



World Energy

The Past and Possible Futures 2007

Marwan Masri, President & CEO, Canadian Energy
Research Institute

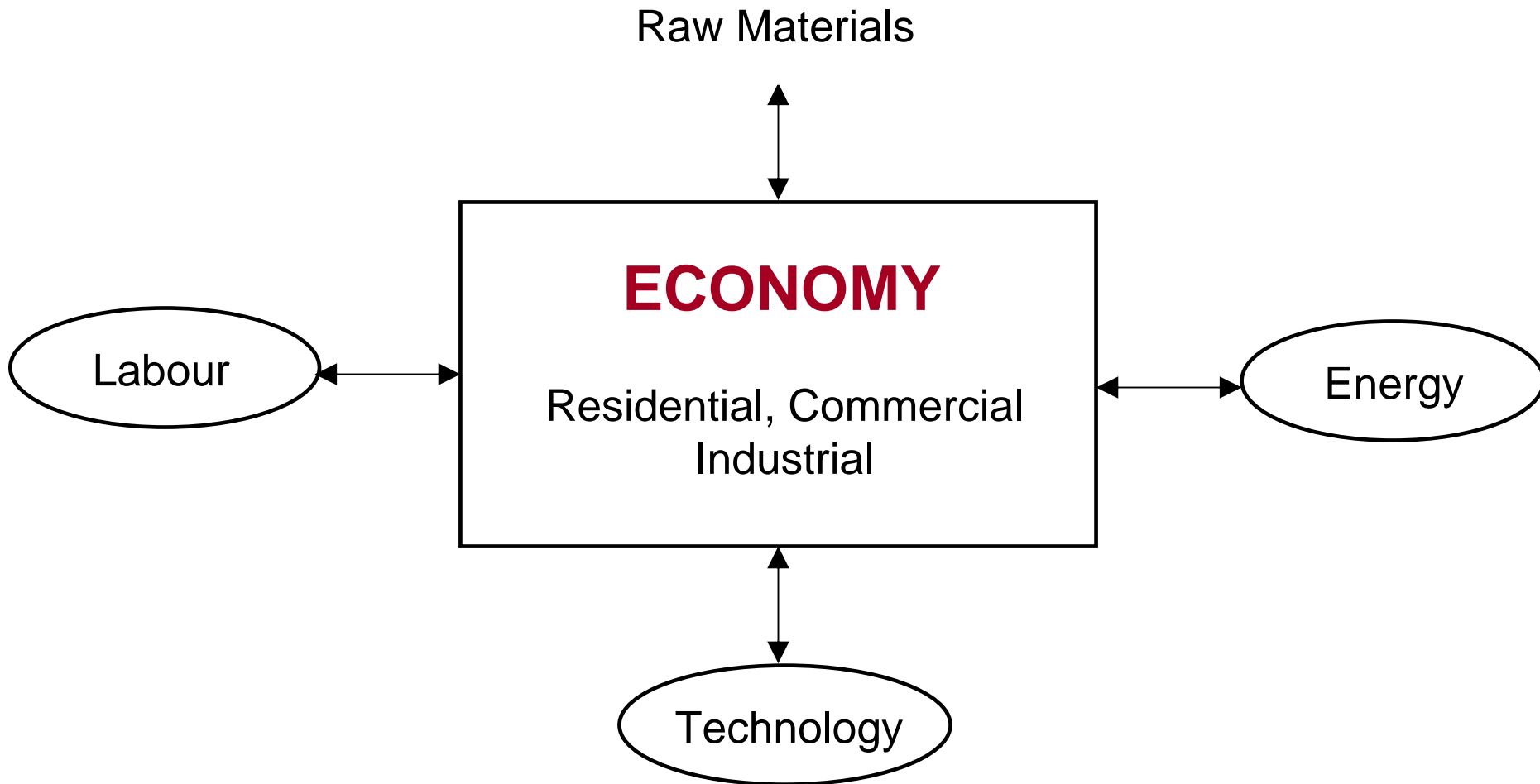
Annual Seminar 2008
Canadian Nuclear association
Ottawa, February 27-29

- Not-for-profit energy economics and
- environmental research
- Established 1975
- Jointly by government, industry, academia
- Short courses and training
- Four annual conferences
- Monthly Publications
- Public education

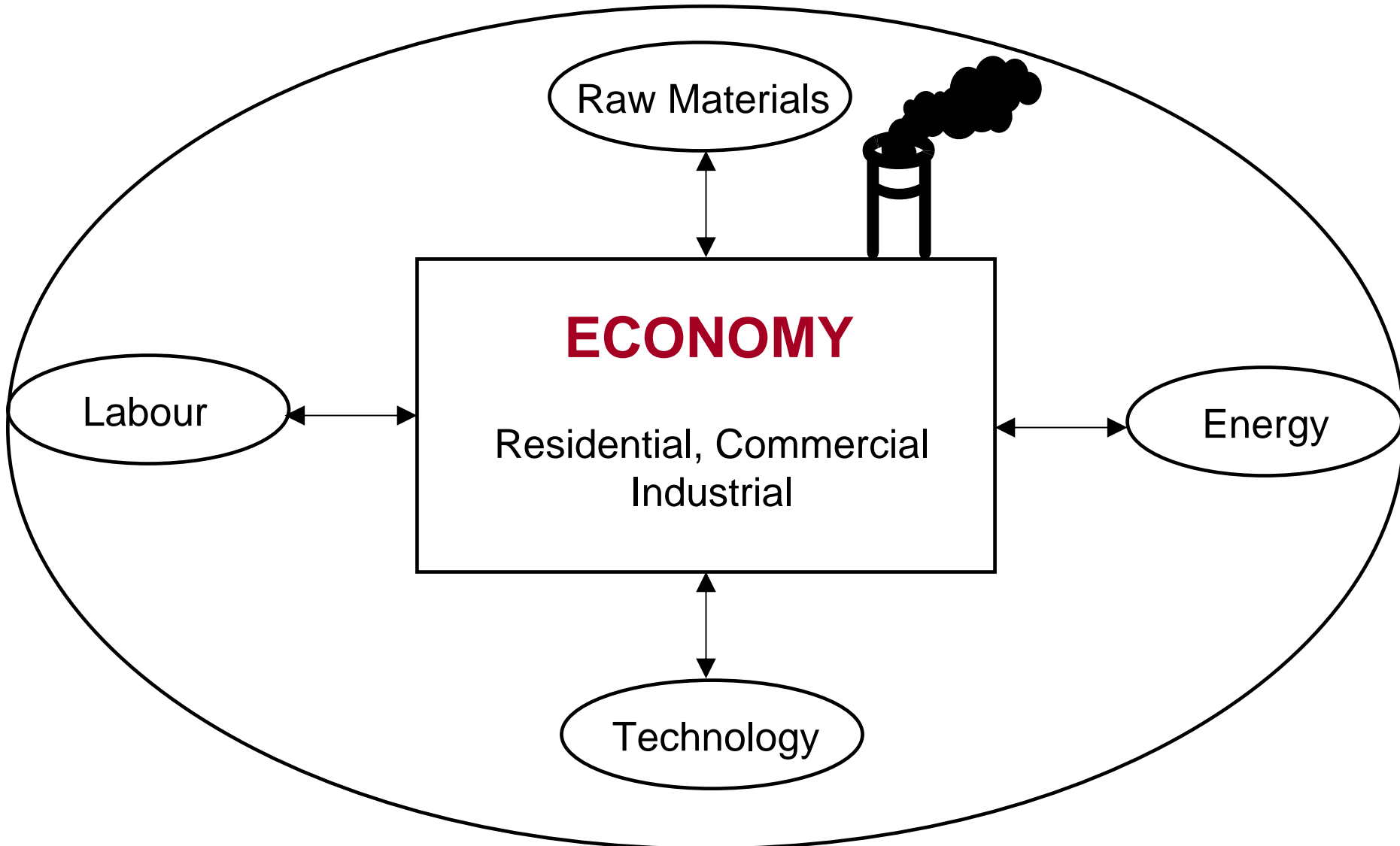
Independent - Objective - Relevant

- **Introduction and Background**
- Energy Consumption
- Energy Supply
- Energy and the Environment
- Alternative World Energy Futures
- North America Energy Outlook
- Summary and Conclusions

A Simple Economy: No Constraints

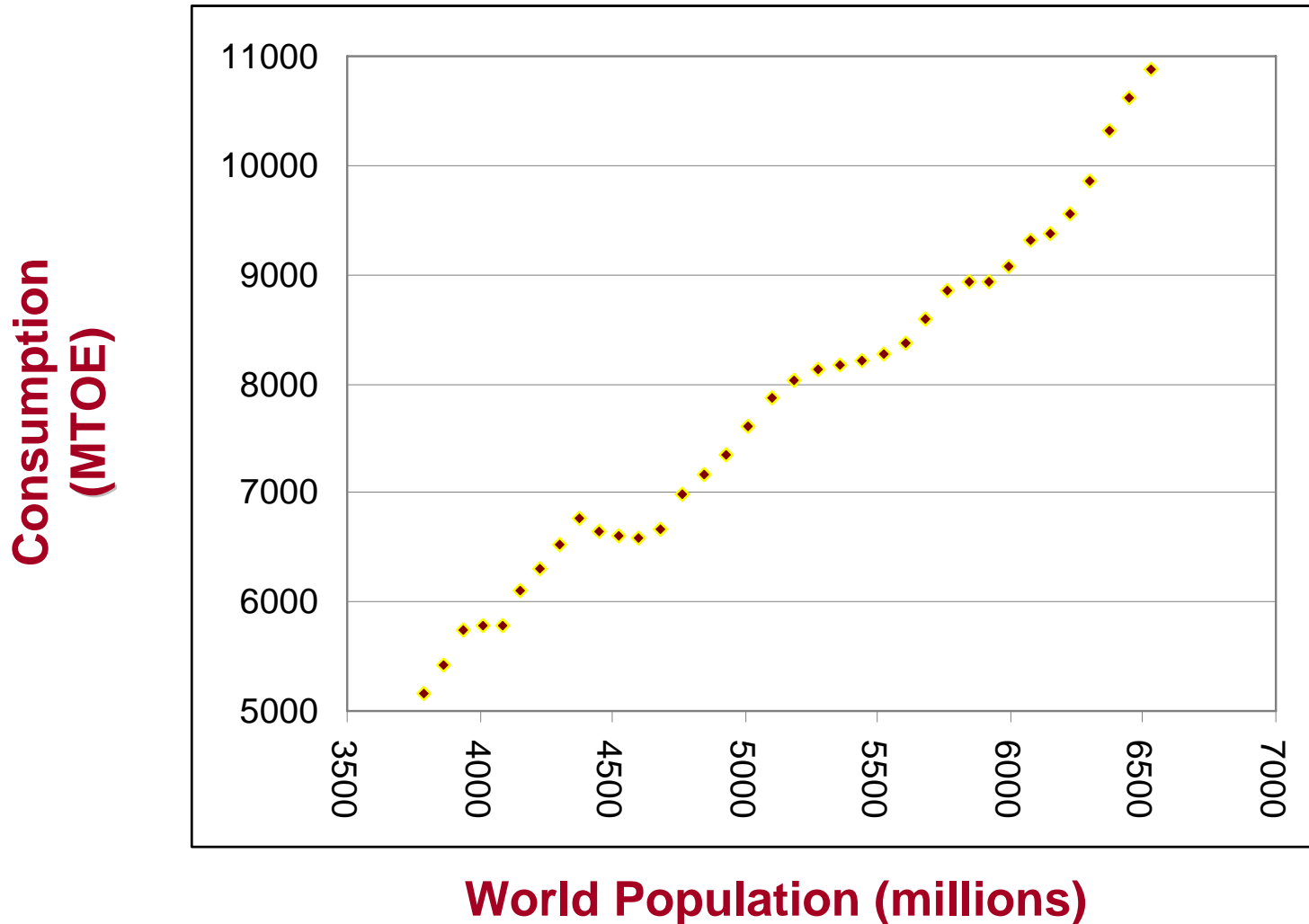


A Simple Economy: Limited Waste Absorption Capacity



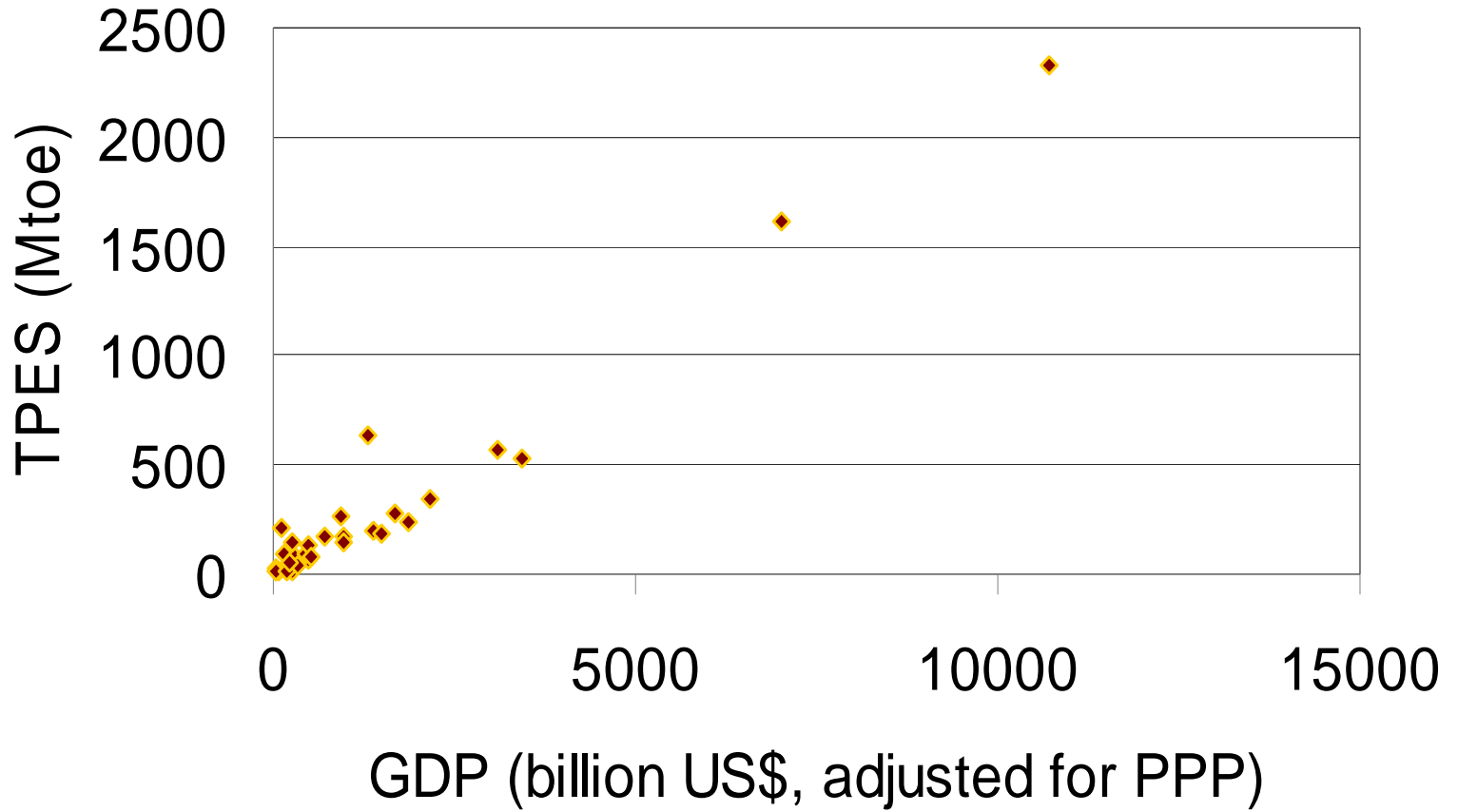
- Major Drivers of Energy Consumption
 - Population Growth
 - Economic Growth
 - Energy Intensity

