Academia Engelberg 2004

The Global Energy System of the Future: Key Determinant of Climate Change

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Energy and Biosphere: Dissipative Structures

- Living organisms are structures of large complexity in an environment of less differentiation. To sustain their internal order they depend on a steady flux of degradable energy.

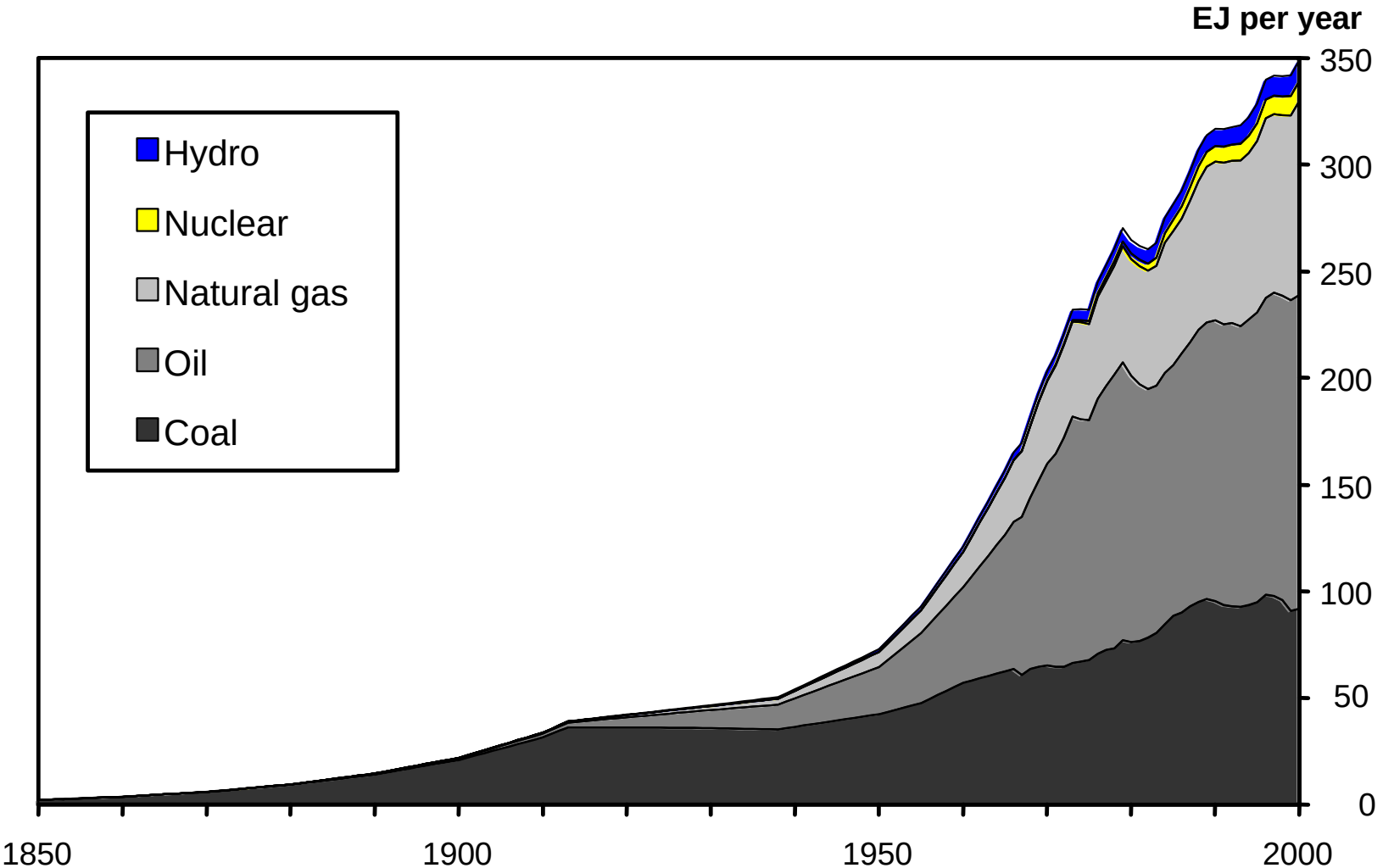
- I. Prigogine coined the term dissipative structure for these kind of ‚complexity islands‘.

- The anthroposphere is a super dissipative structure. During most of the history of man, the sun was nearly the only source of degradable energy.

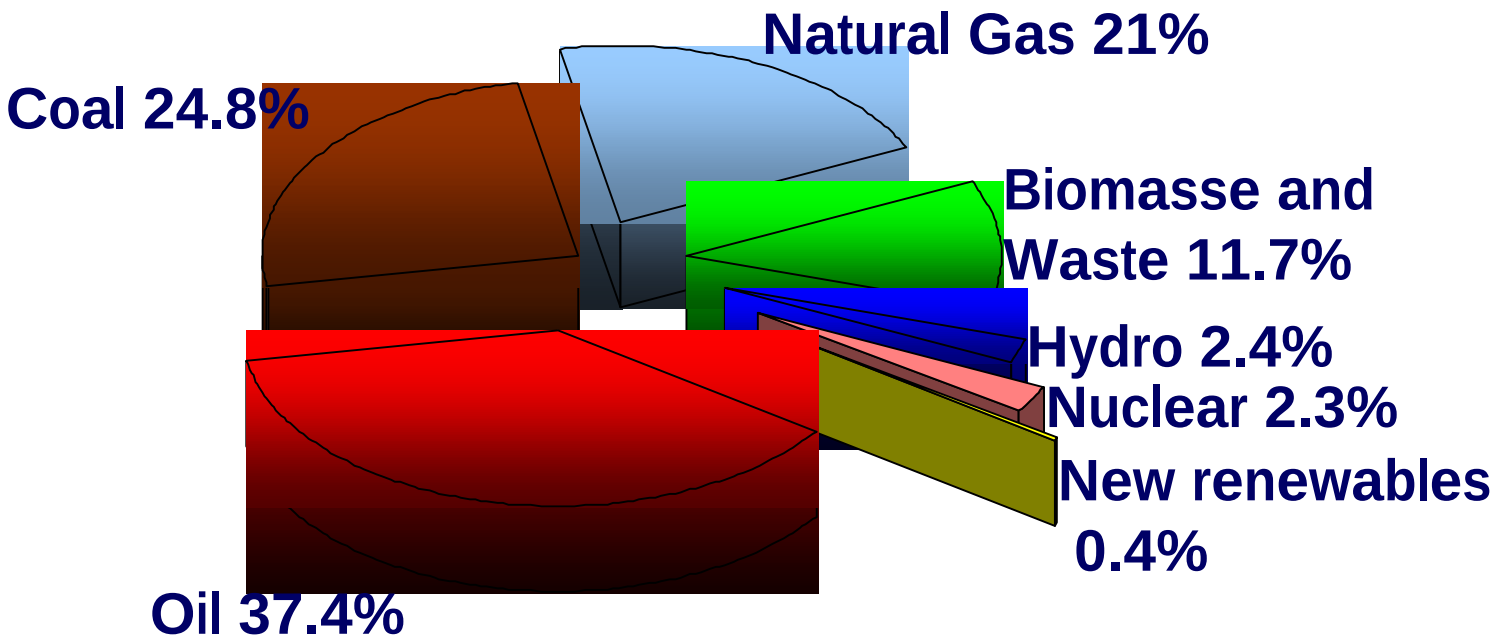
Global solar *vs* anthropogenic energy fluxes

	Per area (Watt per m^2)	**Total** (TeraWatt)
Total solar radiation at surface of the earth	240	122‘000
Global commercial energy demand	0.02	12
Physiological energy demand of mankind (100 Watt per person)		0.6
Total biological primary production (ocean and land)	0.25	130

