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LAV

Our energy future(s)

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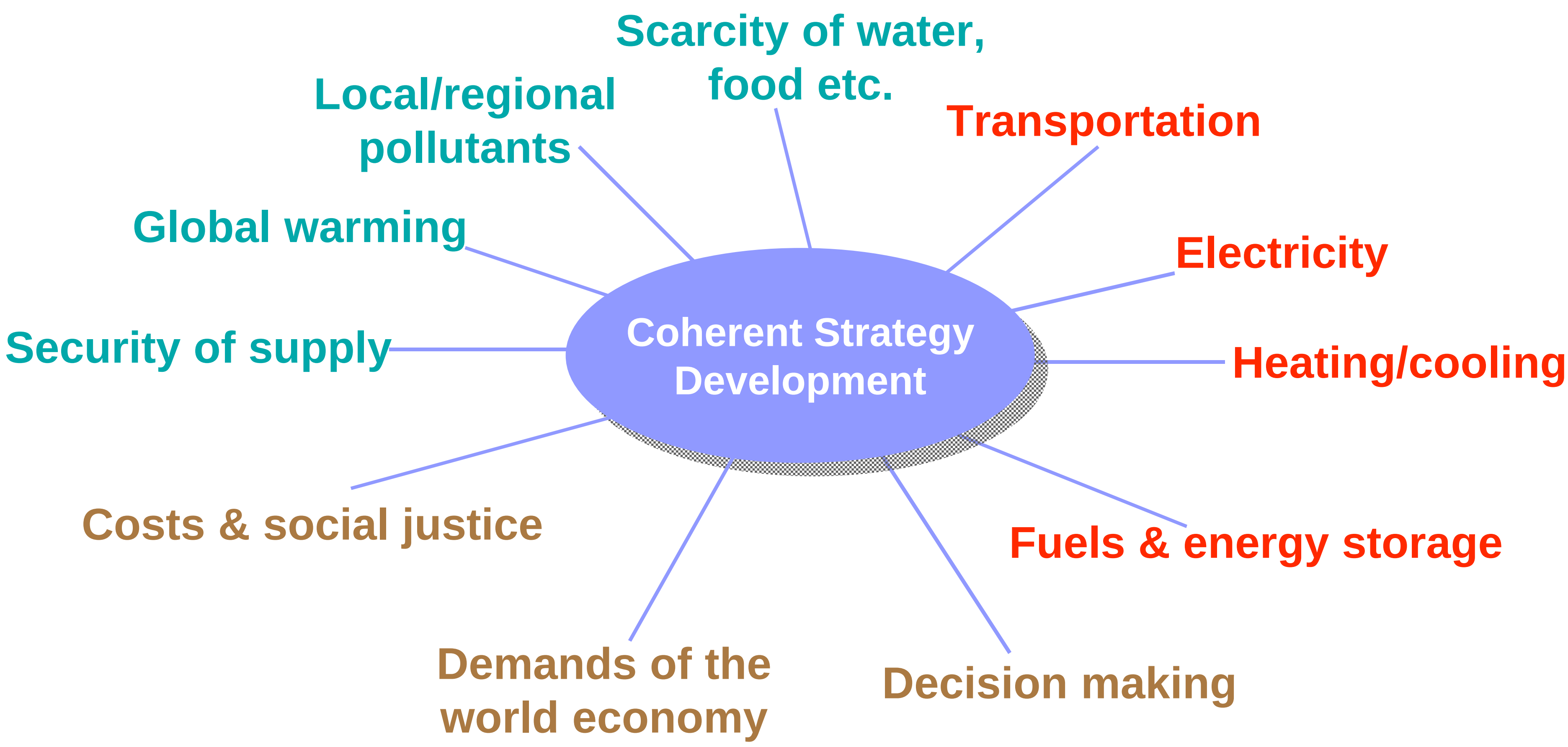
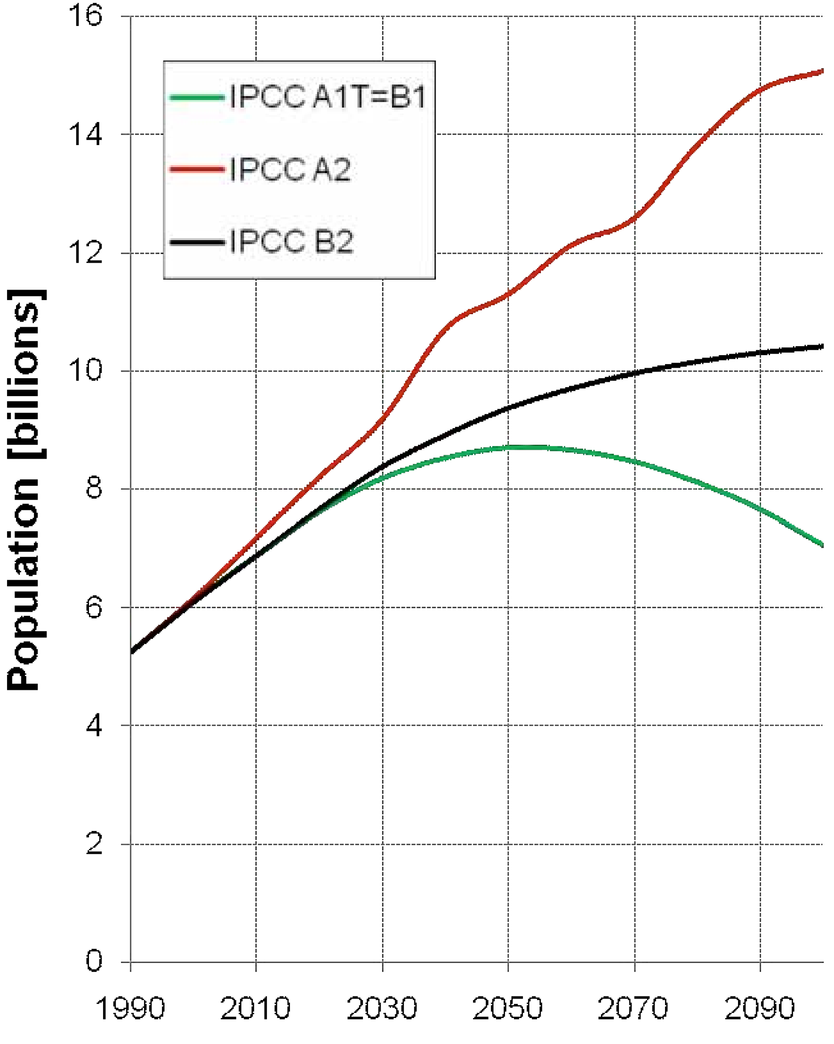
Question and possible answers

