Nuclear Energy for Unconventional Fossil-fuel Resource Recovery

Ahmed Badruzzaman, Jeff Hedges, Trevor Demayo
and Harry Sigworth
Chevron Energy Technology Co, Richmond, CA

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PRESENTATION OUTLINE

2007 National Petroleum Council Study: *Facing The Hard Truths About Energy*

(A Comprehensive View to 2030 of Global Oil & Natural Gas)

A view of nuclear power

Applications in Unconventional Resource Recovery

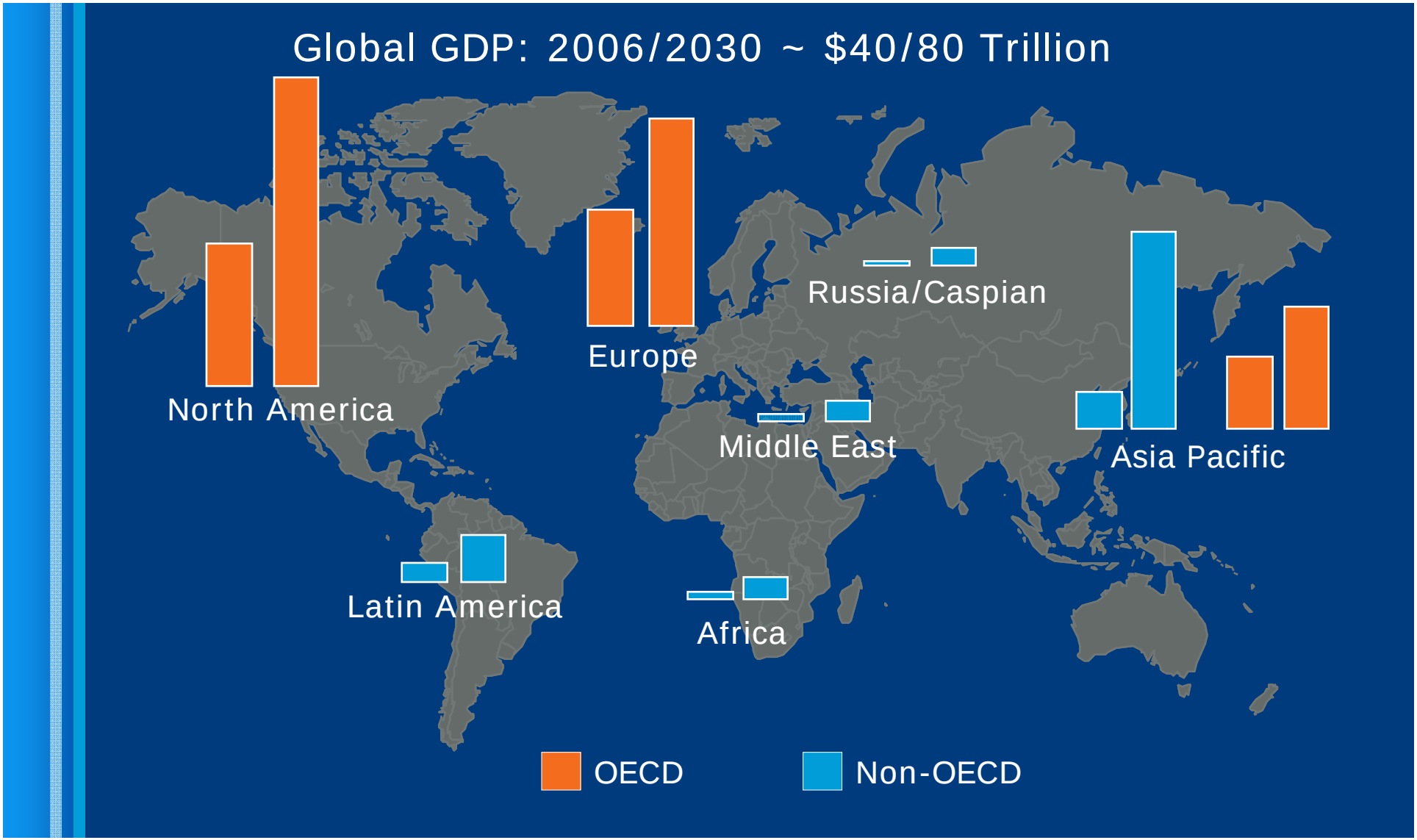
Summary

National Petroleum Council

Facing The Hard Truths About Energy

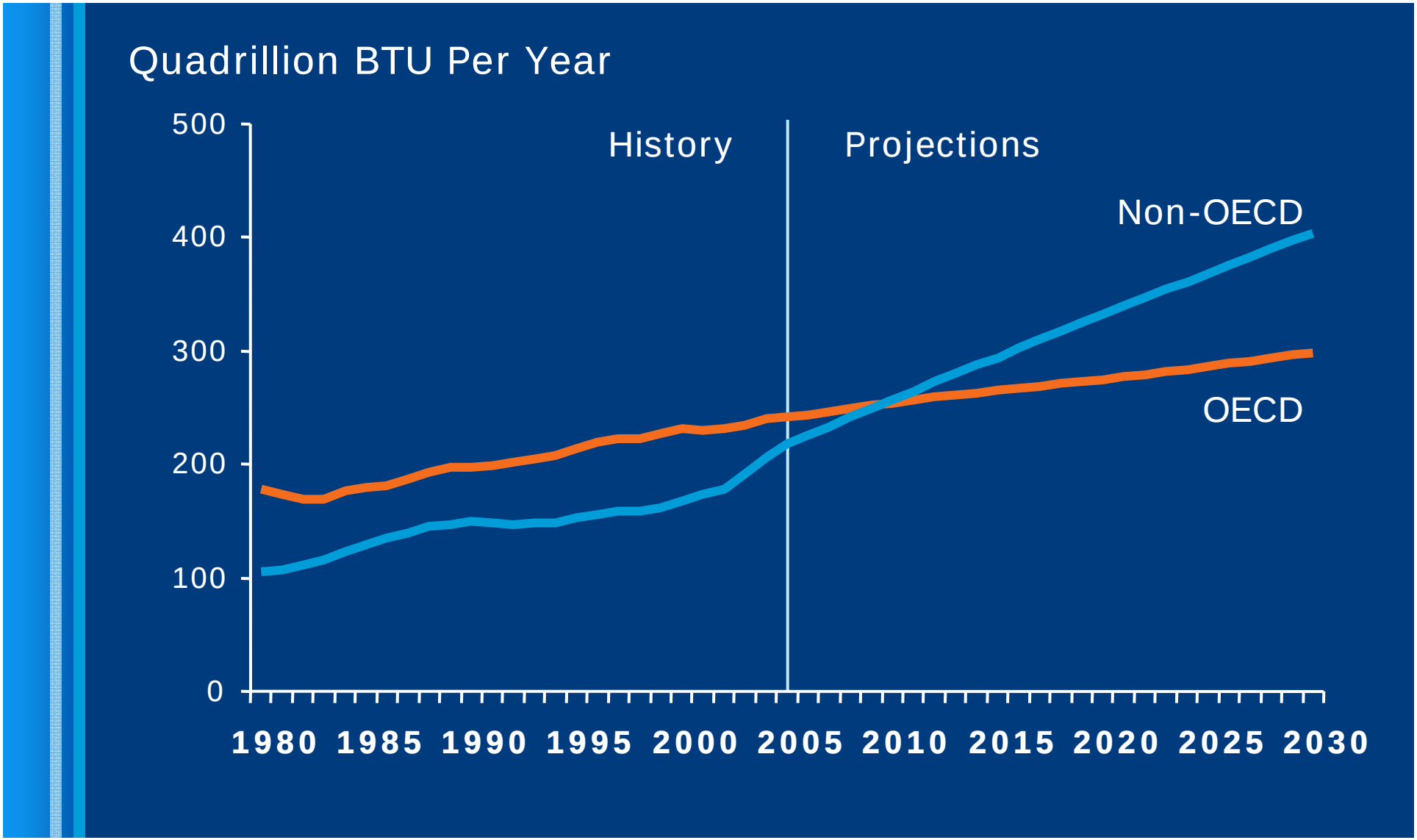
A Comprehensive View to 2030 of Global Oil & Natural Gas

Projected Global Economic Growth



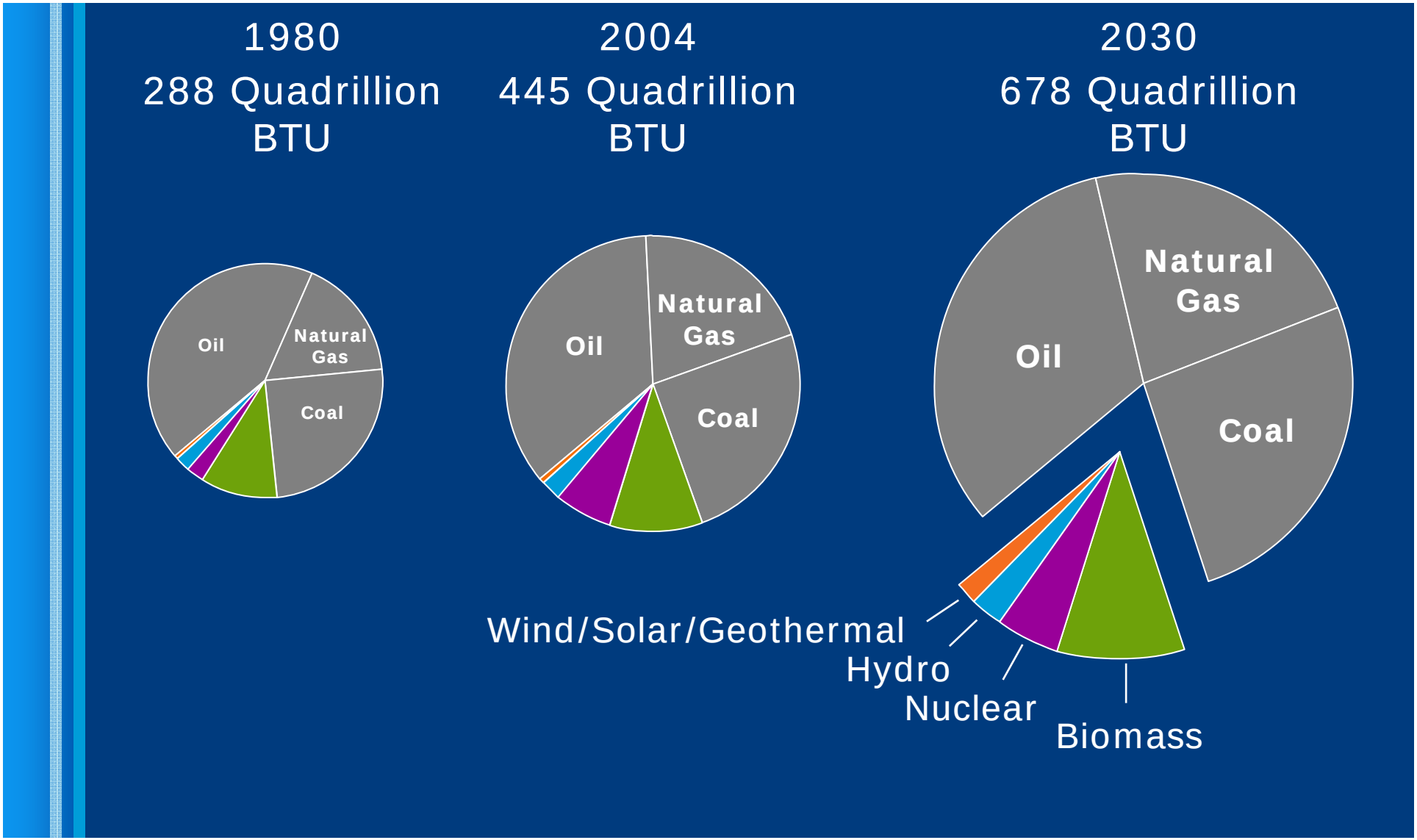
Illustrative Projection. Source EIA, IEA & Other Outlooks