Global Energy Demand 1850 - 2000

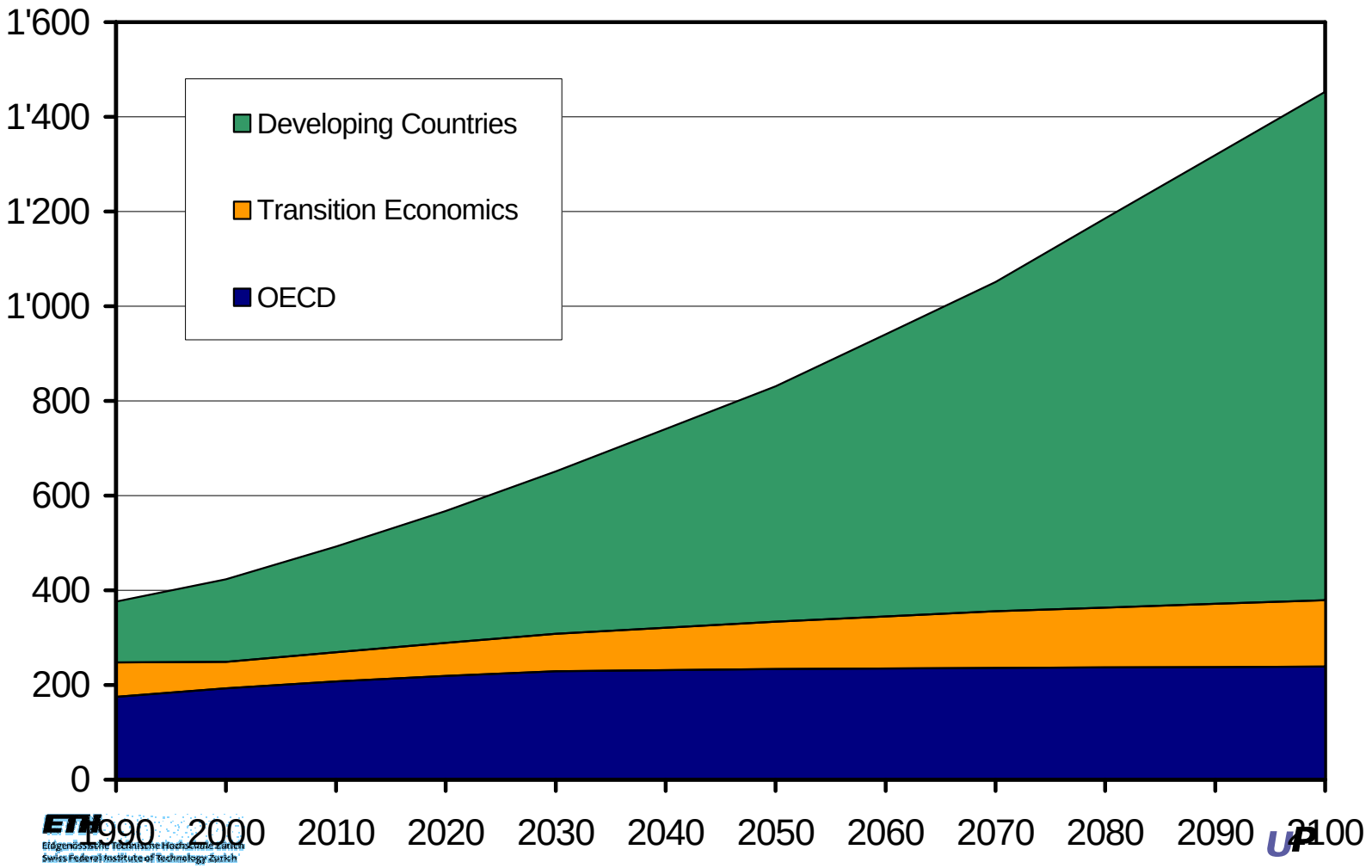


Global Primary Energy demand 2000



Total 380 E J / year = 2‘100 Watt / Person

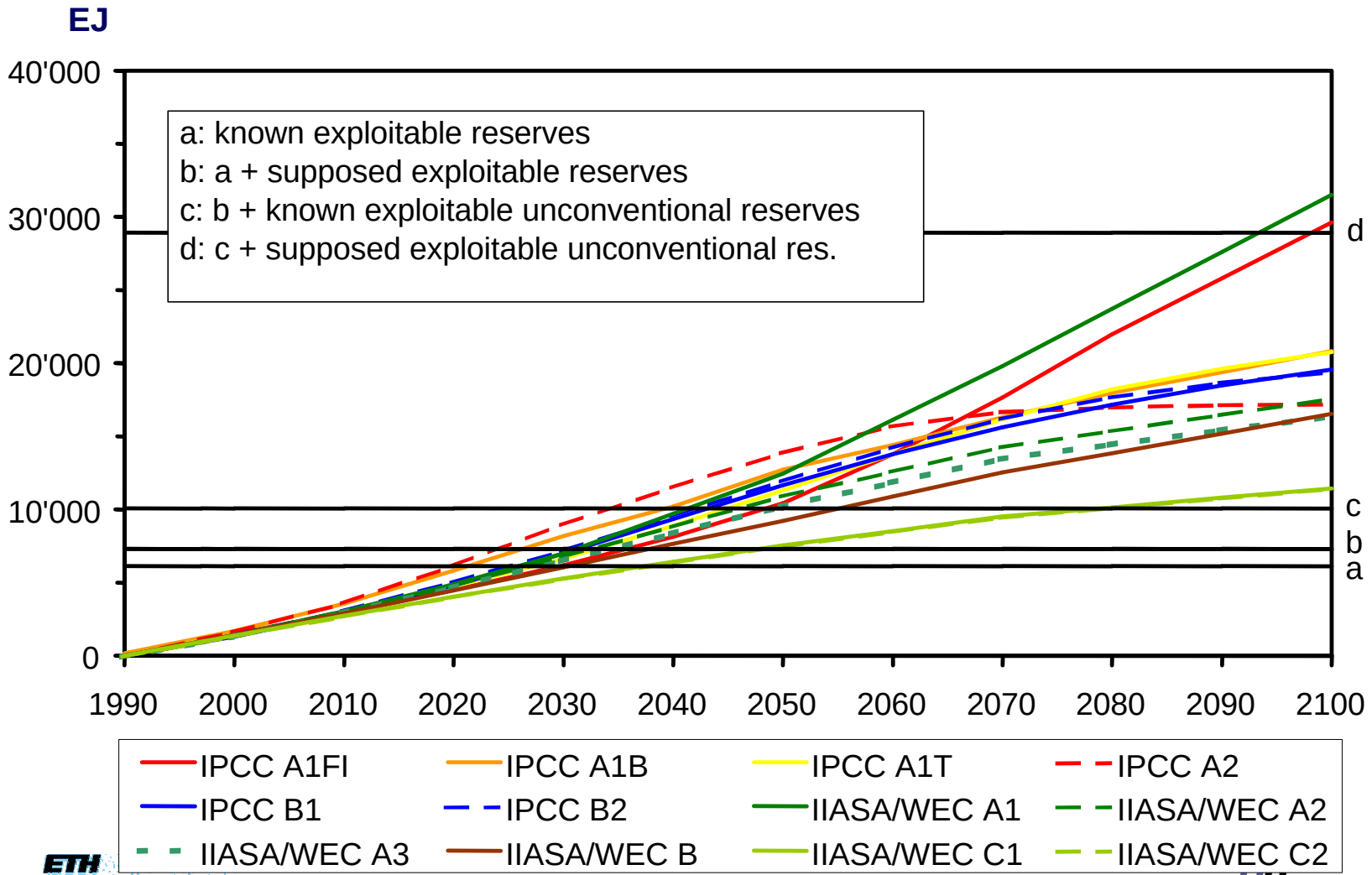
Energy Forecast [EJ/year])



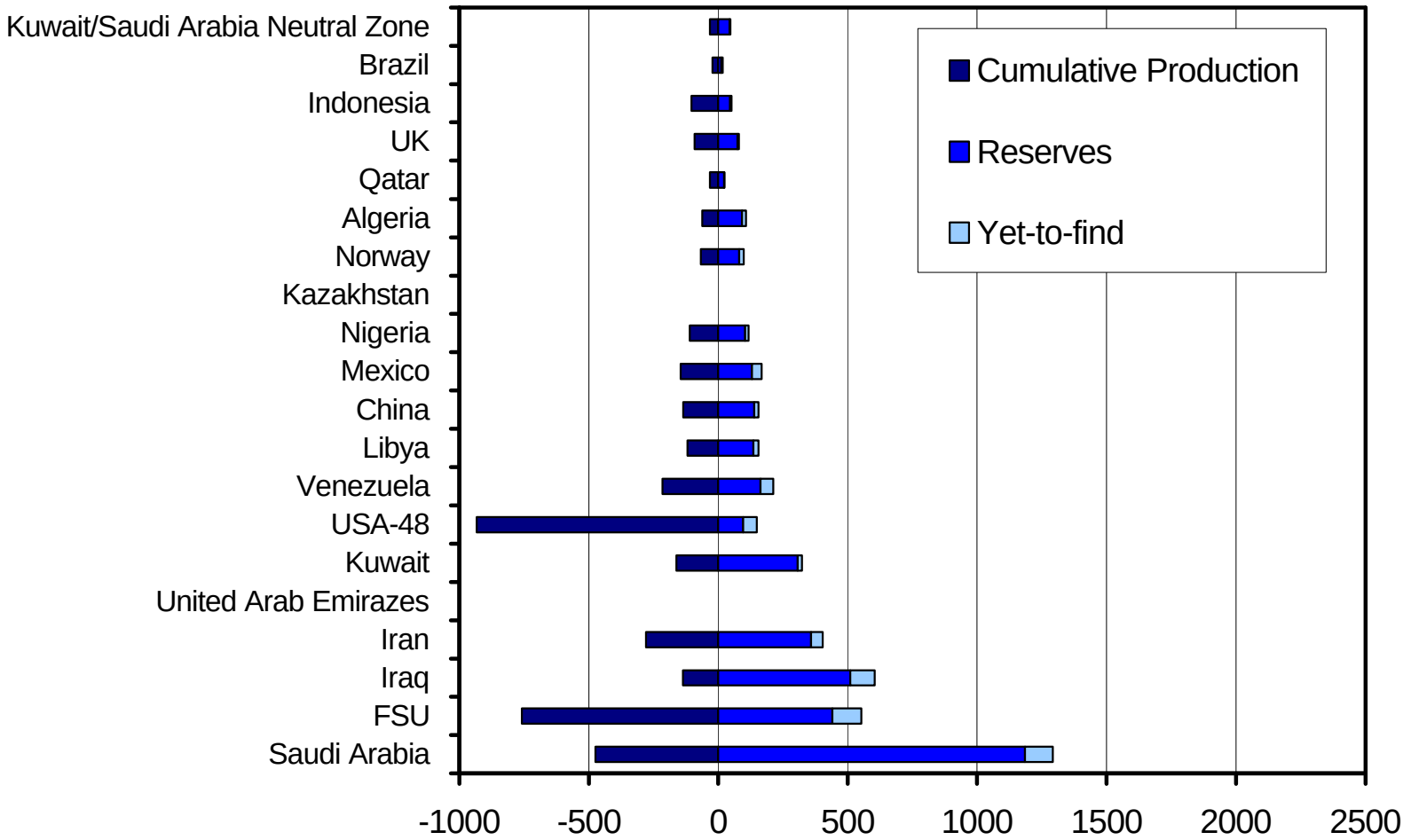
Relevant Energy Resources

- Fossil fuels
- Nuclear energy (fission and fusion)
- Hydroelectricity
- Other solar energies (solar heat, photovoltaic, biomass…)
- Geothermal energy
- **Efficiency**

Integrated Oil Production and Reserves



Oil Resources [EJ]



The role of electricity in the global energy system

(Source: Key World Energy Statistic, IEA, 2001)