- Which are the „Grand Challenges“ with regard to energy?
  - A definition of strategic priorities for energy in the 21st century
  - Current patterns and anticipated future trends
  - A robust long-term transformation path for a sustainable energy system
  - How can all this be accomplished?
  - Conclusions and Outlook

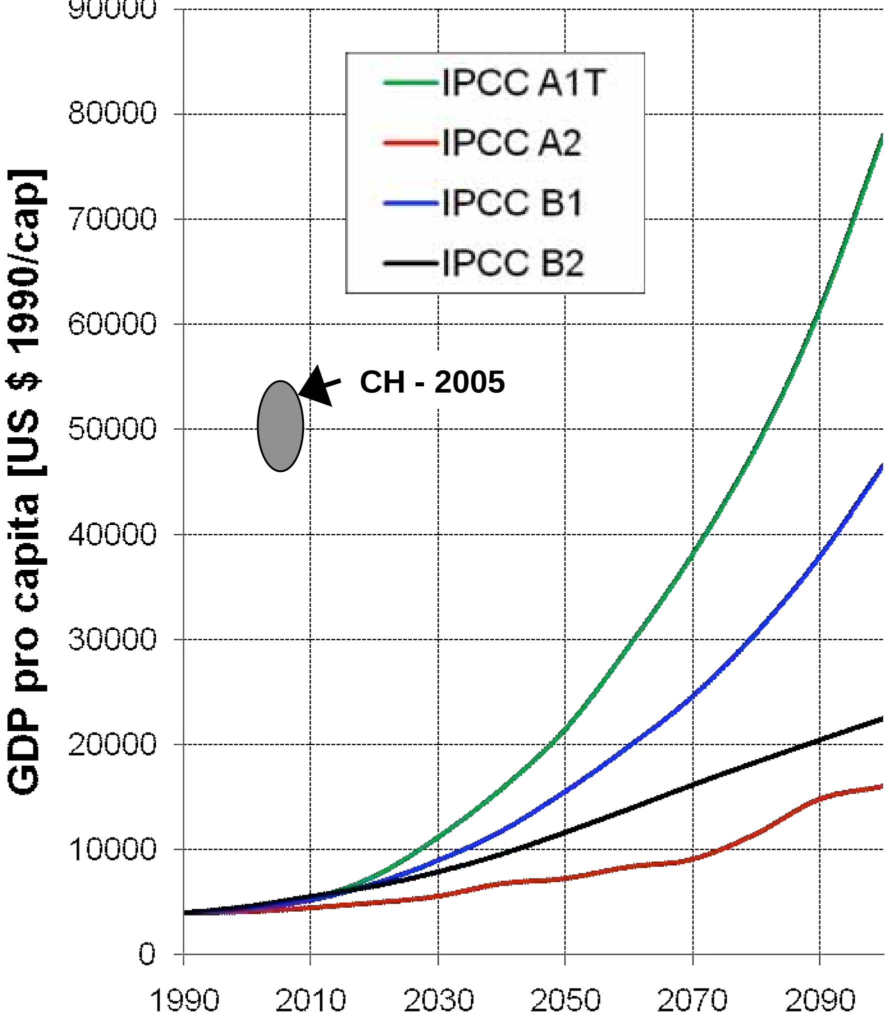
Dimensions of the energy challenge



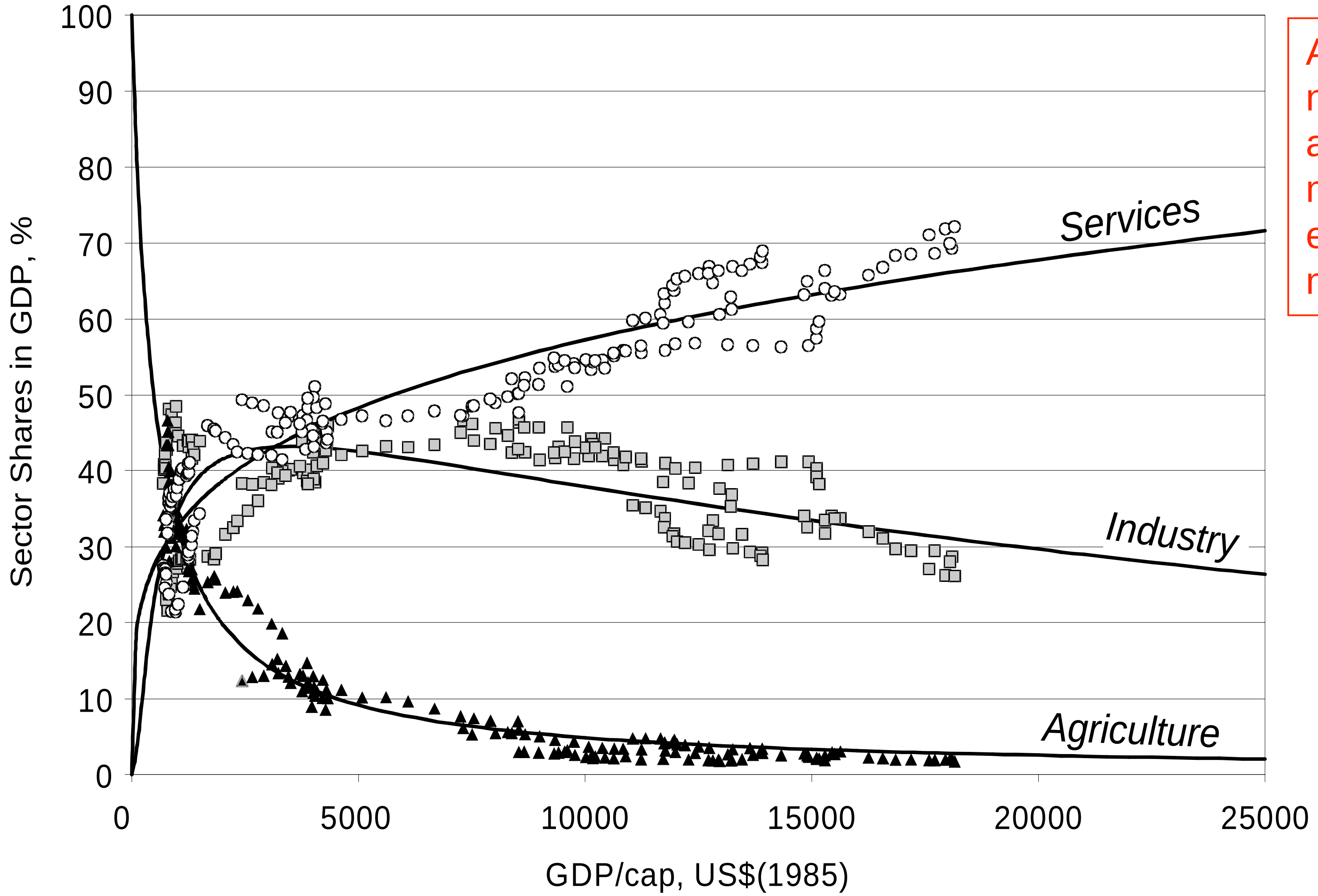
IPCC SRES-Scenarios: boundary conditions



Source: IPCC



Structural change of the economy



Affluent societies need less heat and, instead, more energy for electricity and mobility!

