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Joint ICTP-IAEA Workshop on Sustainable Energy Development: Pathways and Strategies after Rio+20

1 - 5 October 2012

Finding CLEWs
Exploring Sustainable Energy Developments: Looking at Climate-Land-Energy-Water Interactions
Energy and its central role within CLEWs

Sebastian Hermann

KTH, Royal Institute of Technology, Stockholm
Sweden

Strada Costiera, 11 - 34151 - Trieste - Italy • Tel. +39 0402240111 • Fax. +39 040224163 • sci_info@ictp.it • www.ictp.it
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Finding CLEWs

Exploring Sustainable Energy Developments:
Looking at Climate-Land-Energy-Water Interactions

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Joint ICTP-IAEA Workshop on Sustainable Energy Development:
Pathways and Strategies after Rio20

01-05 October, 2012, Trieste, Italy

Overview

Intro

Energy Generation

Energy Use

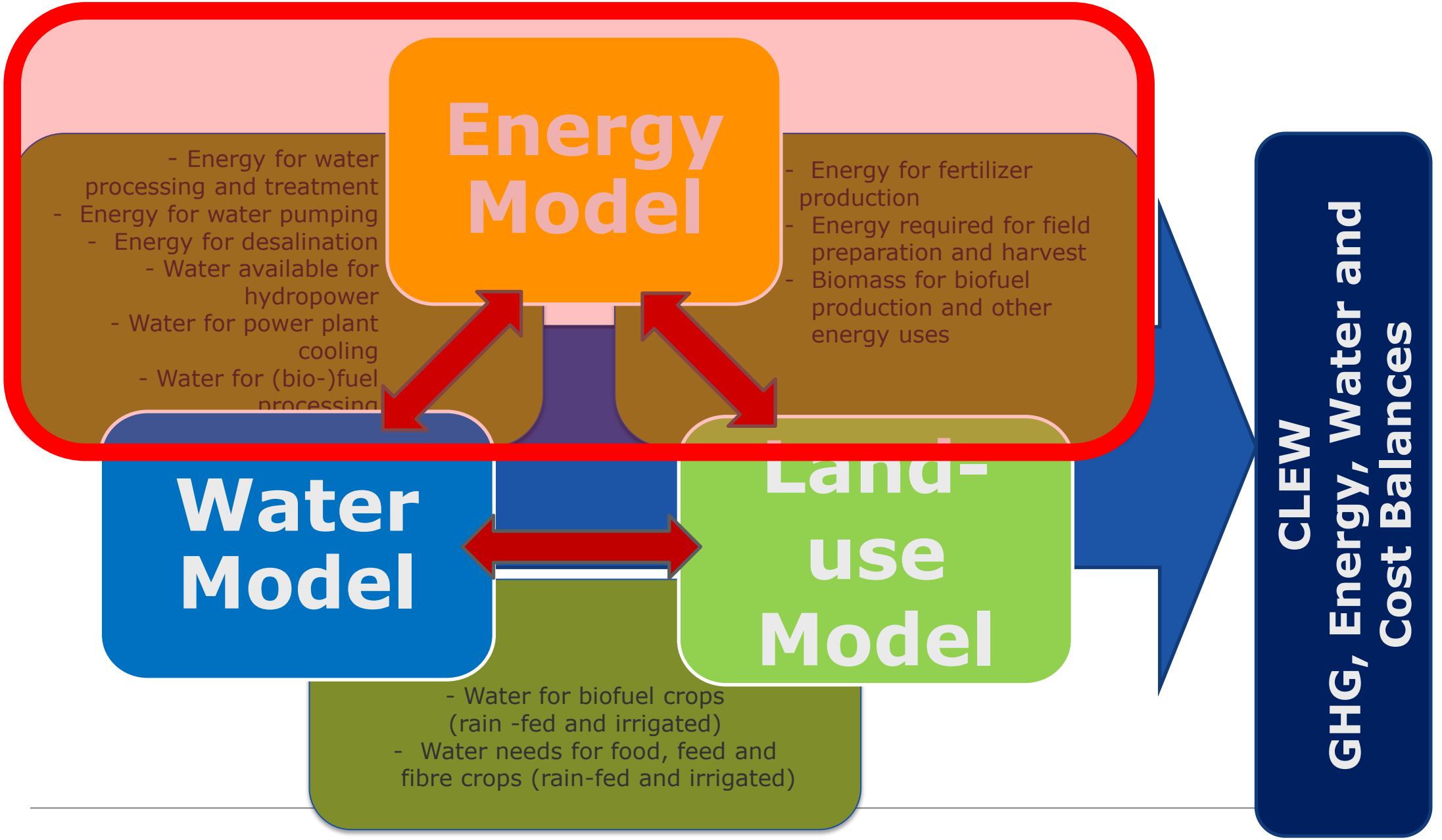
Summary

1. Introduction:

2. Energy and its Central Role within CLEWS
   a) Energy Generation and its Implications for water, land and climate
   b) Energy input into water and land sectors

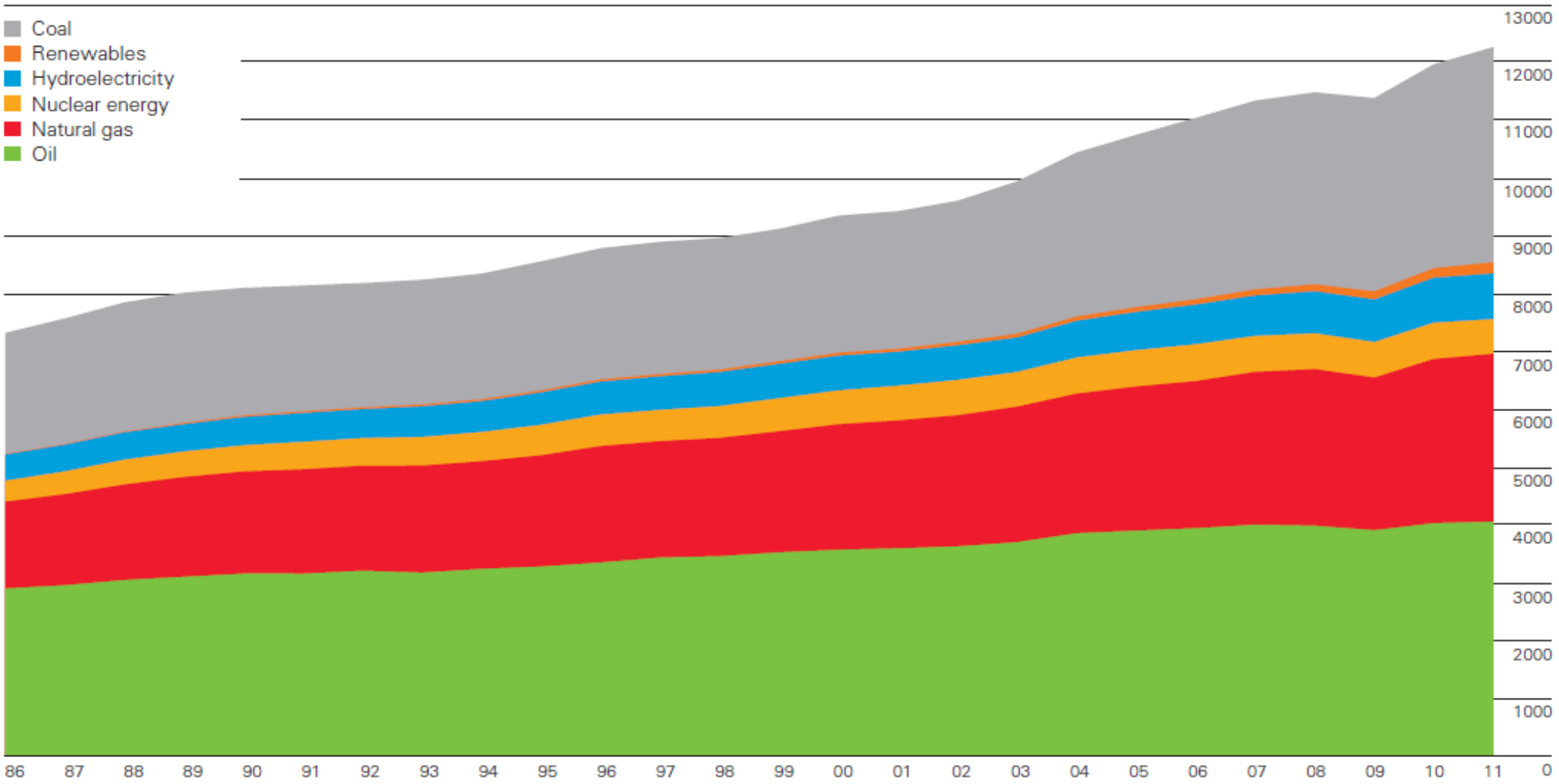
3. Summary

The CLEWS Framework



World consumption

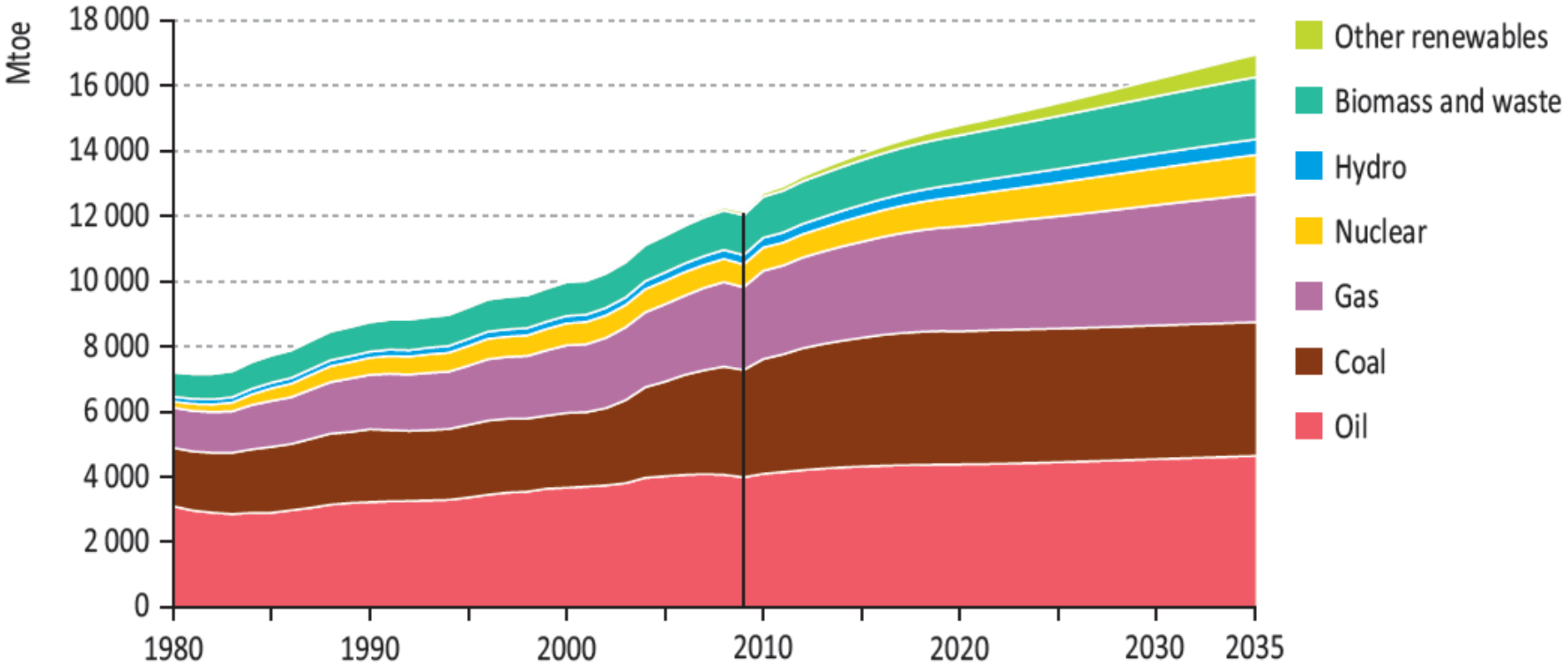
Million tonnes oil equivalent



World primary energy consumption grew by 2.5% in 2011, less than half the growth rate experienced in 2010 but close to the historical average. Growth decelerated for all regions and for all fuels. Oil remains the world's leading fuel, accounting for 33.1% of global energy consumption, but this figure is the lowest share on record. Coal's market share of 30.3% was the highest since 1969.

