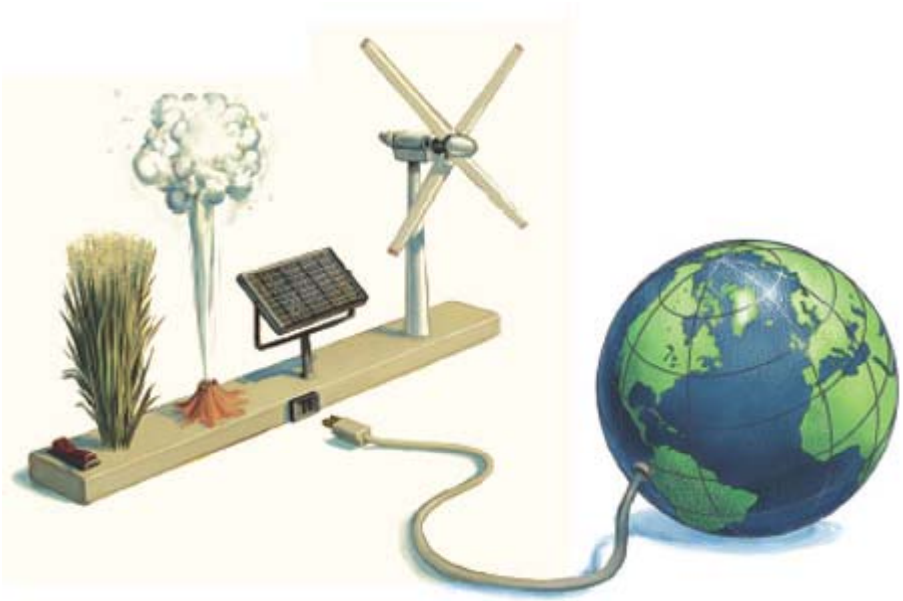
Introduction to Renewable Energy Technology



Marianne Salomón

Outline

- Definition of Renewable
- Definiton of Non-renewable
- World Energy Outlook
- Renewable Energy
  - Hydropower
  - Biomass
  - Wind Energy
  - Solar Energy
  - Geothermal Energy
  - Tidal Energy
  - Wave Energy
  - Ocean Thermal Energy Conversion (OTEC)
- Advantages of Renewable Energy
- Problems and Limitations
- Current Trends
- Potential & Forecasts

Renewable Energy

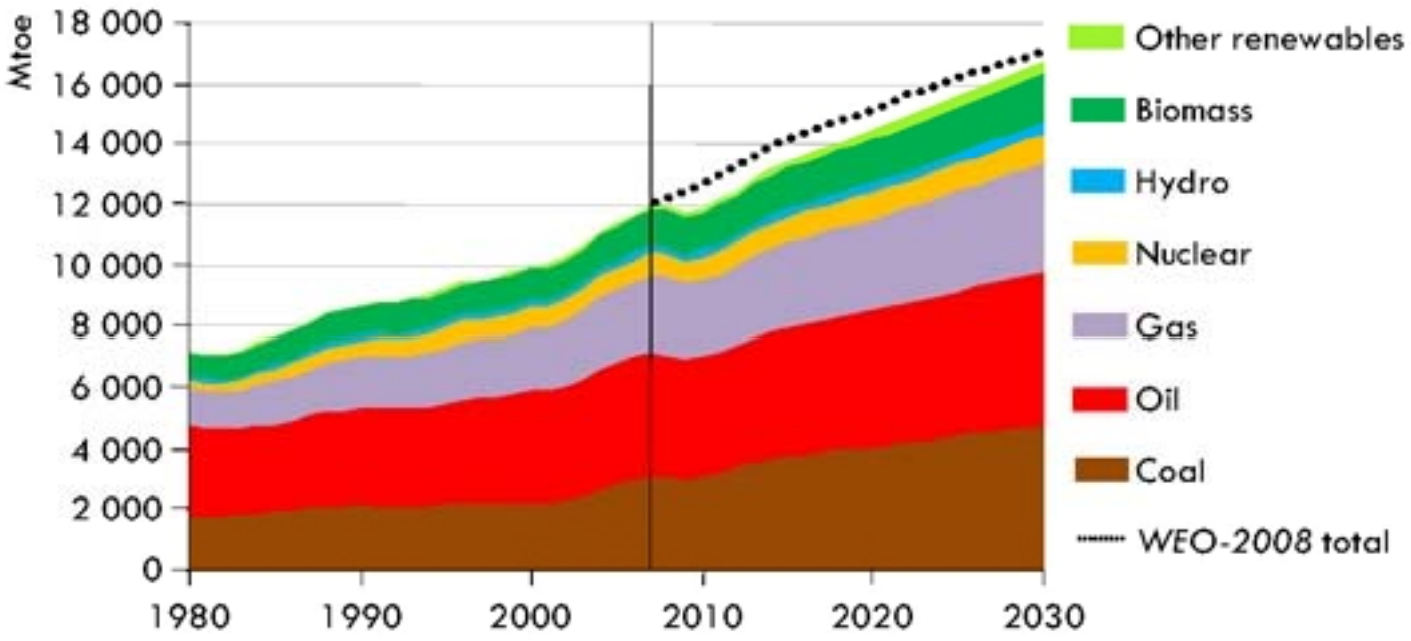
- Renewable energy is the term used to cover those energy flows that occur naturally and repeatedly in the environment and can be harnessed for human benefit.
  - The ultimate sources of most of this energy are the sun, gravity and the earth's rotation.

Nonrenewable Energy

- *Nonrenewable energy* is energy obtained from static stores of energy that remain bound unless released by human interaction.
  - Examples: nuclear fuels and fossil fuels (coal, oil, natural gas). The energy is initially an isolated energy potential and external action is required to initiate the supply of energy for practical purposes.
  - Nonrenewable energy supplies are also called finite supplies.

World Energy Outlook

- Predominance of fossil fuels (about 80%)

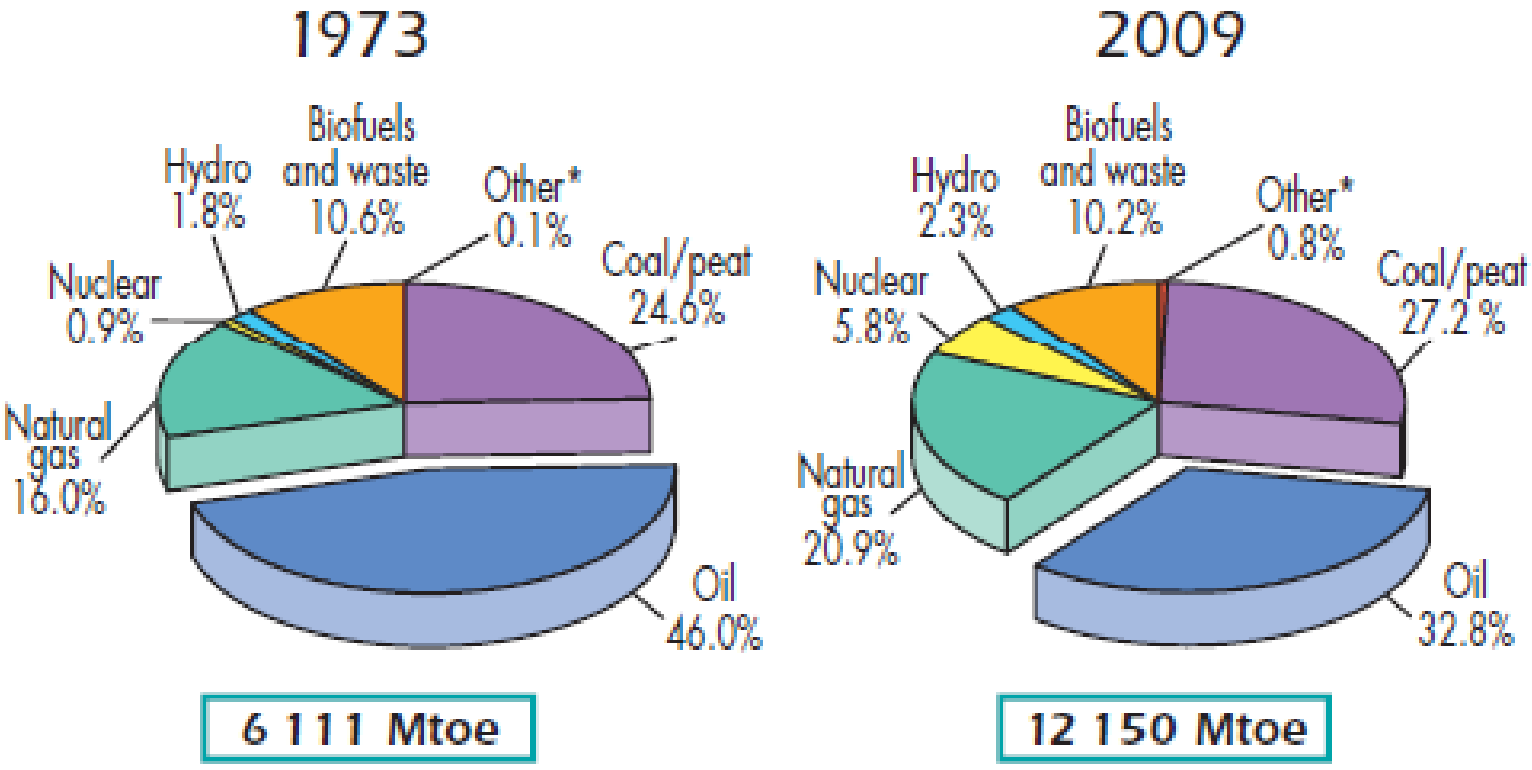


World Primary Energy Demand by Fuel – reference scenario
Source: IEA World Energy Outlook 2009

Global demand grows by 40% between 2007 and 2030, with coal use rising most in absolute terms

World energy demand expands by 45% between now and 2030 – an average rate of increase of 1.6% per year – with coal accounting for more than a third of the overall rise

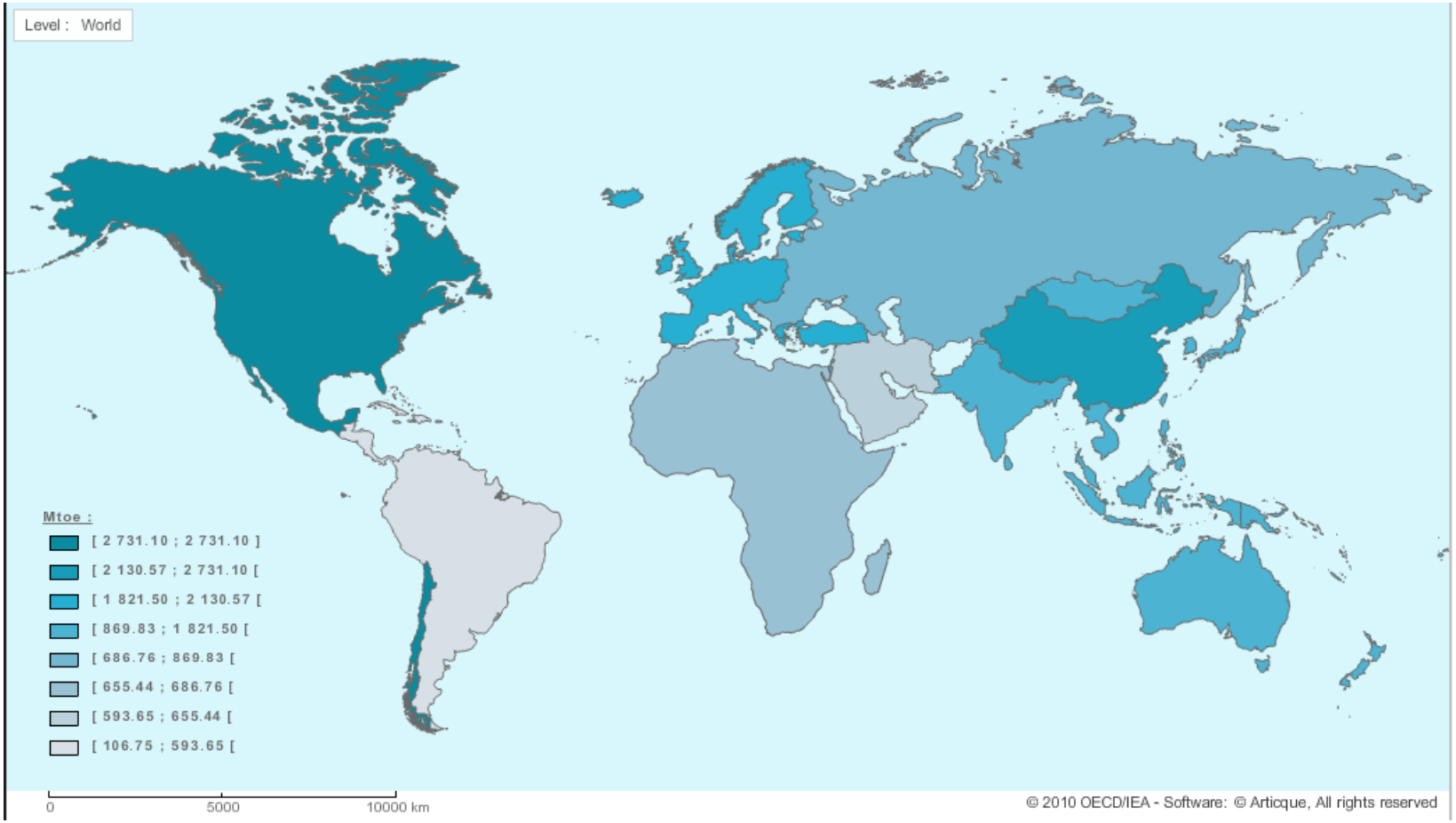
World Total Primary Energy Supply



**Other includes geothermal, solar, wind, biofuels and waste, and heat

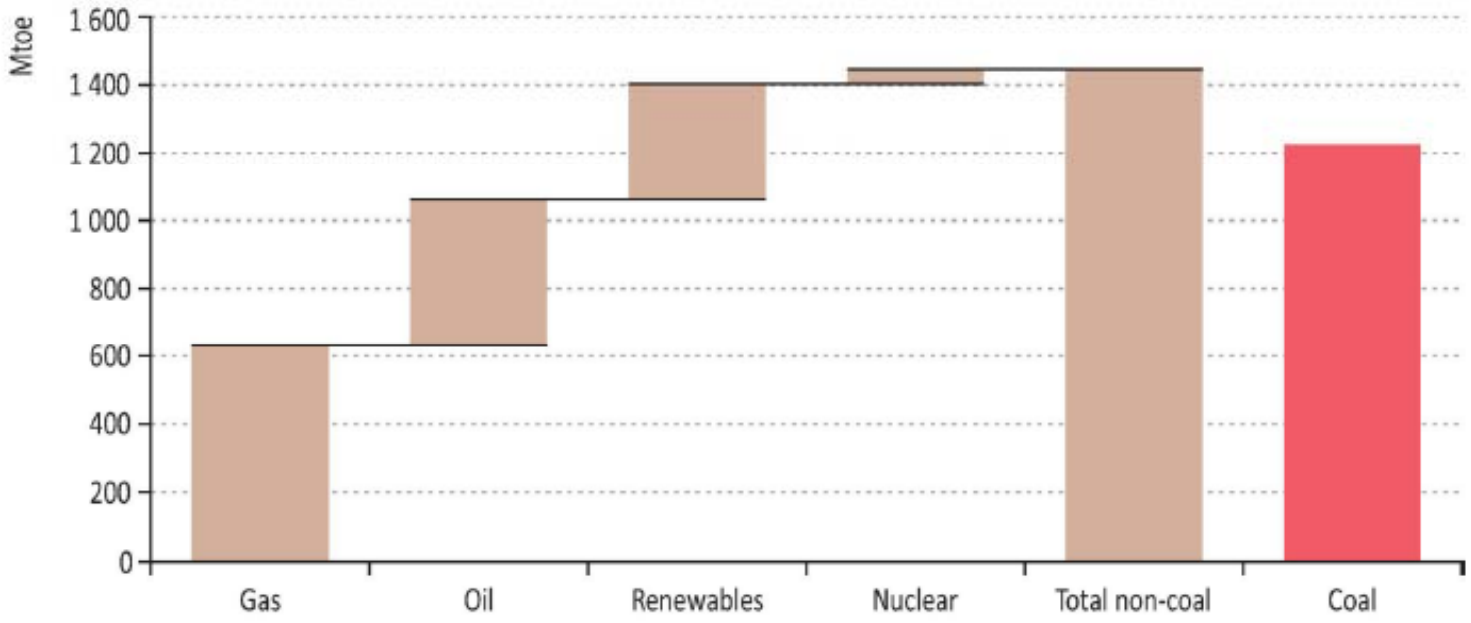
Source: IEA (2011) World key energy statistics

Primary Energy Consumption



Source: IEA

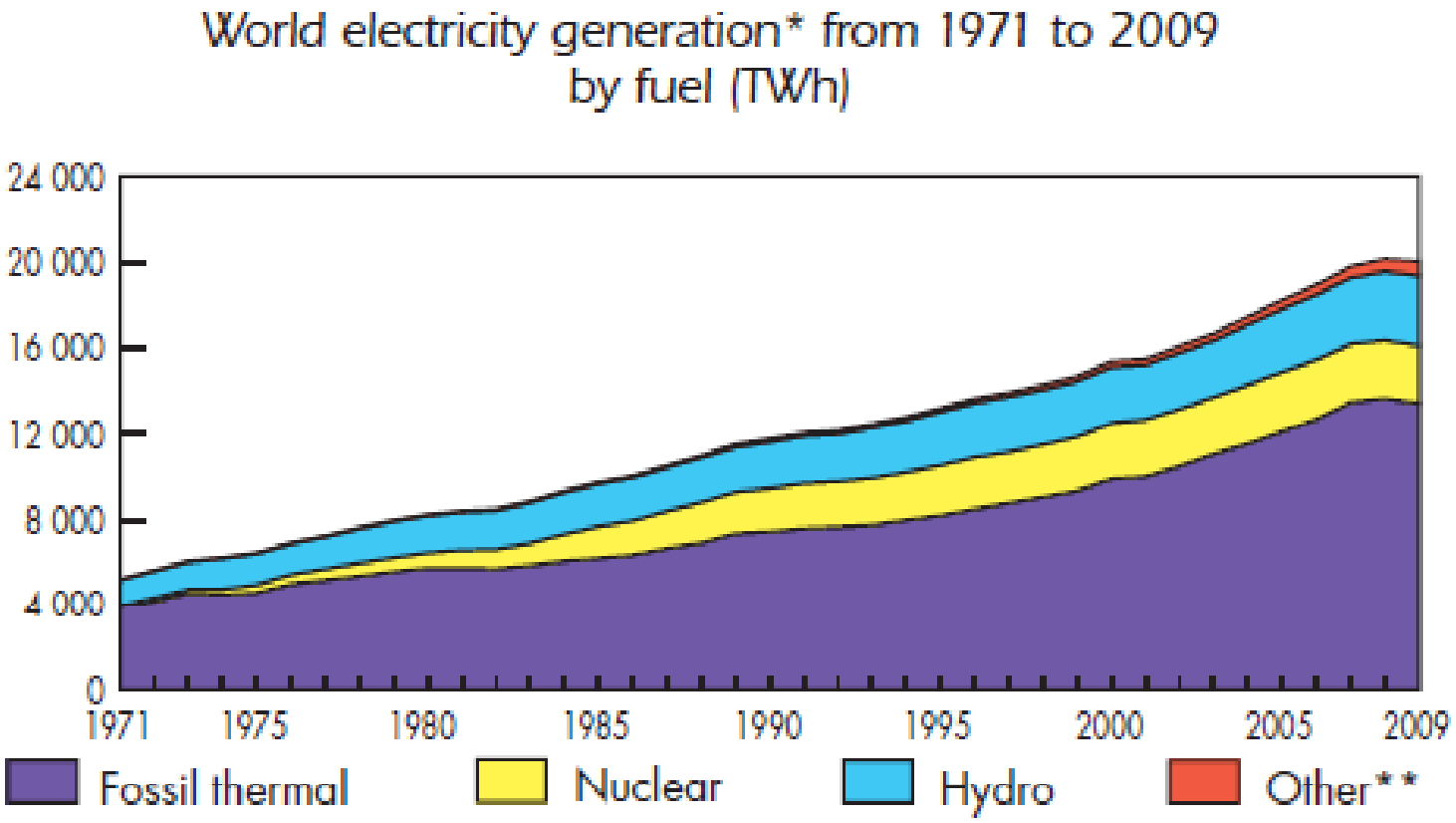
Incremental world primary energy demand by fuel, 2000-2010



Coal accounted for nearly half of the increase in global energy use over the past decade, with the bulk of the growth coming from the power sector in emerging economies

Source: IEA - World energy outlook 2011

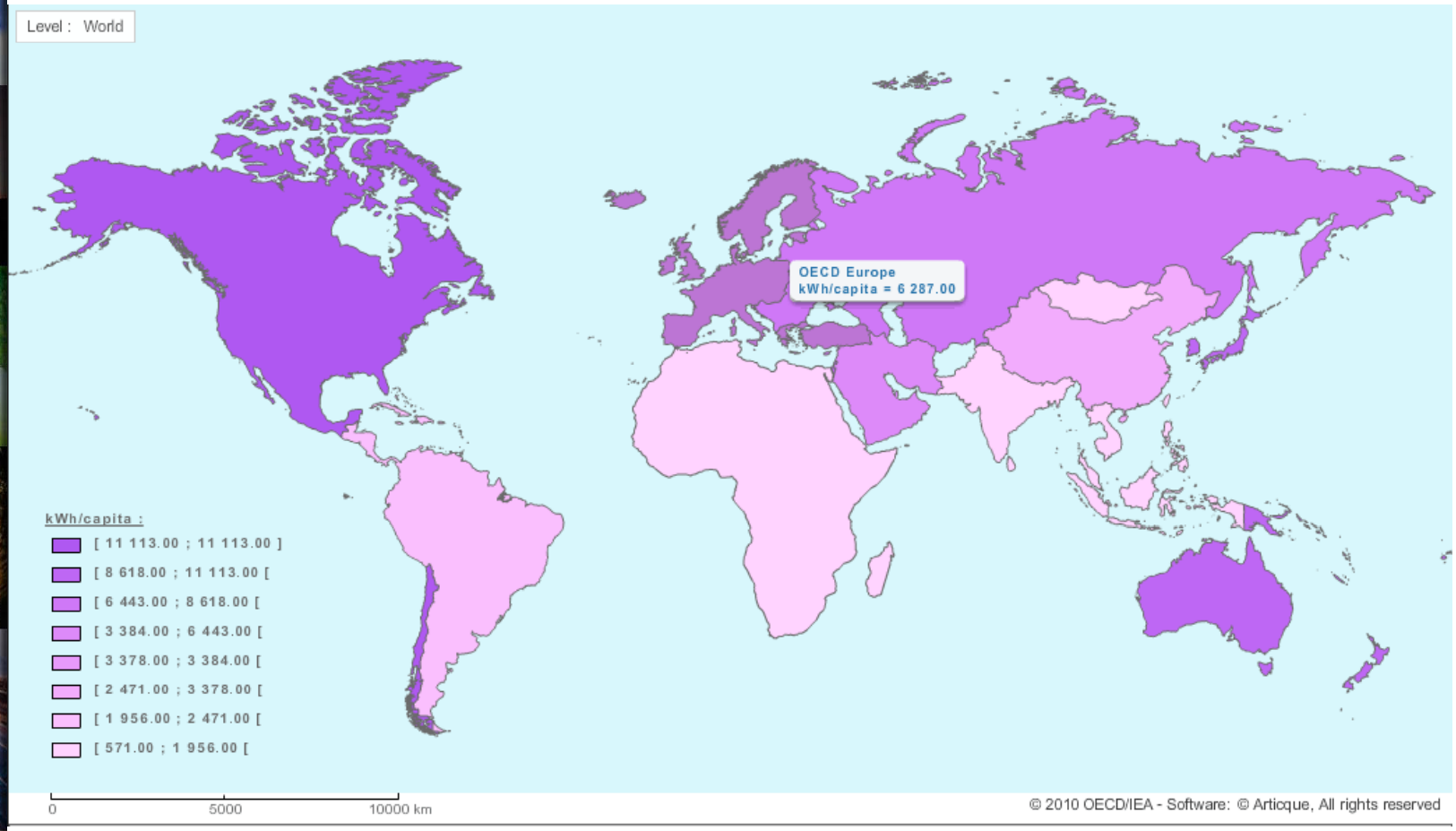
World electricity generation



**Other includes geothermal, solar, wind, biofuels and waste, and heat.

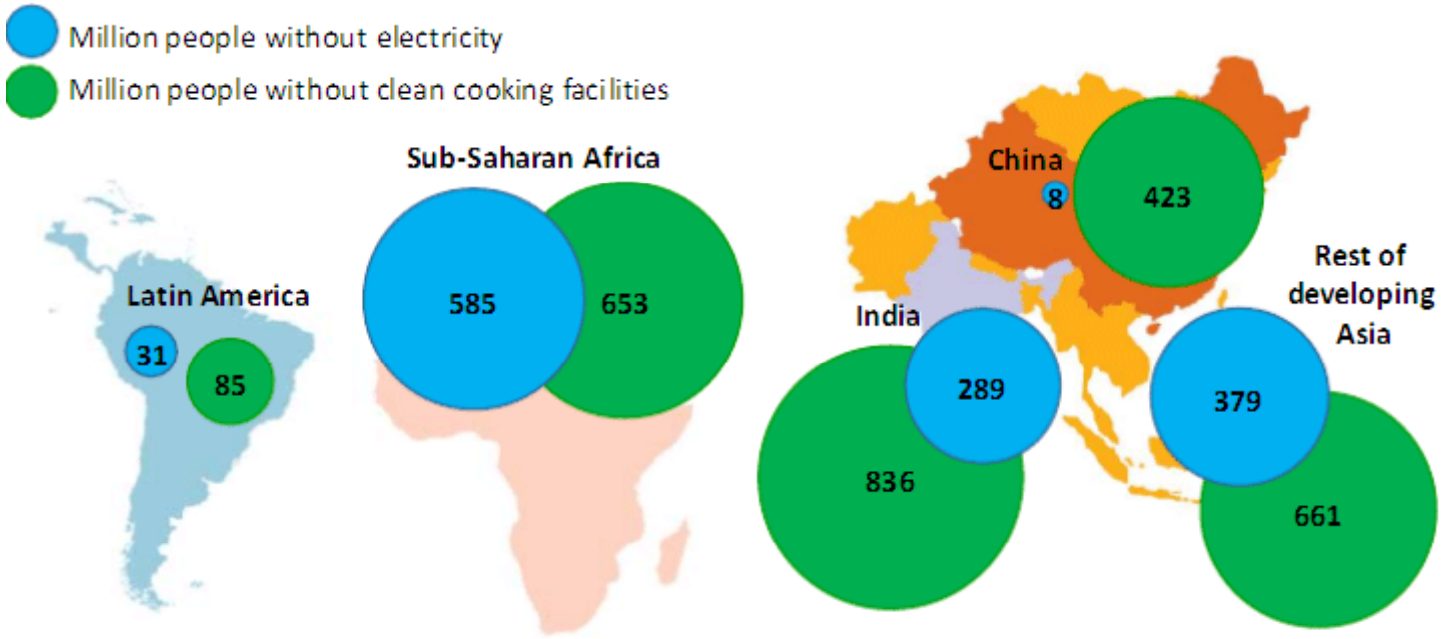
Source: IEA (2011) World key energy statistics