… Energy Demand Growth Follows



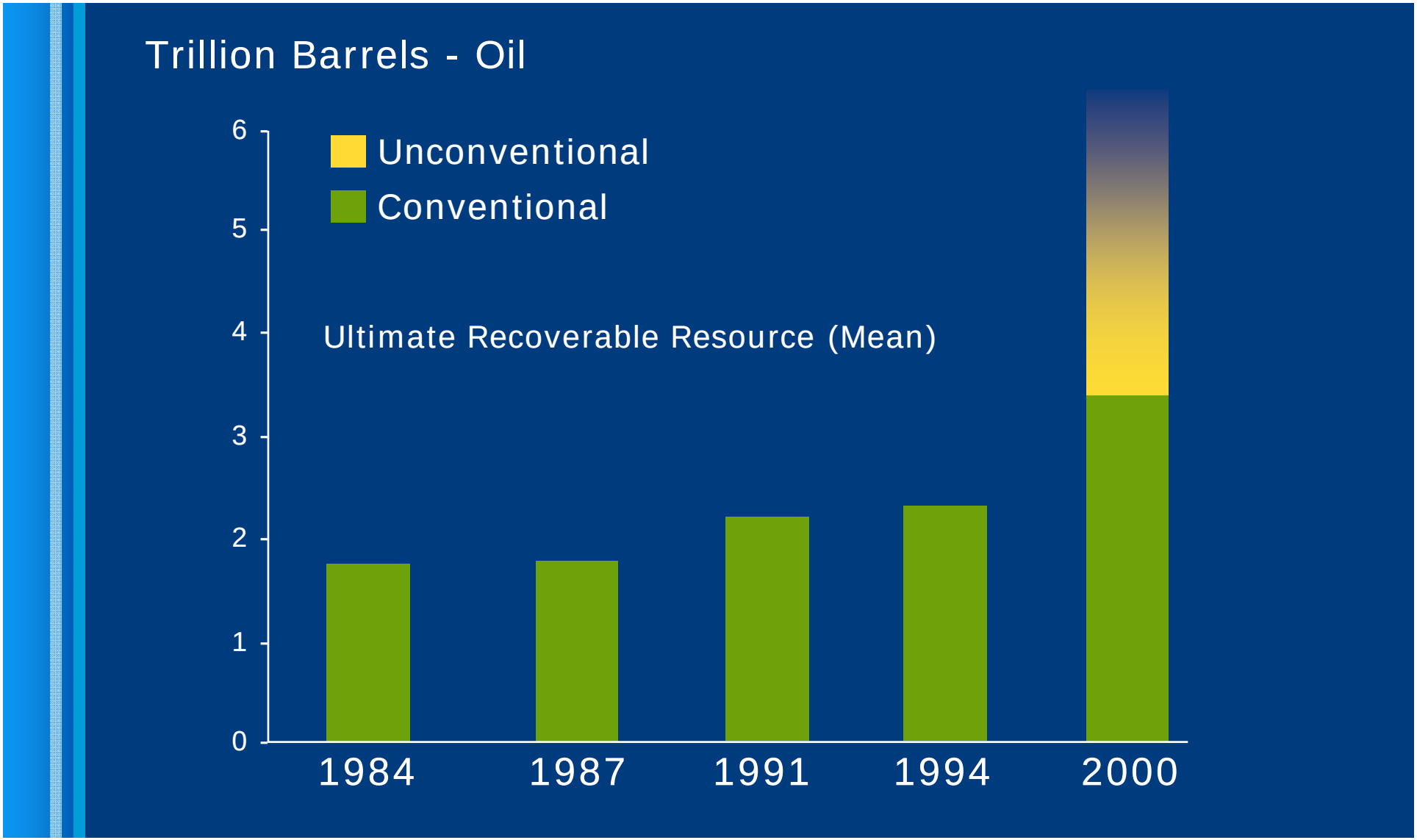
Source: EIA 2007

Coal, Oil, and Natural Gas Remain Indispensable



