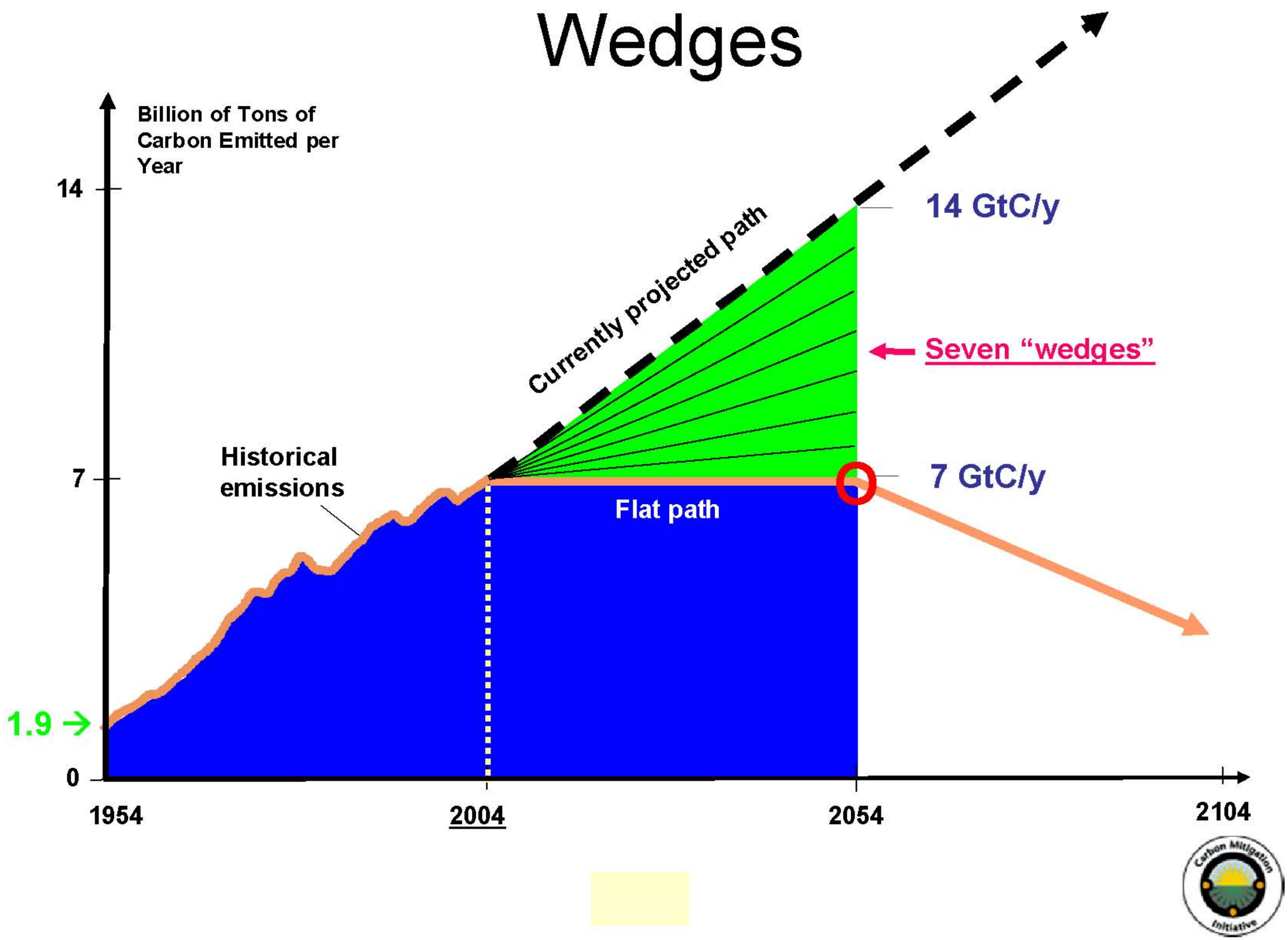
The Stabilization Triangle: Beat doubling or accept tripling



Values in parentheses are ppm. Note the identity (a fact about the size of the Earth's atmosphere): 1 ppm = 2.1 GtC.

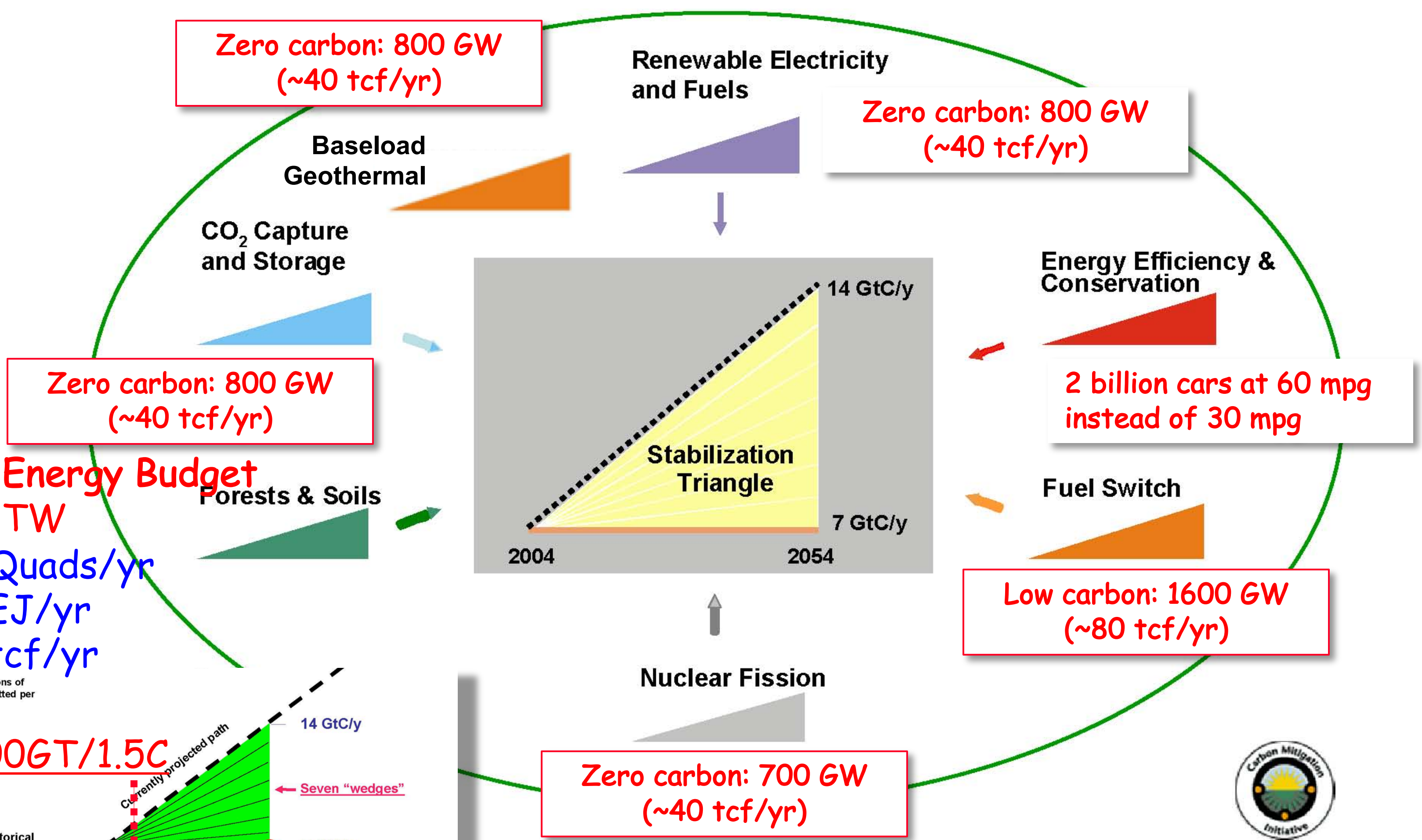
[**Rationale in:** Pacala & Socolow, *Science*, 2004, www.stabilisation2005.com/day3/**Socolow**.pdf]

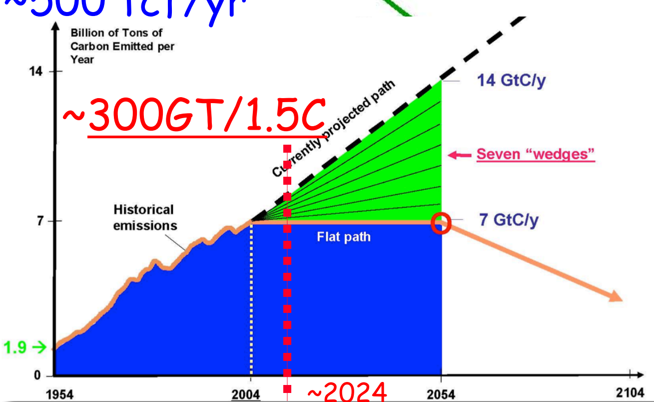
Capacity Needs – Socolow Wedges



[**Rationale in:** Pacala & Socolow, *Science*, 2004, www.stabilisation2005.com/day3/**Socolow**.pdf]

Capacity Needs – Stabilization Wedges





[**Rationale in:** Pacala & Socolow, *Science*, 2004,
www.stabilisation2005.com/day3/**Socolow**.pdf]

Sub-Surface Energy/Engineering Solutions

Low-Carbon Fuel Solutions?

Unconventional Hydrocarbons

- Gas shales
- Coalbed methane
- Methane hydrates

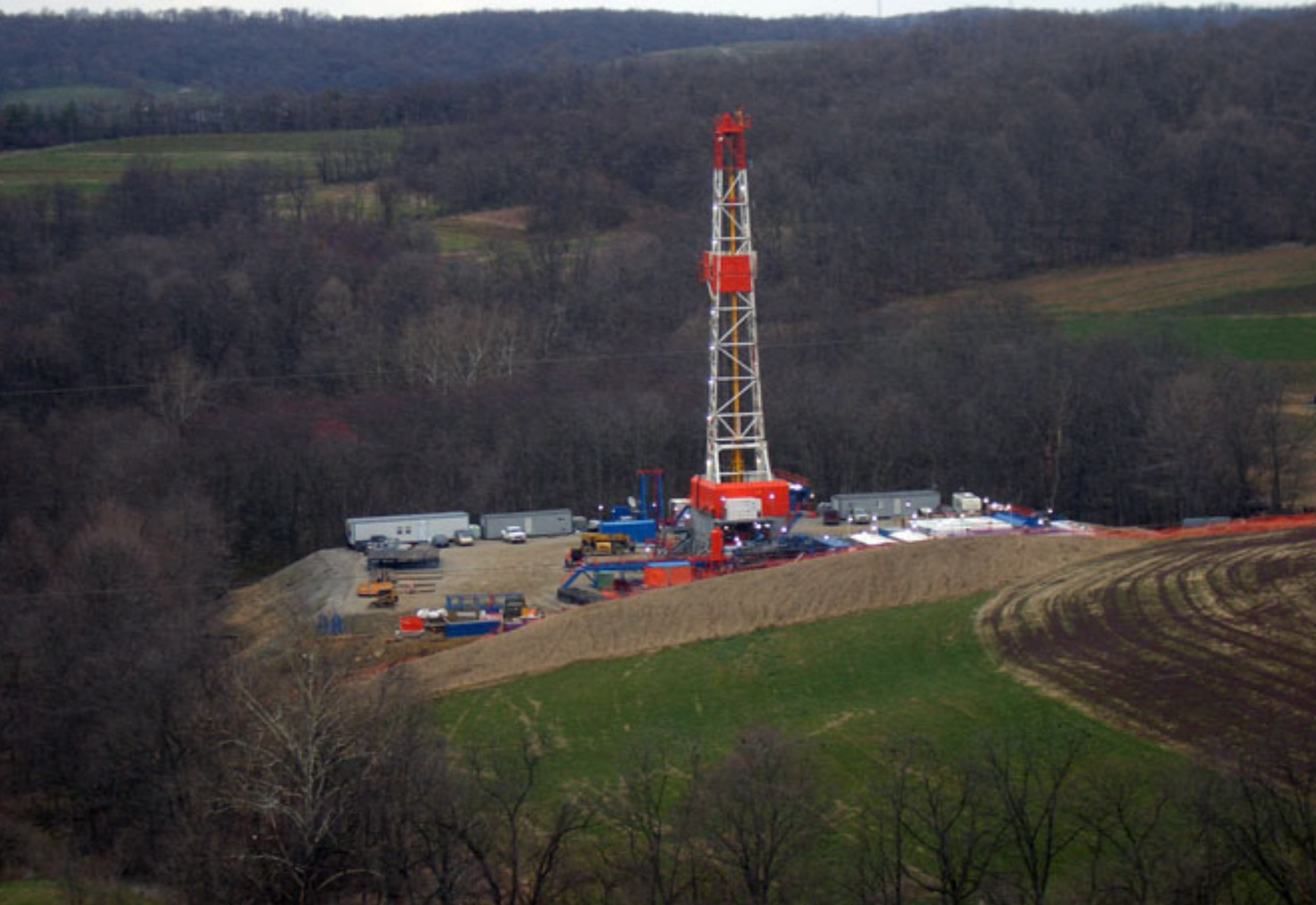
Carbon Management Solutions?