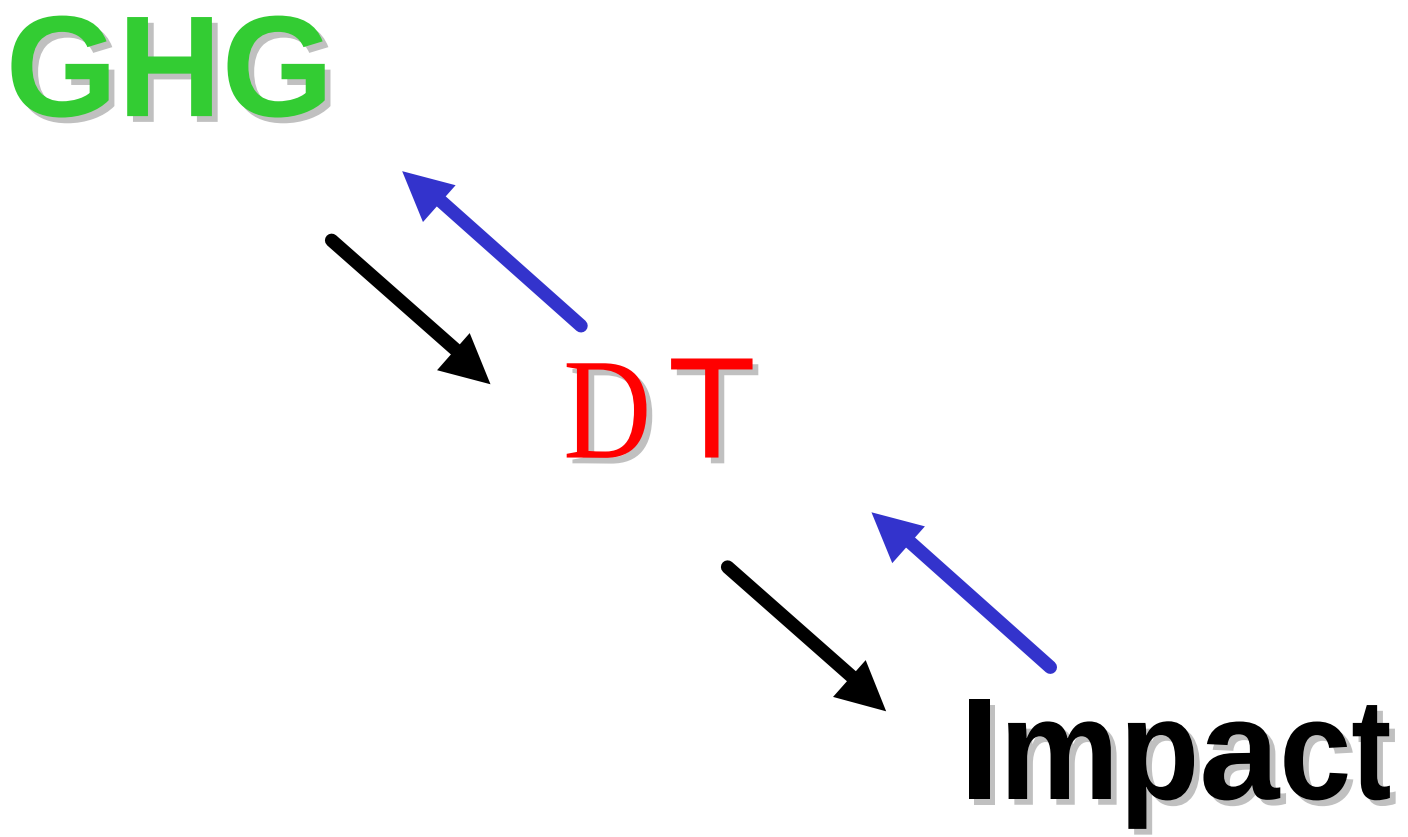
Global commercial energy demand (1999)	**11.3 TW**	
Production of electricity	**1.7 TW**	**(15%)**
Coal/wood	38.1%	
Oil	8.5%	
Natural gas	17.1%	
Total fossil	**63.7%**	
Nuclear	**17.2%**	**(290 GW)**
Hydroelectricity	17.5%	
Others (geothermal, wind, biomass, solar)	1.6%	

Potential of Solar Energy

	Average yearly power Watt/m^2	
Photovoltaic (Electricity)	**3 - 6**	
Solar heat	**30 - 60**	
Biomasse: Plants	**3 - 6**	
Biomasse: Wood	**0.1 - 0.2**	

Potential of Solar Energy Production in relation to energy demand of Switzerland

Physiological energy demand	**100 Watt/capita**
From plant biomass (1 Watt/m²)	**100 m²/capita**
For Switzerland:	**700 km²**
Swiss crop land	**13 times larger**
Anthropogenic energy demand	**6‘000 Watt/Pers.**
(including grey energy import)	
From Photovoltaic(5 Watt/m²)	**1‘200 m²/capita**
For Switzerland:	**8‘400 km²**
„Constructed Switzerland„	**2‘500 km²**

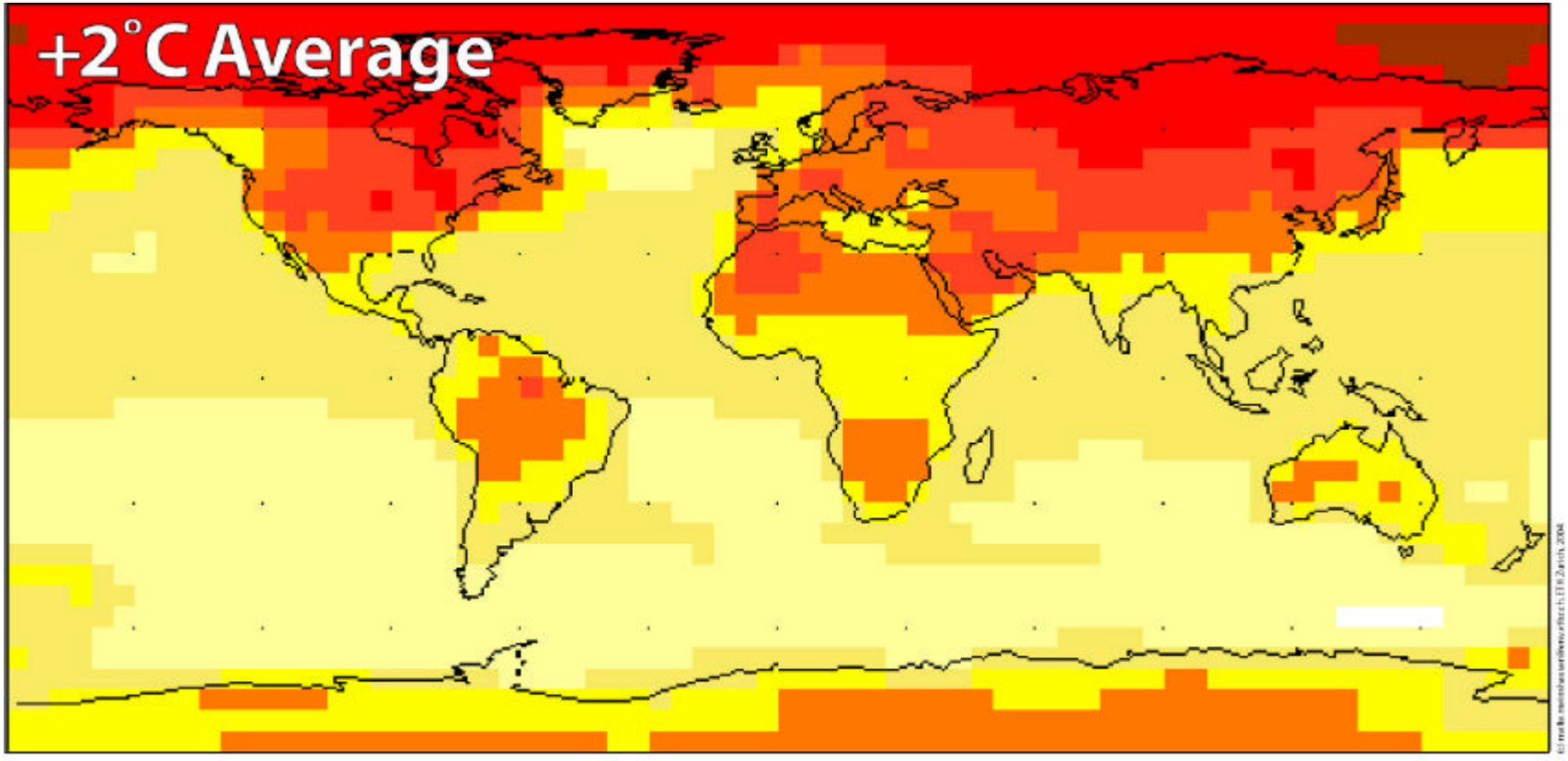

GHG
DT
Impact

EU's 2°C target

- *"the Council [...] acknowledges that to meet the ultimate objective of the UNFCCC to prevent dangerous anthropogenic interference with the climate system, overall global temperature increase* ***should not exceed 2ºC above pre-industrial levels****; [...]"*

(Spring European Council 2004, 25-26 March 2004)
(Doc 7631/04 (ANNEX), page 29)

Temperature increase higher over land

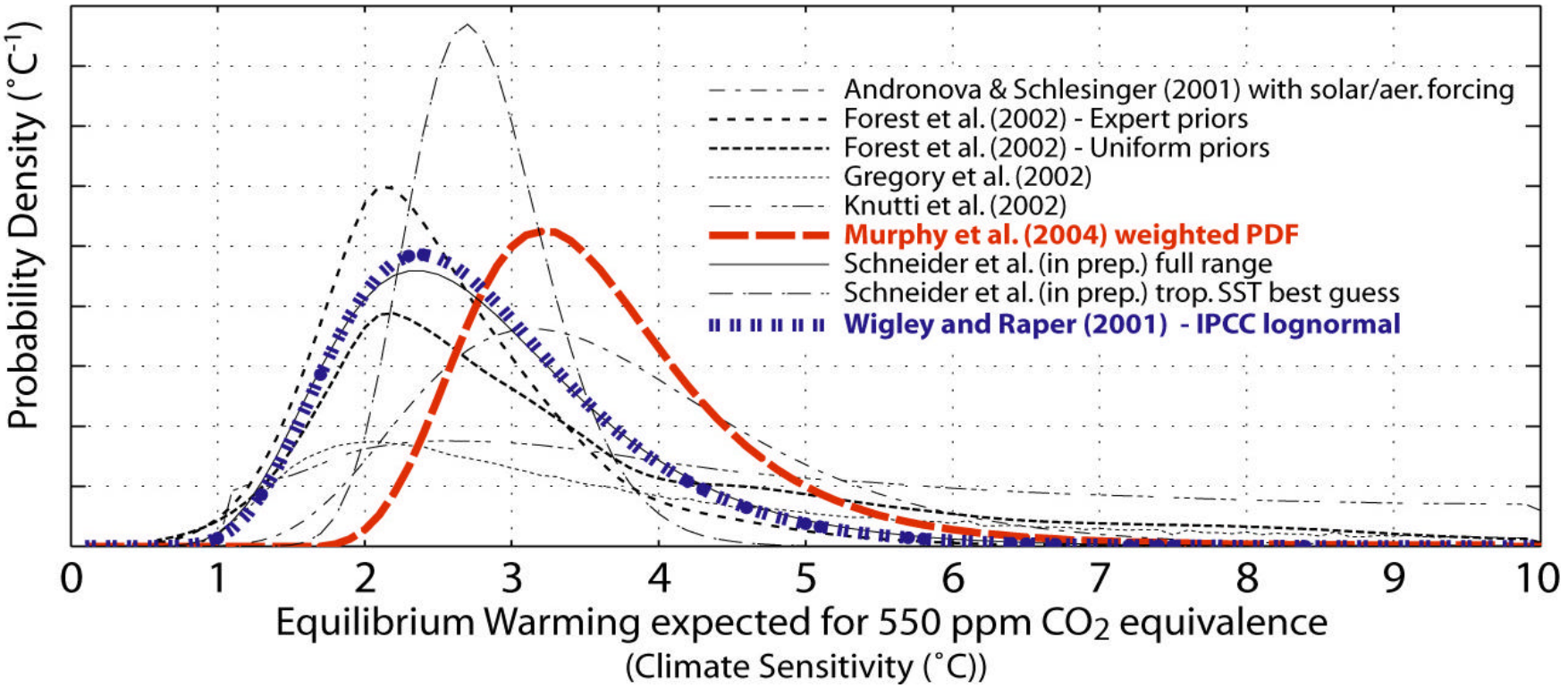


Approximate annual mean surface temperature distribution for global increase by 2°C