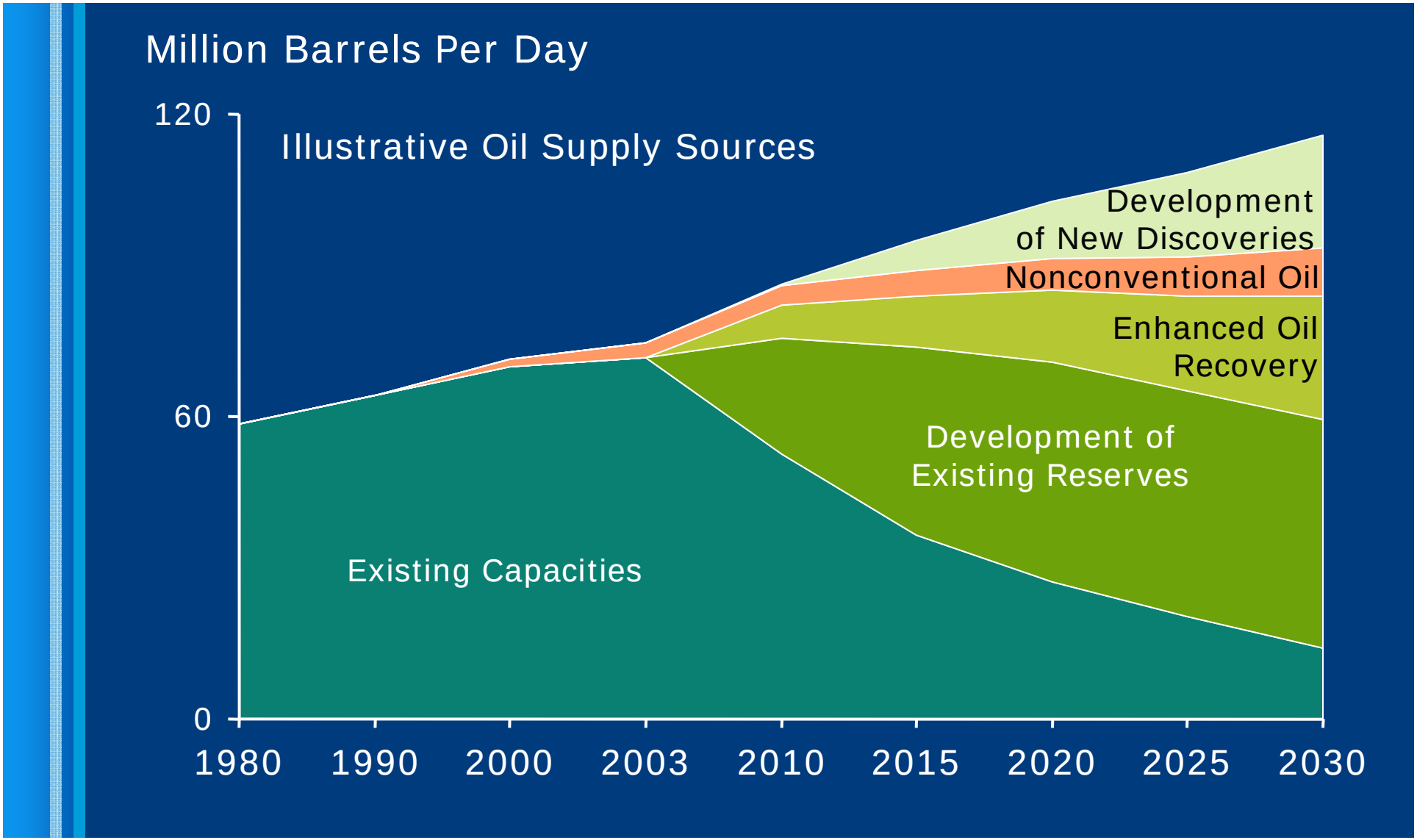
Source: IEA REFERENCE CASE

Large Oil Resource Base



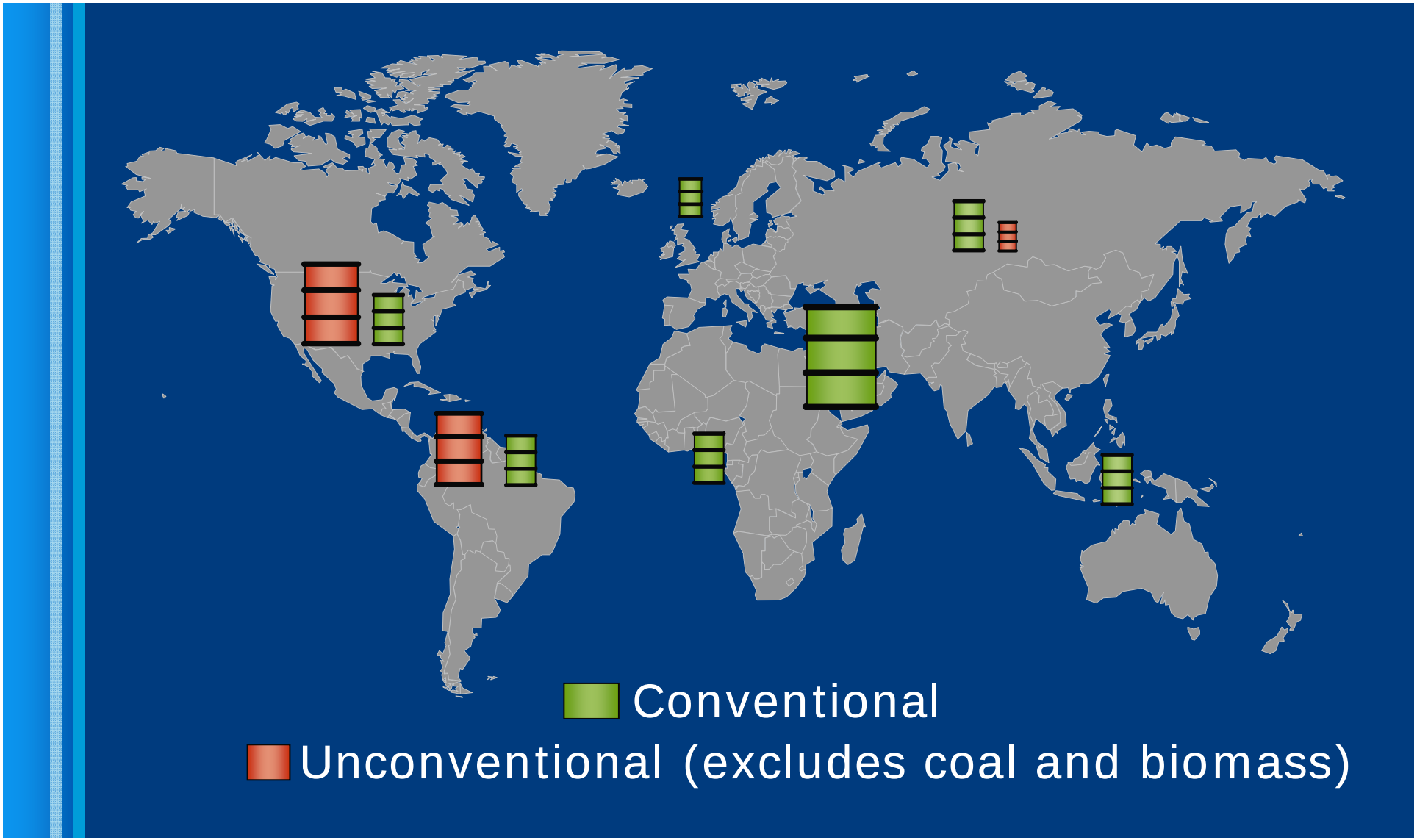
