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Challenges of a sustainable energy future:
What role for nuclear?

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Nuclear Power in Society- Finding the Balance
Council for Clean and Reliable Electricity
Hampton Inn Conference Centre
Ottawa, ON
Oct 26, 2009

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World at Night

Lack of Affordable Energy: What does it mean?

Energy's link to human development:

- **Productivity**
- **National Income**
- **Health**
- **Education**
- **Social Development**

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World at Night

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Enhanced Well Being
Life Expectancy: 80 yrs

10^4

IMPROVED LIFE QUALITY
Life Expectancy: 60 yrs

10^3

BASIC QUALITY OF LIFE
Life Expectancy: 60 yrs

10^2

SURVIVAL
Life Expectancy: 40 yrs

Annual
$GDP/Capita

Annual
kWh/capita

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Population Growth, Energy, Income

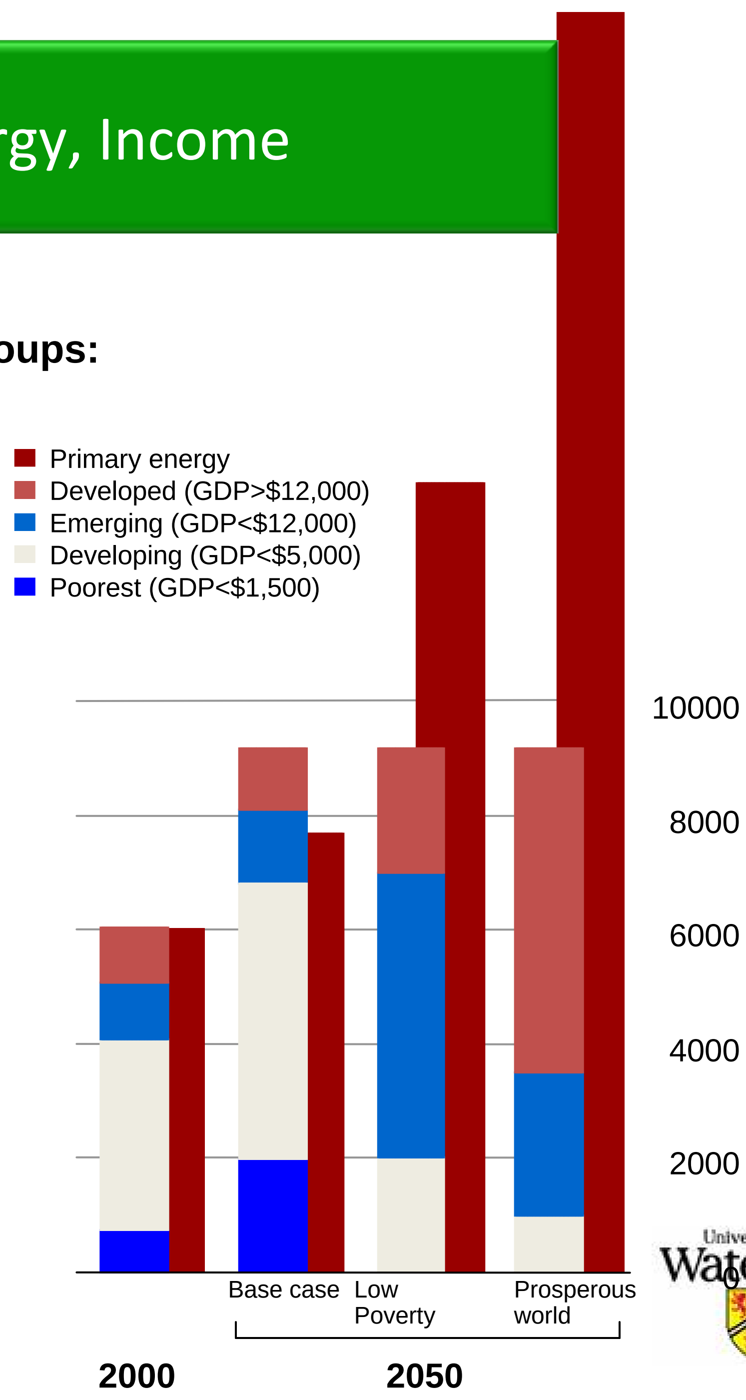
Global population divided into income groups:

- **Poorest (GDP < $1,500)**
- **Developing (GDP < $5,000)**
- **Emerging (GDP < $12,000)**
- **Developed (GDP > $12,000)**

Population expected to rise to 9 billion by 2050, mainly in poorest and developing countries.

Shifting the development profile to a "low poverty" world means energy needs double by 2050

Shifting the development profile further to a "developed" world means energy needs triple by 2050



Source: WBCSD adaptation of IEA 2003

Source: WBCSD 2007

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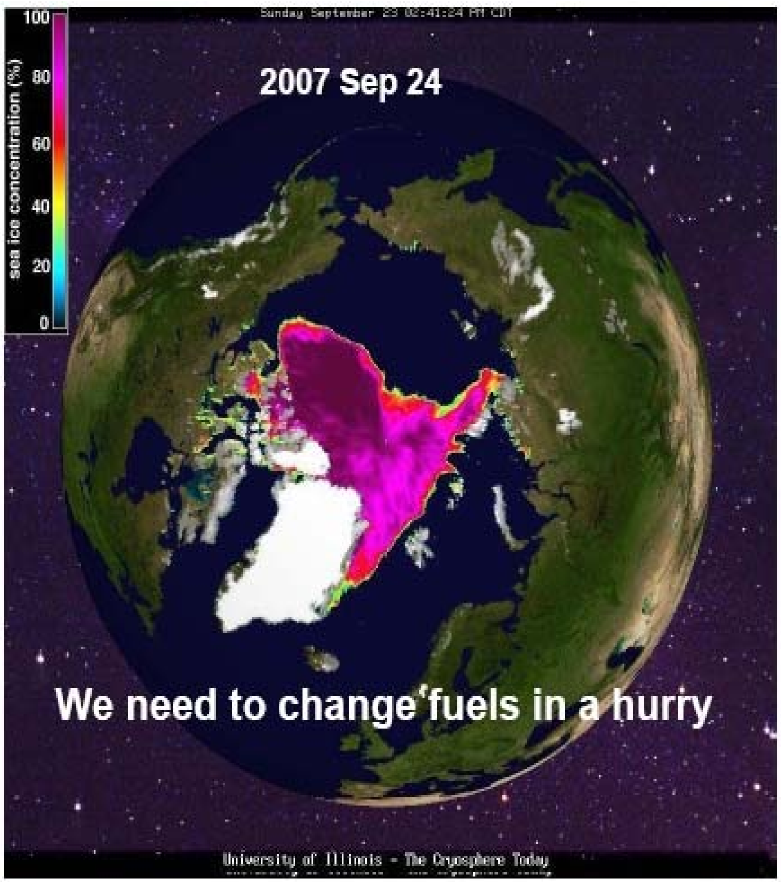
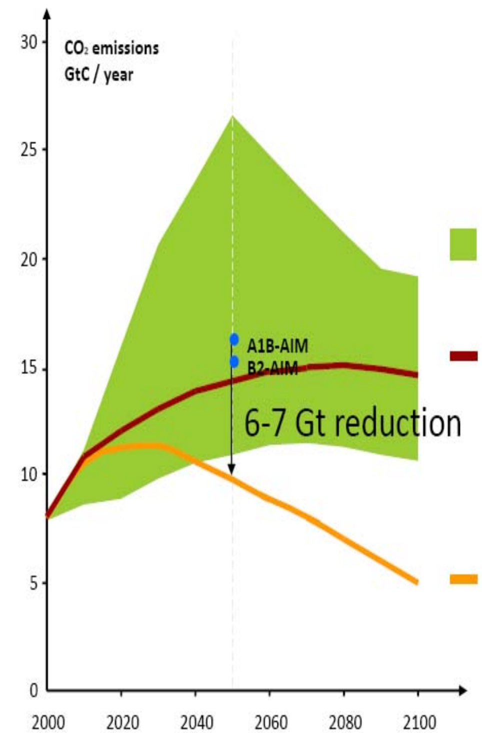
The global challenge: how to de-carbonize



Achieving a lower CO_2 stabilization



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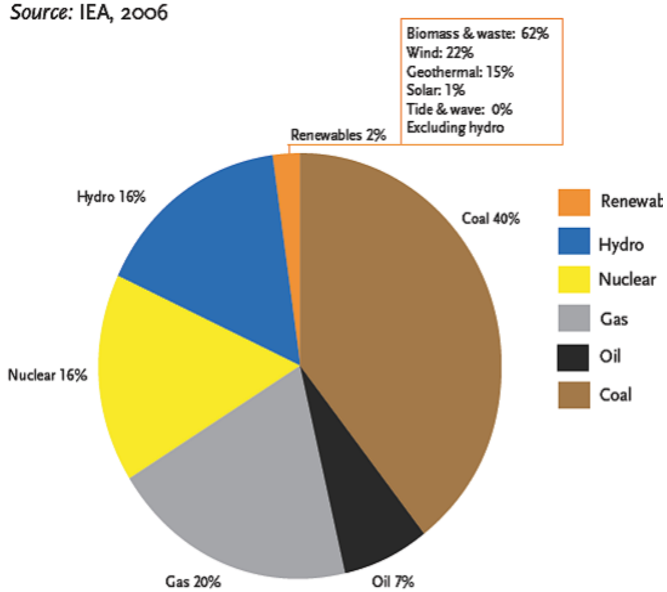
Nuclear share in primary energy and electricity

Source: IEA, 2006



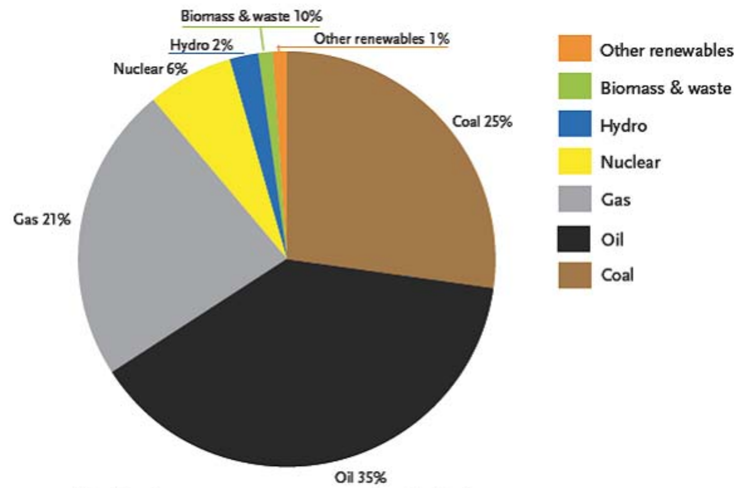


Figure 1.3 World primary energy consumption by fuel, 2004

Note: Total world primary energy consumption in 2004 was 11,204 megatons oil equivalent (or 448 exajoules).