Source: A. Schäfer, MIT, 2001

Fossile Energy Resources – How long will they last ?

large uncertainty, also due to cost and price variabilities

- conservative estimates in years (only proven resources)

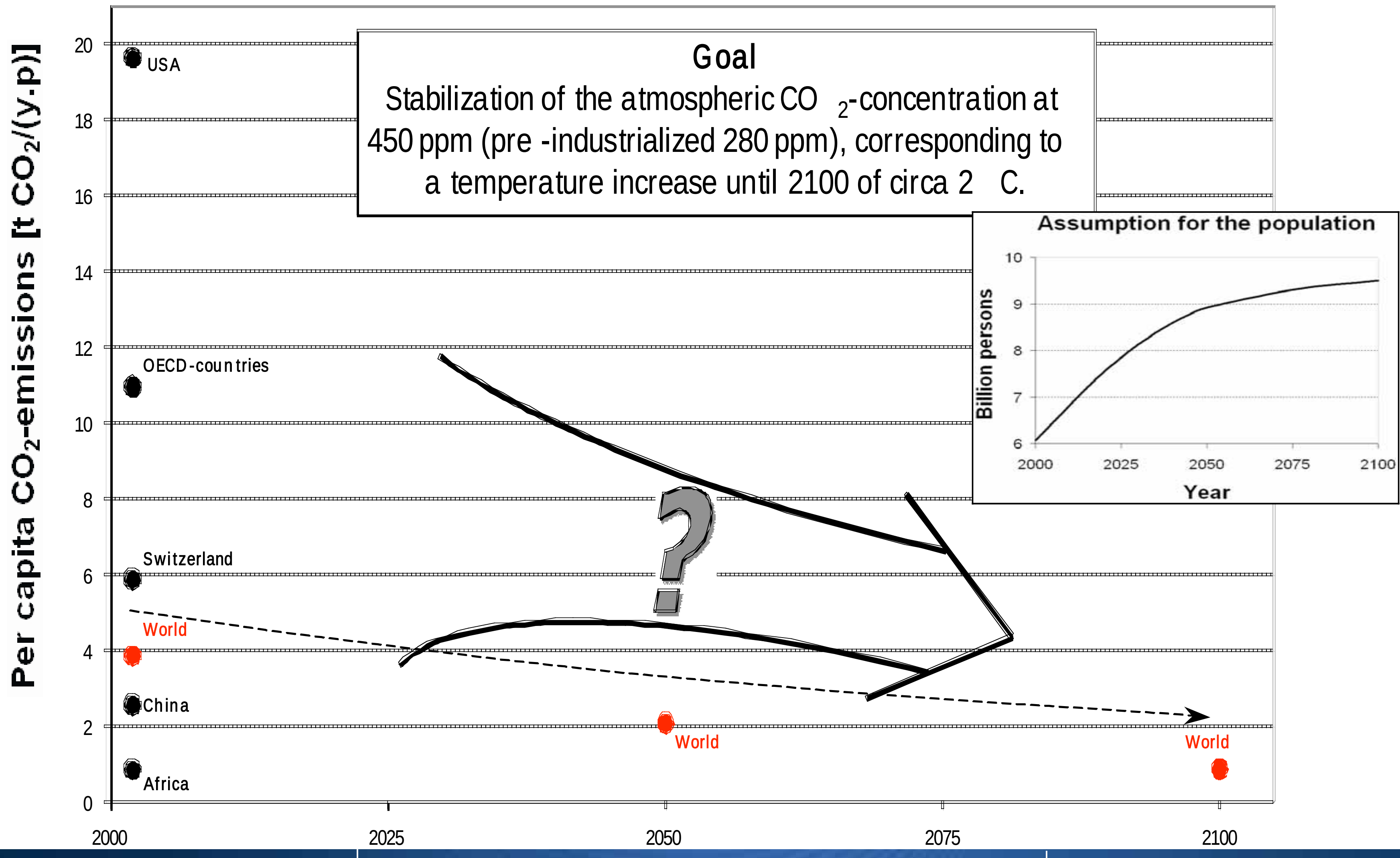
energy carrier	global % of total primary energies	range according to current consumption levels	Range at average consumption in 21st century
oil	38 %	50 – 100 y	25 – 50 J
gas	23 %	60 – 120 y	30 – 60 J
coal	25 %	250 – 500 y	125 – 250 J