- Carbon Capture and Sequestration

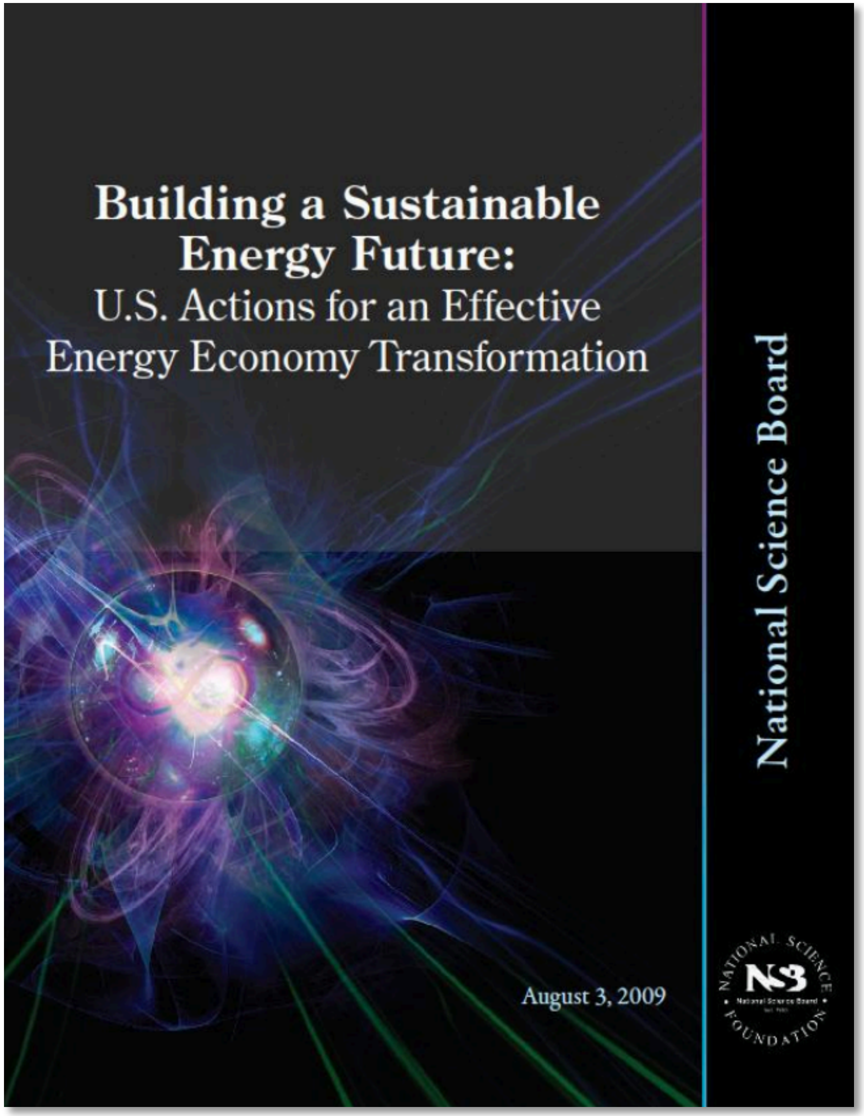
Zero-Carbon Solutions?

- EGS Geothermal - The new landscape
- Nuclear power
- Hydropower/Pumped storage/CAES
- Wind
- Solar PV and thermal

Low-Carbon Fuel Solution? – Gas Shales



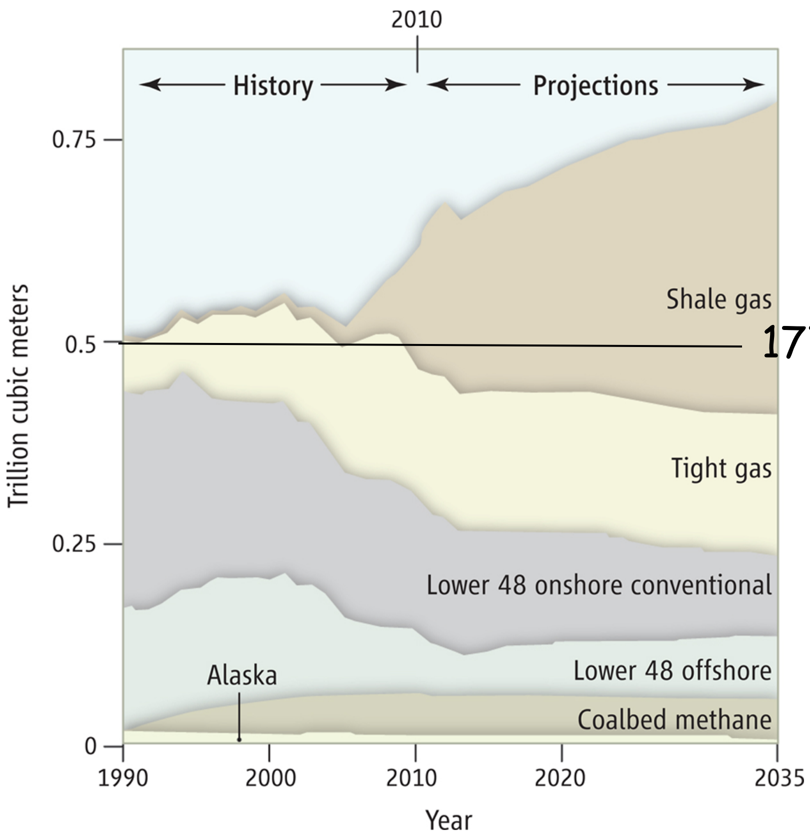
Implications for Energy Independence, Energy Security and for Climate Change?



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

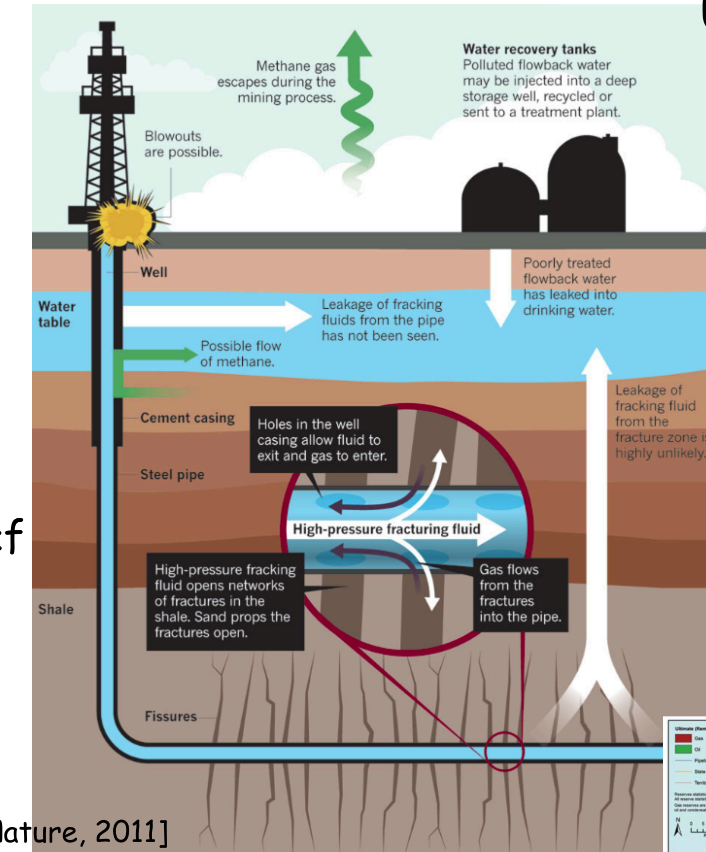
Projected Growth and Opportunities

Natural Gas Utilization



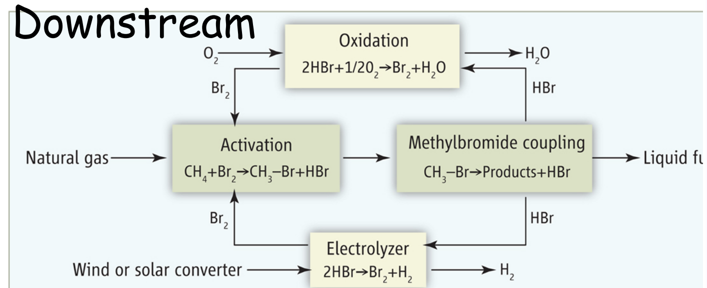
[Science, Oct 18, 2012]

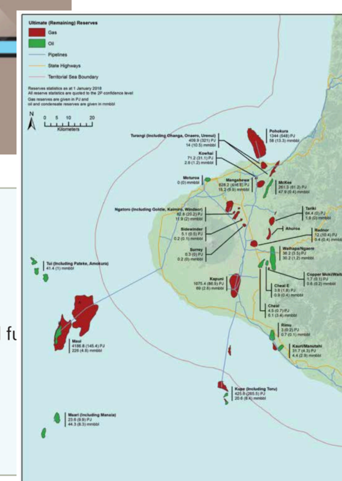
Upstream



[Nature, 2011]

Downstream



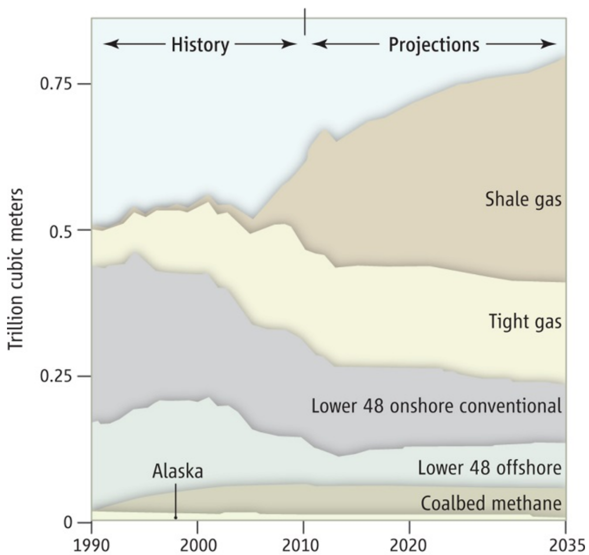


Microbially-Enhanced CBM (MECBM)