Source: USGS

Global Liquids Production Profile



Source: IEA 2004 World Energy Outlook

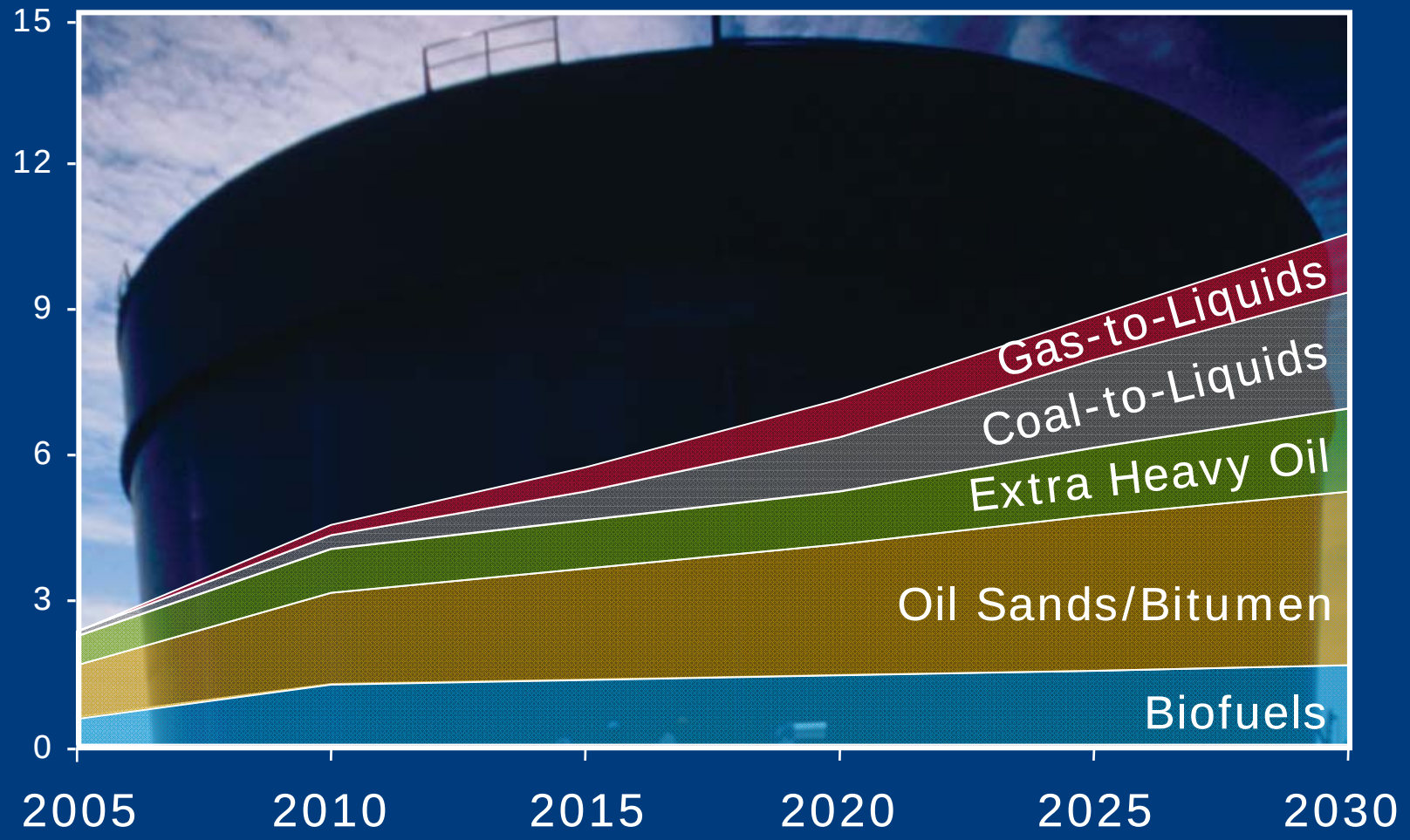