World Energy Consumption vs Population 1971-2006



Source: *BP Statistical Review of World Energy, 2007*

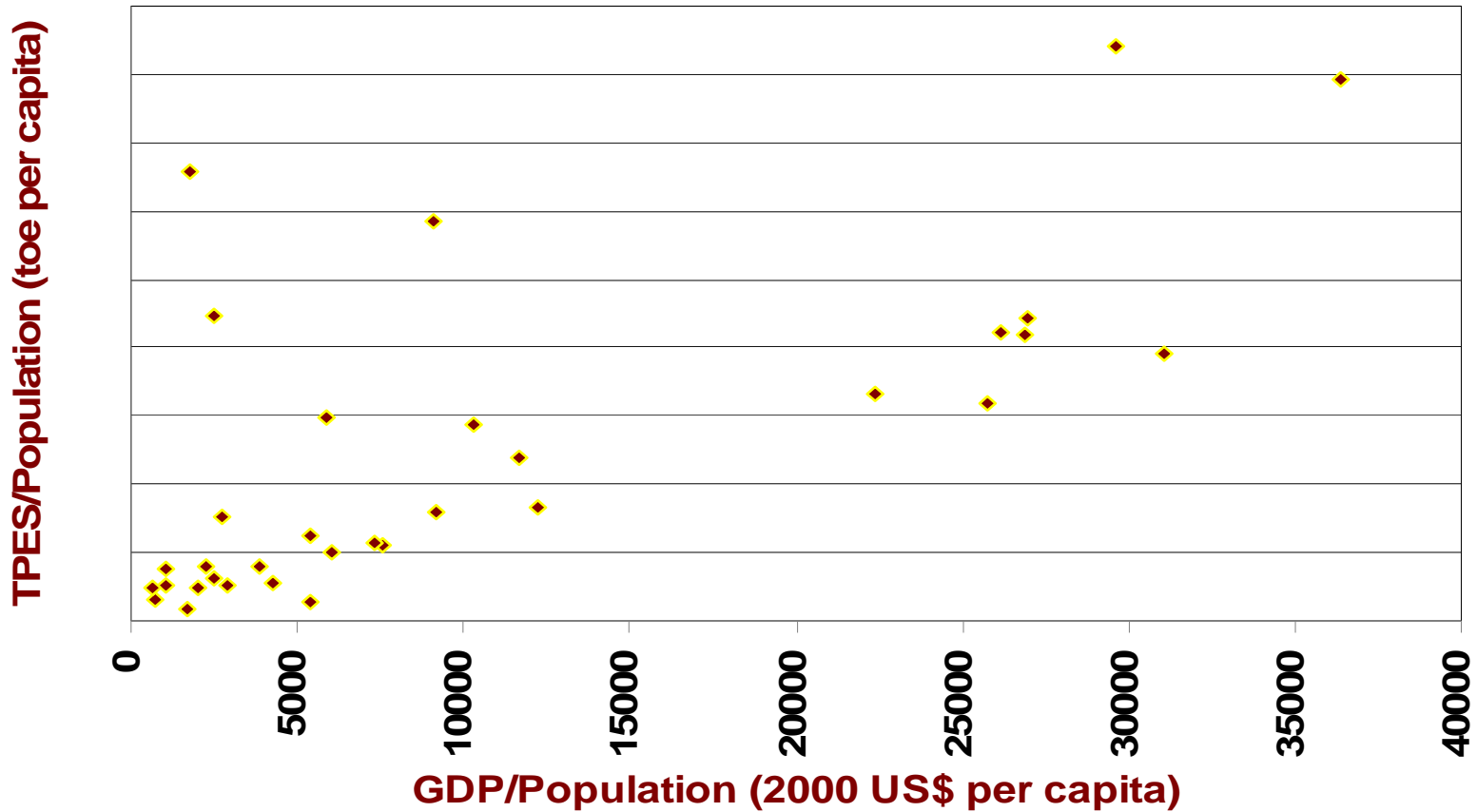
Total Primary Energy Supply vs GDP



Source: IEA



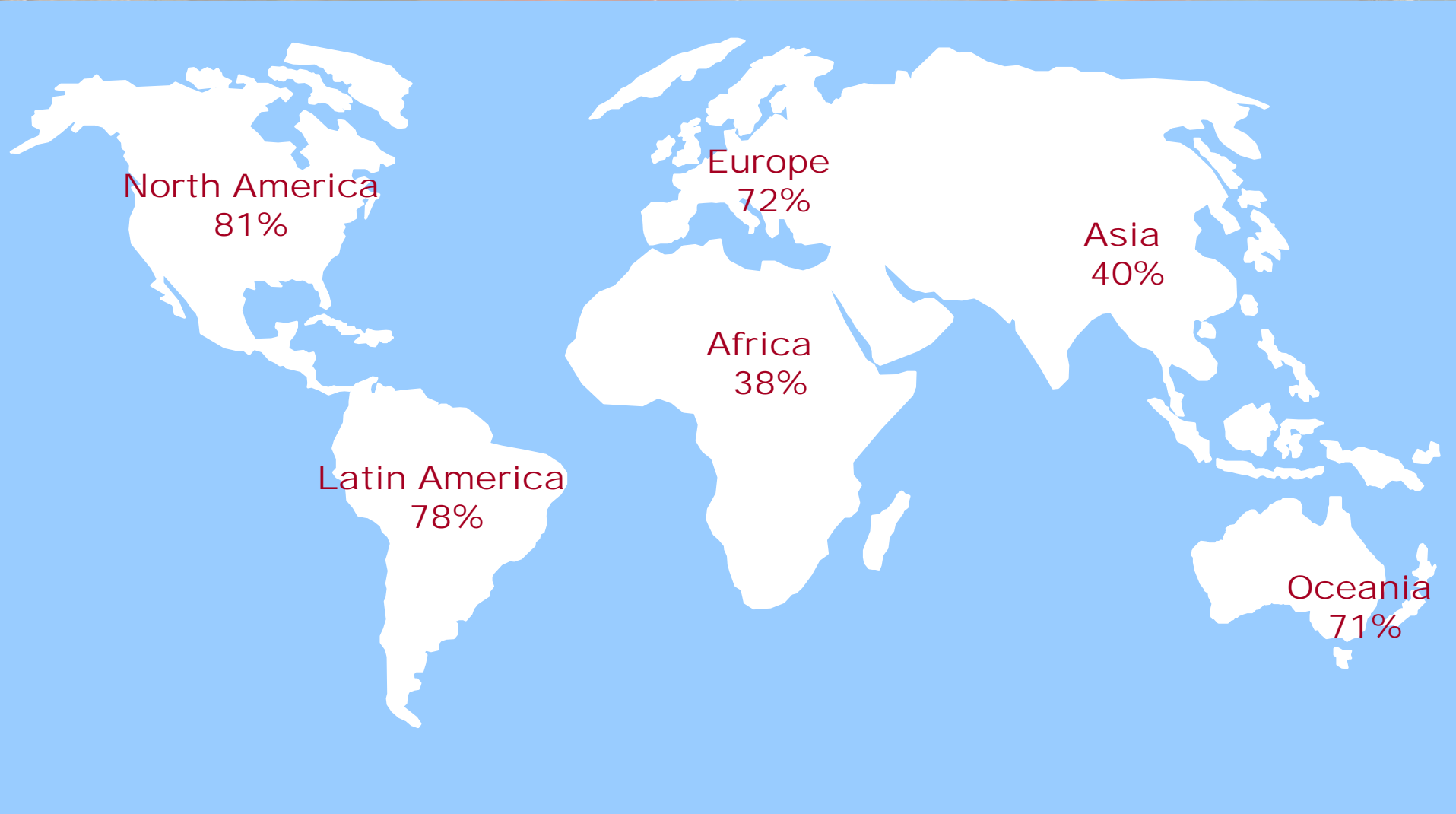
Total Primary Energy Supply vs GDP (per capita)



Source: IEA



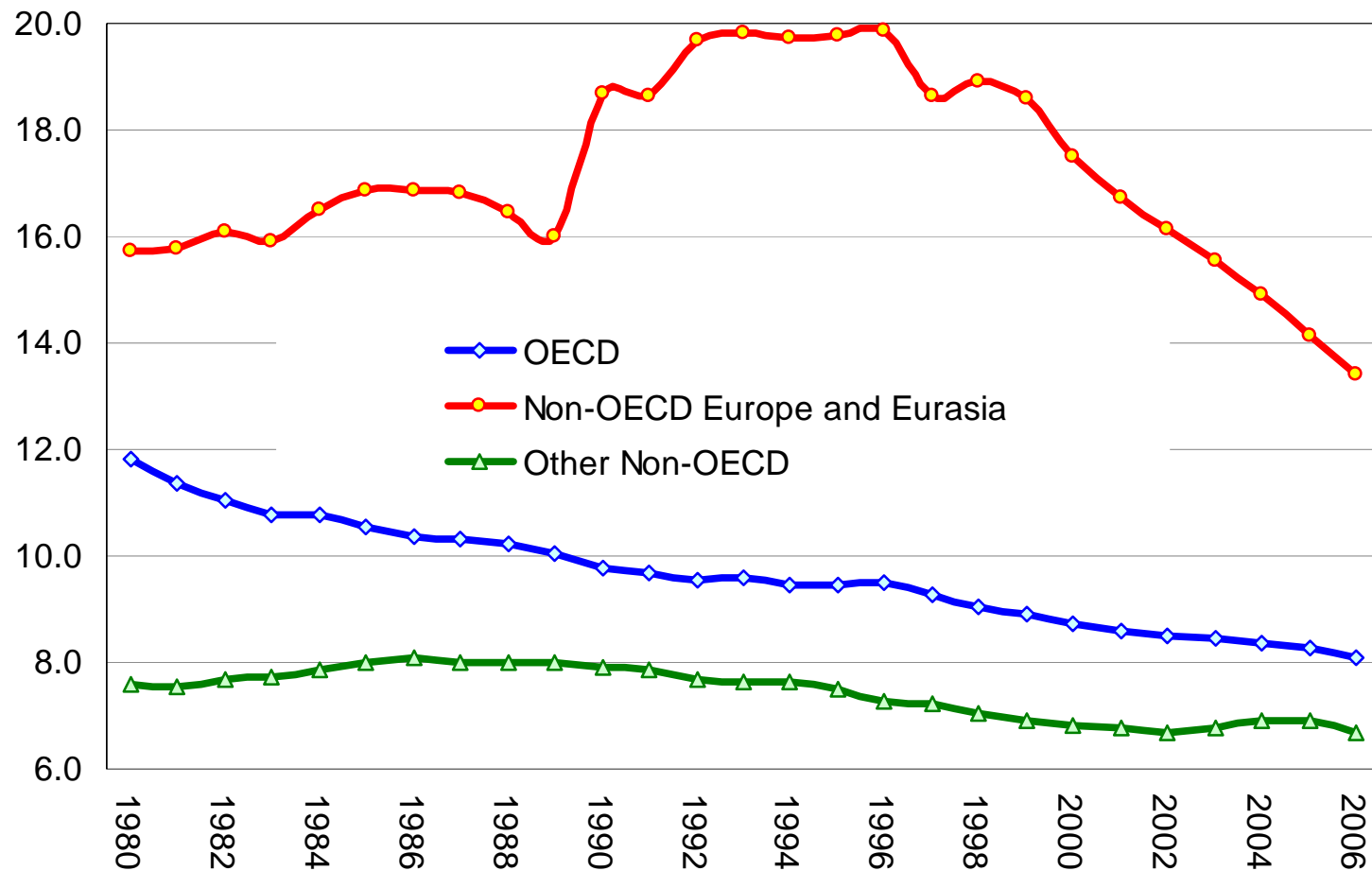
Urbanization Rate by Region 2005



Source: UN. *World Urbanization Prospects: The 2005 Revision*.



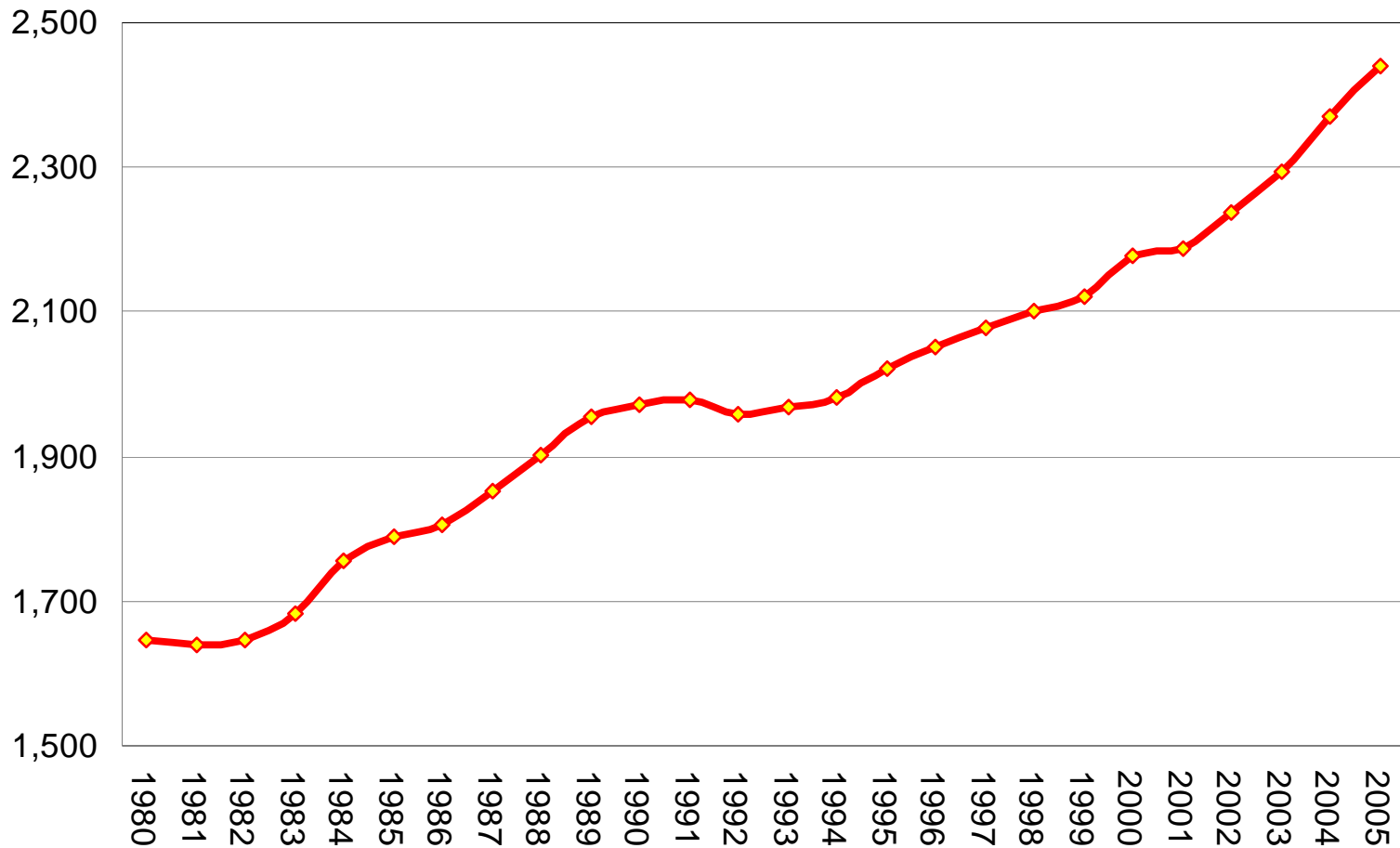
Energy Intensity 1980-2006 (thousand Btus per US\$ of GDP)



Source: EIA, *International Energy Outlook*, 2007

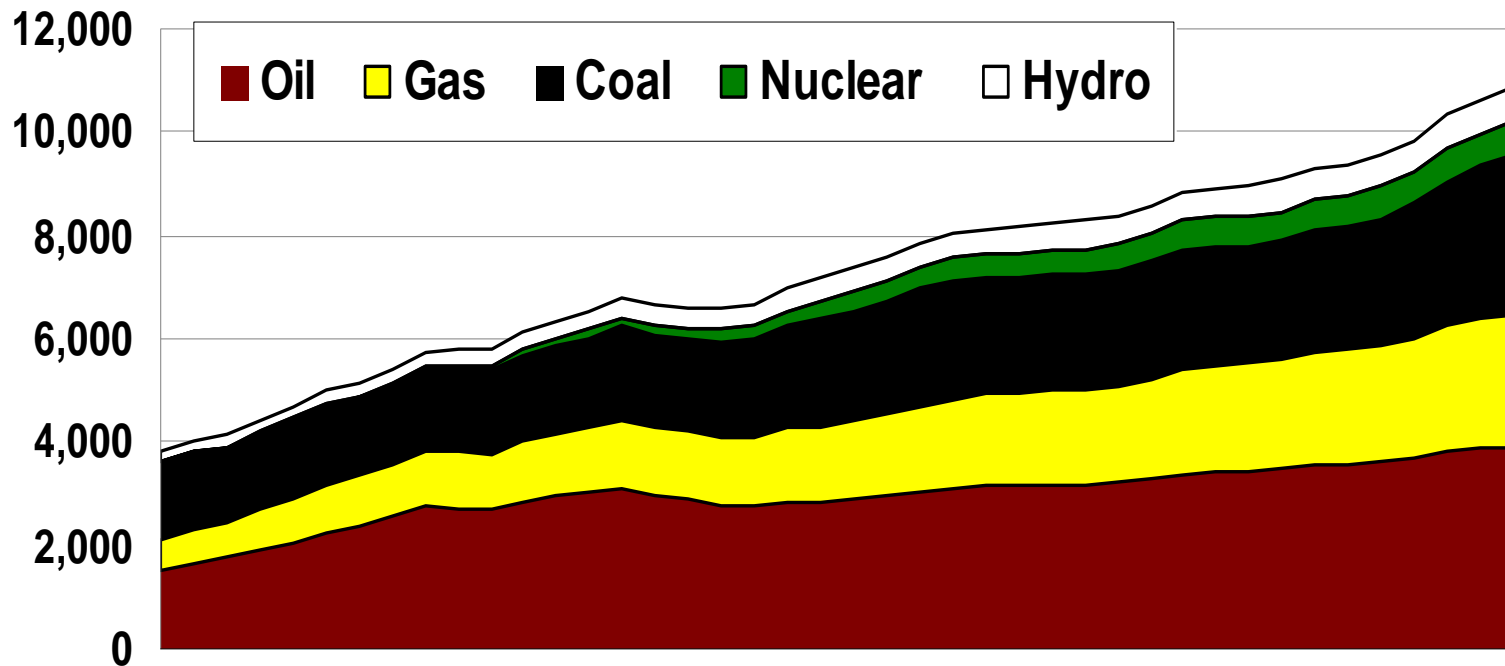
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Per Capita World Electricity Consumption 1980-2004 (kWh)



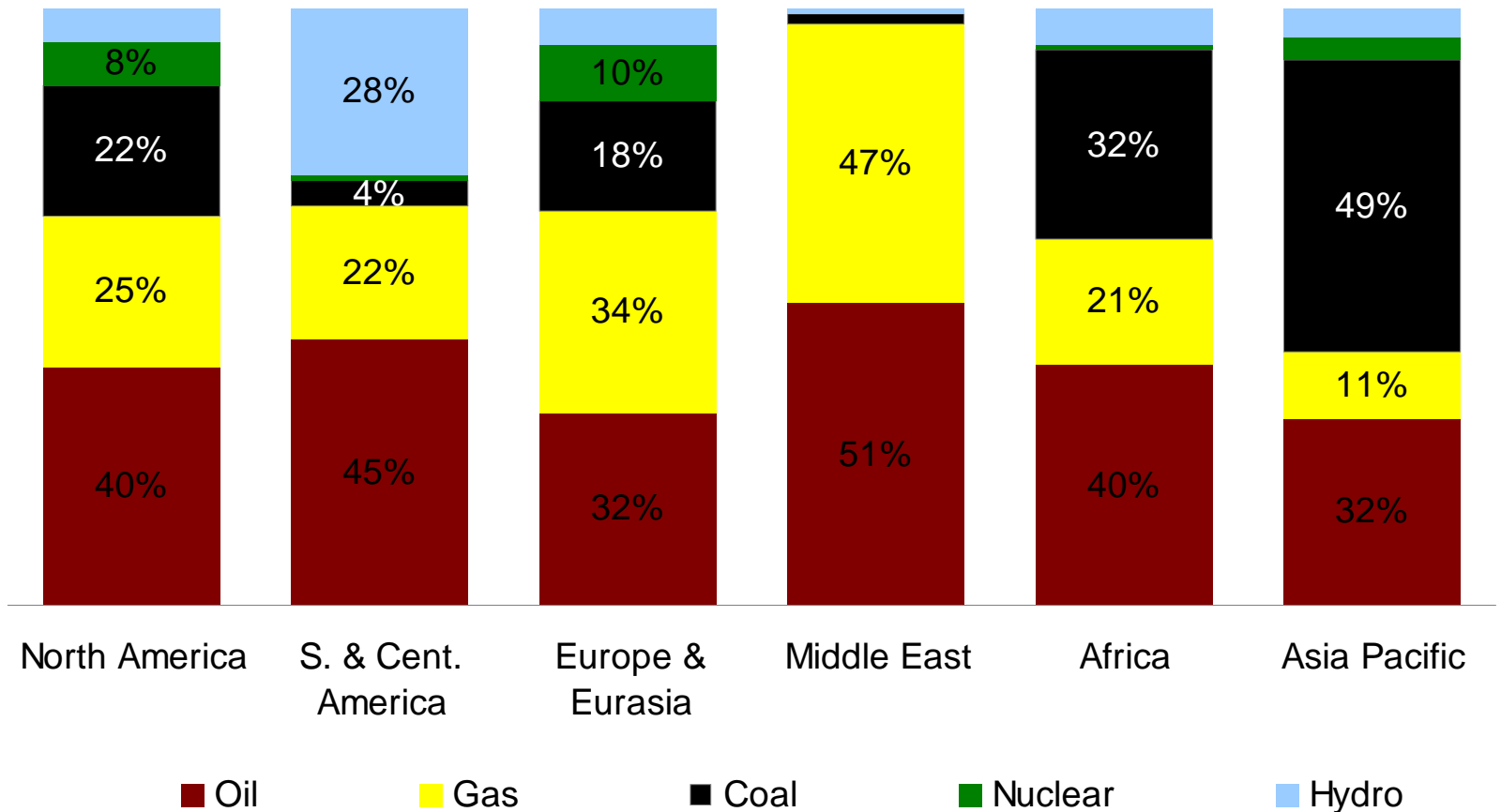
Source: EIA, *International Energy Outlook*

World Consumption of Primary Energy 1965-2006 (MTOE)



