Fossil Energy Primer

A view of the Himalayas from Lhasa

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U.S. Energy Independence

- Fossil fuels run 85 percent of U.S. economy directly, and the remainder has a variable but non-negligible fossil fuel content
- Electricity is produced almost entirely from domestic energy sources
- Natural gas is the swing fuel for electricity generation
- Natural gas could aid in the electrification of railroads
- Natural gas could supplement petroleum as an automotive fuel

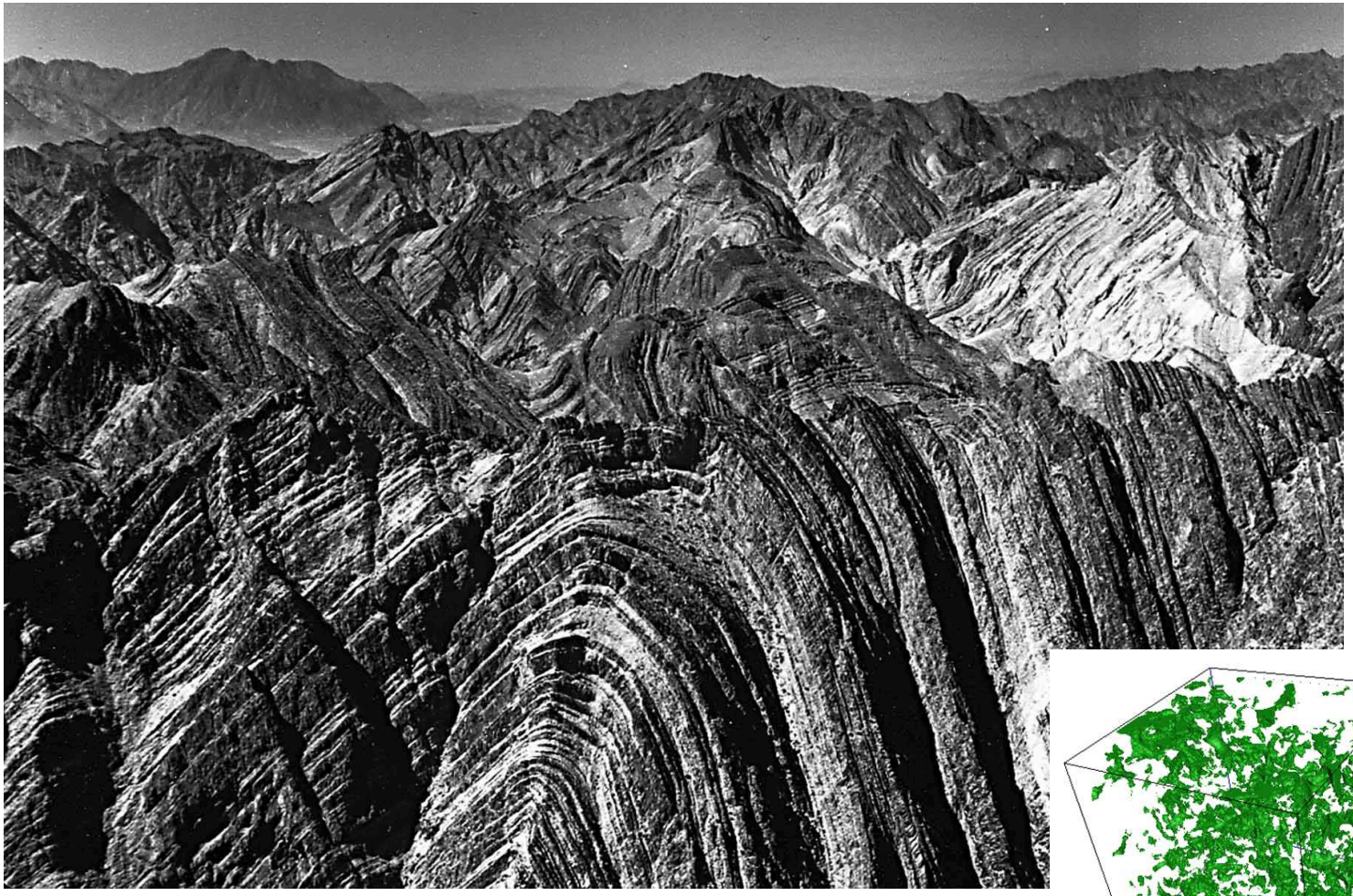
Summary of Conclusions...

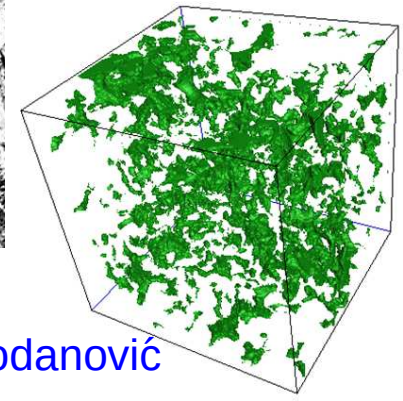
- The global rate of production of oil is peaking now, coal will peak in 2-5 years, and natural gas in 20-50 years
- There is PLENTY of fossil fuels ("resources") left all over the Earth
- The resource size (current balance of a banking account) is mistakenly equated with the speed of drawing it down (ATM withdrawals)
- Few understand the ever more stringent daily withdrawal limits imposed by nature on our ATM cards (oil & gas wells and coal mines)
- Even fewer understand the high minimum balances (resource left behind) imposed on all oil, coal and gas recovery deposits

Summary of Conclusions...

- Economists, business people, and policy makers generally have poor understanding of banking
- They know what the rate of withdrawals (energy demand) should be, but have little idea about the withdrawal limits (energy supply)
- Offshore and unconventional fields will be producing an increasing portion of global oil supply
- Solar energy flow-based solutions (wind turbines, photovoltaics, and biofuels) will require most radical changes of our lifestyles
- Thermodynamically, industrial-scale biofuels are not sustainable, and will damage the Earth's most vital ecosystems