BP Statistical Review of World Energy, June 2012

Figure 2.6 • World primary energy demand by fuel in the New Policies Scenario

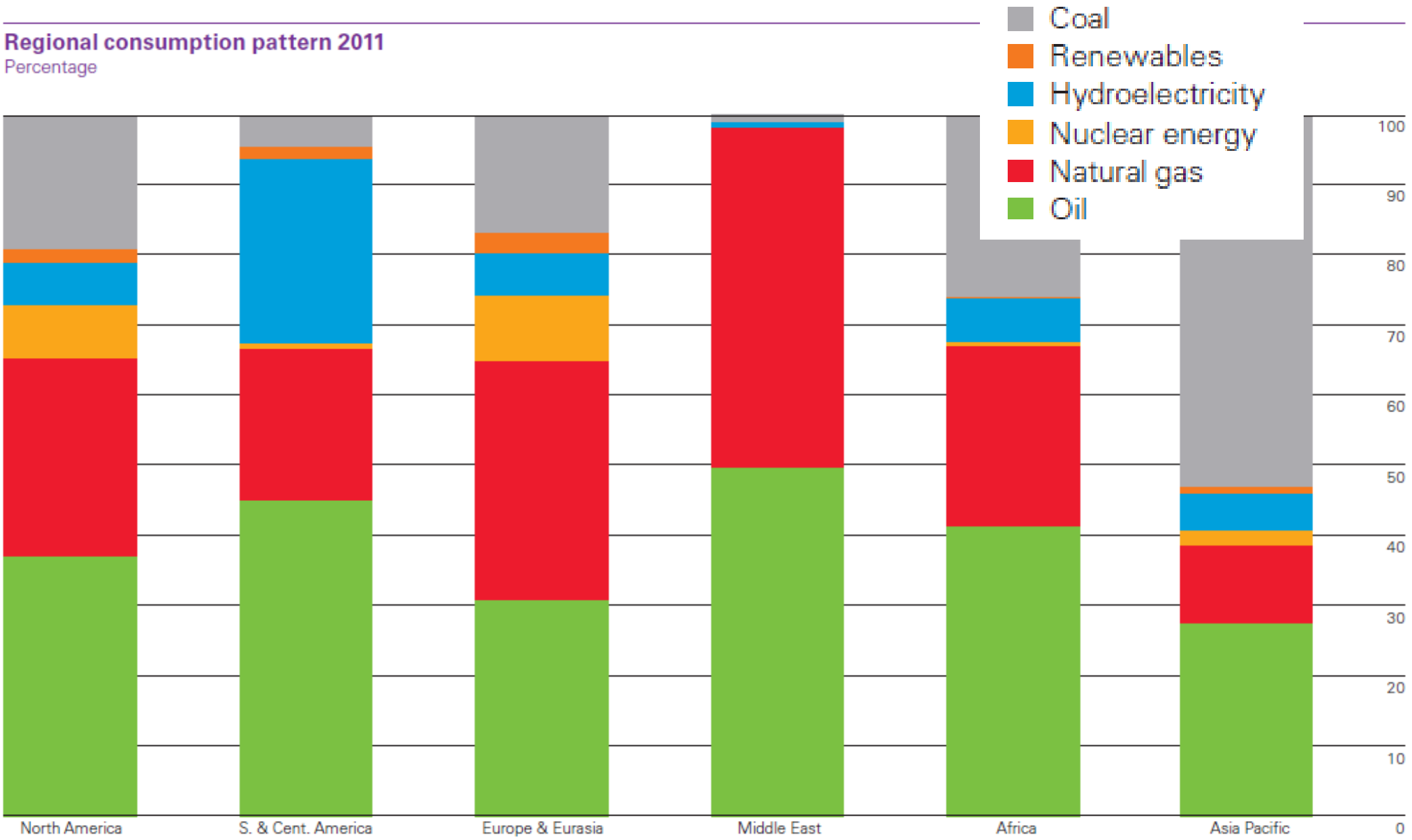


Biomass included!

IEA – 2011 - World Energy Outlook

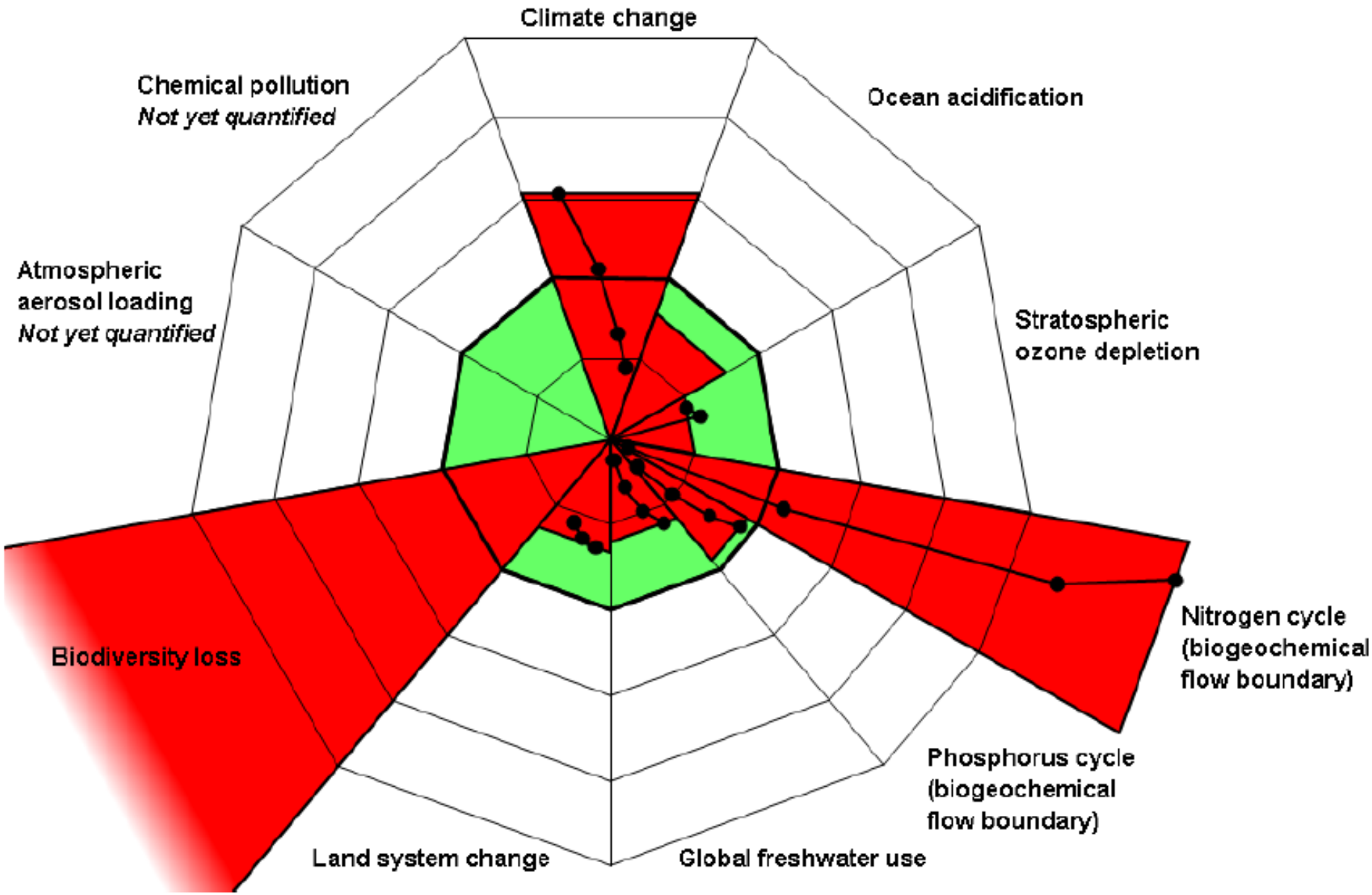
Regional consumption pattern 2011

Percentage



The Asia Pacific region is the world's largest energy consumer, accounting for 39.1% of global energy consumption and 68.6% of global coal consumption; the region also leads in oil consumption and hydroelectric generation. Europe & Eurasia is the leading region for consumption of natural gas, nuclear power, and renewables. Coal is the dominant fuel in the Asia Pacific region; natural gas is dominant in Europe & Eurasia, and oil is dominant in all other regions.

BP Statistical Review of World Energy, June 2012



Rockström et al.