Geographic Distribution

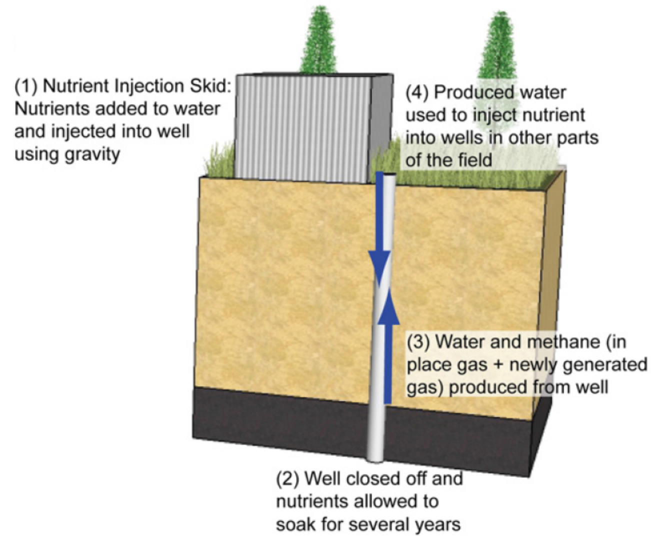
Coalbed methane fields, lower 48 states [~100 Tcf recoverable]

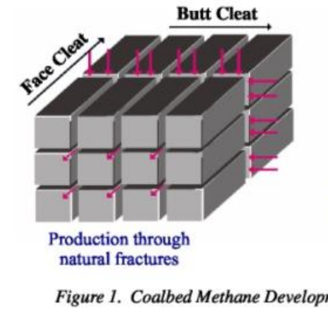
Projected US Gas Production



Year [Science, Oct 18, 2012]

Methods of production

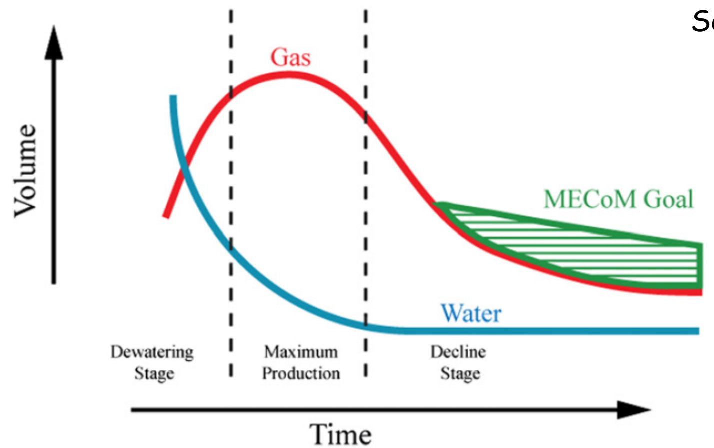




Principal Issues

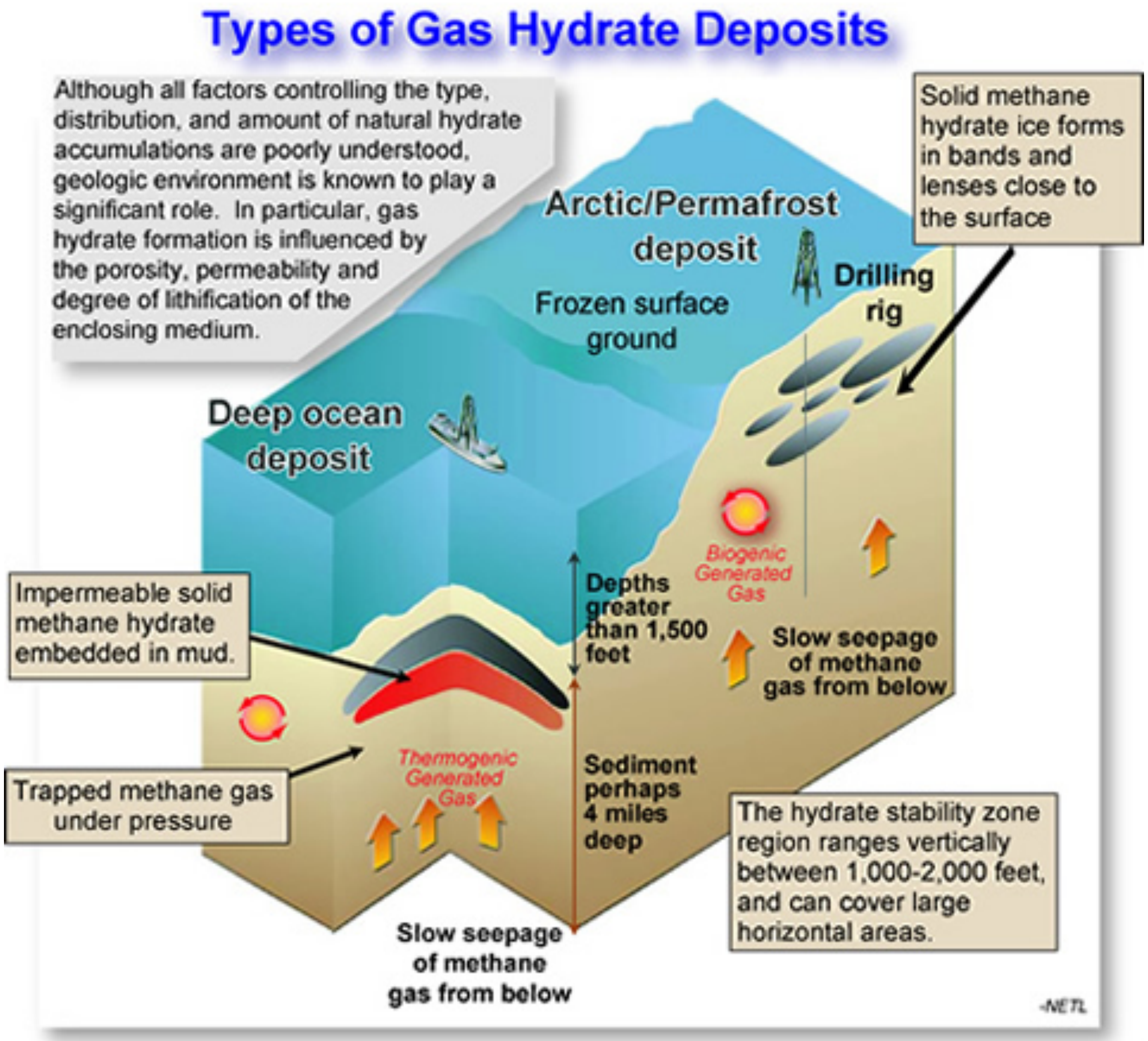
Environmental Effects
Rate Limits on Production
Dewatering
Desorption - Capacity
Advection – Perm Evolution
Sequestration

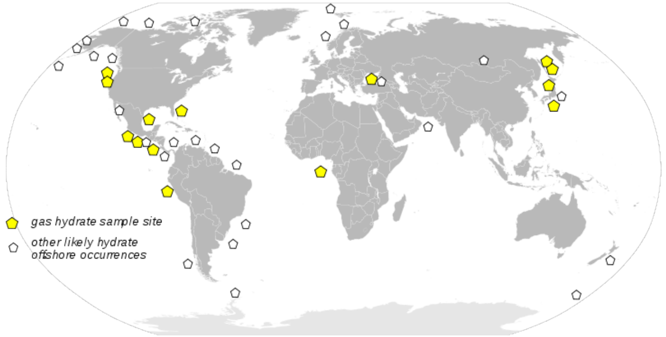
MECBM Scheduling



[Nuccio, 2000]

Low-Carbon Fuel Solution? – Methane Hydrates





Projected Clathrate Reserve/Resource: - / 10^5-10^6 Tscf

Capacity Needs – Socolow Wedges

Replace Coal Fired Plants with Gas-Fired Generation

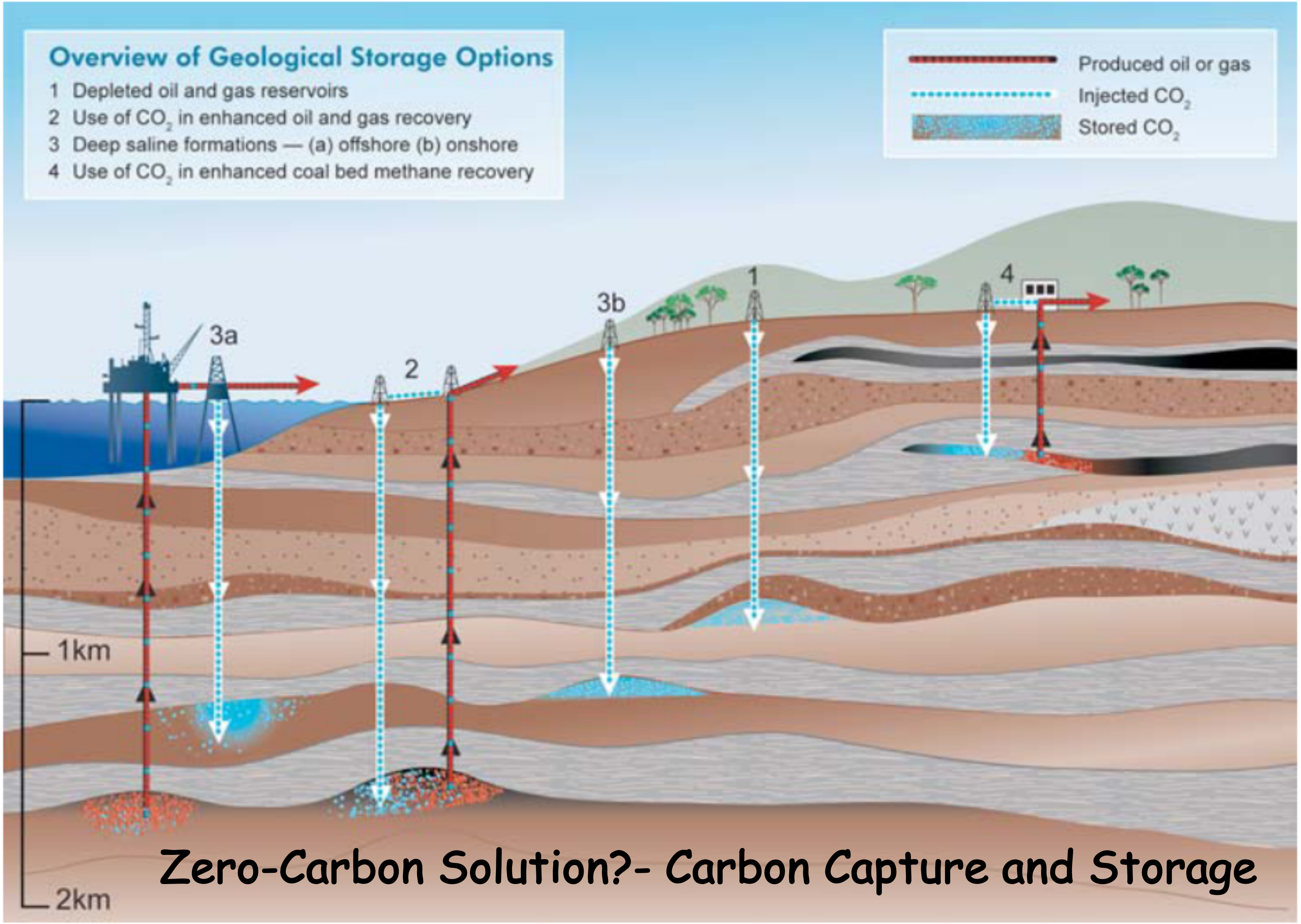
Pulrose Gas Power Station, Isle of Man, UK

Effort needed by 2054 for 1 wedge:

1600 GW of coal-fired generating capacity

~80 Tcf/yr Natural gas

CO_{2coal}/CO_{2gas} ratio is ~1.78 for equivalent thermal energy

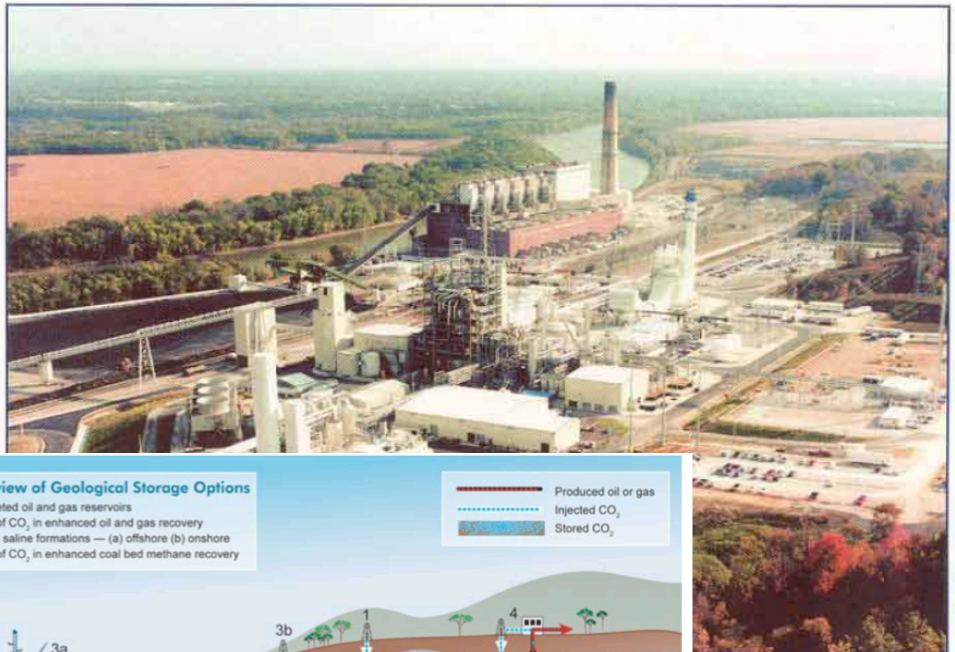


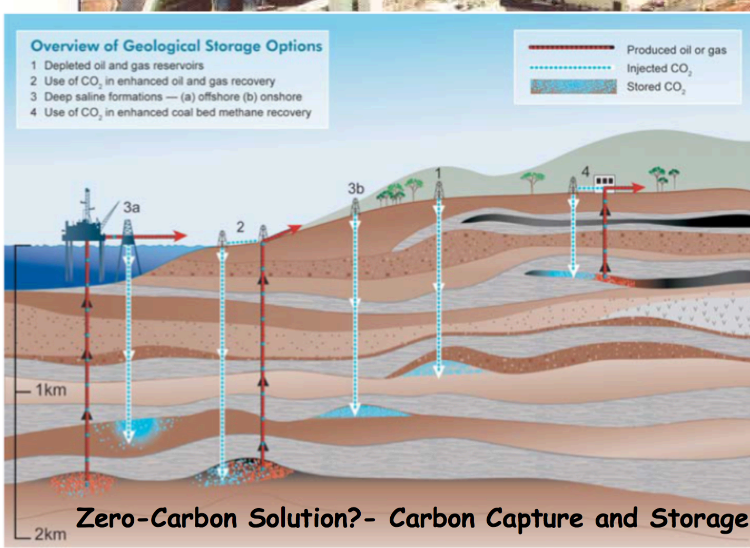
Zero-Carbon Solution?- Carbon Capture and Storage

Courtesy of CO2CRC, http://www.co2crc.com.au/

Capacity Needs – Socolow Wedges

Power with Carbon Capture and Storage





Zero-Carbon Solution?- Carbon Capture and Storage

Courtesy of CO2CRC, http://www.co2crc.com.au/

Project

Effort needed by 2054 for 1 wedge:

Carbon capture and storage at 800 GW coal power plants.

~40 Tcf/yr Natural gas

[**Rationale in:** Pacala & Socolow, *Science*, 2004, www.stabilisation2005.com/day3/**Socolow**.pdf]

Zero-Carbon Solution? - Enhanced Geothermal Systems

Challenges

- Prospecting (characterization)
- Accessing (drilling)
- Creating reservoir
- Sustaining reservoir
- Environmental issues

Observation

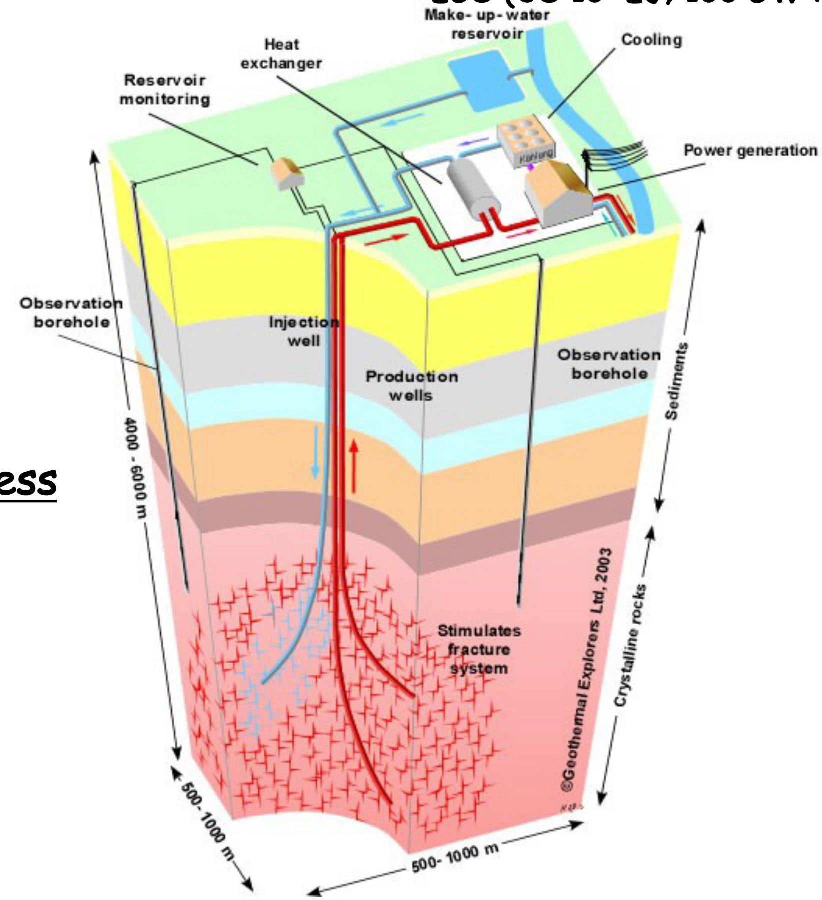
- Stress-sensitive reservoirs
- T H M C all influence via effective stress
- Effective stresses influence
  - Permeability
  - Reactive surface area
  - Induced seismicity

Understanding T H M C is key:

- Size of relative effects of THMC(B)
- Timing of effects
- Migration within reservoir
- Using them to engineer the reservoir

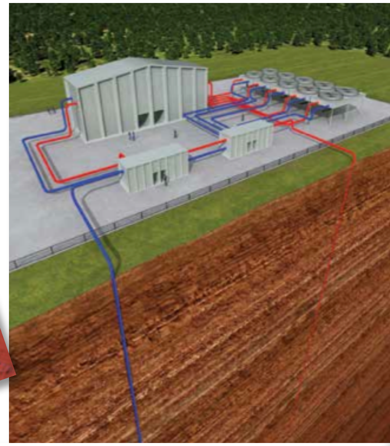
Resource

- Hydrothermal (US:10^4 EJ)
- EGS (US:10^7 EJ; 100 GW in 50y)



- Permeability
- Reactive surface area
- Induced seismicity

Hydrothermal v Engineered Geothermal Reservoirs



SedHeat Initiative

http://geothermal.tcu.edu

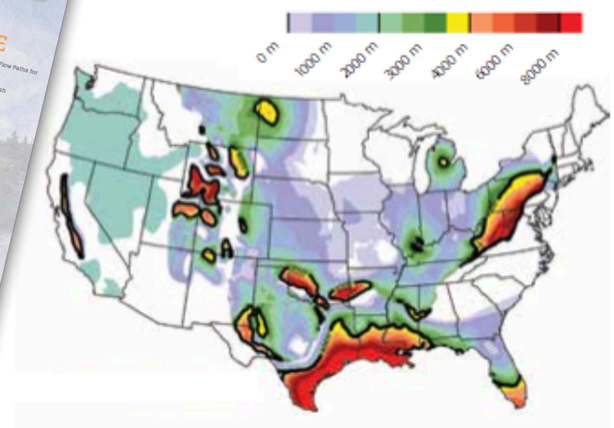


Figure 1: Distribution of sediment thickness in the conterminous U.S. 4 km isopach in black. Numerous Basin and Range basins over 4 km excluded for small resolution (Tester, et al., 2006)

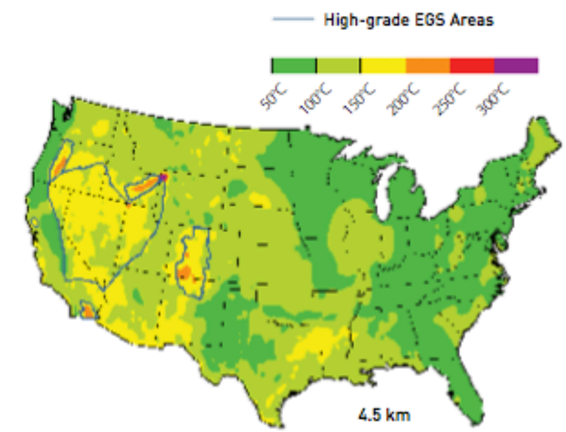
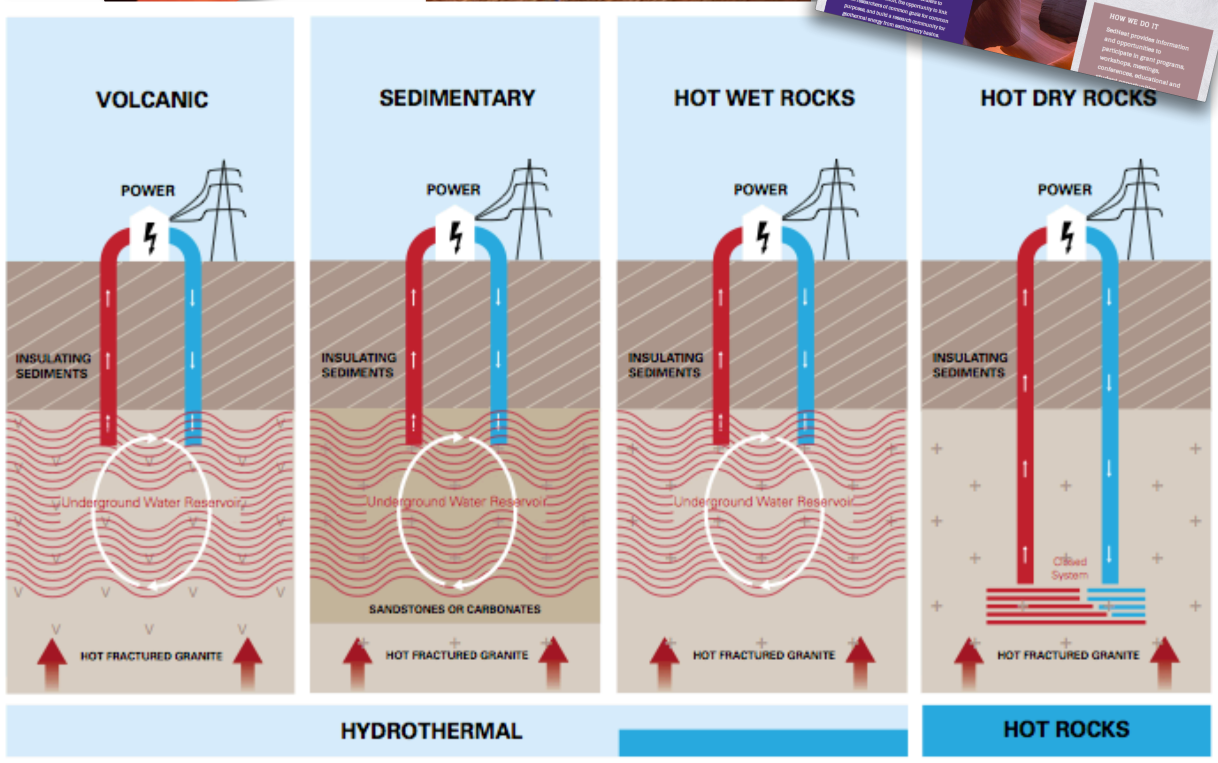
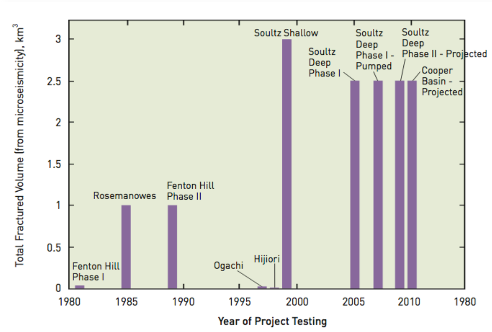
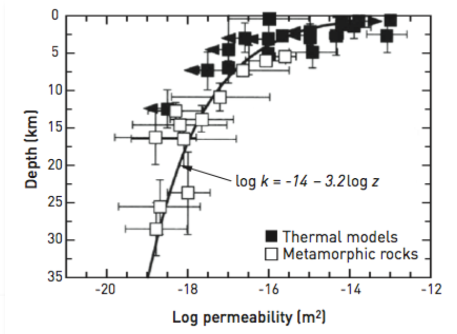