Oil Resource Concentration



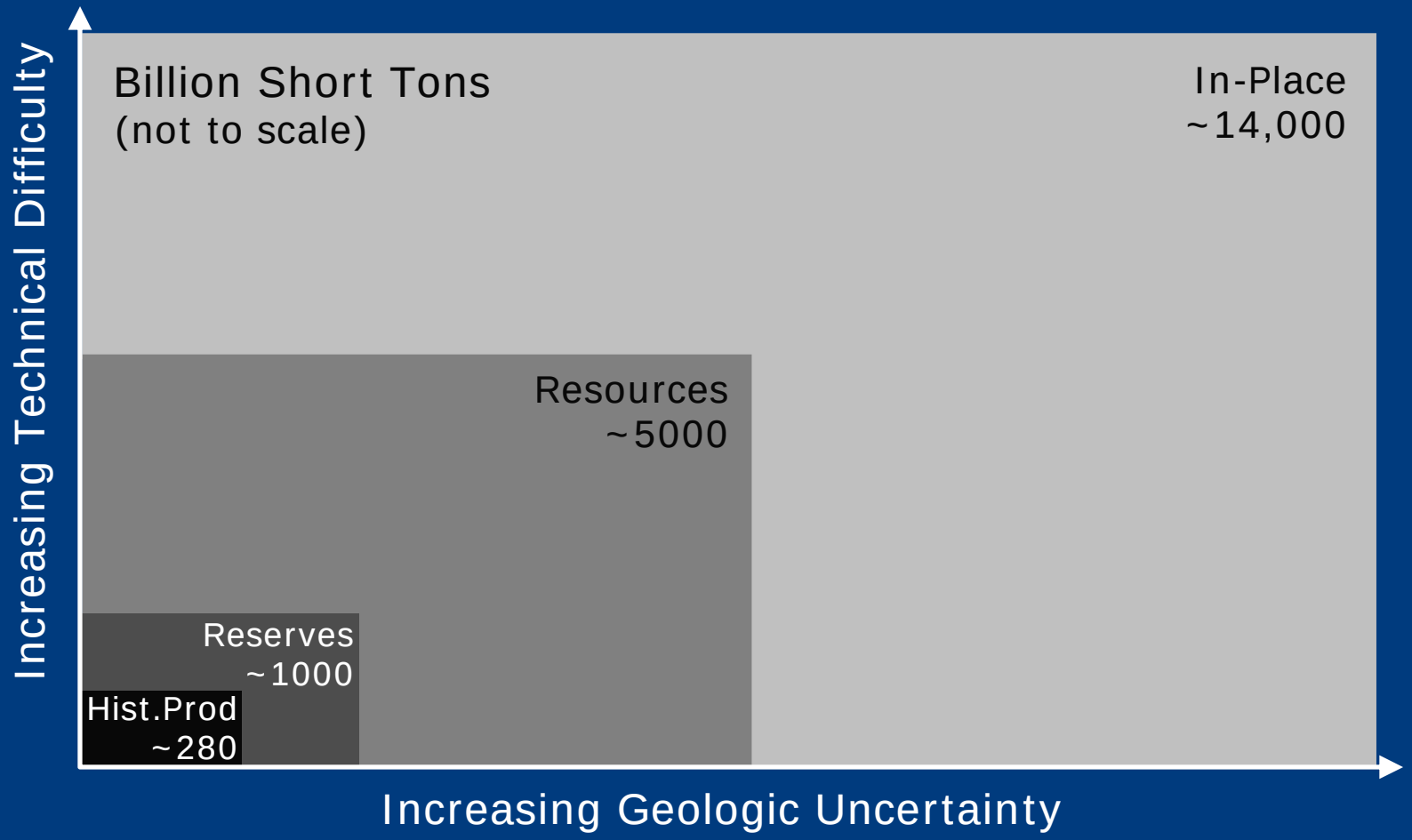
Source: USGS2000 Illustrative Projection