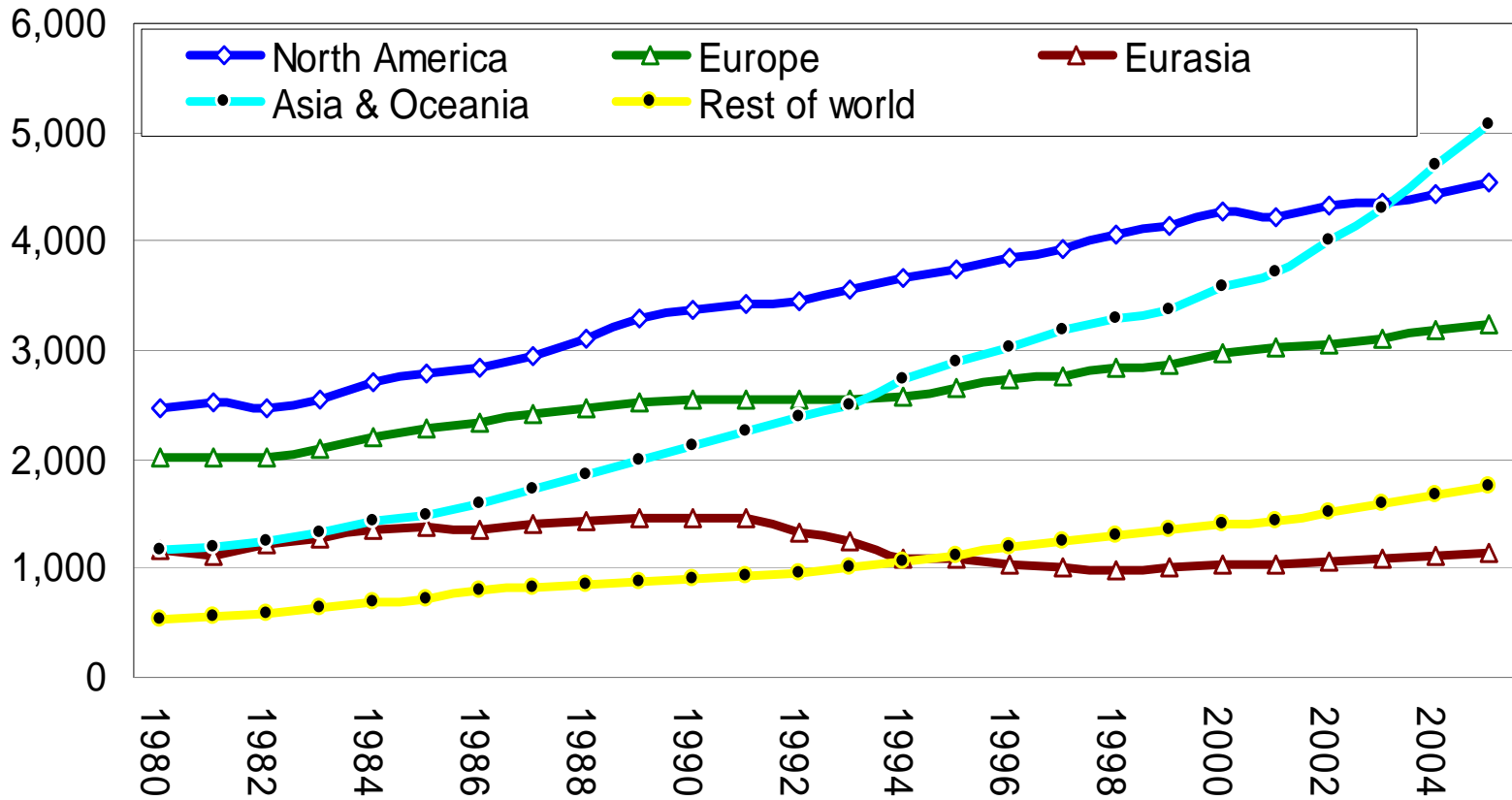
Source: *BP Statistical Review of World Energy, 2007*

Regional Consumption of Primary Energy by Fuel



Source: *BP Statistical Review of World Energy, 2007*

Regional Electricity Consumption 1980-2005 (terawatt hours)



Source: EIA

Energy Consumption: Summary

- **Population growth**
- **Energy intensity**

These have determined demand in past
and will continue to determine future demand

Future energy mix

Transportation needs \longrightarrow oil

Low emissions \longrightarrow natural gas, nuclear, Renewables

Use of renewables will continue to depend on society's willingness to pay for them.

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Historical Energy Supply

Pre-Industrial Revolution

- Per-capita energy use very low
- biomass, beasts of burden

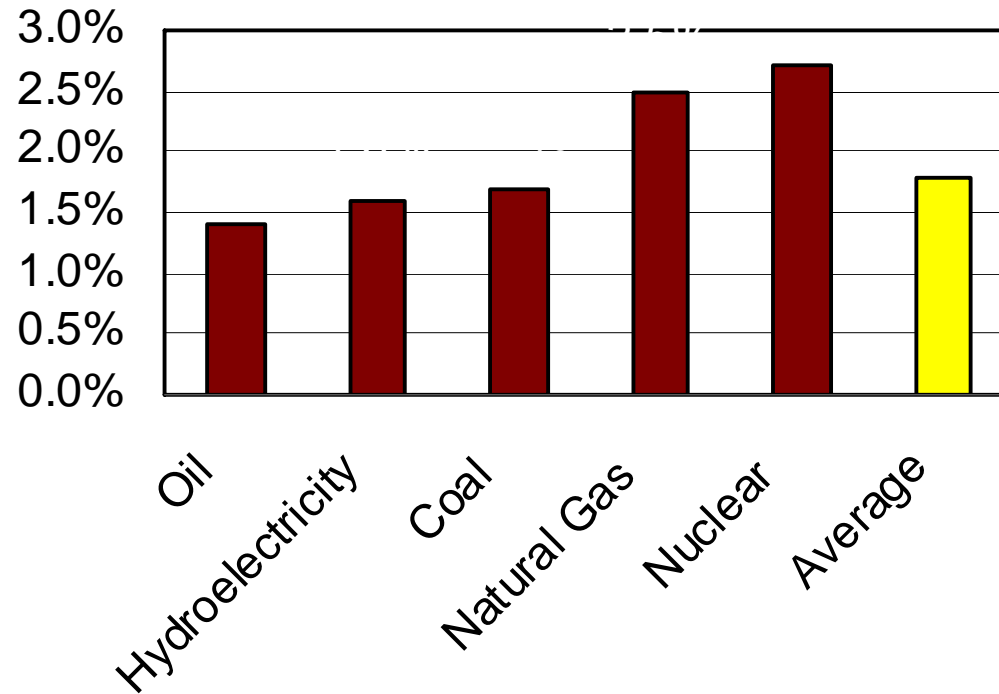
Industrial Revolution → coal

Internal Combustion Engine → oil

2006

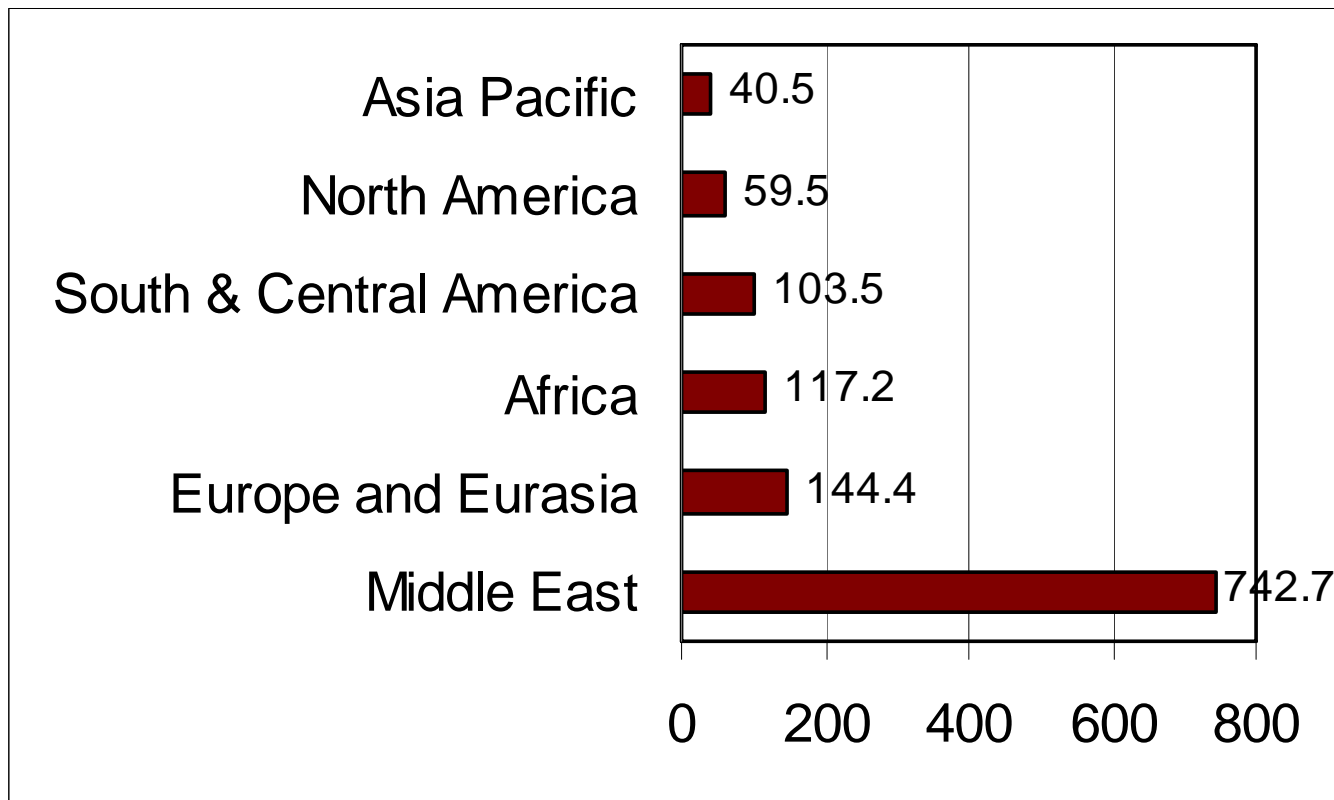
- fossil fuels = 88.6% of worldwide primary energy supply

Growth in Primary Energy Supply 1986-2006



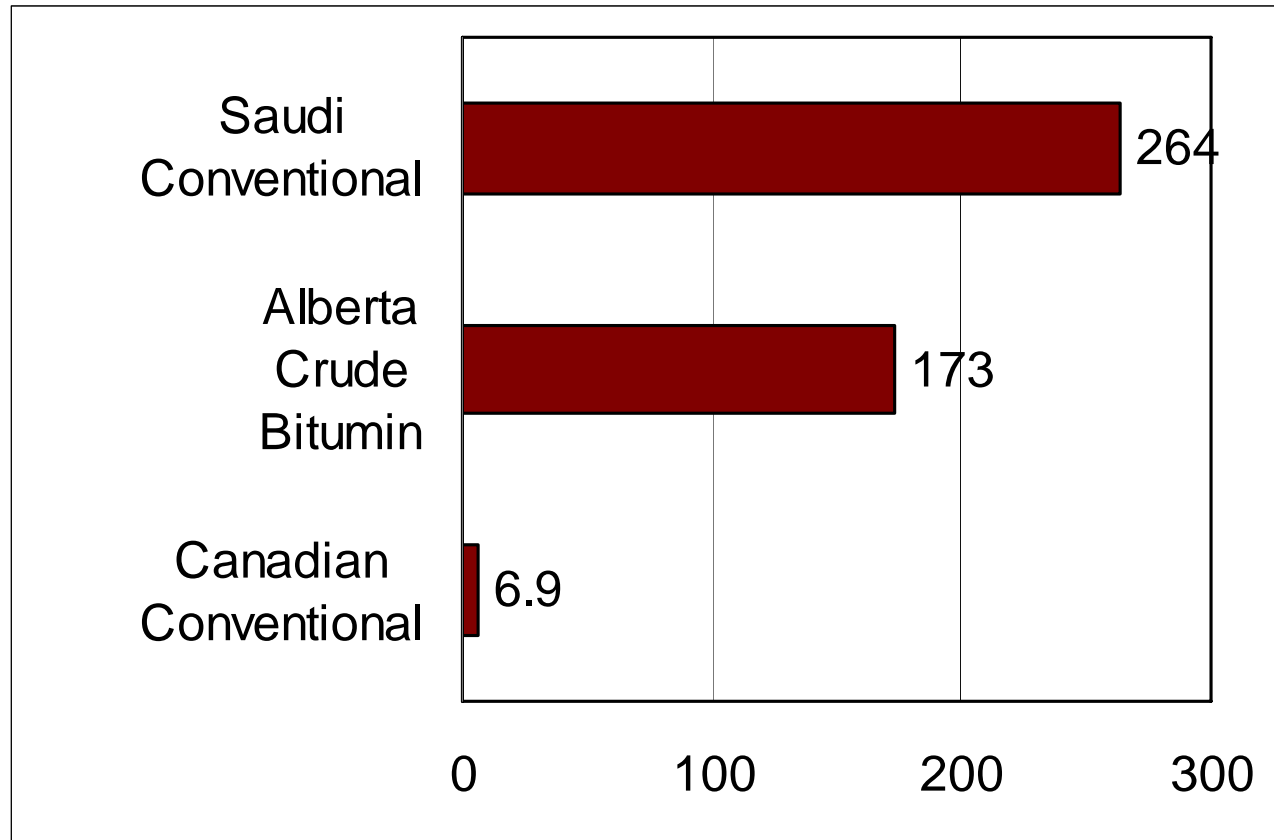
Source: BP, *Statistical Review of World Energy*, 2007

Regional Proved Oil Reserves - 2006 (billion barrels)



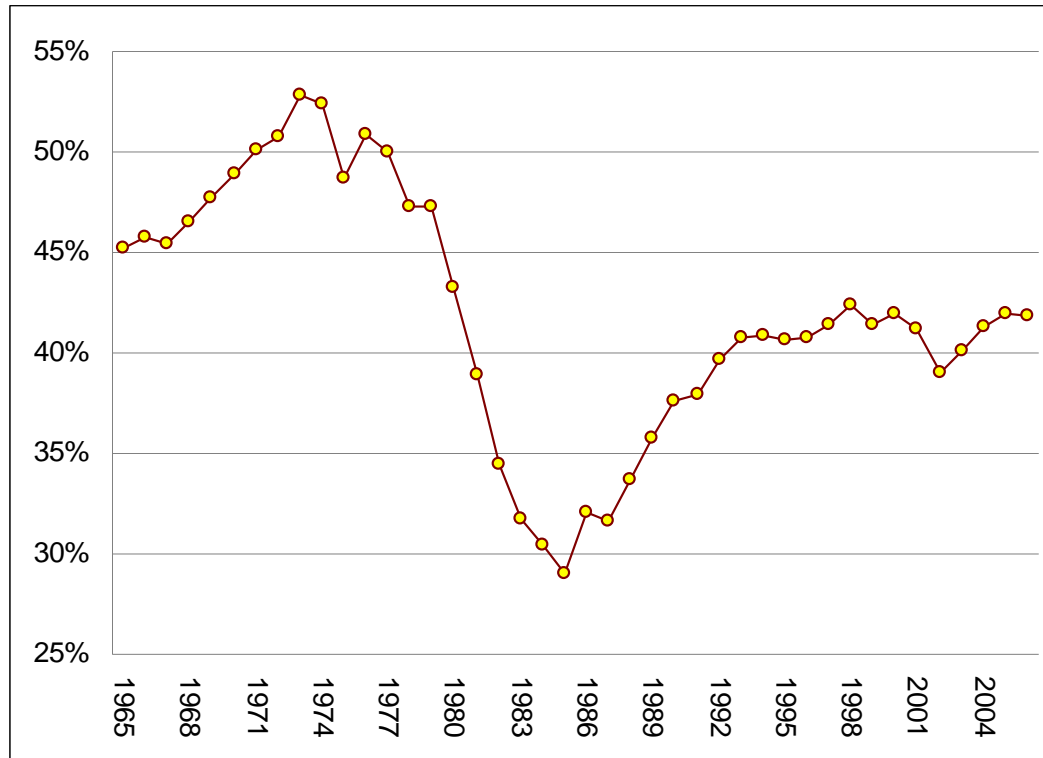
Source: BP *Statistical Review of World Energy*, 2007

Canadian & Saudi Oil Reserves - 2006 (billion barrels)



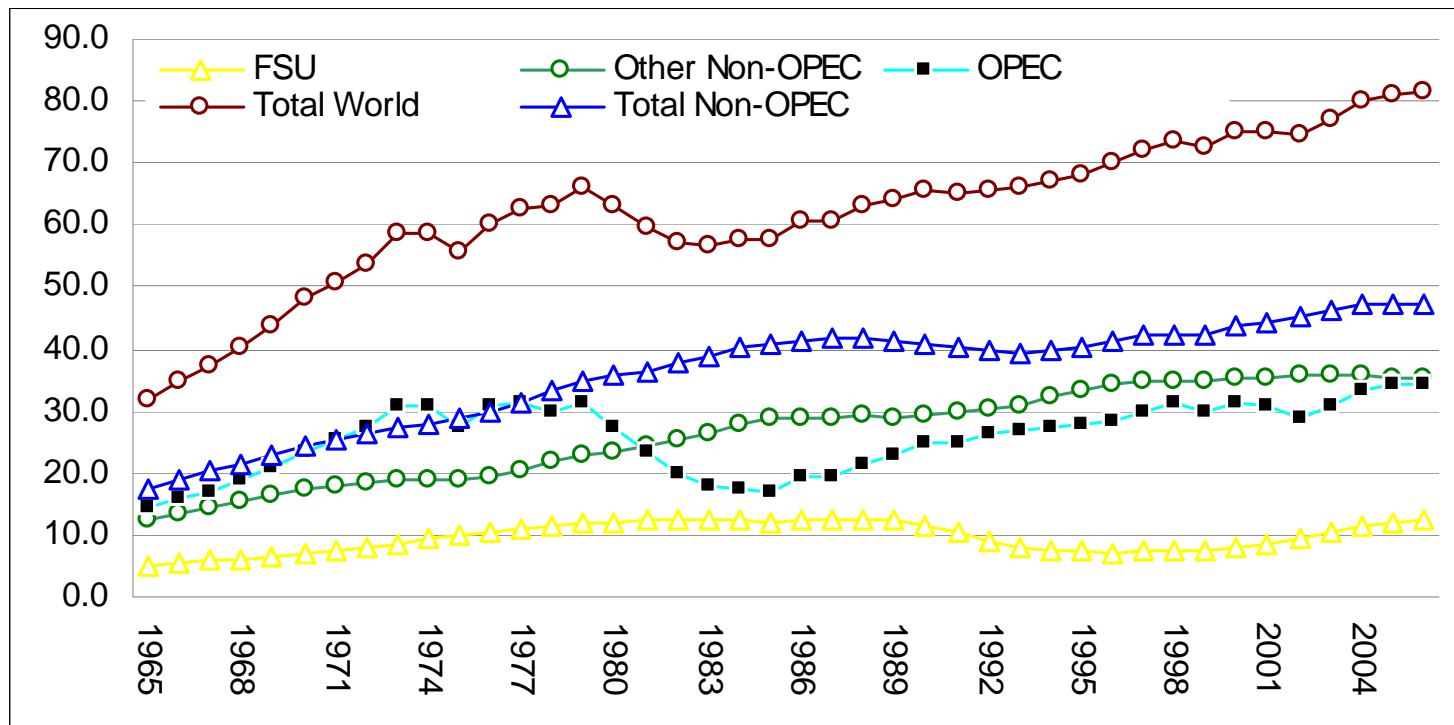
Source: BP *Statistical Review of World Energy, 2007*

OPEC Market Share (percent)