Electricity consumption per capita



Electricity use

Millions of people without access to electricity

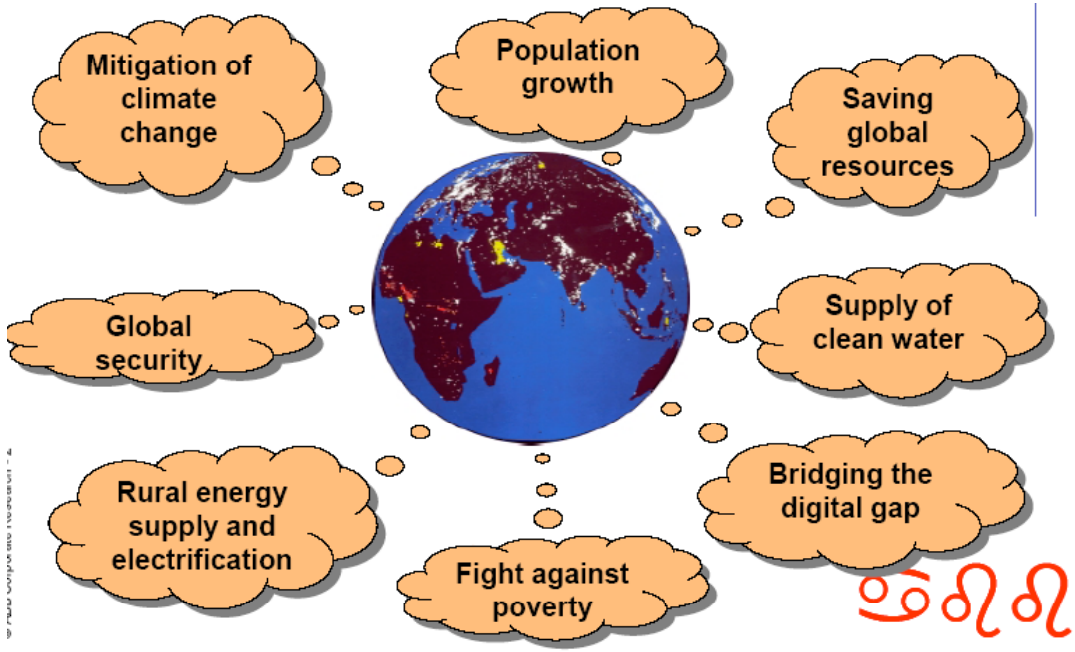


1.3 billion people in the world live without electricity and 2.7 billion live without clean cooking facilities

Source: IEA WEO 2011

Why Should We Use Renewable Energy

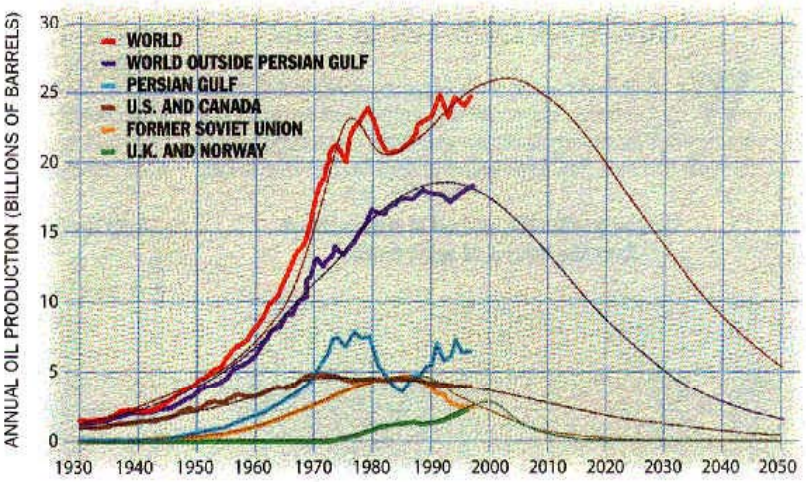
- Non-renewable resources are limited
- Security of Supply
- Increase in the world energy consumption
- Sustainability
  - Energy
  - Environment
  - Society
  - Economy



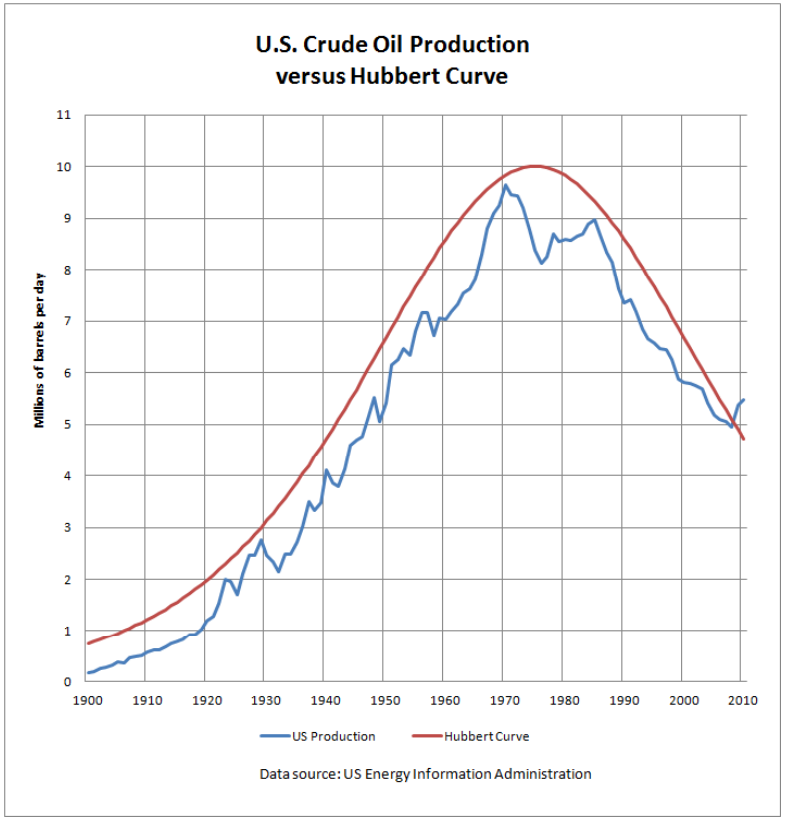
Limited resources

- Technology has improved very much over the last 10 to 15 years ⇨ reserves increased.

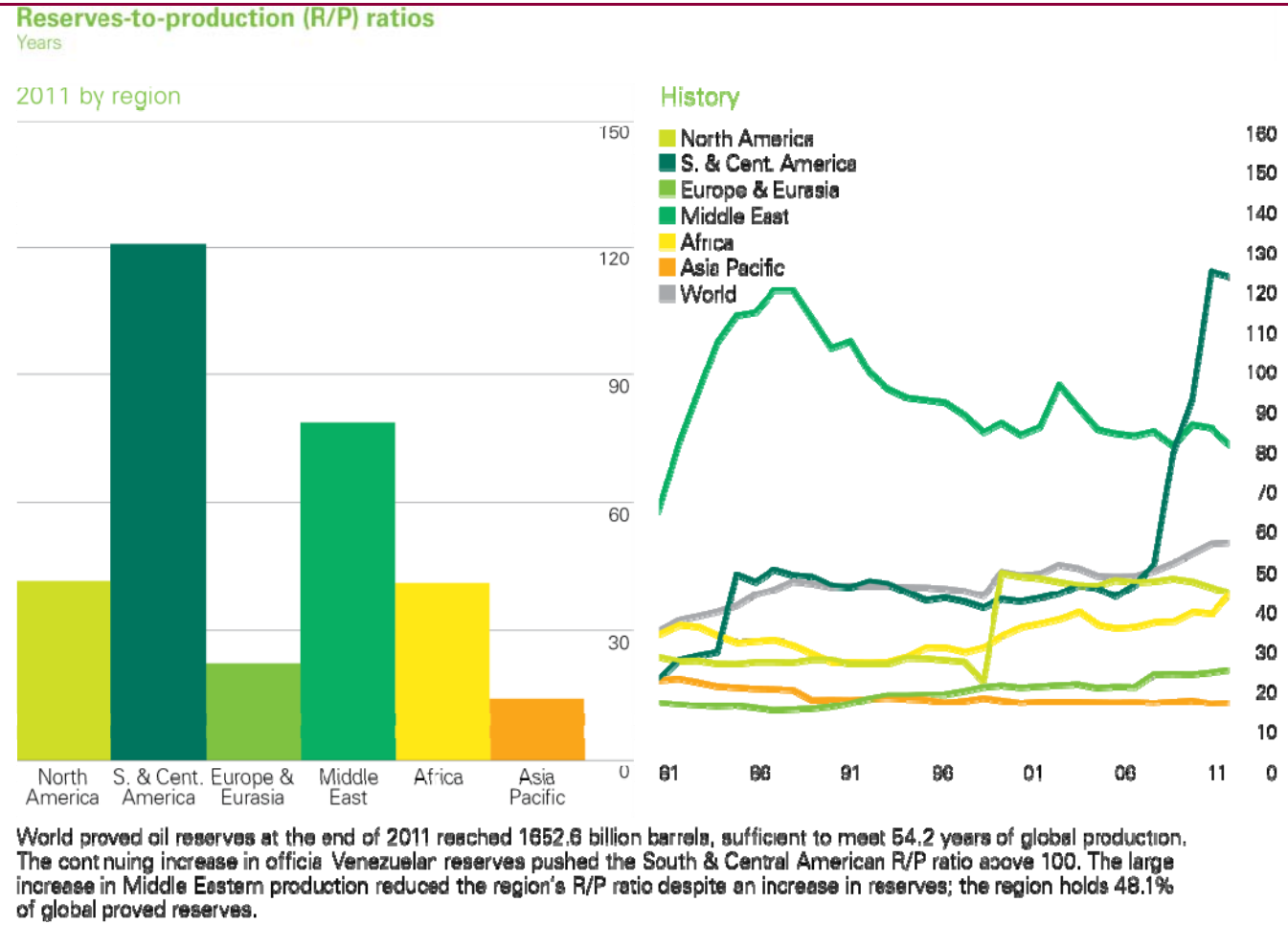
- Estimated max for next 100 years. For Western Europe it is estimated to last for 10 years and for North America about 25 years.



Renewa



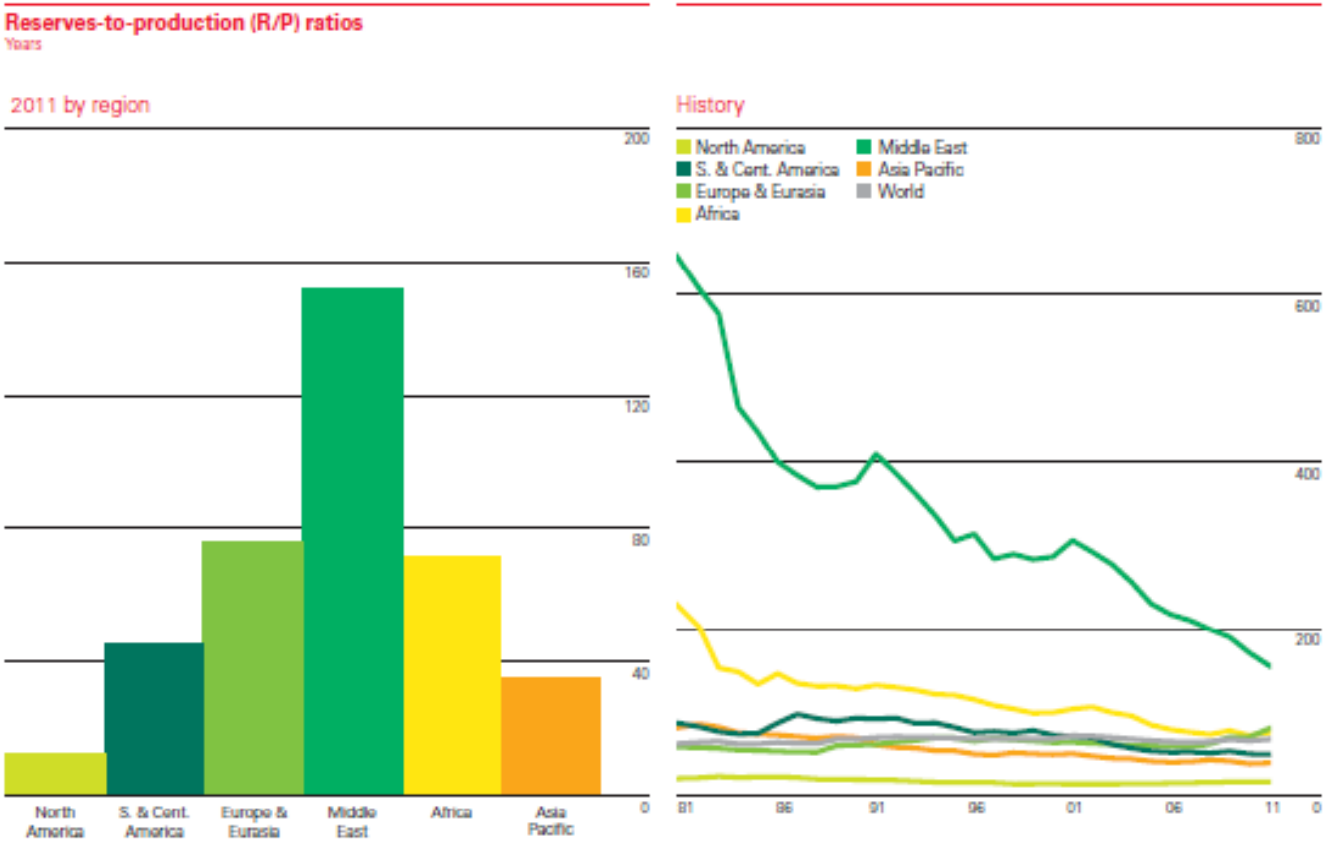
Security of supply - oil



World proved oil reserves at the end of 2011 reached 1652.6 billion barrels, sufficient to meet 54.2 years of global production. The continuing increase in official Venezuelan reserves pushed the South & Central American R/P ratio above 100. The large increase in Middle Eastern production reduced the region's R/P ratio despite an increase in reserves; the region holds 48.1% of global proved reserves.

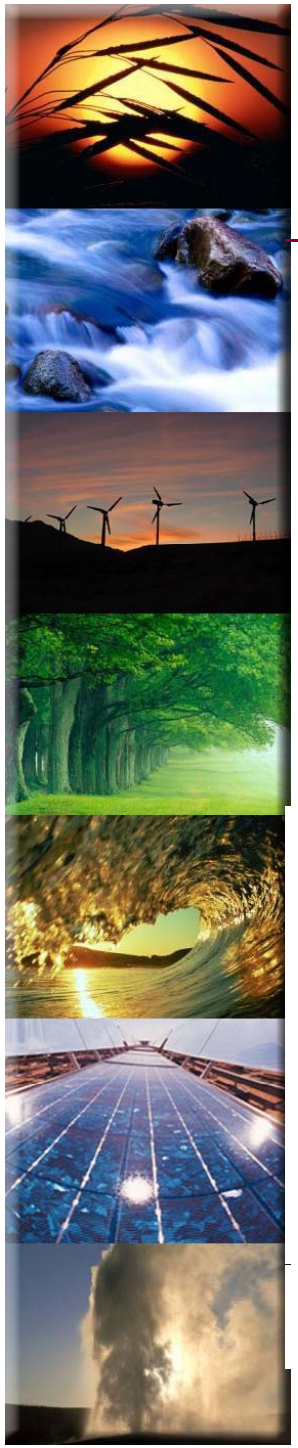
Middle east holds 61% of the world oil reserves and Europe&Eurasia 11% (source: BP, 2012)

Security of supply – natural gas



World proved natural gas reserves at end-2011 were sufficient to meet 63.6 years of production. A large increase in Turkmen reserves pushed the R/P ratio for Europe & Eurasia to 75.9 years. The Middle East still holds the largest reserves (38.4% of the world total, compared with 37.8% for Europe & Eurasia) and has an R/P ratio of over 150 years.

Middle east holds 41% of the world natural gas reserves and Europe&Eurasia 33% (source: BP 2012)



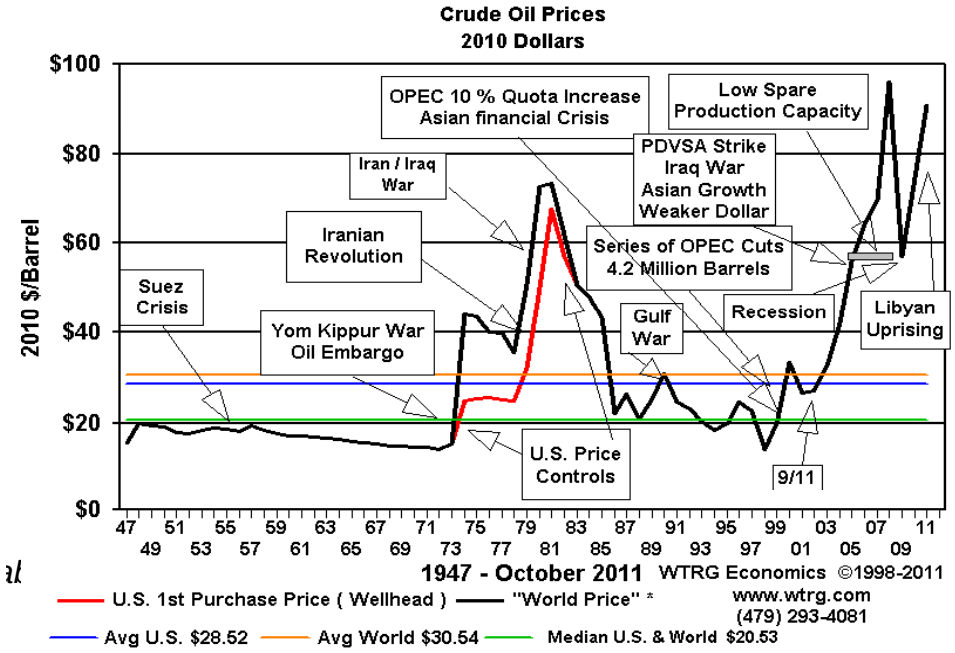
Security of supply

- Possible vulnerabilities:
  - dependence on the resource in question.
  - supply and demand problems.
  - vulnerability and exposure of supply.
  - variety of sources of disruption

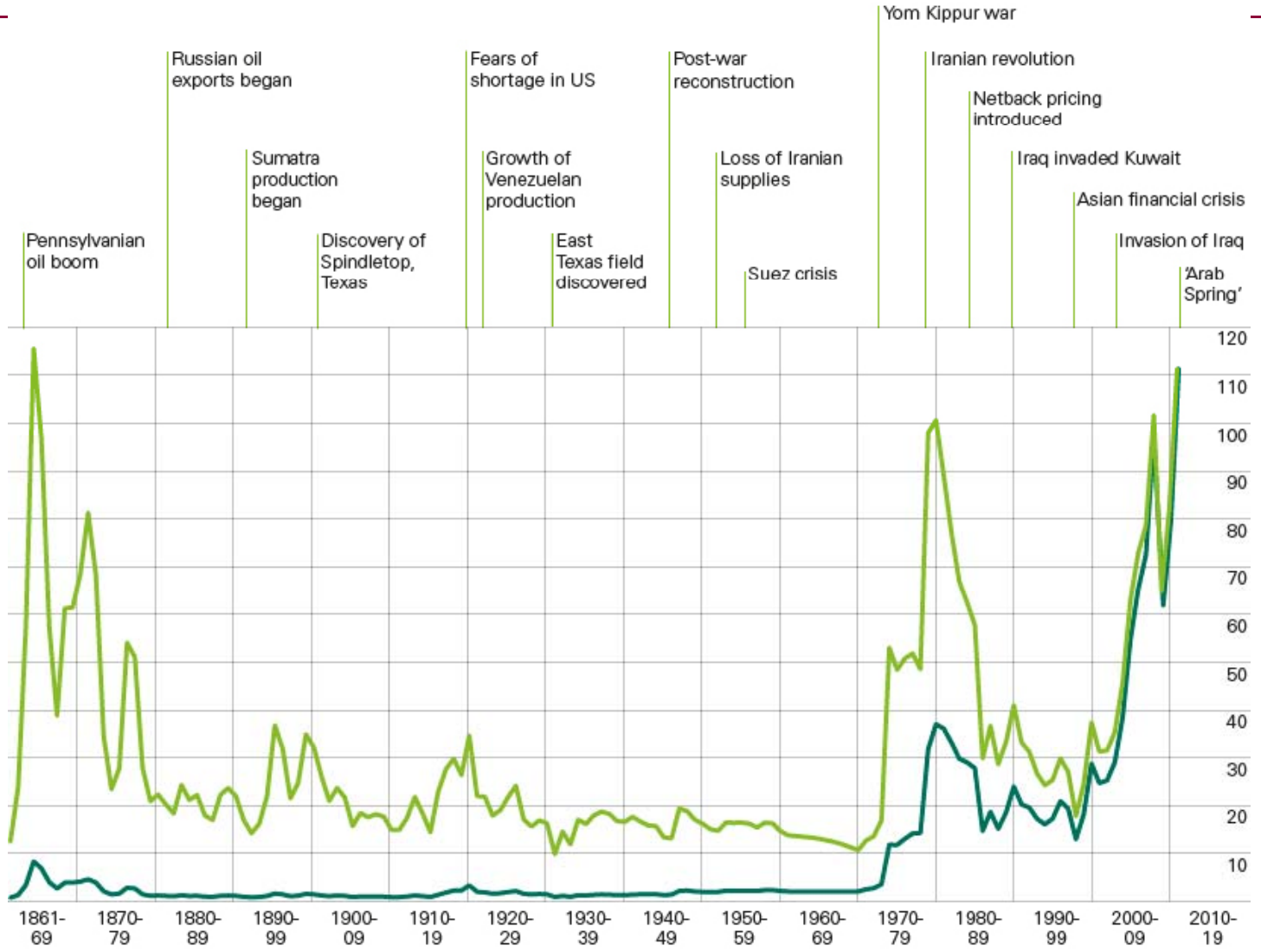
Volatile prices: ”*The price of crude oil by the barrel has seen a degree of volatility in recent weeks (BBC news July 2012)“*

“Crude oil prices are going up as Gulf of Mexico production goes down (Aug. 2012)

Could oil reach $200/barrel within few years?