Figure 1.4 World electricity production by energy source, 2004

Note: Total world electricity production in 2004 was 17,408 terawatt-hou

Source: IEA, 2006.

Near Term View: Today and 2030

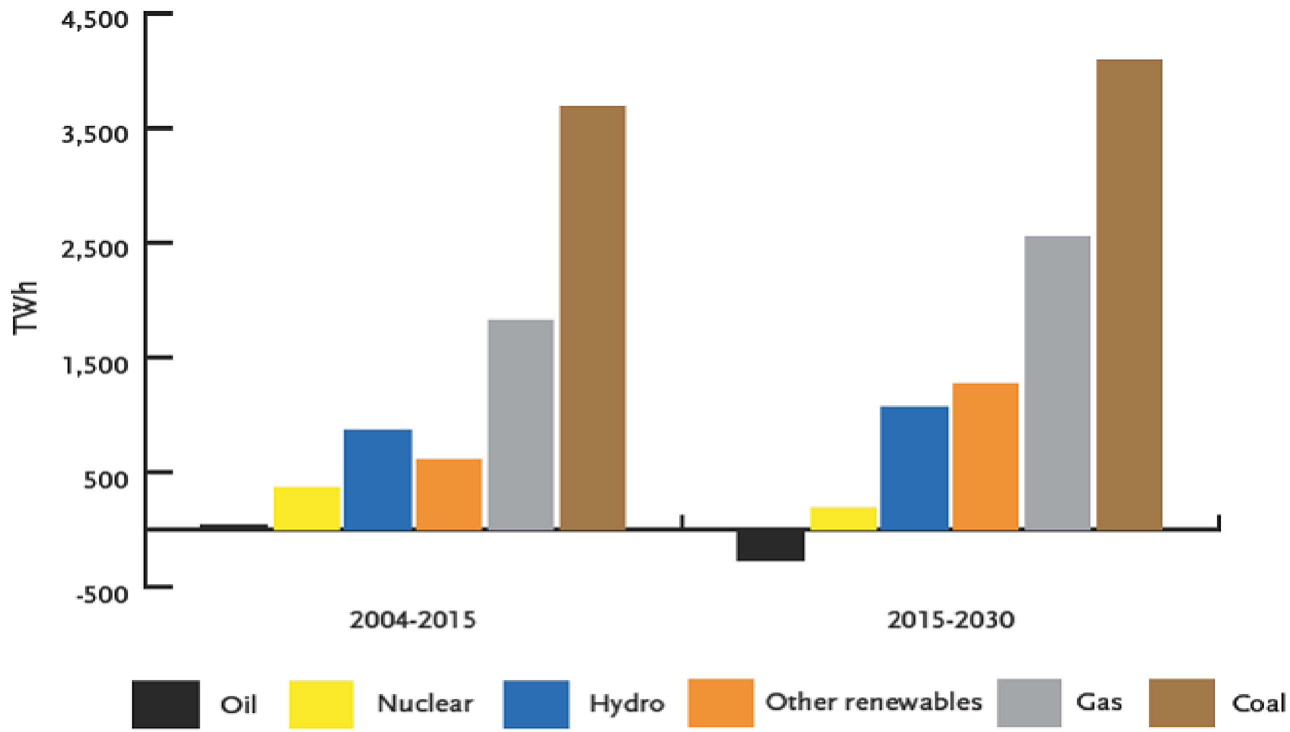


Figure 3.5 Projected world incremental electricity generation by fuel type

Note: 1 terawatt-hour (TWh) equals 3.6 petajoules.

Source: IEA, 2006

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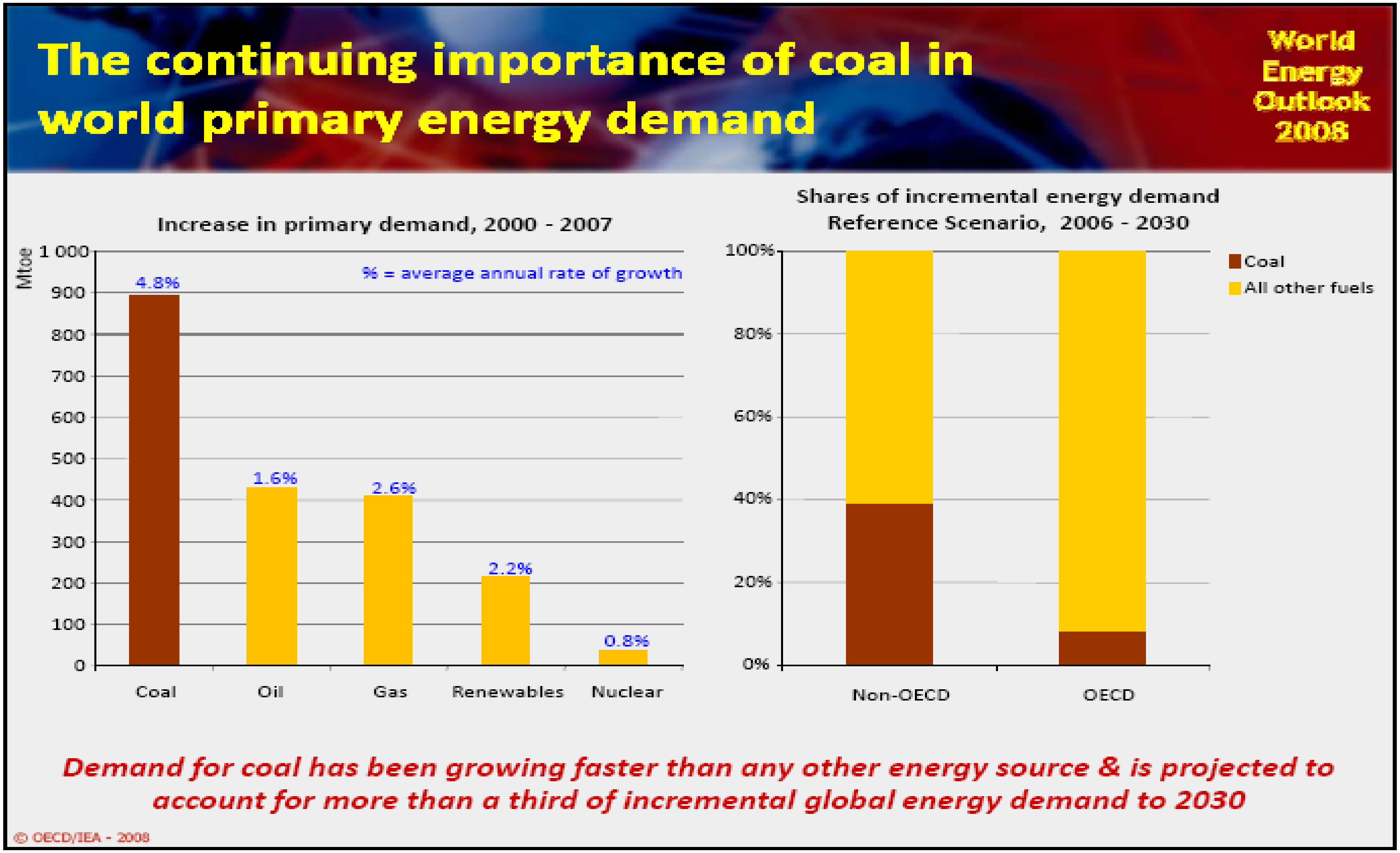
Coal in the global energy system



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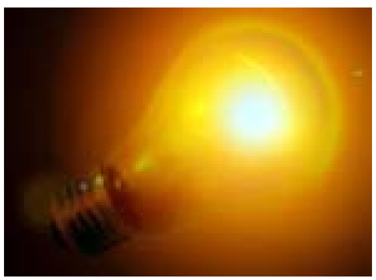
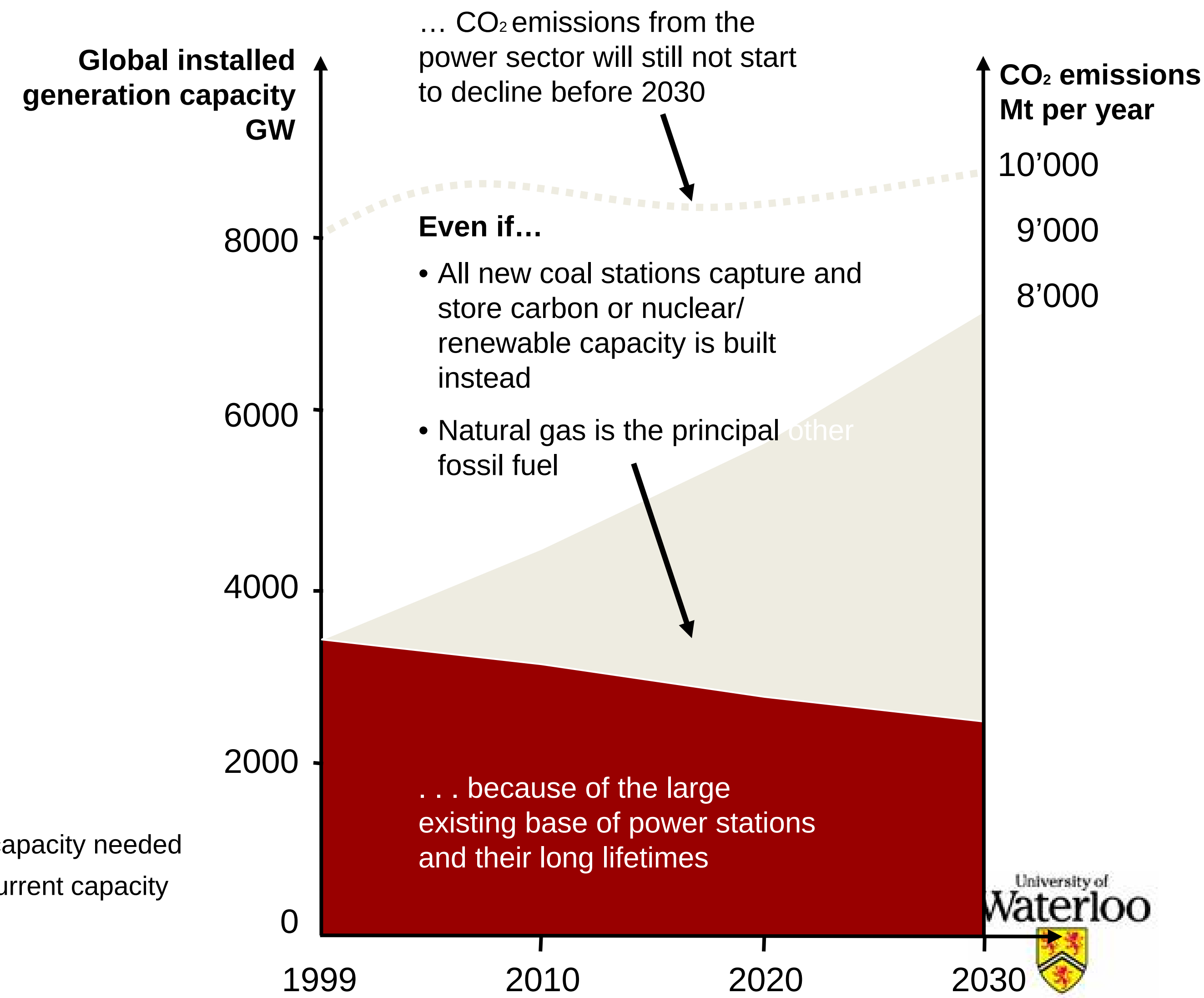
Alternate power generation technologies: Impact on emissions