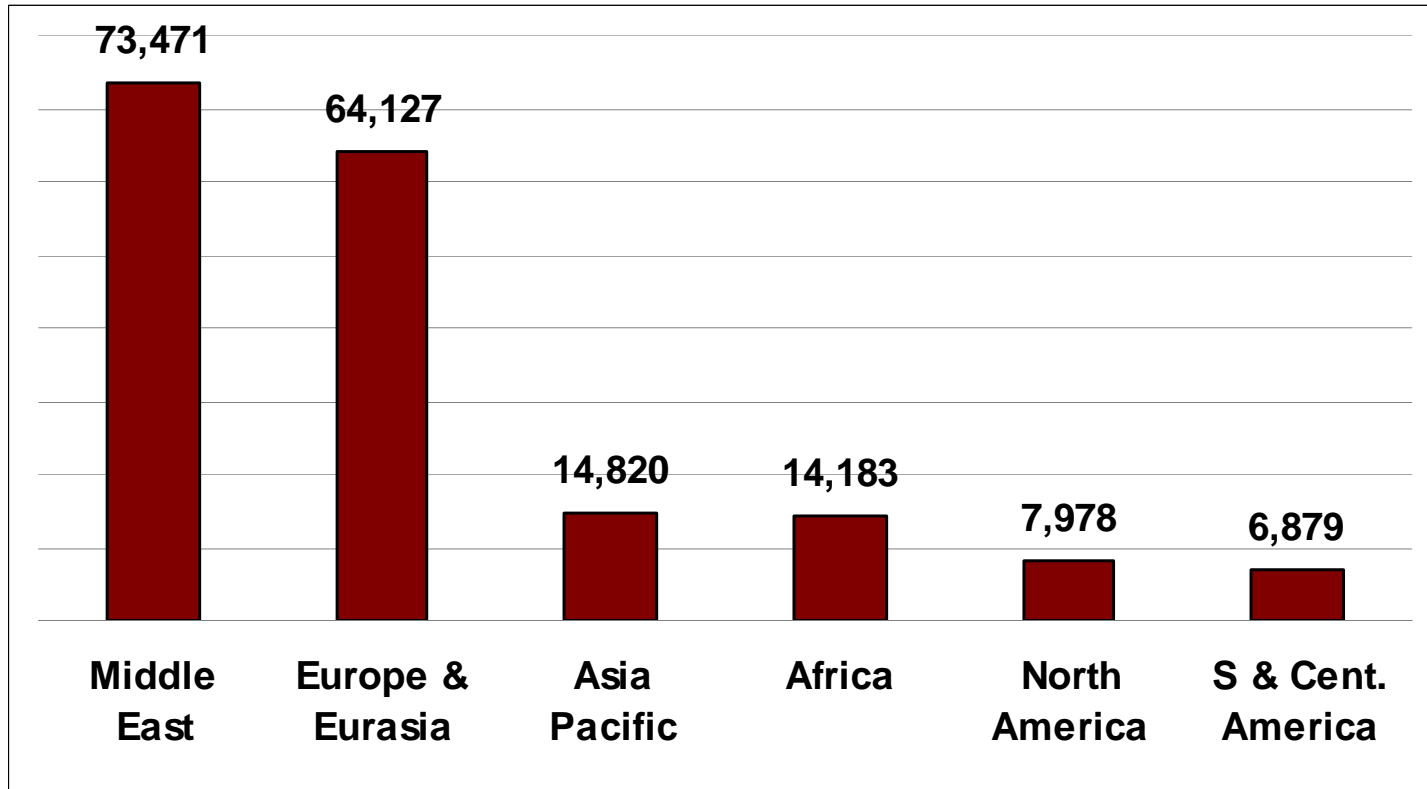
Source: BP. *BP Statistical Review of World Energy, 2007.*

Regional & Total World Oil Production 1965-2006 (millions of barrels/day)



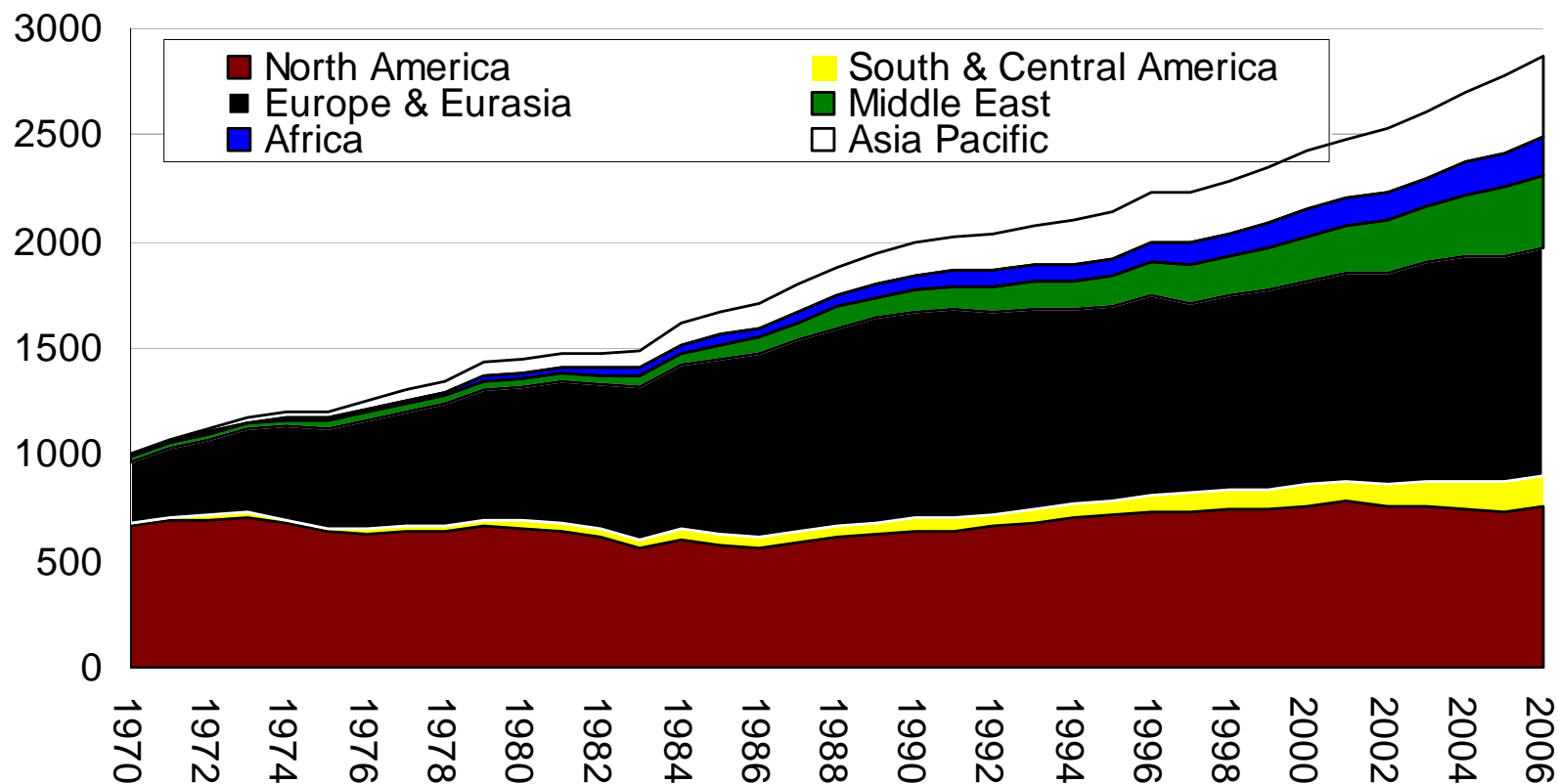
Source: BP. *BP Statistical Review of World Energy, 2007*

Regional Proved Natural Gas Reserves Year-End 2006 (Billion Cubic Meters)



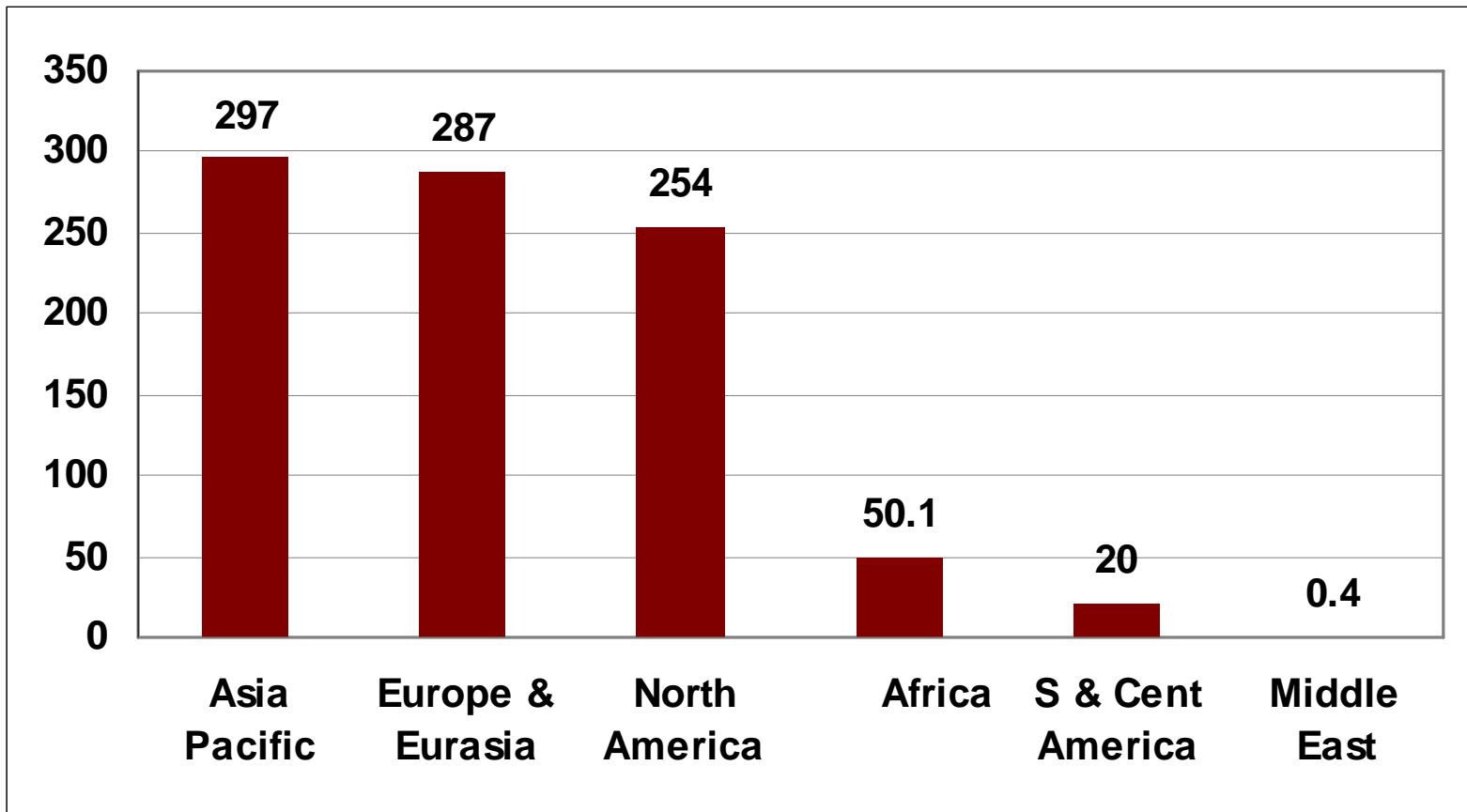
Source: BP. *BP Statistical Review of World Energy, 2007*

Regional Natural Gas Production, 1970-2006 (Billion Cubic Meters)

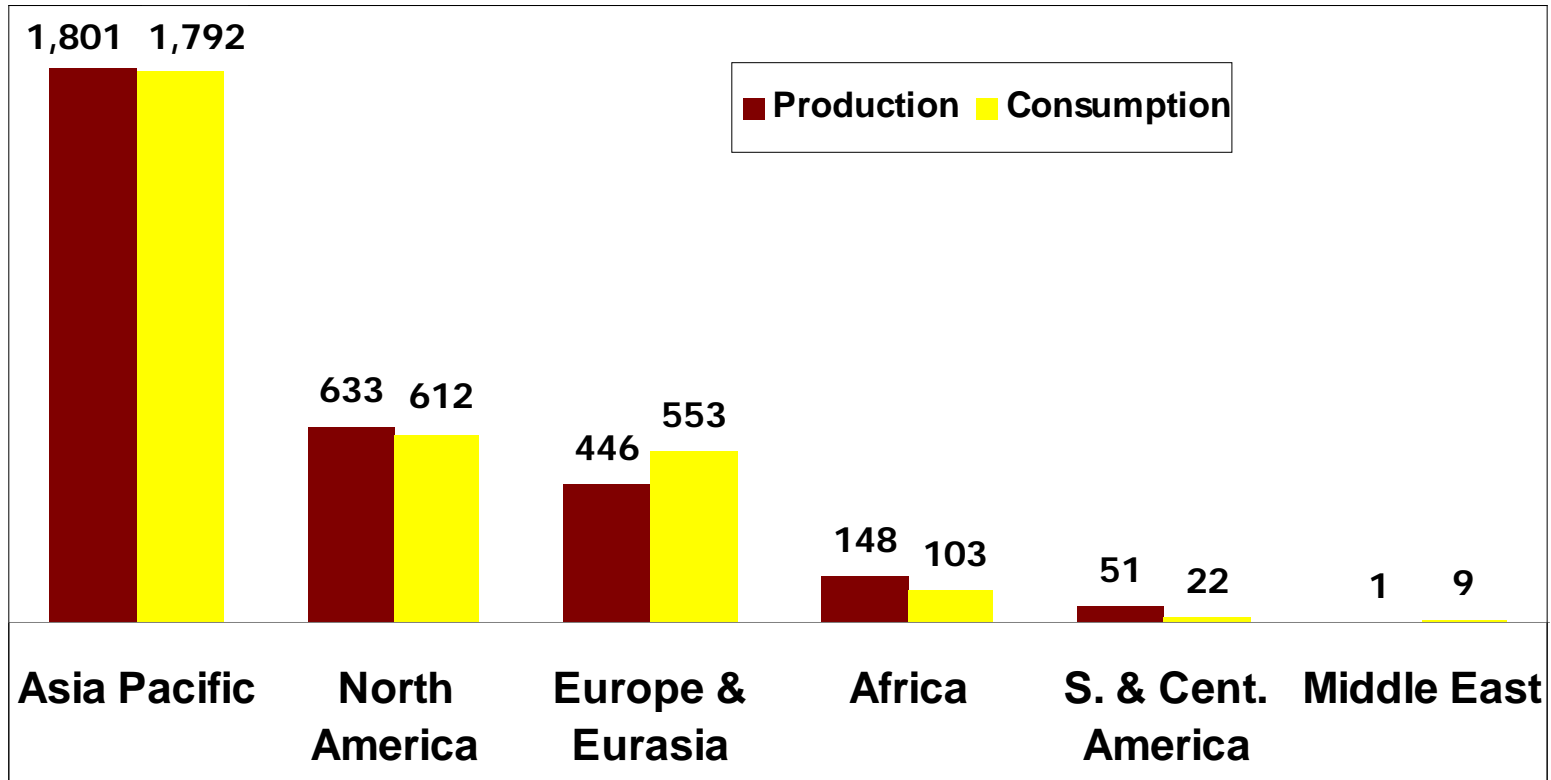


Source: BP. *BP Statistical Review of World Energy, 2007*

Regional Proved Coal Reserves 2006 Year End (Thousand Million Tons)

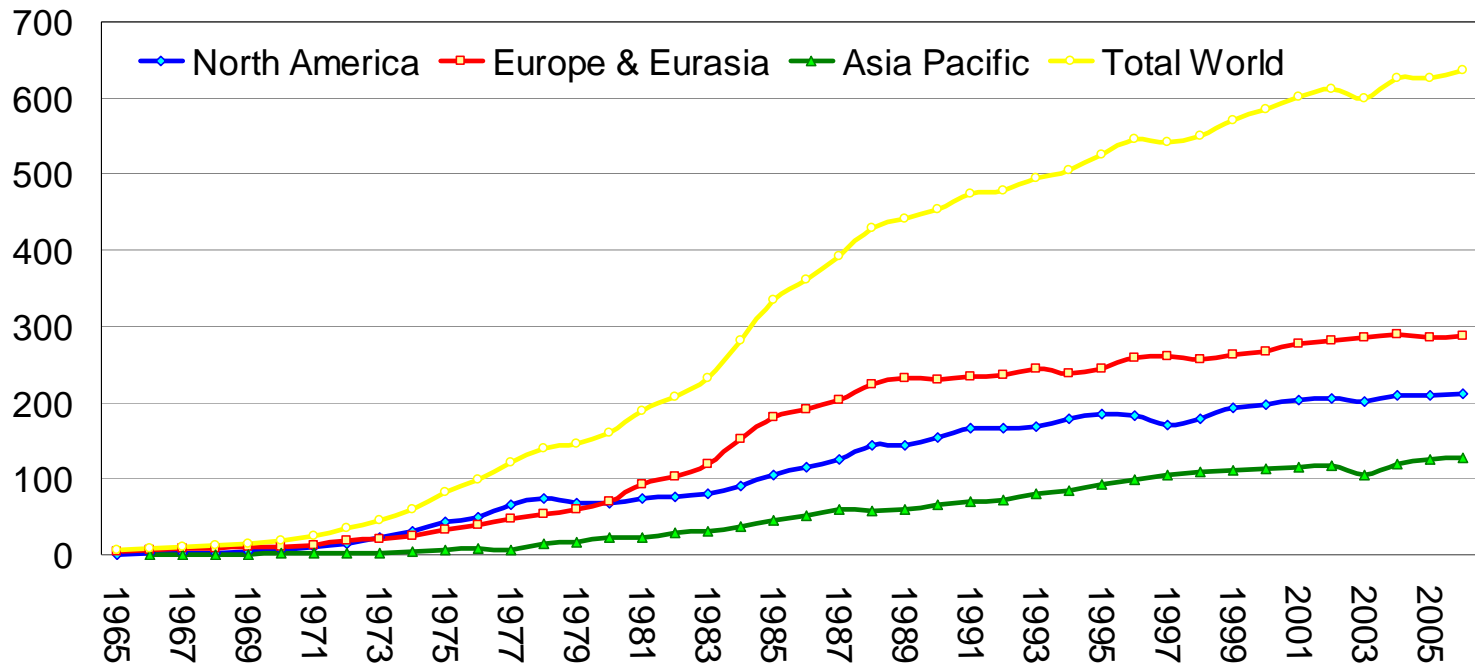


Regional Coal Production & Consumption, 2006 (MTOE)



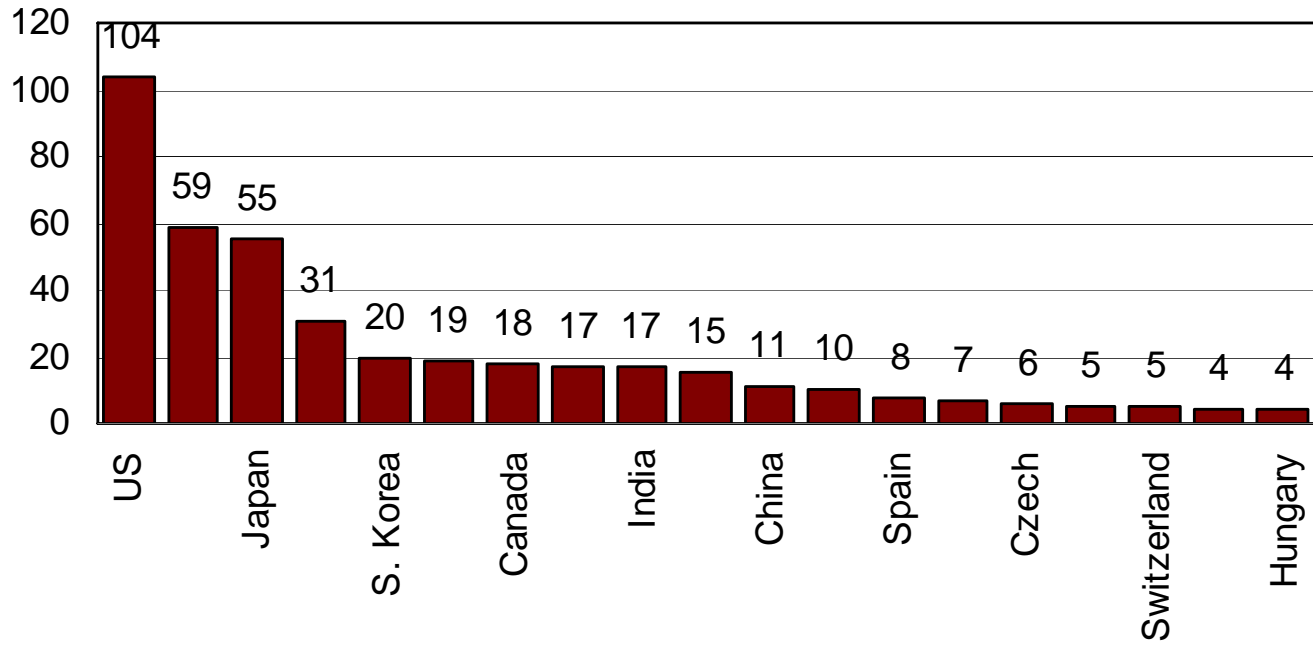
Source: BP. *BP Statistical Review of World Energy, 2007*