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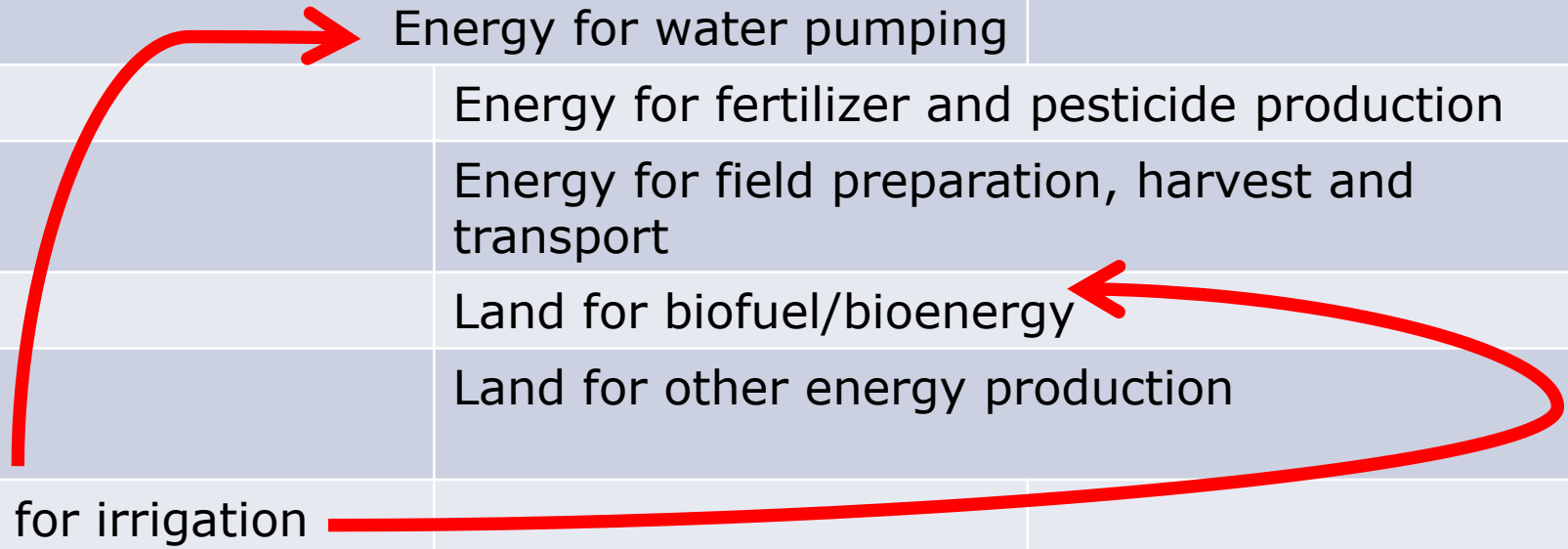
Intersection points

Water	Energy	Land
Water for power station cooling (and industry)		
Water for energy production, processing and refining		
Water for hydropower		
Energy for water treatment and desalination		
Energy for water pumping		
	Energy for fertilizer and pesticide production	
	Energy for field preparation, harvest and transport	
	Land for biofuel/bioenergy	
	Land for other energy production	
Water for irrigation		



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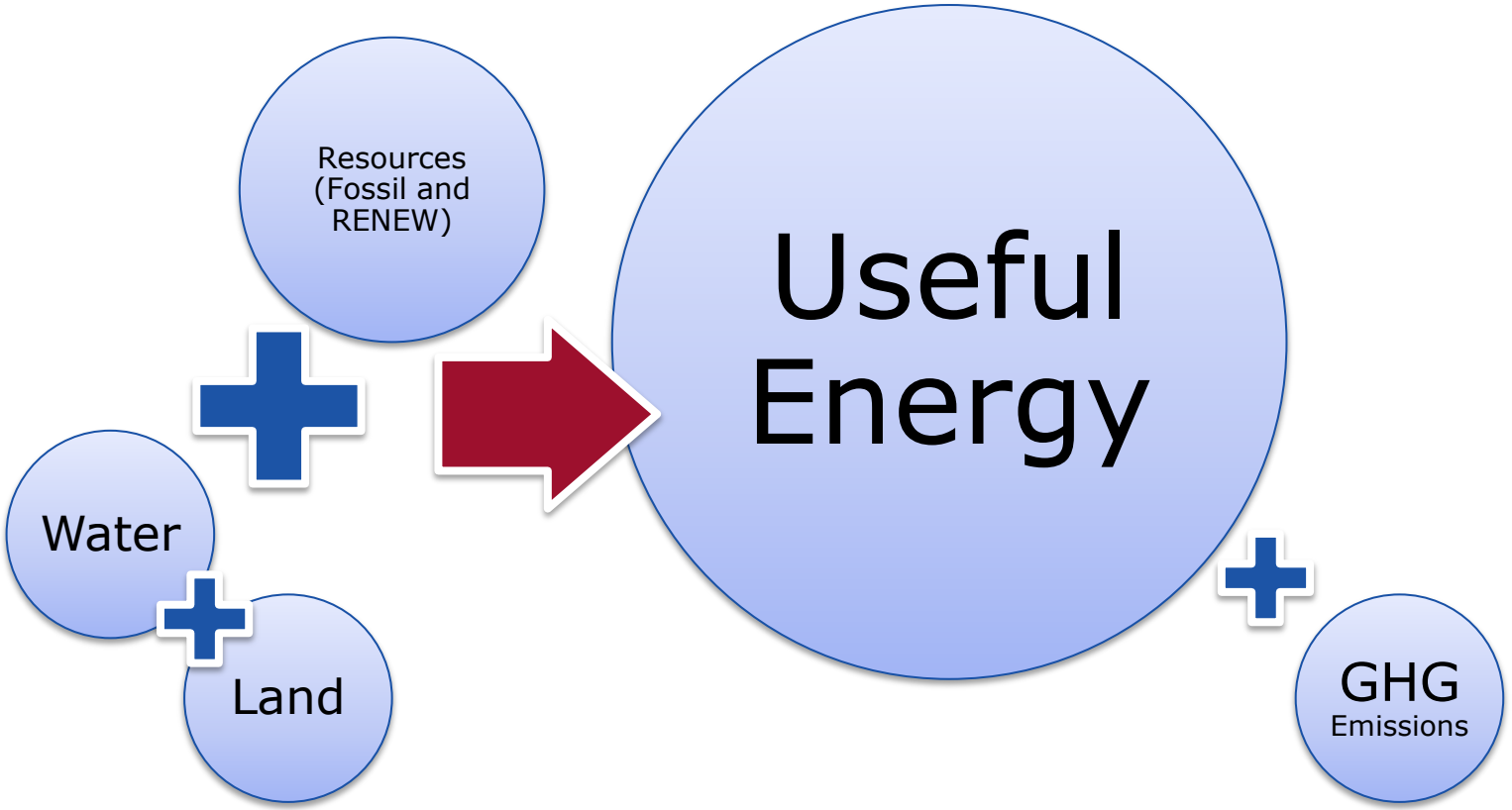
Energy Production and Generation



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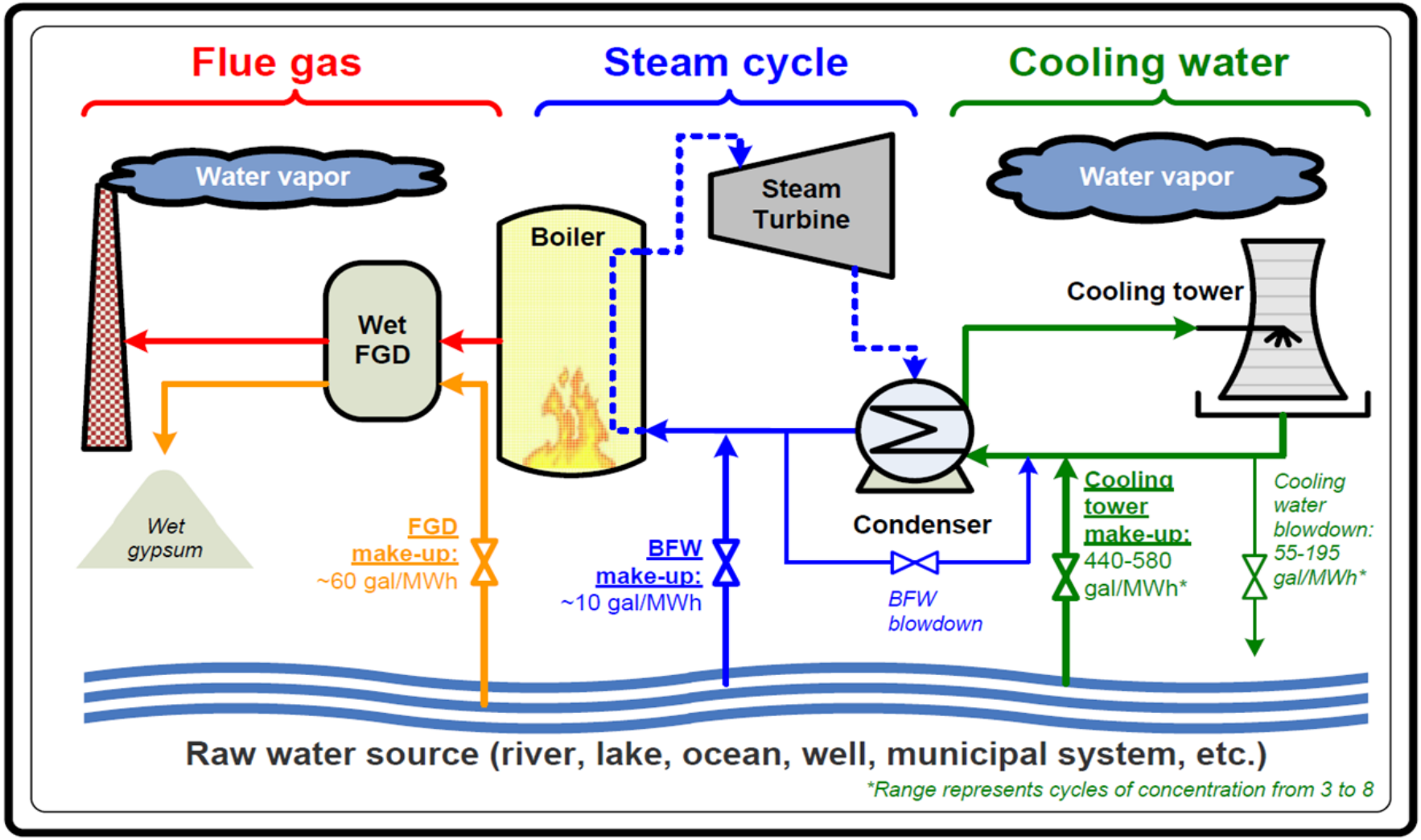
Thermal power station cooling system



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Water consumption for power generation

	Withdrawal [litre/MWh]		Consumption [litre/MWh]	
	Low	High	Low	High
Open-loop	28,000	230,000	380	1,100
Closed-loop w/ tower (1)	870	4,200	680	3,500
Hybrid wet-dry cooling (2)	<380	4,200	190	3,500
Dry	0	0	0	0

Notes: Data presented are at the point of cooling; they do not include water at the point of manufacturing
(1) Ranges include NGCC at low end and nuclear at high end
(2) Ranges include near full dry operation at low end and near full wet operation at high-end