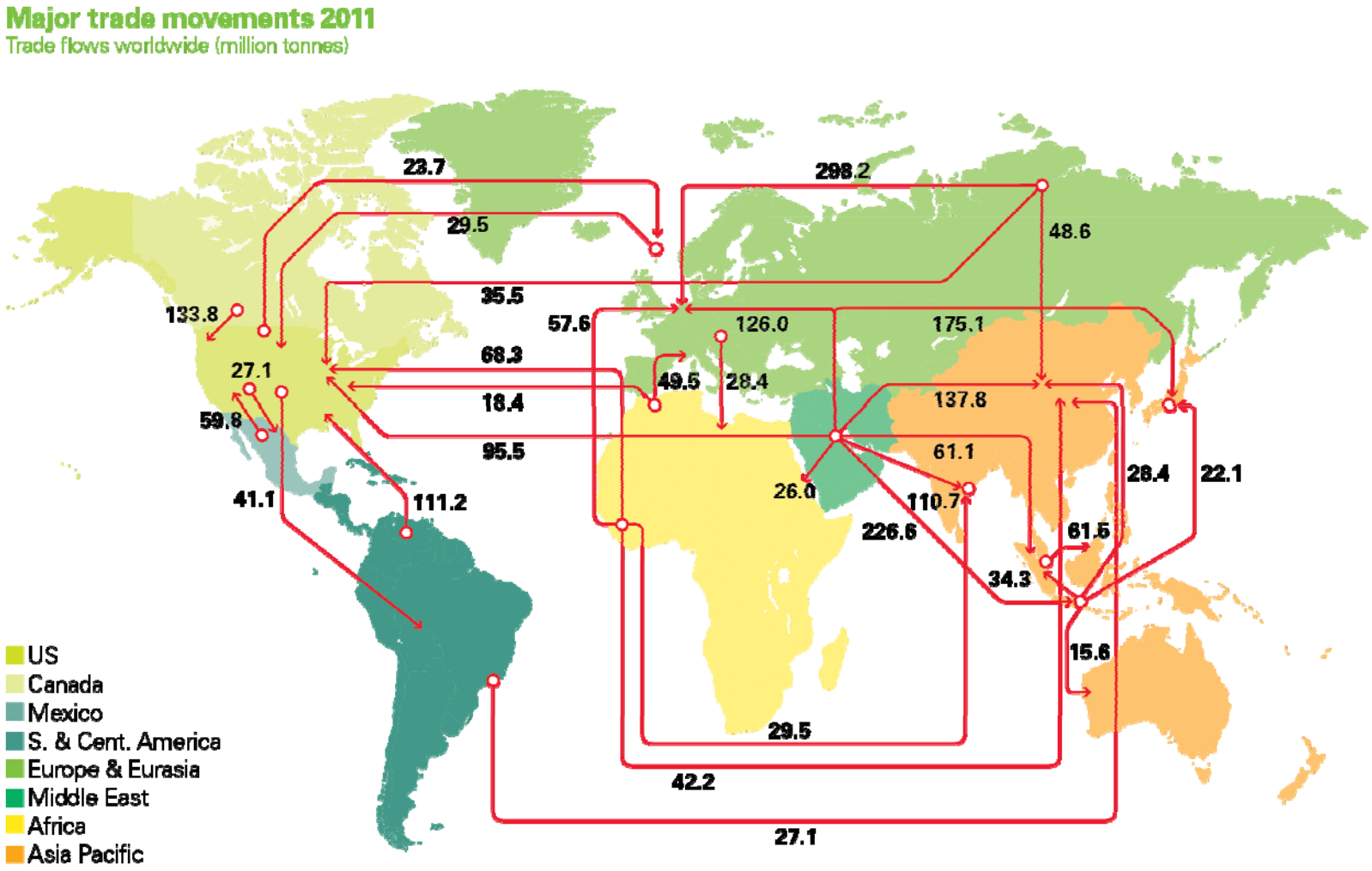


Crude Oil Prices since 1861



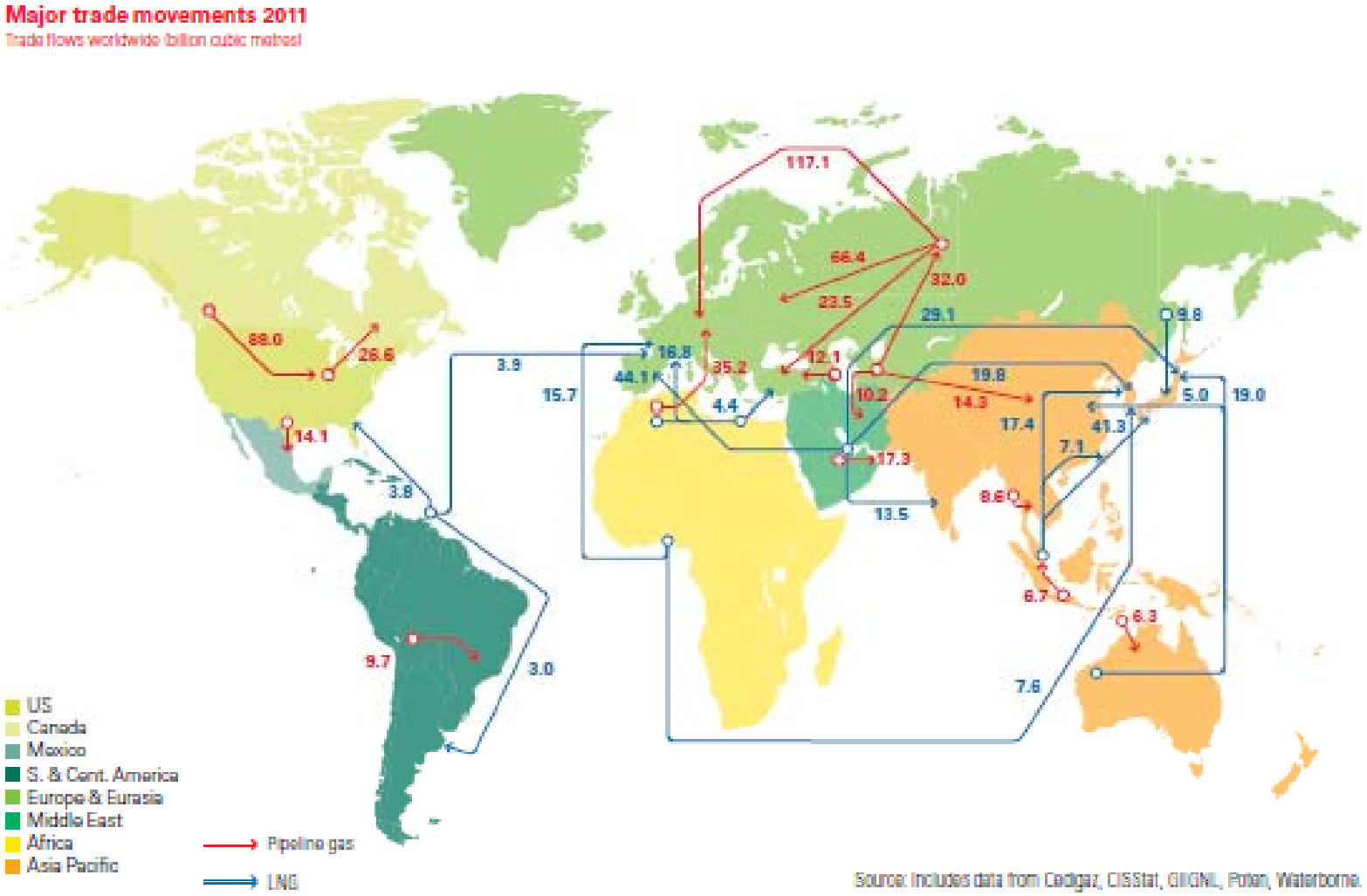
Source: BP, 2012

Oil supply



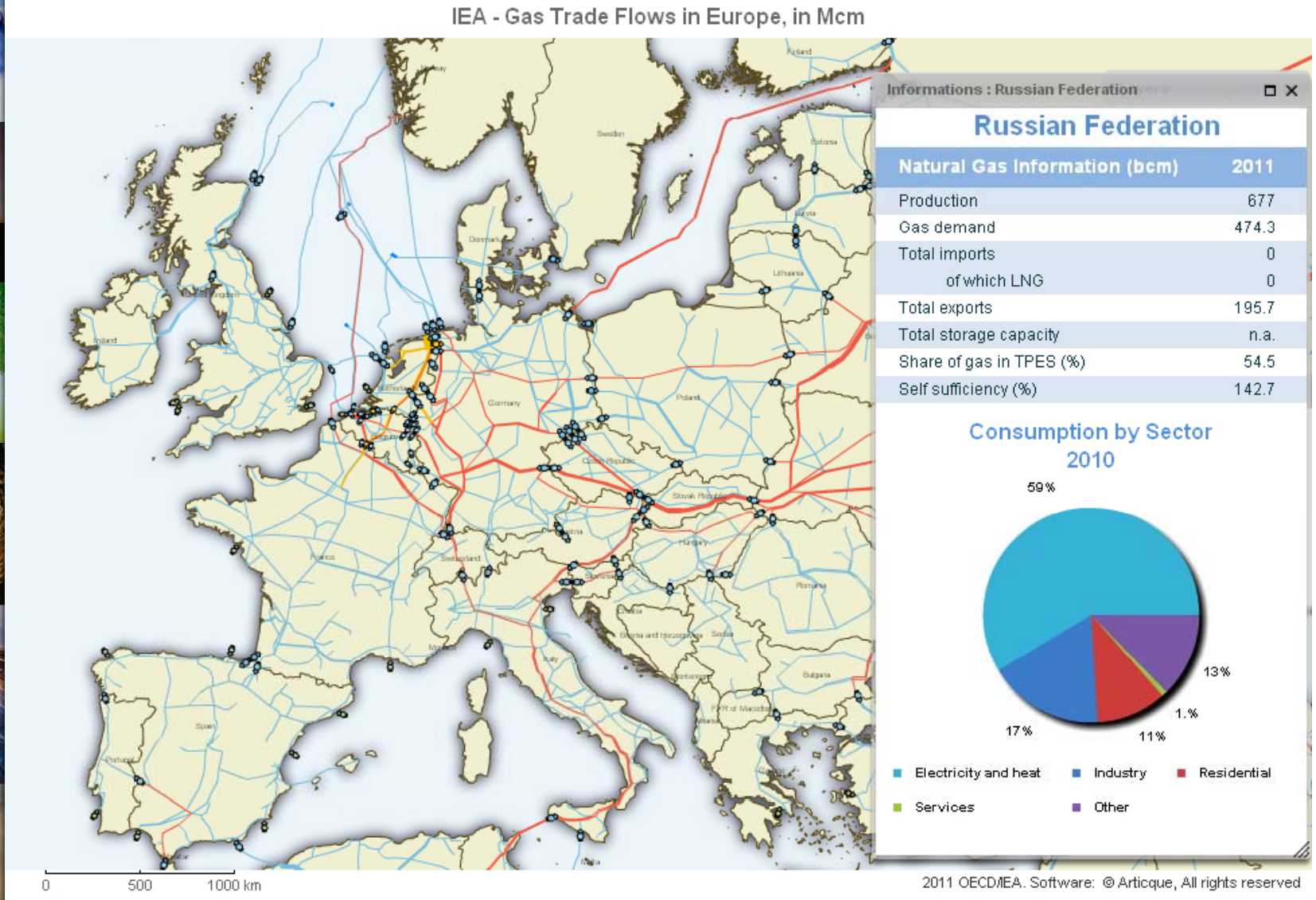
Source: BP, 2012

Natural Gas

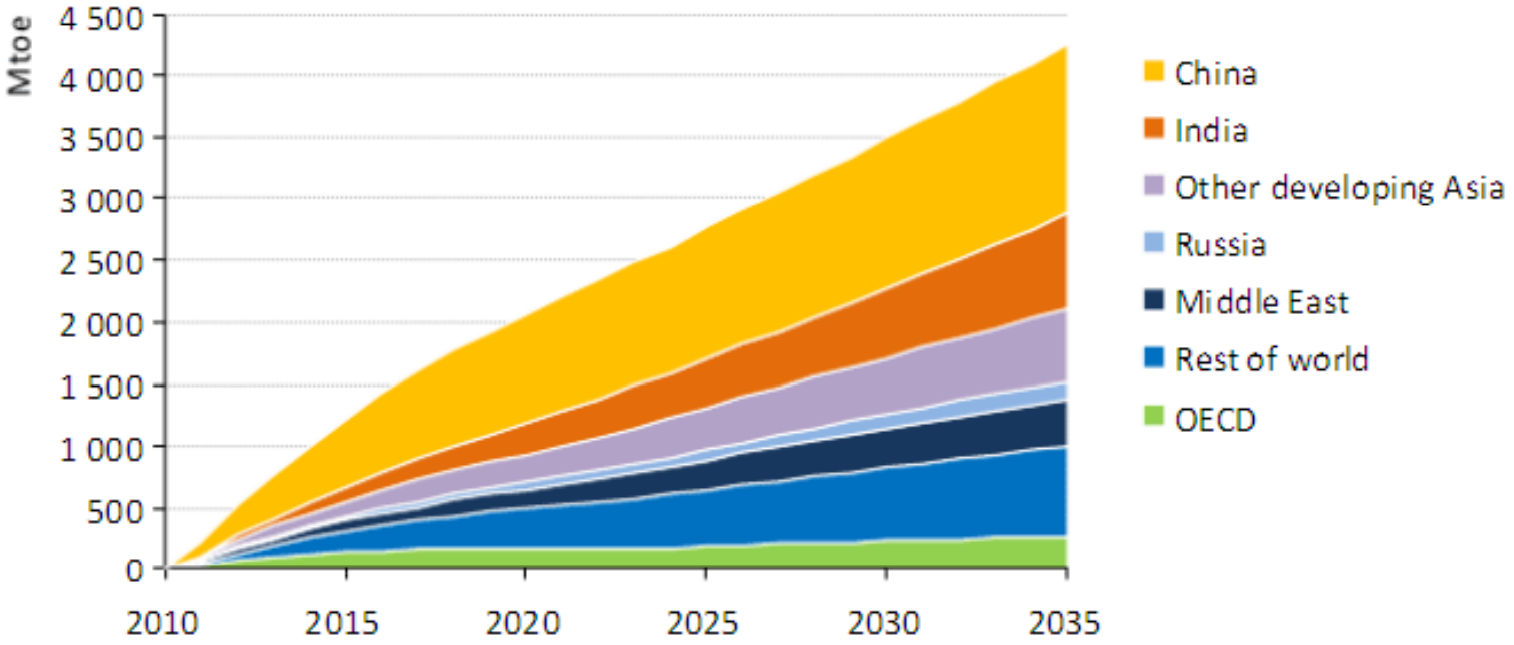


Source: BP

Natural gas Europe



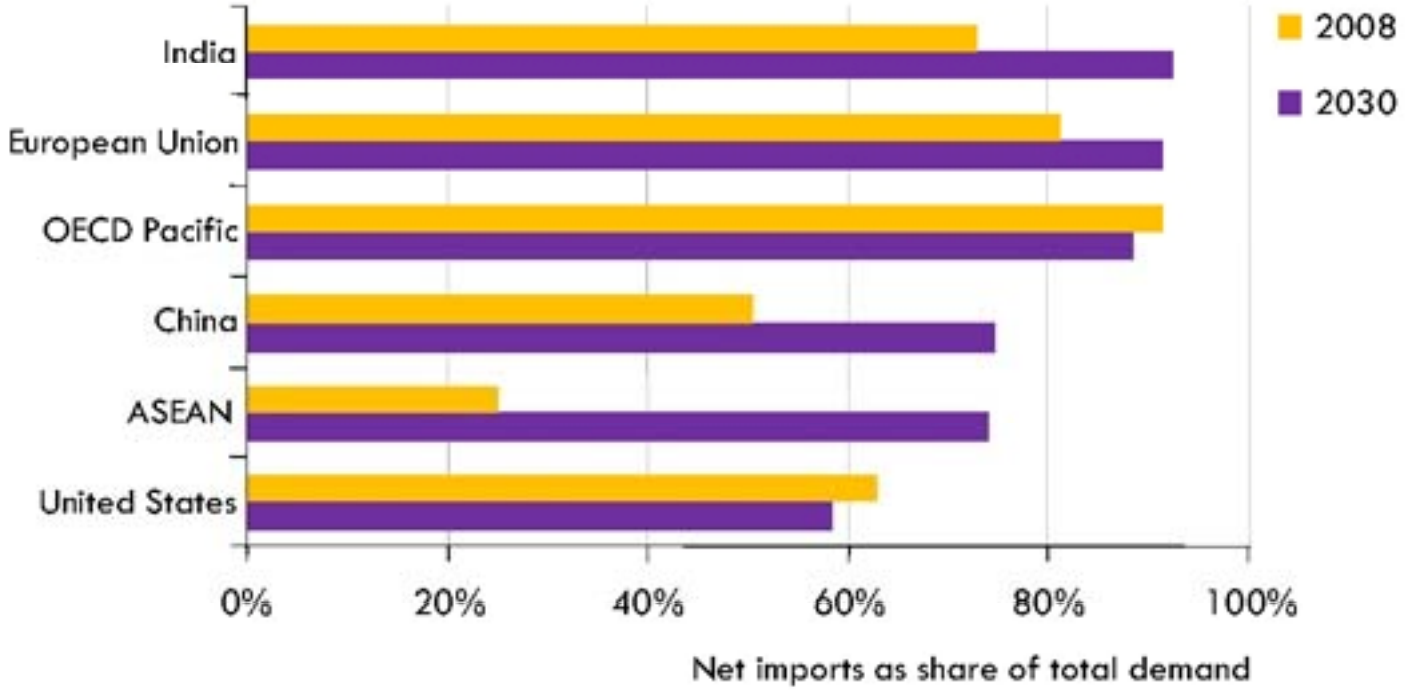
Growth in primary energy demand



Global energy demand increases by one-third from 2010 to 2035, with China & India accounting for 50% of the growth

Source: International Energy Agency. World Energy Outlook 2011

Net oil import dependence in main importing countries/regions



Reference scenario. Source: IEA WEO 2009

Import dependence falls in the United States & OECD Pacific, but increases in all other importing regions – most markedly in Asia

Sustainability

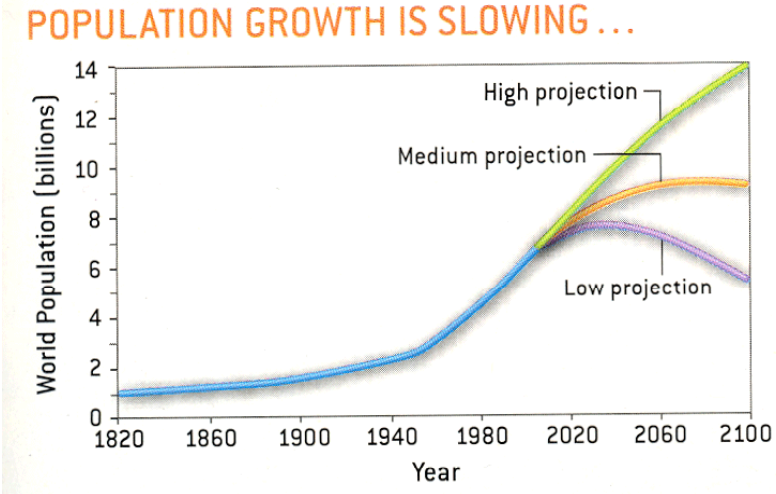
- **Definition:** "*Meeting the needs of the present generation without compromising the ability of future generations to meet their needs."* Brundtland-1987
  - The world has finite resources and a finite capacity to absorb the ecological burdens that humans may put on it was widely discussed by many scientists during this period.
  - Concerns raised from the exponential growth of human population and the effect of this growth on the environment.

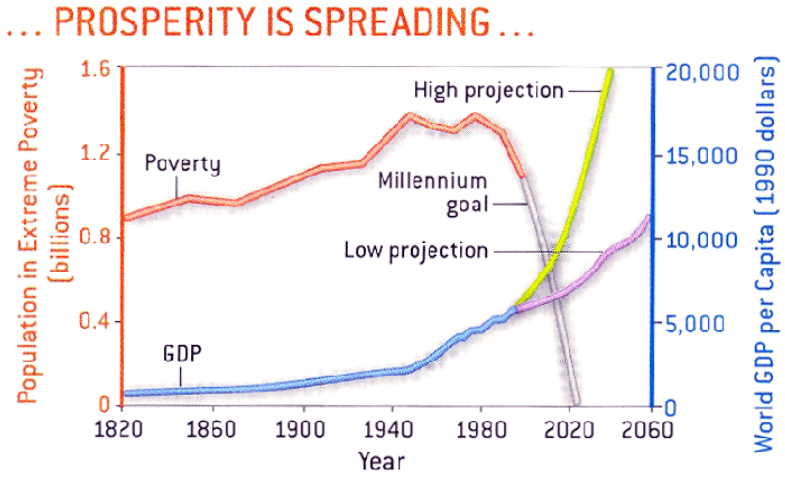
Human effects on the environment

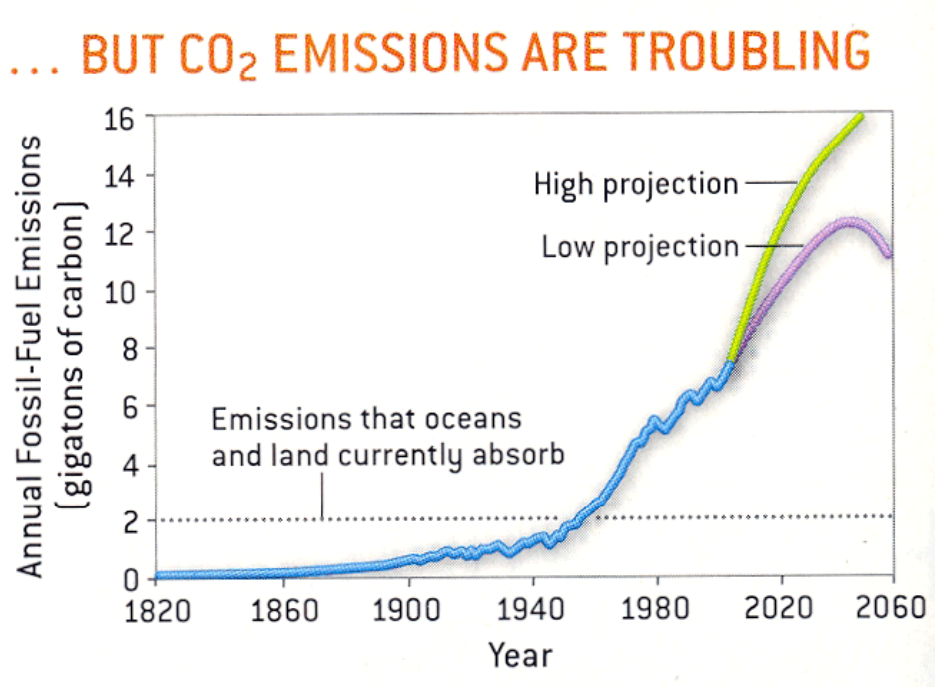
- Stratospheric ozone depletion
- Greenhouse gas emissions
- Global warming
- Acid rain
- Unsafe drinking water
- Hazardous/solid waste disposal
- Loss of plant and animal species, and human health and well-being.

- Environmental protection has usually taken the form of end-of-pipe solutions that often required considerable money and natural resources affect industry profit

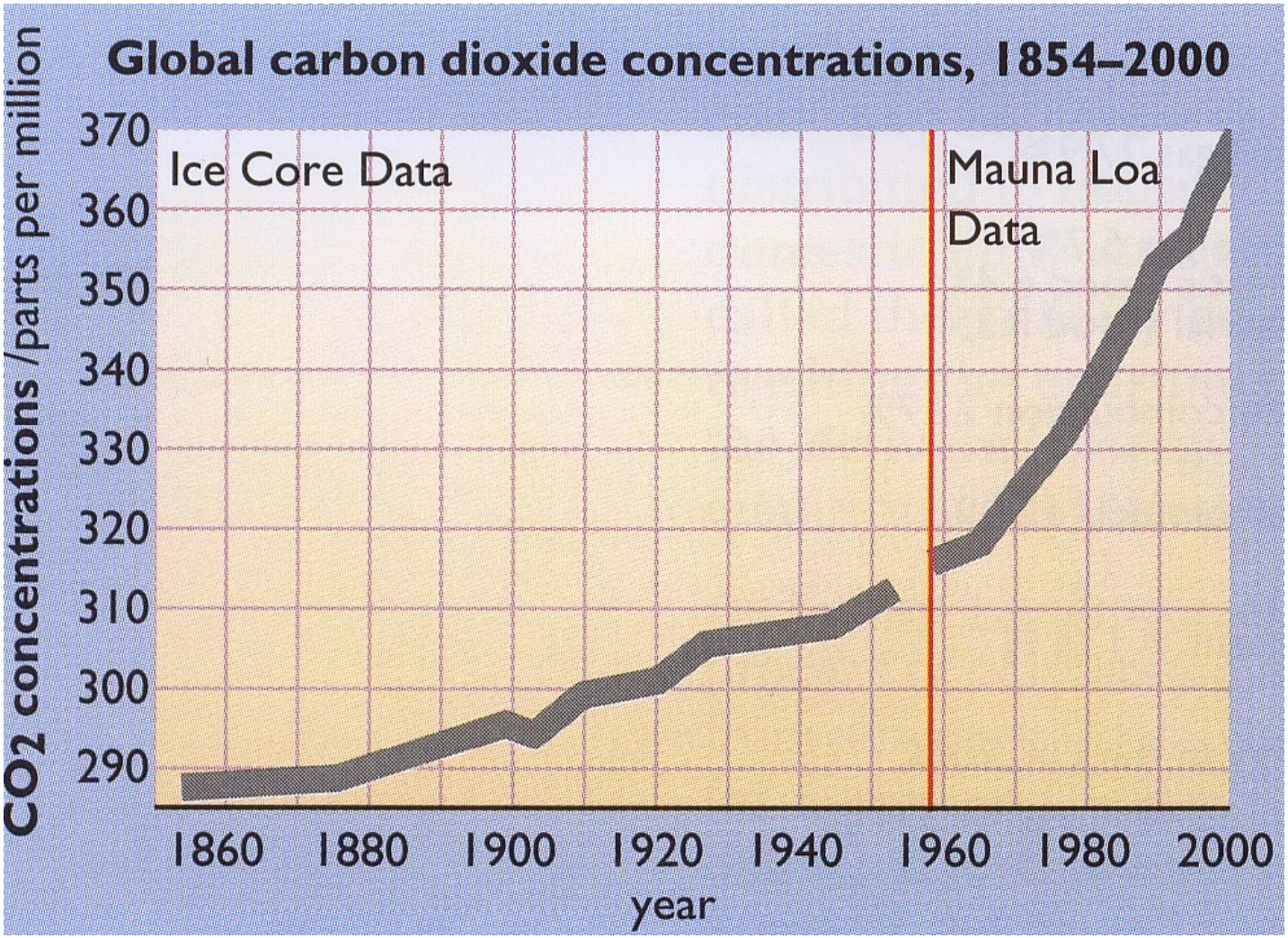
Population Growth - Emissions





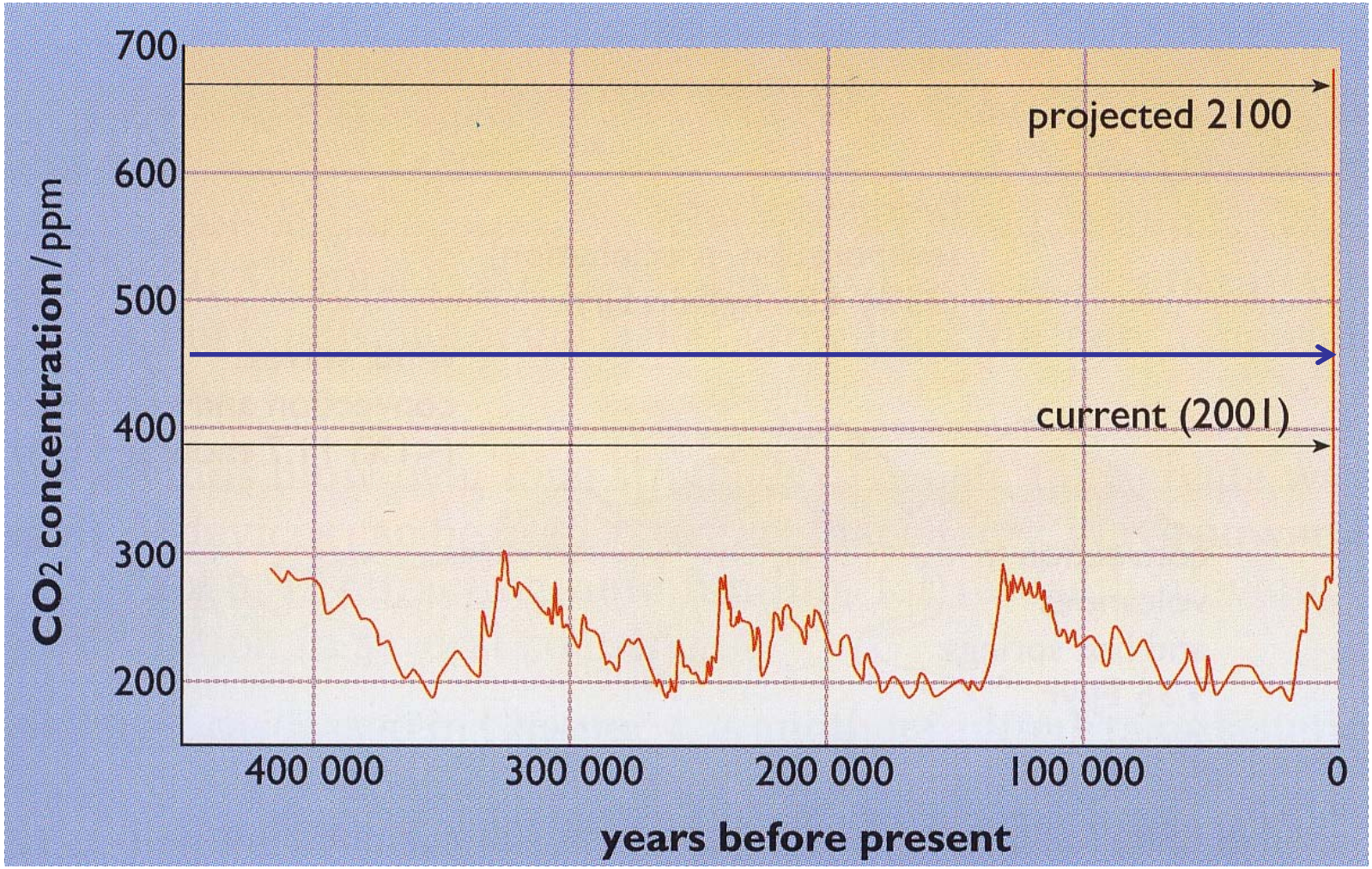


CO2 concentration in the atmosphere



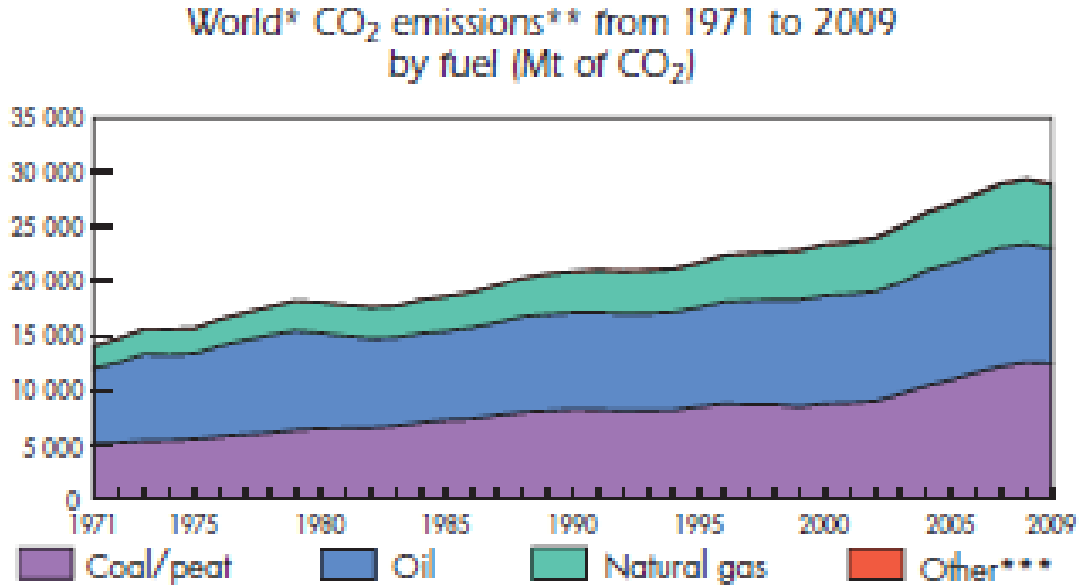
Source: Boyle, G. 2004

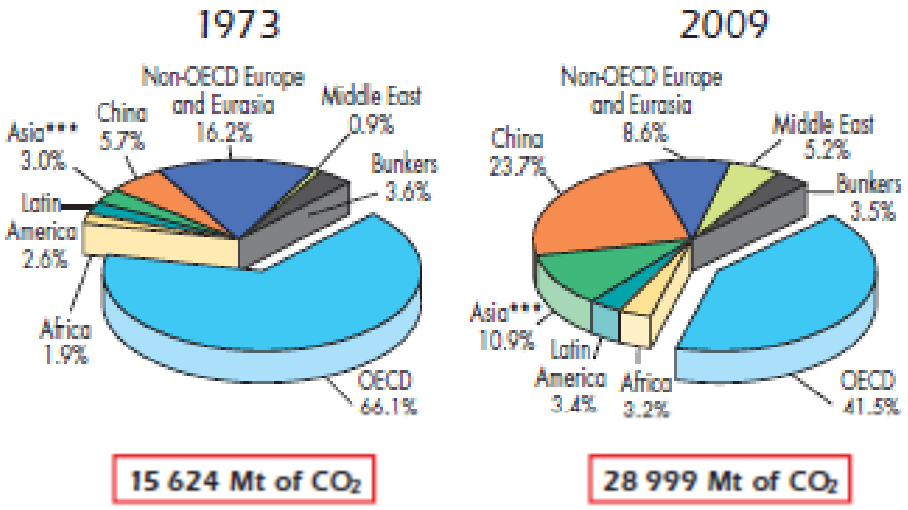
CO2 concentrations - forecast



Source: Boyle, G. 2004

CO2 emissions by Region



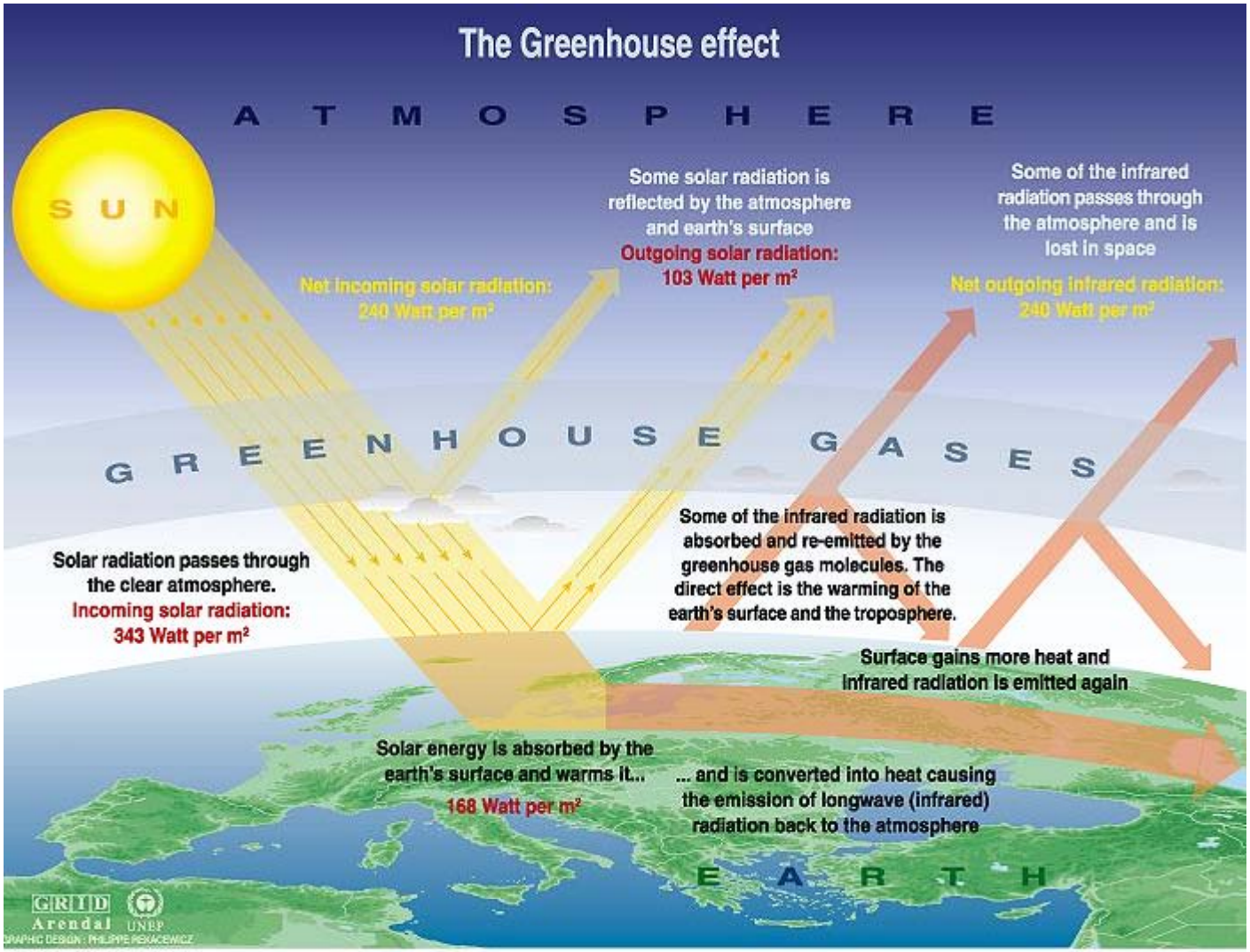


15 624 Mt of CO_2 **28 999 Mt of CO_2**

**World includes international aviation and international marine bunkers, which are shown together as Bunkers. **Calculated using the IEA's energy balances and the Revised 1996 IPCC Guidelines. CO_2 emissions are from fuel combustion only. ***Asia excludes China.*