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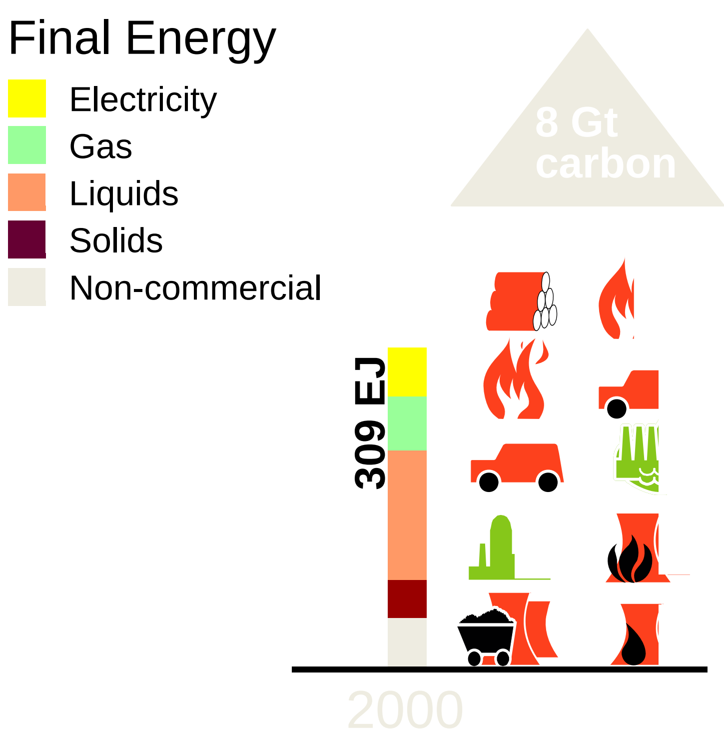
Today’s energy infrastructure



Direct burning of fuel	3-4 Gt
800 million vehicles	1+ Gt
700+ coal power stations	1.5 Gt
Non-commercial biomass	1 Gt
800 gas or oil power stations	0.7 Gt
Non emmitting technologies	0 Gt
	8.0 Gt

25EJ per year solar	500,000 5MW wind turbines	1000 1GW coal power stations	1000 1GW coal stations with sequestration	1000 1GW oil power stations	1000 1GW gas power stations	1000 1GW nuclear plants	1000 1GW hydro/ tidal /geothermal	500 million vehicles (Biofuels)	500 million low CO_2 (Biofuels)	50EJ non-commercial fuel	100 EJ direct fuel use (Biofuels)

Source: WBCSD 2007

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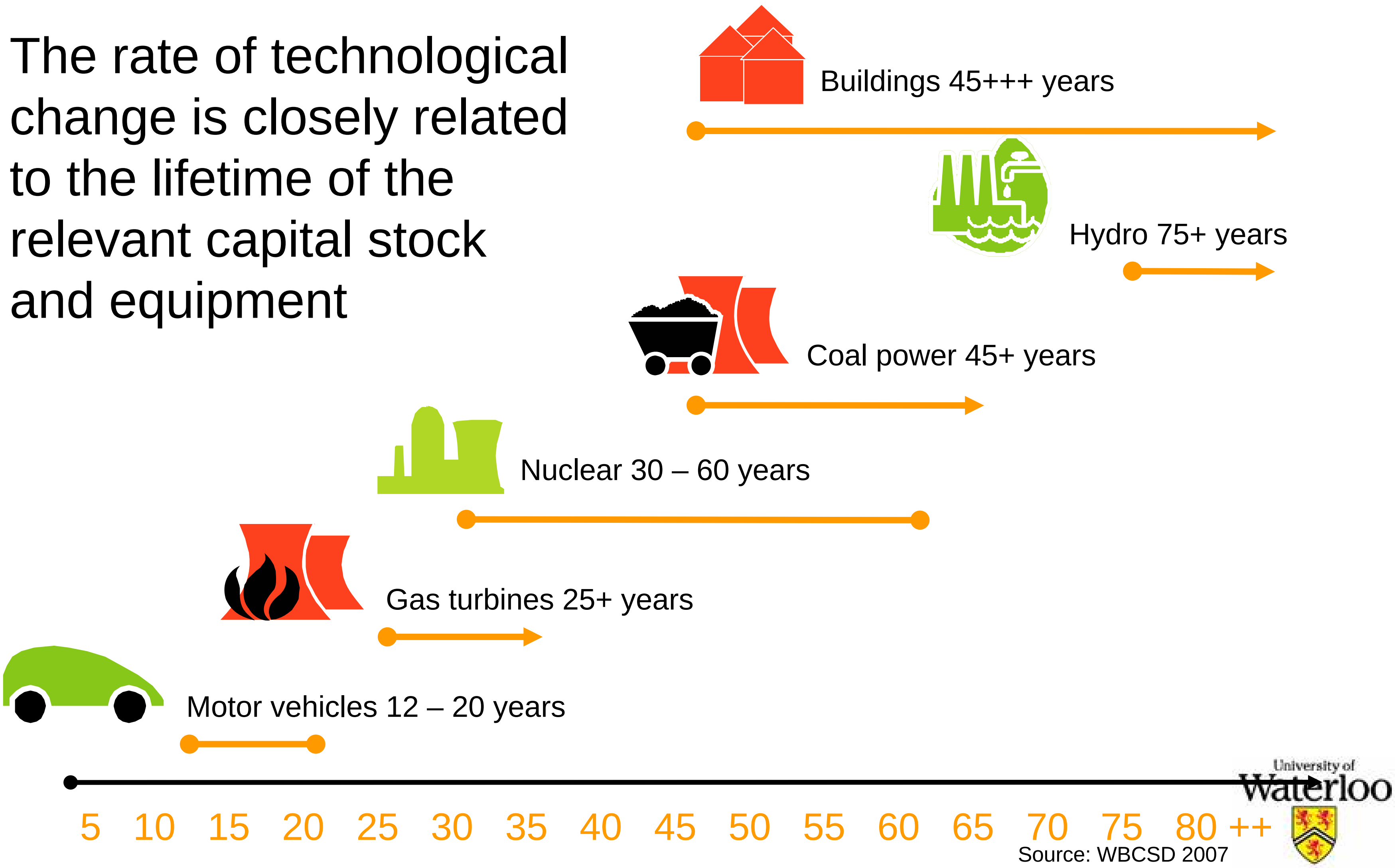
The lifetime of energy infrastructure

The rate of technological change is closely related to the lifetime of the relevant capital stock and equipment



Energy sector will be driven towards a quantifiable, long term pathway for reduced GHG emissions

if so

- ? **How do we get there**
- ? **What role for innovation**
- ? **What capacity for change**
- ? **What is the status of the infrastructure**
- ? **What are the governance and policy issues**