Source: King et al, "Coherence between water and energy policies", OECD 2011

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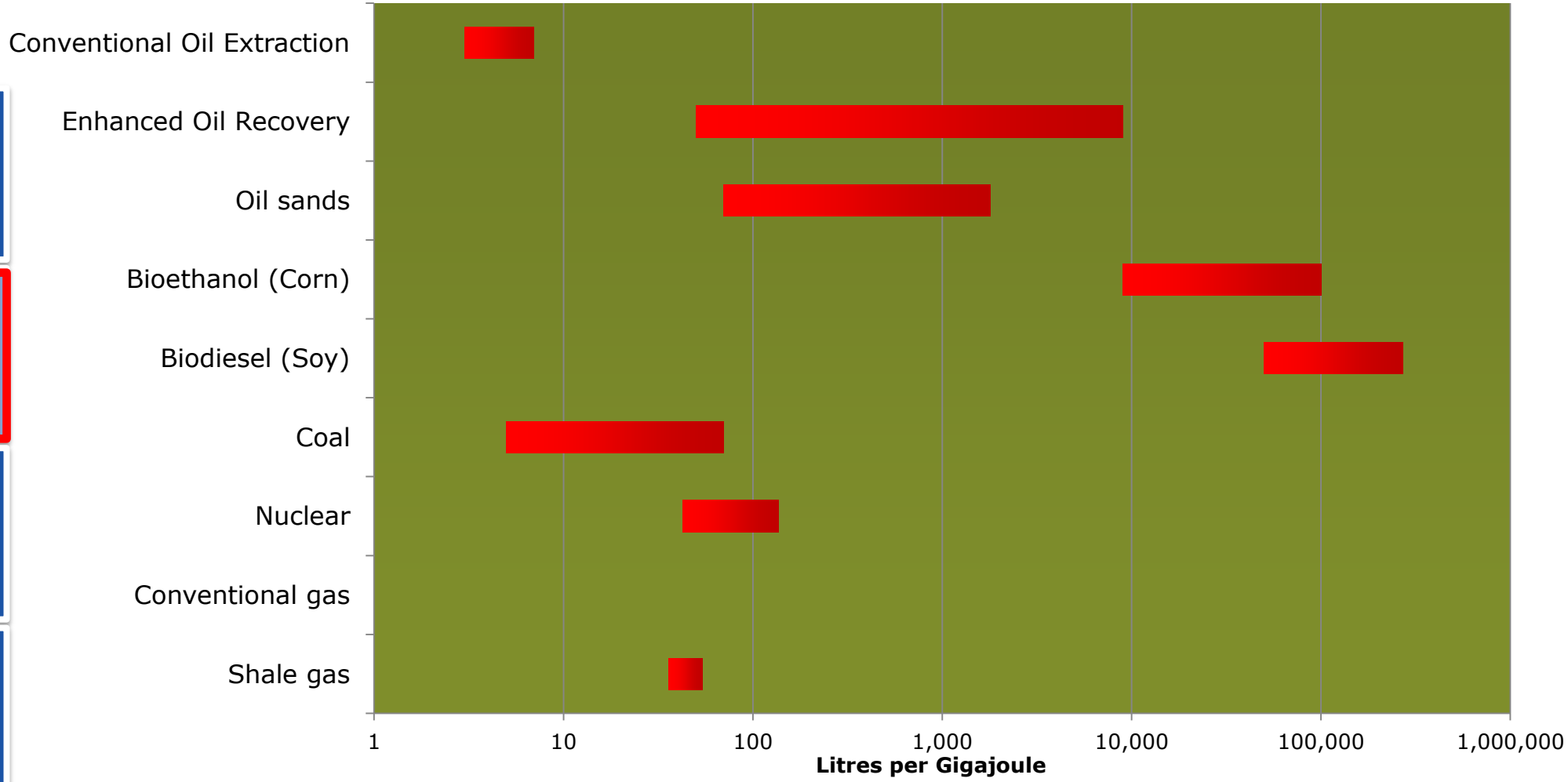
Water use for energy production



Sources: US DOE, "Energy Demand on Water Resources, Report to Congress on the Interdependence of Energy and Water", 2006
Cambridge Energy Research Associates

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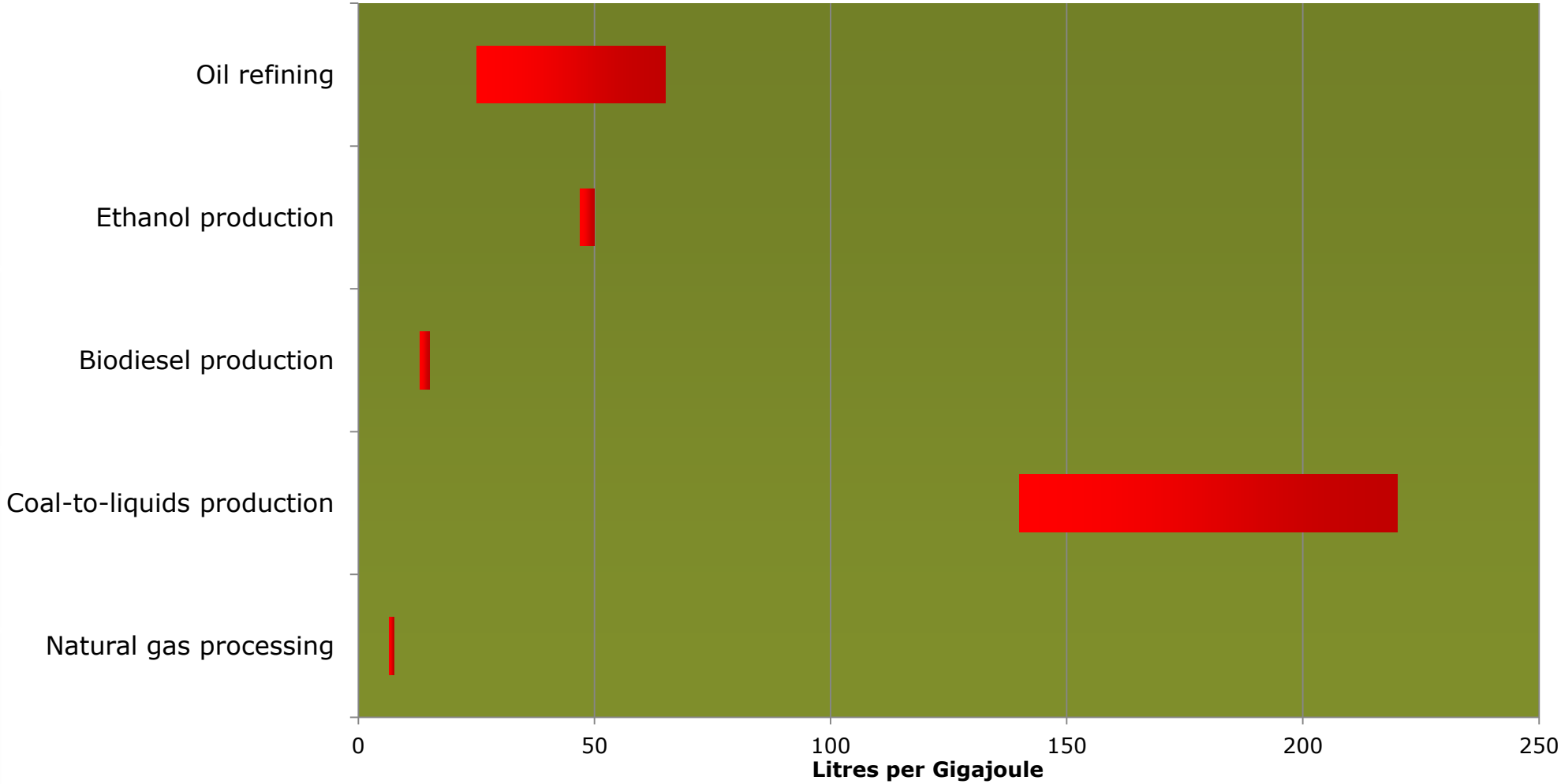
Water use for refining and processing



Sources: US DOE, "Energy Demand on Water Resources, Report to Congress on the Interdependence of Energy and Water", 2006
Cambridge Energy Research Associates

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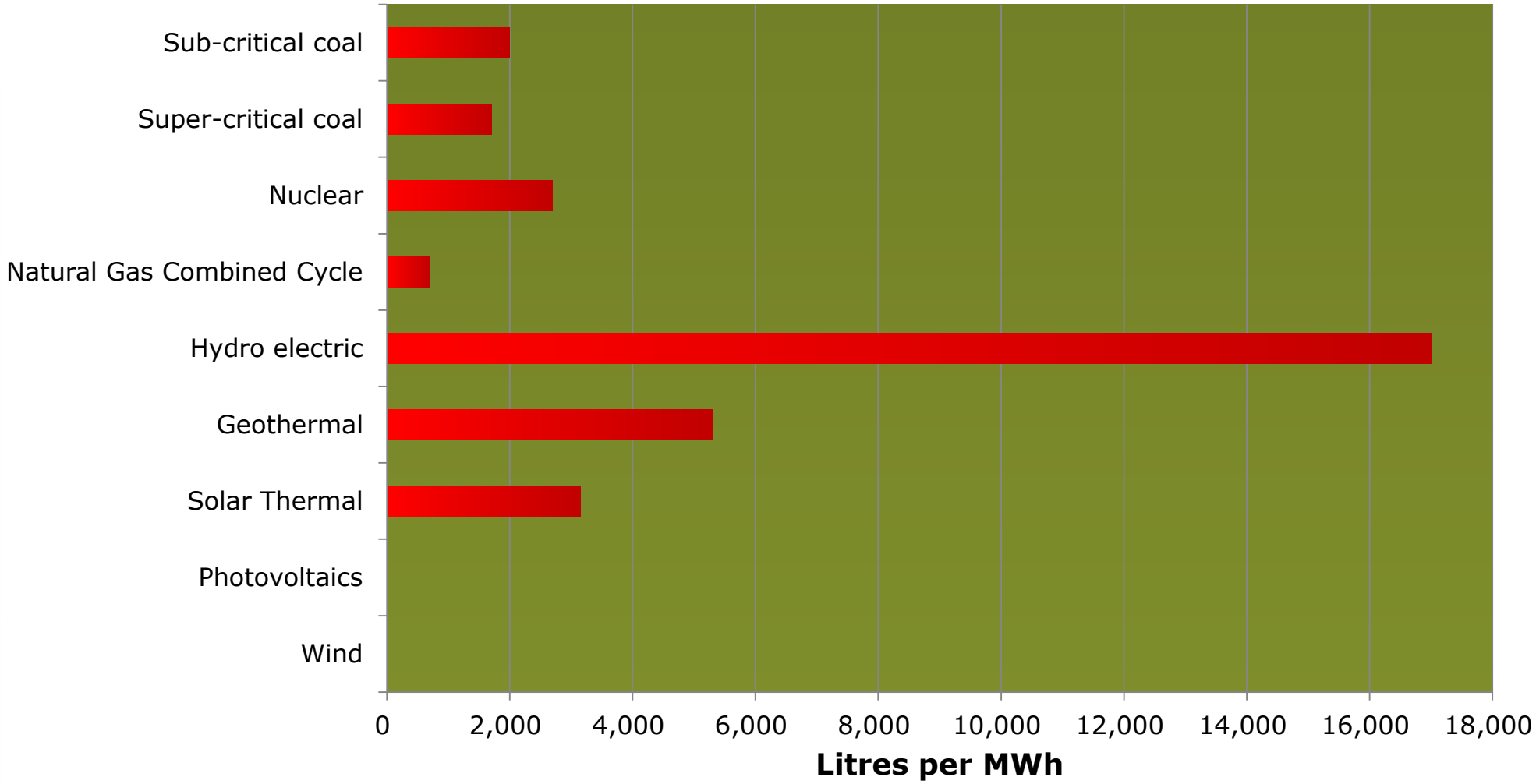
Water consumption for power generation



Note: These represent typical values. Actual water consumption will vary widely by technology and local conditions. Consumption values are on-site plants and does not include upstream water consumption for extraction, fuel processing or delivery