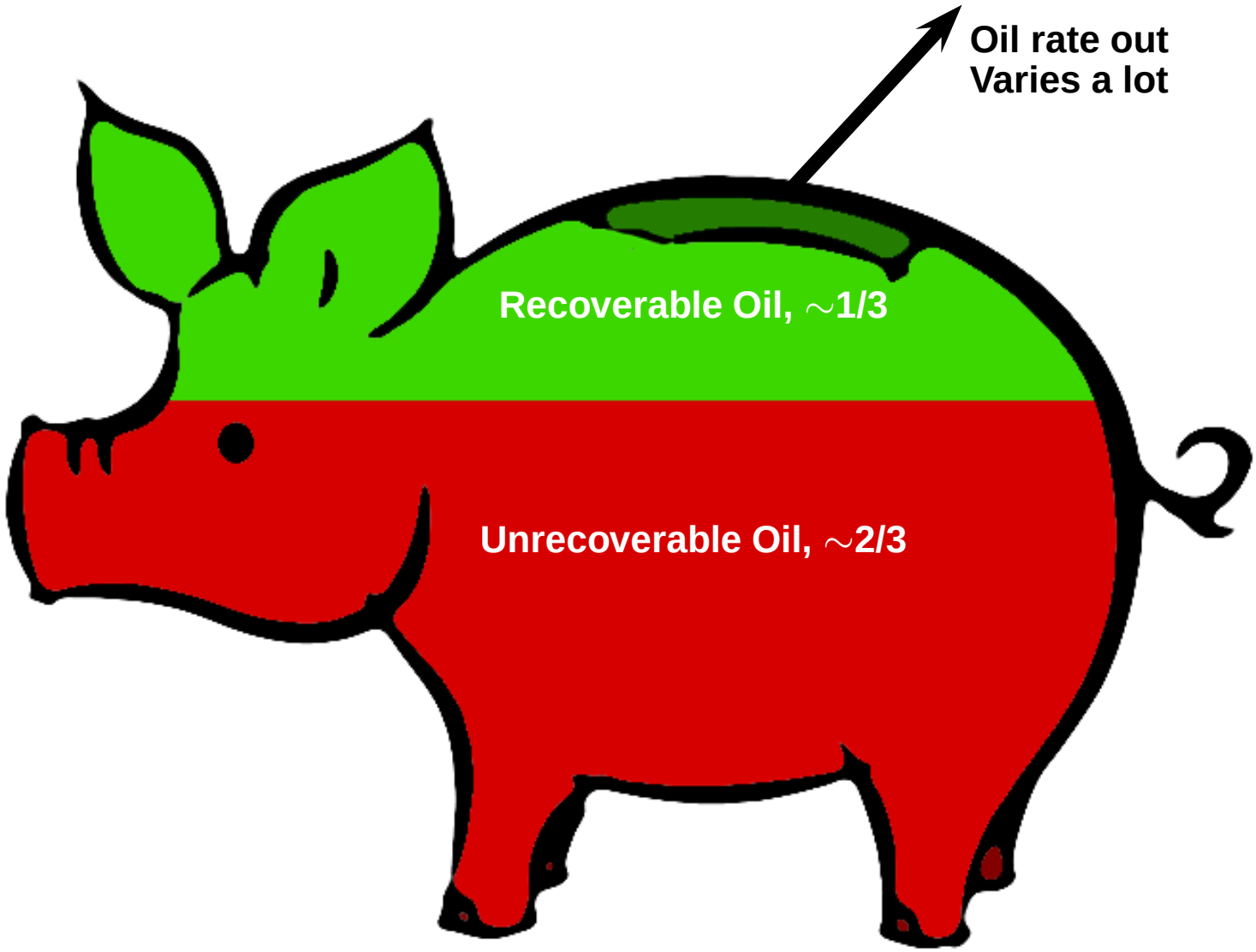
Oil Resides in Deep Subsurface





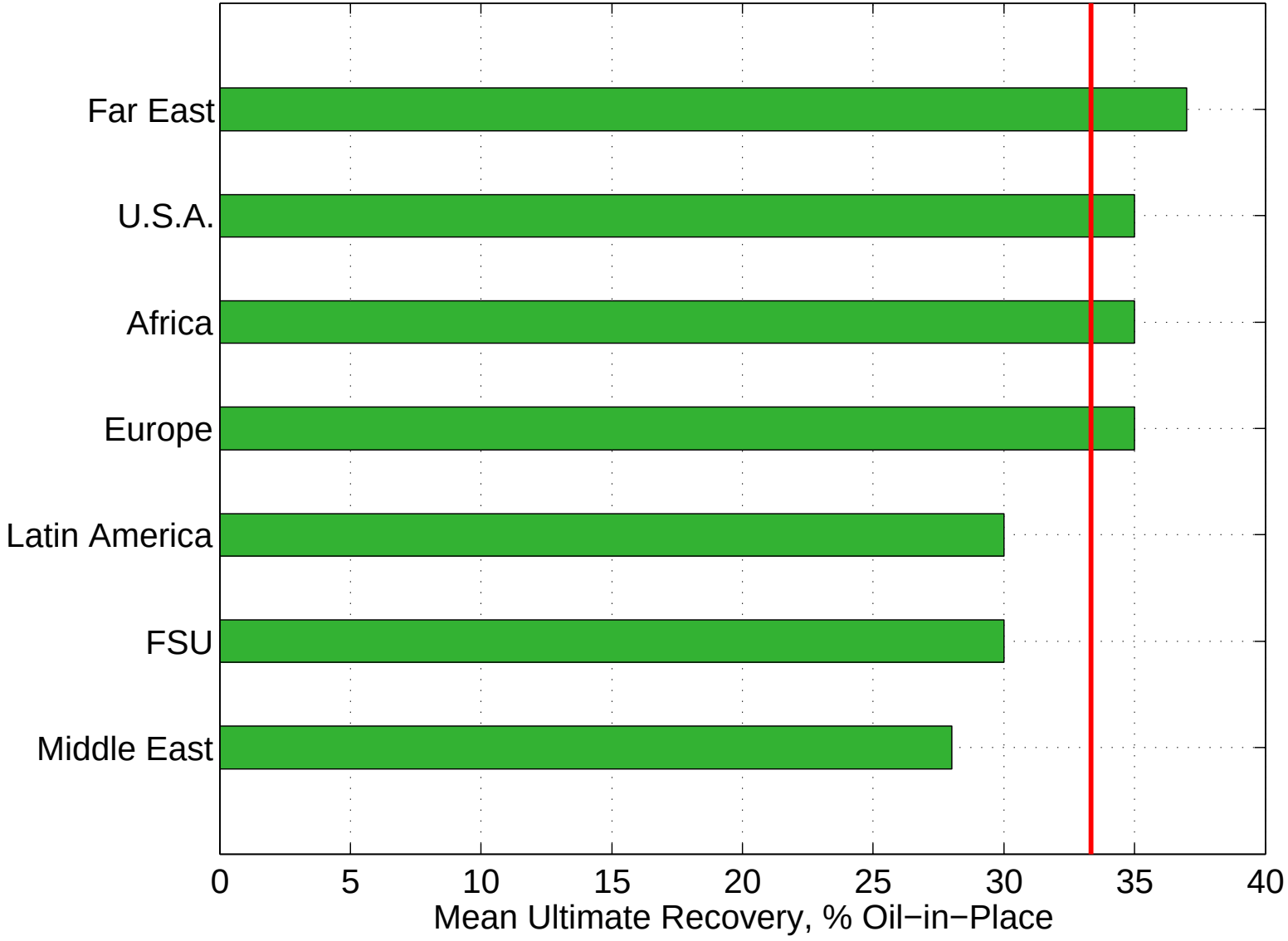
Zagros Mountains by J. T. Daniels (NASA), pore scale by Maša Prodanović

Accumulation vs. Production



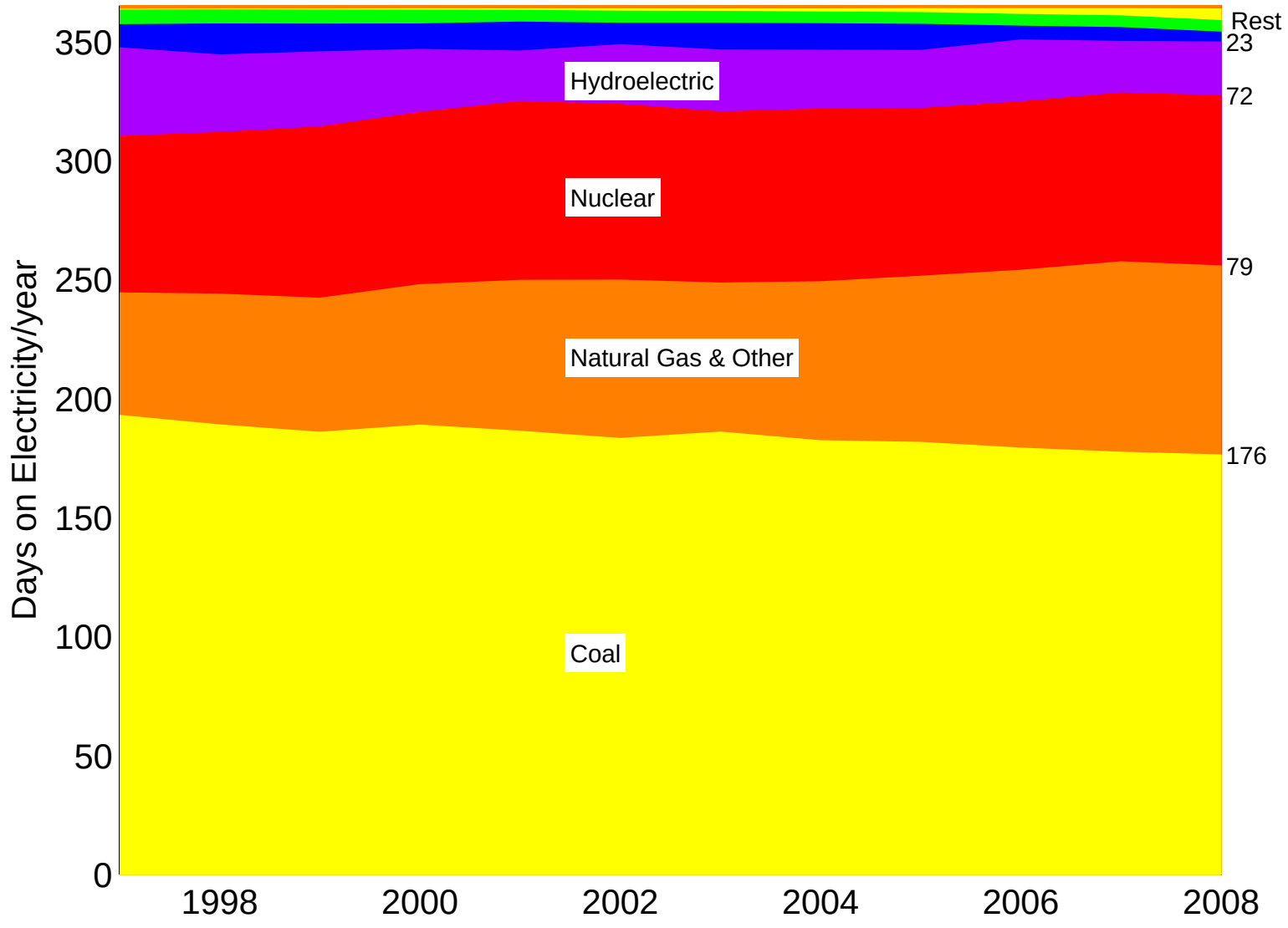
Accumulation = Piggy Bank, Coin Slot = Oil Wells, Injection Wells, and Surface Facilities