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One View

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Another View

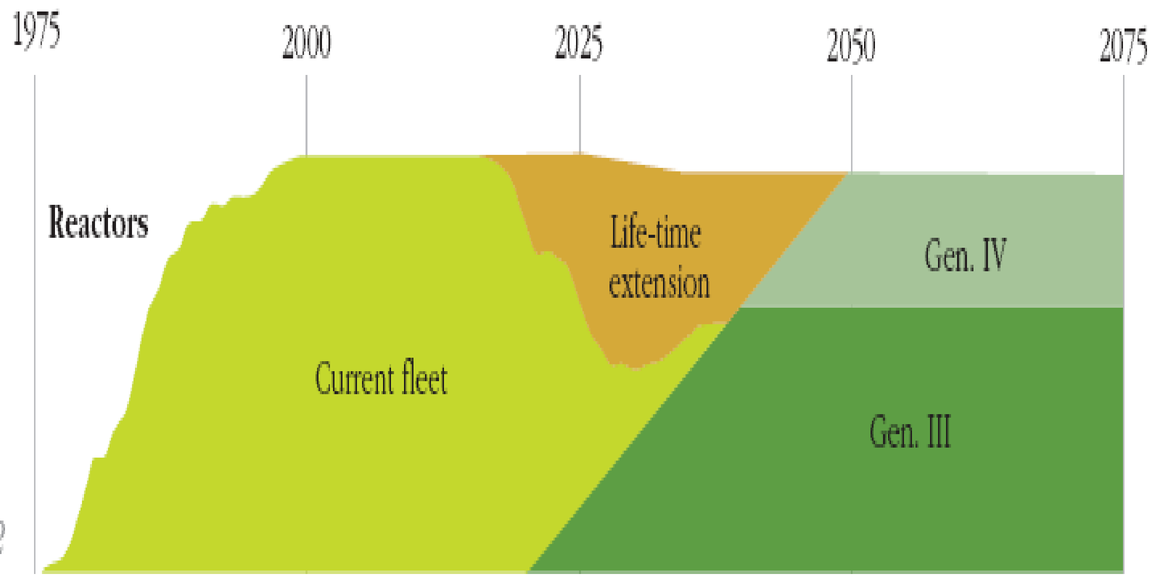
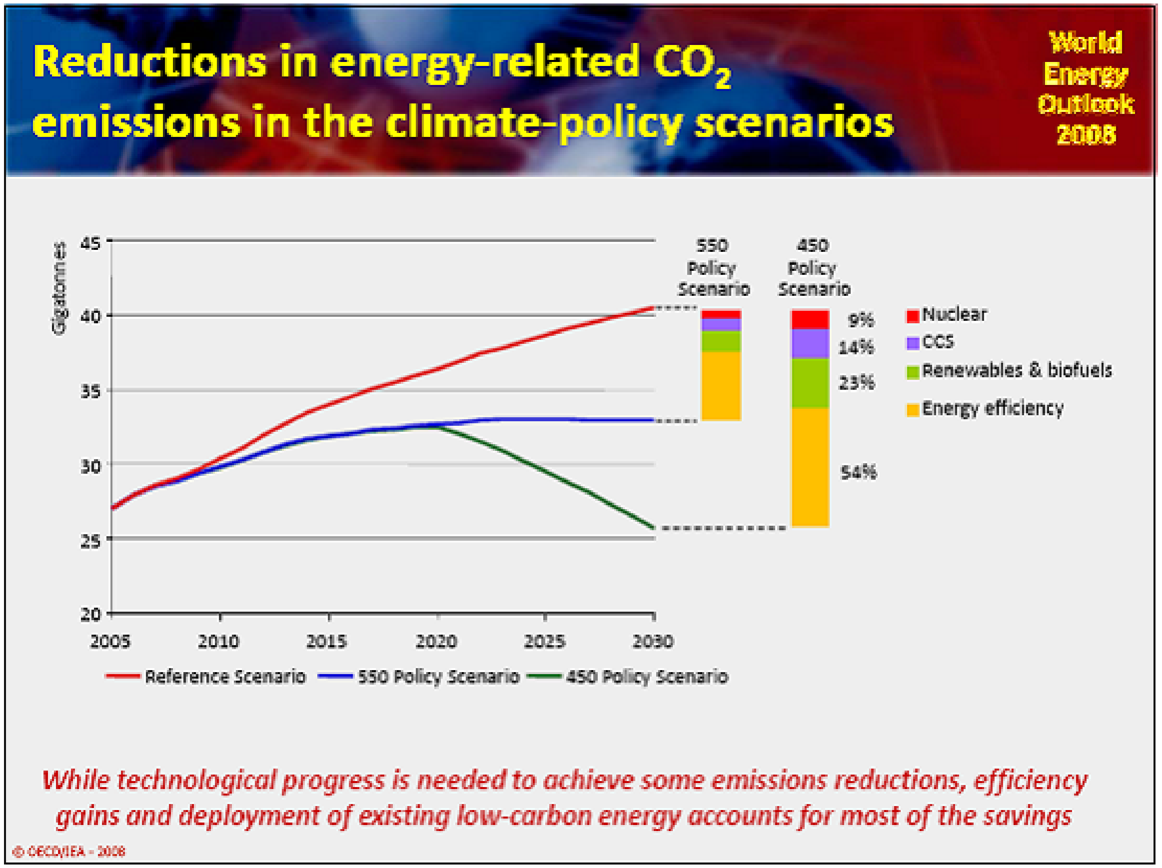


Fig. 12: Deployment of generation-III and -IV reactors in the 21st century

Source: EDF, ENC, 2002

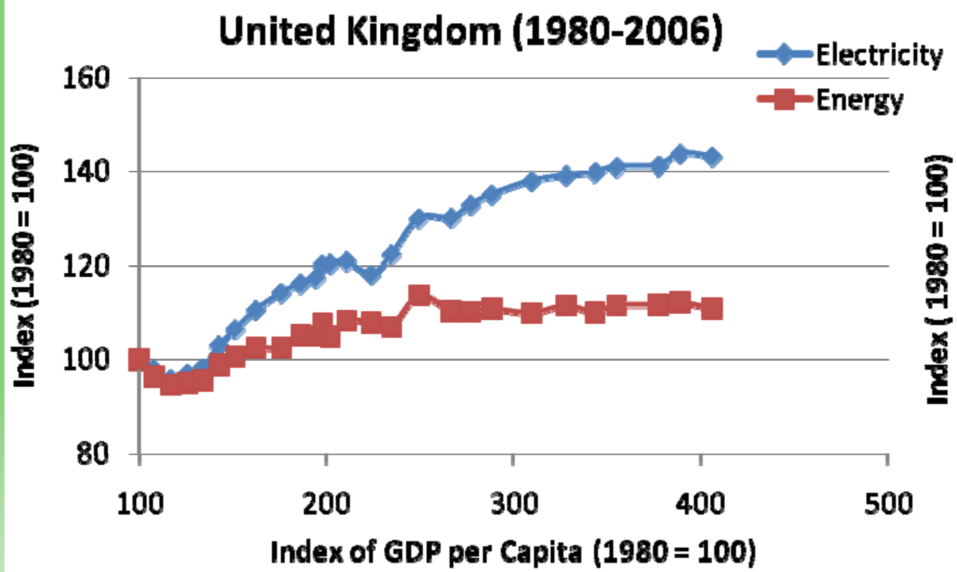
Moderate Steps, Moderate Results

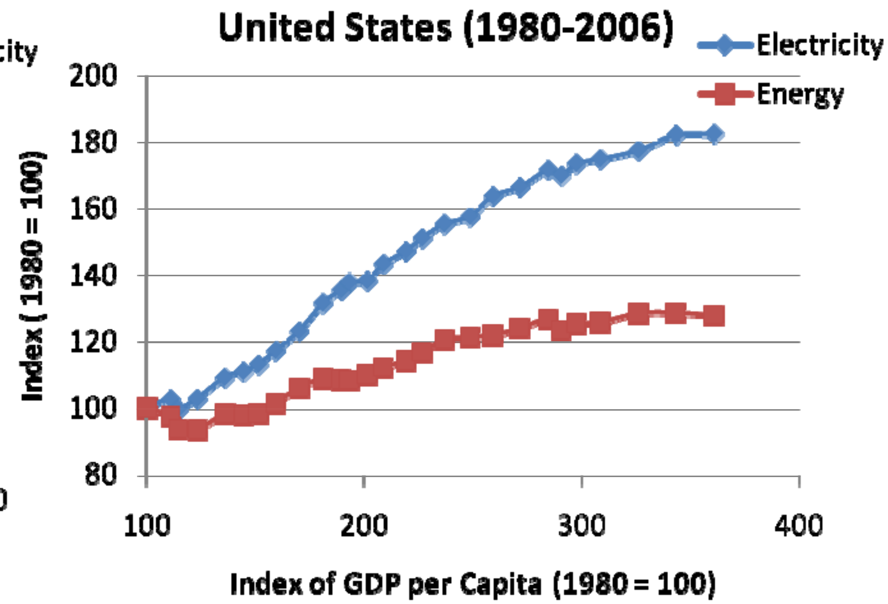


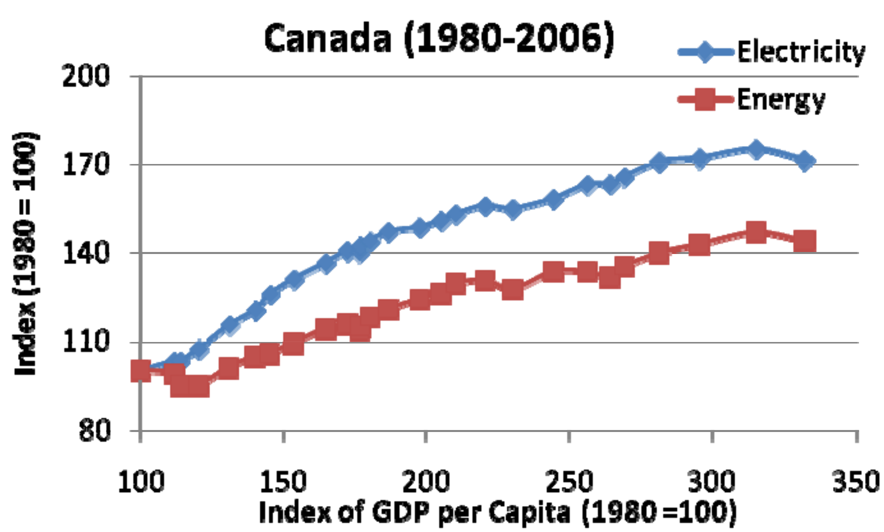
Electricity as vector of change:

A look at the contrast between energy and electricity

Electricity and Energy Contrast







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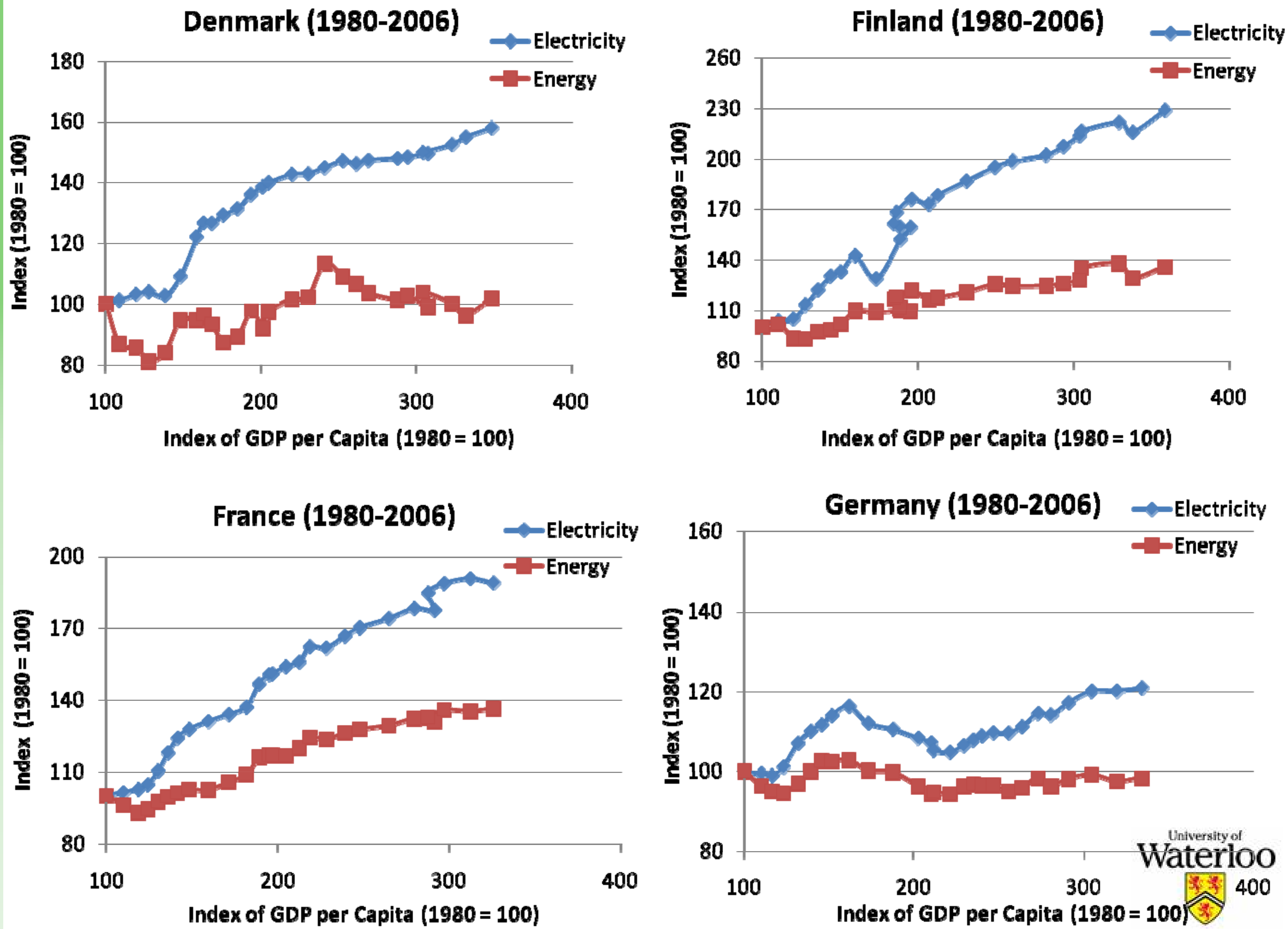
Electricity and Energy Contrast