Sources: US DOE, "Energy Demand on Water Resources, Report to Congress on the Interdependence of Energy and Water", 2006
and NETL, "Water Requirements for Existing Emerging Thermoelectric Plant Technologies", August 2008

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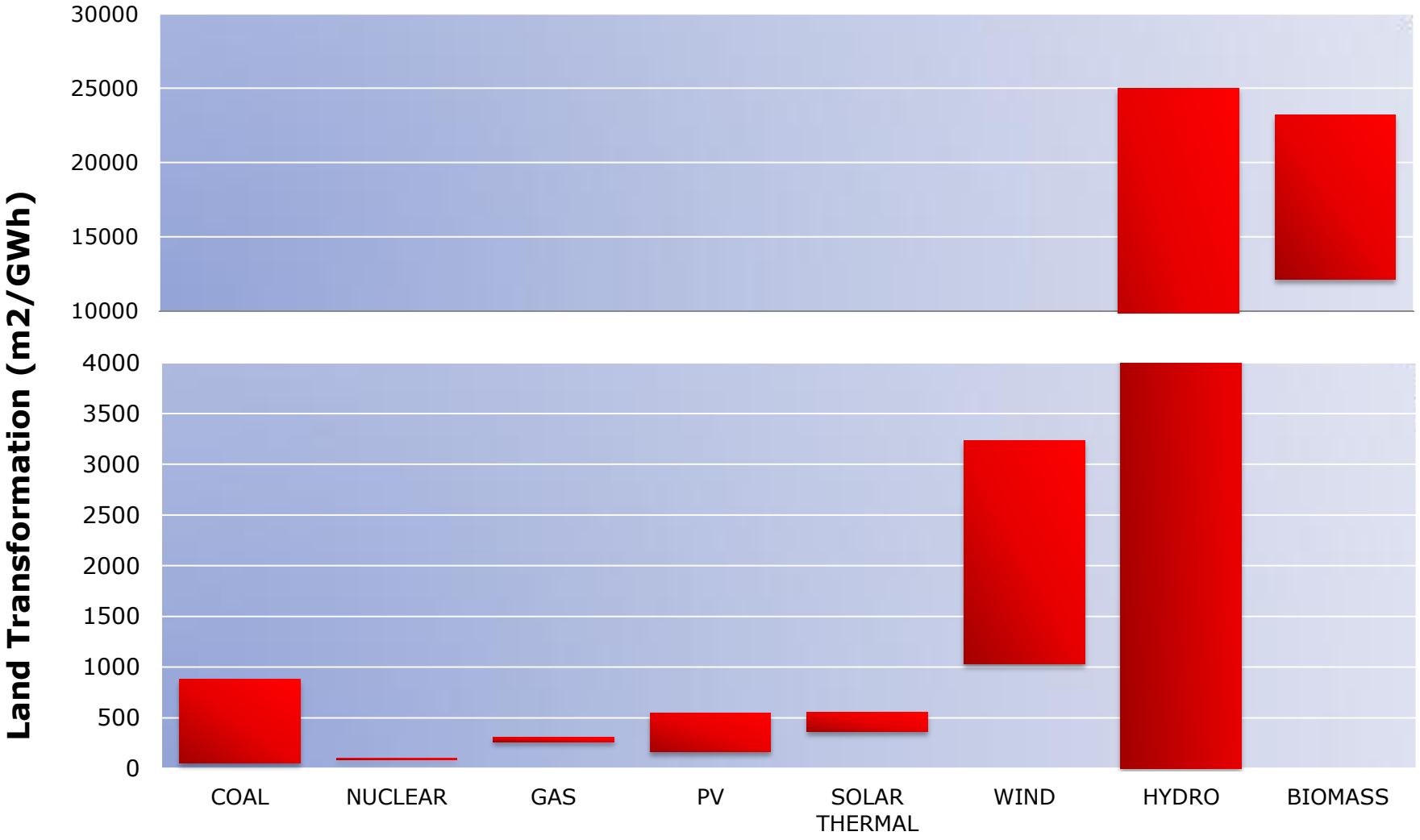
Land for energy

Intro

Energy Generation

Energy Use

Summary



Source: Fthenakis, V., Kim, H.C, "Land use and electricity generation: A life-cycle analysis" Renewable and sustainable energy reviews, 2008

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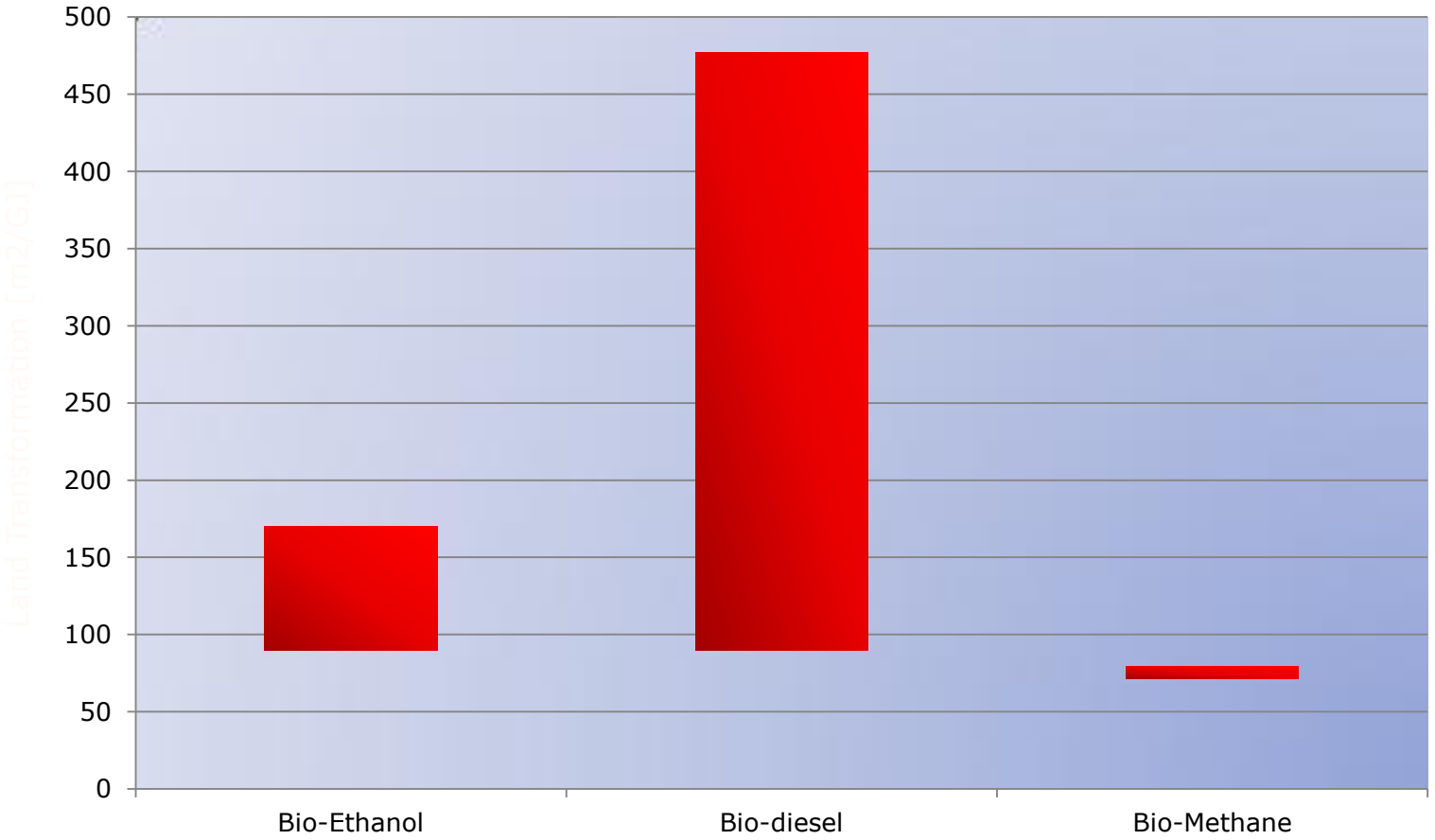
Land for energy



Source: International Energy Agency "Technology Roadmap - Biofuels for Transport", IEA, 2011

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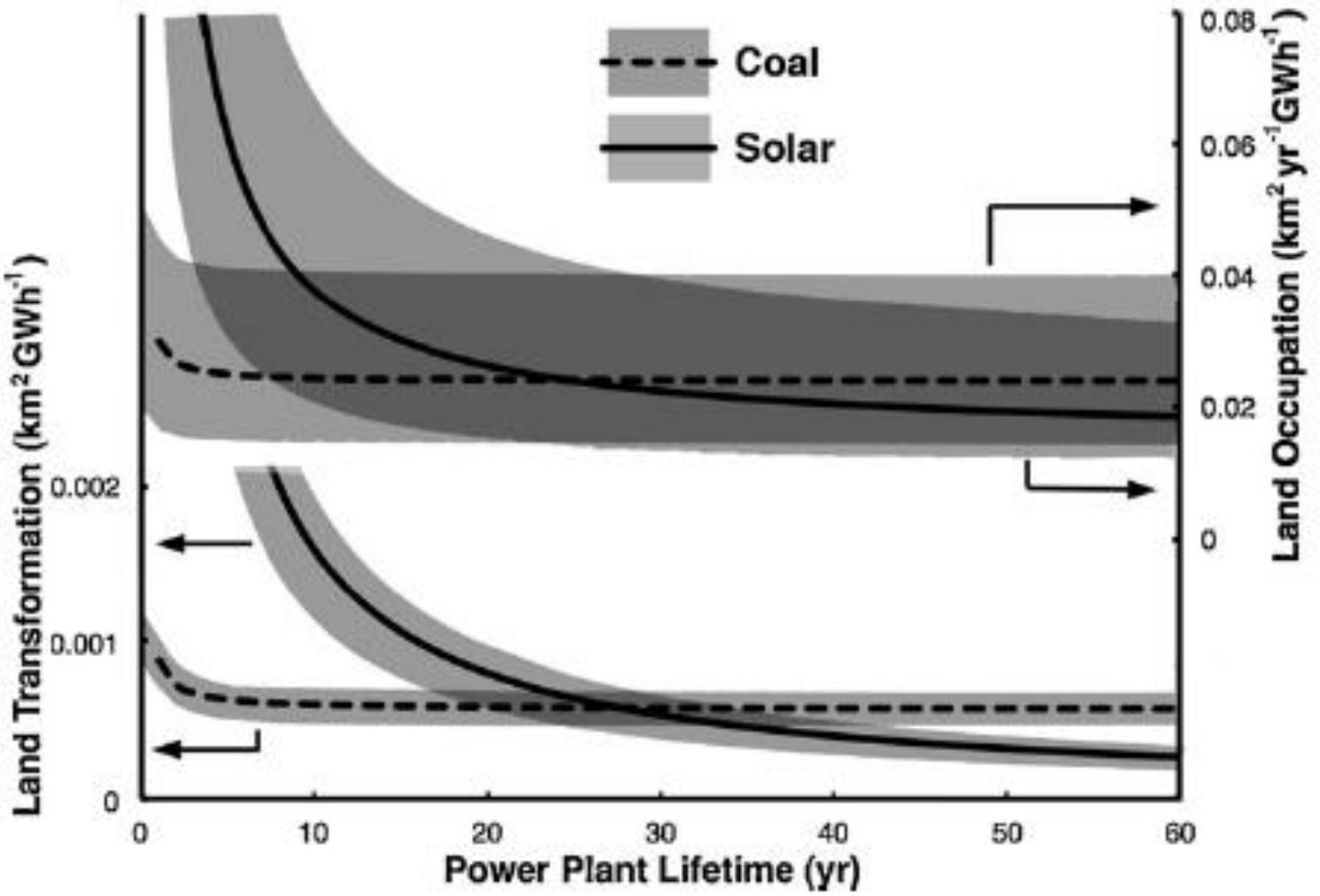
Land for energy