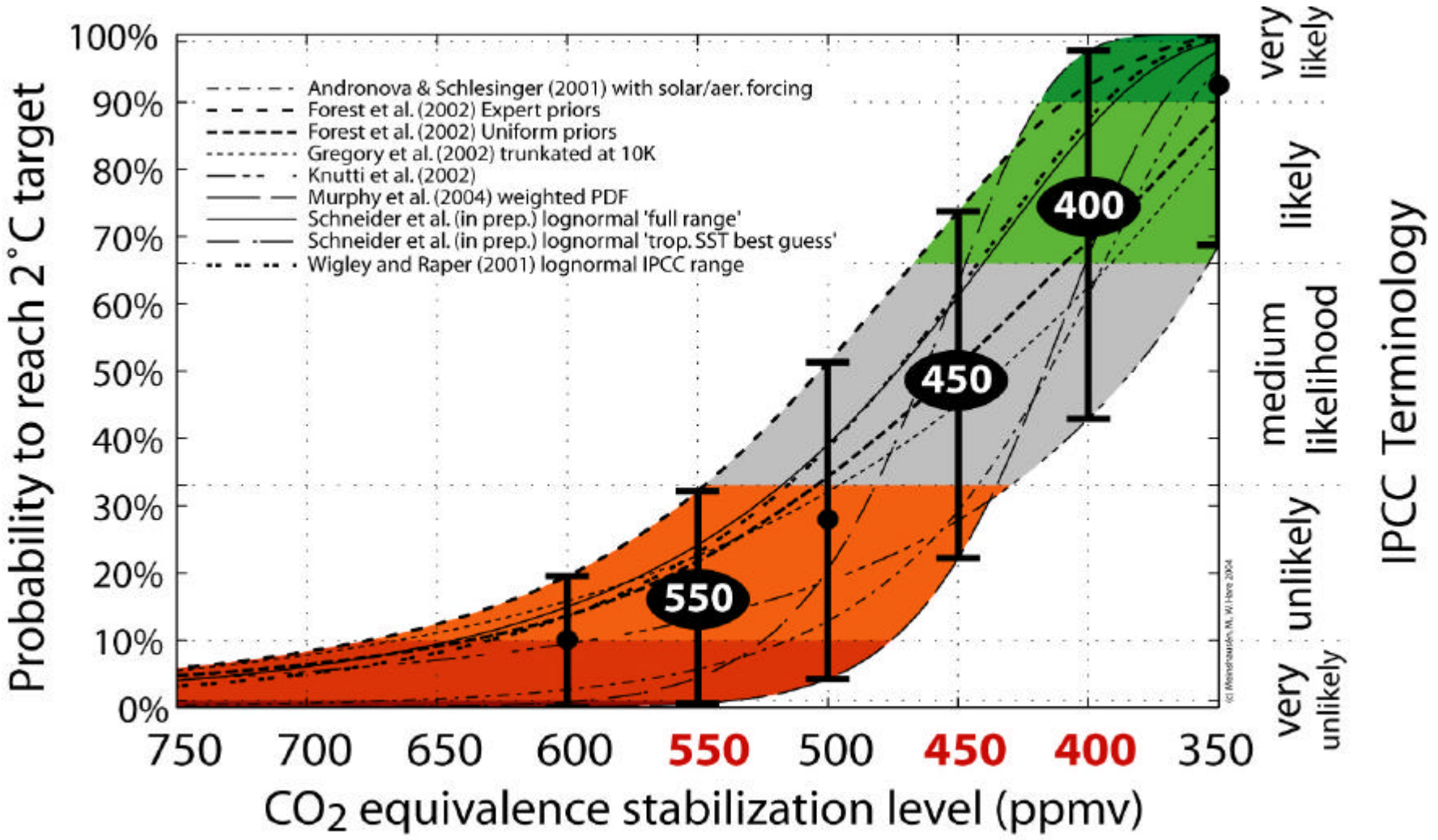
Note: Employed linear pattern scaling method as implemented in the SCENGEN model (by Wigley et al.).
The displayed pattern is the average of the default set of models, namely CSM (1998), ECHAM3 (1995), ECHAM4 (1998), GFDL (1990), HADAM2 (1995), HADAM3 (2000).
The pattern has been derived for a temperature increase of 2°C above 1990 in a transient run with emission scenario IPCC SRES B2. Note that the equilibrium temperature pattern for a 2°C increase above pre-industrial levels will be quantitatively different, although qualitatively similar.

Expected warming for 550ppm CO_2eq

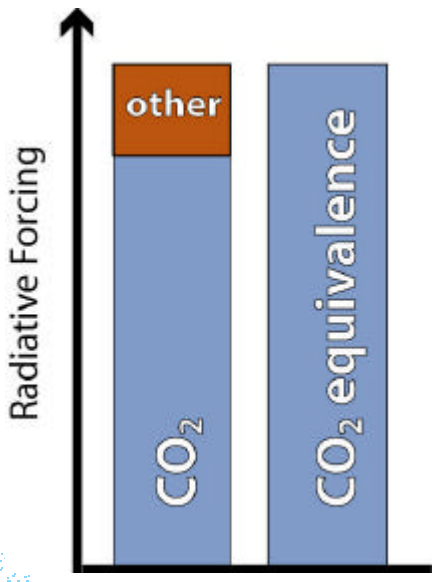
- New research cannot exclude very high warming levels (e.g. > 4.5°C) for stabilization of greenhouse gases at 550ppm CO_2 equivalence
- "*The fact that we are uncertain may actually be a reason to act sooner rather than later*" (Eileen Claussen)



The probability to reach the 2°C

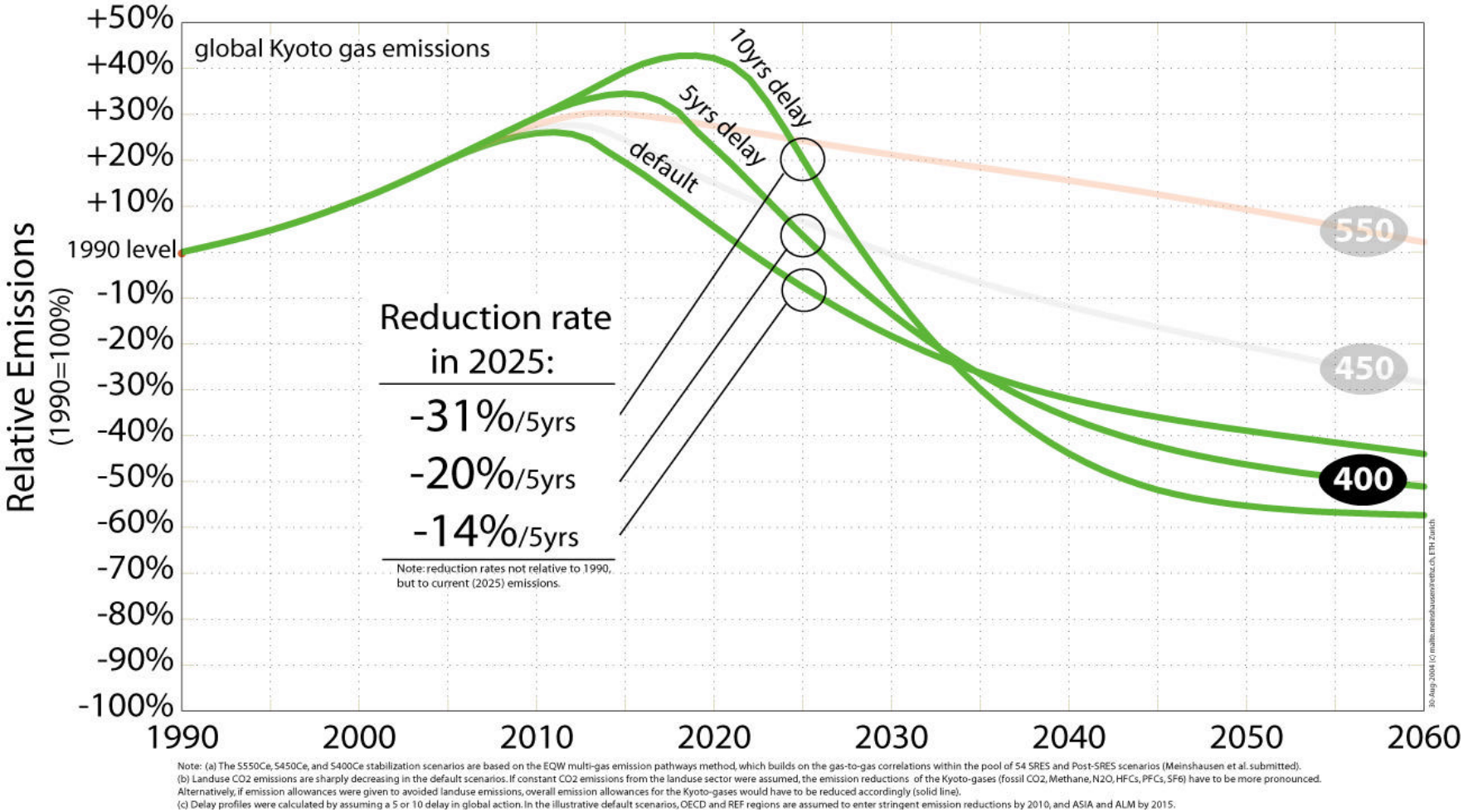


- "CO_2equivalence" summarizes the climate effect ('radiative forcing') of all human-induced greenhouse-gases and aerosols, as if we only changed the atmospheric concentrations of CO_2.