Contribution of Unconventional Liquids

Global Production - Million Barrels Per Day

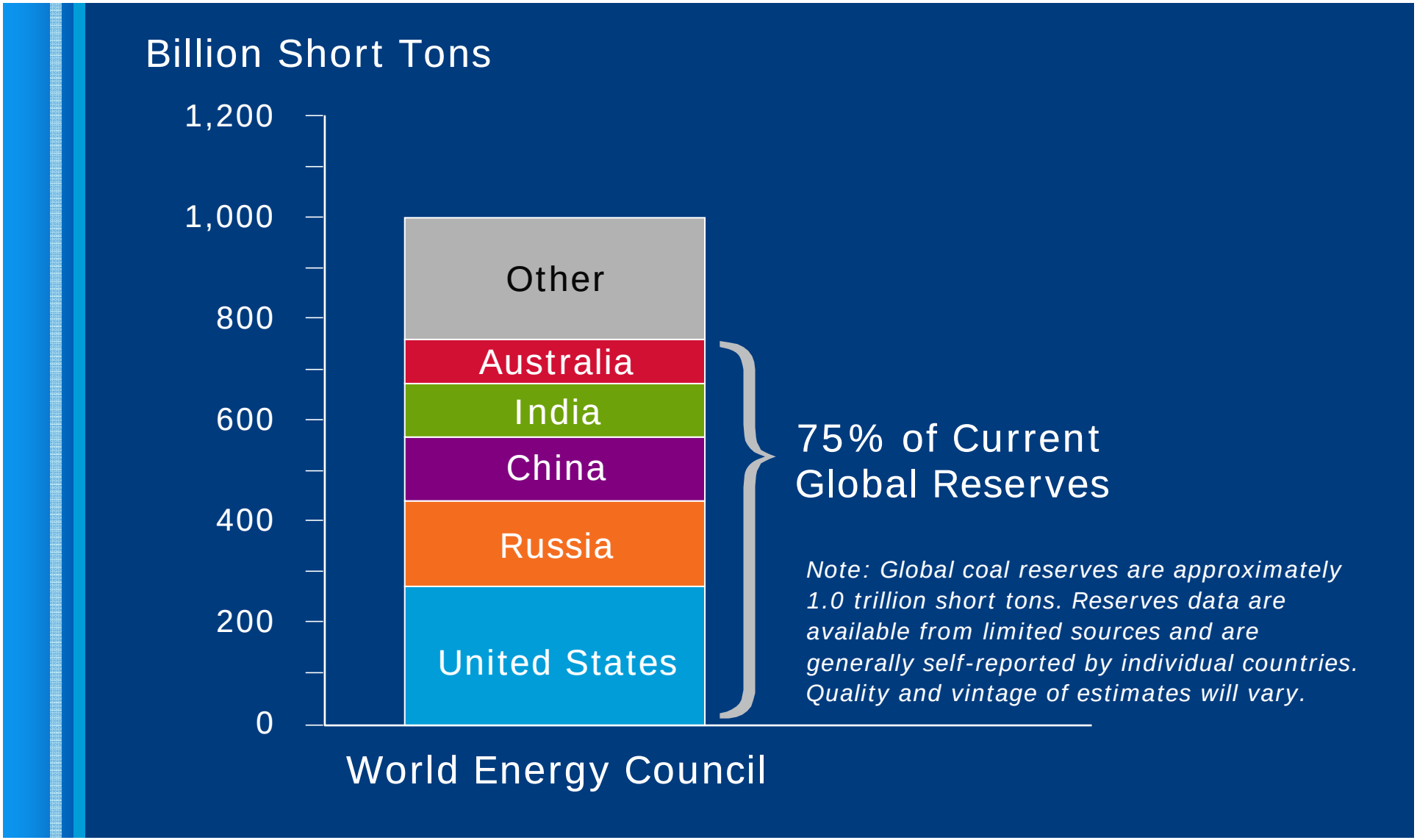


Global Coal Endowment



Data Sources: (1) 1800 to 1980: Bernardo F. Grossling, "World Coal Resources", Financial Times Business Information, London, 1981; 1981 to 2005: Energy Information Administration, International Energy Annual. (2) World Energy Council, "Survery of Energy Resources", 2004. (3) Rogner, H-H, "Annual Review - Energy Environment", Institute for Integrated Energy Systems, 1997.

Concentration of Coal Reserves



CO_2 Emission Limits Will Alter Energy Strategies

Growing concern that climate is warming and CO_2 concentrations in the atmosphere play a role.

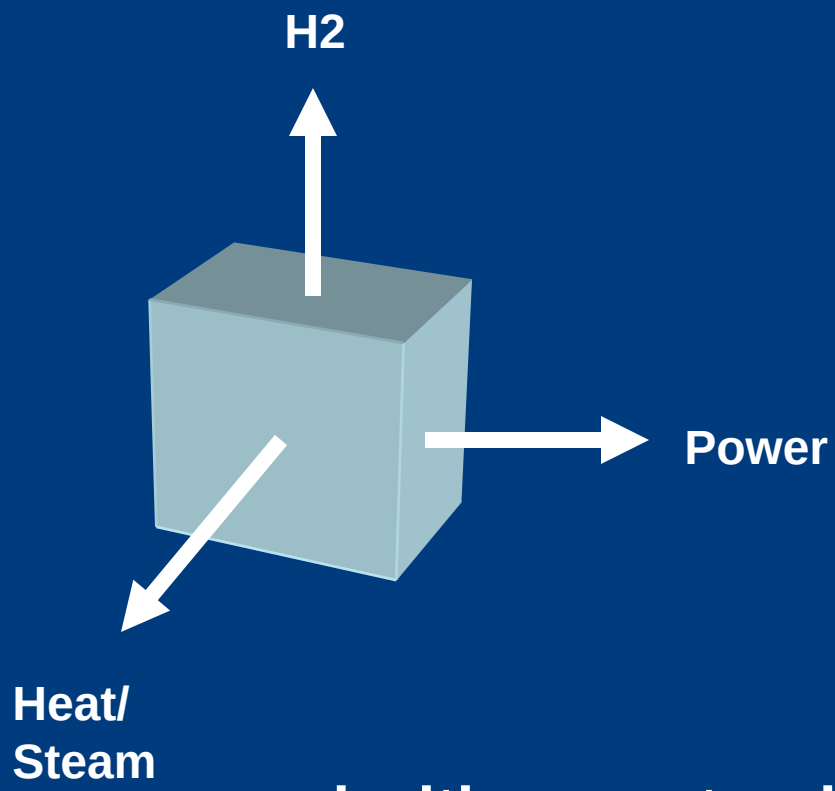
The challenge of significantly reducing CO_2 emissions is unprecedented and will require:

- Global, broad actions on multiple fronts
- Long-time horizons
- Major additional investments