Turney and Fthenakis (2011)

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Bio-Energy an controversial and intersecting topic …

Intro

Energy Generation

Energy Use

Summary

Potential concerns and Problems:

- Land use conflict
- Deforestation
- Desertification
- Erosion
- Visual impact
- Reduction in biological diversity
- Typically high input of energy required (fertilisers, harvesting processing)

- Plantations
- Erosion/desertification
- Clear cutting and burning of native forest

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Environmental Impacts from Bio-Energy Production (1/2)

- New agricultural land, less retention of water in soil, desertification (higher evapotranspiration)
- Use of scarce water
- Improper irrigation of energy crops => soil salinity
- Ground water pollution due to fertilisers
- H_2O for biogas production and distilleries => production of waste water rich in N_2, phosphorous and potassium.

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Environmental Impacts from Bio-Energy Production (2/2)

- Local effects - indoor pollution (biomass for heating)
- Regional effects - the main pollutants, SO_2 and NO_x. Soil and water acidification, damage to fish population, degradation of plants, effects on human respiratory function.
- Global effects – emissions of GHG
  - Power generation: < 1/10 amount of CO_2 as compared to coal (ca 1 kg CO2/kWh)
  - Transportation: typically reduced CO_2 emissions compared to gasoline

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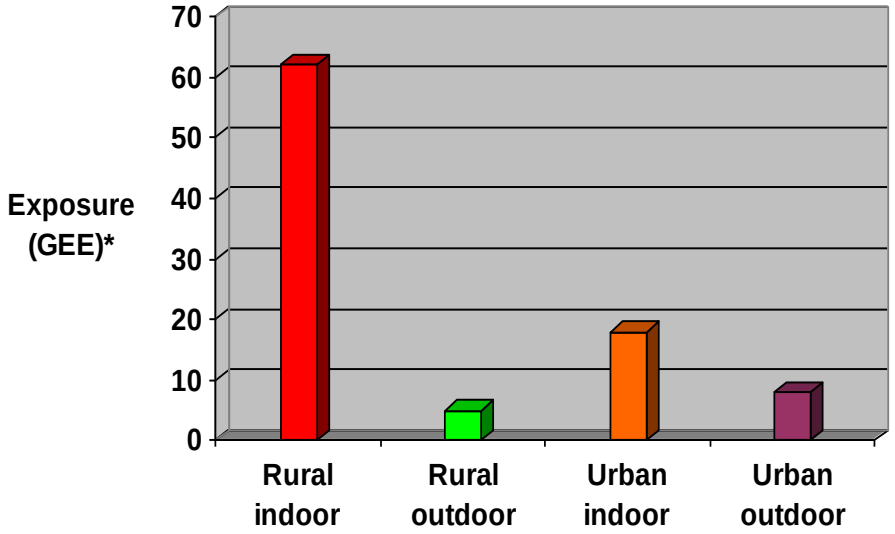
Biomass in developing countries

Particulate Exposures in Developing Countries



GEE is the Global exposure equivalent, based on the pollutants concentration and the hours of exposed to the pollutant

- Most of biofuels in developing countries are used in households for cooking or heating

- Respiratory infections
- Chronic lung diseases
- Low birth weight

- Cancer
- Eye irritation

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Positive Impacts of Biomass

- Reduction of greenhouse gas (GHG) emissions along with odor by landfill gas extraction for bioenergy
- Reduction of NO_x emissions (compared to fossil)
- Reduction of sulfur oxides emissions
  - using biomass for 5% of a coal-fired power plant's heat input would reduce SO_2 emissions by approx. 5%
- Avoided emissions & landfill requirements by municipal solid waste combustion (MSWC) technology
- Provision of clean gas (biogas) for cooking, heating etc.
- Job creation/rural development

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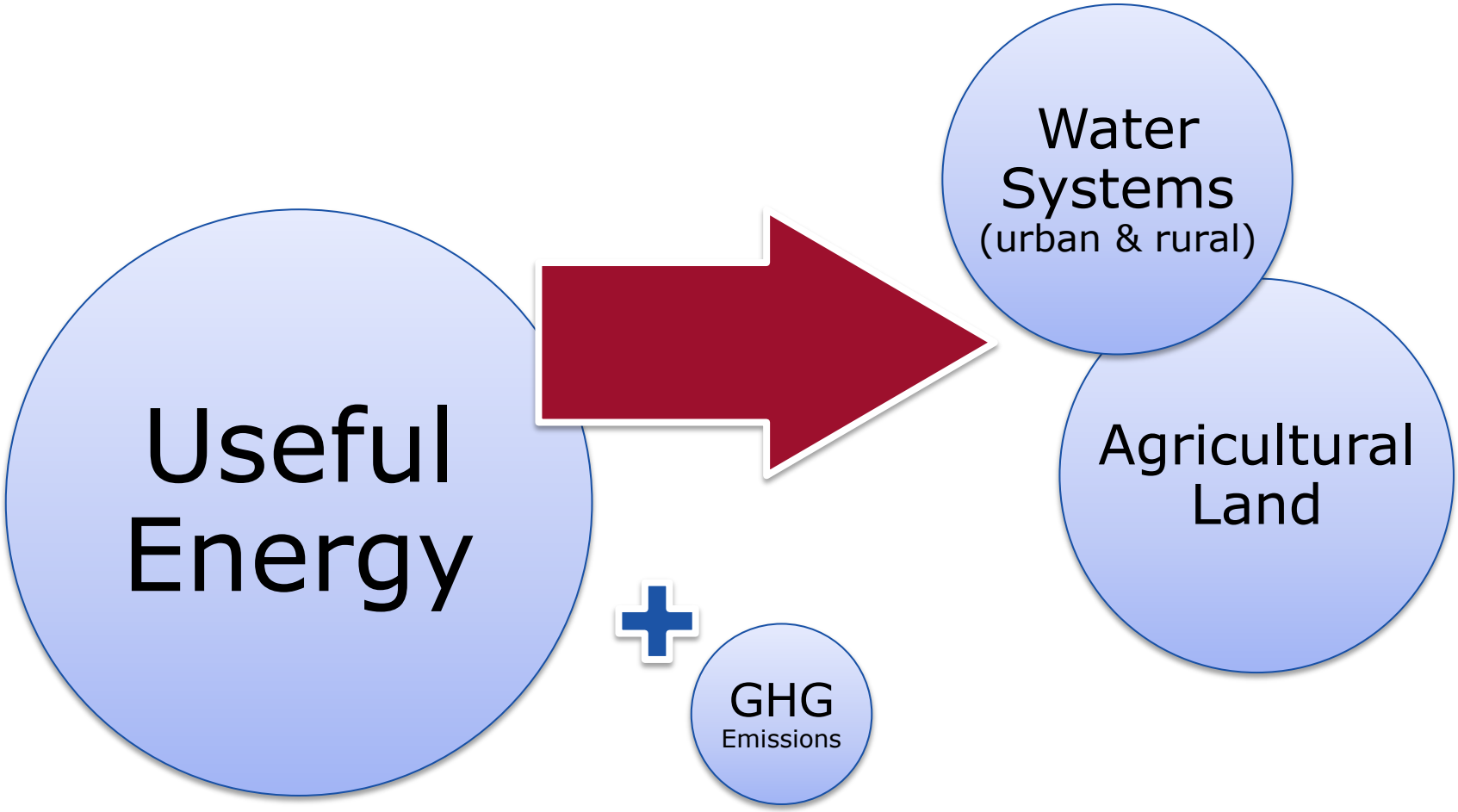
Energy Input in Water and Agricultural Sectors



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Intro

Energy Generation

Energy Use

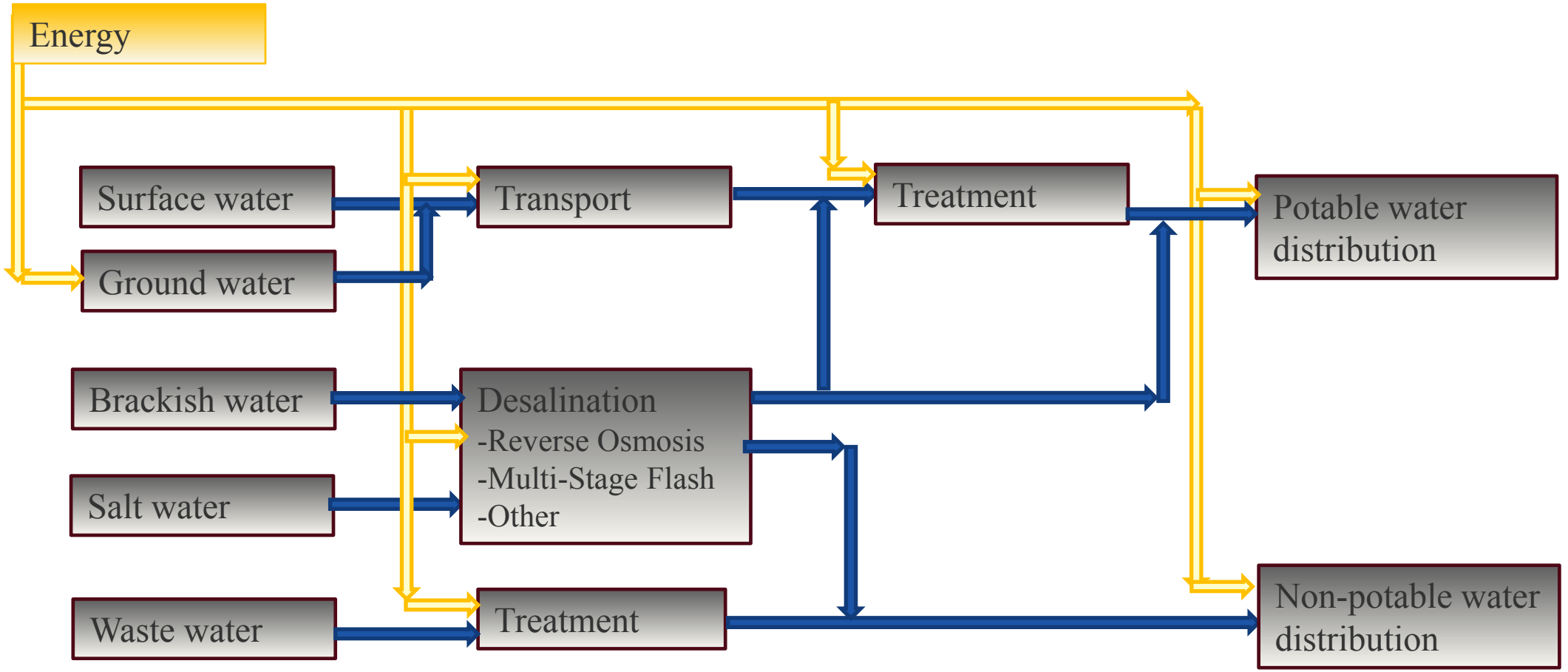
Summary

Energy use in the water supply chain

- Supply:
  - Surface water: 0-2400 kWh per million litre depending on distance and change in elevation
  - Groundwater: Varies with depth (e.g. 140 kWh per million litre at 120 ft and 530 kWh per million litre at 400 ft)
- Treatment:
  - 26 kWh per million litre for high quality groundwater
  - 300-1400 kWh per million litre for brackish groundwater desalination
  - 3600-4500 kwh per million litre for seawater desalination
- Distribution:
  - Average of 290 kWh per million litre, but varies widely depending on distance and change in elevation