Electricity and Energy Contrast

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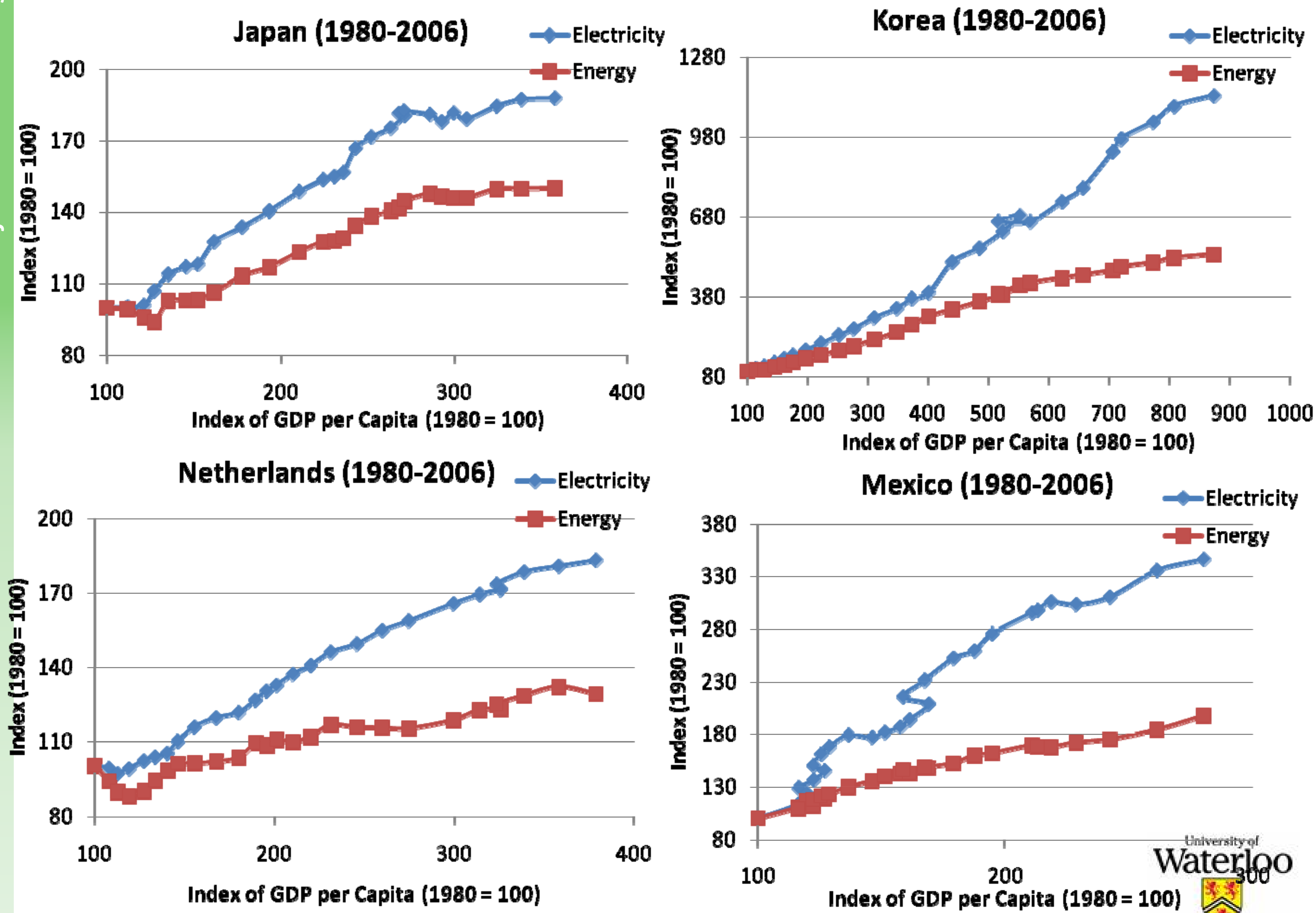

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Electricity and Energy Contrast

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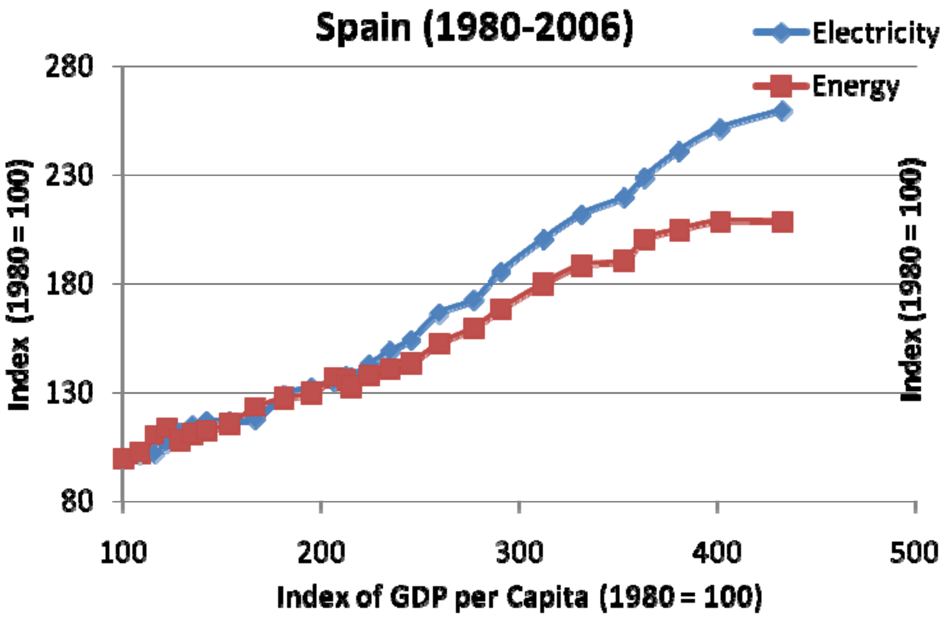