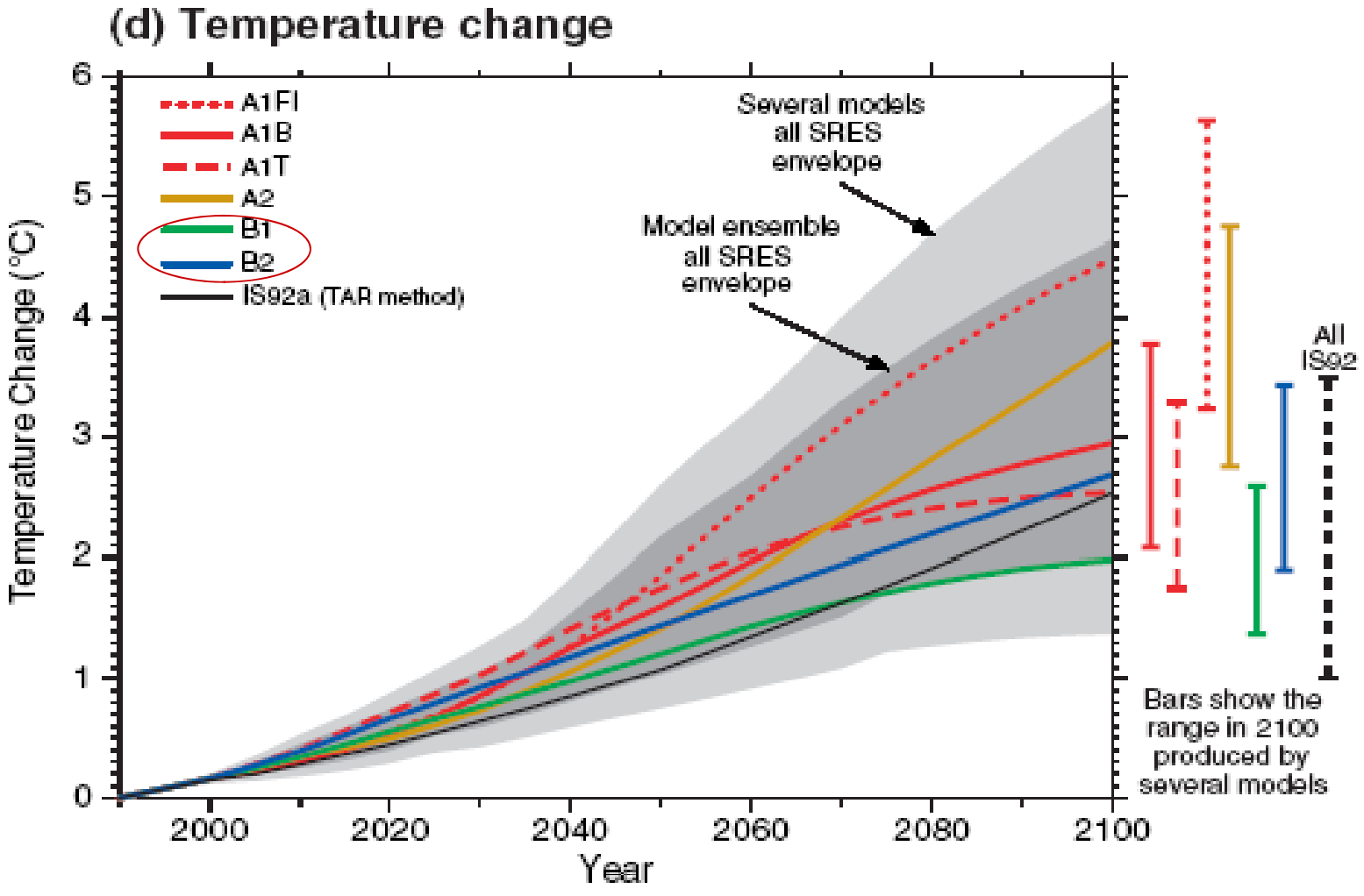
Source: IEA key energy statistics 2011

Global warming



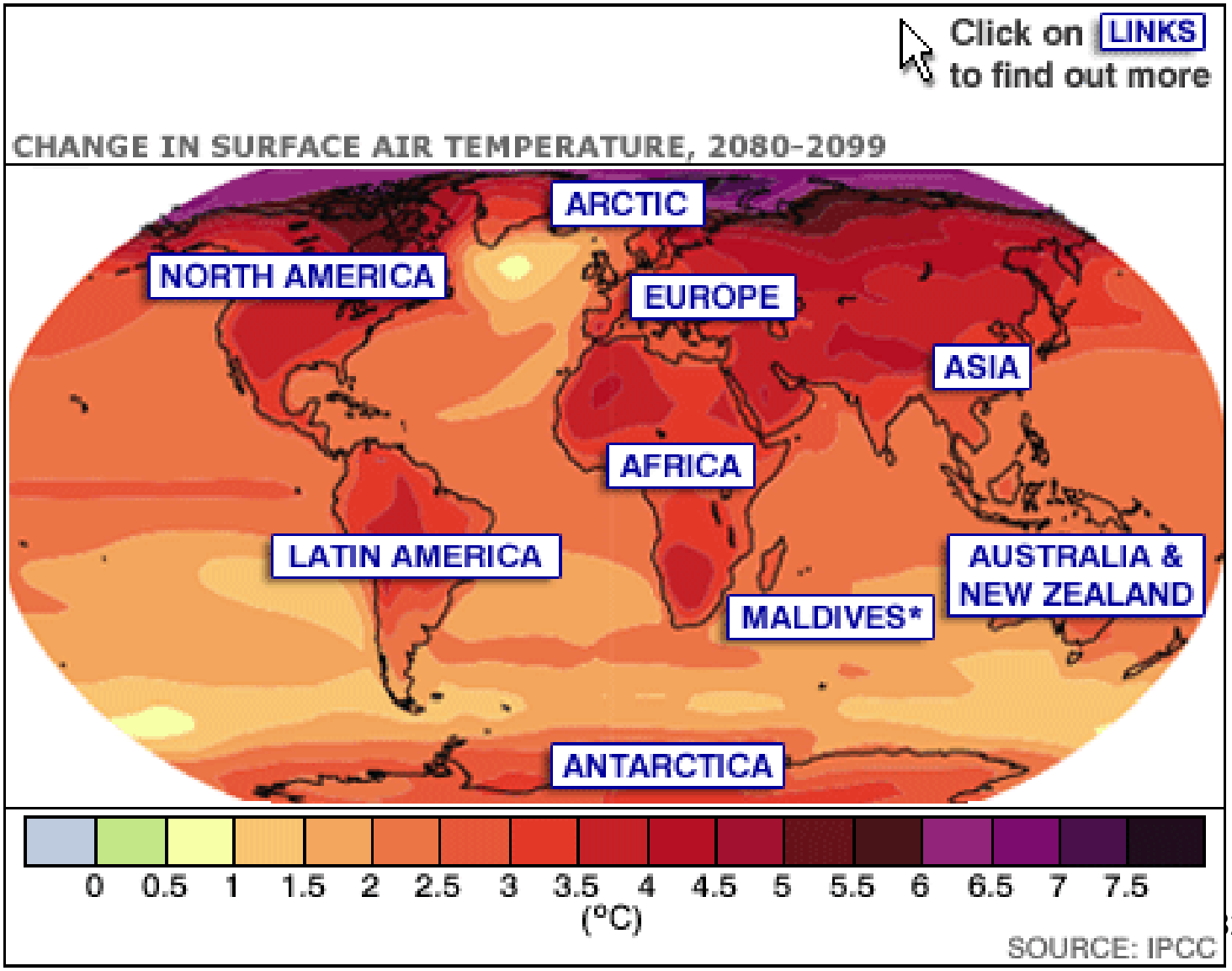
Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Climate change

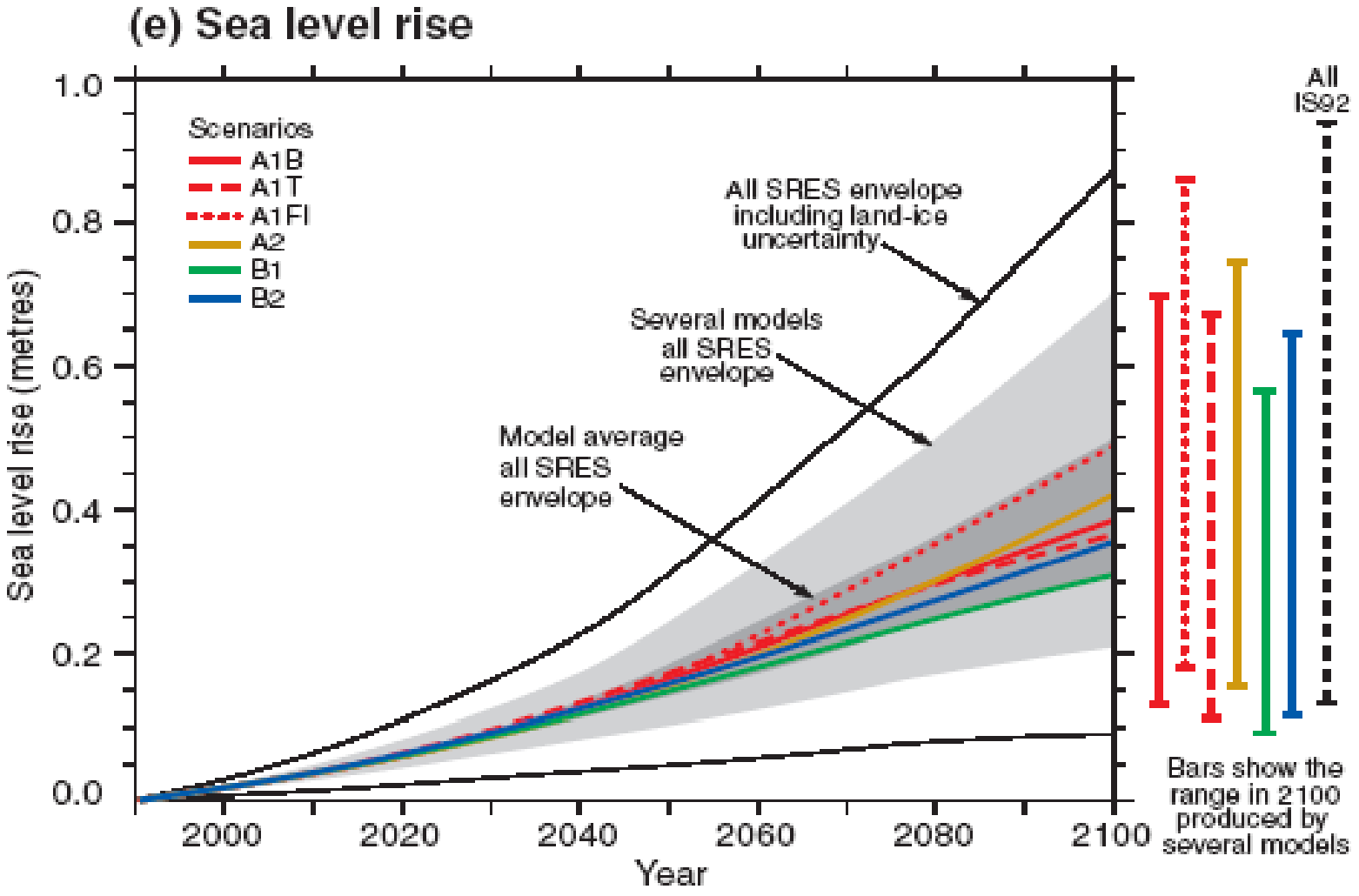


Source: IPCC

Global Warming - Forecast

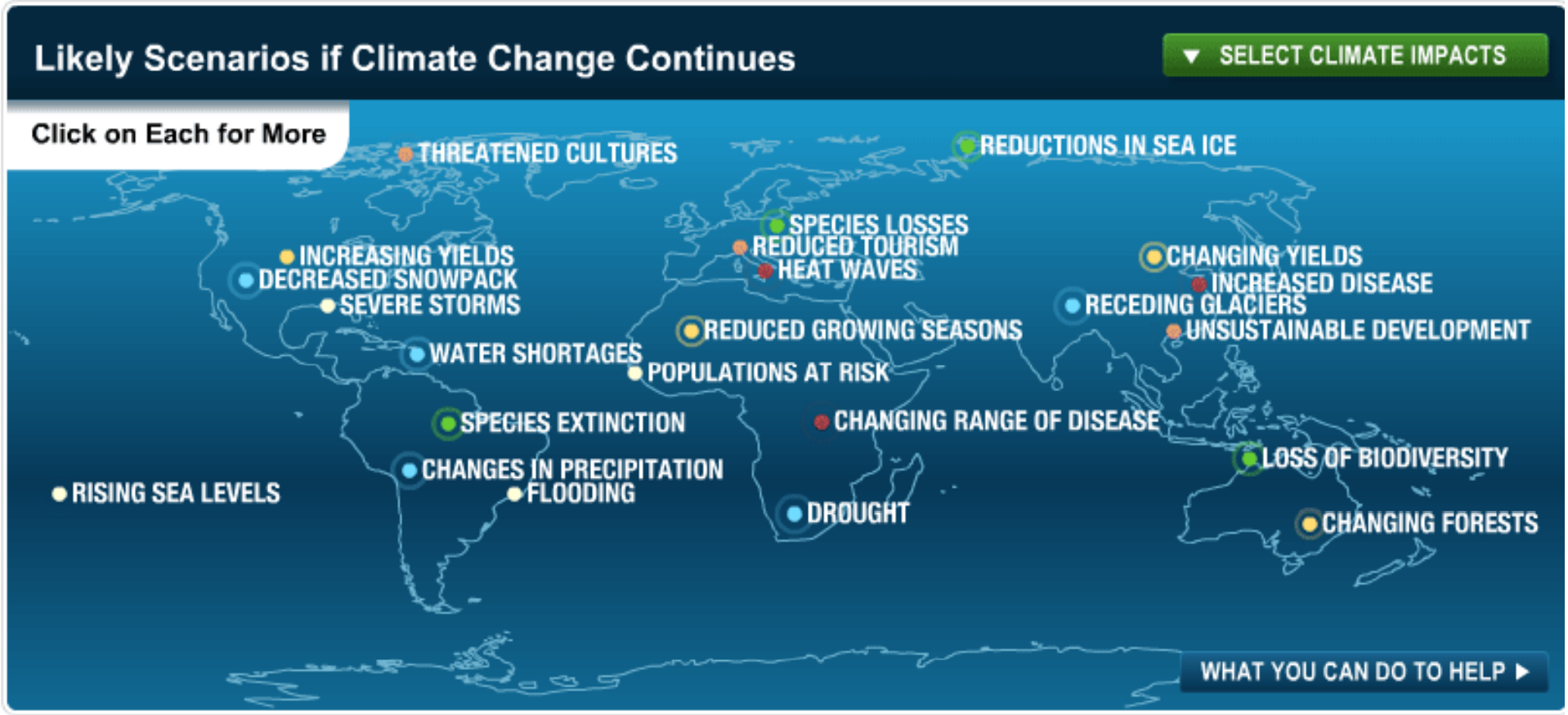


Climate change II



Source: IPCC

Climate Change Scenarios



Based on Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability, Summary for Policymakers, Intergovernmental Panel on Climate Change, April 2007.

Source: National Geographic

Climate change forecast

From the national geographic

- http://www.youtube.com/watch?v=2_ZQRIsn2pA&feature=PlayList&p=779E289383DA723E
- http://www.youtube.com/watch?v=P-0_gDXqYeQ&feature=PlayList&p=779E289383DA723E&index=4
- http://www.youtube.com/watch?v=6rdLu7wiZOE&feature=PlayList&p=779E289383DA723E&index=3
- http://www.youtube.com/watch?v=skFrR3g4BRQ
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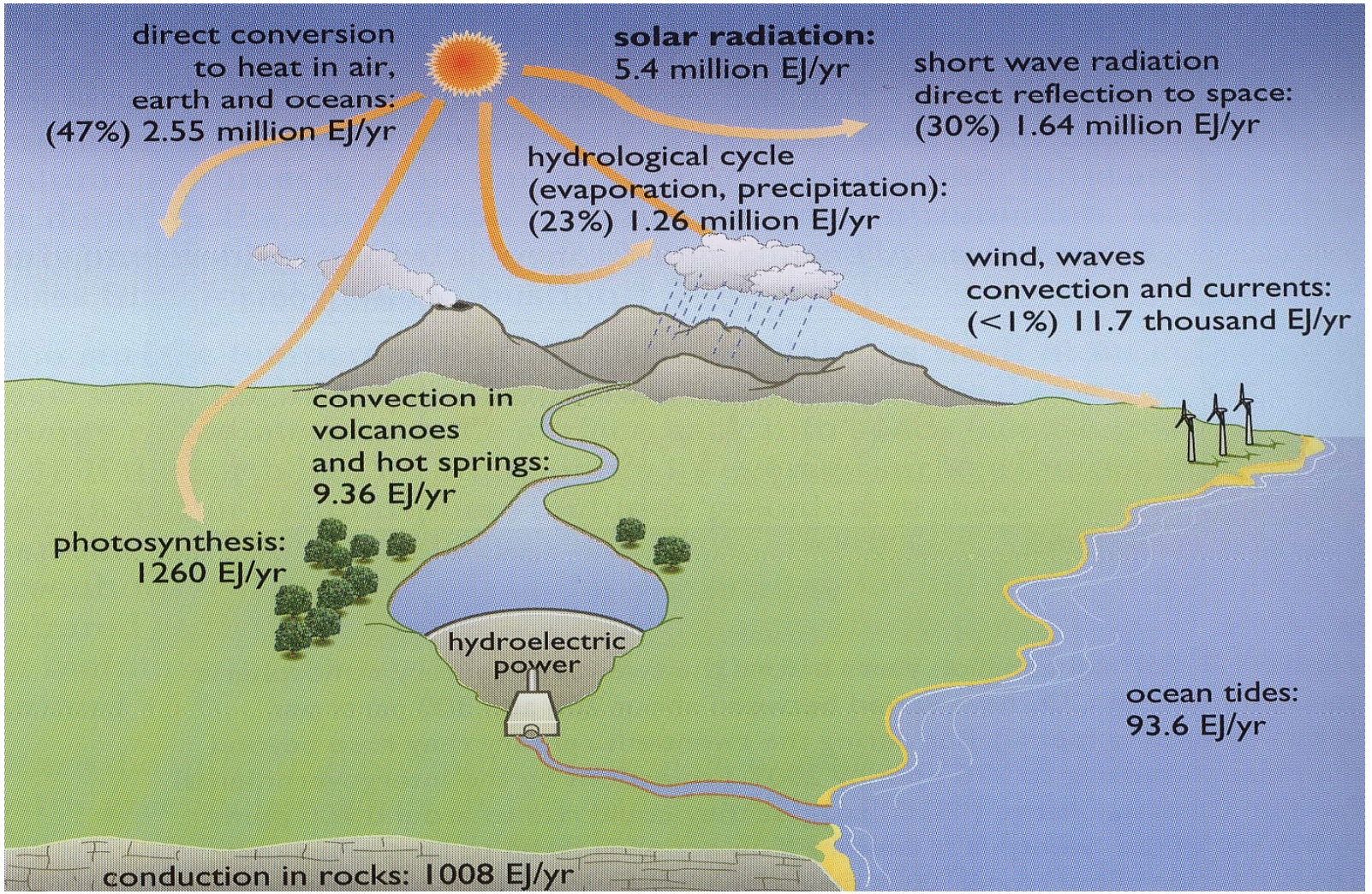
- http://www.youtube.com/watch?v=O8qmaAMK4cM

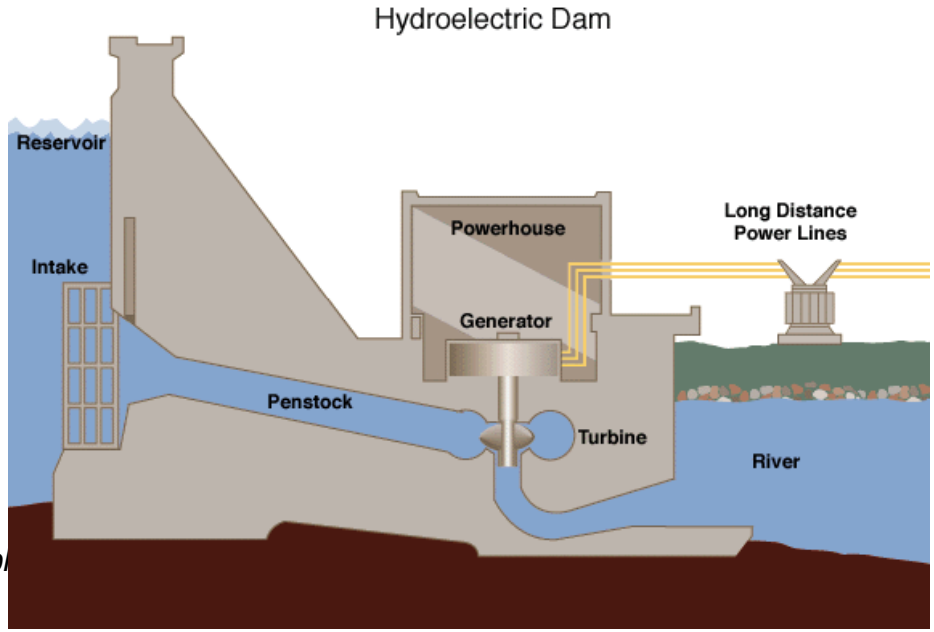
Renewable energy



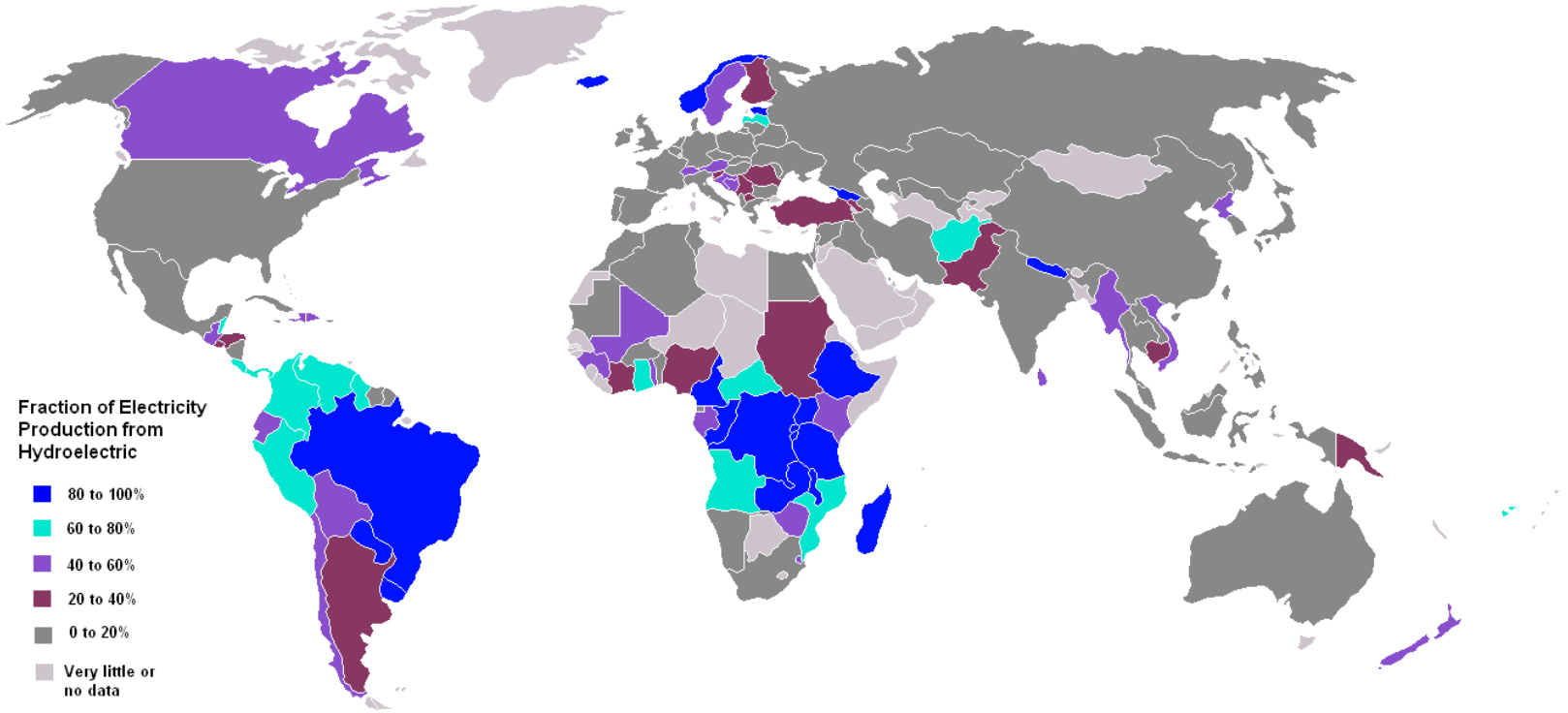
Source: Boyle, G. 2004

Hydropower

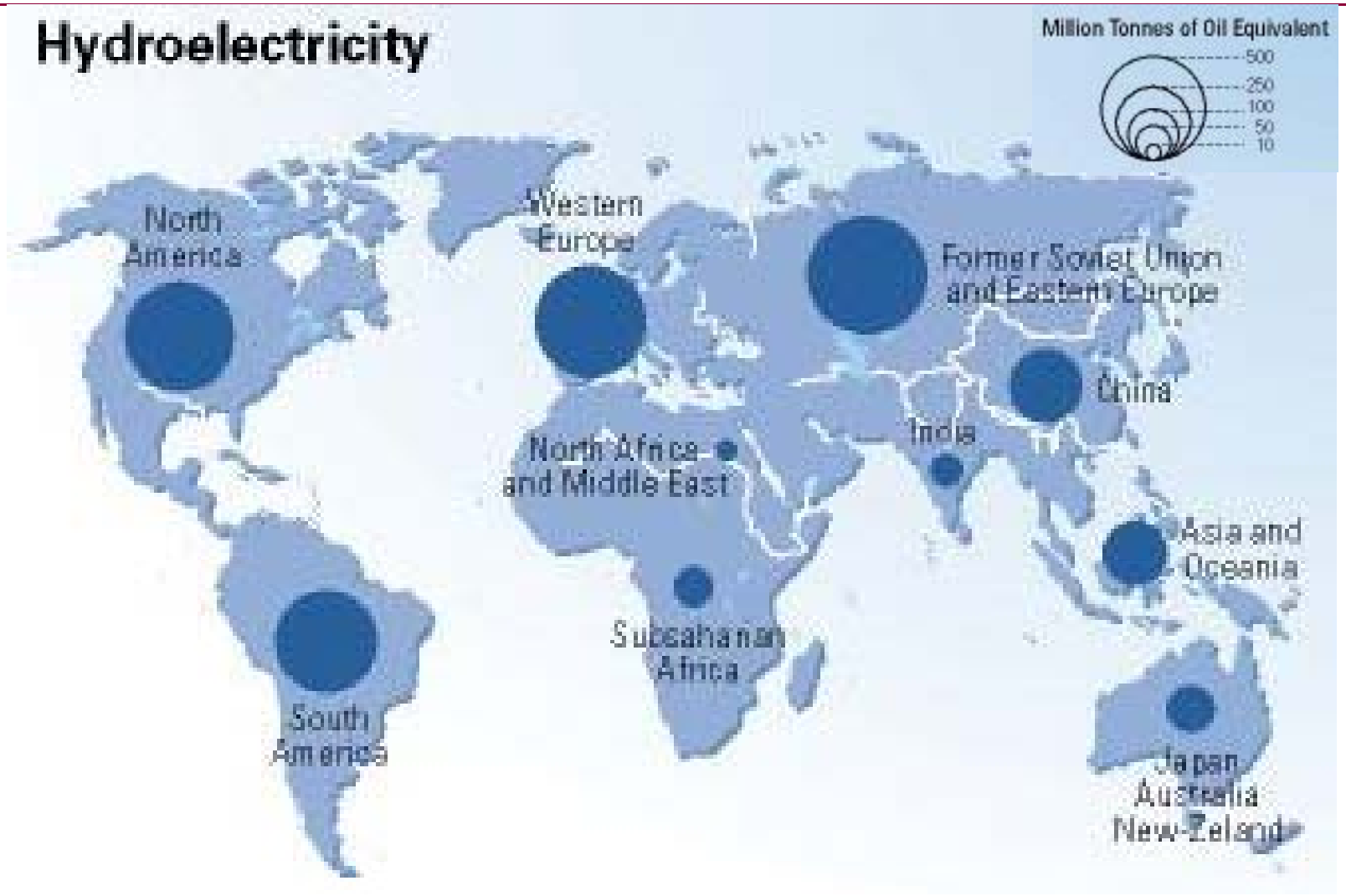
- Is one of the prevailing energy-producing technologies.
- It provides about 20% of the world's electricity. In the "developing world" the proportion rises up to 40%.
- Hydrologic Cycle