Sources: Cambridge Energy Research Associates
NRDC and Pacific Institute, "Energy down the drain: The hidden costs of California's water supply", 2004
US DOE, "Energy Demand on Water Resources: Report to Congress on the Interdependence of Energy and Water", 2006
EPRI, "Water and sustainability (Vol 4): US Electricity consumption for water supply and treatment – The next half century, 2000

Energy use for water supply and treatment



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Energy use in agriculture

Some interdependencies:

- Energy requirements (e.g. GJ diesel, electricity etc), or
- Service requirements (e.g. hectares of land to be ploughed, irrigated, fertilized etc.)
- Prices; If coupling with an optimization model like MESSAGE (or other economic model)

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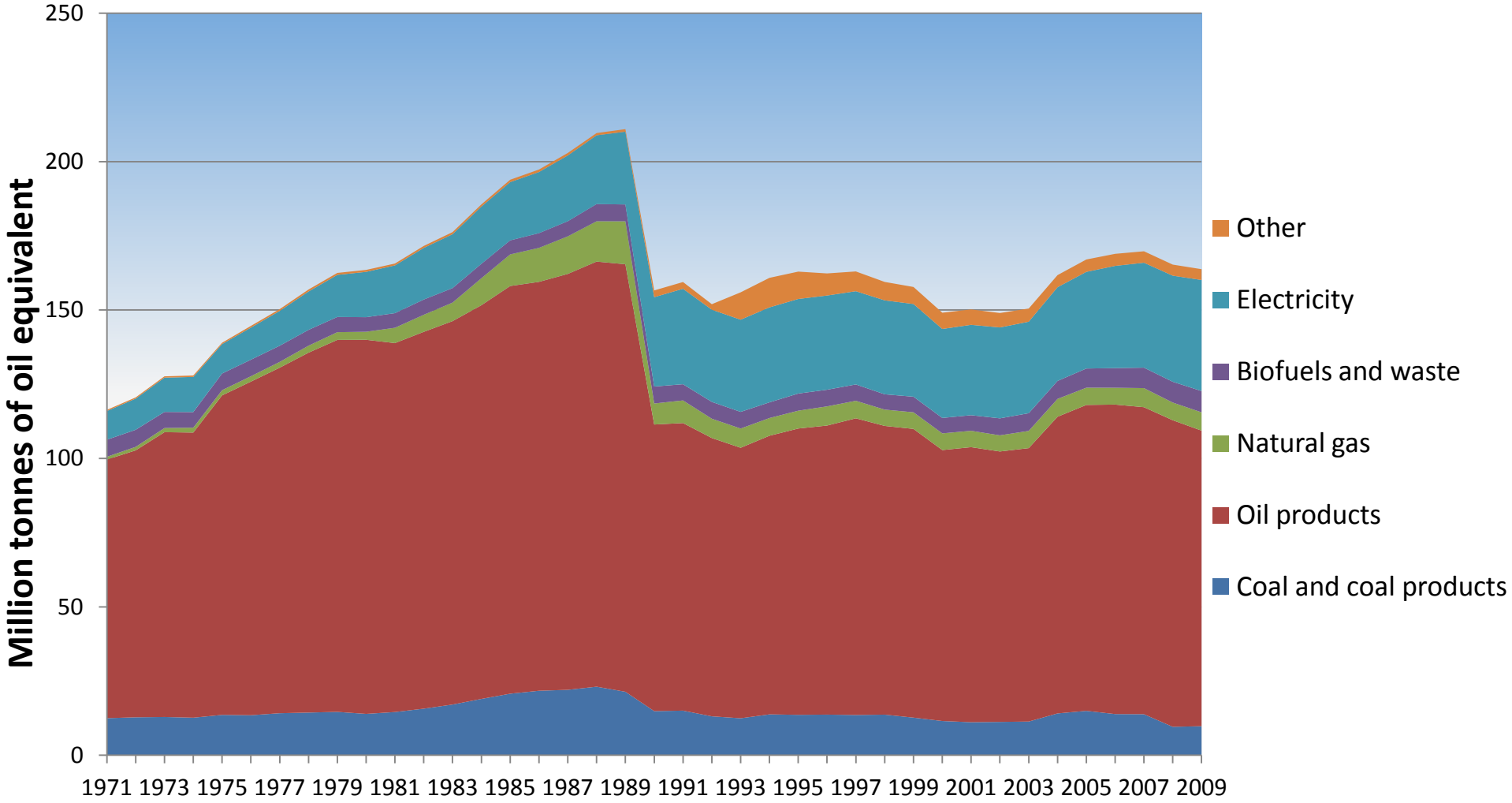
Energy use in Agriculture



Source: International Energy Agency

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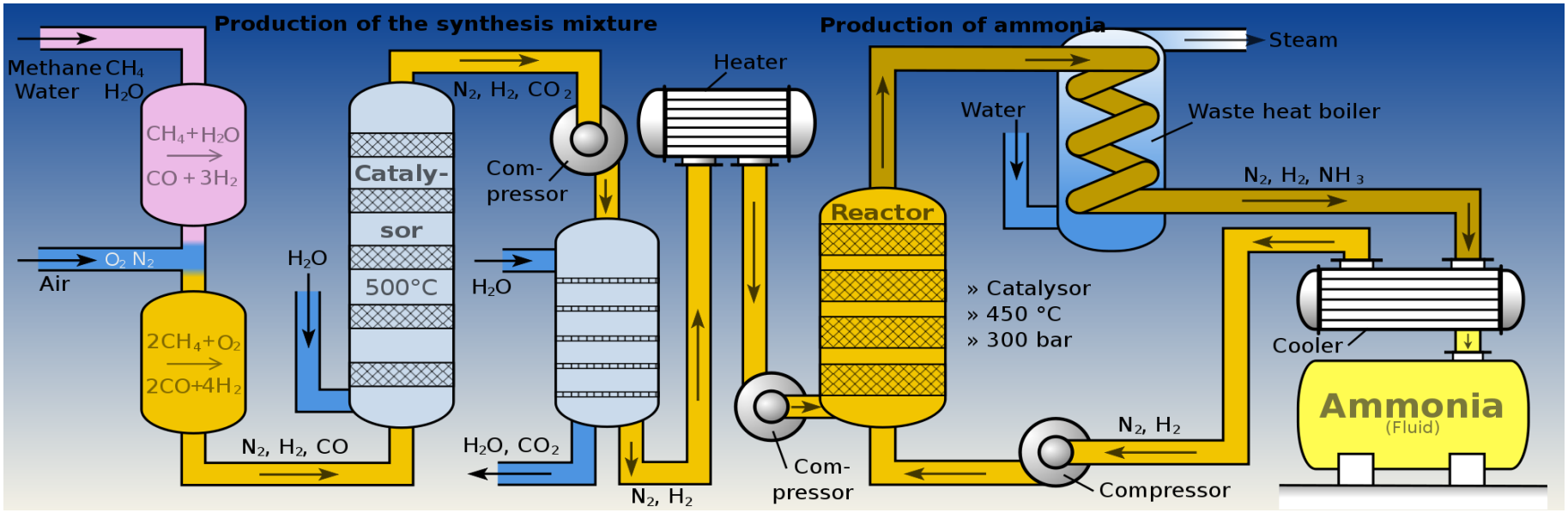
Intro

Energy Generation

Energy Use

Summary

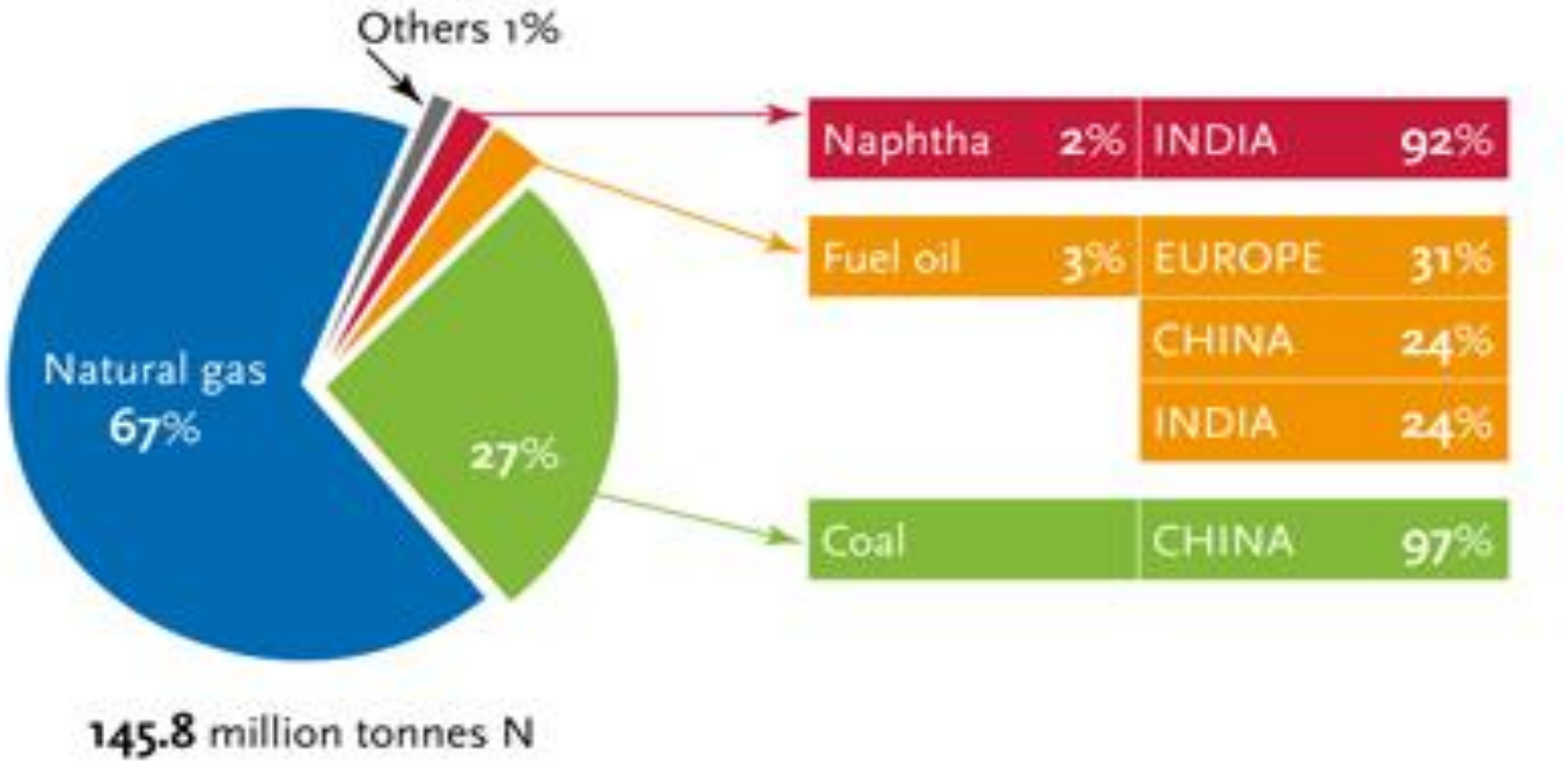
Energy for fertilizer production



Energy intensity of ammonia synthesis: 28-52 GJ/t, average around 41-42 GJ/t, depending on size, age, feedstock and technology