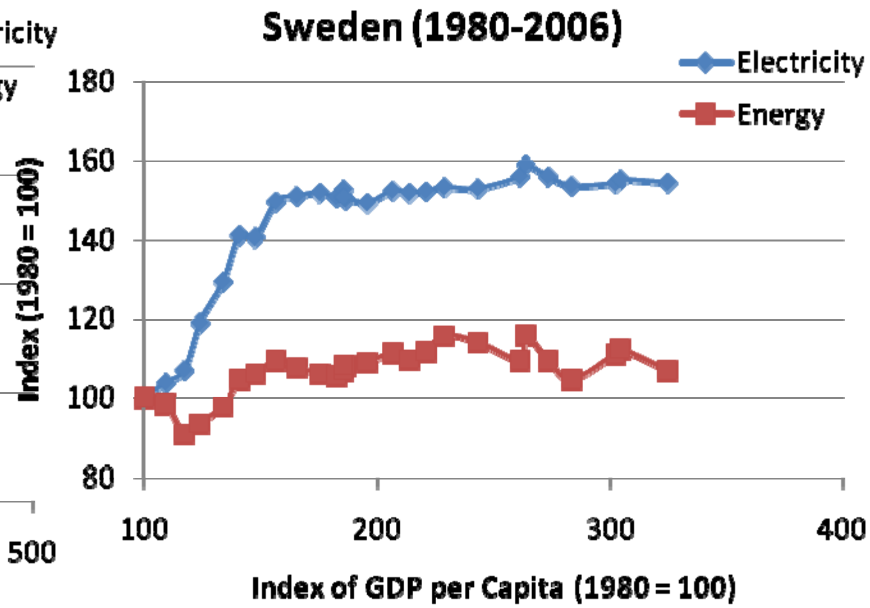

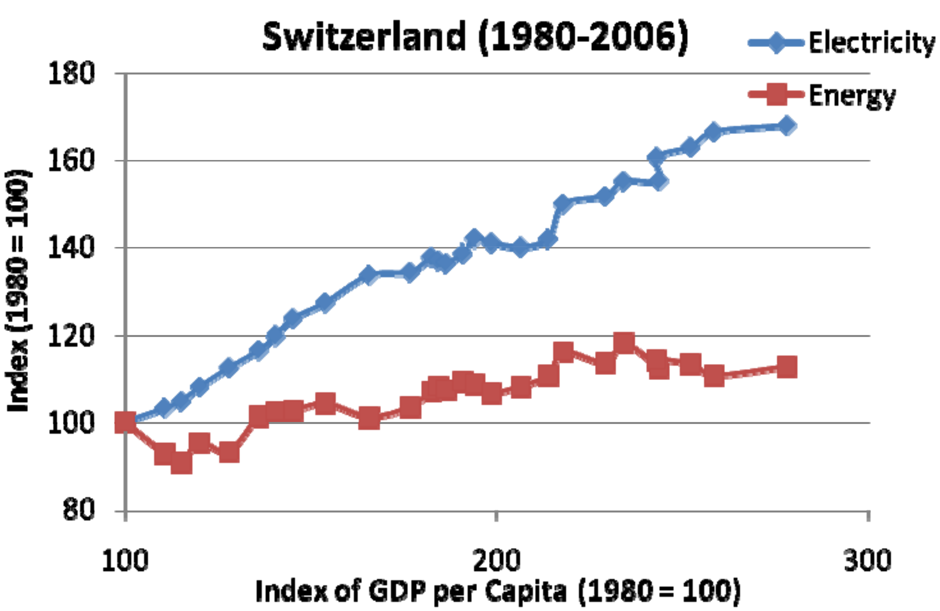

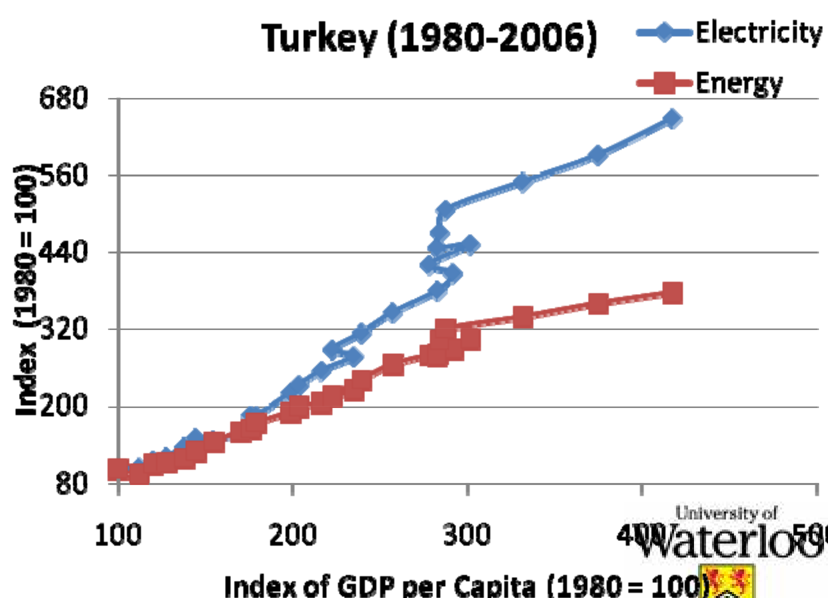

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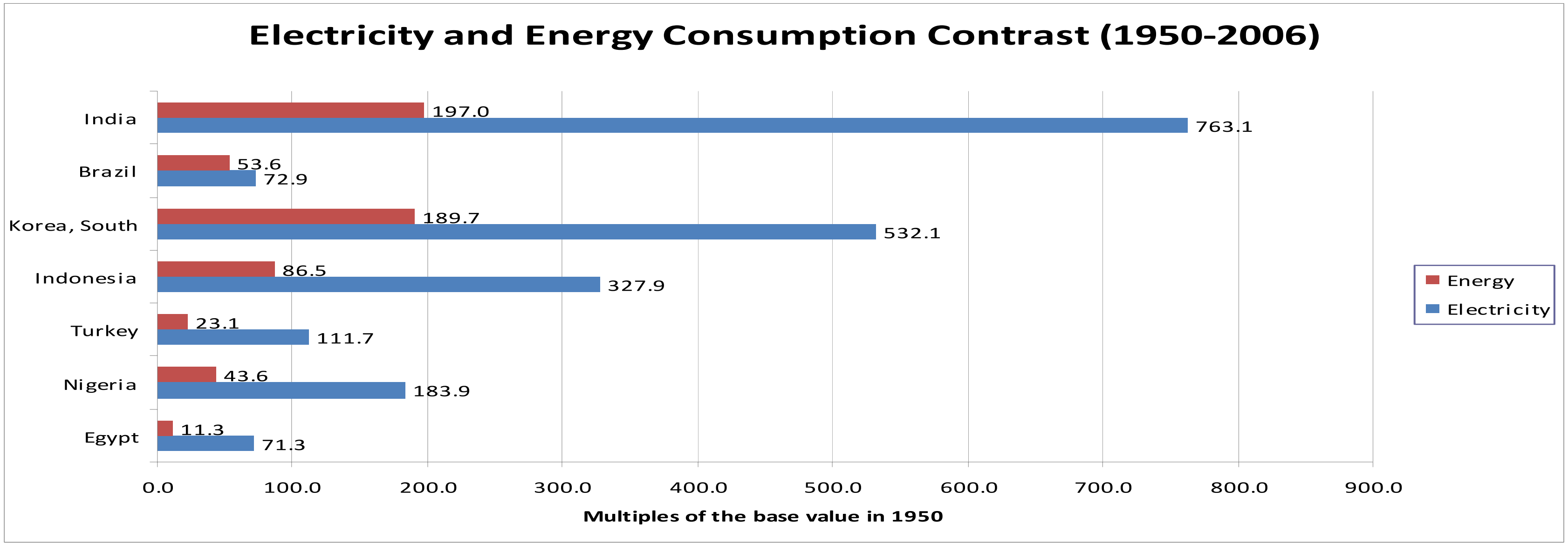
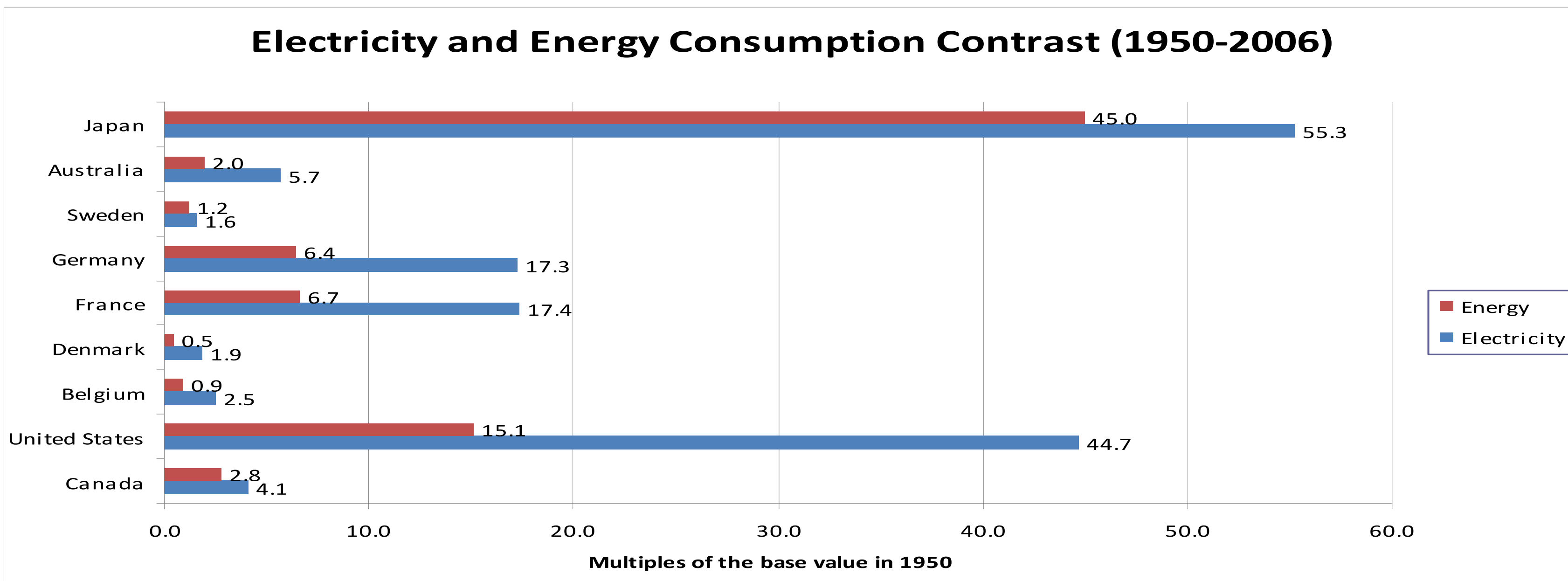
Electricity and Energy Contrast





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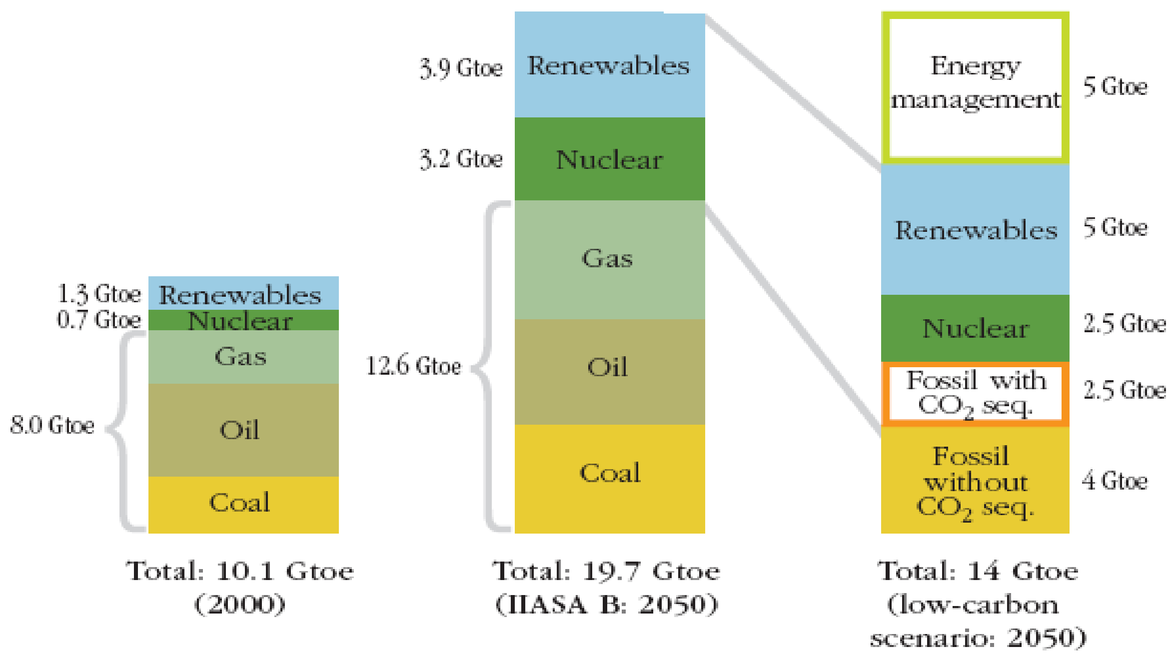
An expansive view

Fig. 8: Possible role of nuclear energy in different scenarios for 2050: example of a 14-Gtoe/year scenario [22] where nuclear energy would represent 2.5 Gtoe (corresponding to an installed capacity of 1 300 GWe)