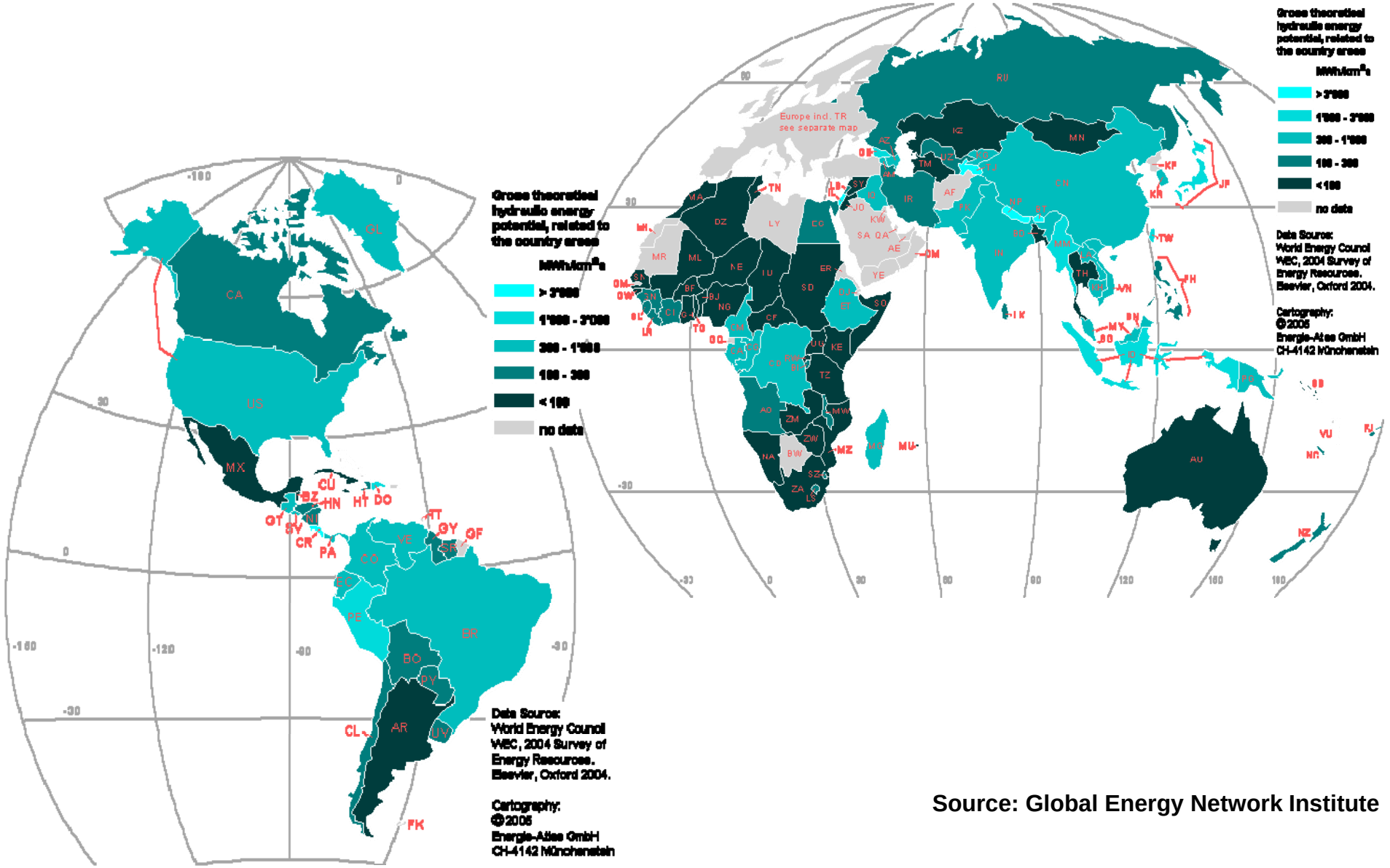
Electricity Production from Hydropower



Hydropower Potential

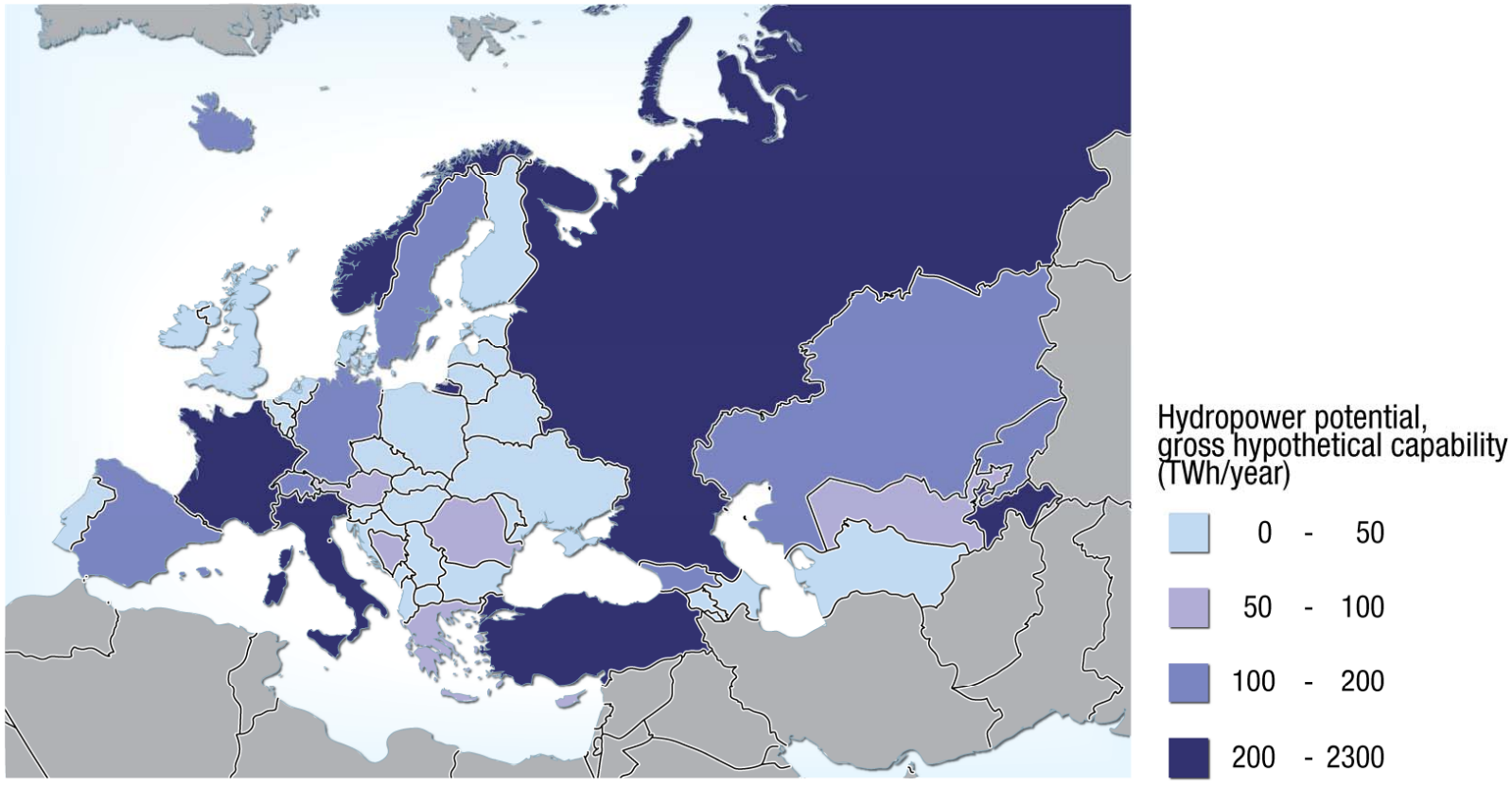


Hydropower Potential by Region



Source: Global Energy Network Institute

Hydropower potential in Europe



Source: 2012 UNEP/GRID-Arendal

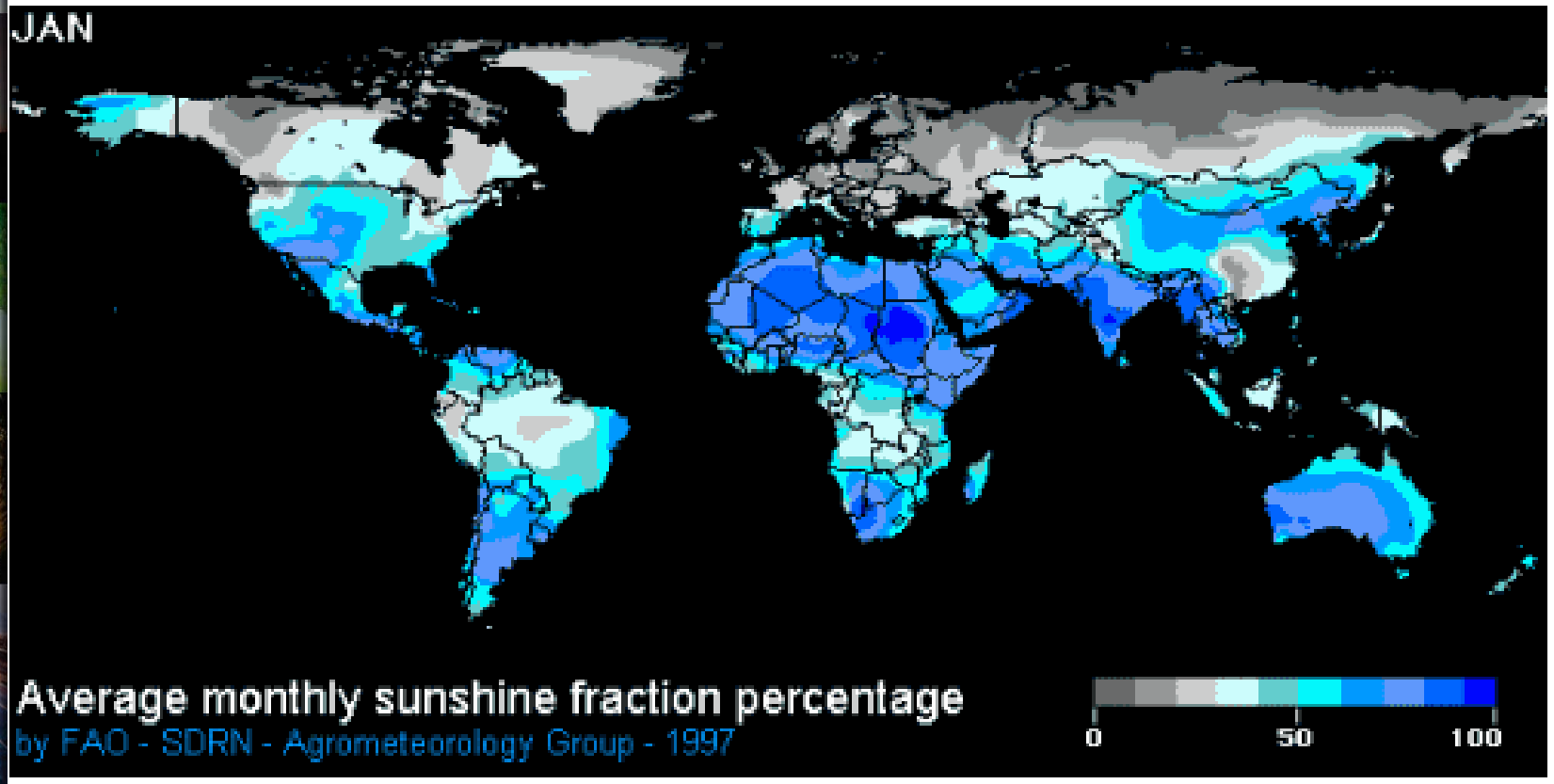
Solar Energy

- The amount of solar energy incident on the earth every year is:
  - Equivalent to 160 times the energy stored in the world’s proven reserves of fossil fuels
  - Equivalent to more than 15 000 times the world's annual use of fossil and nuclear fuels and hydropower

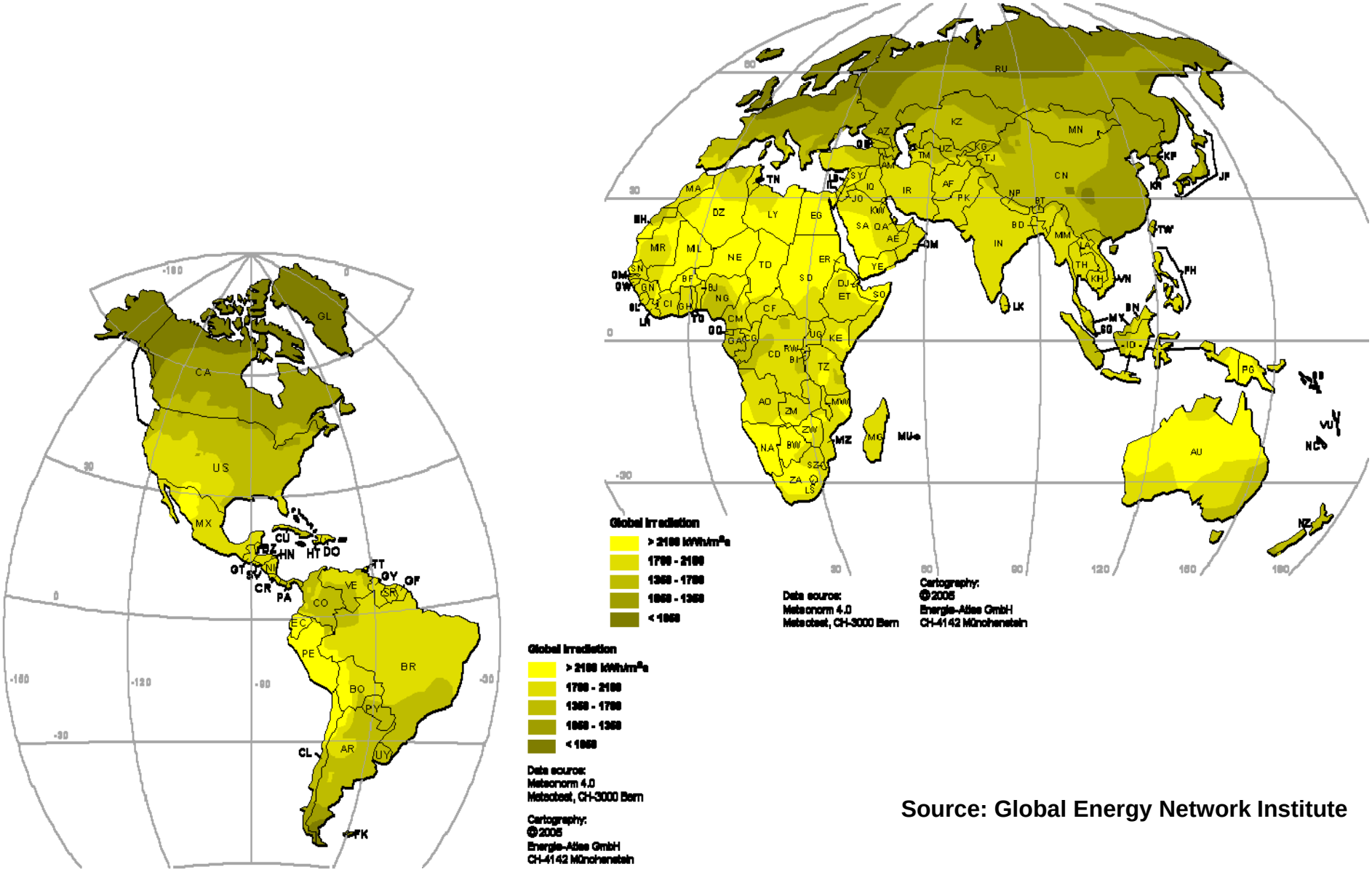
Solar energy

- Three different technologies contribute to the capture and application of solar energy: **solar photovoltaics** (PV) and **concentrating solar power** (CSP) to provide electricity, and **solar collectors** to provide directly usable heat (or cooling).

Solar Energy



Solar energy irradiation on the earth every year

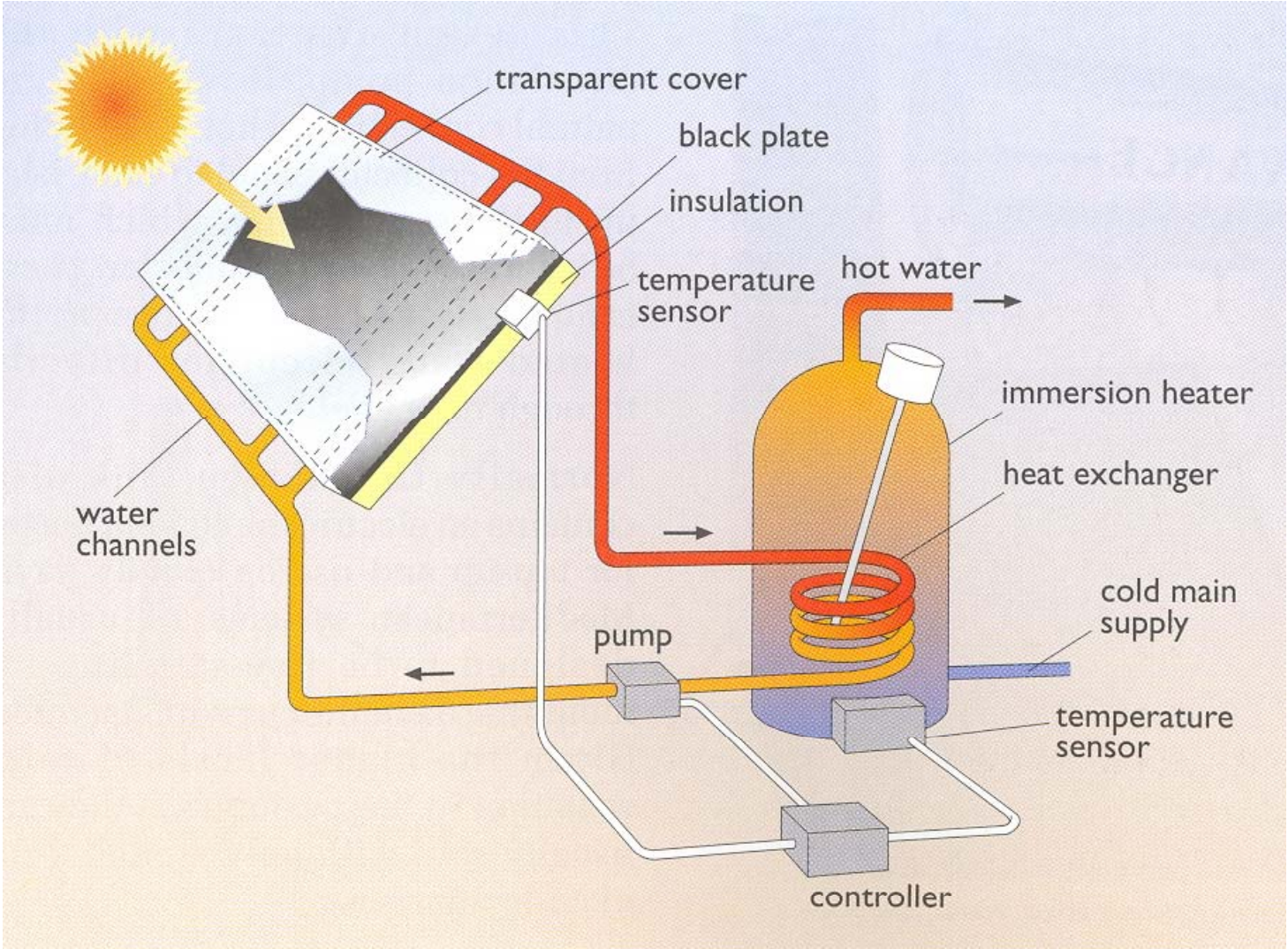


Source: Global Energy Network Institute

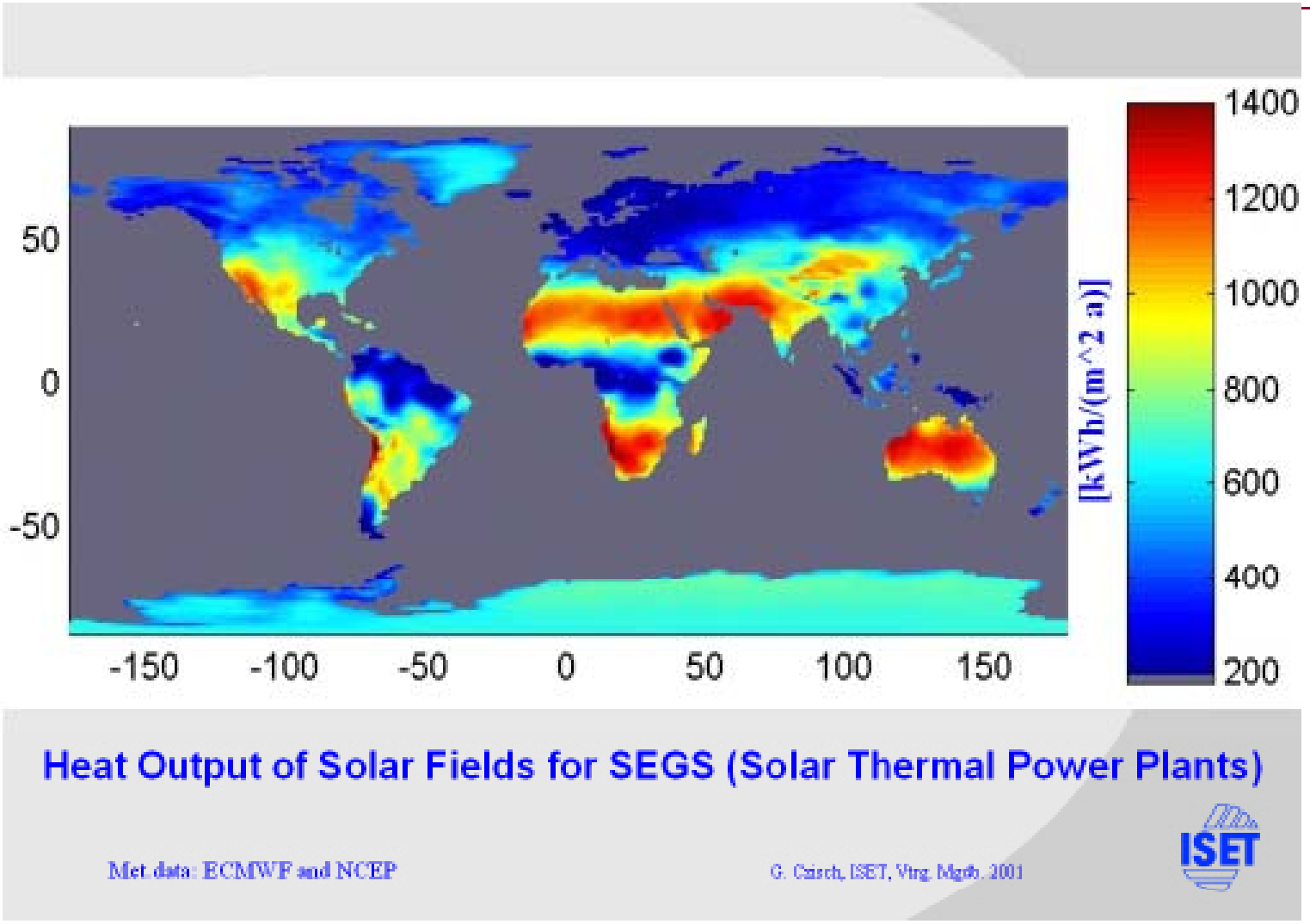
Solar Thermal

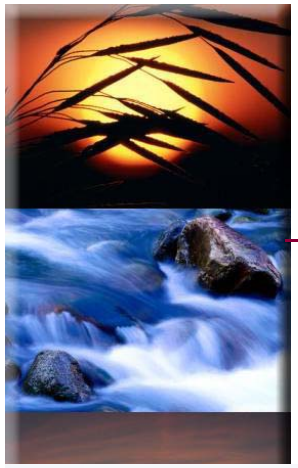
- Solar energy can be used directly for different purposes such as:
  - Space or water heating at relative low temperatures by absoption in solar collectors.
  - Passive heating in buildings designed to take advantage of solar energy.
  - Generation of electricity by concentrating the solar energy in parabolic mirrors that heat up the water to several thousand C