Conversion Table for > 2100		
CO_2 (ppmv) + other GHG + aerosols		CO_2eq (ppmv)
350 + other	~	400
390 + other	~	450
470 + other	~	550
550 + other	~	650

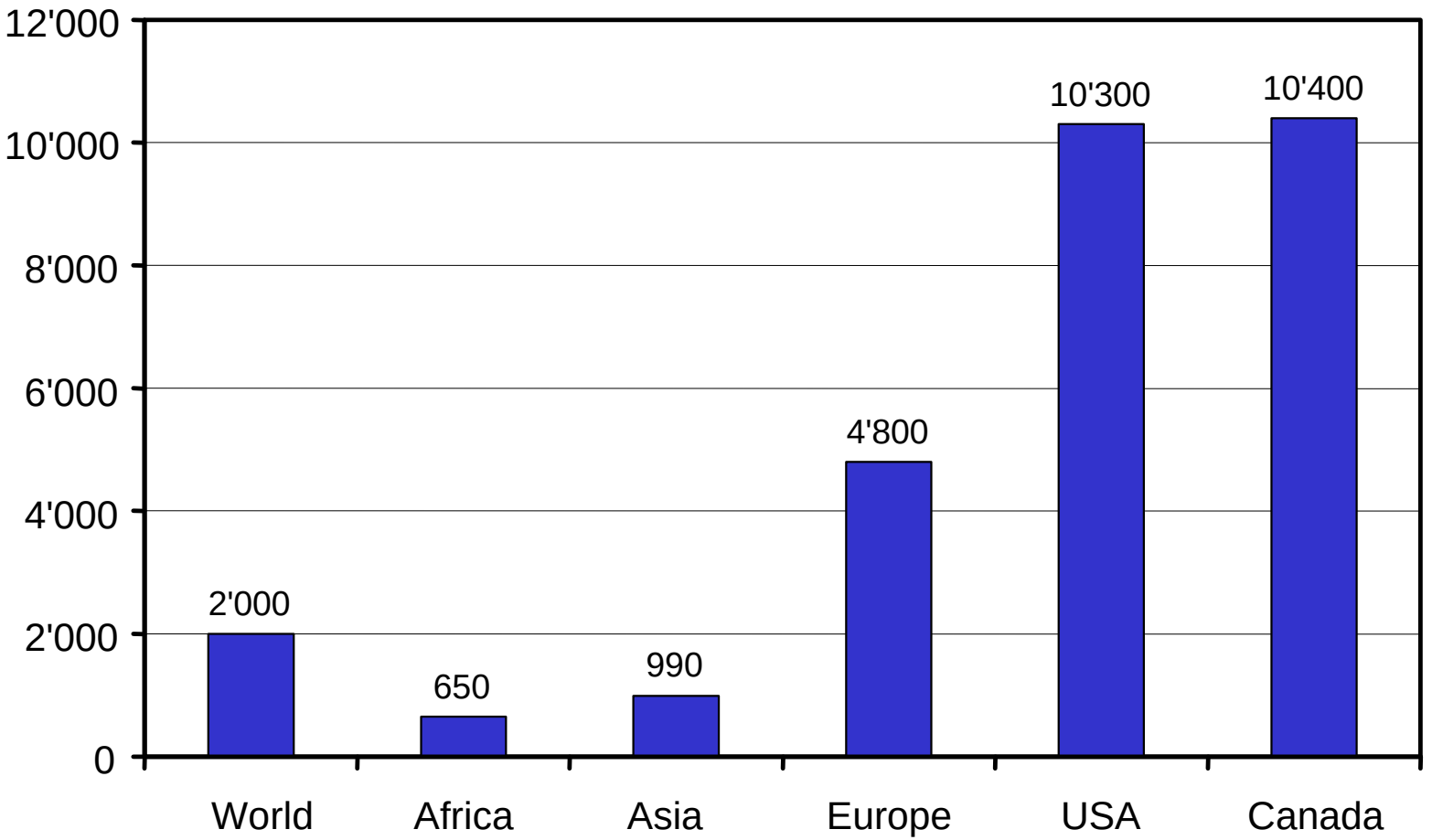
"*Delaying action for a decade, or even just years, is not a serious option*" Sir David King (Science, 9 January 2004)



Note: (a) The S550Ce, S450Ce, and S400Ce stabilization scenarios are based on the EQW multi-gas emission pathways method, which builds on the gas-to-gas correlations within the pool of 54 SRES and Post-SRES scenarios (Meinshausen et al. submitted).
(b) Landuse CO_2 emissions are sharply decreasing in the default scenarios. If constant CO_2 emissions from the landuse sector were assumed, the emission reductions of the Kyoto-gases (fossil CO_2, Methane, N_2O, HFCs, PFCs, SF_6) have to be more pronounced. Alternatively, if emission allowances were given to avoided landuse emissions, overall emission allowances for the Kyoto-gases would have to be reduced accordingly (solid line).
(c) Delay profiles were calculated by assuming a 5 or 10 delay in global action. In the illustrative default scenarios, OECD and REF regions are assumed to enter stringent emission reductions by 2010, and ASIA and ALM by 2015.

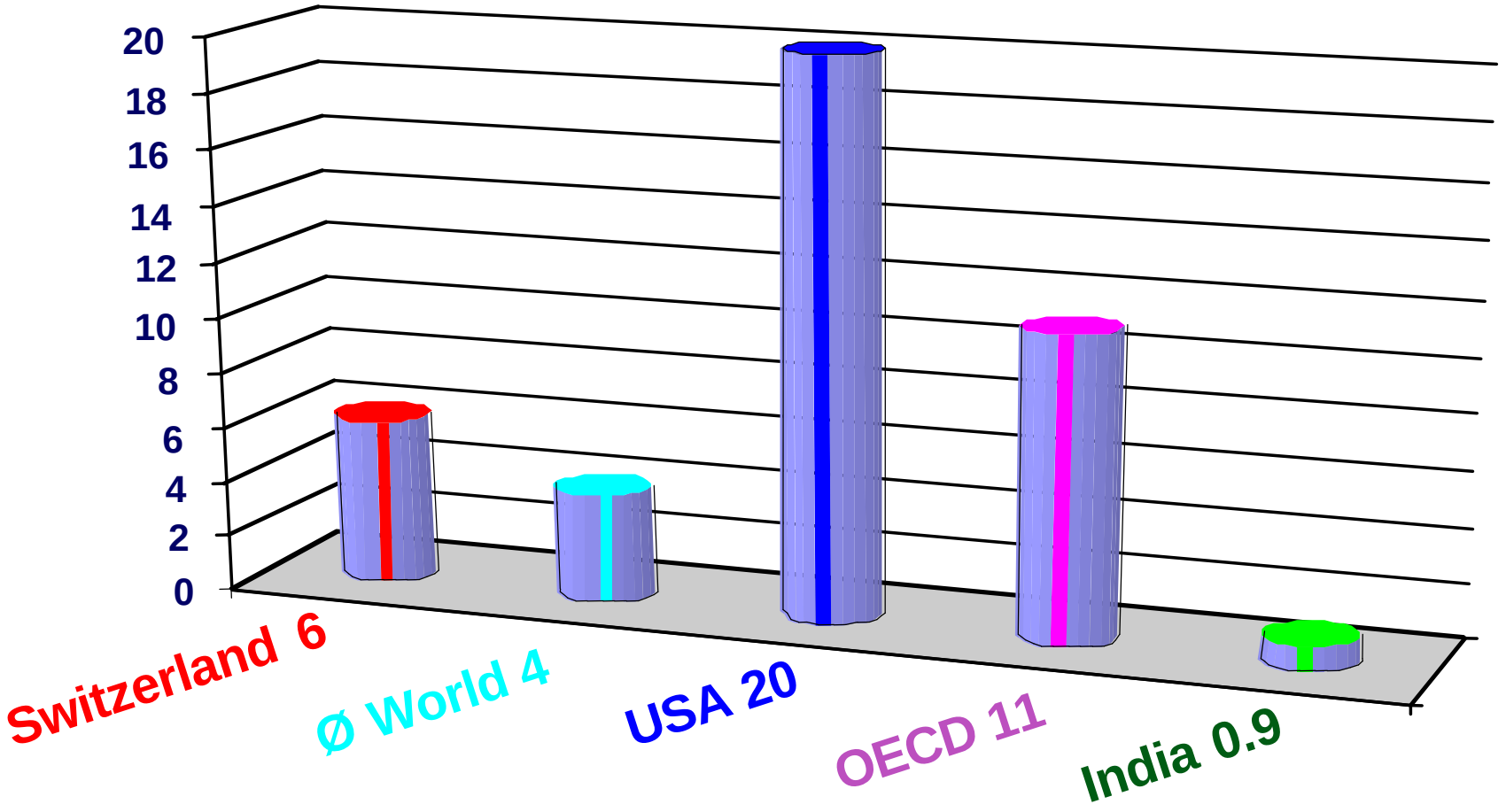
Lord John Browne, CEO BP

“But if we are to avoid having to make dramatic and economically destructive decisions in the future, we must act soon.”
(*Foreign Affairs*, July/August 2004)


12'000
10'000
8'000
6'000
4'000
2'000
0
2'000
650
990
4'800
10'300
10'400
World
Africa
Asia
Europe
USA
Canada