Mean Ultimate Recoveries



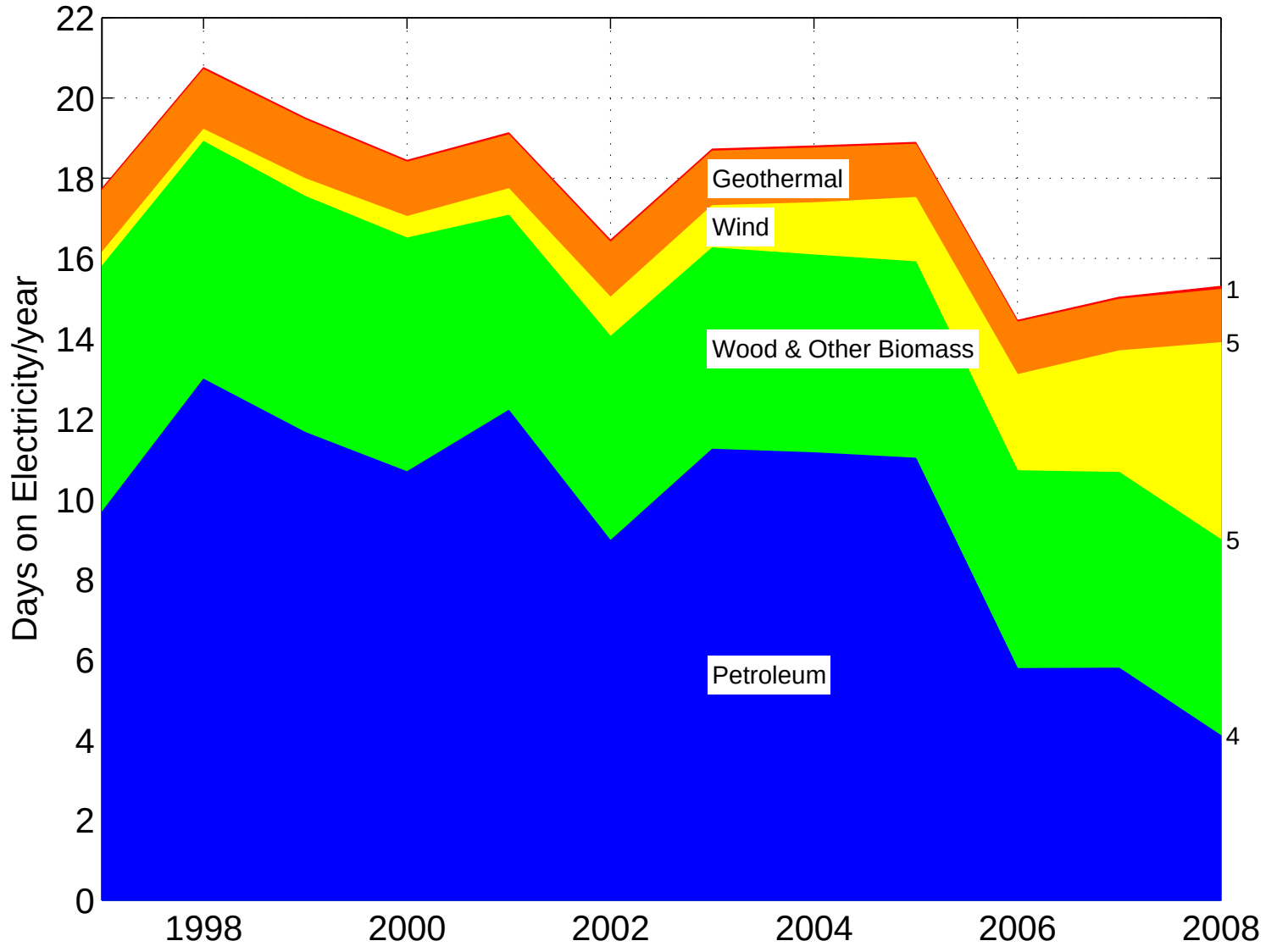
Sources: Laherrere, 2002, other sources

Electricity generation



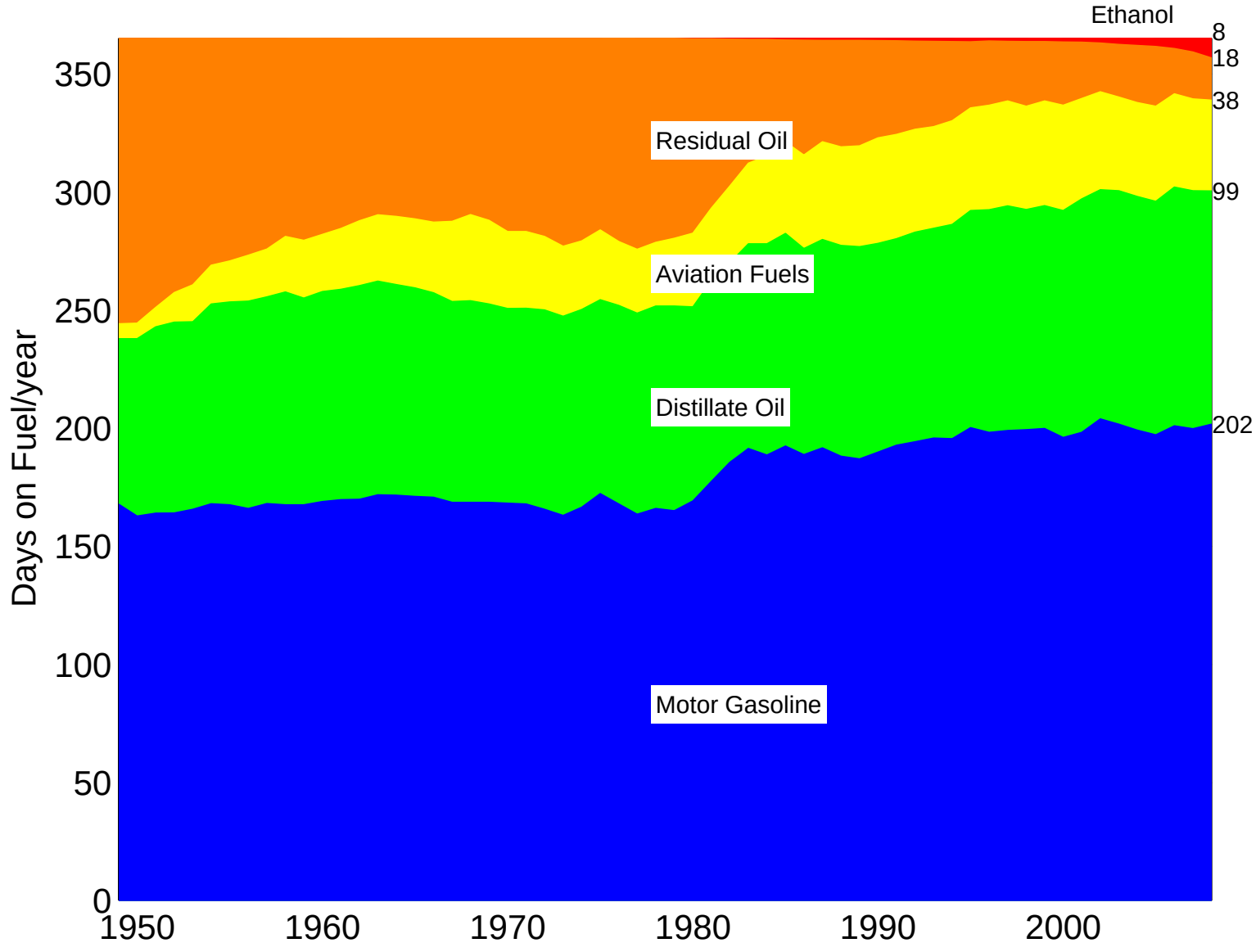
37% of U.S. primary energy use. Source: DOE EIA, accessed 03/28/2010

Electricity generation – Rest



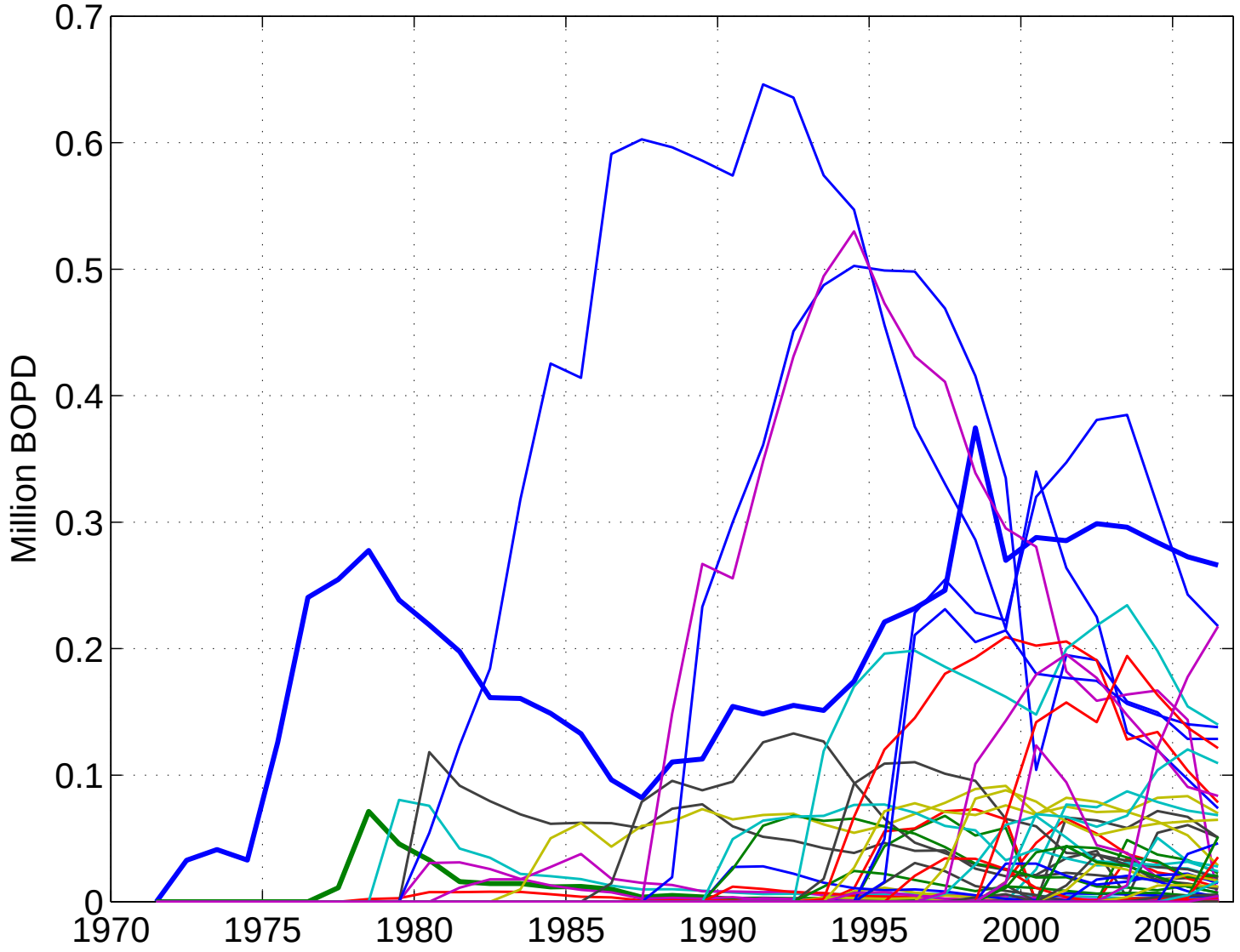
Solar thermal and PV = 1 hour of U.S. electricity. Source: DOE EIA, accessed 03/28/2010

Transportation Fuels



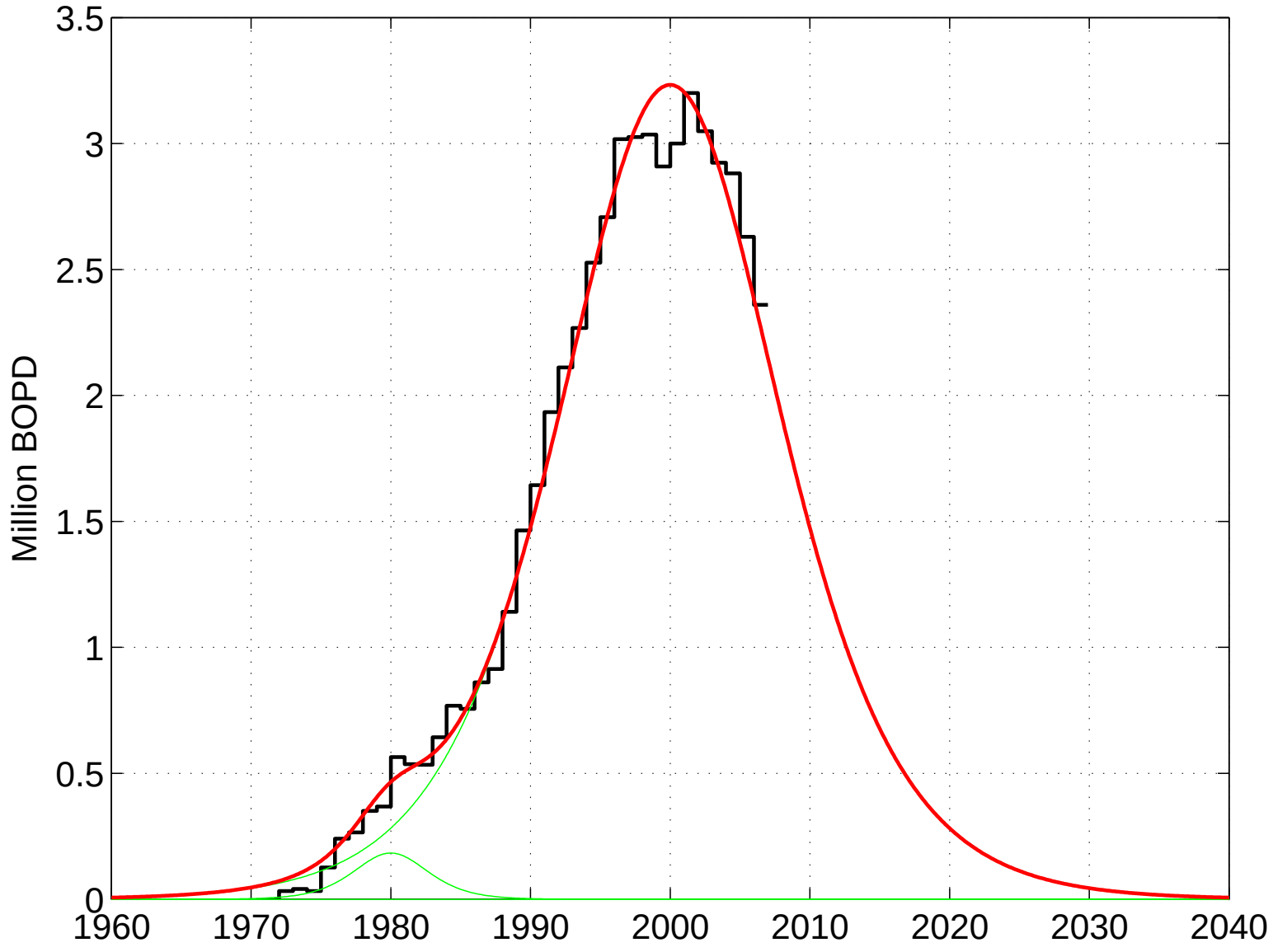
31% of U.S. primary energy use. Source: DOE EIA, accessed 03/28/2010