Solar Thermal Collectors



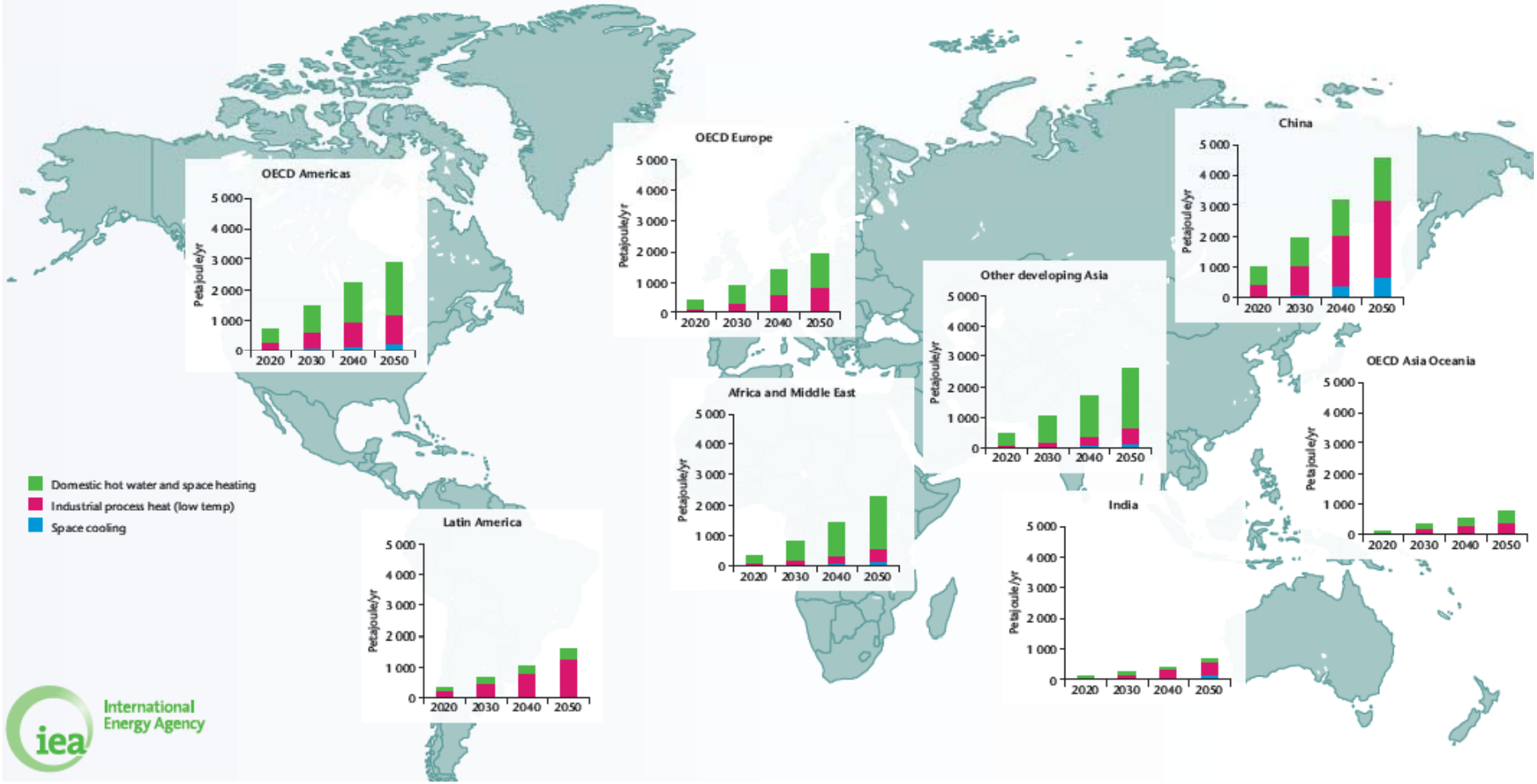
Solar Thermal Production





Solar heating and cooling potential

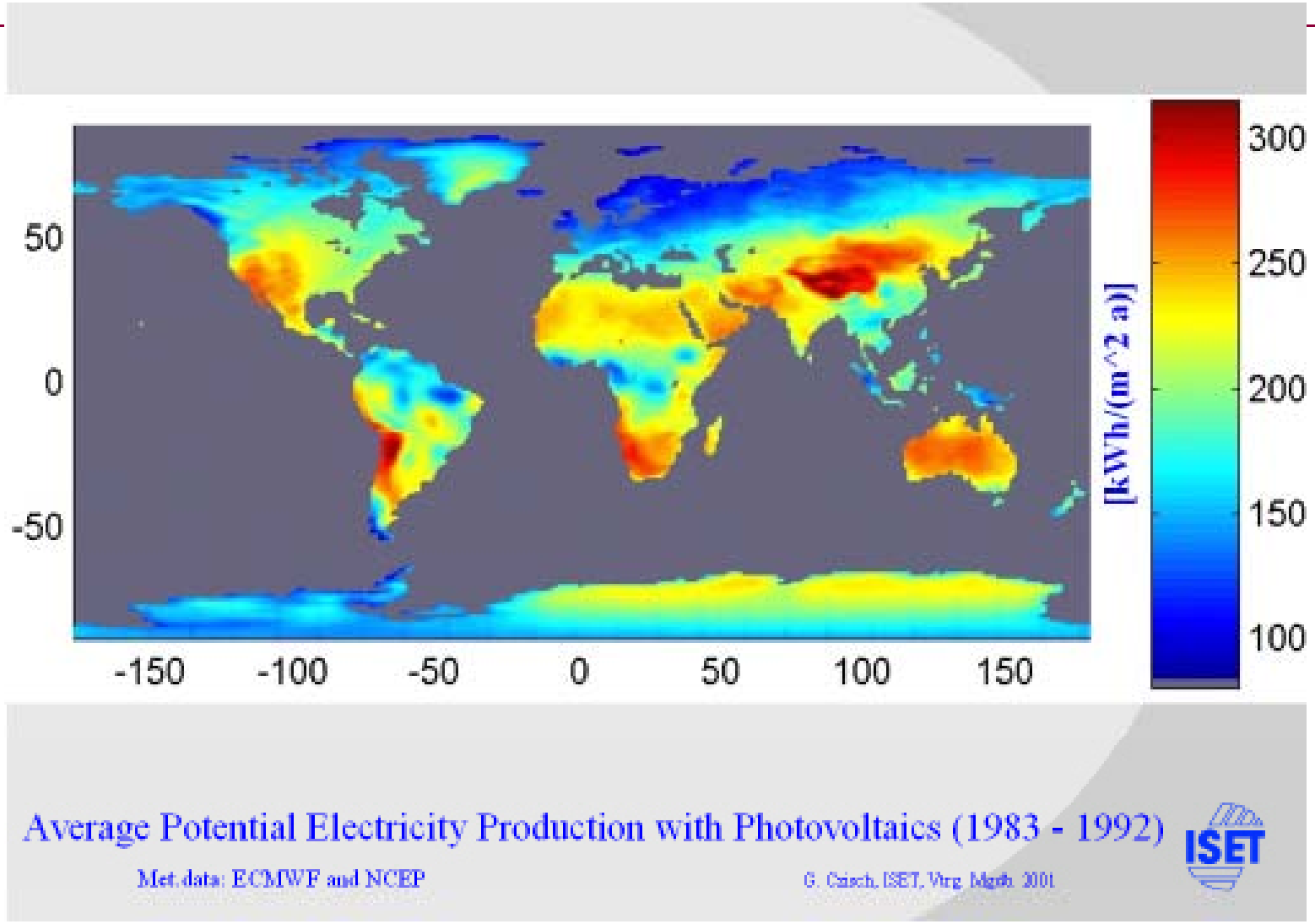
Regional solar heating and cooling generation in the buildings sector and industry



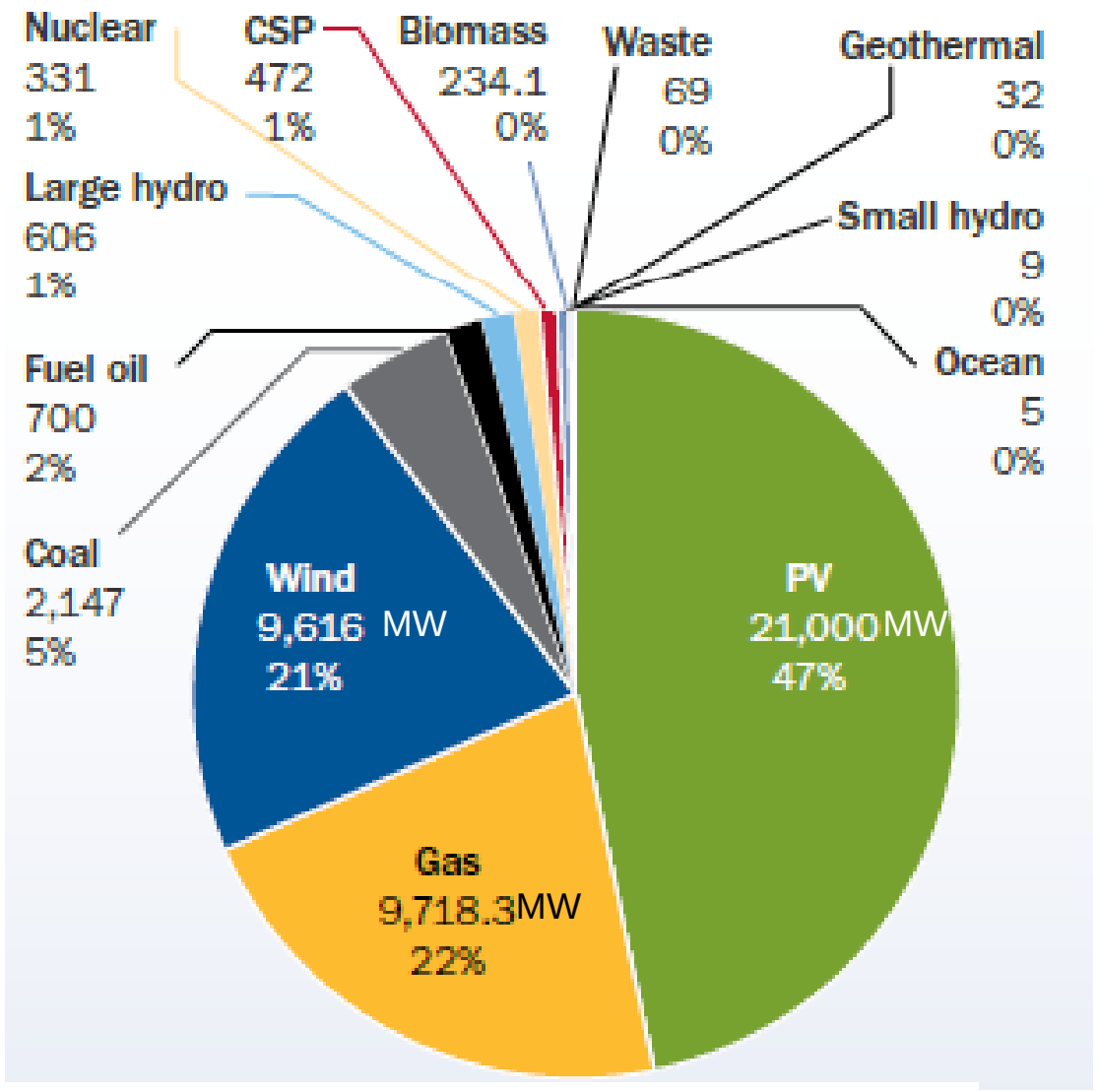
Photovoltaics

- Photovoltaics (PV) convert directly the solar energy into electricity in a solid-state device made from silicon.
- It is based on the photovoltaic effect.

Electricity Production with PV



PVs in Europe – Sahre of the installed capacity in 2011



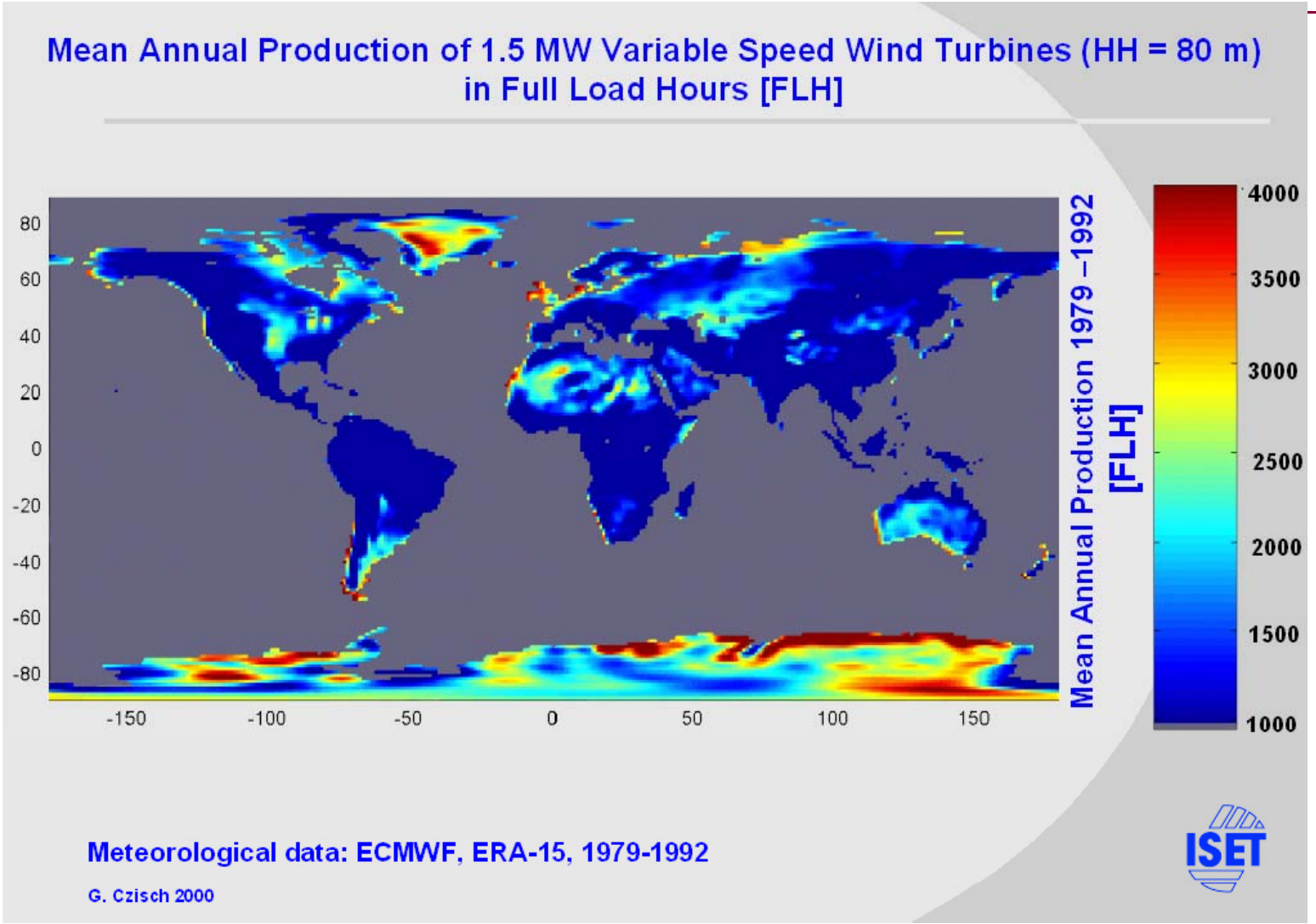
Source: The European Wind Energy Association, 2012

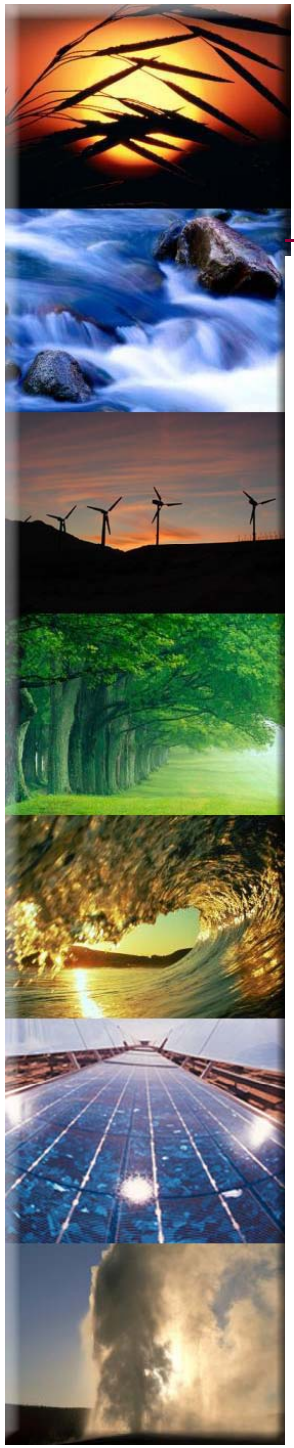
Solar Energy Potential

Wind Energy

- Wind energy offers the potential to generate substantial amounts of electricity without the pollution problems of most conventional forms of energy

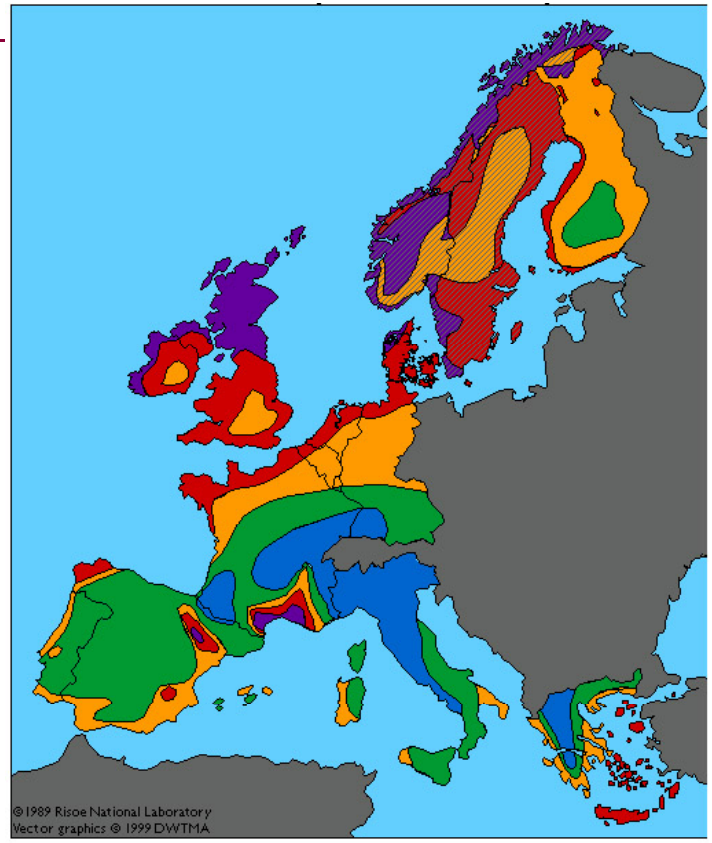
Wind Energy


Mean Annual Production of 1.5 MW Variable Speed Wind Turbines (HH = 80 m)
in Full Load Hours [FLH]
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
Mean Annual Production 1979 –1992
[FLH]
4000
3500
3000
2500
2000
1500
1000
Meteorological data: ECMWF, ERA-15, 1979-1992
G. Czisch 2000
ISET



Wind Energy in Europe

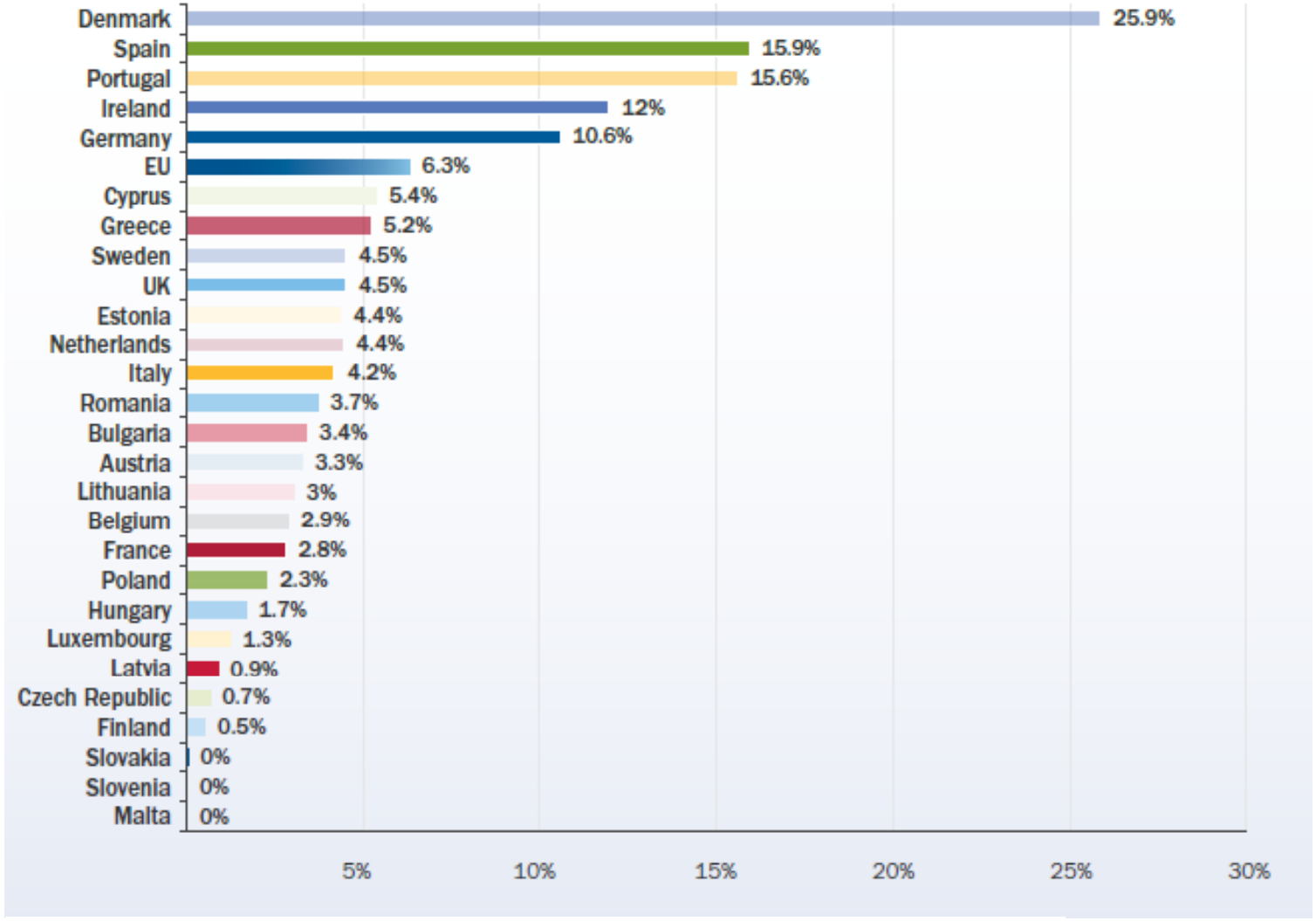
- The EU's total installed power capacity was 895'878 MW, with wind power increasing its share to 10.5% (93,957 MW).
- The wind capacity installed (2011) would, in a normal year, produce 204 TWh of electricity, representing 6.3% of electricity consumption



Wind Resources at 50 (45) m Above Ground Level

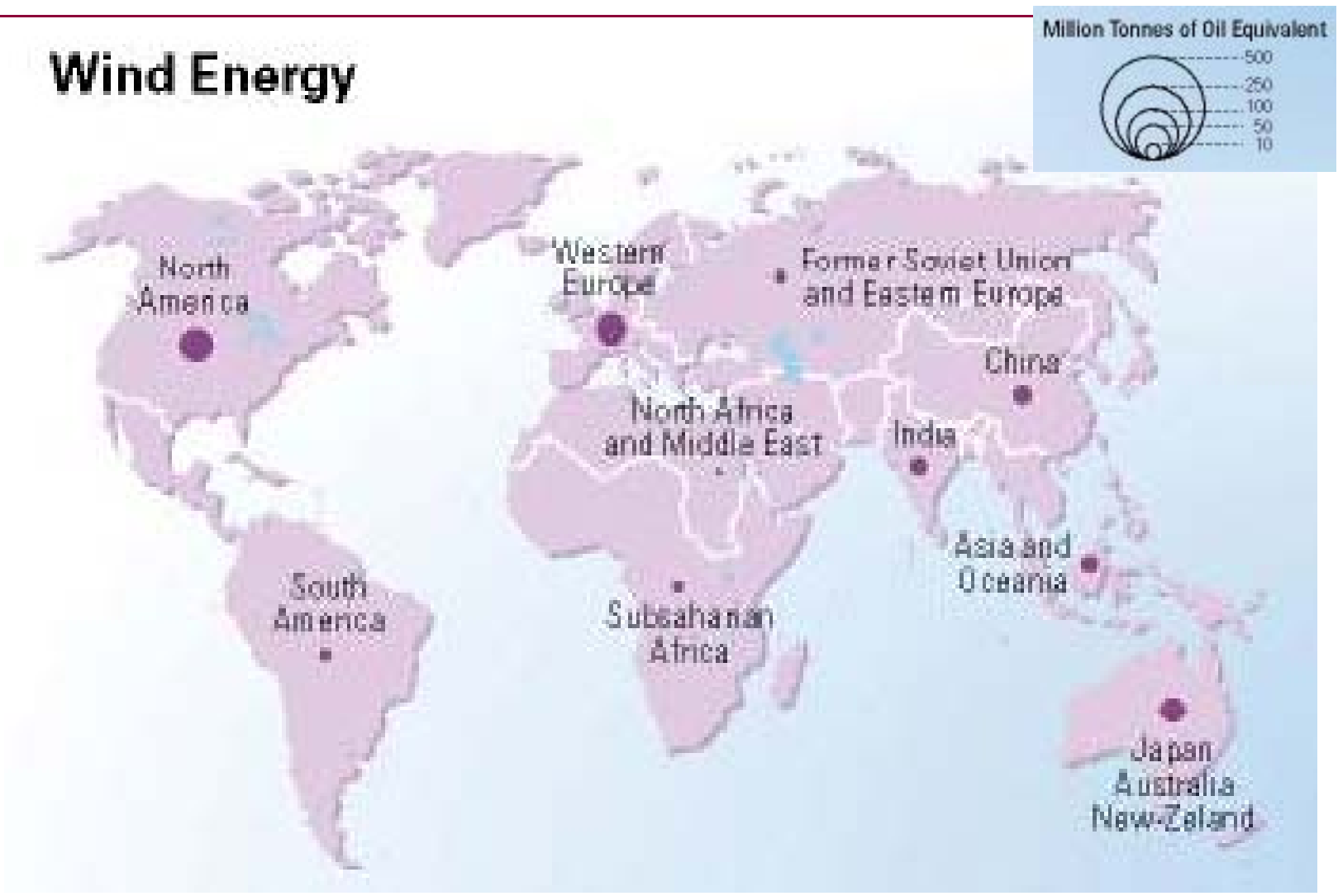
Colour	Sheltered terrain		Open plain		At a sea coast		Open sea		Hills and ridges	
	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²
	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400
			>7.5							
			5.5-7.5							
			<5.5							

Wind share of total electricity consumption in Europe (2011)