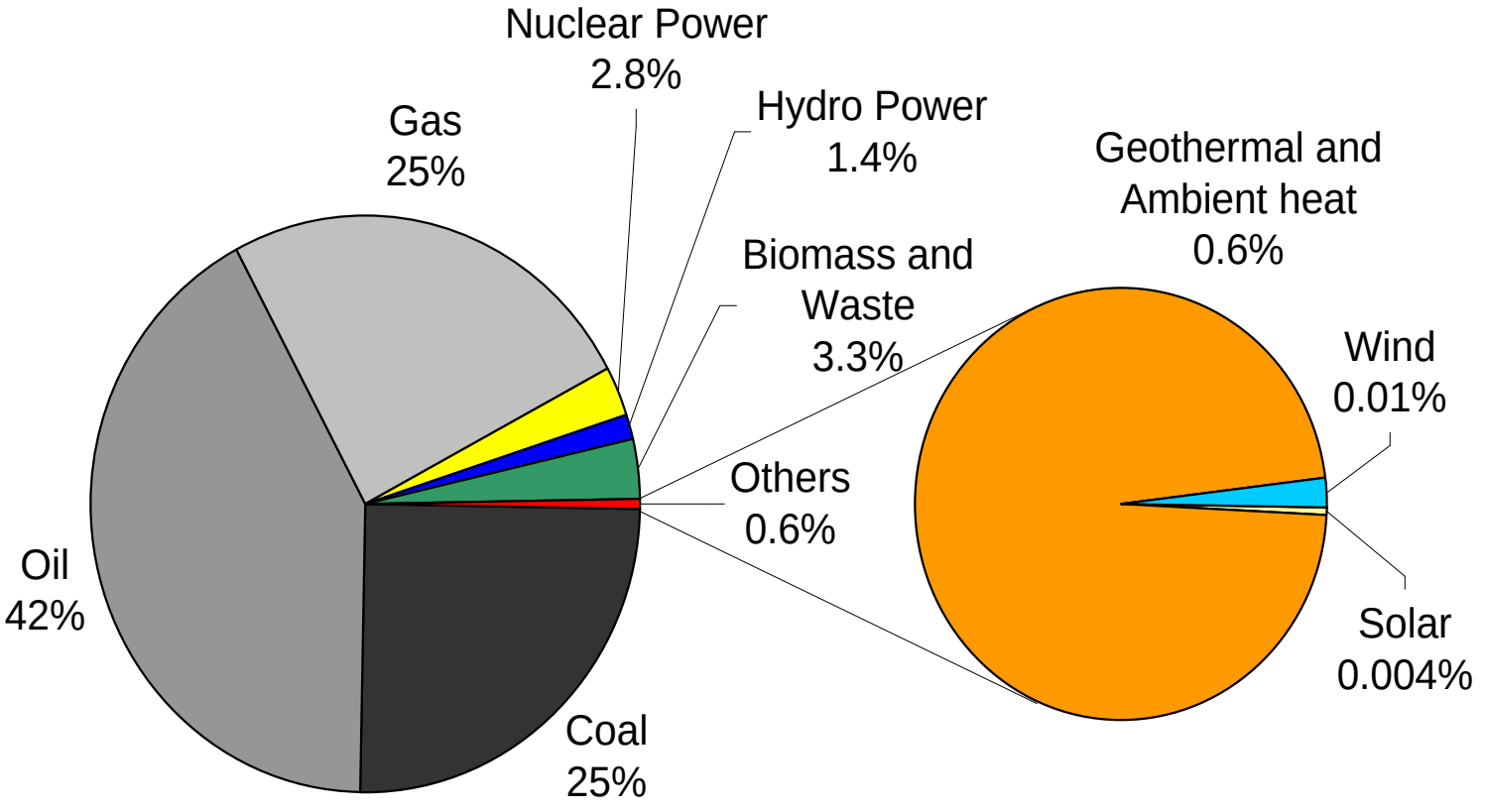
Present global CO_2-emissions

(metric tons per capita and year) –– Total 23 Gt/yr



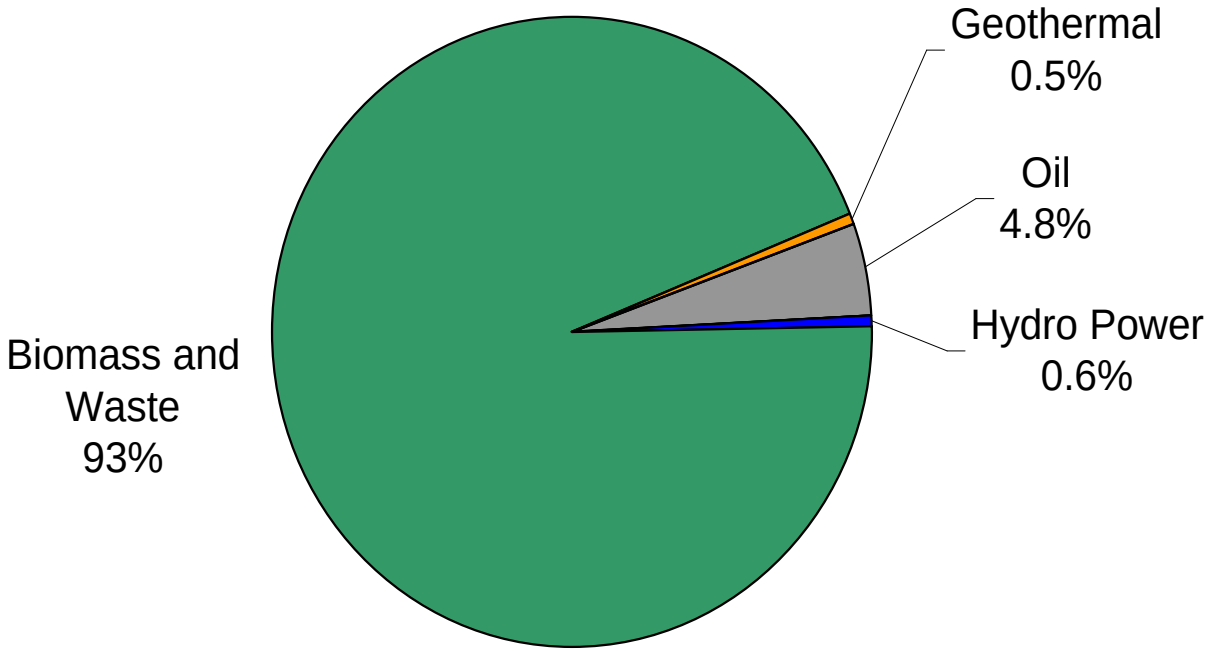
Energy Consumption - USA

Total: 86 EJ
Per Capita: 10‘500 W

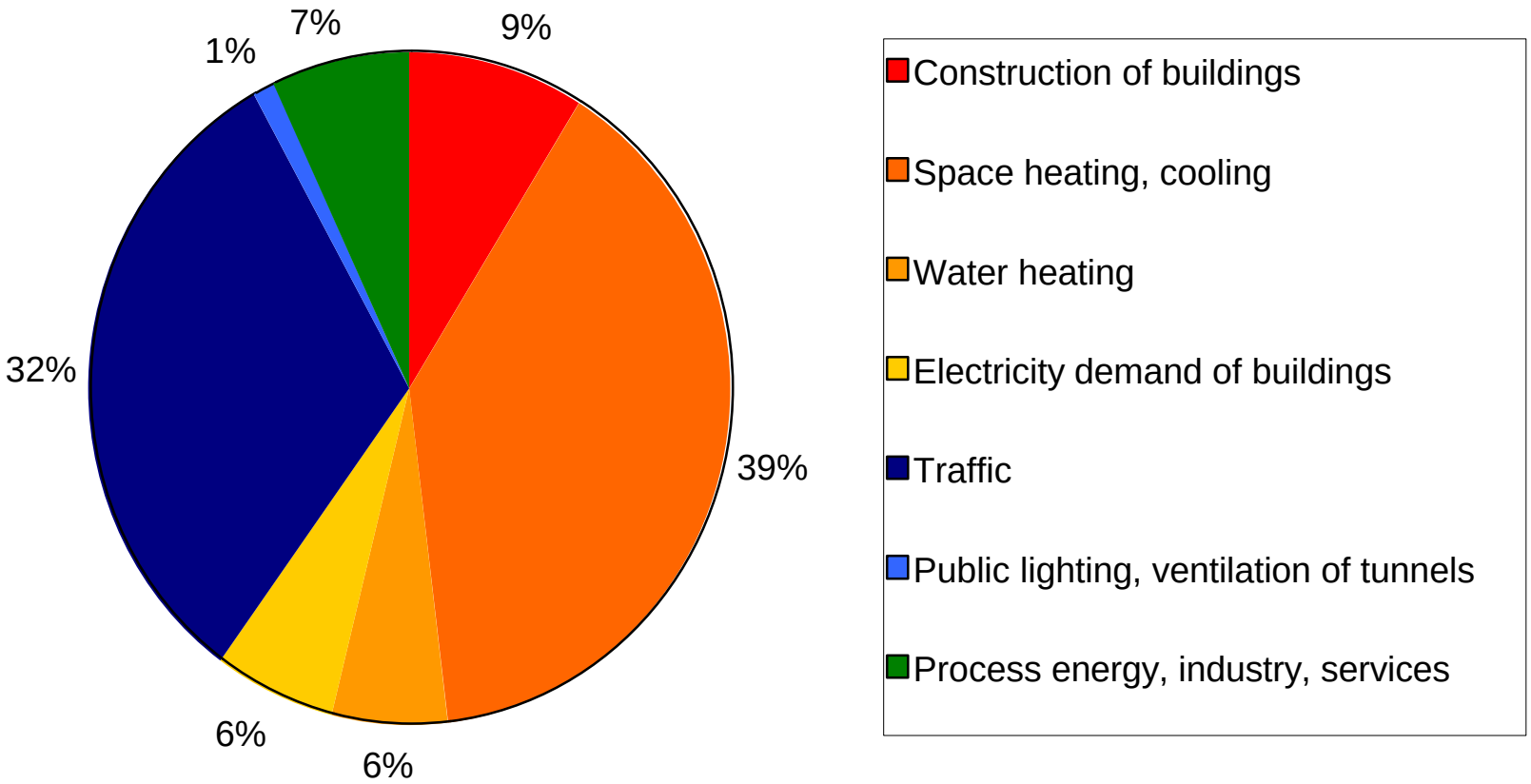