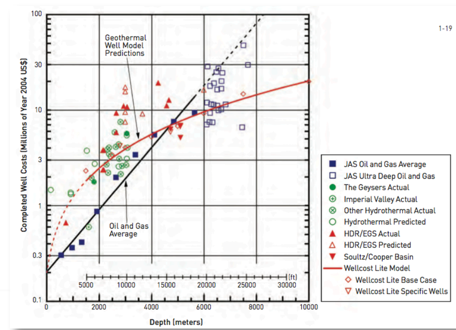
Figure 2: Average temperature at 4.5 km, conterminous United States. (Tester, et al., 2006, after Blackwell and Richards, 2004)

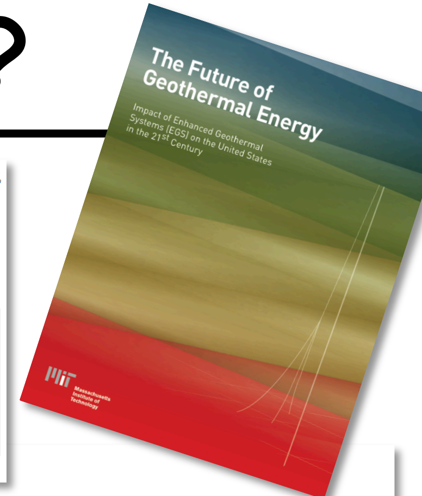


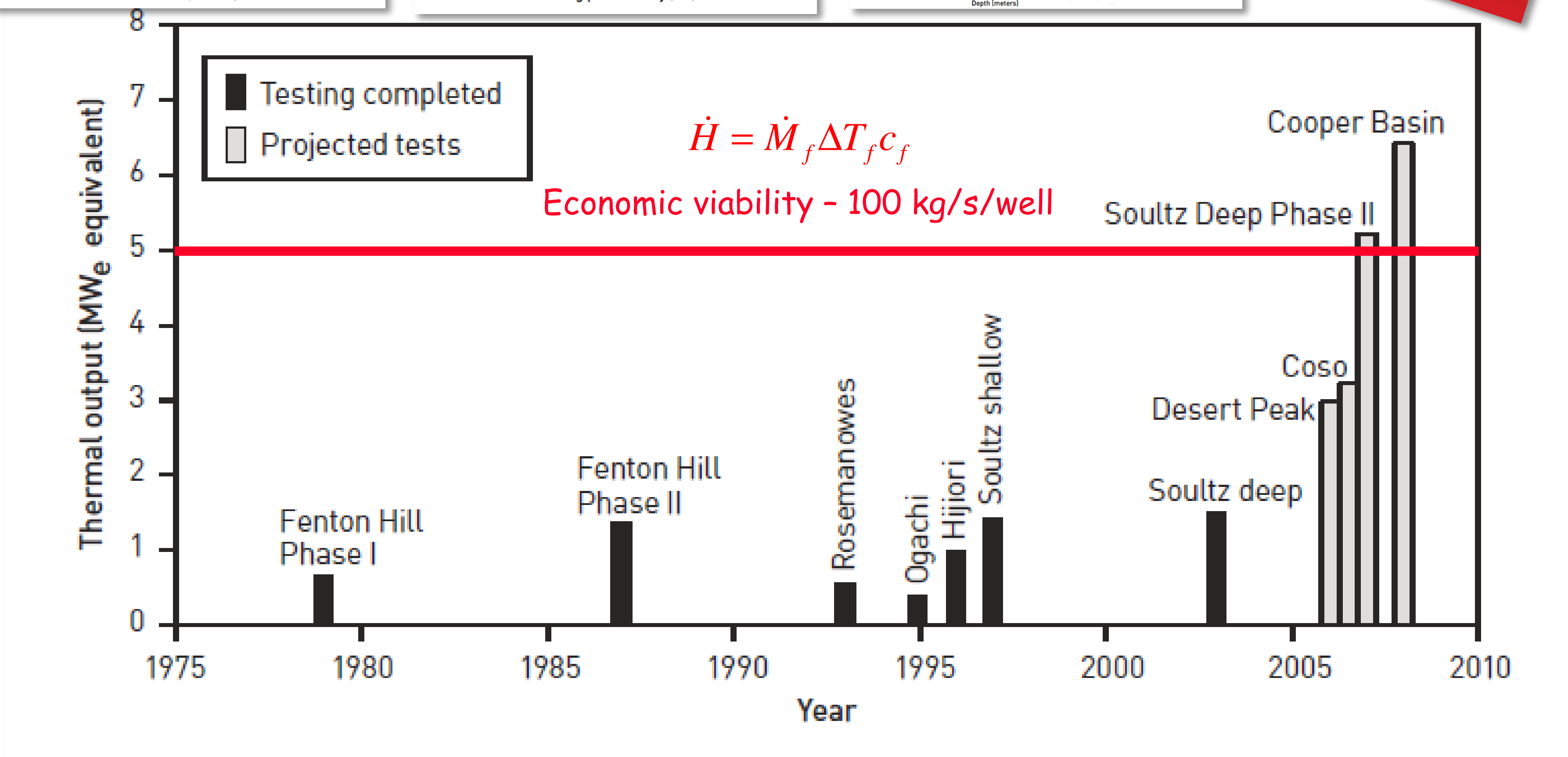
Can EGS ever be Viable?





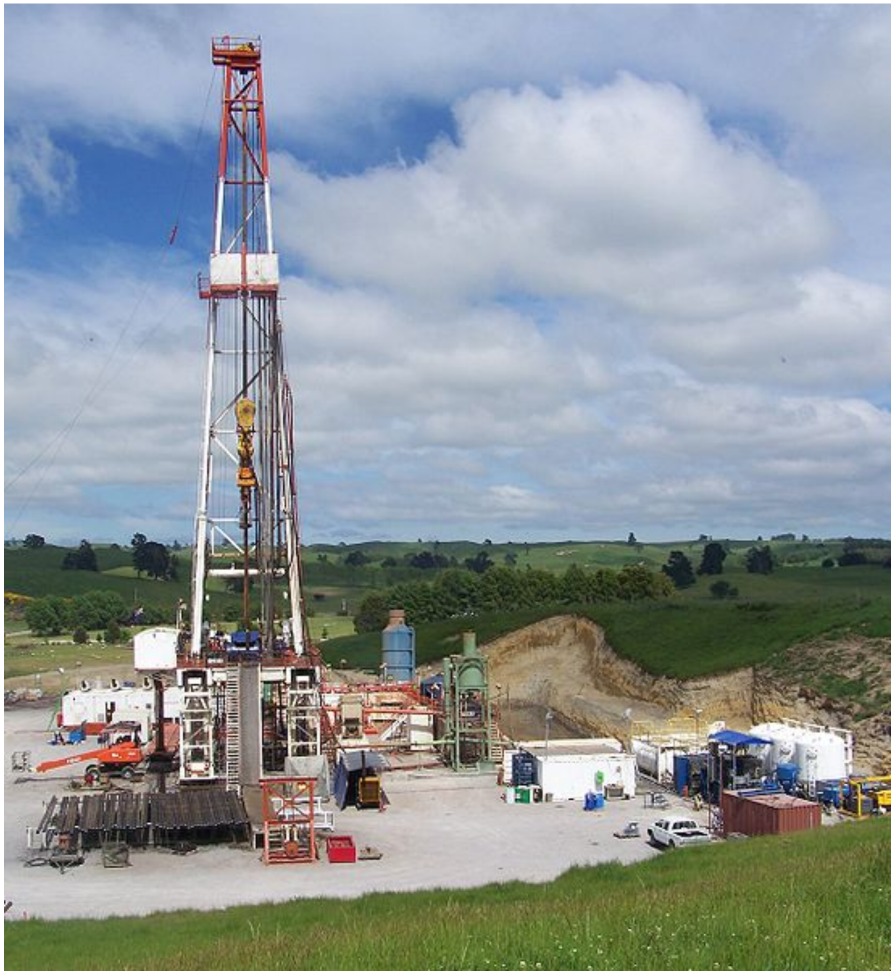






Capacity Needs – Socolow Wedges

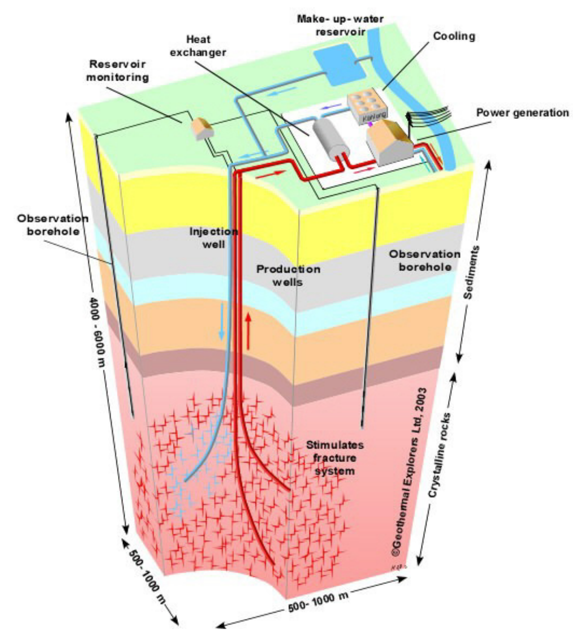
Retire Coal Fired Plants and Replace with EGS



Effort needed by 2054 for 1 wedge:

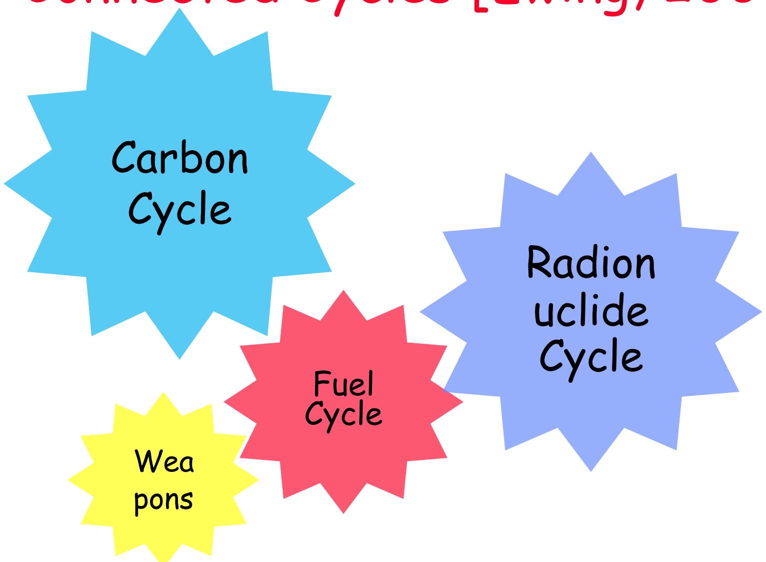
800 GW of EGS capacity

~40 Tcf/yr Natural gas



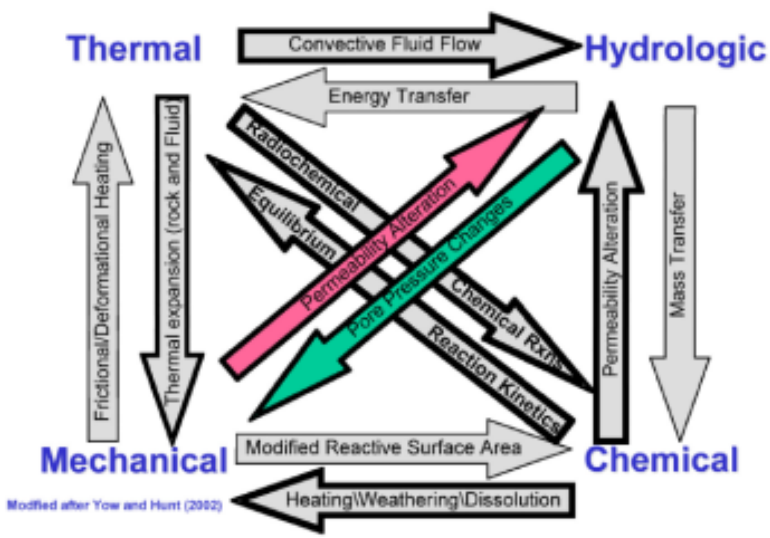
Zero Carbon Solution? – Nuclear Power

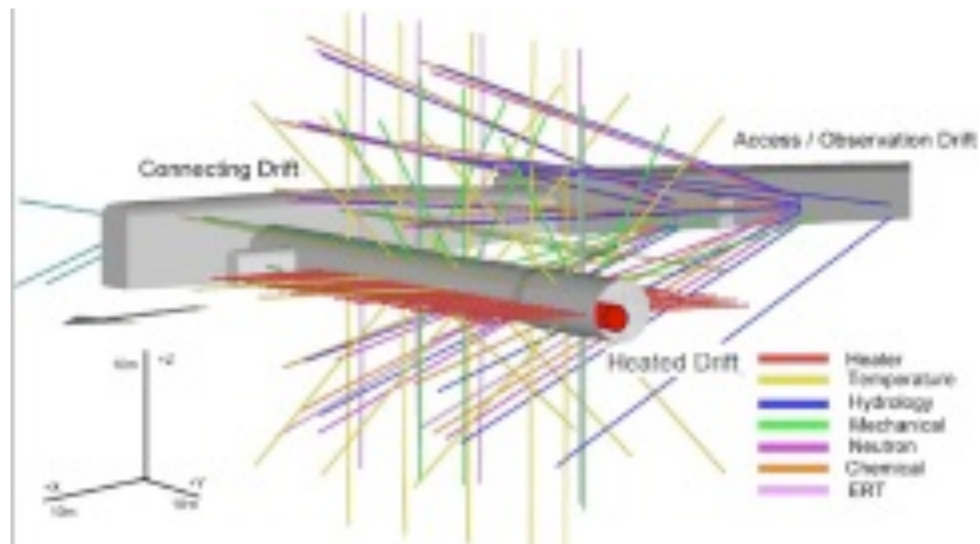
Connected Cycles [Ewing, 2007]



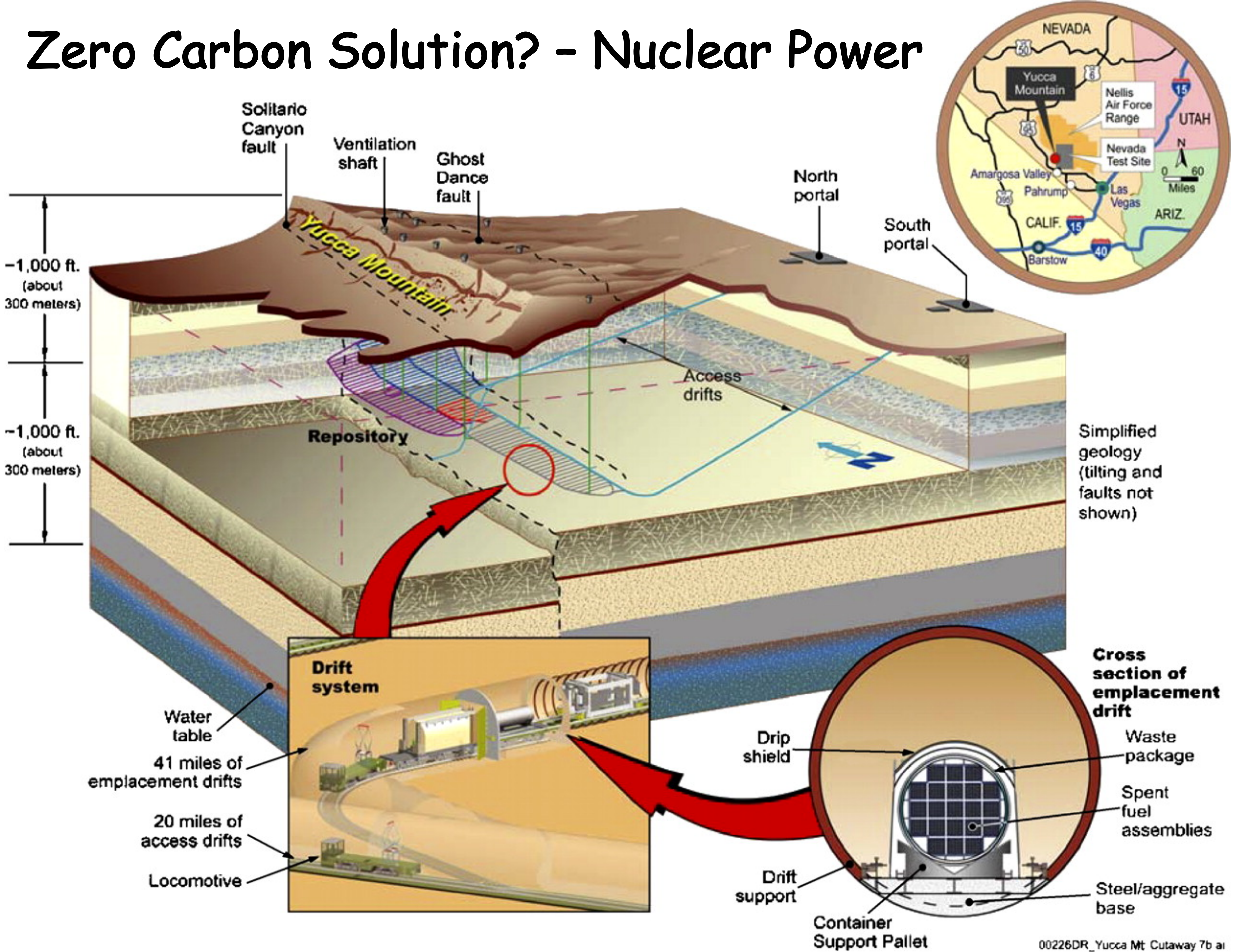
Waste Disposal and Politics

Intense Process Feedbacks





Zero Carbon Solution? – Nuclear Power



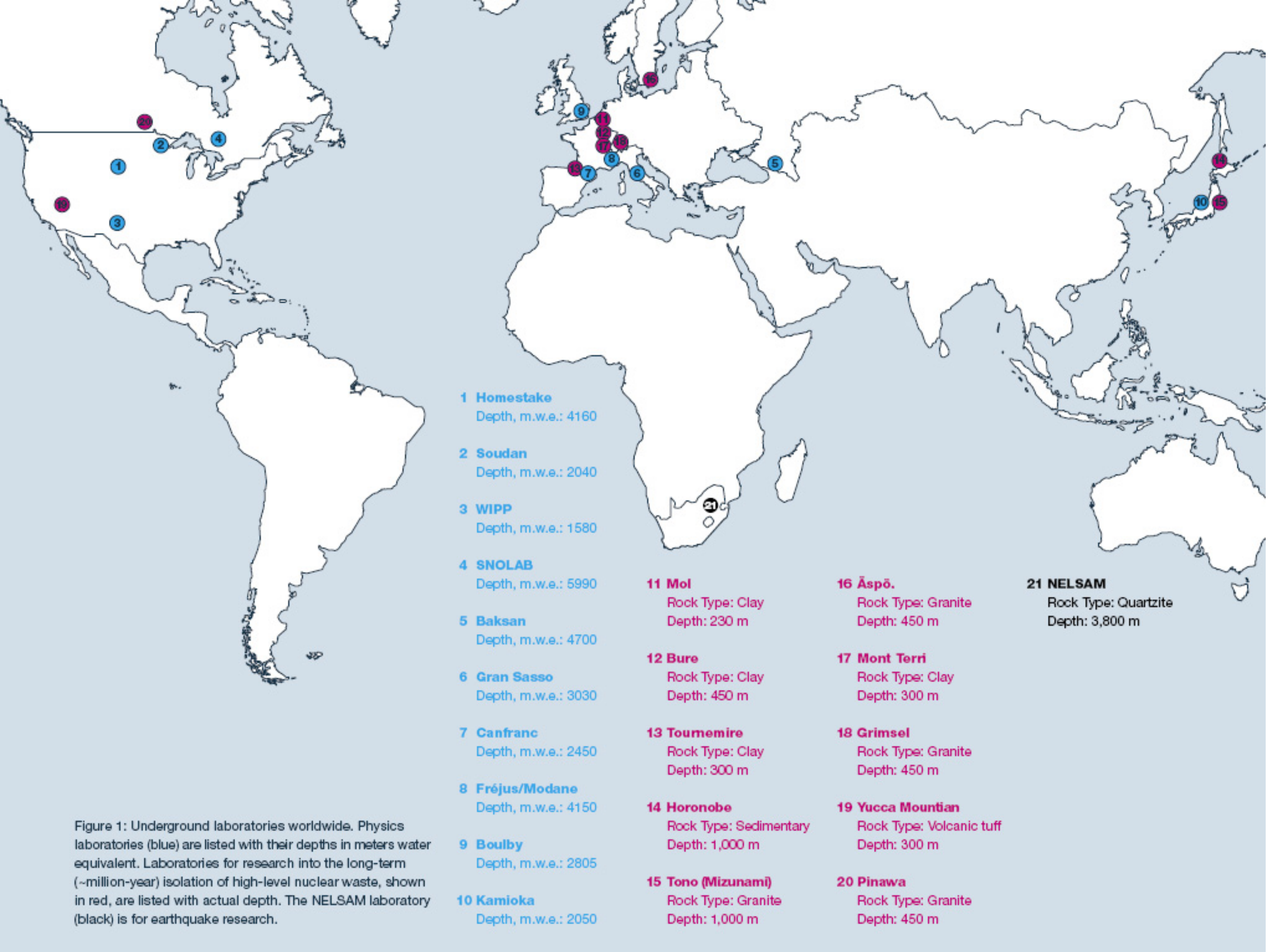


Figure 1: Underground laboratories worldwide. Physics laboratories (blue) are listed with their depths in meters water equivalent. Laboratories for research into the long-term (~million-year) isolation of high-level nuclear waste, shown in red, are listed with actual depth. The NELSAM laboratory (black) is for earthquake research.