Nuclear Energy Applications for Unconventional Resource Recovery

Our View of a Nuclear Power Plant

A “Black Box” that produces power, heat and H2…



and with some trepidation

Our view of the State of Nuclear Energy

Renewed interest: Energy demand & security; CO2 mitigation

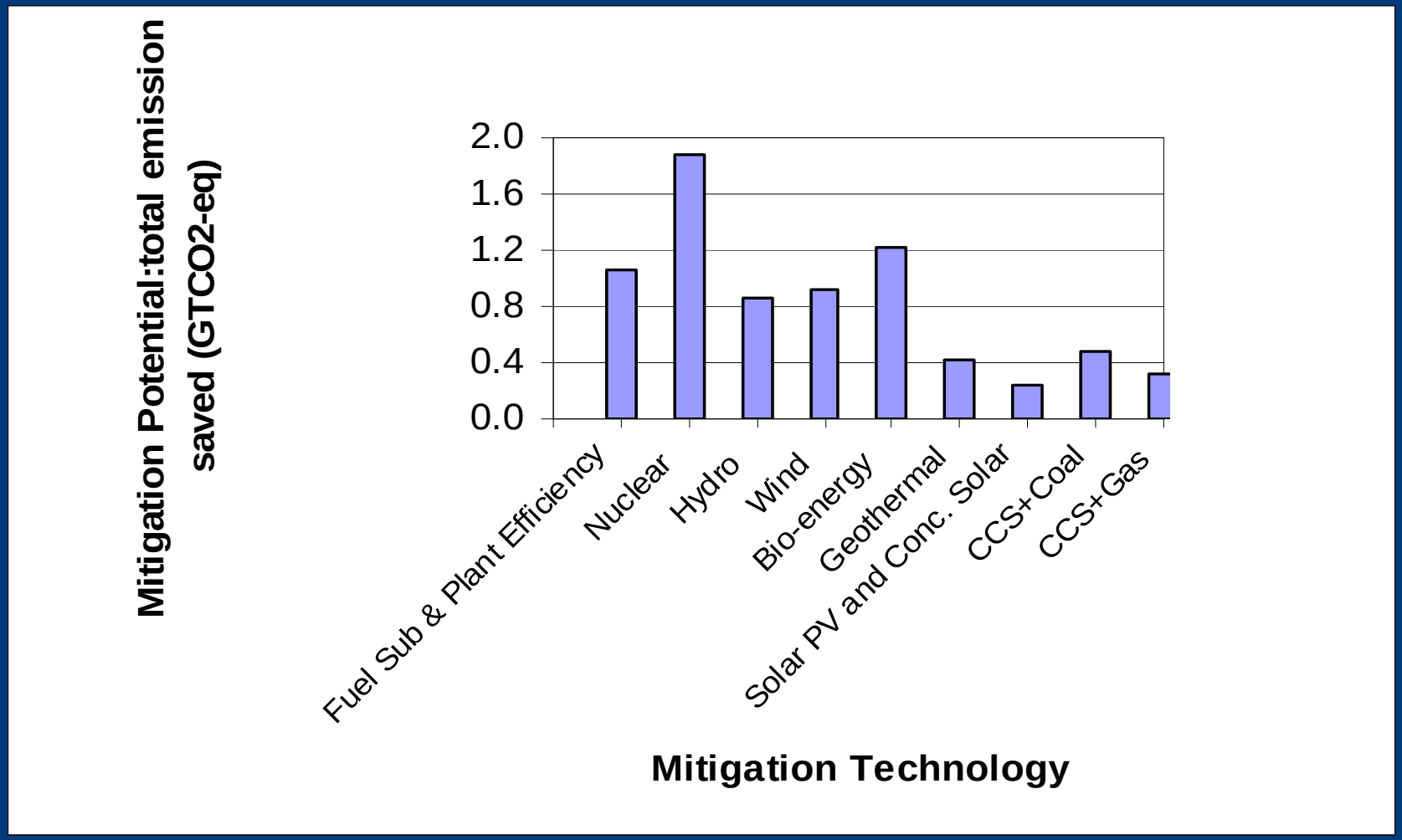
Advances: Operations, safety, economics. Inherently safer designs and novel concepts with potential applications in petroleum, chemical and coal industries, and H2 production

Government initiatives: Streamlined US licensing, new plant and R&D support, Government/private sector R&D partnerships

Challenges: Public acceptance, resources, licensing of novel designs, etc.

Potential greenhouse gas emission savings in 2030

(Data from Barker, et al, IPCC, Working Group III, 2007)



Unconventional Fossil Fuel Resource Recovery

Heavy crude & bitumen: Total: 6 trillion barrels in place

- Heavy oil: Modern monitoring continues to add millions of barrels
- Steam flood recovery in California and Duri, Indonesia
- Alberta oil sands: 173 billion bbl recoverable, 142 billion bbl by in-situ methods ⇒ Steam-assisted-gravity-drainage (SAGD)

Oil shale: 2.6 trillion barrels in place, primarily in the US

Coal to liquid (anticipated): 600,000 bbl/d in 2020 and 1.8 million bbl/d in 2030: H2, steam and power required

Unconventional resource recovery will likely increase CO2 emission

CTL and H2 Production w/ Nuclear

CTL: Two approaches

- **Indirect:** Coal to syngas to liquid: can benefit from H2 addition
- **Direct:** Powdered coal mixed with solvent and hydrogen

In both approaches, nuclear can be used for H2 production and process heat/power

Note: A 100,000 BPD plant $\Rightarrow$ 4 million MT CO2/yr if natural gas used for H2

Hydrogen production

- Current approach: Electrolysis
- R&D: Assisted Steam Methane Reforming and Thermo-chemical techniques under study

Implementation Issues in Unconventional Recovery

Power and footprint: Oil fields can be congested

- A single steam generator unit in Kern River: 15 MWth and 75ft x25 ft

- Modern HTGR: 500 MWth, ~425m exclusion zone: ~98 times sq. ft per MWth. Can replace multiple gas-fired units; can place multiple plants on same site

- Conventional nuclear plant: ~3,300 MWth, 10-mile exclusion zone

Facilities and proximity: Process-dependent

- Gas-based steam plants can be sited close by

- Steam can be transported ~ 15 km. Multiple plants will be needed if production area is large.

Implementation Issues in Unconventional Recovery (Contd.)

Licensing and permitting: Co-located facilities make issues more complex

Safety philosophy: Nuclear vs. non-nuclear segments- Will Nuclear protocols prevail over entire operation?

Life cycle considerations: Nuclear plant: 40-60 years. Enhanced recovery projects: Variable and stage-dependent; Kern River steam flood ~20 yrs left; SAGD is just starting

Uncertainty of nuclear resurgence and lead time: A plant needed in 2017-2018 time frame may need to be under construction by 2010-2011

Economics: Power, heat and hydrogen costs must compete with conventional fossil fuel sources

Temperature rating: Varies across applications. Design must be versatile

Summary

Nuclear-generated process heat can significantly reduce CO_2 footprint in unconventional fossil fuel recovery

Conserves natural gas as a resource for other uses

H_2 production not cost competitive using current technologies, it will be needed and R&D underway

Net economic benefits more complex to define, but appear reasonable in some applications

Summary (Contd.)

The usual challenges of nuclear in general, plus

a number of complex implementation issues in unconventional resource recovery

Despite the challenges nuclear energy merits consideration for these applications

- Further, in-depth assessment of technology and applications: Likely source government/private partnerships
- Develop internal awareness of nuclear capabilities and monitor R&D on specific applications

Thank You!