World & Regional Consumption of Nuclear Energy 1965-2006 (MTOE)



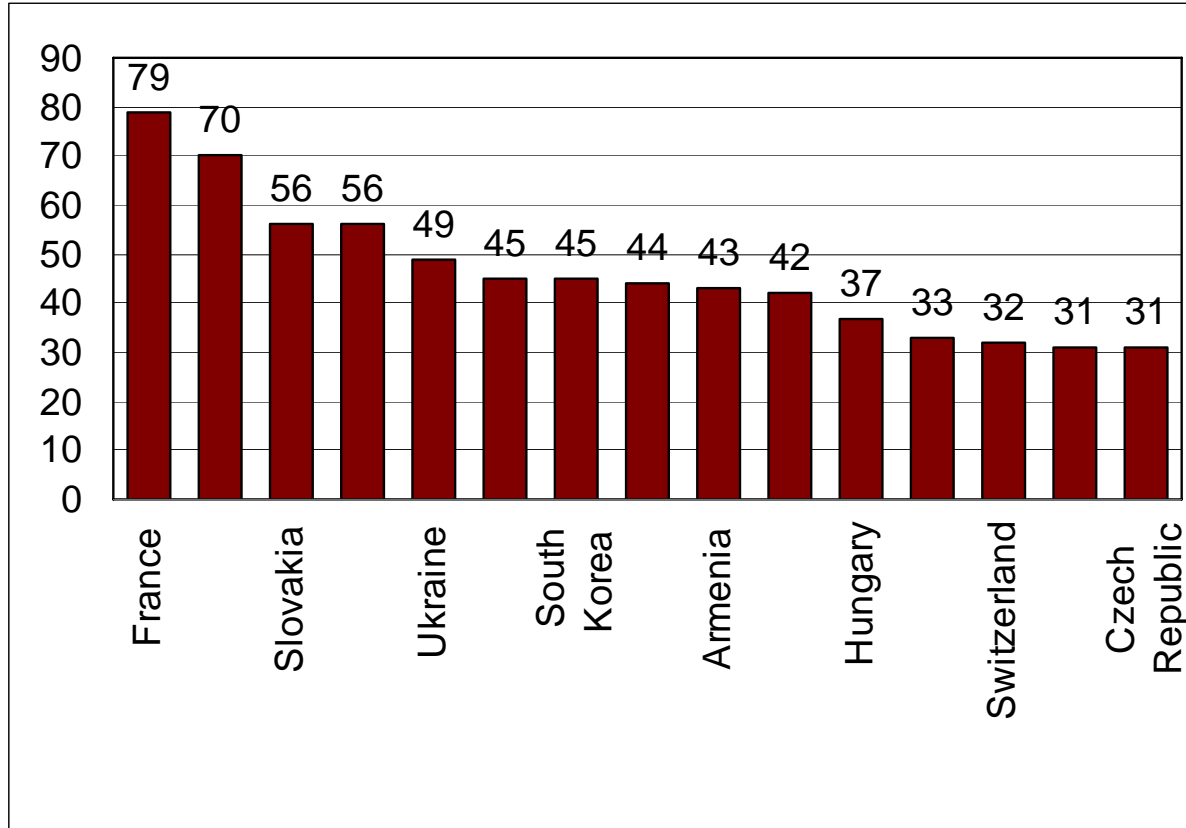
Source: BP. *BP Statistical Review of World Energy, 2007*

Number of Reactors by Country 2007



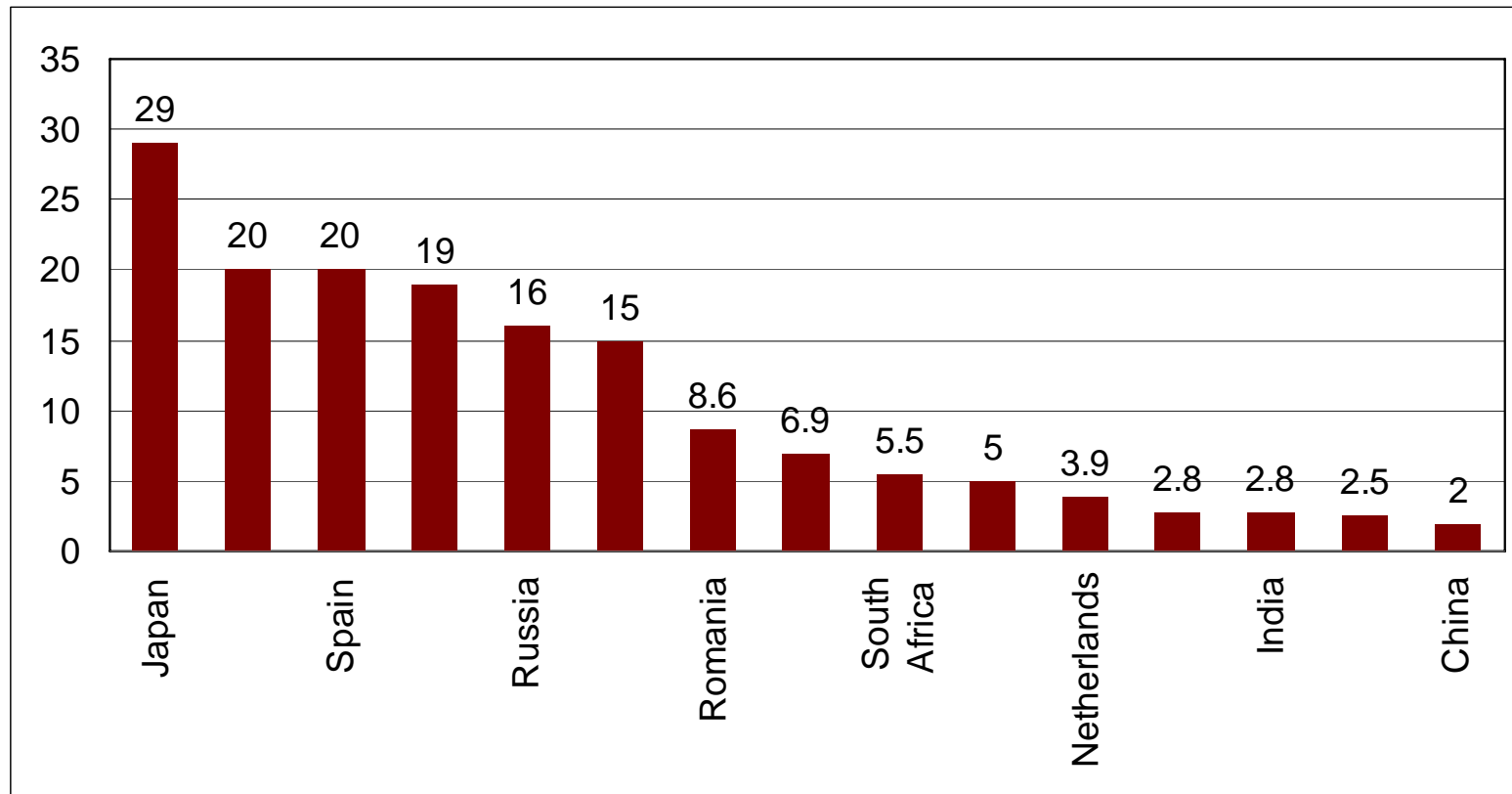
Source: www.iaea.org/cgi-bin/db.page.pl/pris.reaopucct.htm

Nuclear Generation > 30 Percent of Total Generation 2006



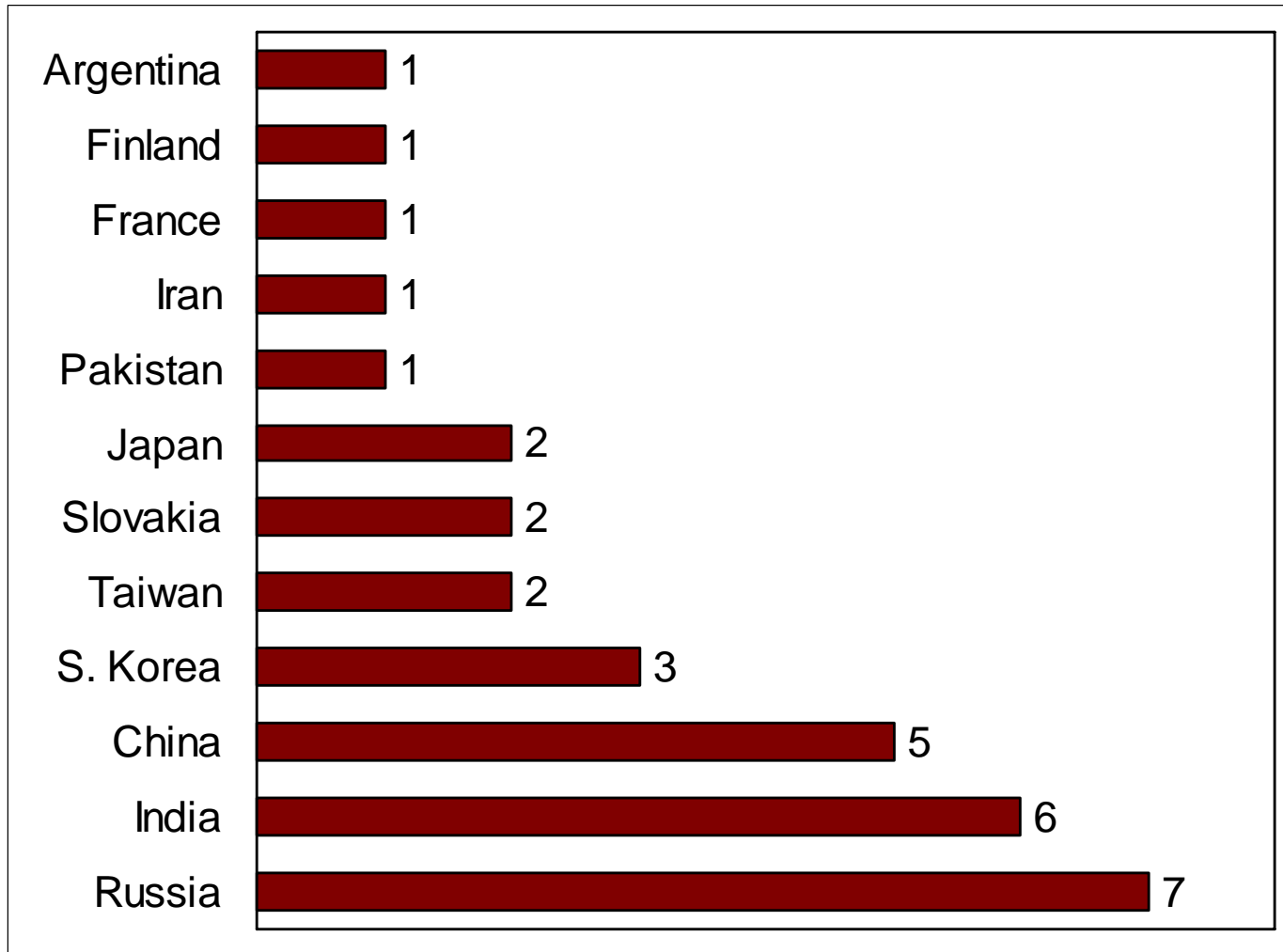
www.world-nuclear.org/info/reactors.htm

Nuclear Generation < 30 Percent of Total Generation 2006



www.world-nuclear.org/info/reactors.htm

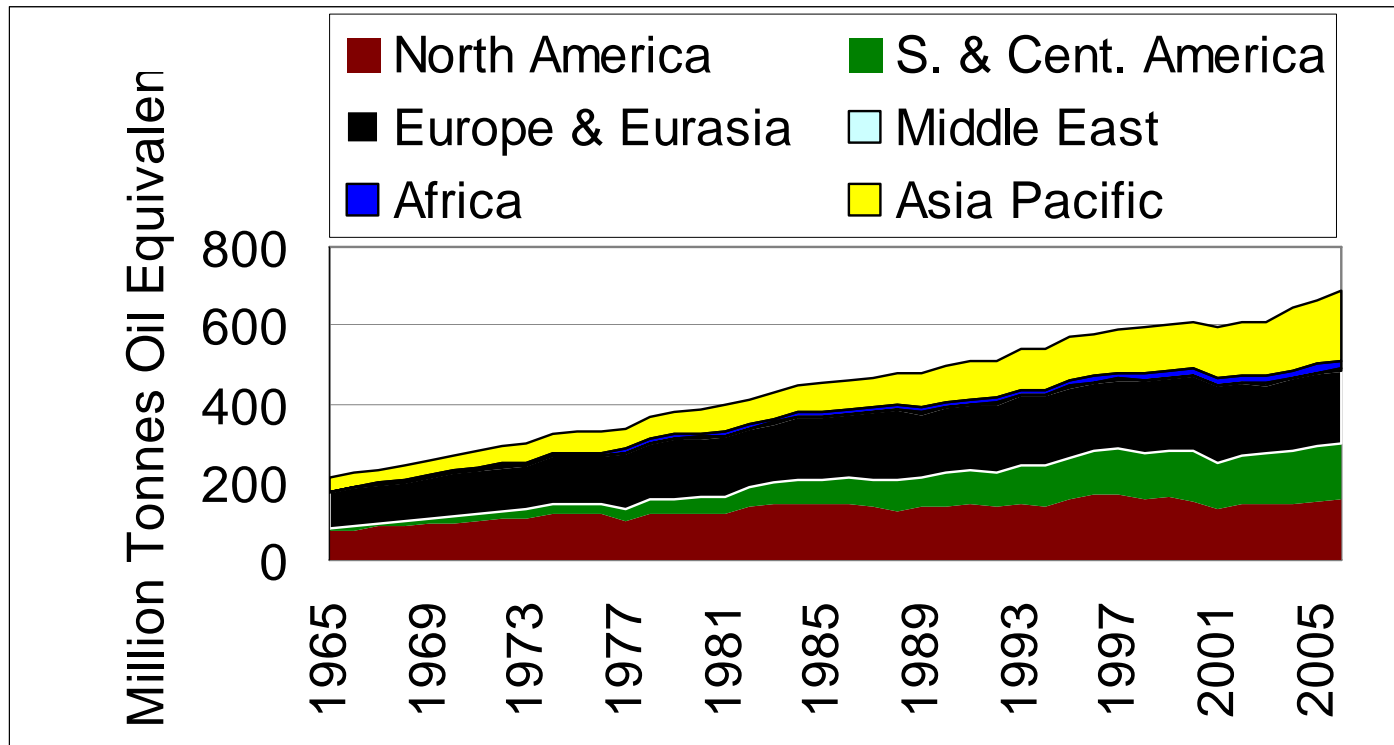
Nuclear Reactors Under Construction January 2008



Source: Australian Uranium Association



Hydroelectricity - Regional Consumption 1965-2006 (MTOE)



Oil and Geopolitics -- Beginnings

WWI

- Established oil as key strategic commodity
- Horses & trains gave way to tanks, trucks, airplanes, automobiles

WWII

- Armies in N. Africa, Europe, Soviet Union crippled when oil supply interrupted
- First large petrochemical plants build during war to produce synthetic rubber

Oil & Geopolitics – Major Post-war market disruptions

1951	P.M. Mossadegh nationalizes Iranian oil industry
1956	Suez crisis
1967	Six-Day War
1973	Yom Kippur War; Arab oil embargo
1979	Iranian Revolution
1990	Gulf War
Present	US invasion of Iraq

Middle East

- When will Iraq's production be fully restored?
- Will civil unrest and terrorism disrupt oil production?
- When/how will Iran's nuclear issue be resolved?
- Israeli-Palestinian Conflict

OPEC

- How will political uncertainty in Venezuela and Nigeria affect the oil industry?

Russia

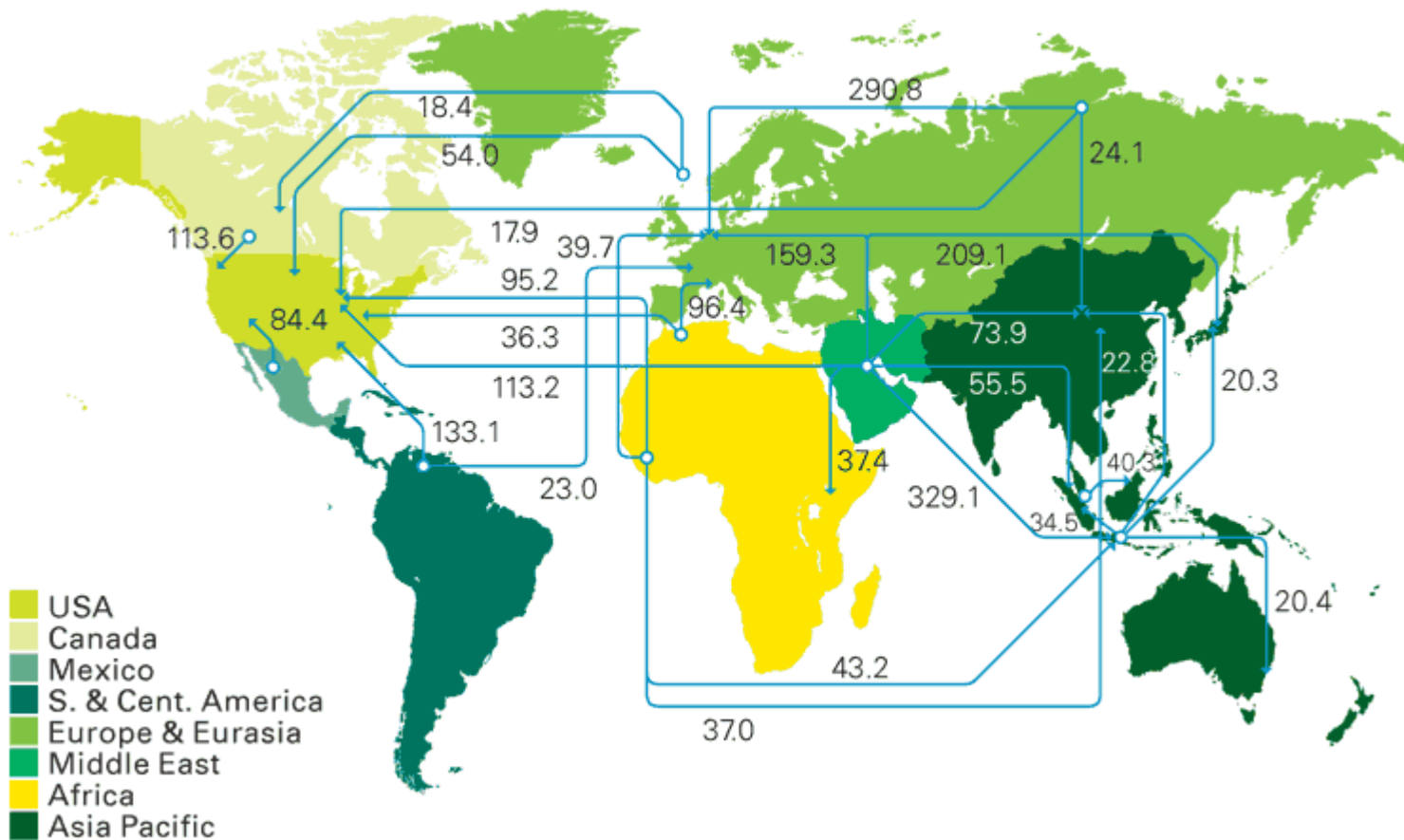
- Will there be stable exports?