Yucca Mountain in the News

Off-Again?

[NYT, January 29, 2009]

New Panel Will Study Disposal Of Waste

By MATTHEW L. WALD
Published: January 29, 2010

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WASHINGTON

The Energy Department plans to announce on Friday the formation of a "blue ribbon" commission to study the disposal of nuclear waste.

The commission is to be led by Lee H. Hamilton, a former member of Congress and co-chairman of the Sept. 11 commission, and Brent Scowcroft, a retired Air Force general and former presidential adviser, said a staff member of a member of Congress from Nevada.

The Obama administration promised to appoint such a study group almost a year ago, after announcing that it would cease study of Yucca Mountain, a volcanic structure about 100 miles from Las Vegas that had been chosen by Congress as the leading candidate for nuclear waste disposal.

The Senate majority leader, Harry Reid, Democrat of Nevada, had made killing the Yucca Mountain option a priority. Energy Secretary Steven Chu has said that the commission will not consider Yucca Mountain. Dr. Chu has spoken of alternatives to the burial of nuclear waste, including new reactors that might reuse some of the waste by turning it into energy, and the commission will consider those possibilities.

The federal government faces billions of dollars in damages in lawsuits by utilities, because in the early 1980s it signed contracts agreeing to begin taking the waste in 1998. The utilities, in exchange, paid the government one-tenth of a cent per kilowatt-hour produced by the reactors. On Jan. 12, the United States Court of Appeals for the Federal Circuit ruled against the Energy Department's most recent argument, that it could not be forced to pay because the delay was unavoidable.

Yucca Mountain in the News

Or On-Again?

[NYT, June 29, 2010]

Administration Cannot Drop Bid for Nuclear Waste Dump in Nevada, Panel Finds

By MATTHEW L. WALD
Published: June 29, 2010

WASHINGTON — In a setback for the Obama administration, a panel of judges at the Nuclear Regulatory Commission ruled on Tuesday that the Energy Department could not withdraw its application to open a nuclear waste dump at Yucca Mountain in Nevada.

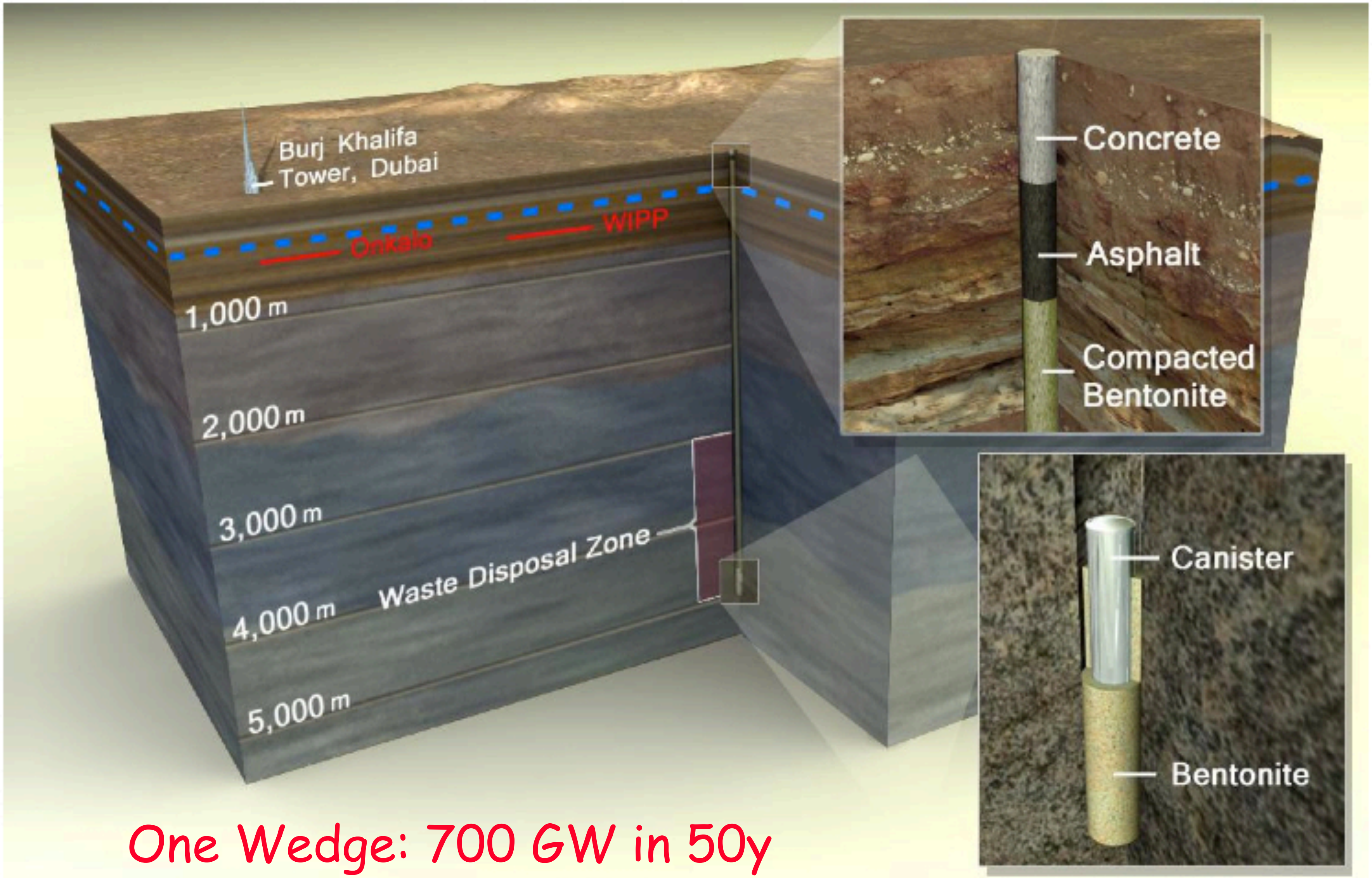
The New York Times

Congress selected the Yucca Mountain location in 1987.

Making good on a campaign pledge by President Obama, the Energy Department had formally sought to drop its plan for Yucca Mountain, a volcanic structure about 100 miles from Las Vegas. But states with major accumulations of waste from nuclear weapons production had petitioned to prevent the department from doing so.

In a 47-page decision, the three-member panel of administrative judges said the Energy Department lacked the authority to drop the petition because it would flout a law passed by Congress.

The New US Plan



One Wedge: 700 GW in 50y
40 Tcf/y

[http://www.forbes.com/]

Sub-Surface Energy/Engineering Solutions

Low-Carbon Fuel Solutions?

Unconventional Hydrocarbons

- Gas shales
- Coalbed methane
- Methane hydrates

Carbon Management Solutions?

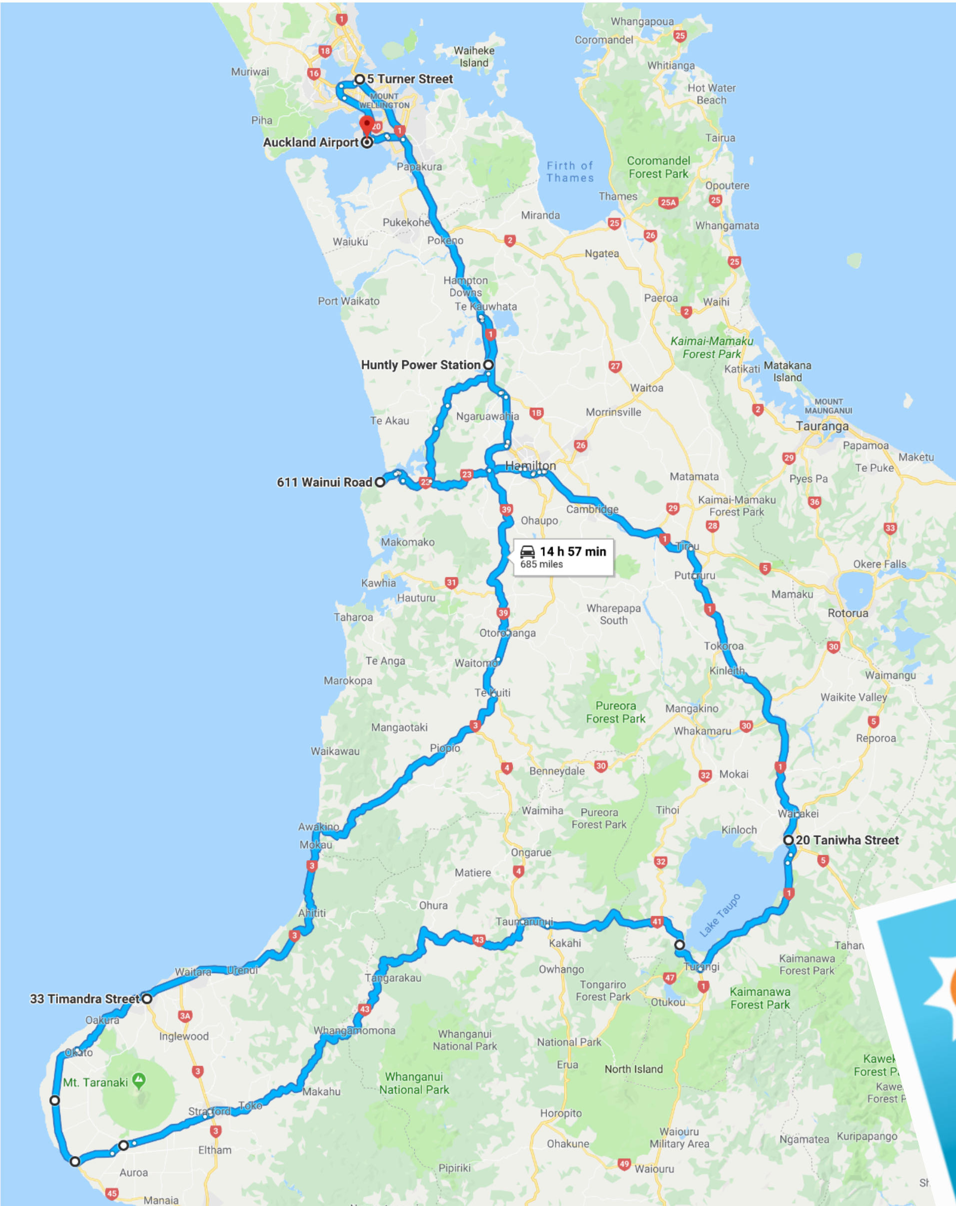
- Carbon Capture and Sequestration

Zero-Carbon Solutions?