Predicting the Future…



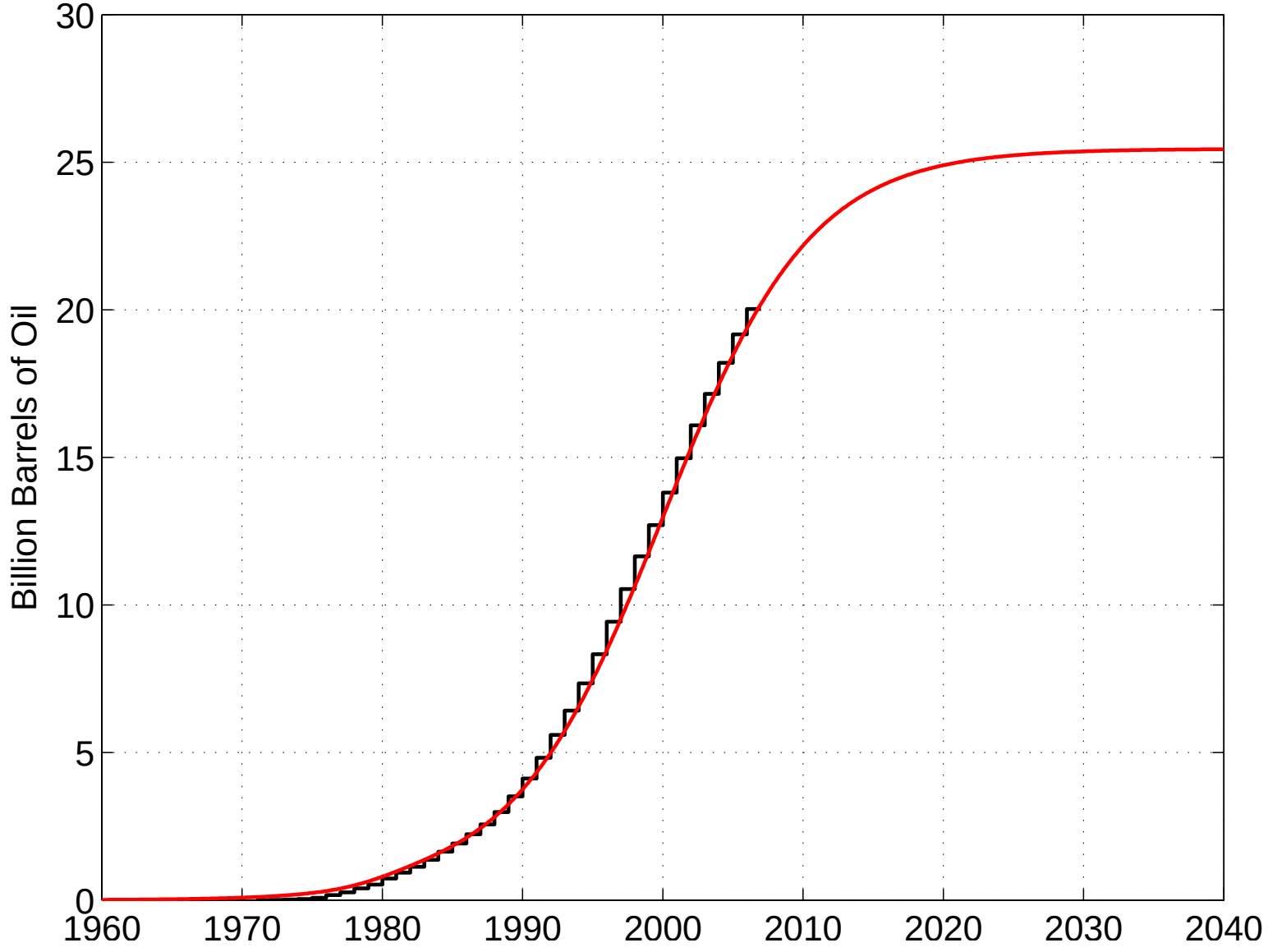
Production histories of 65 oilfields in the North Sea. Sources: Norwegian Government (2009), Patzek & Croft (2010). The thick lines are Ekofisk and Ekofisk West

. . . Emergent Behavior . . .



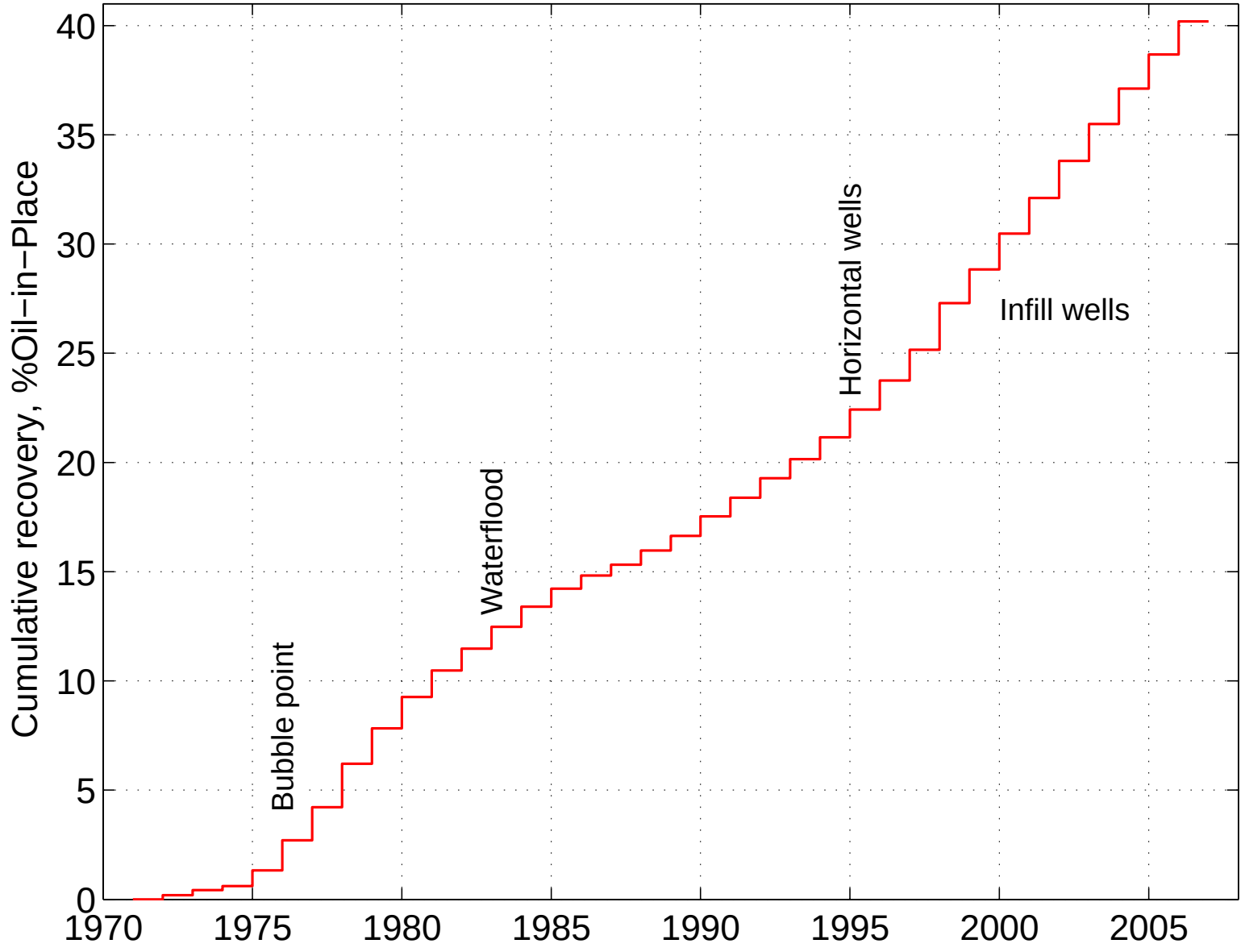
A single Hubbert curve explains almost all of Norwegian production in the North Sea