Caspian Sea

- How quickly can Caspian oil be brought to market?

Major oil trade movements

Major trade movements 2006
Trade flows worldwide (million tonnes)



Oil Sands

- 173 billion barrels established reserves

Coal Bed Methane

- 4.7 billion m³ 2006 production with prospect of significant growth



Solar, wind, biomass, geothermal energy

- Potential of all largely untapped

Hydroelectric

- Still potential for development in Canada and Mexico; less in US

Energy Supply to 2050

- **Crude oil** will dominate in transportation
- Cleaner **natural gas** elsewhere
- **LNG** trade will grow in scale
- **Hydro & nuclear** will interest
- **Solar, geothermal wind and other renewables** will take hold.
- **Environmental concerns** will affect the mix of energy sources

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Toxic substances

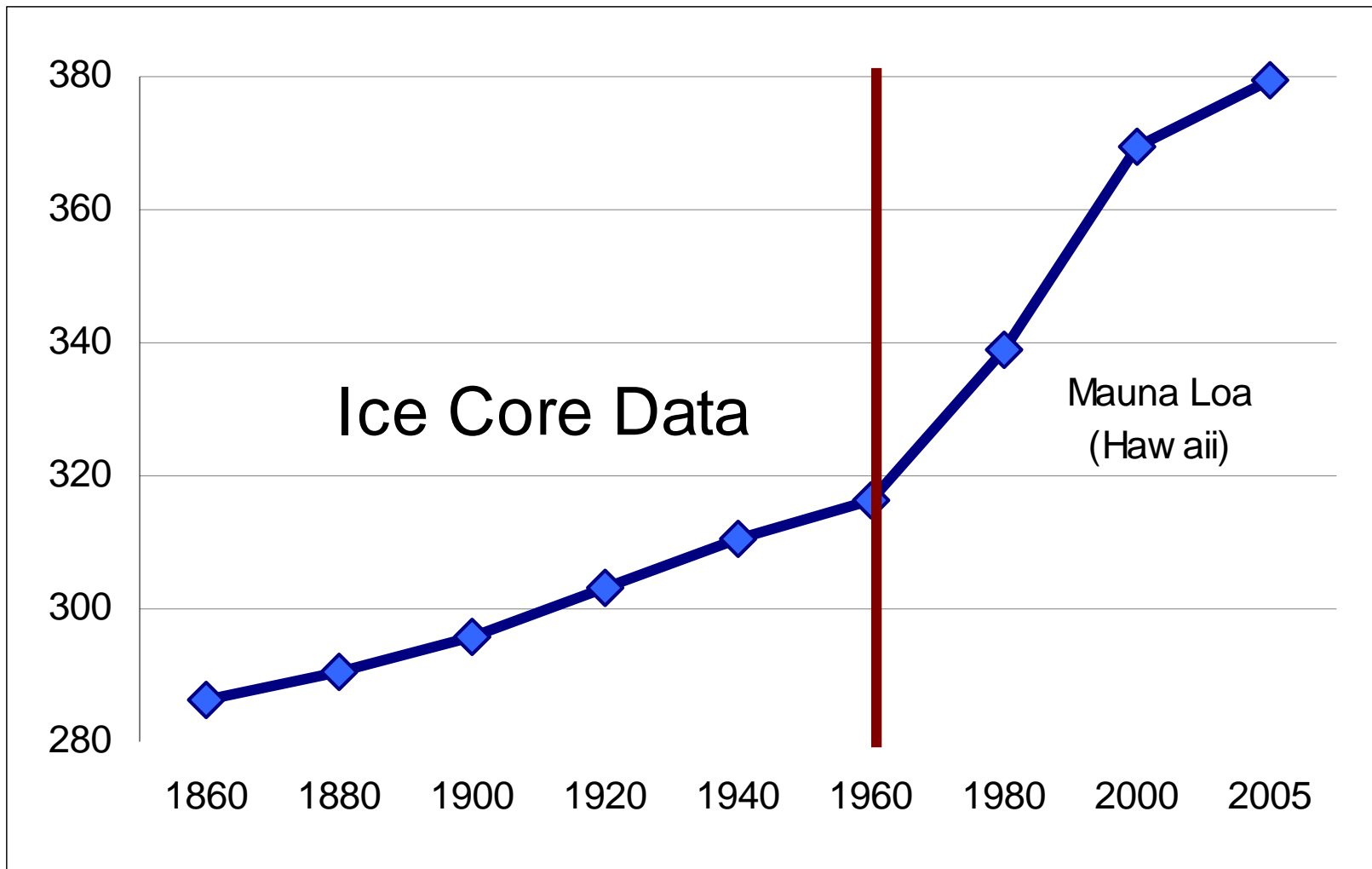
- sulphur compounds, nitrogen, and mercury

Greenhouse gases

- Water vapour, Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and others

Particulates

- naturally occurring and man-made

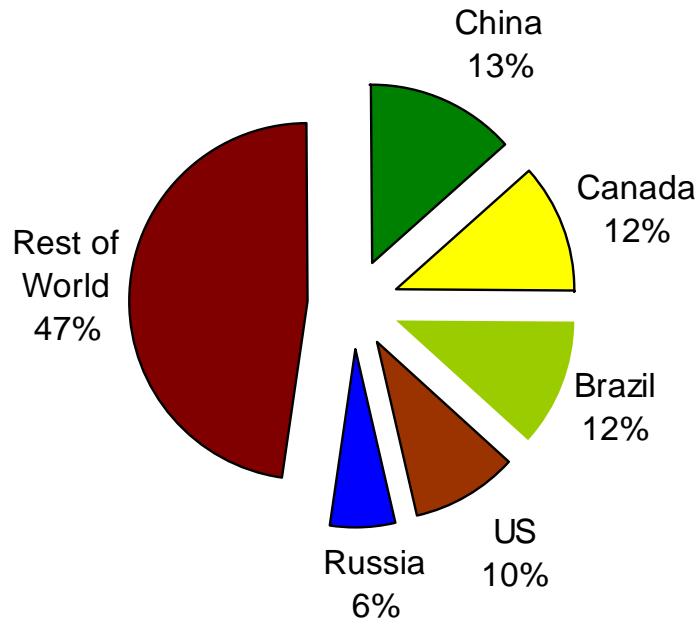


Potential Effect of a Doubling of CO₂ Emissions

- Increase of global mean temperatures by about 2.5°C
- Changing circulation, precipitation, volatility, soil moisture, ocean currents
- Ecology altered with unpredictable results

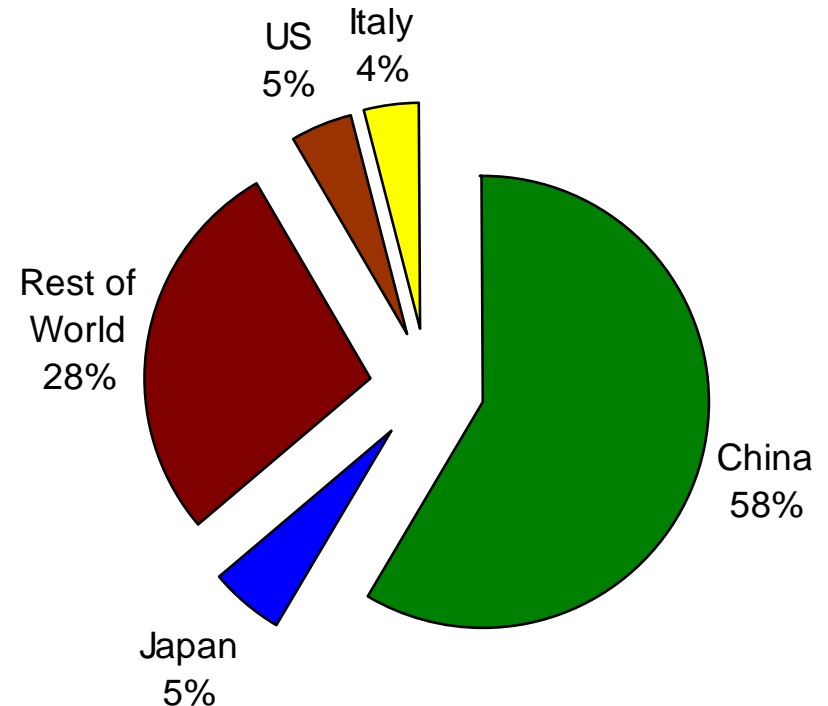
Energy Sources Availability & Impact -- Hydro

Percentage of World's Total Hydro Power



Source: BP Statistical Review of World Energy 2007.

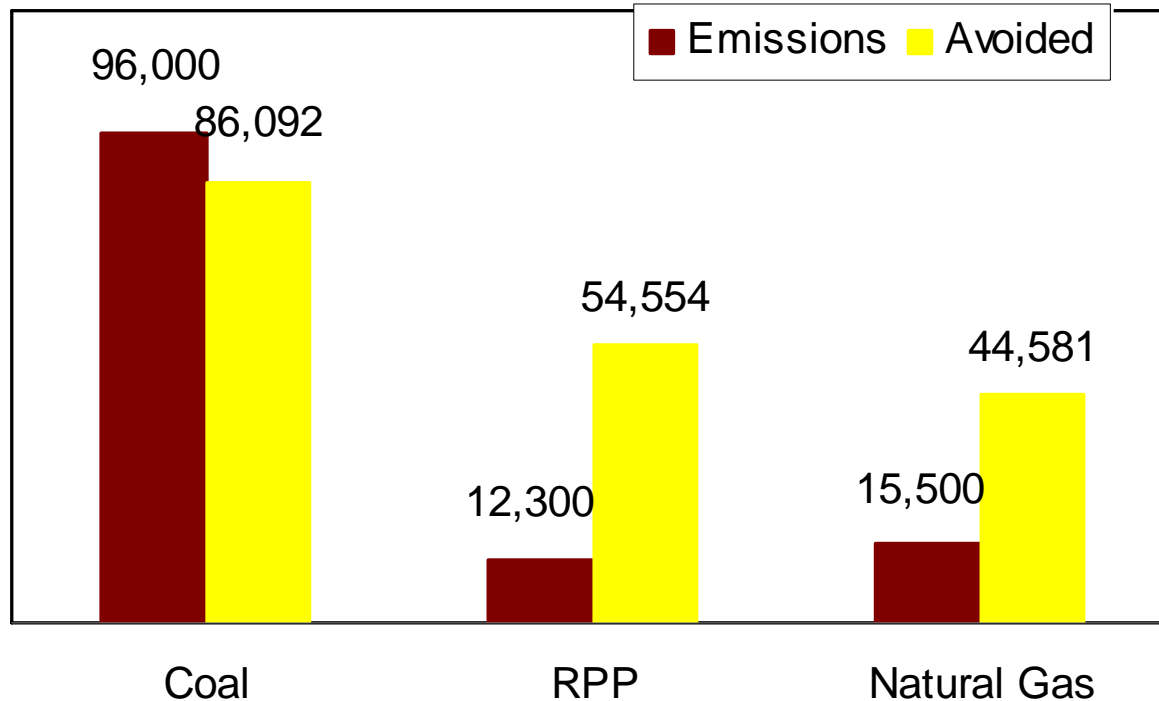
Percentage of World's Small Hydro Power



Source: IEA, Energy Technology Perspectives 2006

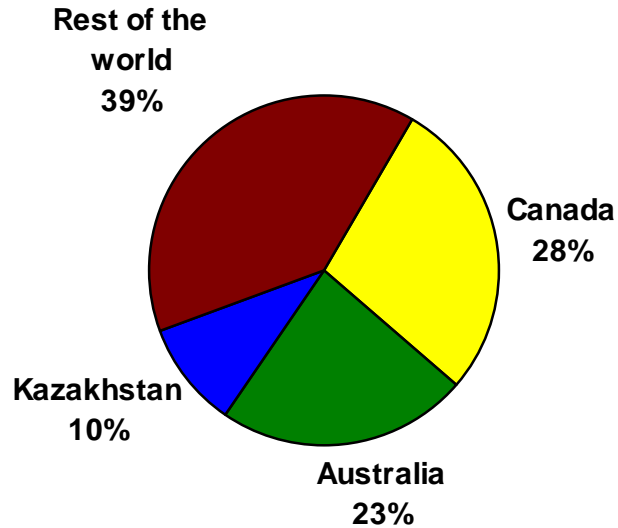
Energy Sources Availability & Impact -- Nuclear

Emissions Avoided By Use of Nuclear Generation in Canada – 2004
Kt CO₂ Equivalent

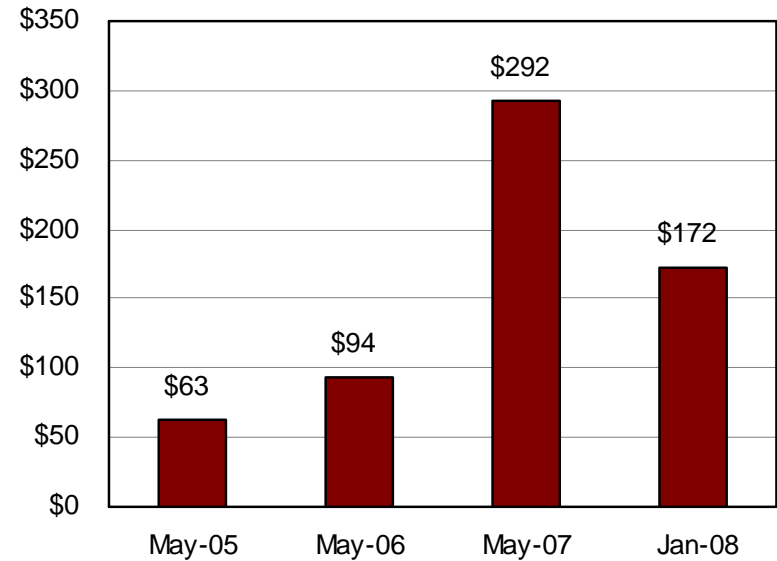


Sources: Environment Canada, National Inventory – Annex 9; CERI Estimated Avoided GHG

Energy Sources Availability & Impact -- Nuclear



Uranium Production 2005



Uranium prices/kg – recent trends

Energy Sources Availability & Impact -- Nuclear

Issues

- Safety
- Proliferation
- Environment
- High Capital Cost
- Negative Public Perception

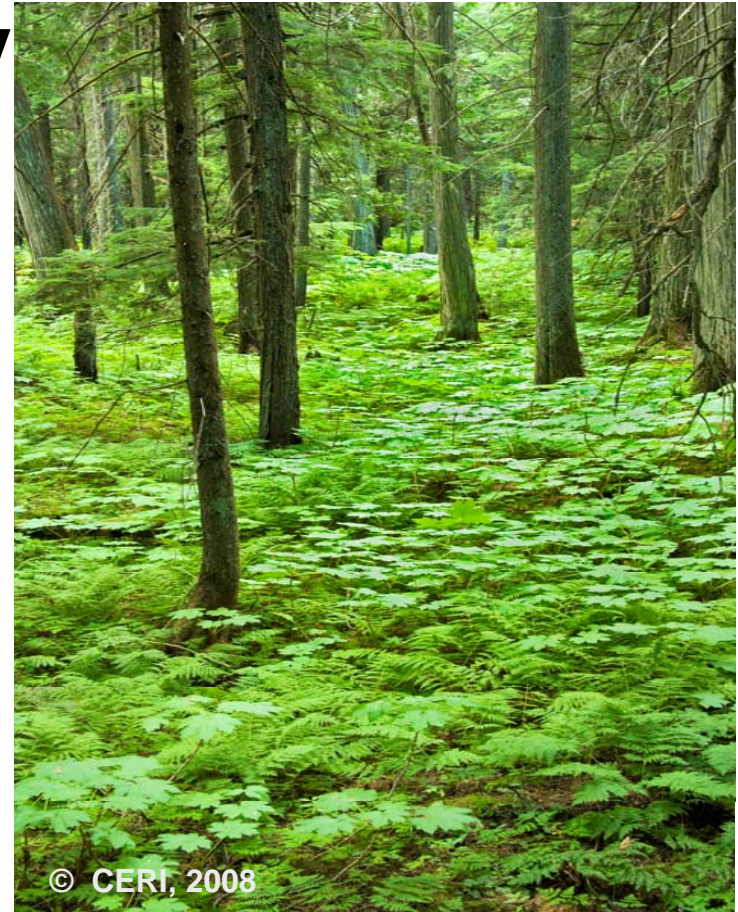
Potential

- Low GHG's

Energy Sources

Future Availability & Impact -- Biomass

- 10% of world's primary energy
- 22% of developing world's primary energy
- Plant-based biomass or Municipal solid waste
- Converts to a liquid
i.e. ethanol or biodiesel
- renewable



**If properly managed, biomass need not make
a net contribution to GHG's**

Energy Sources

Future Availability & Impact -- Wind



© CERI, 2008

- Emissions-free operations
- Costs high but falling
- Technology improving
- High theoretical capacity but location-dependent
- Transmission
- System integration

Energy Sources

Future Availability & Impact -- Solar

Photovoltaic Solar Power

- Capture sunlight energy and convert to electricity
- Efficiency improving
- Costs falling
- Emissions-free operations



Energy Sources

Future Availability & Impact -- Geothermal

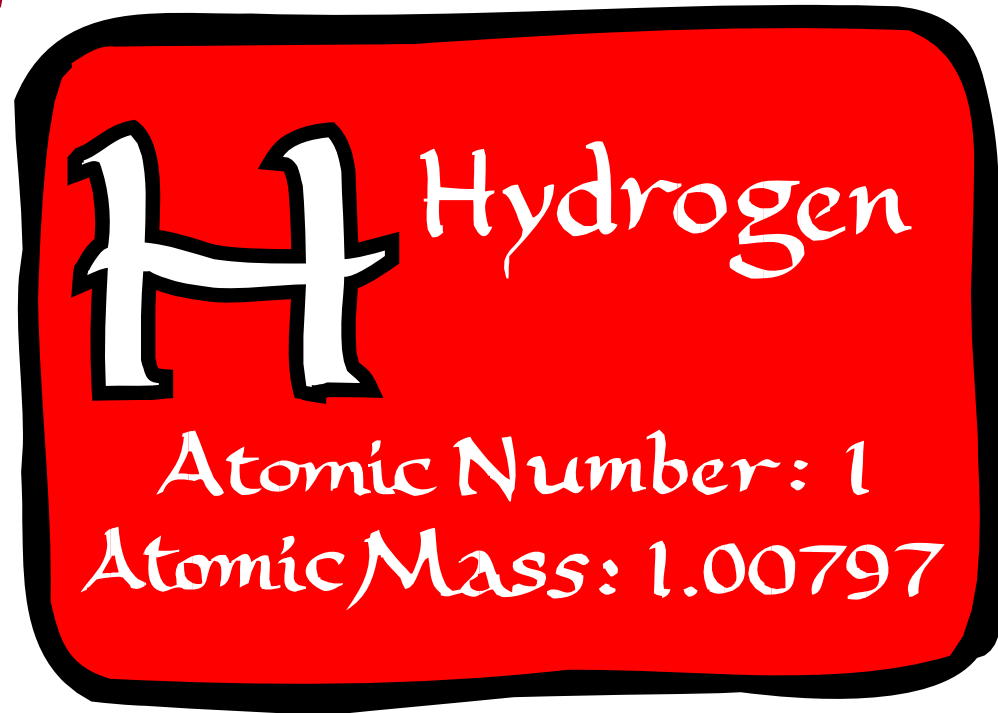


- Highly efficient – between 50-70%
- Competitive cost
- Resources in 80 countries worldwide
- Low accessibility

Energy Sources Future Availability & Impact -- Hydrogen

“My personal opinion is that we are at **the peak of the oil age** and at the same time **the beginning of the hydrogen age**. Anything else is an interim solution in my view...”