Seq. = sequestration



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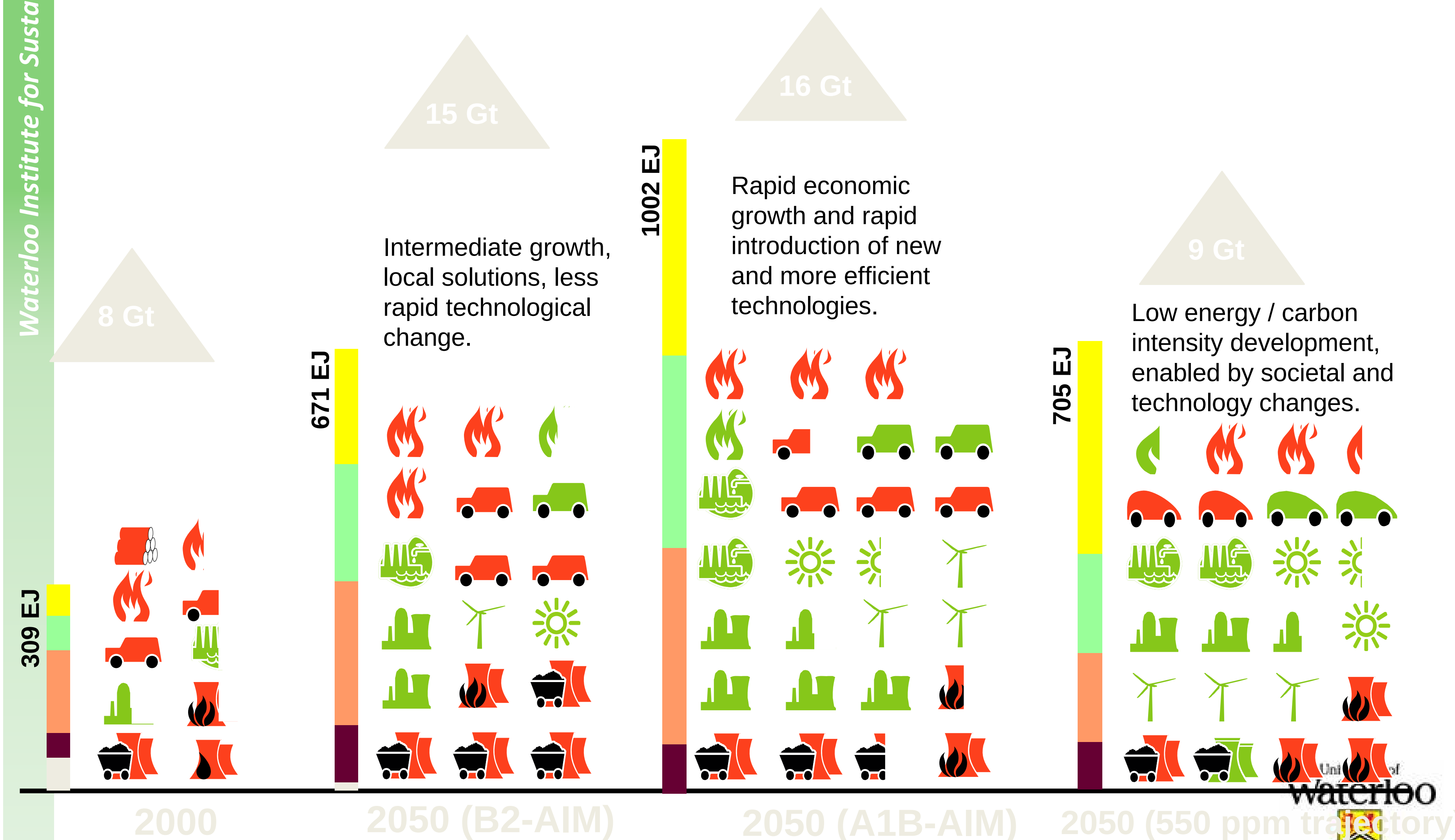
A Balanced Mix of Options



Source: WBCSD, 2007

Guideposts that may shape future directions

1. Energy flows through the global economy are massive: huge inertia
2. Scale and complexity of change suggests transition to a low GHG economy will take a long time
3. Growth, development, energy demand and environmental performance are intricately linked
4. Historical trends away from consumption of primary fuels directly to electricity will continue
5. The power sector will be characterized by a low carbon intensity
6. The electricity sector as the “cleaning agent” of the transport sector is an idea that is only beginning to emerge.
7. A balanced mix: renewables, nuclear, efficiency gains, conservation and clean(er) fossil resources would allow for sustainable prosperity and good environmental performance.

Nuclear Power in Society: Finding the Balance

Cost

- **What level of confidence do we have that nuclear can meet the test of affordability and provide true value to society?**
- **What are the costs of energy from nuclear fission?**
- **How do they compare with other low carbon energy sources?**
- **What lessons from the past?**
- **Are there any specific commercial arrangements or policy fixes required for the next generation reactors to deliver lower cost energy?**
- **Are resources of uranium (or fissionable material) adequate at reasonable cost to be considered sustainable for a major role in the global energy system?**

Nuclear Power in Society: Finding the Balance

Safety

- **Is the existing technology sufficiently safe?**
- **Are next generation reactors a pre-requiste for an expanded role in the future?**
- **What confidence can we gain from experience as it relates to design and safe operation to date?**
- **Is the risk of exposures to ionizing radiation from the fuel cycle low enough?**
- **Is the regulatory framework, both national and international, sufficiently robust to provide societal confidence in a continuing role for nuclear or even an expanded role?**
- **What is the best strategy for aligning safety goals with social acceptance?**

Nuclear Power in Society: Finding the Balance

Waste

- **Can the nuclear waste be safely isolated given the state of existing technology?**
- **What confidence do we have in our present plans for the long term management of existing nuclear waste?**
- **What are the critical considerations for broader social acceptance?**

Social, environmental, political,

- **Can nuclear be considered a sustainable solution without a social consensus on its role?**
- **What role or recognition for nuclear in any carbon "cap and trade" system?**
- **International trade: What are the risks of proliferation, how can they be mitigated and will there be a need for an updated NPT?**
- **What specific policy initiatives would be required to enable timely decisions on a commercial basis?**

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The Waterloo Institute for Sustainable Energy (WISE)

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Table 1.1 World primary energy demand by fuel

	Million ton oil equivalent (Mtoe)					Average annual growth rate
	1980	**2004**	**2010**	**2015**	**2030**	**2004-2030**
Coal	1,785	2,773	3,354	3,666	4,441	1.8%
Oil	3,107	3,940	4,366	4,750	5,575	1.3%
Gas	1,237	2,302	2,686	3,017	3,869	2.0%
Nuclear	186	714	775	810	861	0.7%
Hydro	148	242	280	317	408	2.0%
Biomass and waste	765	1,176	1,283	1,375	1,645	1.3%
Other renewables	33	57	99	136	296	6.6%
Total	7,261	11,204	12,842	14,071	17,095	1.6%

Note: 1 million ton oil equivalent equals 41.9 petajoules.