Energy Consumption - Ethiopia

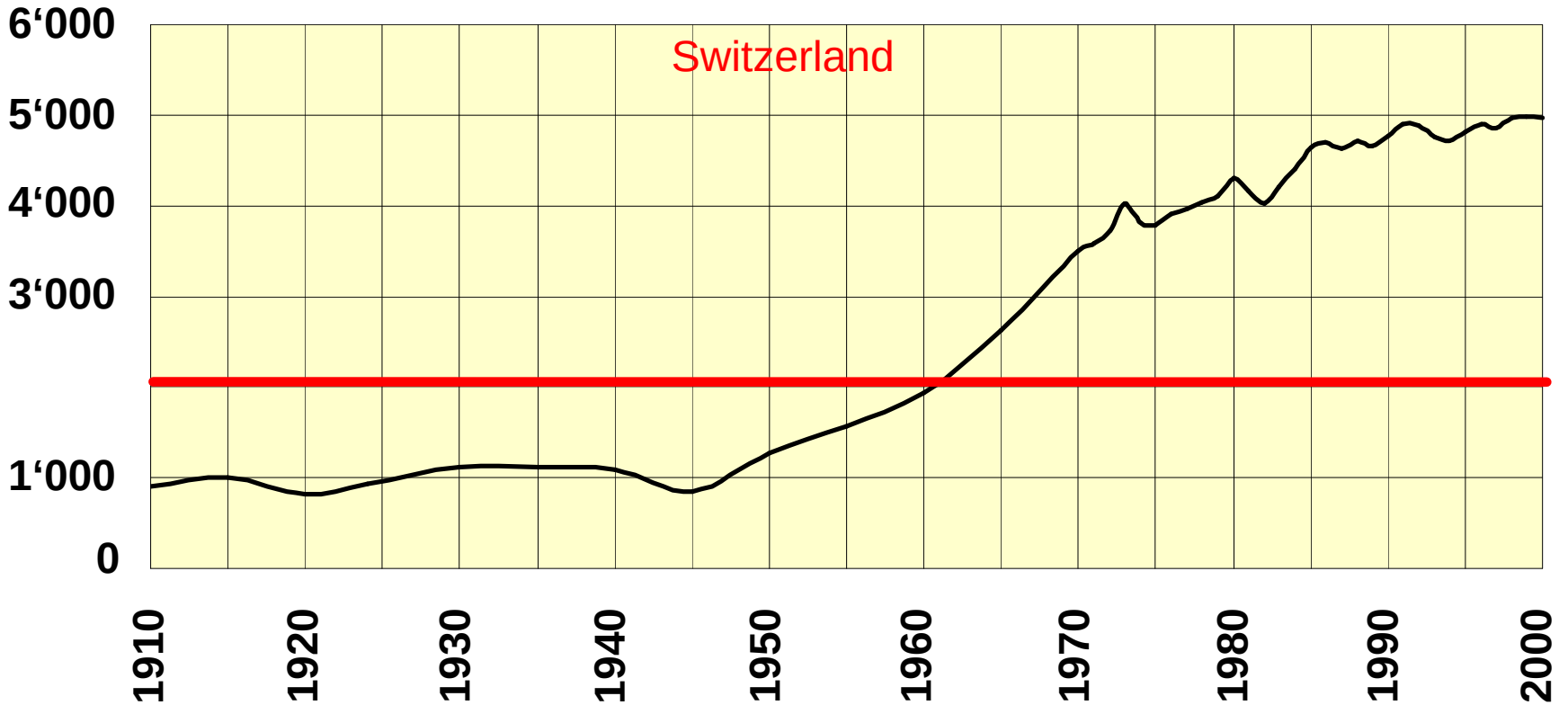
Total: 0.7 EJ
Per Capita: 390 W



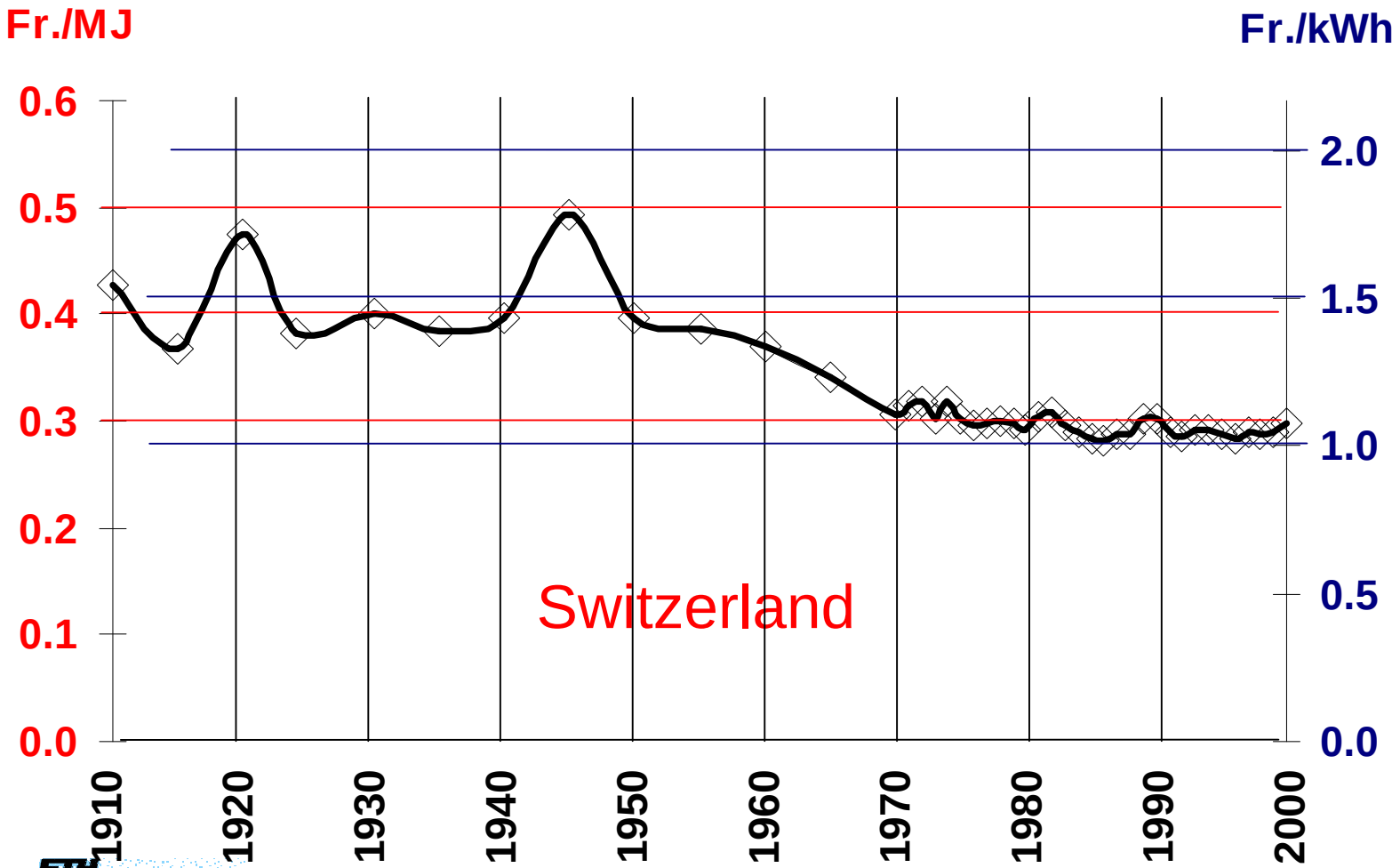
Demand of end energy Switzerland



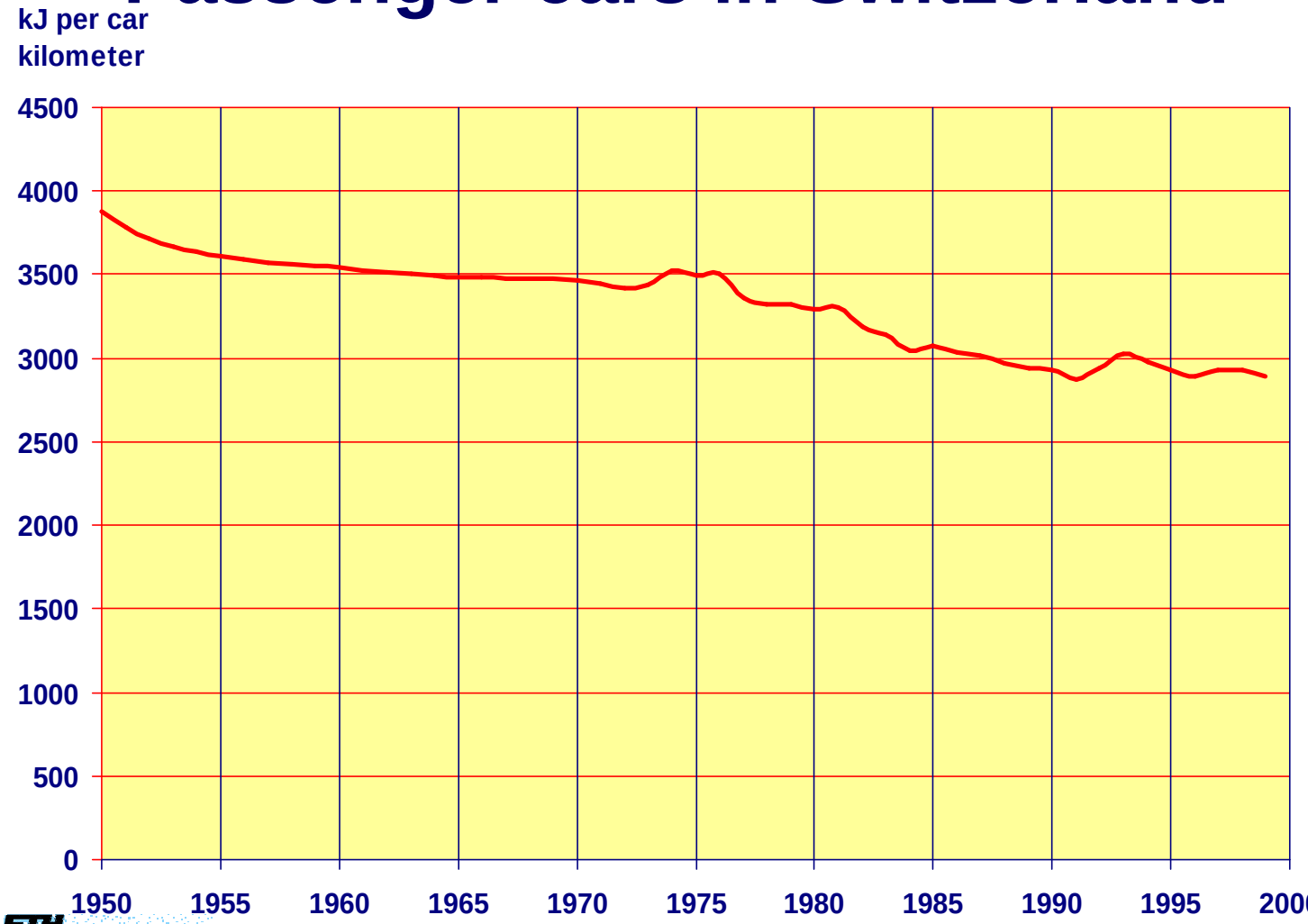
Primary Energy Demand per capita [W]