Source: International Energy Agency, “Tracking industrial energy efficiency and CO2 emissions” , IEA, 2007

Energy use in Fertilizer production



Global ammonia capacity by feedstock, 2007 (Source: IFA 2008a)

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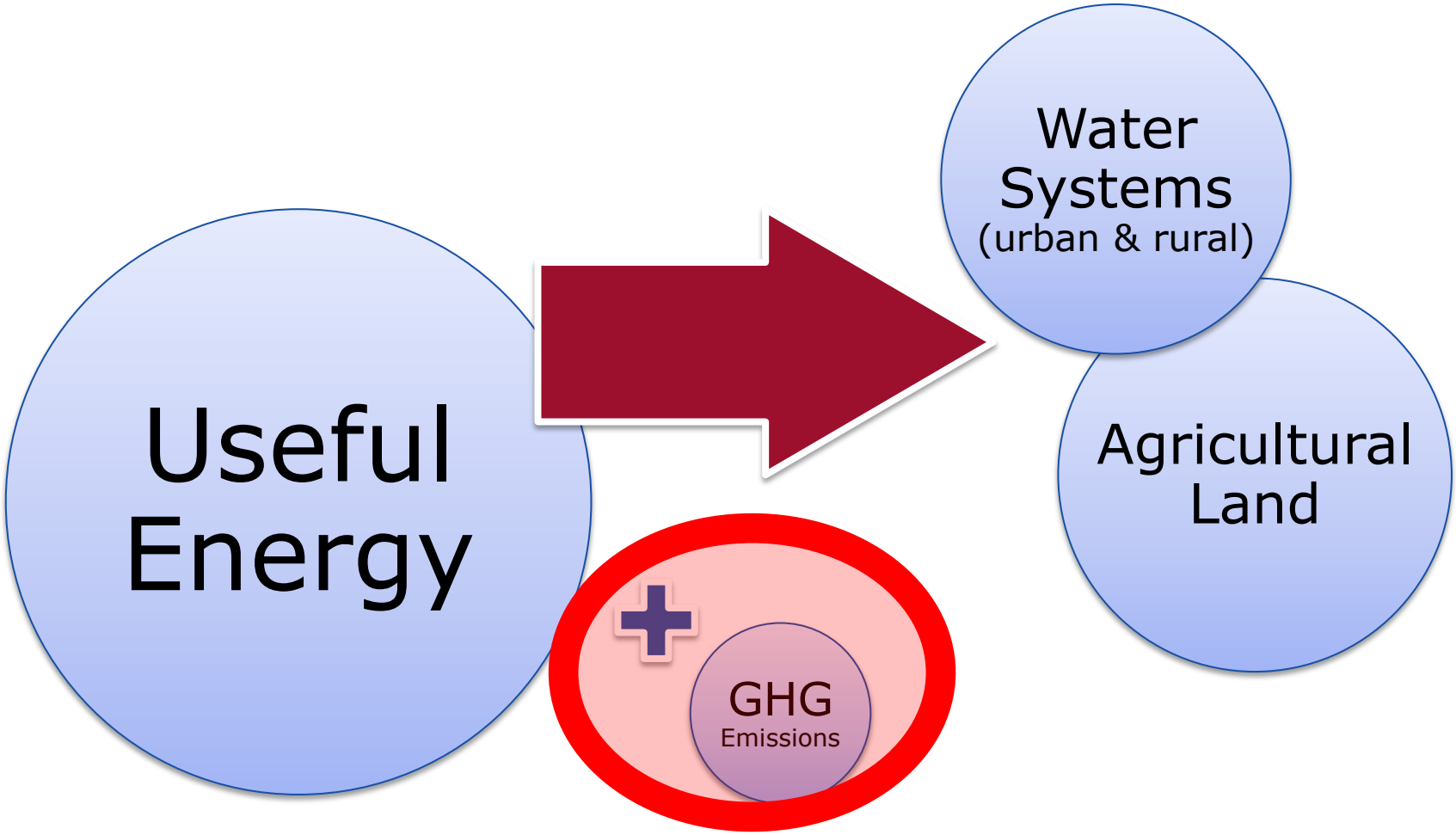
Energy and GHGs



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Lifecycle estimates for electricity generators[a]

Technology	Capacity/configuration/fuel	Estimate (gCO_2e/kWh)
Wind	2.5 MW, offshore	9
Hydroelectric	3.1 MW, reservoir	10
Wind	1.5 MW, onshore	10
Biogas	Anaerobic digestion	11
Hydroelectric	300 kW, run-of-river	13
Solar thermal	80 MW, parabolic trough	13
Biomass	Forest wood Co-combustion with hard coal	14
Biomass	Forest wood steam turbine	22
Biomass	Short rotation forestry Co-combustion with hard coal	23
Biomass	FOREST WOOD reciprocating engine	27
Biomass	Waste wood steam turbine	31
Solar PV	Polycrystalline silicone	32
Biomass	Short rotation forestry steam turbine	35
Geothermal	80 MW, hot dry rock	38
Biomass	Short rotation forestry reciprocating engine	41
Nuclear	Various reactor types	66
Natural gas	Various combined cycle turbines	443
Fuel cell	Hydrogen from gas reforming	664
Diesel	Various generator and turbine types	778
Heavy oil	Various generator and turbine types	778
Coal	Various generator types with scrubbing	960
Coal	Various generator types without scrubbing	1050

Benjamin K. Sovacool
2008

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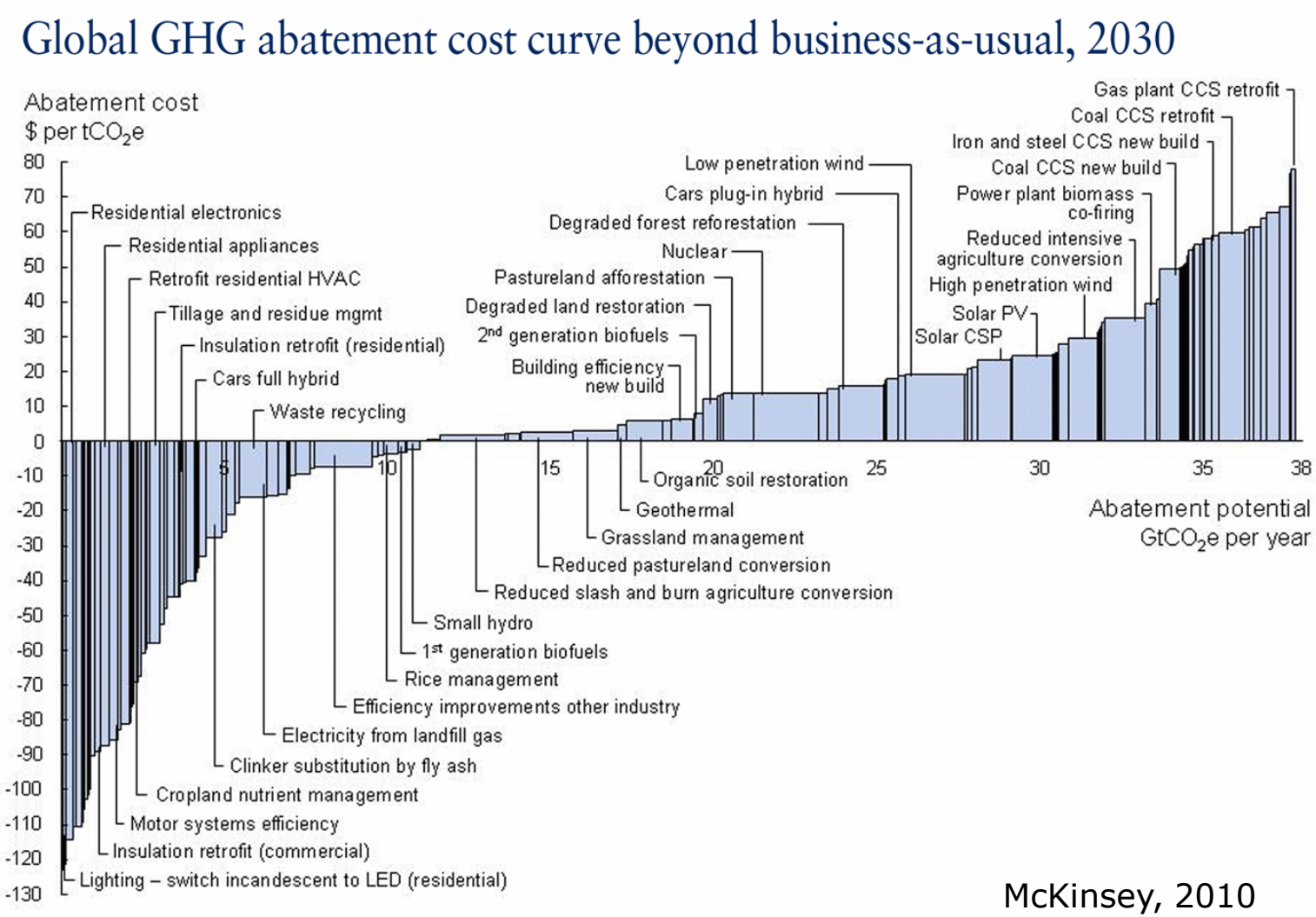
Energy and GHG emissions …



McKinsey, 2010

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Summary

- Trends:
  - Energy supply is becoming more water and land intensive
  - Water supply is becoming more energy intensive
  - Land-use is not necessarily getting more energy or water intensive, but overall demand is still increasing
- Challenge:
  - Provide integrated analysis
  - Support coherent policy formulation

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Thank You