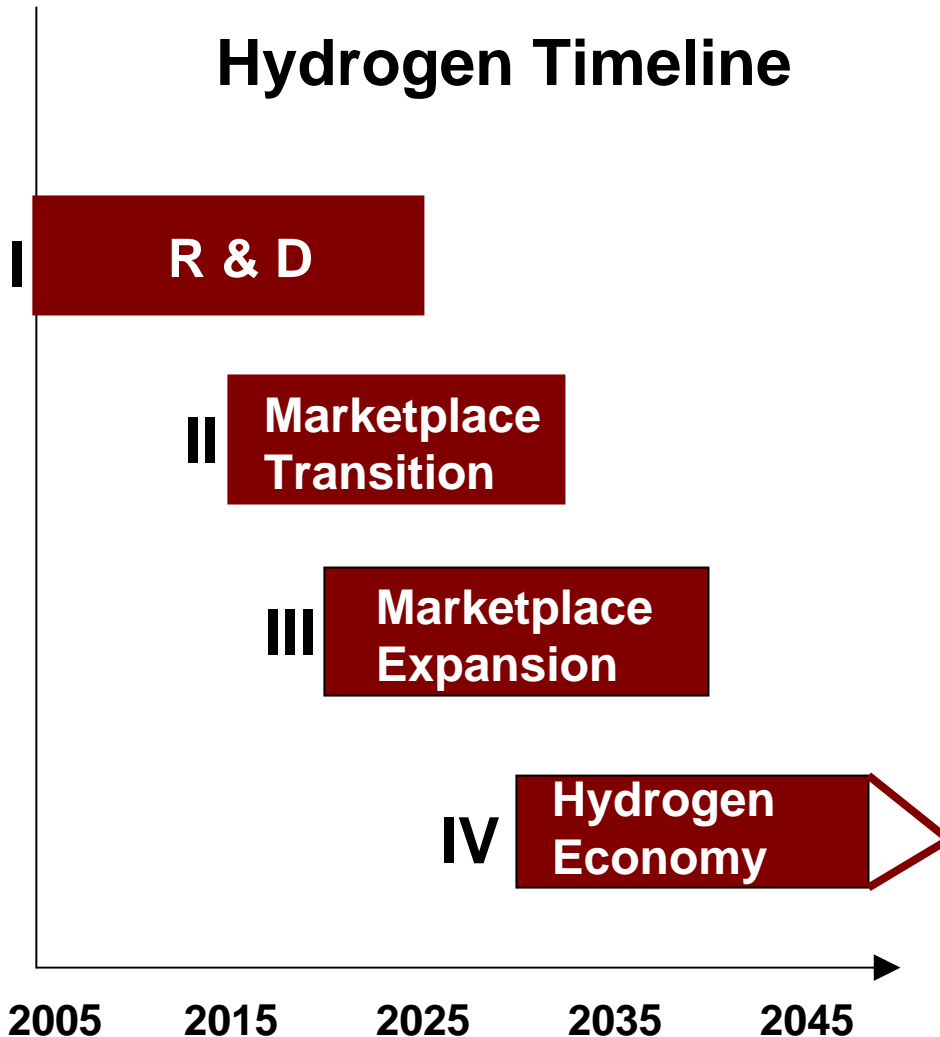
**Herman Kuipers,
Business Team Manager,
Innovation & Research,
Shell Global Solutions,
21 Nov. 2000.**



Energy Sources

Future Availability & Impact -- Hydrogen

Hydrogen Timeline

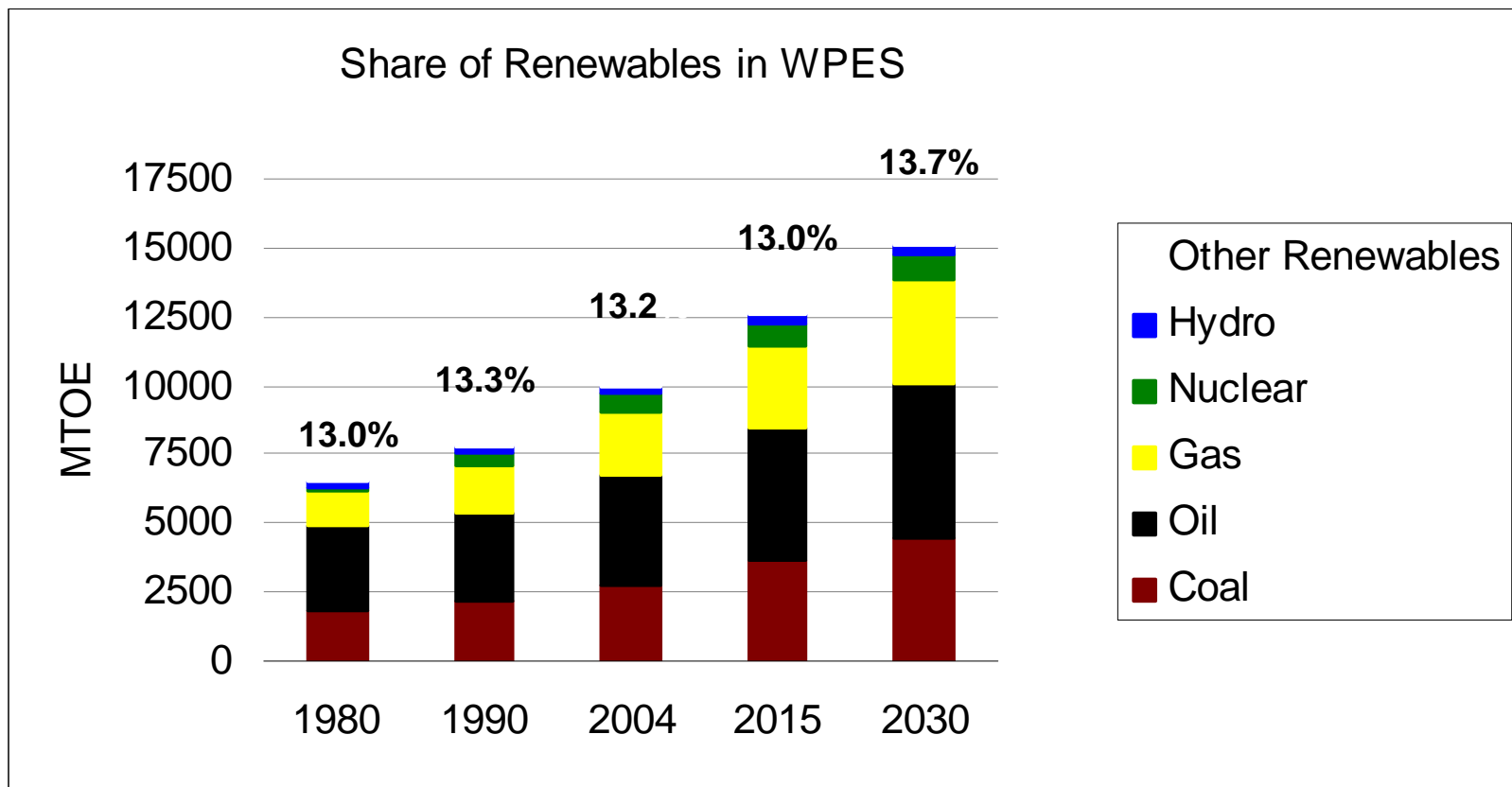


- The “forever fuel”
- Abundantly available in hydrocarbons & water
- Produces no CO₂ when burned

Source: US Dept. of Energy “Hydrogen Posture Plan, 2004”

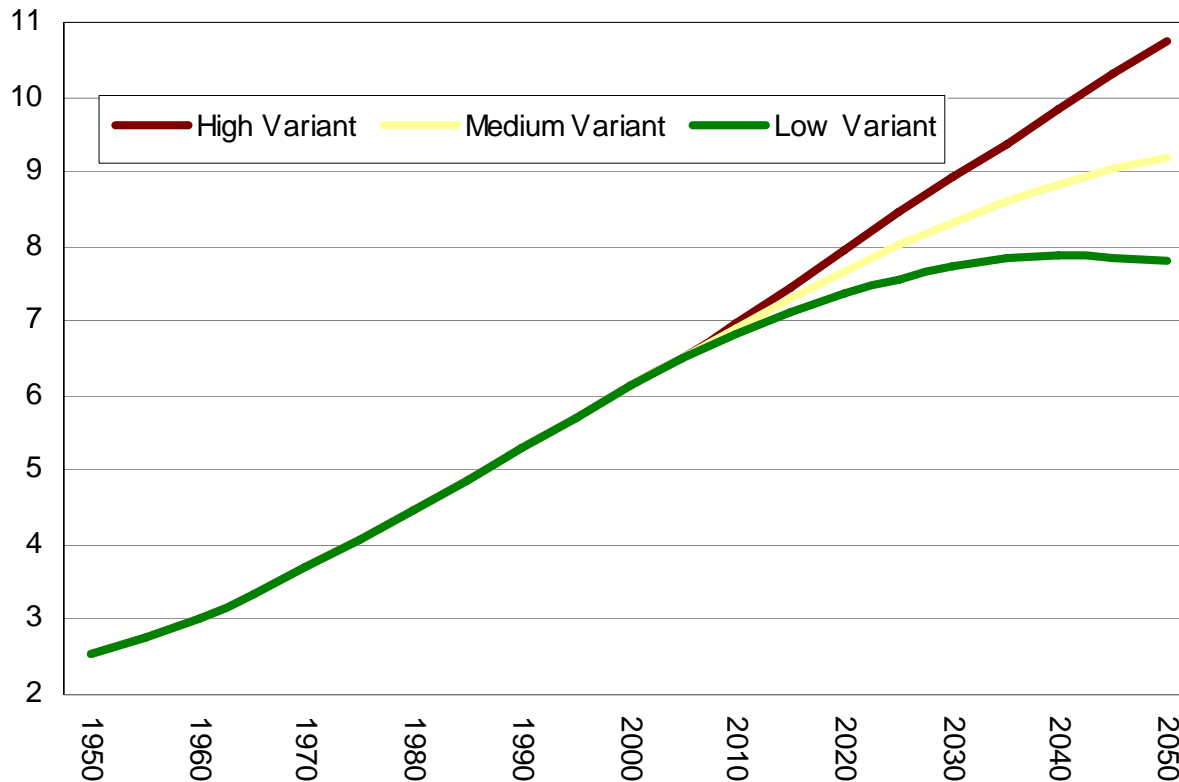
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World Primary Energy Supply 1980-2030



Source: IEA, *World Energy Outlook, 2006*

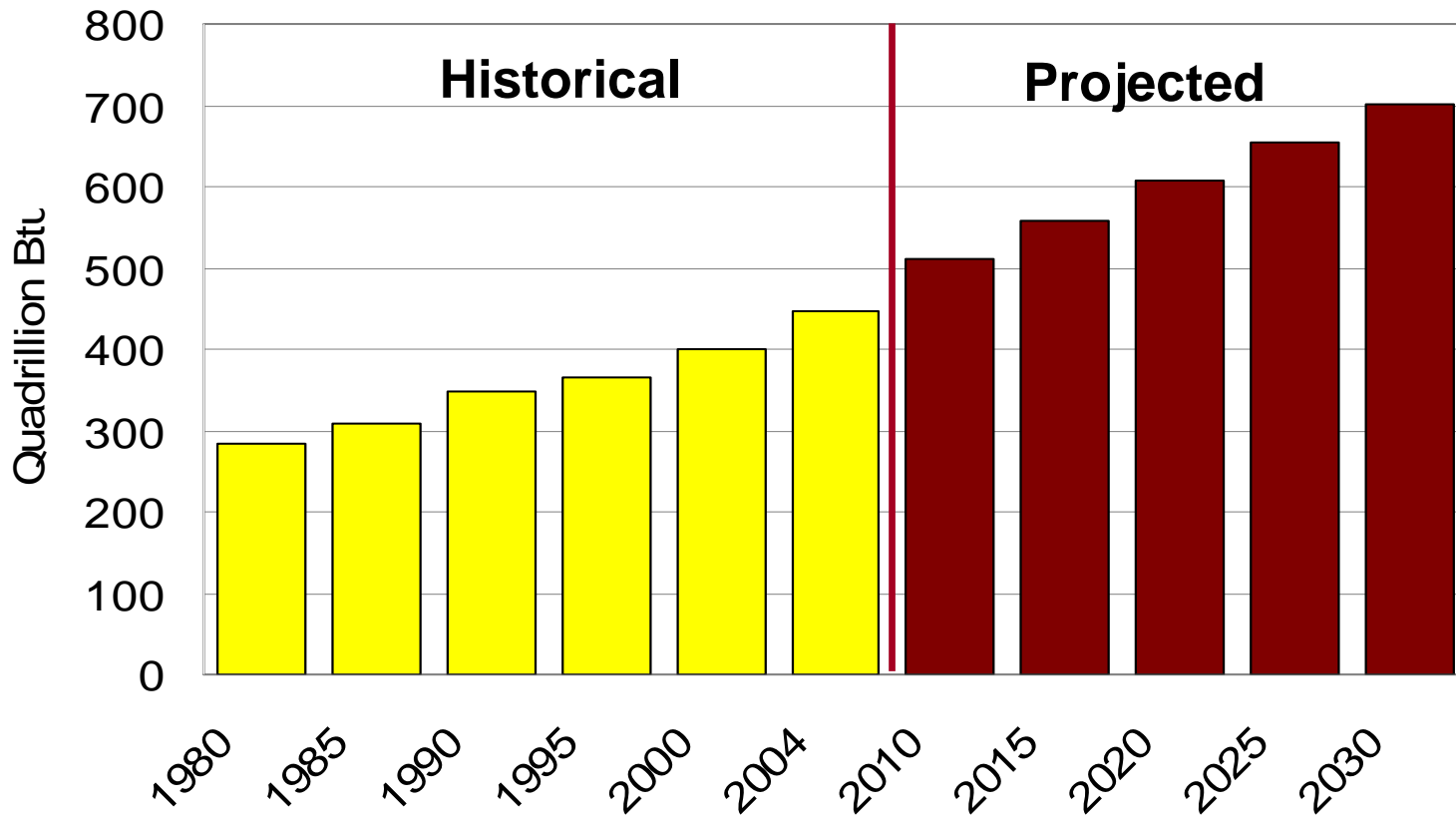
World Population 1950-2050 (billions)



Source: UN Population Division, *World Population Prospects: The 2006 Revision*

World Marketed Energy Consumption 1980-2030

Business as Usual Scenario



Sources: History: EIA *International Energy Annual 2004*.

Projections: EIA *System for the Analysis of Global Energy Markets (2007)*

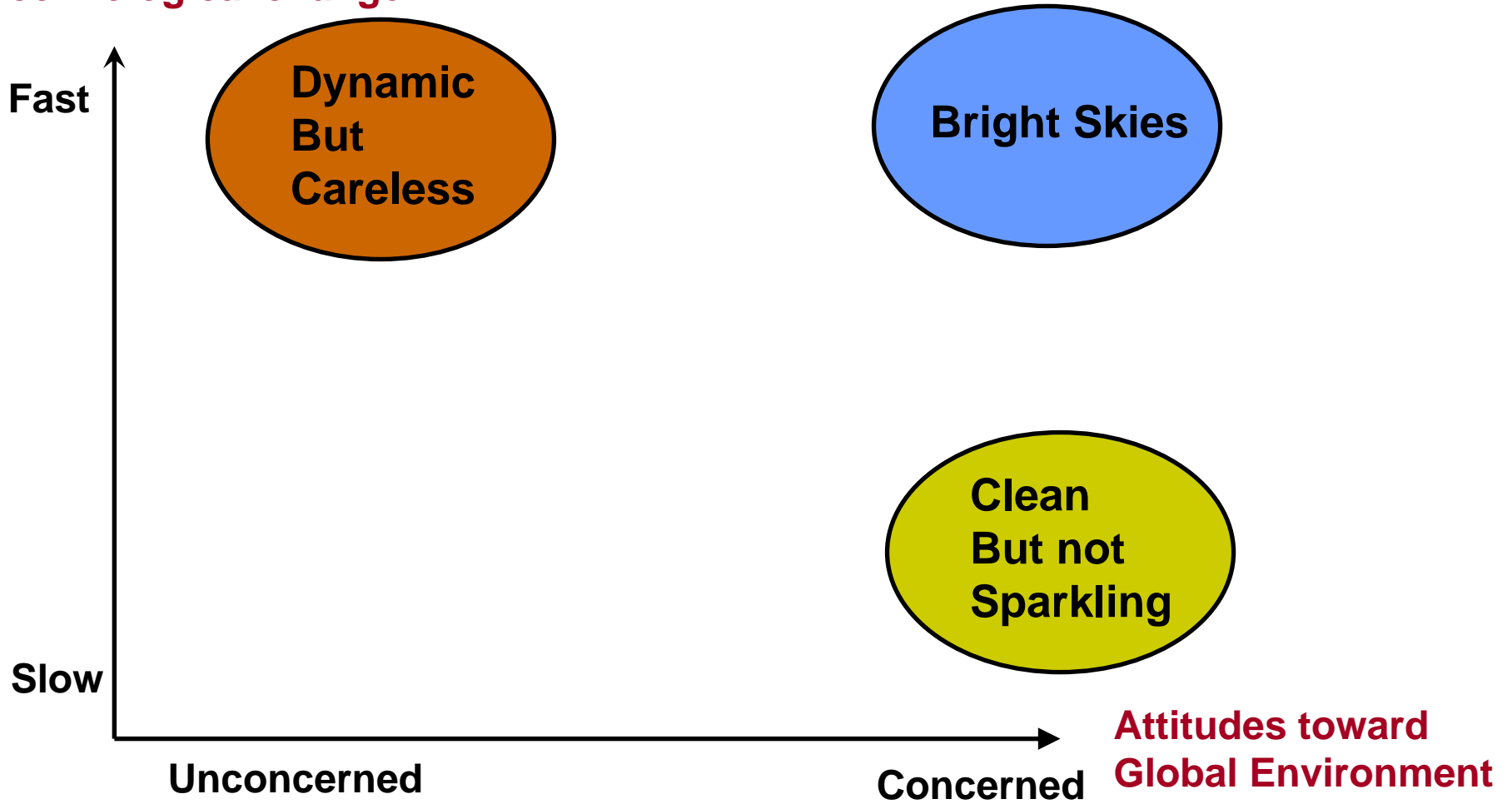
Business as Usual Scenario

- Hydrocarbons continue to dominate
- Energy efficiency improves in developed world
- Developing world uses cheap, available hydrocarbon fuels, accepting emissions
- Continues for 30-50 years despite increasing environmental considerations

1. **Clean**, but not sparkling
2. **Dynamic**, but careless
3. **Bright Skies**

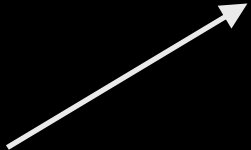
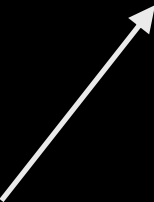

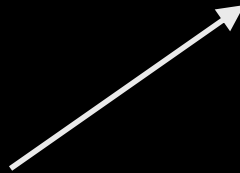

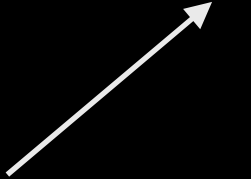

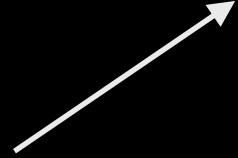

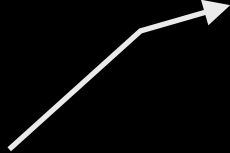
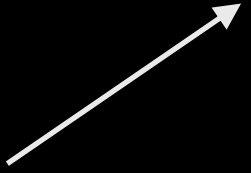
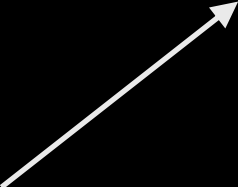

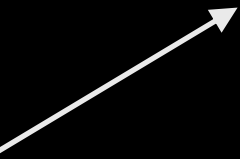

IEA Three Exploratory Scenarios (2003)

Technological change



Source: IEA, *Energy to 2050: Scenarios for a Sustainable Future*. Paris, 2003.