A Future of Norwegian North Sea



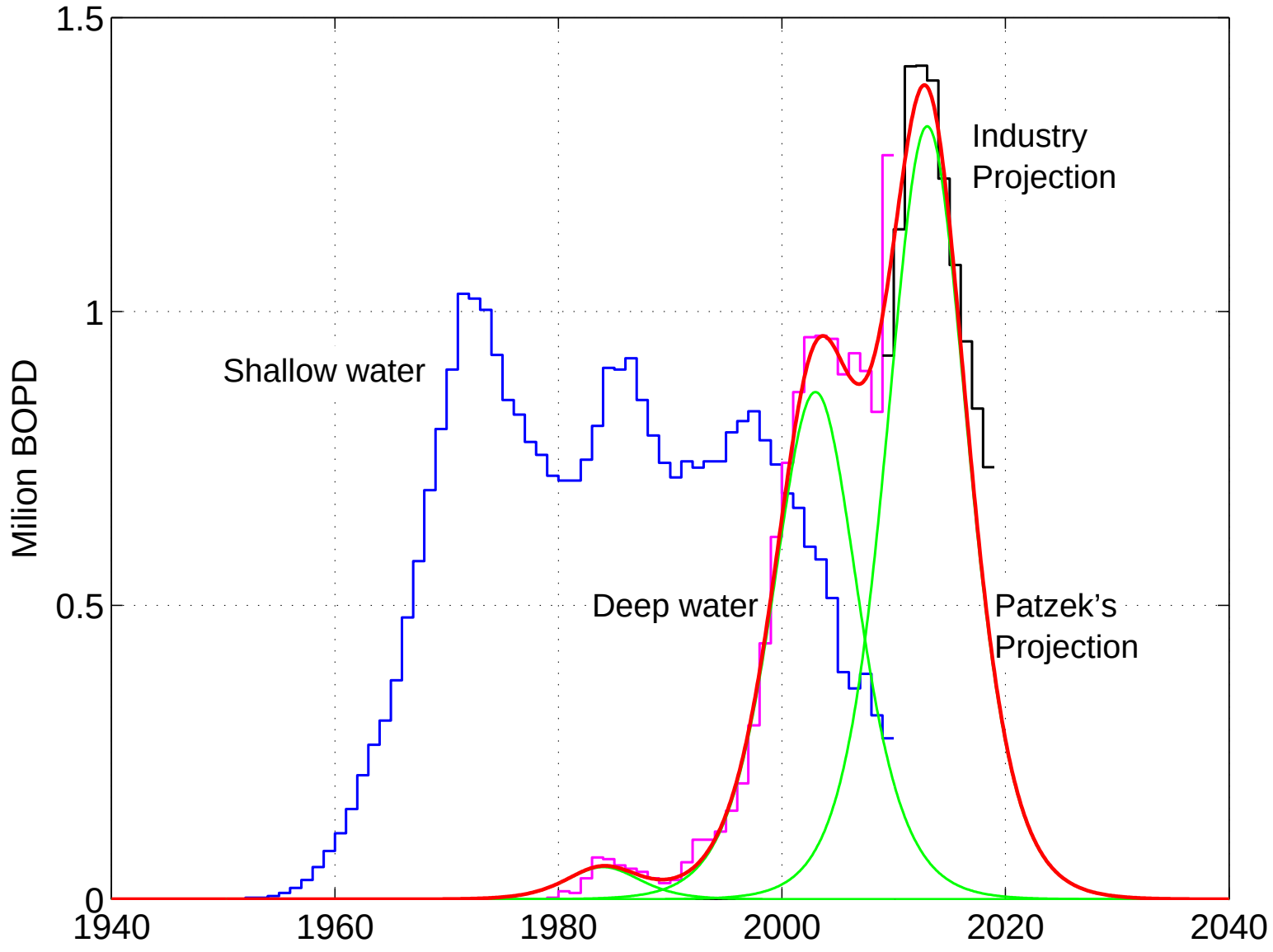
Sources: Norwegian Government (2009), Patzek & Croft (2010)

North Sea: Ekofisk



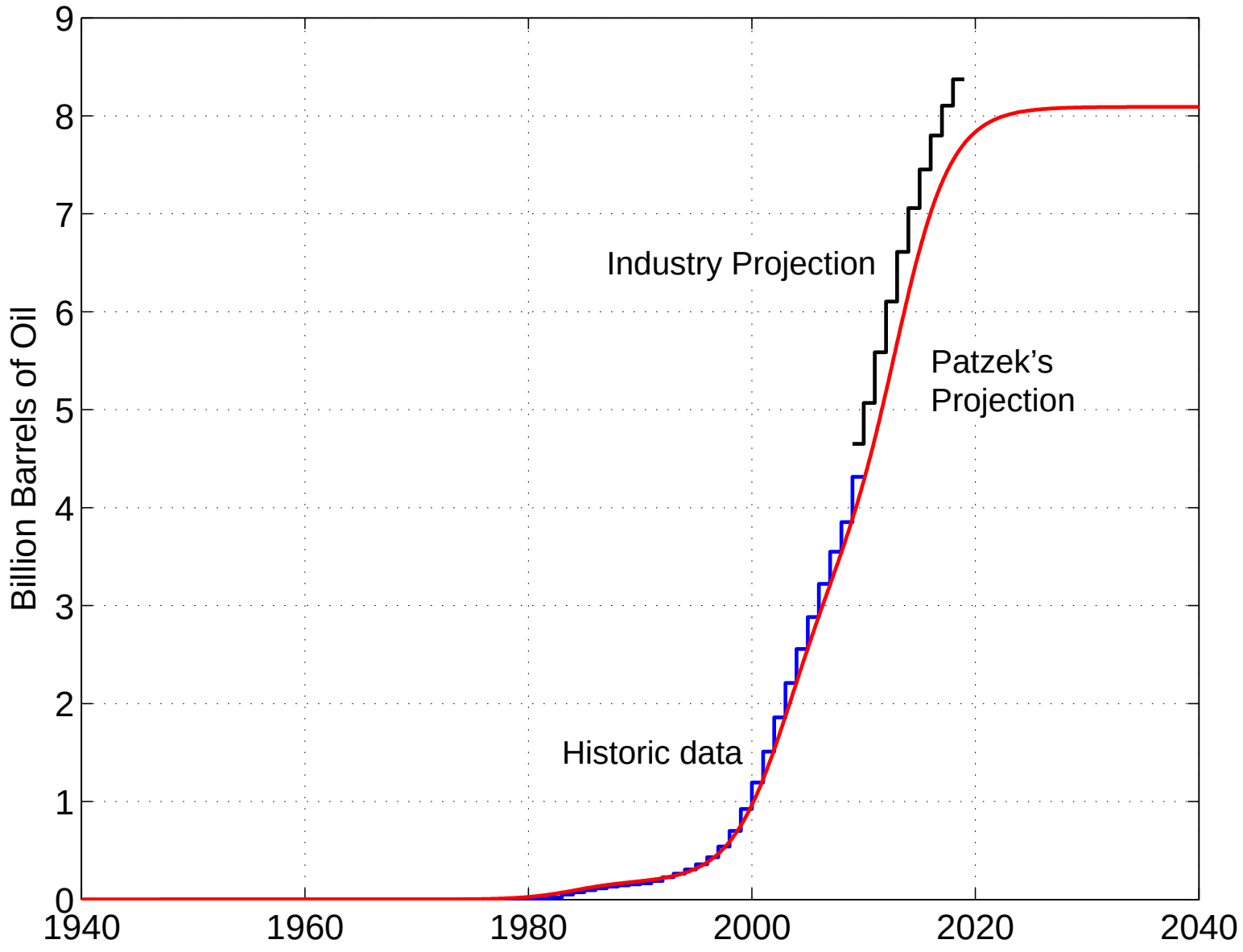
OIP=6.4 billion bbl. Sources: Norwegian Government (2009), Patzek & Croft (2010)

Emergent Behavior in the Gulf…



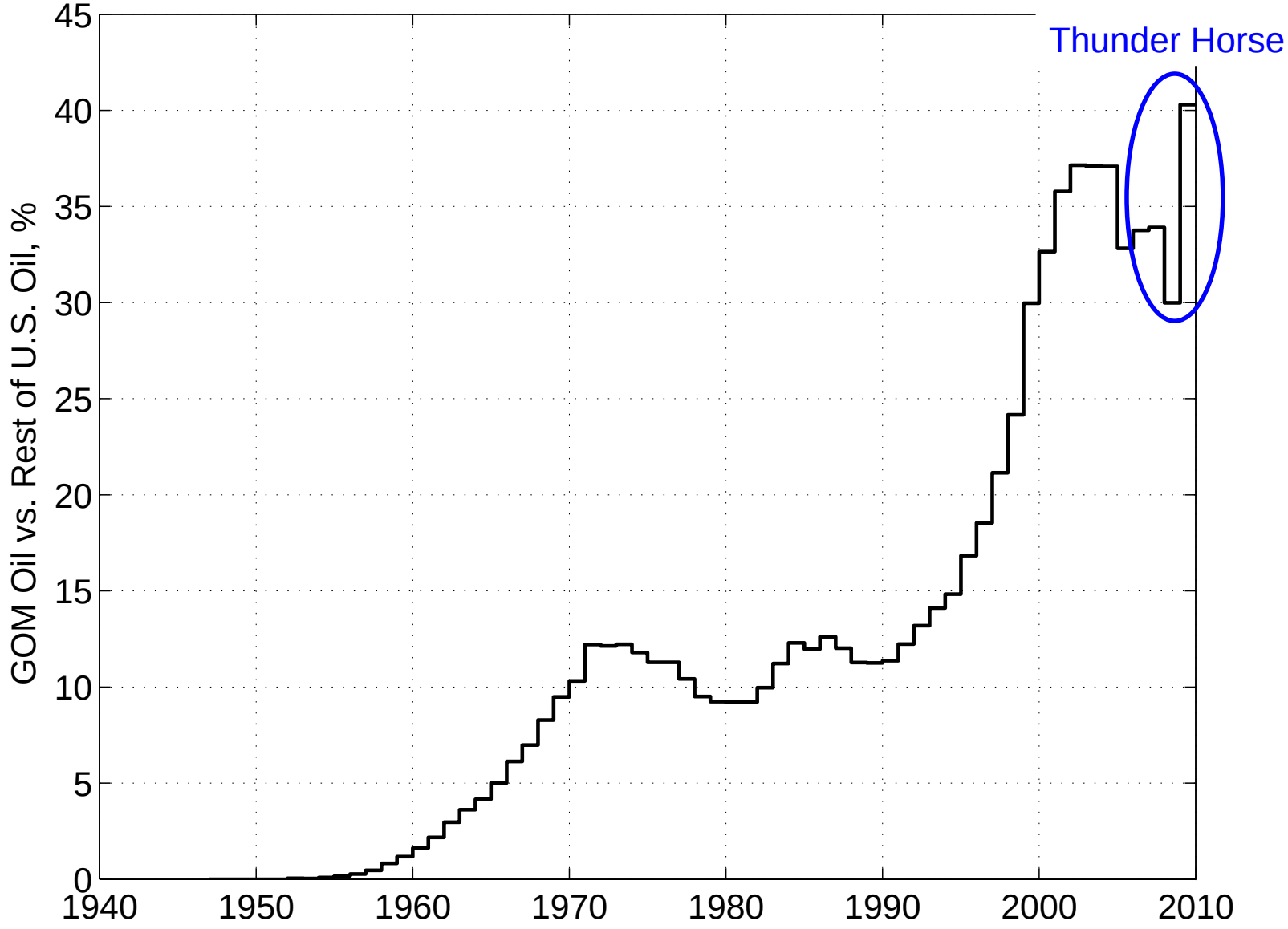
Sources: U.S. DOE EIA, MMS, and Patzek's calculations