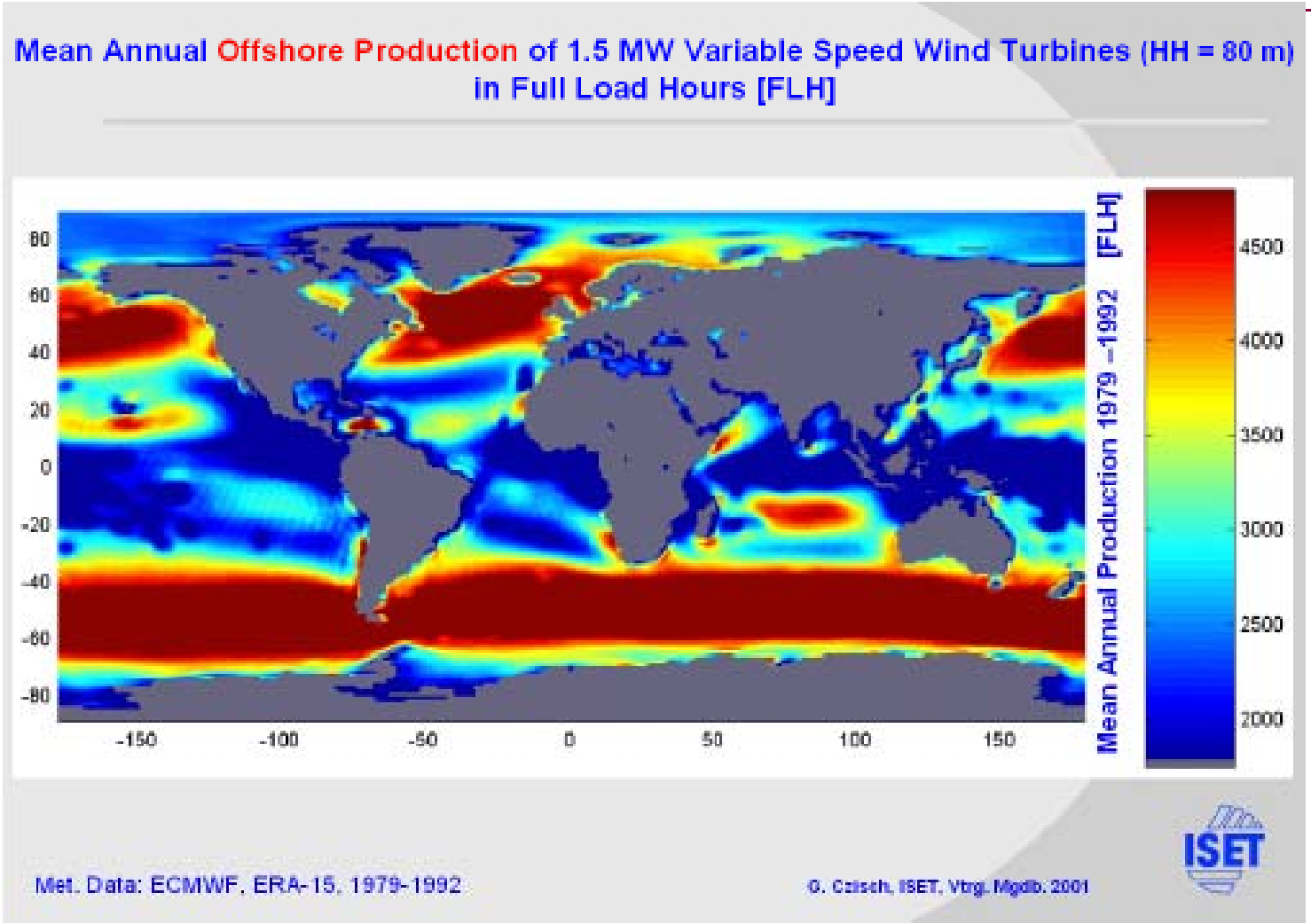


Source: The European Wind Energy Association, 2012

Wind Energy Potential



Offshore Wind Energy

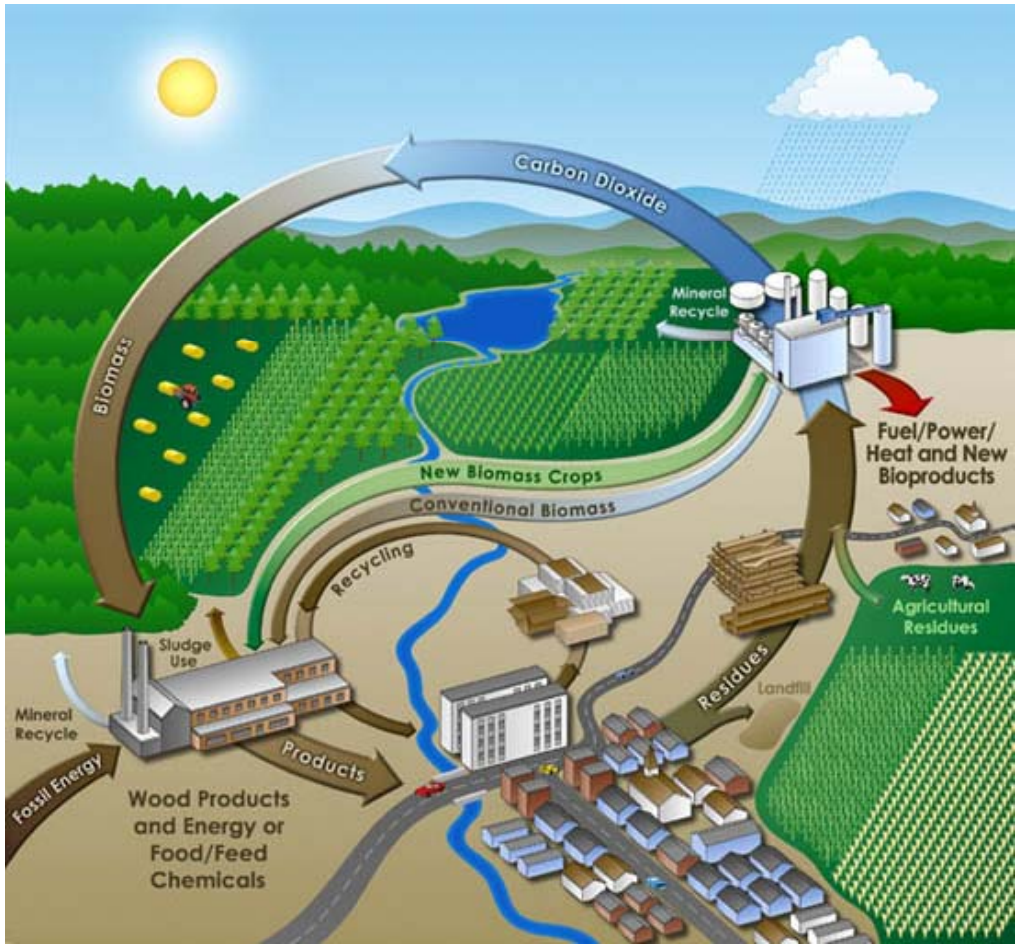


Biomass

- Biomass is one of the major world fuel sources, especially in the third world, wher it provides 40% of the requirements.
- Biomass is also important in some of the forest-rich part of the industrial nations.

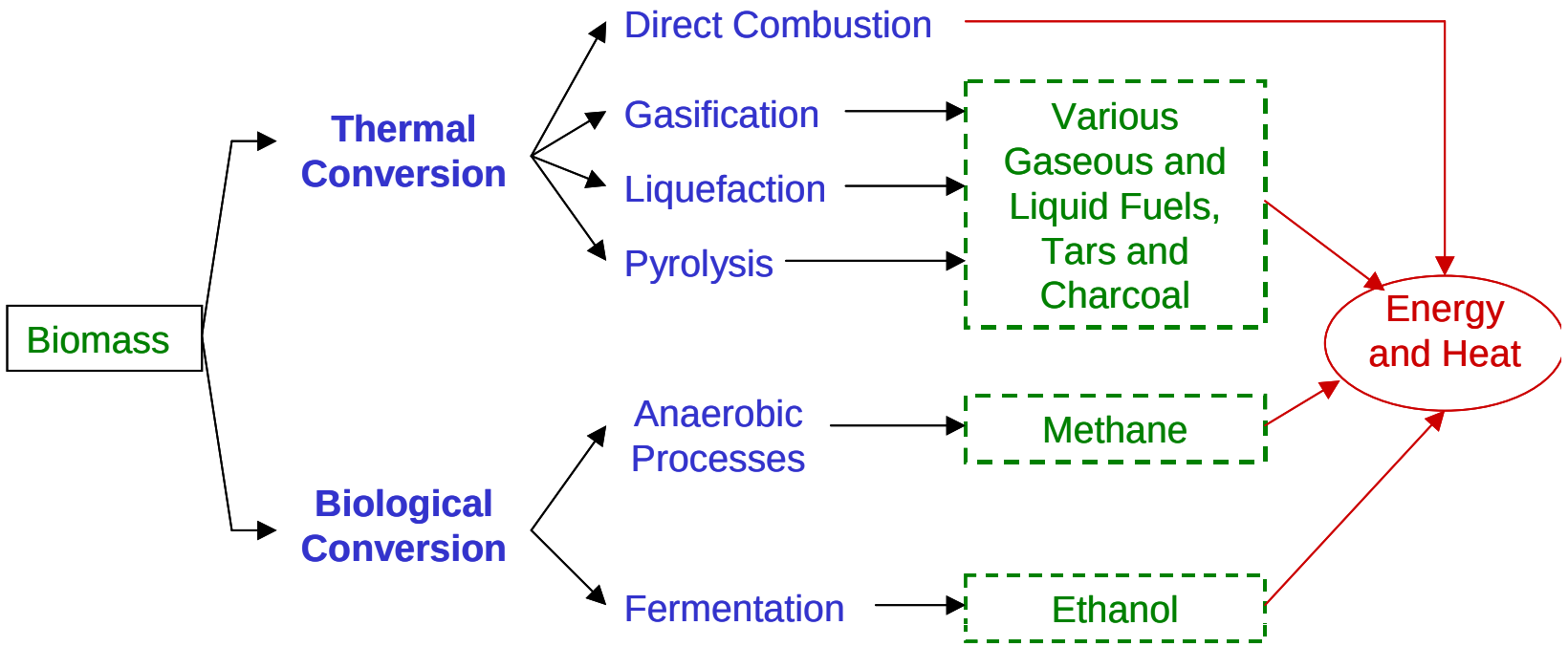
Biomass – CO_2 Neutral

- Biomass is considered CO_2 neutral

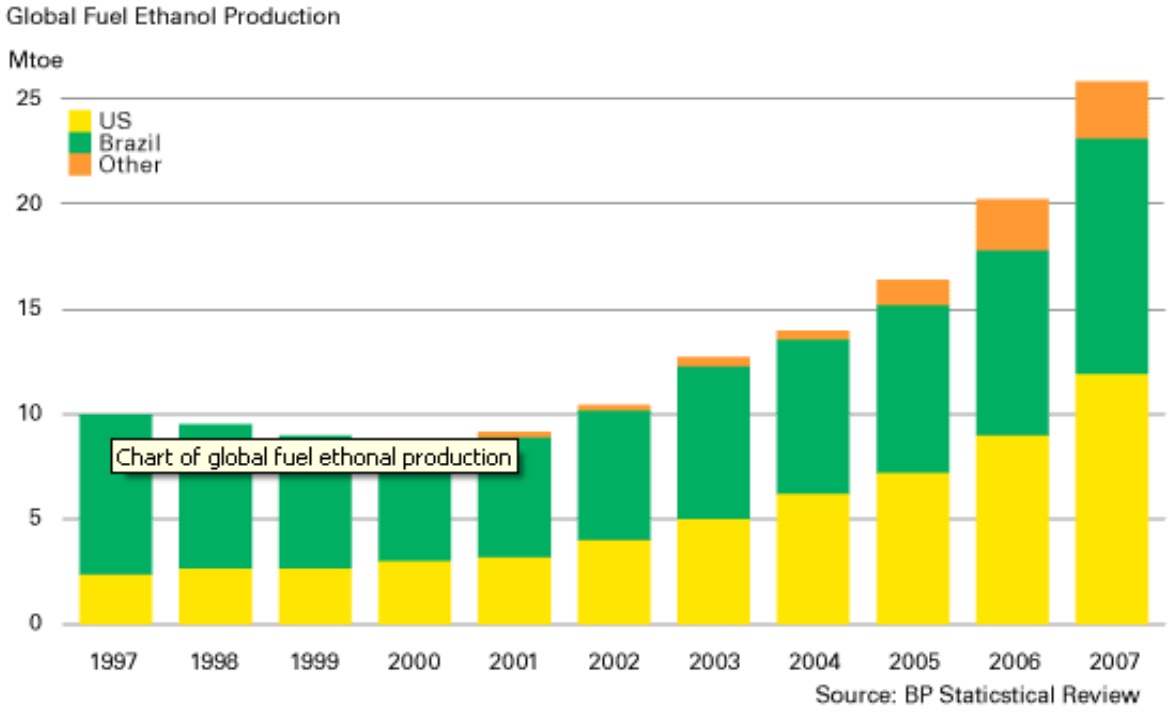


Source: ONRL

Biomass Conversion



Biofuels - Ethanol



Corn ethanol (USA)

- USA Production cost = 1.09 $/gallon
- Energy Balance -> 1 unit fossil fuel energy produces 1.3 units of energy from ethanol
- Greenhouse gases -> 22% less than gasoline (lbs/gallon)

Sugarcane ethanol (Brazil)

- Brazil Production cost = 0.87 $/gallon
- Energy Balance -> 1 unit fossil fuel energy produces 8 units of energy from ethanol
- Greenhouse gases -> 56% less than gasoline (lbs/gallon)

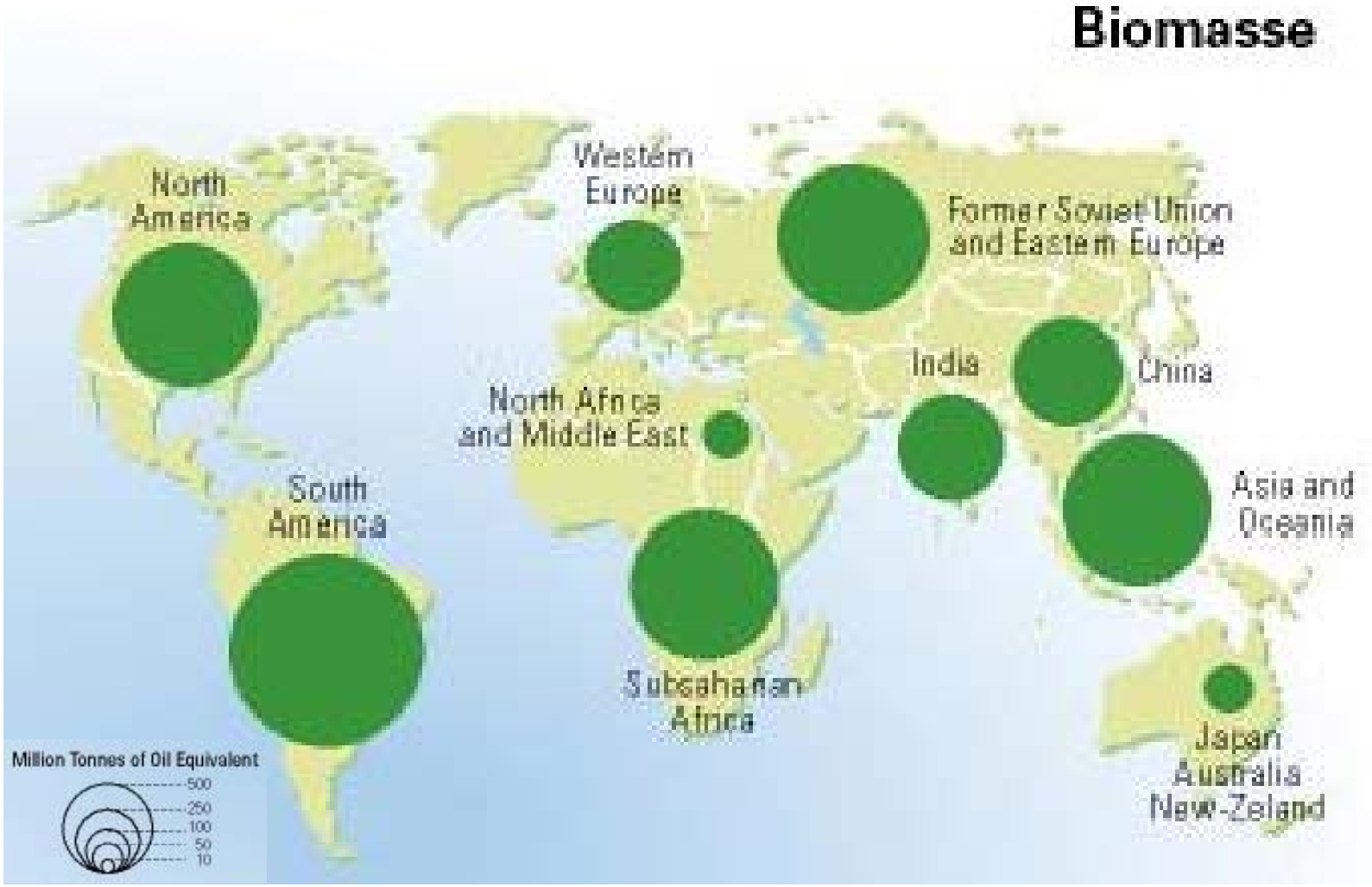
Bioethanol in Sweden

- Ethanol from wheat - Agroetanol (Norrköping)
  - The plant produces annually 50 million liters of ethanol intended for gasoline replacement and 45 000 tonnes of protein feed (DDGS).
  - The steam and electrical power needed to operate the plant both originate from renewable sources. The steam, which is primarily used for destillation and drying of feed, is produced in the bio-fuelled power plant close by.
- Cellulosic Ethanol - SEKAB (Örnsköldsvik)
  - It has a capacity of 300-400 litres of ethanol per 24 hours.
  - Current raw material used in the development process is wood chips from pine trees, but other raw materials such as bagasse from sugarcane, wheat and corn stover, energy grass and recycled waste are also of future interest for the project.

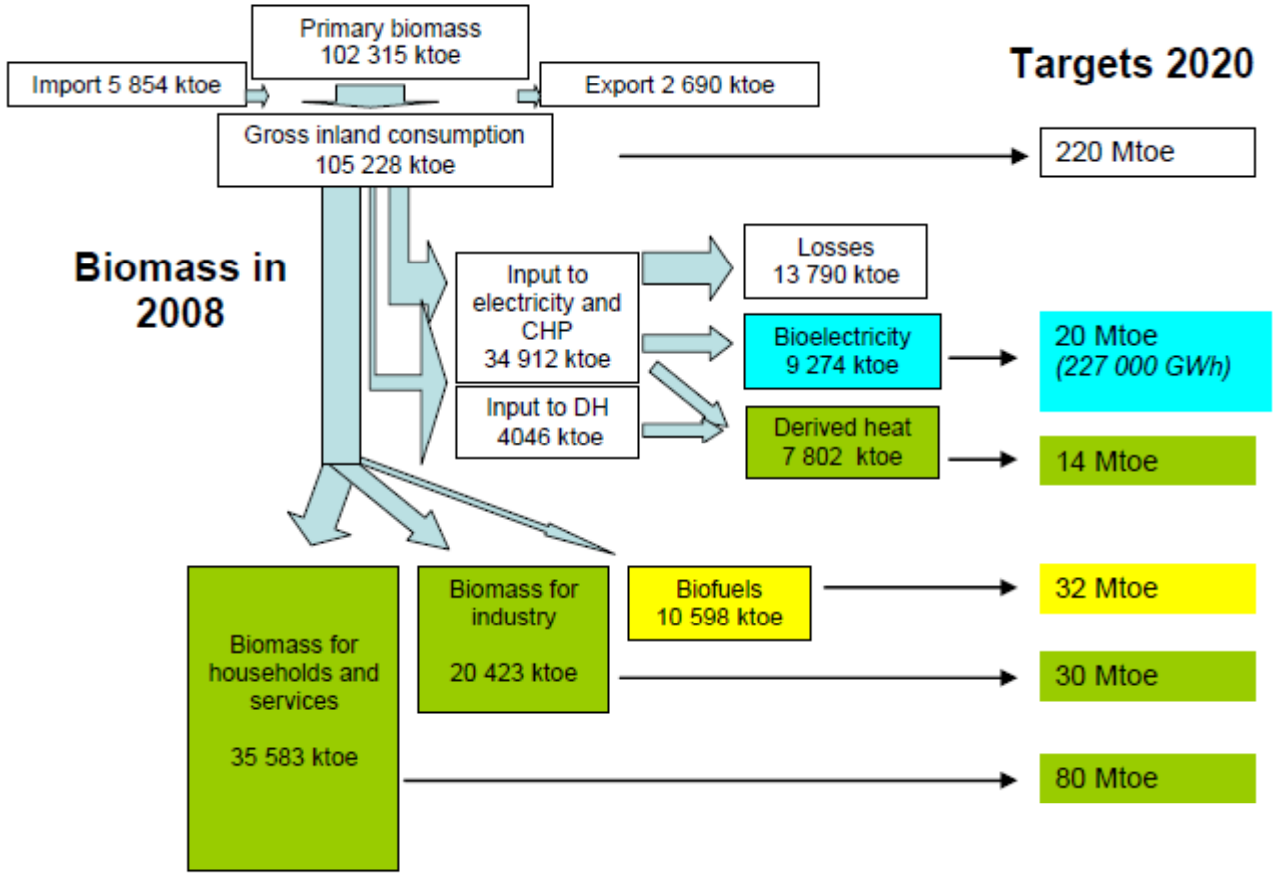
Biodiesel

- Energy balance of biodiesel production from canola oil -> 1 unit fossil fuel energy produces 2.5 units of energy from biodiesel
- Greenhouse gases -> 68% less than gasoline (lbs/gallon)

Biomass Potential



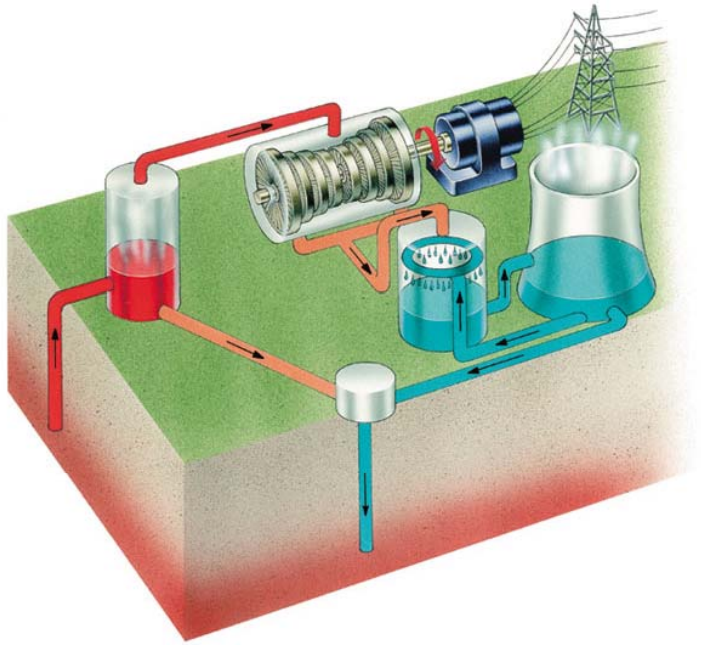
Biomass in Europe



Source: European Biomass Association 2011

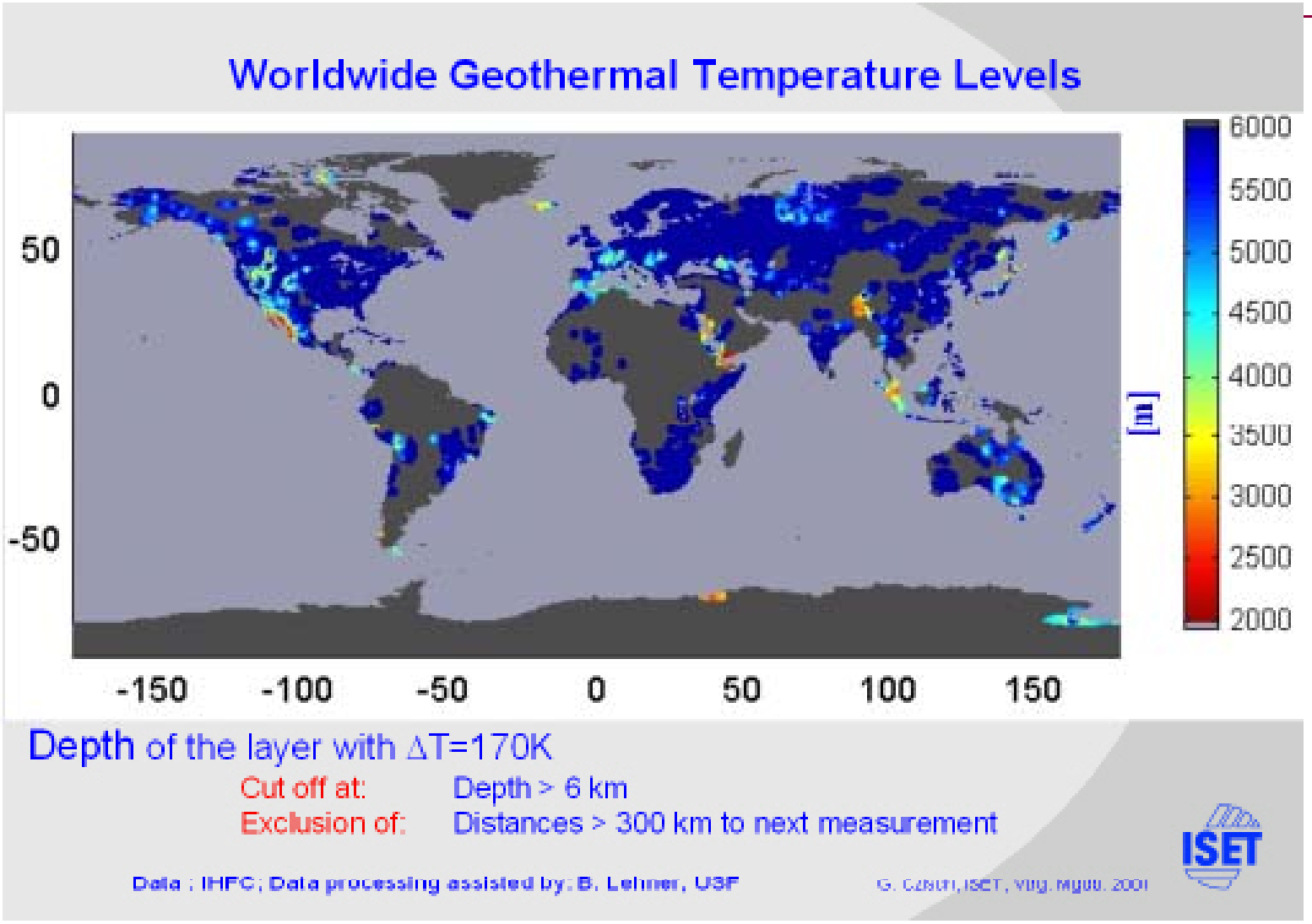
Geothermal Energy

- Geothermal energy results from heat stored in rock by th earth's natural heat flow.
- Geothermal energy can be directly used in industrial processes, space heating, domestic and leisure applications and electricity production.
- Suitable for base load generation