- EGS Geothermal – The new landscape
- Nuclear power
- Hydropower/Pumped storage/CAES
- Wind
- Solar PV and thermal

The Green New Deal

Sustainable Energy in New Zealand

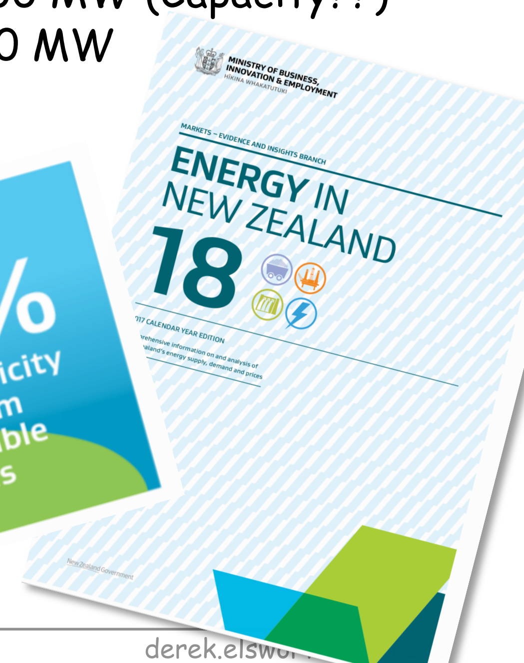


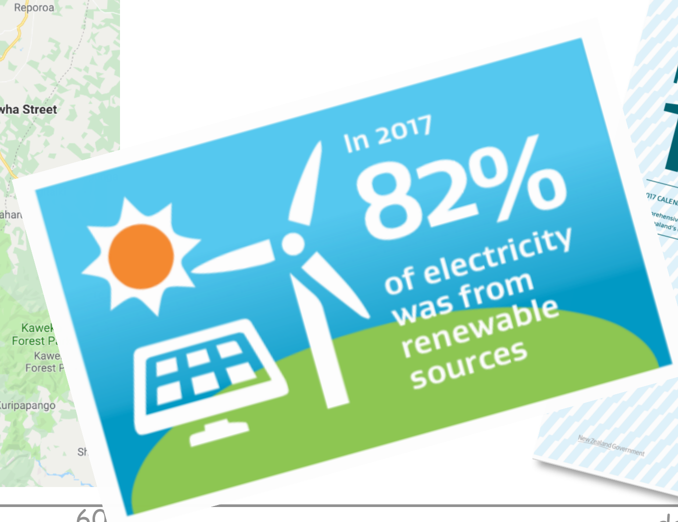
Annual Consumption – 1 EJ (NZ)
100 EJ (USA)

NZ Energy consumption 1 EJ/yr ~ 30 GW

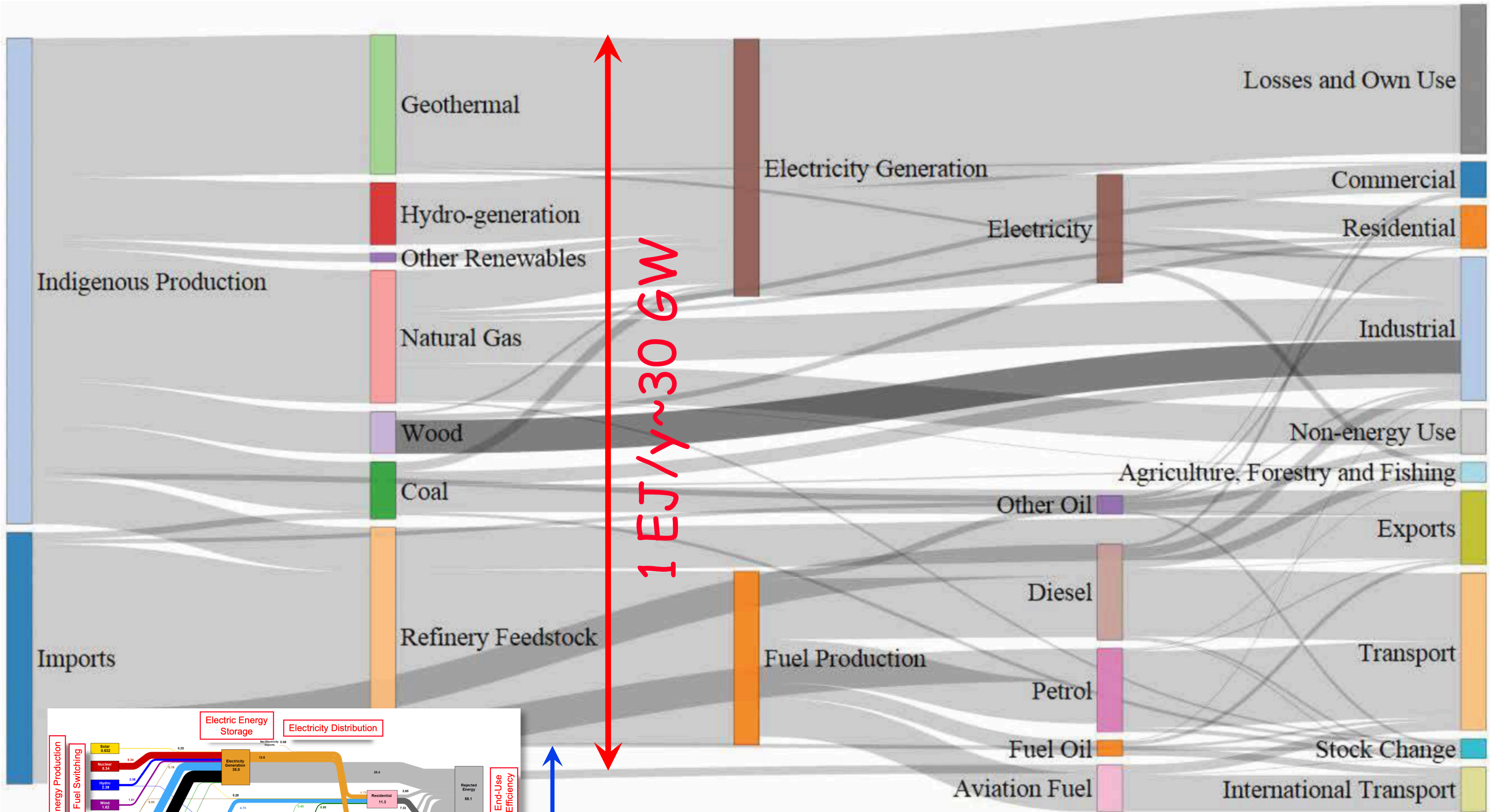
Typically 50/50 Electricity/Transportation

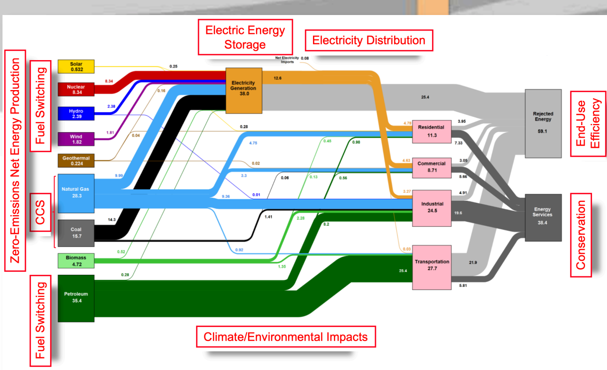
Thermal – 1400 MW (Huntly)
Gas (360 MW)
Coal (4 x 250 MW)
Wind – 2000 MW (Capacity??)
Hydropower – 2000 MW (Capacity??)
Geothermal – 1040 MW





Sankey Chart for NZ Energy Consumption





USA 100 EJ/y~3000 GW (3 TW)

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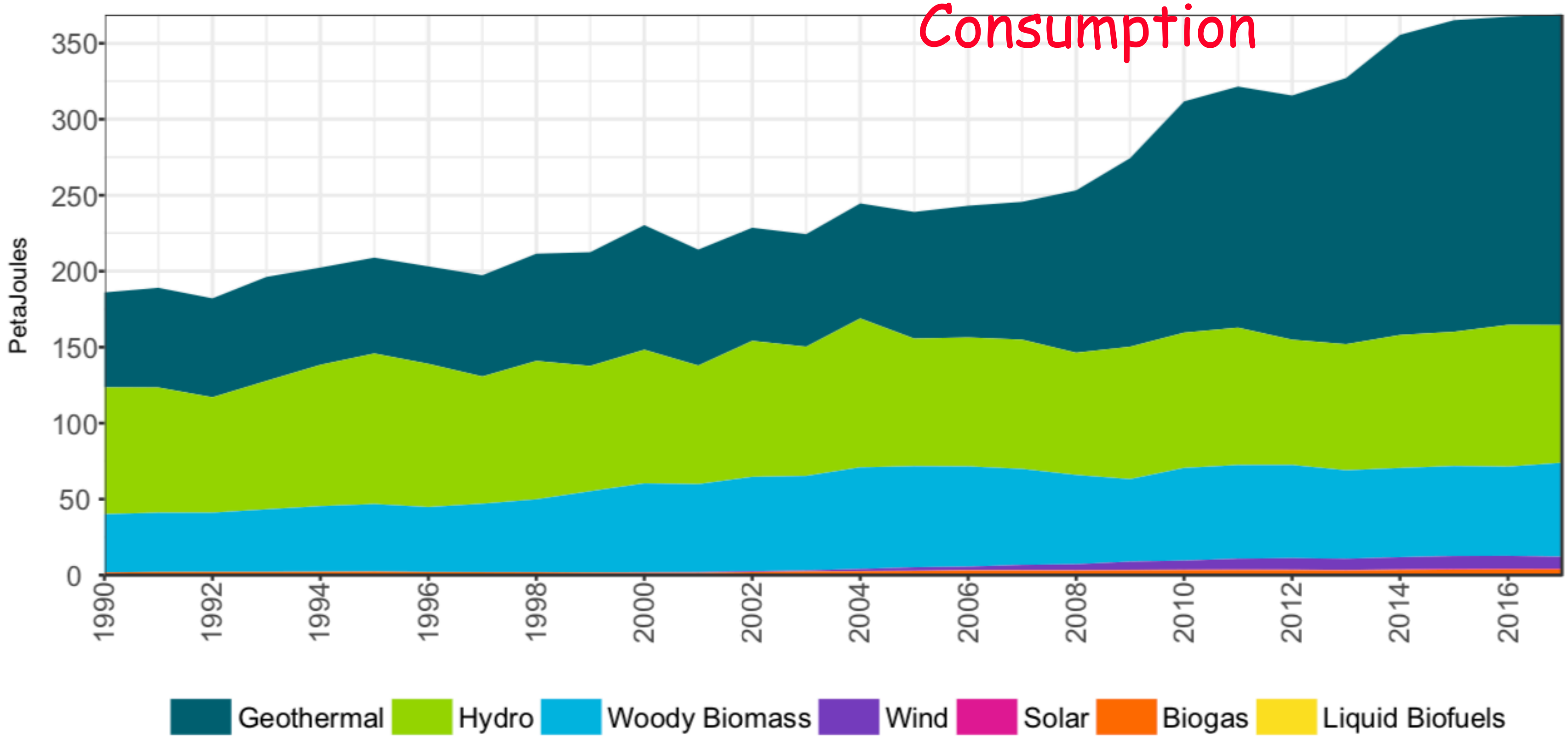
Renewable Energy in NZ (1000 PJ total)

Figure 23: Total Renewable Primary Energy Supply

0.35 EJ of 1 EJ total NZ Consumption



Concluding Remarks

Our current predicament is carbon-energy constrained.....

Low-carbon, carbon-neutral and carbon-negative solutions offer a potential path forward that:

- May mitigate climate change issues
- Are an orderly – non-Malthusian solution

For low(er)-carbon fuels (Natural gas)

- Avoids the policy-based "tragedy of the commons"
- Industry driven with an appropriate profit motive

For others (CCS/EGS/Nuclear/Intermittency Solving)

- Significant investment needed (sub-economic)
- Government-sponsored R&D/legislated/subisdy-abating
- Fascinating science-based problems to solve (IS..)

Your choice for which are Good, Bad or Ugly.... but

……….. any selection is ultimately subject to policy choices

…..(hopefully) based on sound scientific input.....