A Future of Deep Gulf



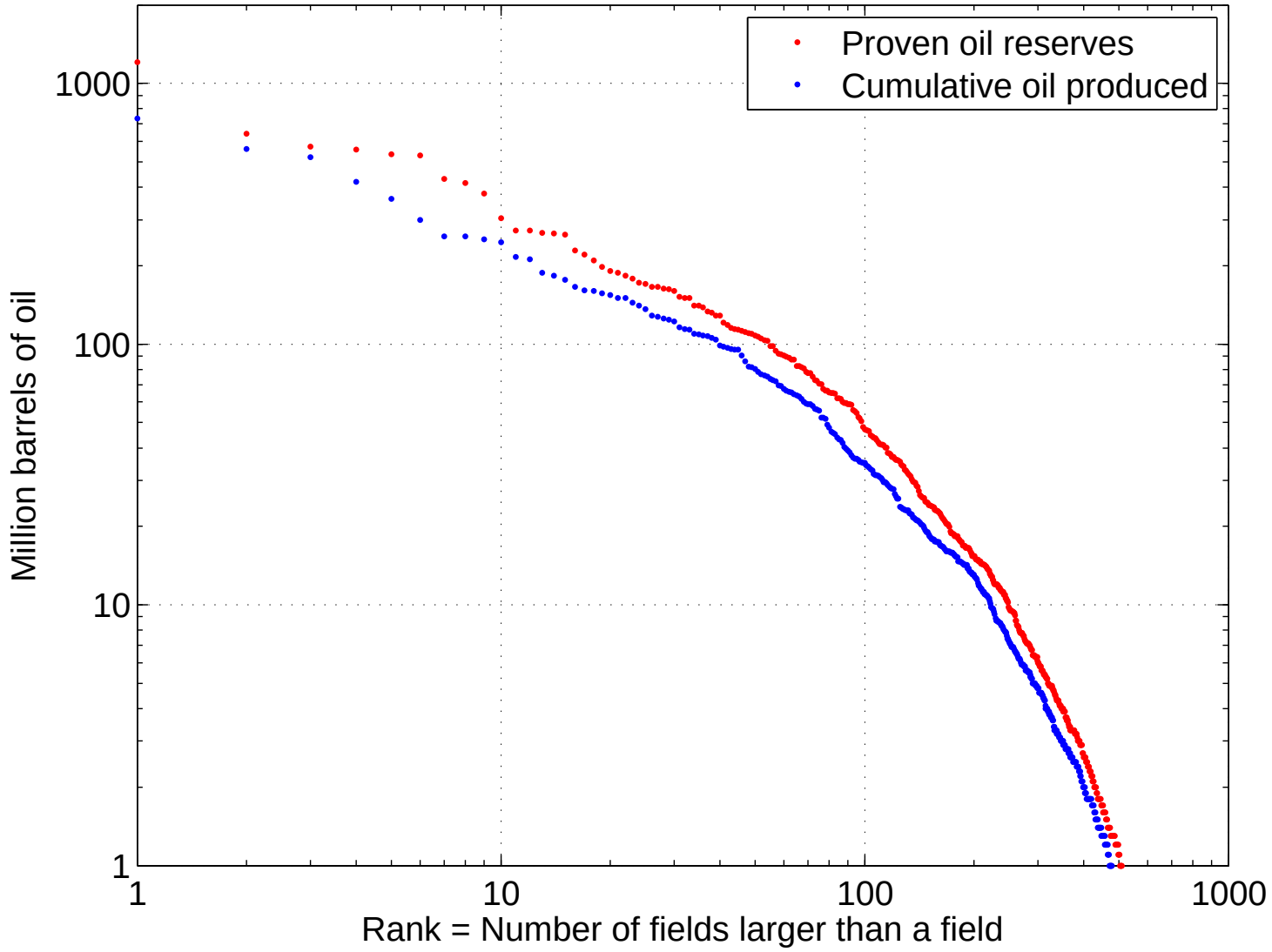
Sources: U.S. DOE EIA, MMS, and Patzek's calculations

Total Gulf Oil/U.S. Oil Elsewhere



Sources: U.S. DOE EIA, MMS, and Patzek's calculations

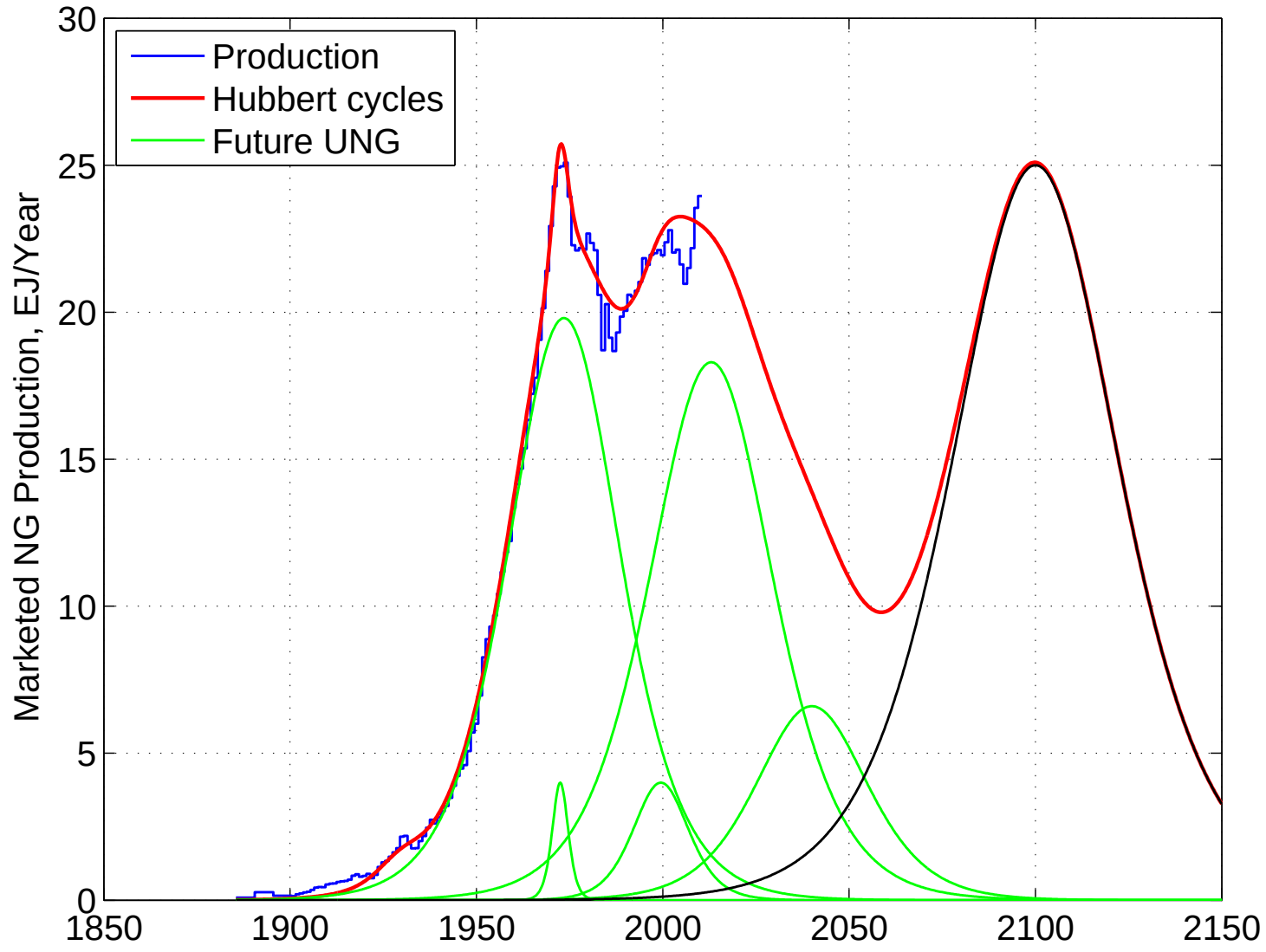
2006 Oil Data for GOM



Source: MMS data, 2006

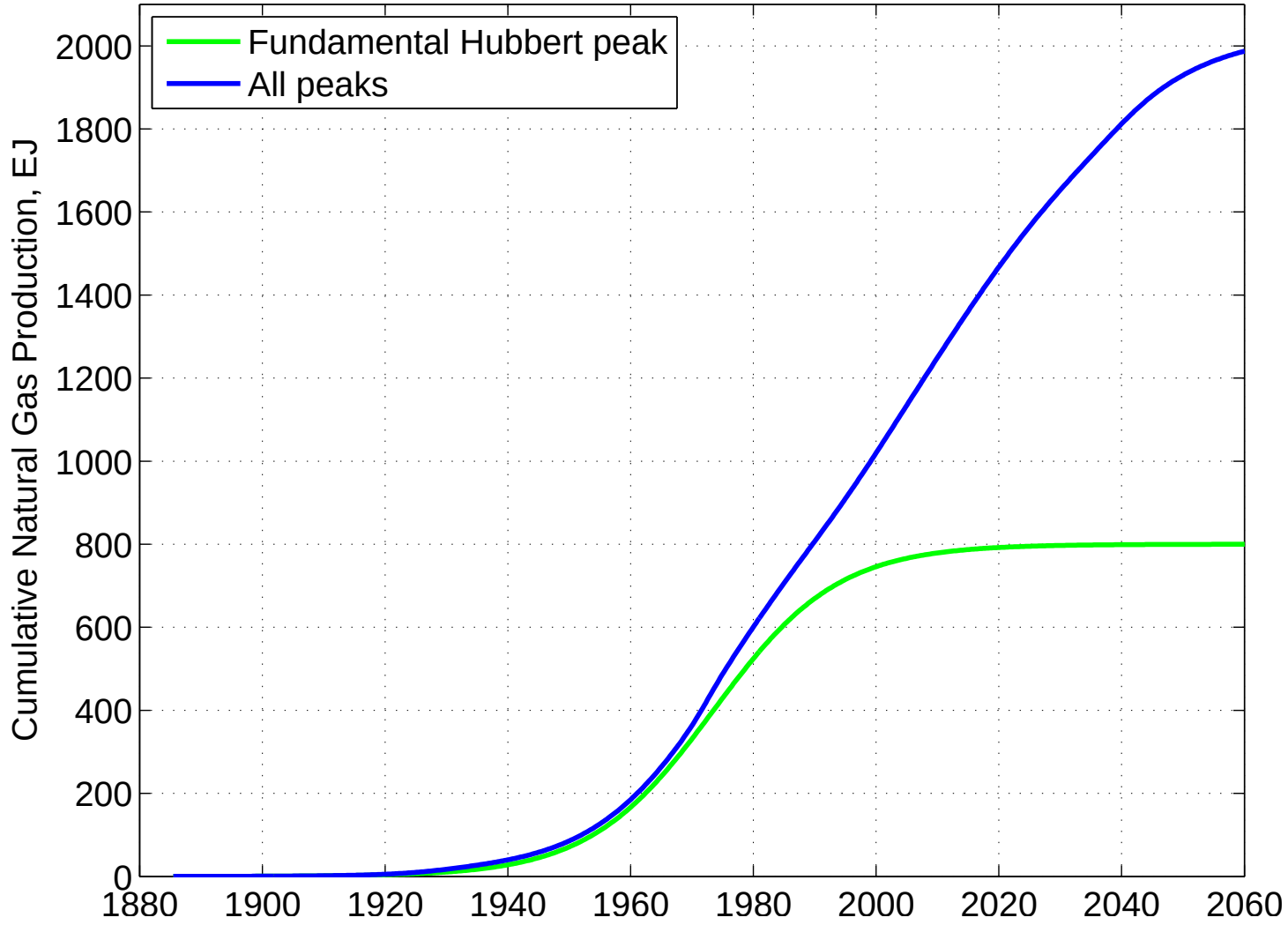
Fractals everywhere! All that is relevant was discovered?