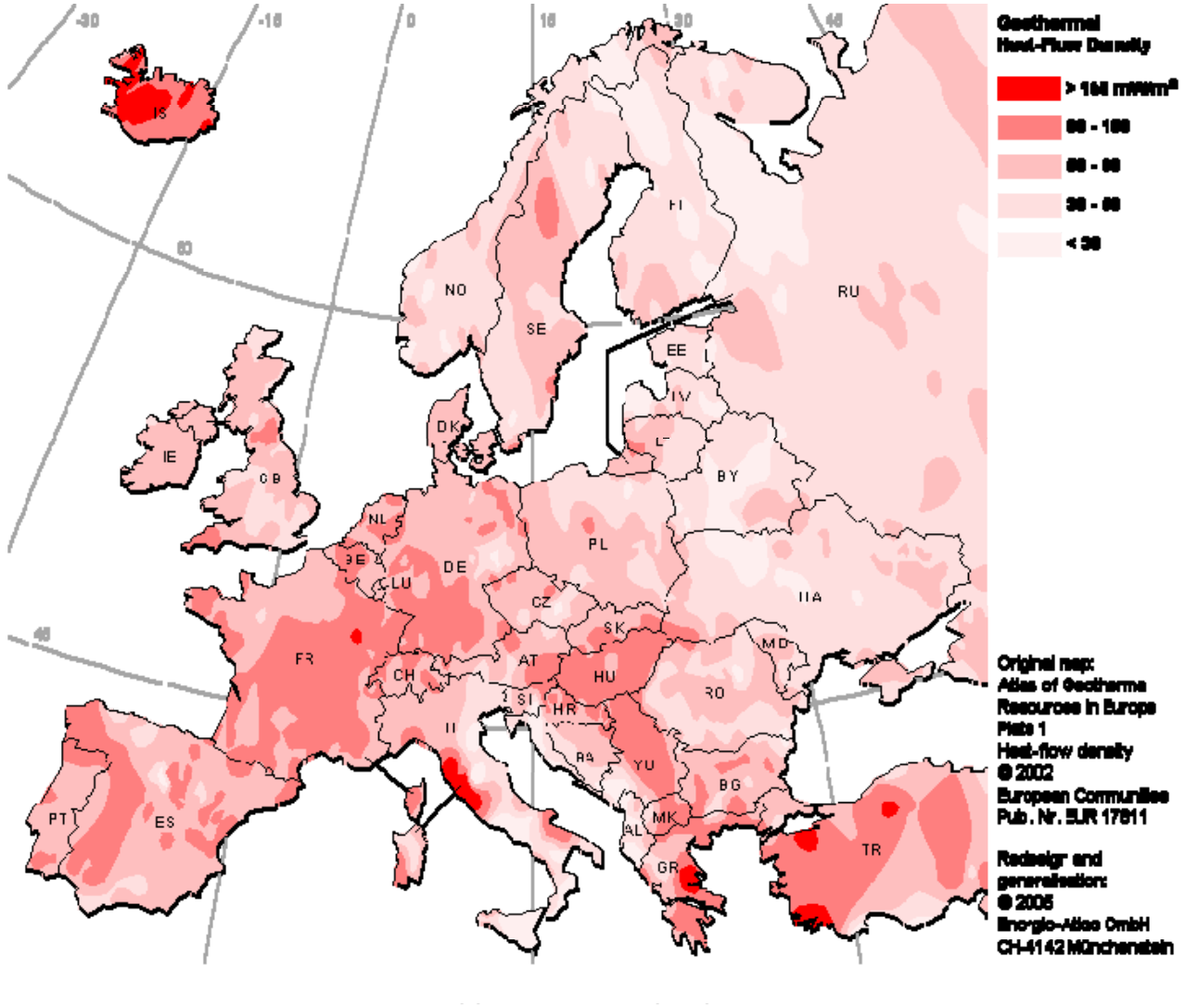


Source: Boyle, G. 2004

Geothermal Energy

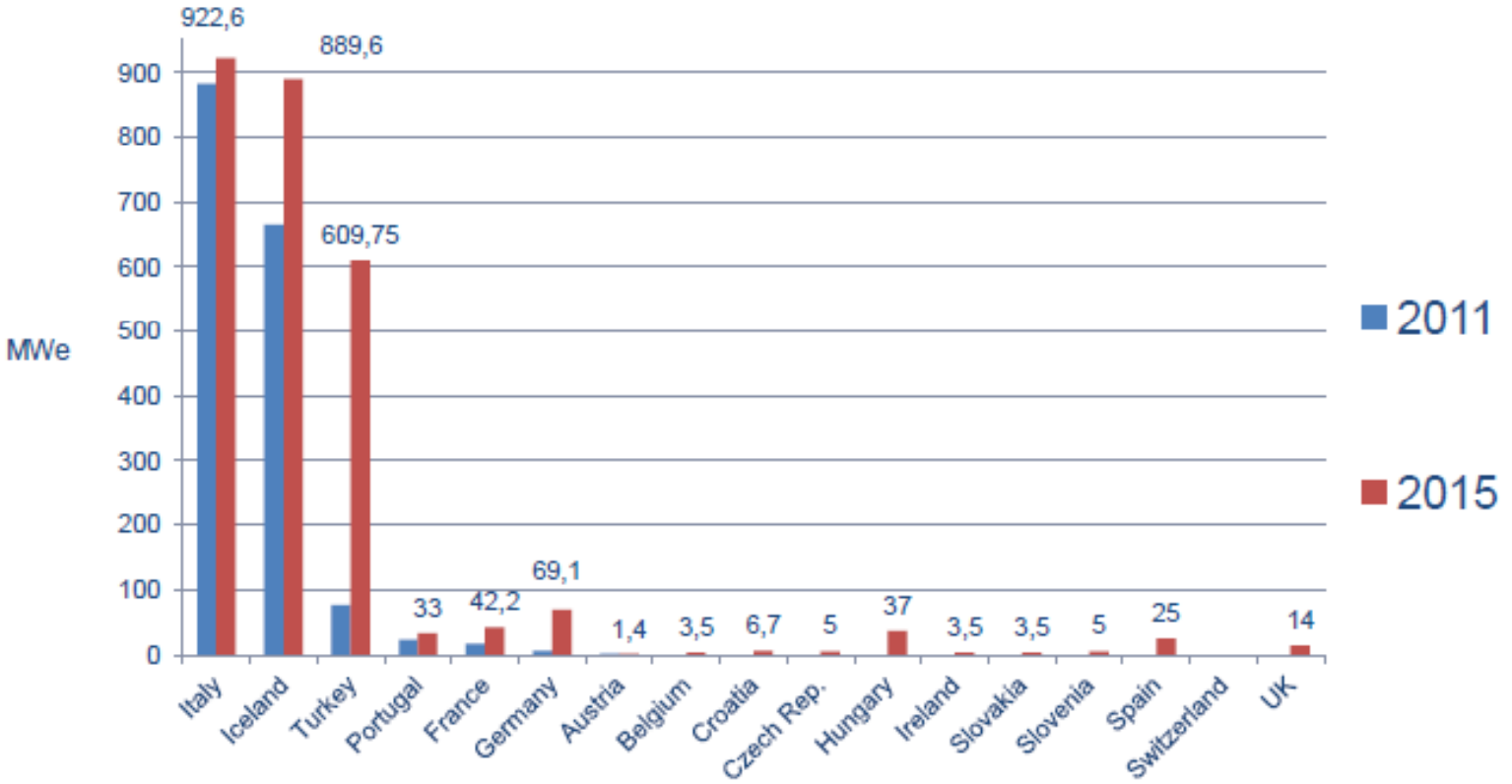


Geothermal Energy in Europe



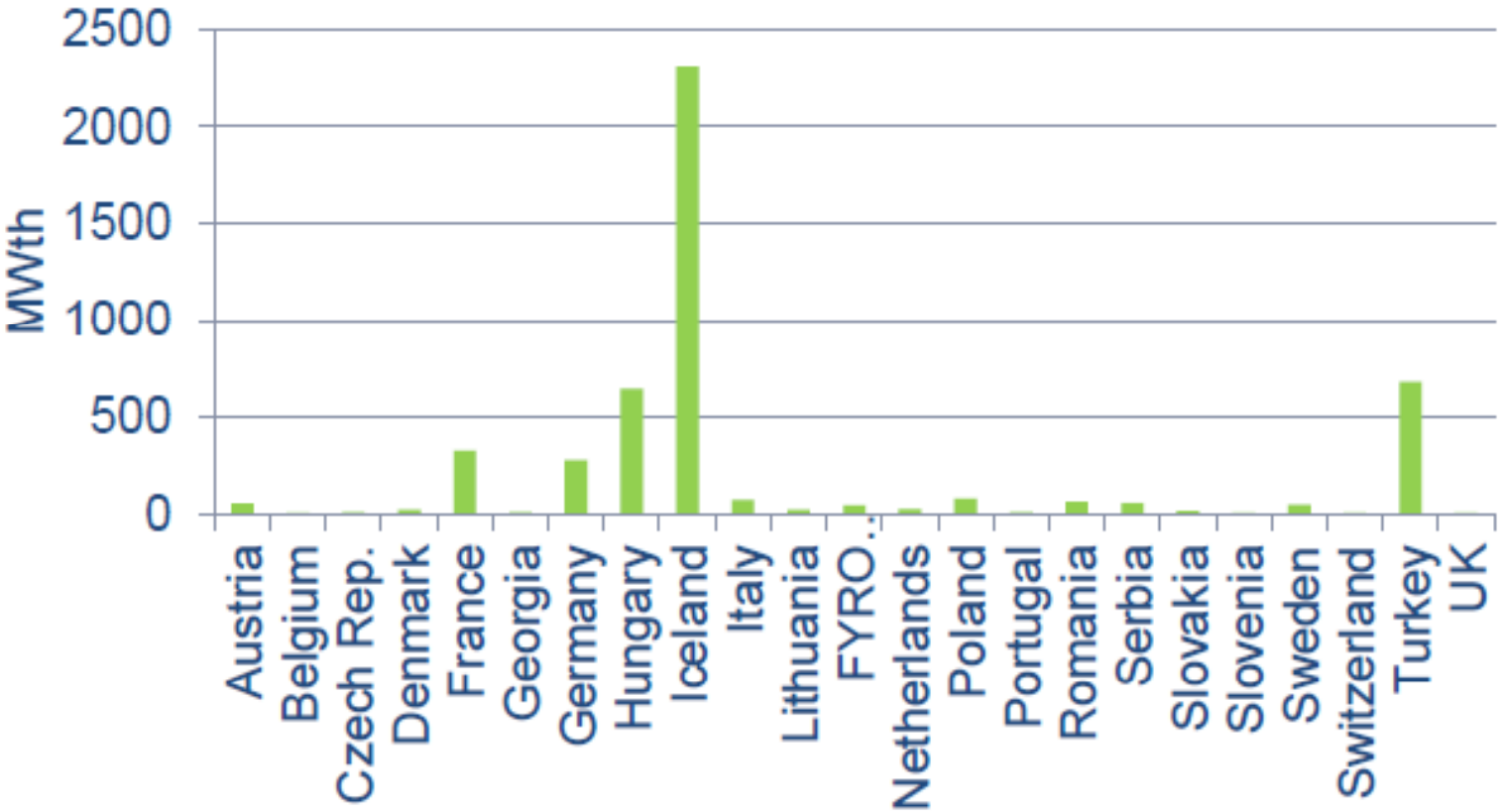
Source: Global Energy Network Institute

Geothermal installed capacity in Europe



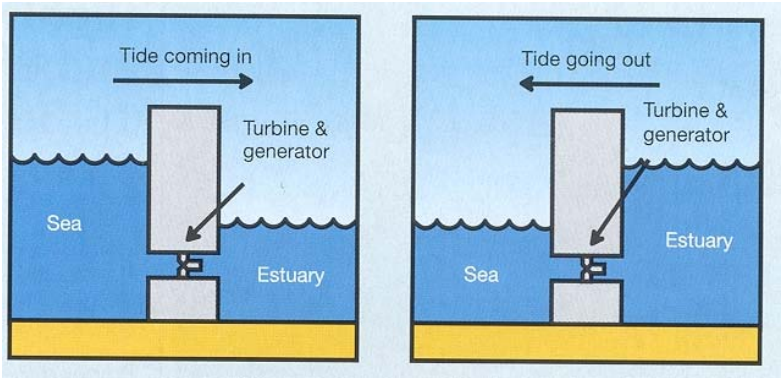
Source: European Geothermal Energy Council, 2012

Geothermal DH Installed Capacity in Europe (2010)



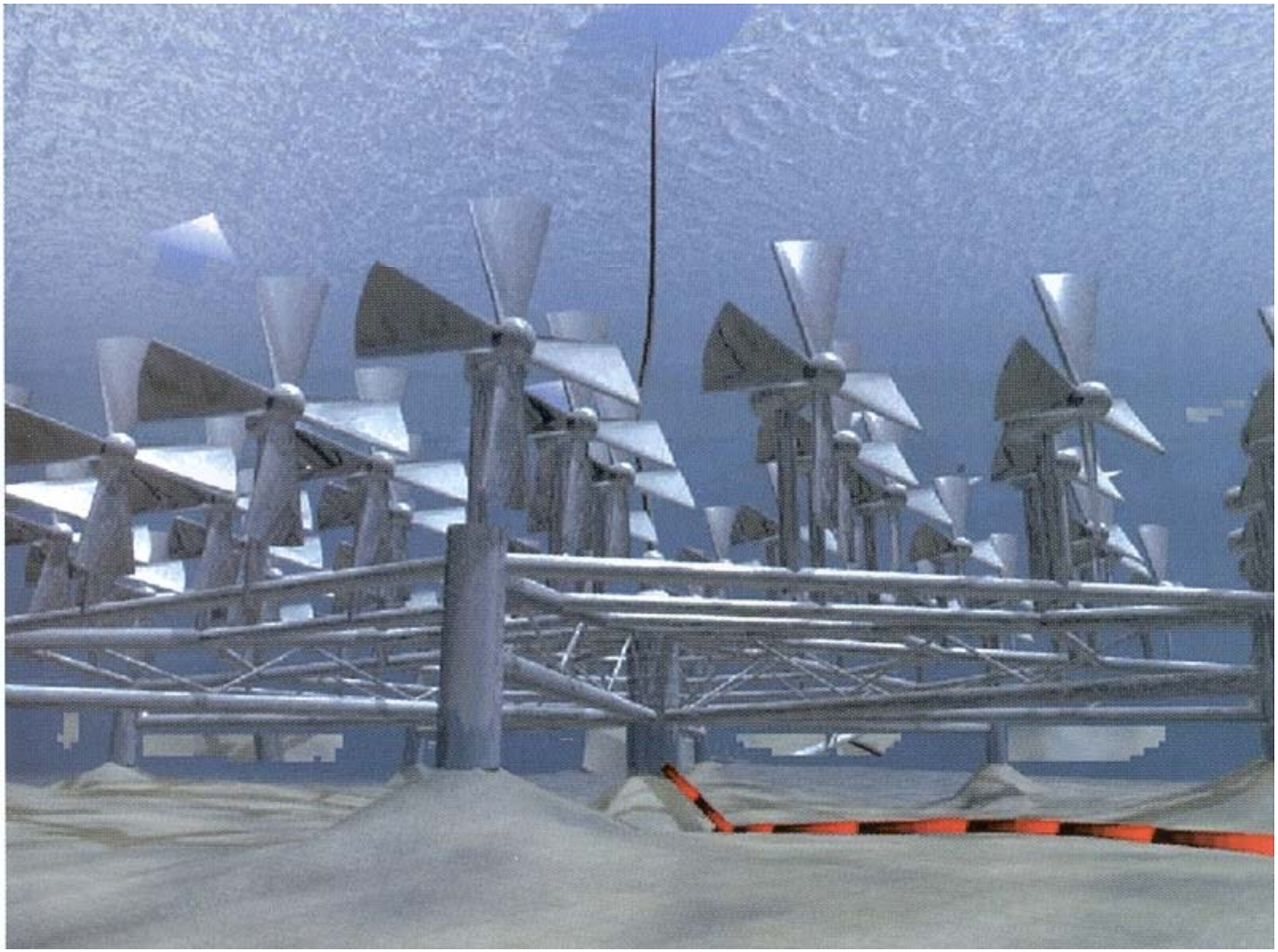
Tidal Energy

- Tidal energy is the result of the interaction of the gravitational pull of the moon and, to a lesser extent, the sun, on the seas.
- Tidal energy traditionally involves erecting a dam across the opening to a tidal basin. The dam includes a sluice that is opened to allow the tide to flow into the basin; the sluice is then closed, and as the sea level drops.



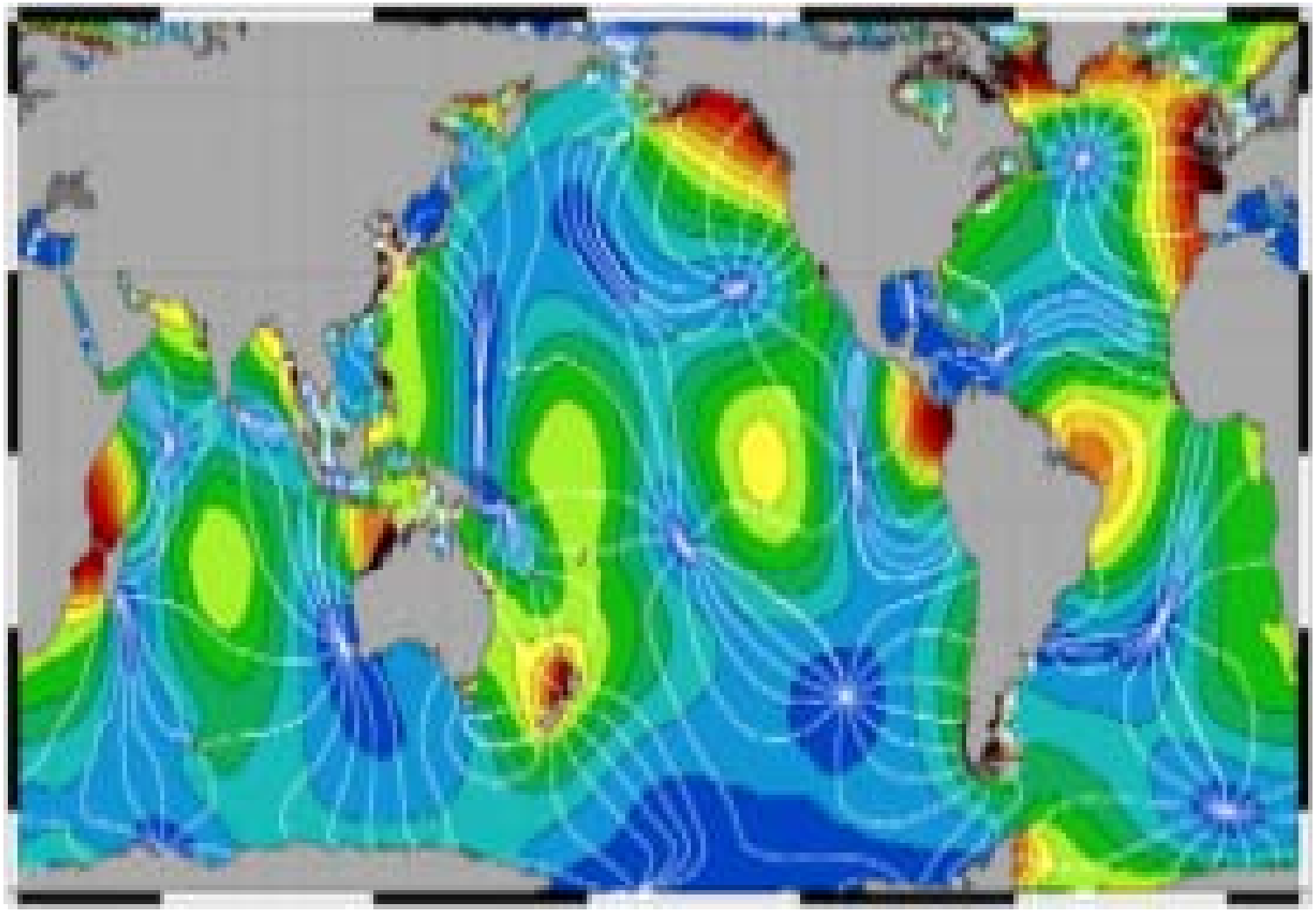
Source: Boyle, G. 2004

Tidal Energy Project in UK



Source: IPG, 2004

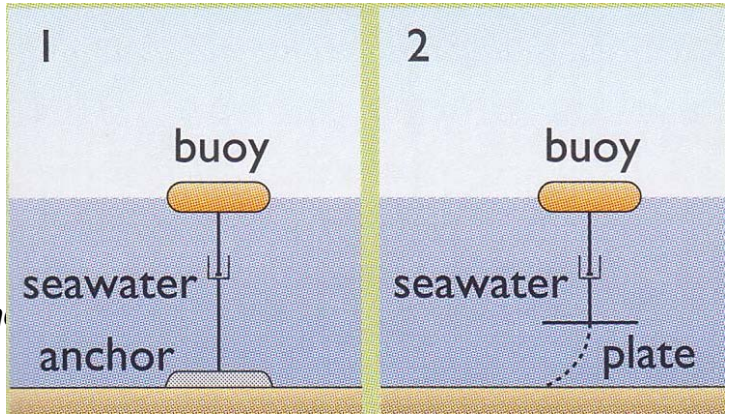
Tidal Energy Potential



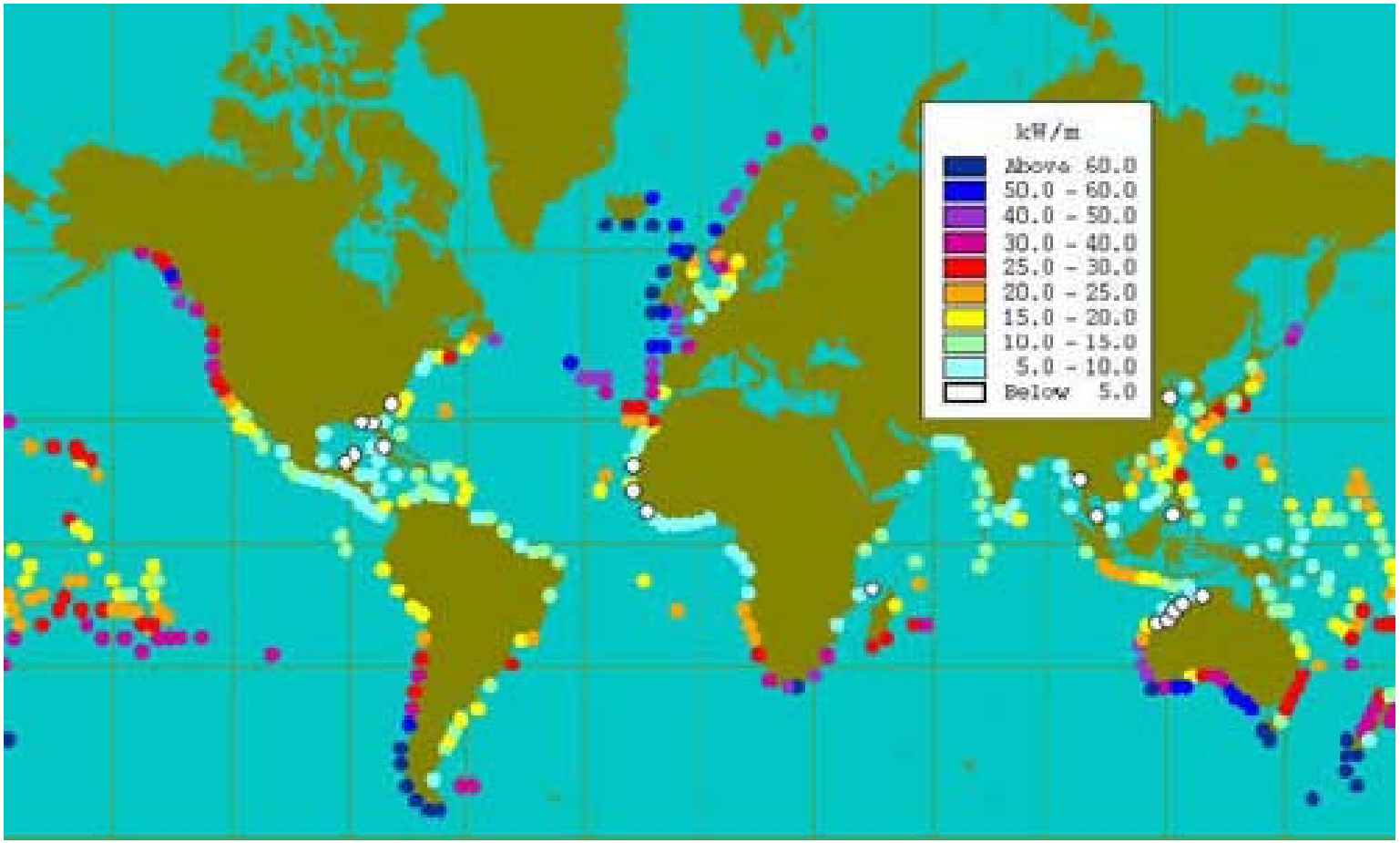
Wave Energy

- Ocean waves are generated by wind passing ove stretches of water.

- The total power of waves breaking on the world's coastlines is estimated at 2 to 3 million megawatts. In favorable locations, wave energy density can average 65 megawatts per mile of coastline.



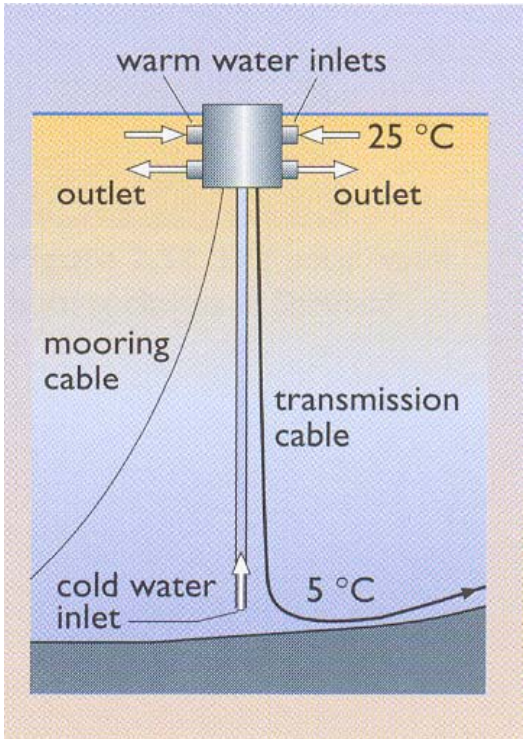
Wave Energy Potential



Source: Global Energy Network Institute

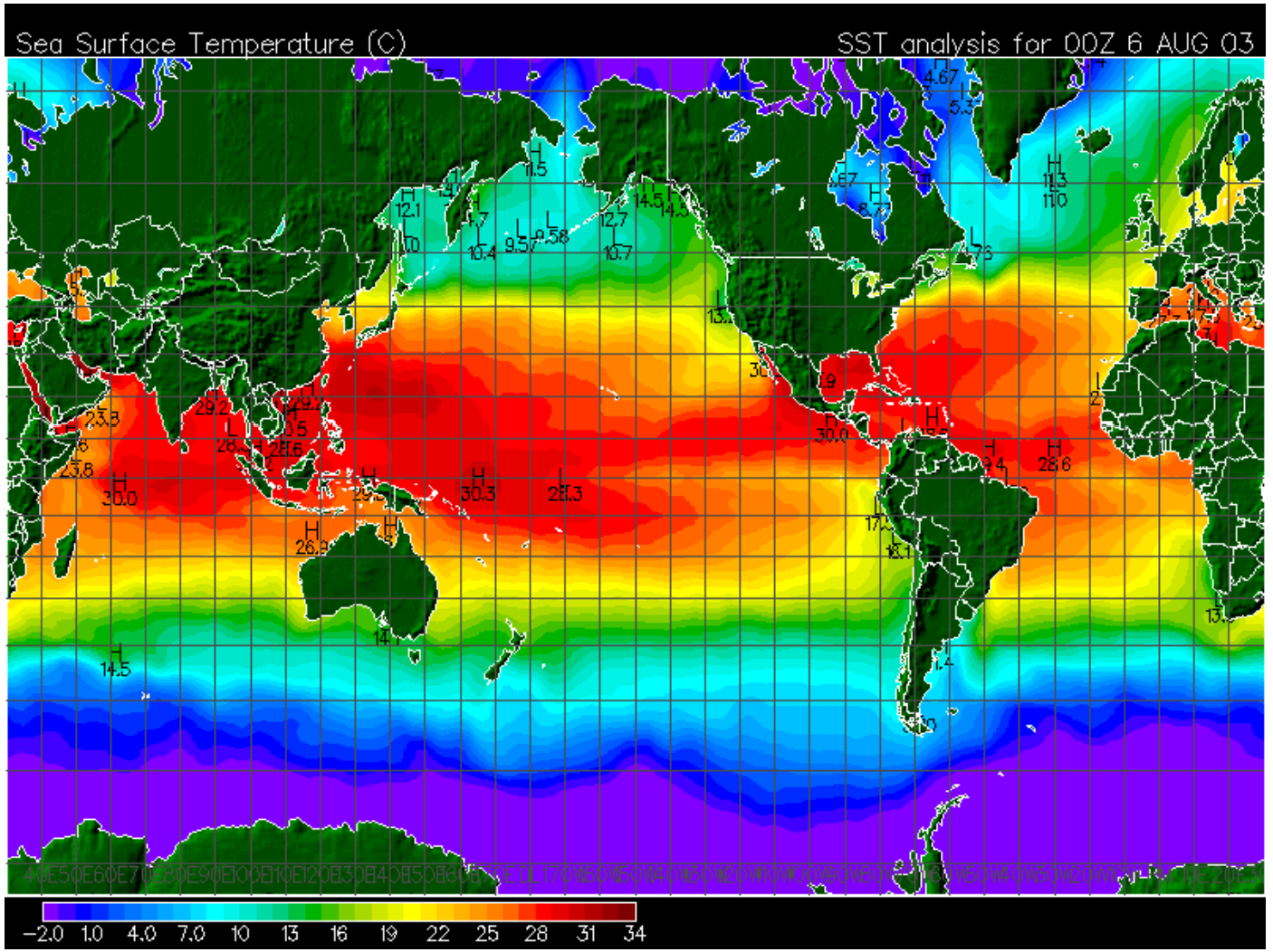
OTEC

- OTEC, or ocean thermal energy conversion, is an energy technology that converts solar radiation to electric power.
- OTEC systems use the ocean's natural thermal gradient (the fact that the ocean's layers of water have different temperatures) to drive a power-producing cycle. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C (36°F), an OTEC system can produce a significant amount of power.
- The oceans are thus a vast renewable resource, with the potential to help us produce billions of watts of electric power.
- Each day, the oceans absorb enough heat from the sun to equal the thermal energy contained in 250 billion barrels of oil.



Source: Boyle, G. 2004

Sea Surface Temperature



Hydrogen

- Although **it is not a renewable energy**, hydrogen is an energy carrier that an be produced from it and has gained relevance in the past years.