Source: IEA 2006

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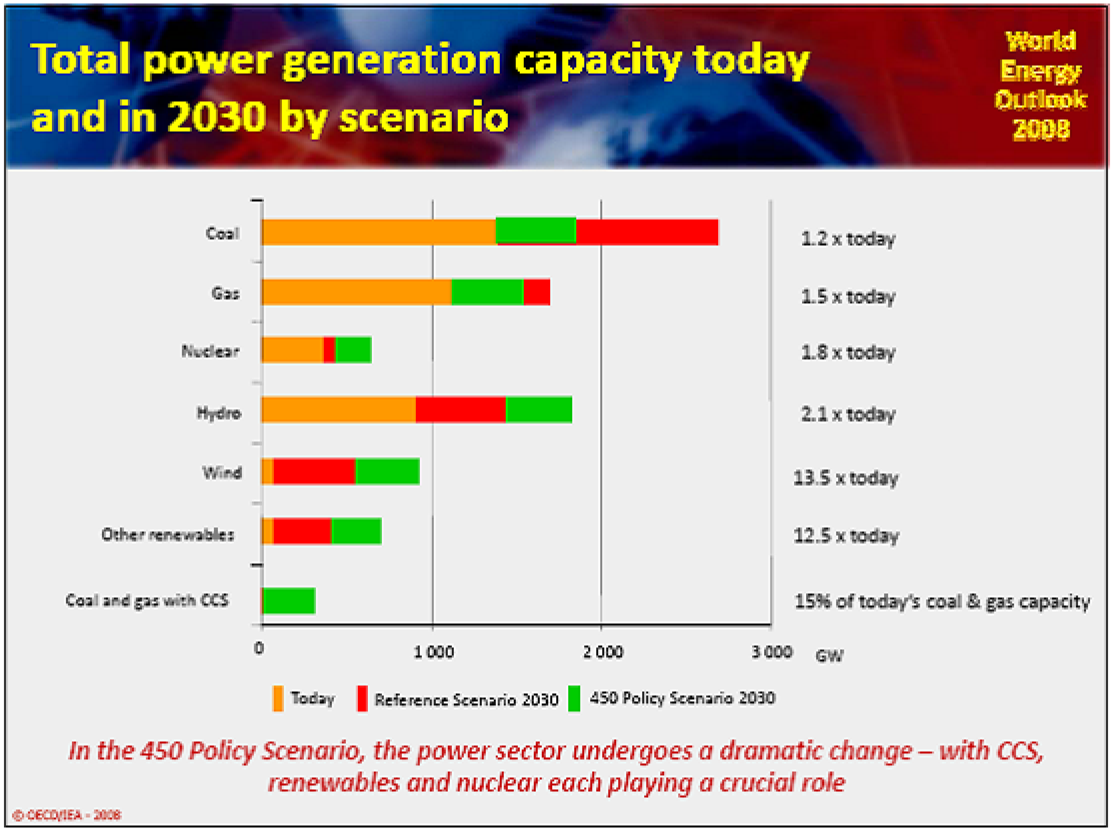
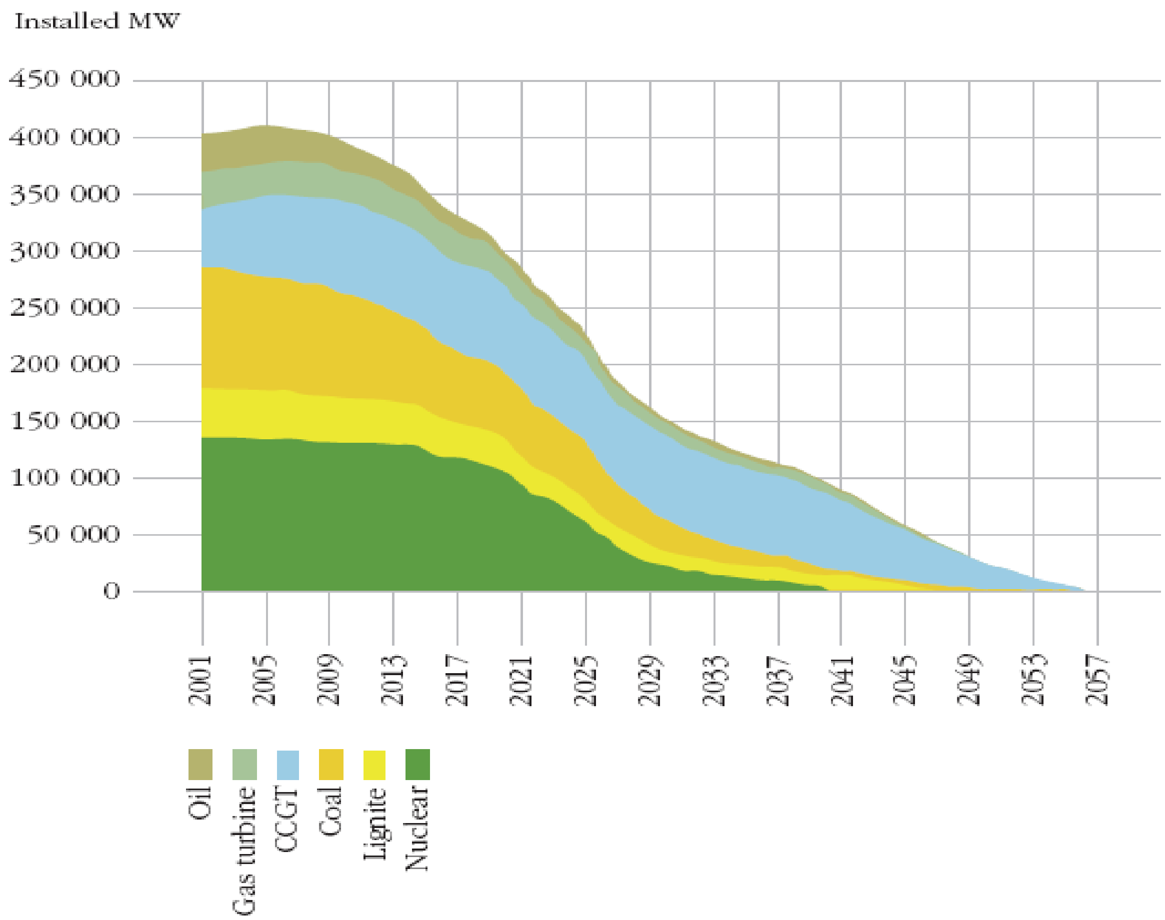
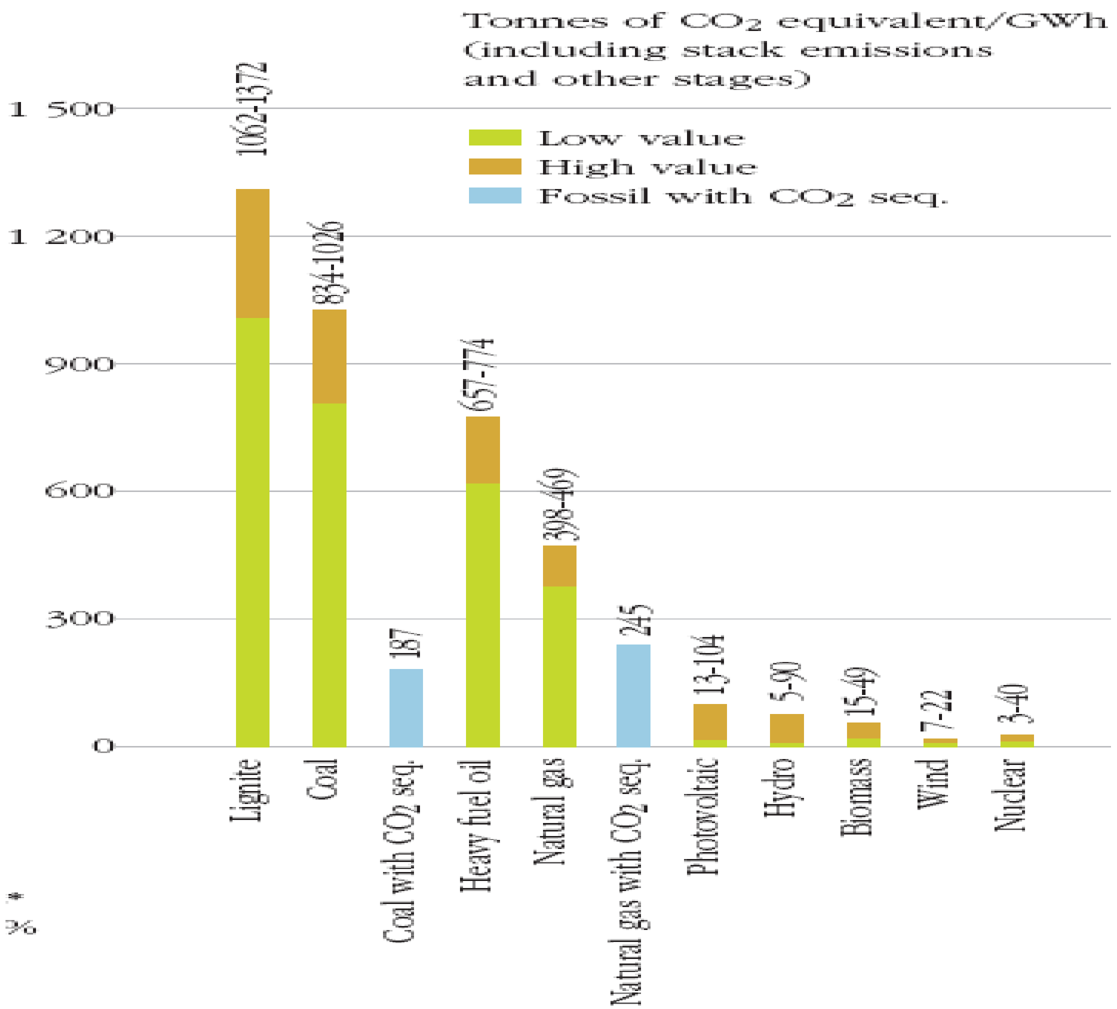

Total power generation capacity today and in 2030 by scenario
World Energy Outlook 2008
Coal
Gas
Nuclear
Hydro
Wind
Other renewables
Coal and gas with CCS
1.2 x today
1.5 x today
1.8 x today
2.1 x today
13.5 x today
12.5 x today
15% of today's coal & gas capacity
0
1 000
2 000
3 000
GW
Today
Reference Scenario 2030
450 Policy Scenario 2030
In the 450 Policy Scenario, the power sector undergoes a dramatic change – with CCS, renewables and nuclear each playing a crucial role
© OECD/IEA - 2008

Decline in installed generation capacity in Europe without new additions



Greenhouse gas emissions for electricity generation options



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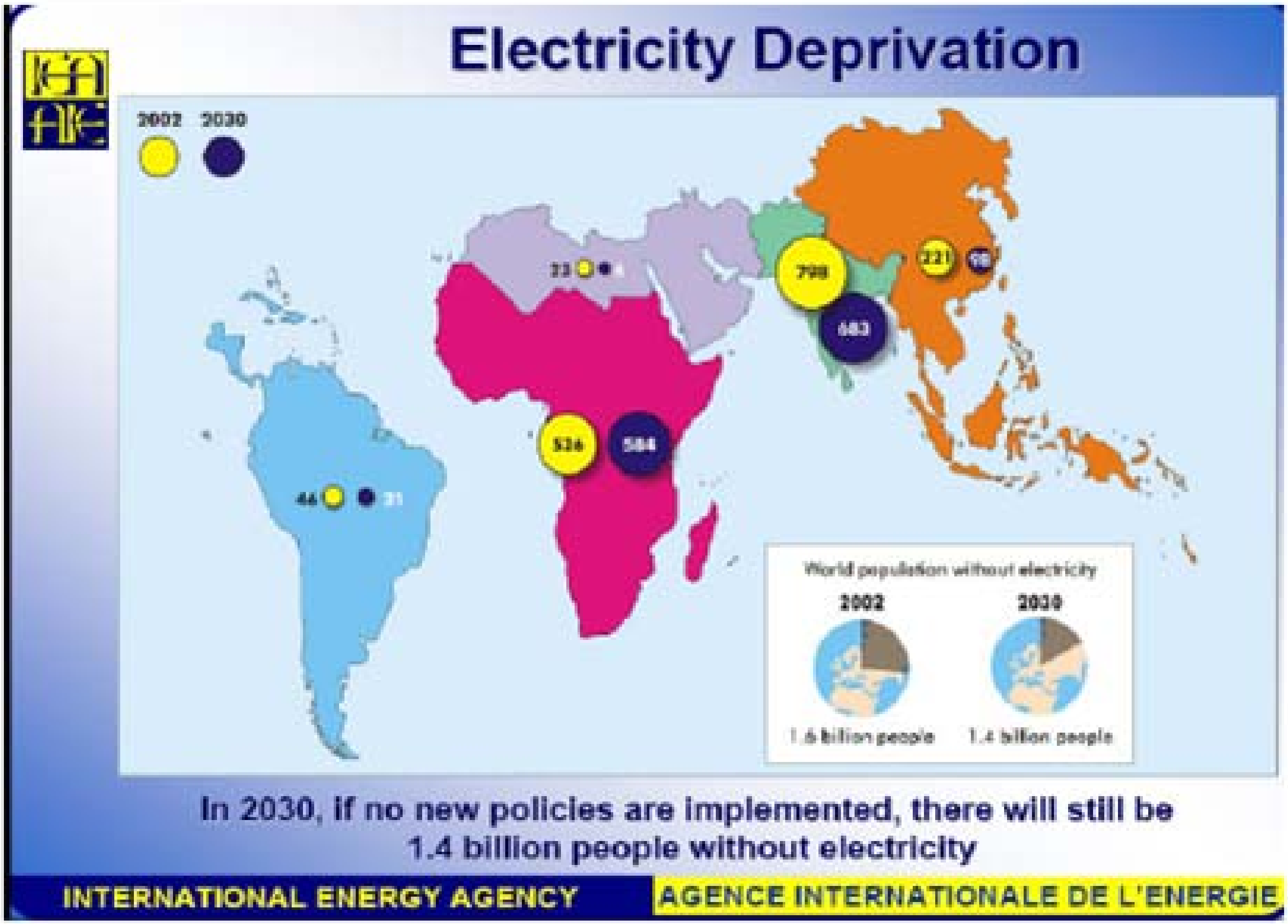
Moderate steps maintains continued misery



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