Second and Third Hubbert Peak



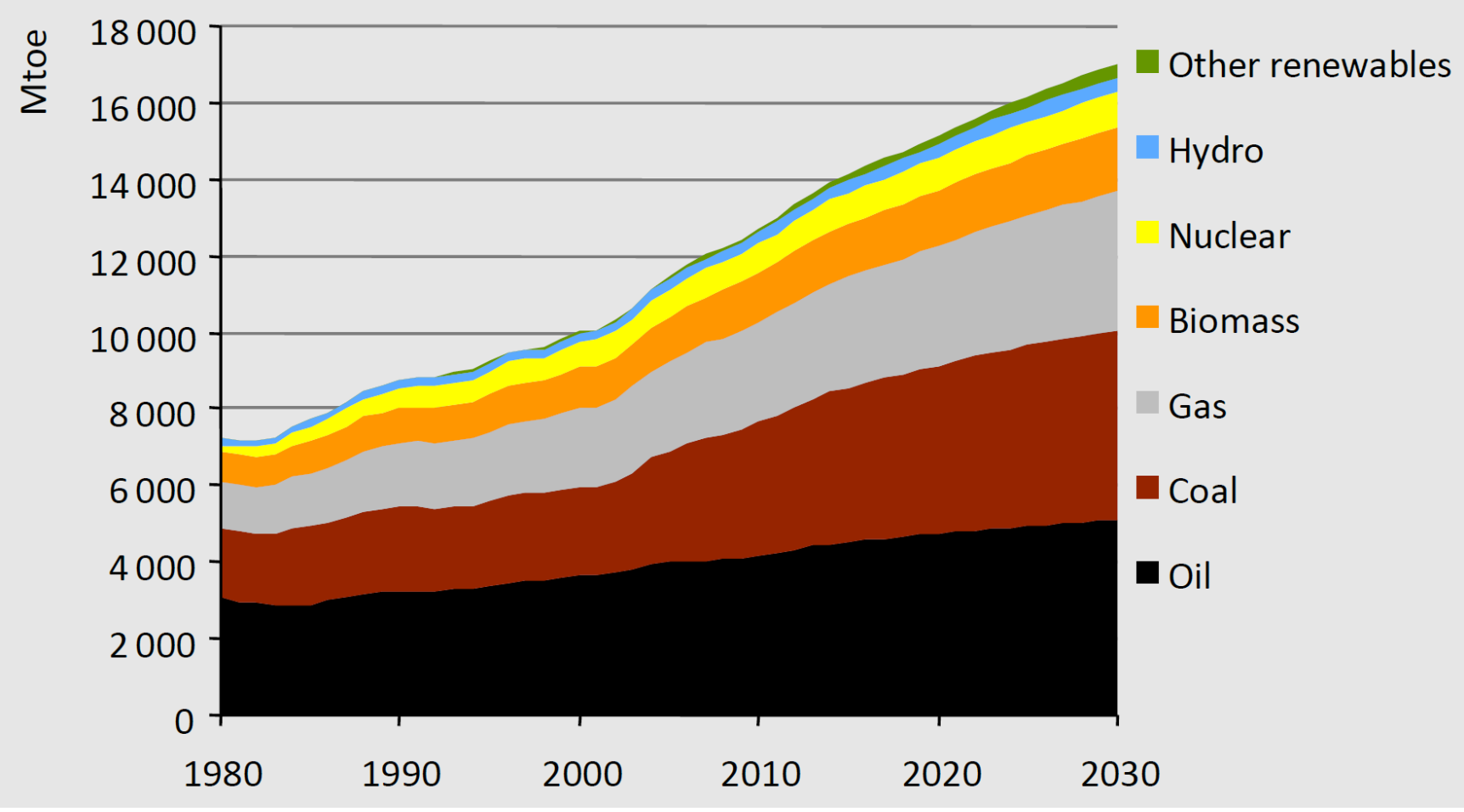
Future Unconventional Natural Gas Cycle = 100 years of U.S. Supply

Unconventional Gas



Extra 1,200 Tcf = $4.3 trillion at $3.6 per mcf, mostly from unconventional gas

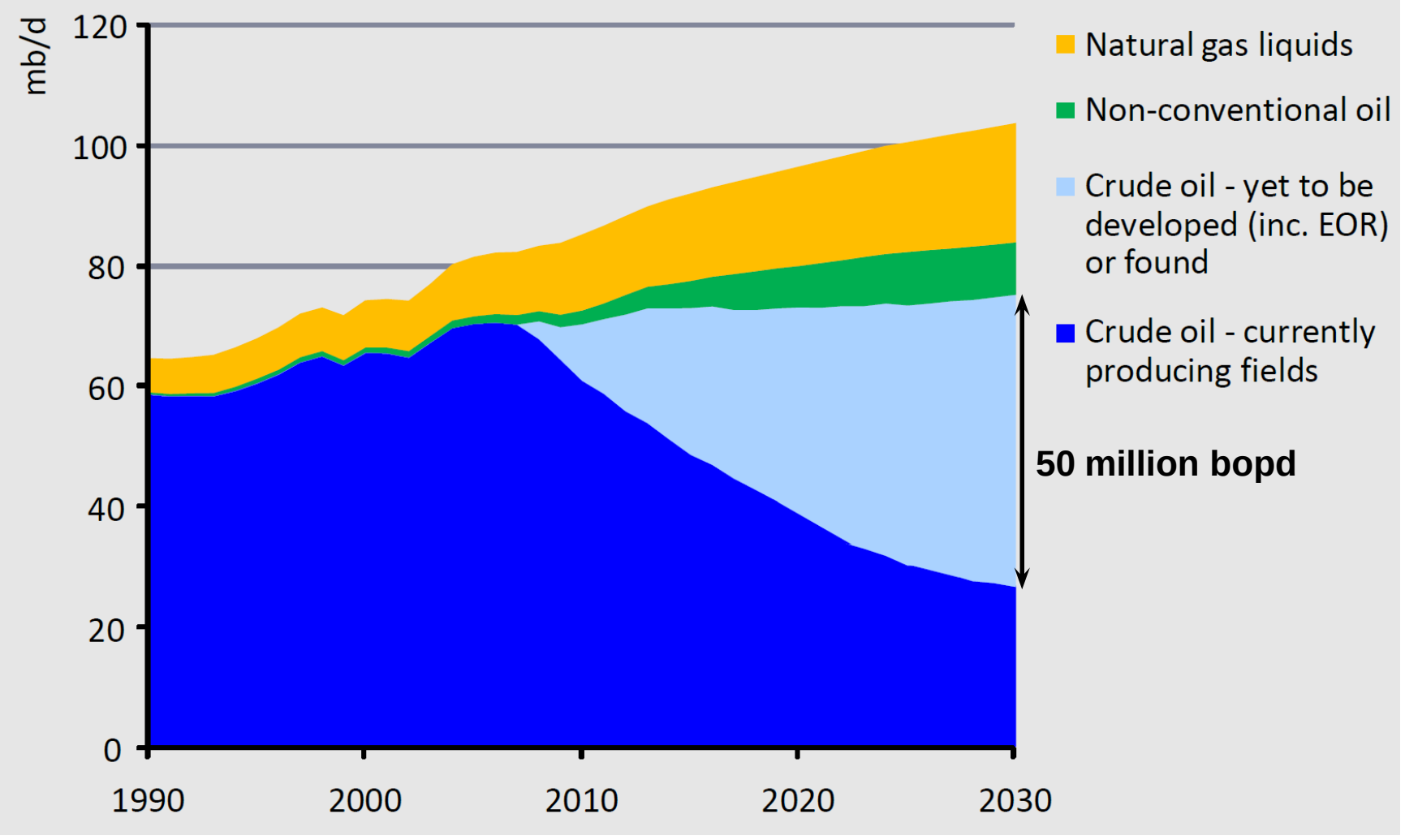
IEA Demand Growth Scenario. . .