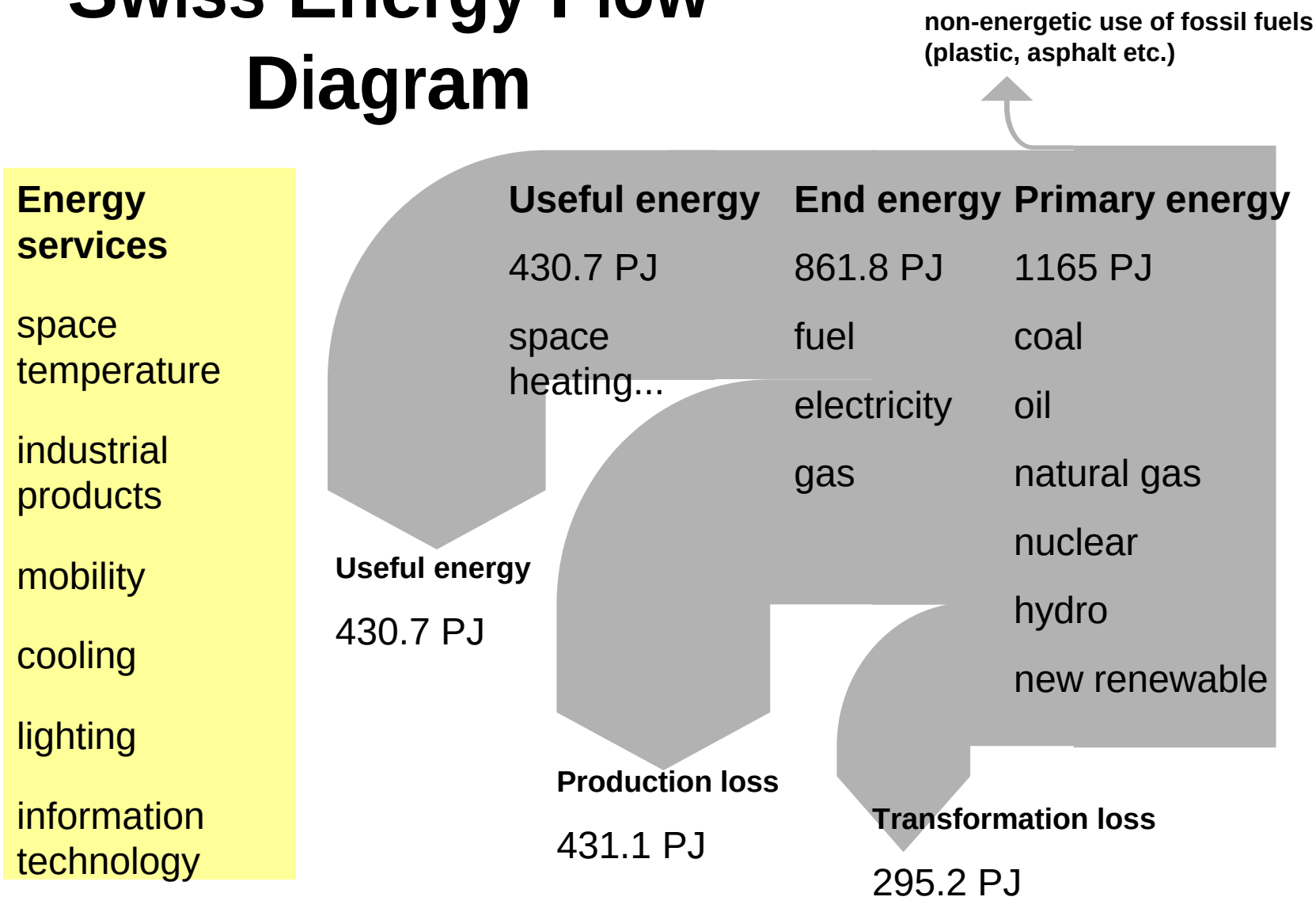
Efficiency of Swiss energy system



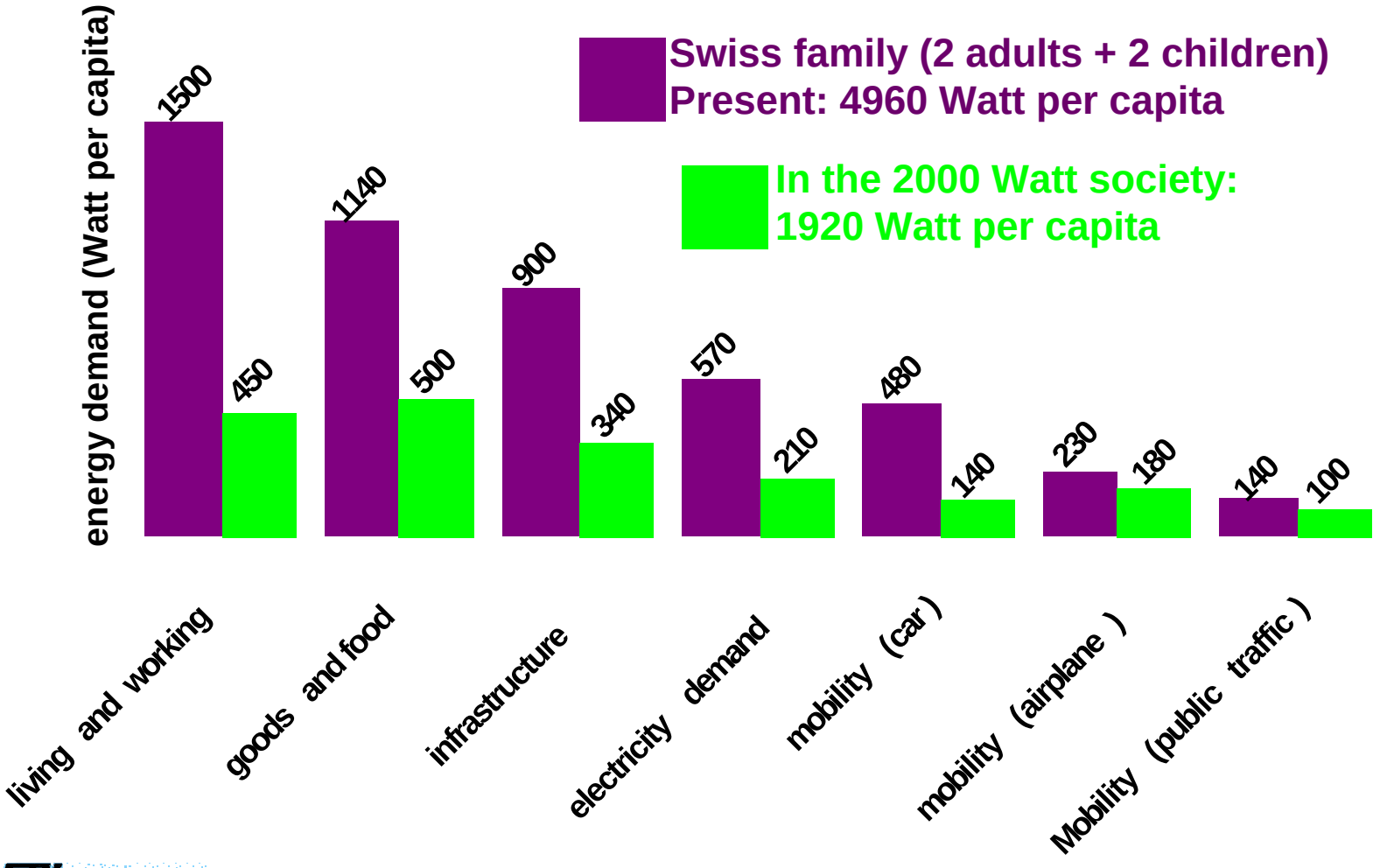
Energie consumption per kilometer Passenger cars in Switzerland



Swiss Energy Flow Diagram

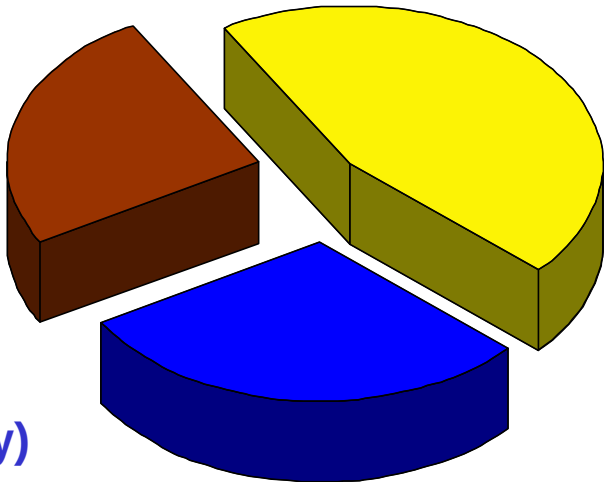


Switzerland as a 2000 Watt society



Possible energy mix in the 2000 W-society

Oil and natural gas
500 Watt per capita



Solar
900 W per capita

Hydroelectricity
600 Watt per capita (as today)

Total 2‘000 Watt per capita

Sustainable Energy Future
(Conclusion)

- The present global energy system is not sustainable. Business-as-usual scenarios will make the situation worse.
- The contributions from renewable energy ressources has to increase significantly.
- The future role of nuclear energy (fission and fusion) is not clear.
- **We must learn to use our energy ressources more efficiently.**
- **Changes need time (2 to 3 generations)**