Implications of IEA's 3 Scenarios (2003)

	Technological Change	Concern for Environment	Growth	Security	Emissions
Clean But not Sparkling					
Dynamic But Careless					
Bright Skies					

Source: IEA, *Energy to 2050: Scenarios for a Sustainable Future*. Paris, 2003.



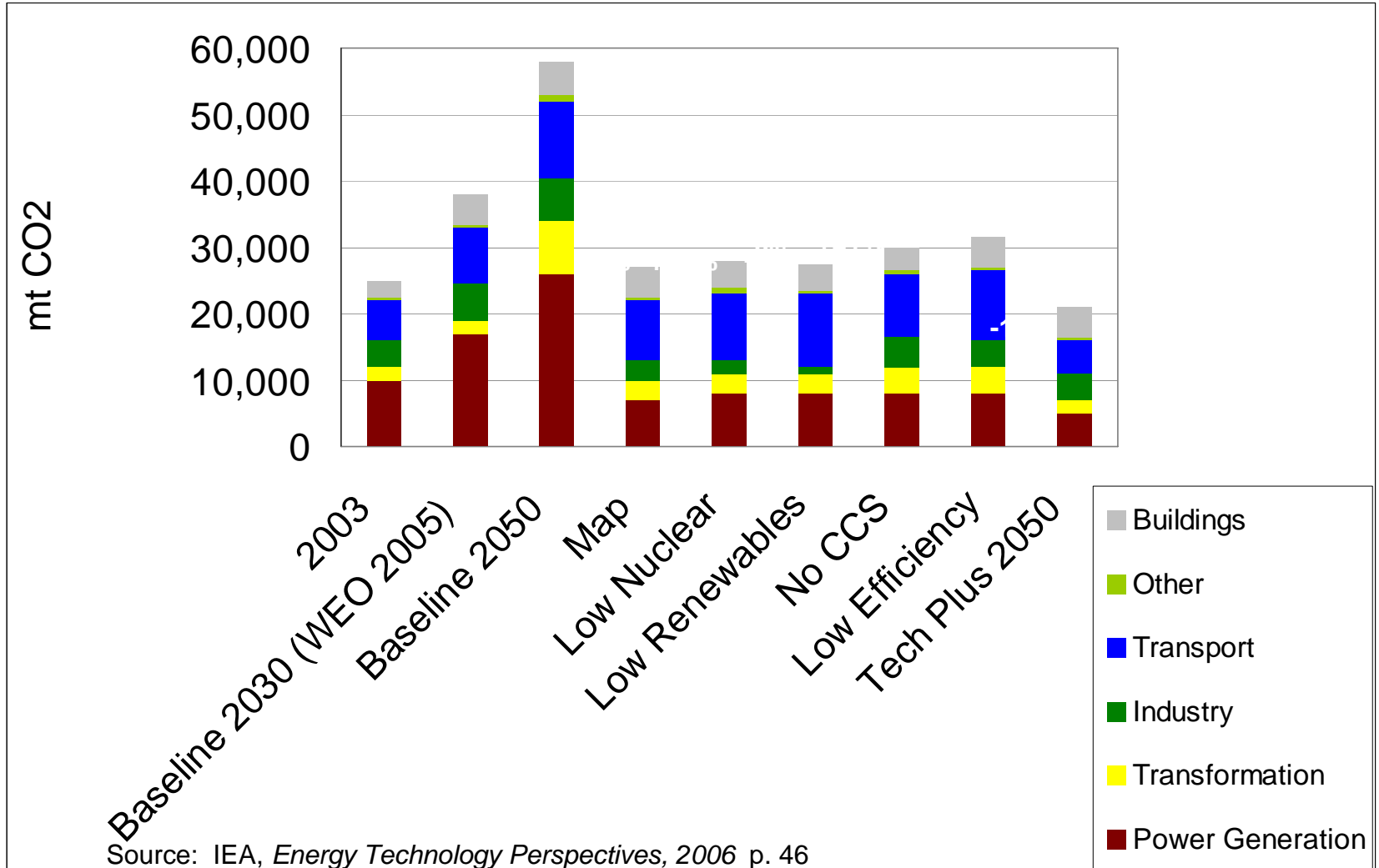
- Developed five new **Accelerated Technology (ACT)** scenarios
- Each focused on a technology that will usher in a more sustainable energy future

IEA Technology Assumptions (2006)

Scenario	Renewables	Nuclear	CCS	H ₂ fuel cells	Advanced Biofuels	End-use efficiency
ACT Map	Relatively optimistic across all technology areas					2.0% p.a. global improvement
ACT Low Renewables	Slower cost reductions					
ACT Low Nuclear	Lower public acceptance					
ACT No CCS	No CCS					
ACT Low Efficiency						1.7% p.a. global improvement
TECH Plus	Stronger cost Reductions	cost reductions & tech. improvements		Breakthrough for fuel cells	Strong cost reductions & improved feedstock availability	

Global CO₂ Emissions in IEA's Baseline, ACT, & TECH Plus Scenarios

Act Scenarios 2050

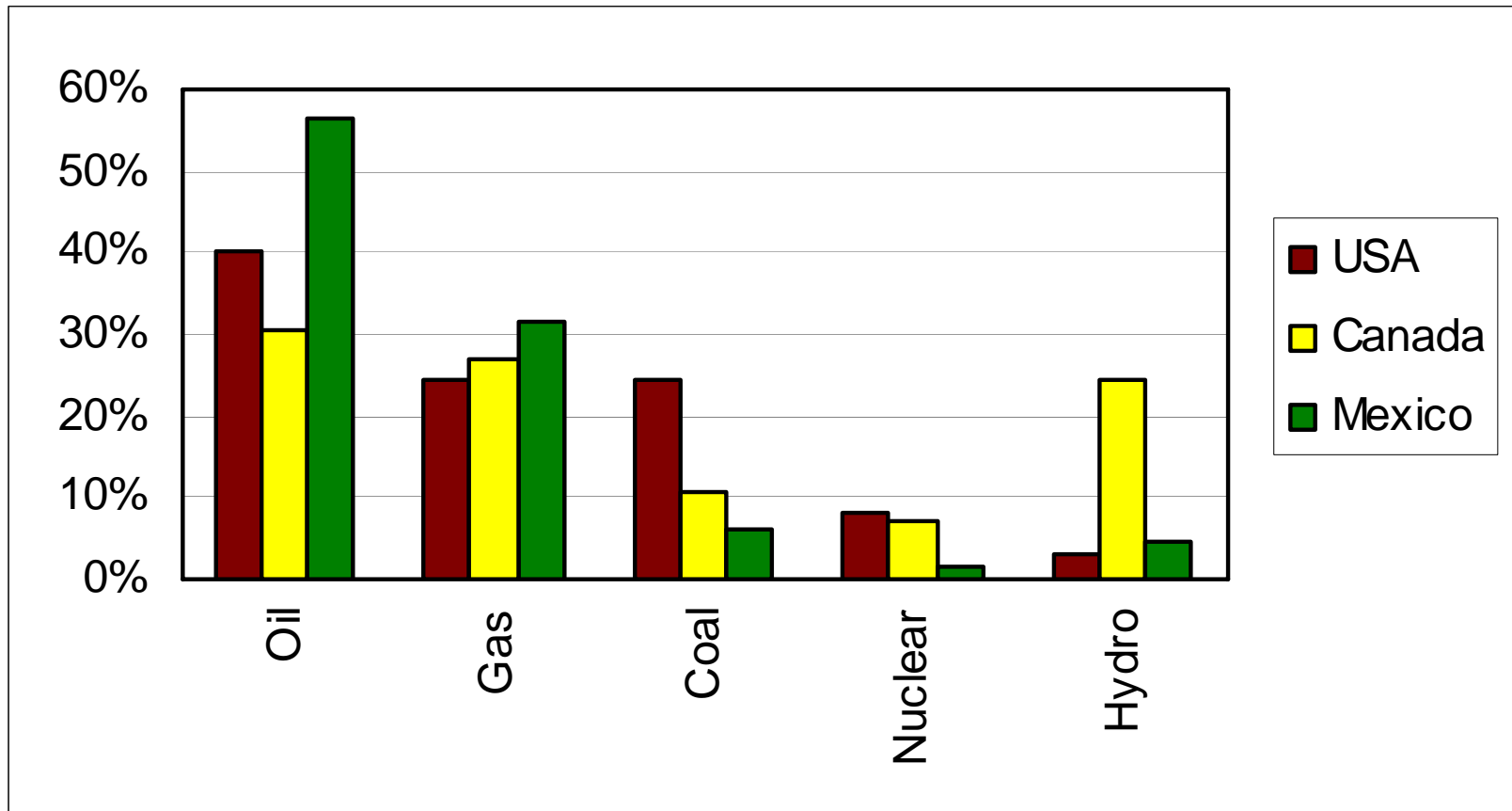


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3 Main Themes

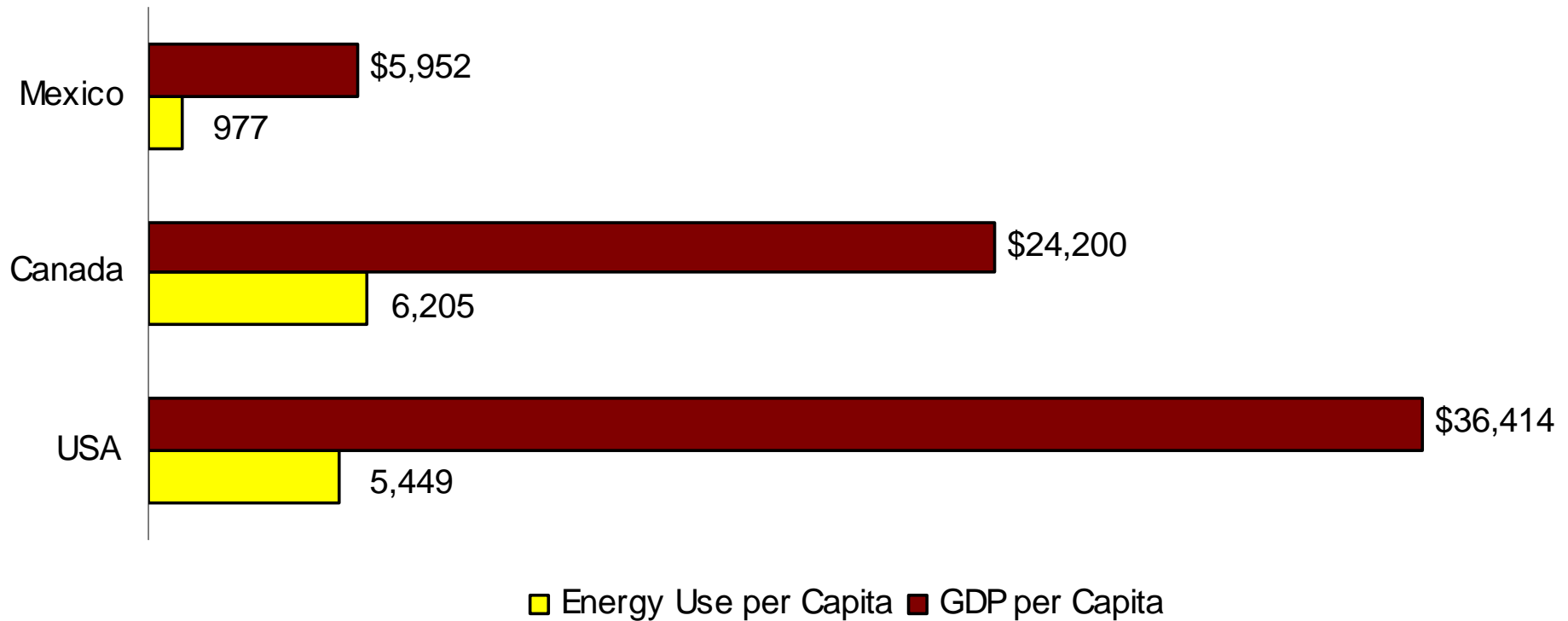
1. **Growing Demand & Security of Supply**
2. **High & Volatile Energy Prices**
3. **Achieving Sustainability**

North America Primary Energy Consumption by Fuel, 2006



Source: BP, *Statistical Review of World Energy 2007*

North America Energy Use and GDP

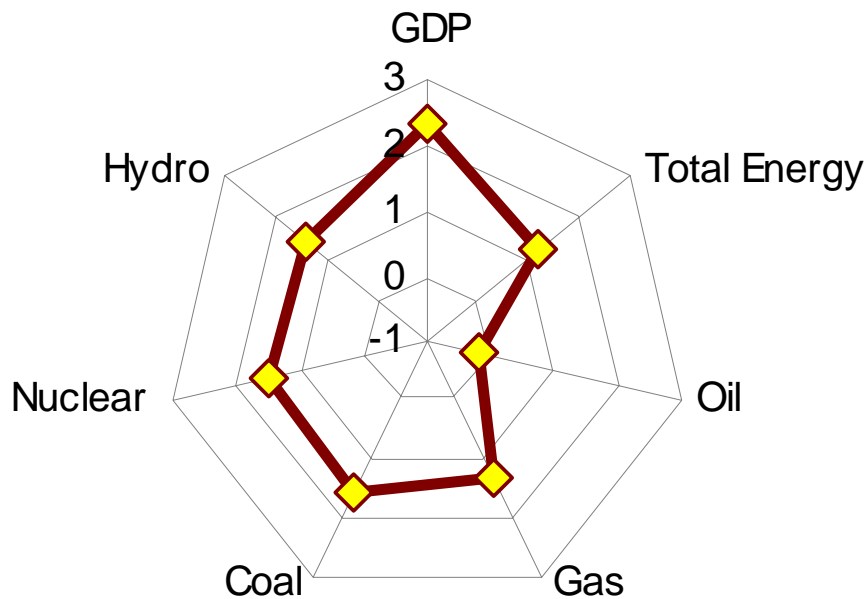


SOURCE: IEA/OECD, *Energy Balances of OECD Countries*, 2006.

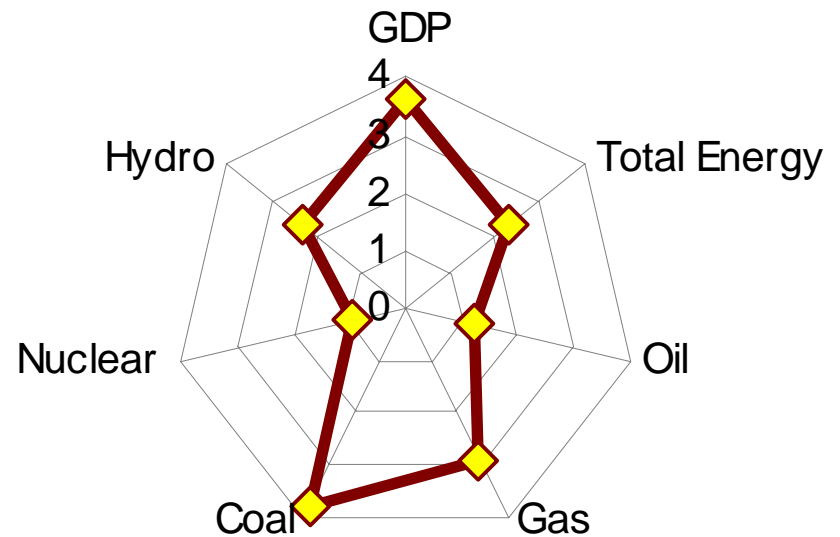


North America Energy Use and GDP Estimates (Average Annual Percentage Growth) 2004-2030

Canada



Mexico

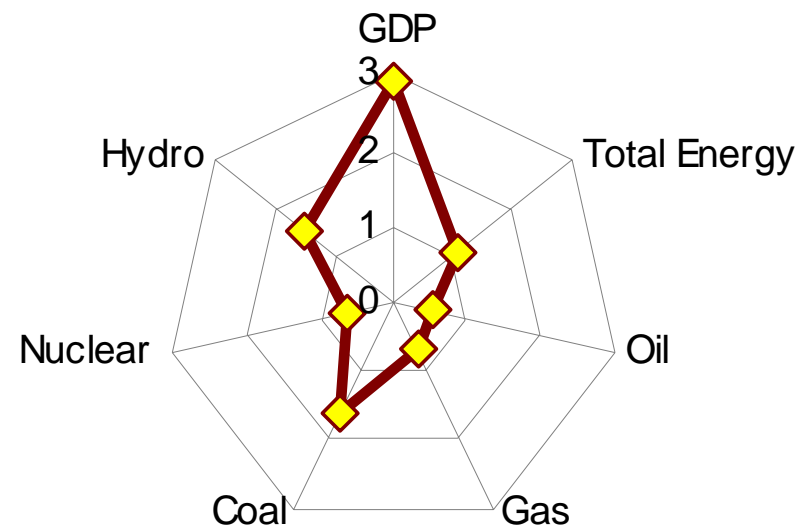
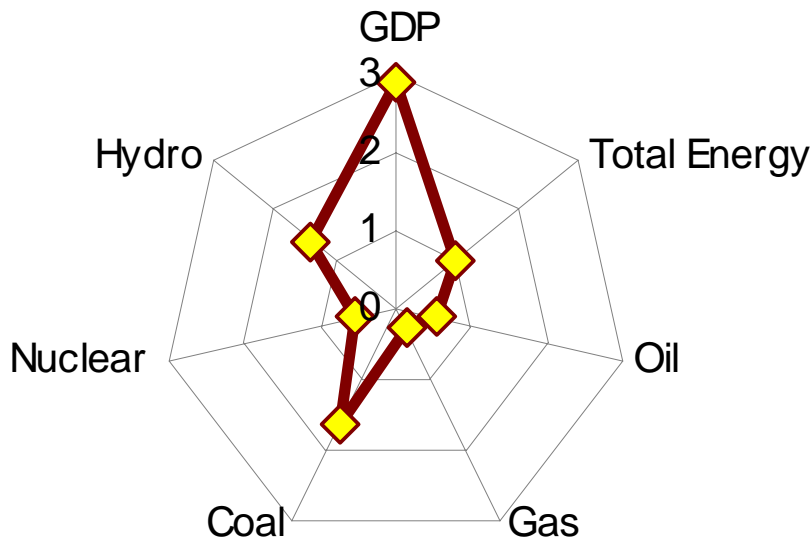


Source: EIA, *International Energy Outlook 2007*, Appendix A

North America Energy Use and GDP Estimates (Average Annual Percentage Growth) 2004-2030

United States

North America



Source: EIA, *International Energy Outlook 2007*, Appendix A

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