OECD/EIA 2008 scenario of annual energy demand in the world

Source: www.iea.org/speech/2008/Tanaka/cop_weosideeven.pdf

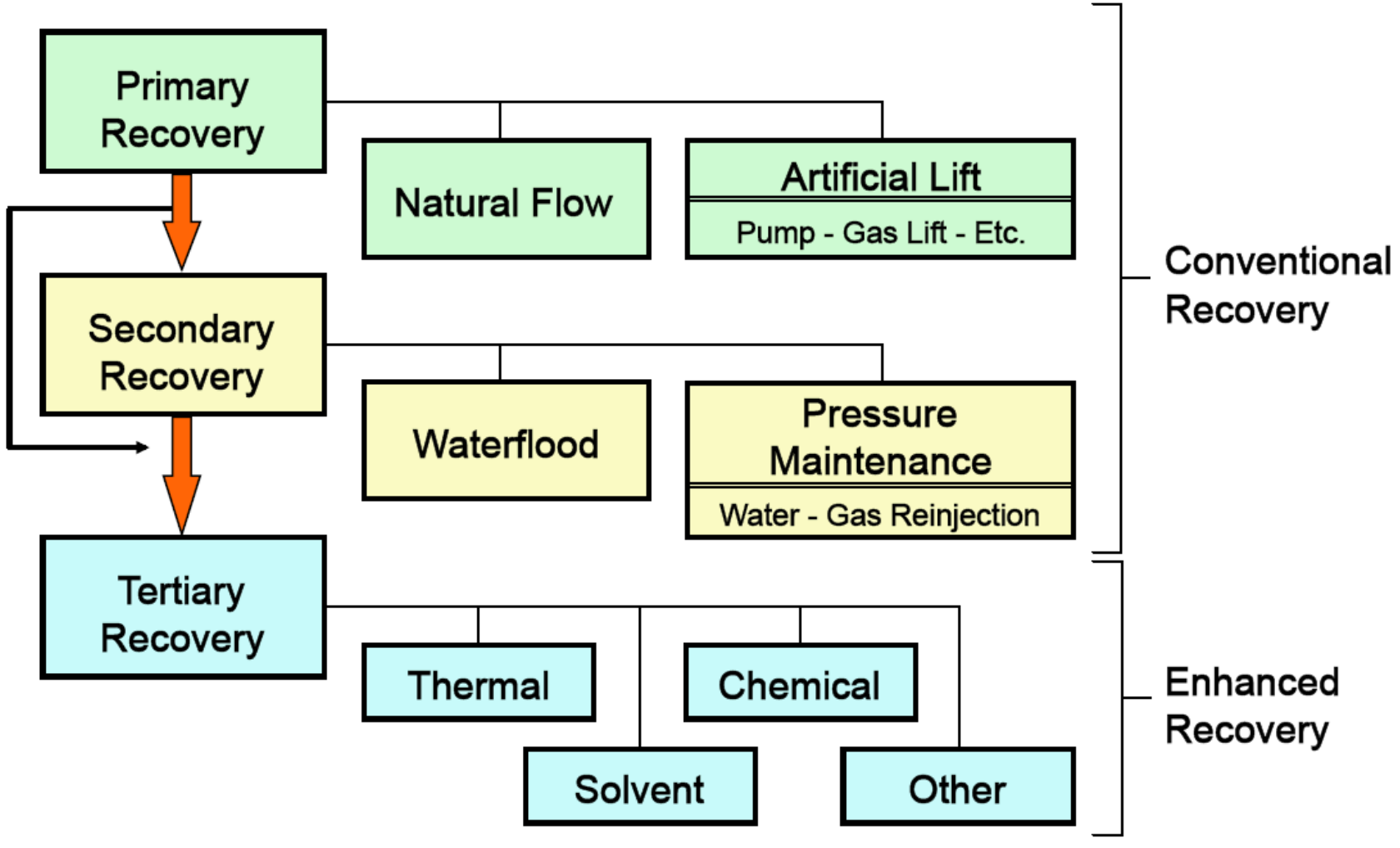
IEA and an Oil Production Peak?!



There is an oil peak and 64 millions barrels of oil per day will be missing by 2030

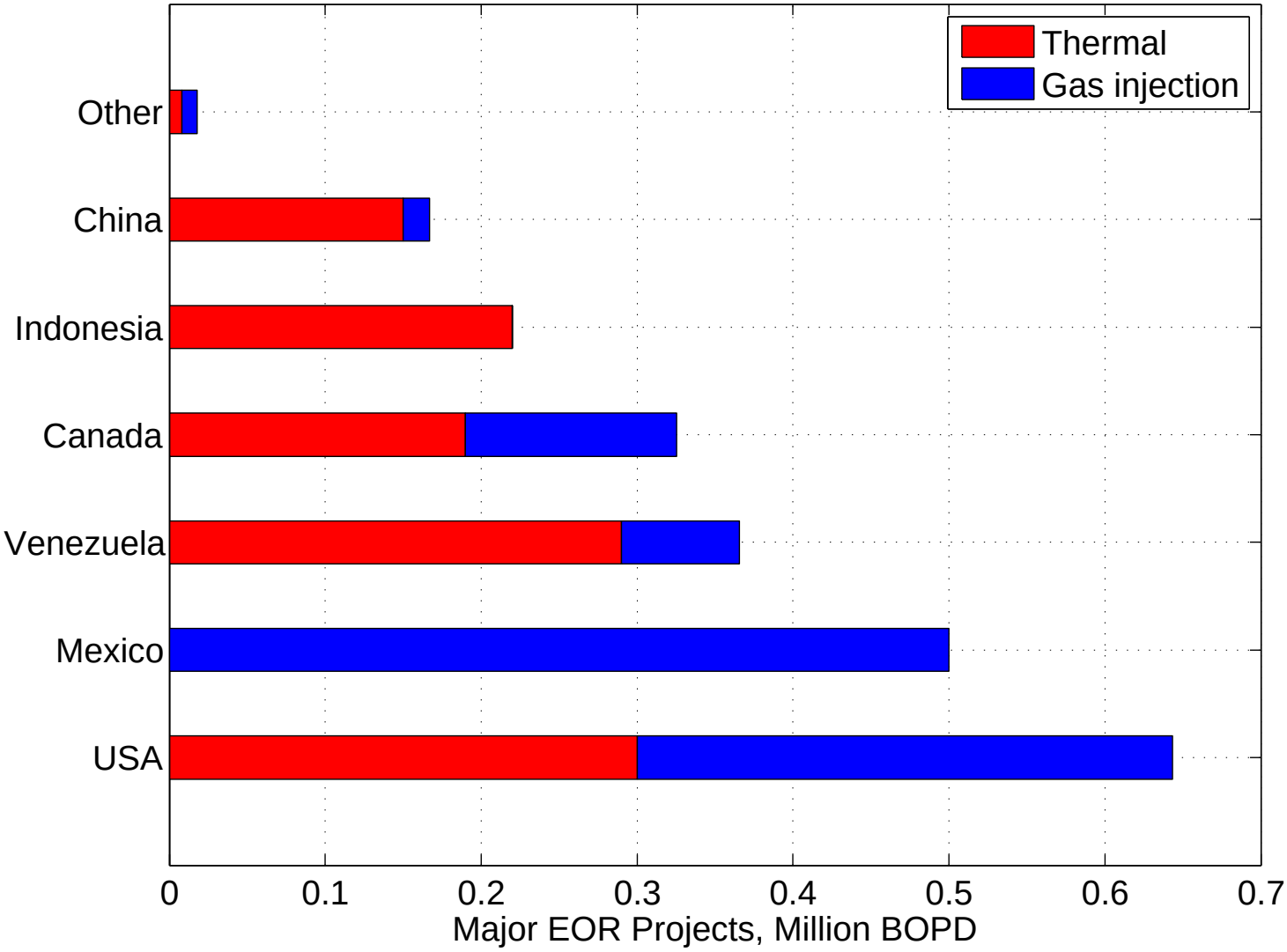
Source: www.iea.org/speech/2008/Tanaka/cop_weosideeven.pdf

Oil Recovery Processes



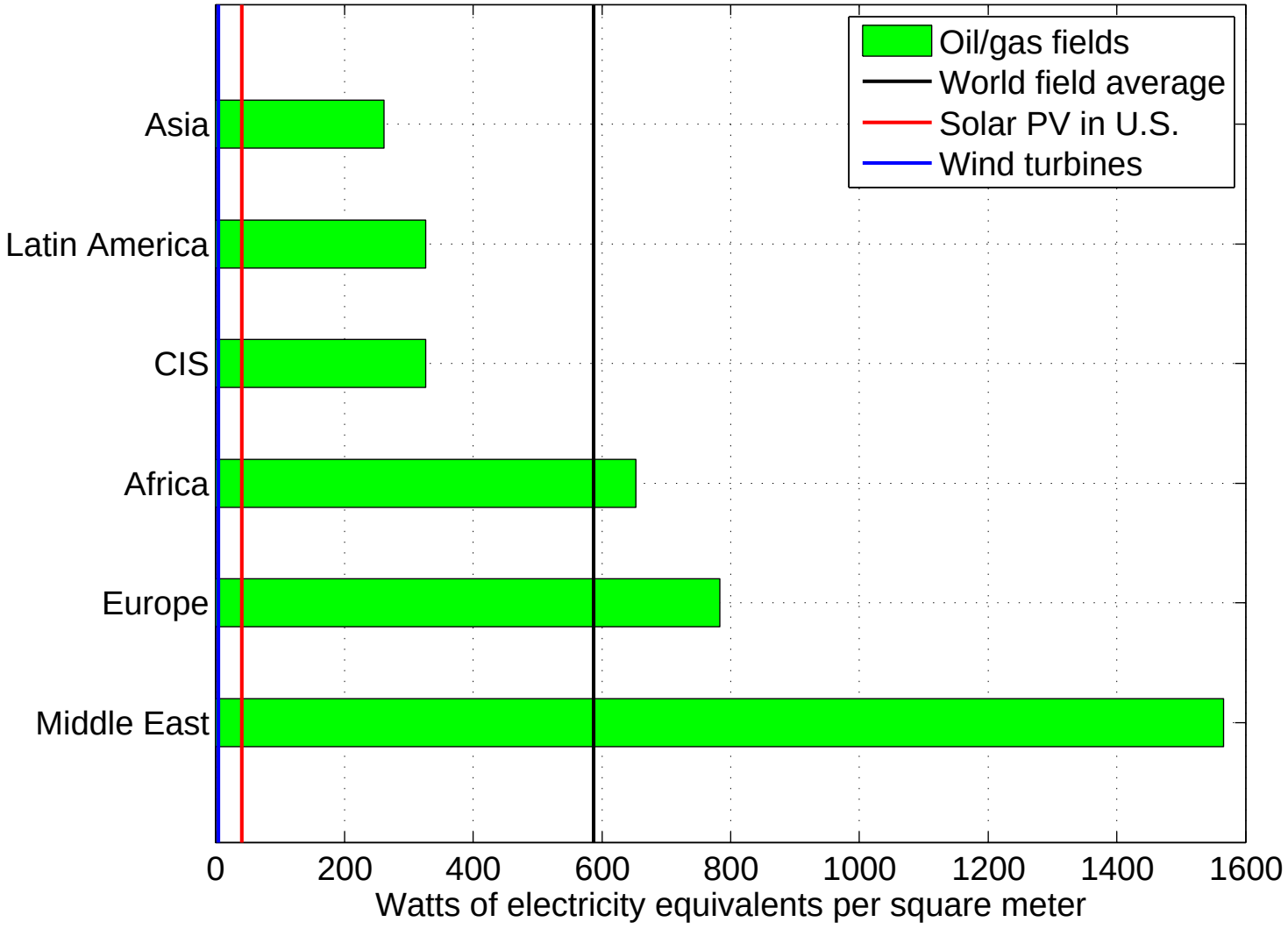
Adapted by Larry Lake from the Oil & Gas Journal, Apr. 23, 1990

World EOR Projects: 2.5 MBOPD



Adapted from the Oil & Gas Journal, Thomas, 2007

Power Density



Adapted from Laherrere, 2003, Patzek, 2007