- Therefore we will face increasing prices, conflicts and adaptation costs – also coal may be back, if only market decides

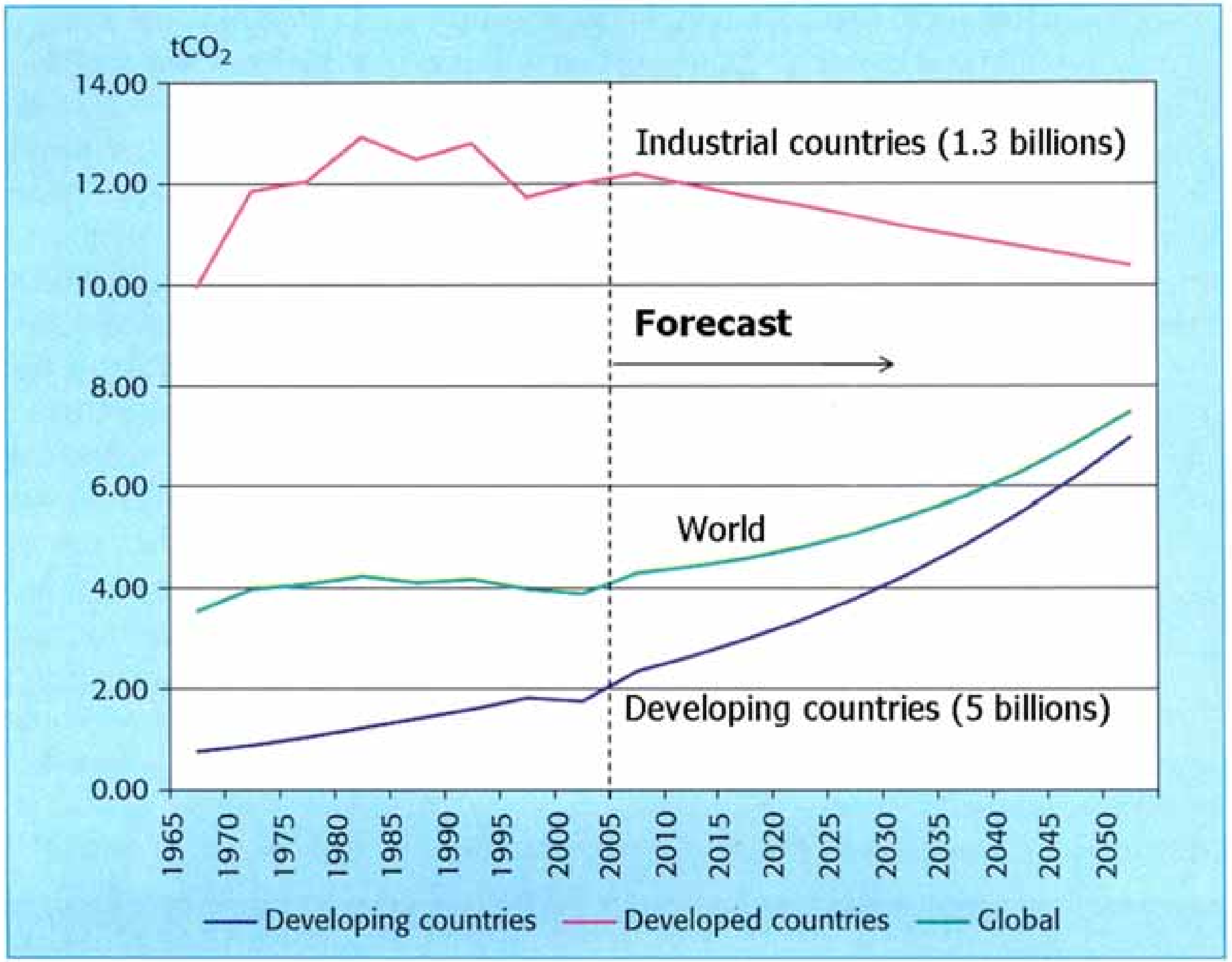
finally

- Switzerland (exemplarily) spends currently almost 5% of its GDP on imports of fossil fuels!

The Great Challenge

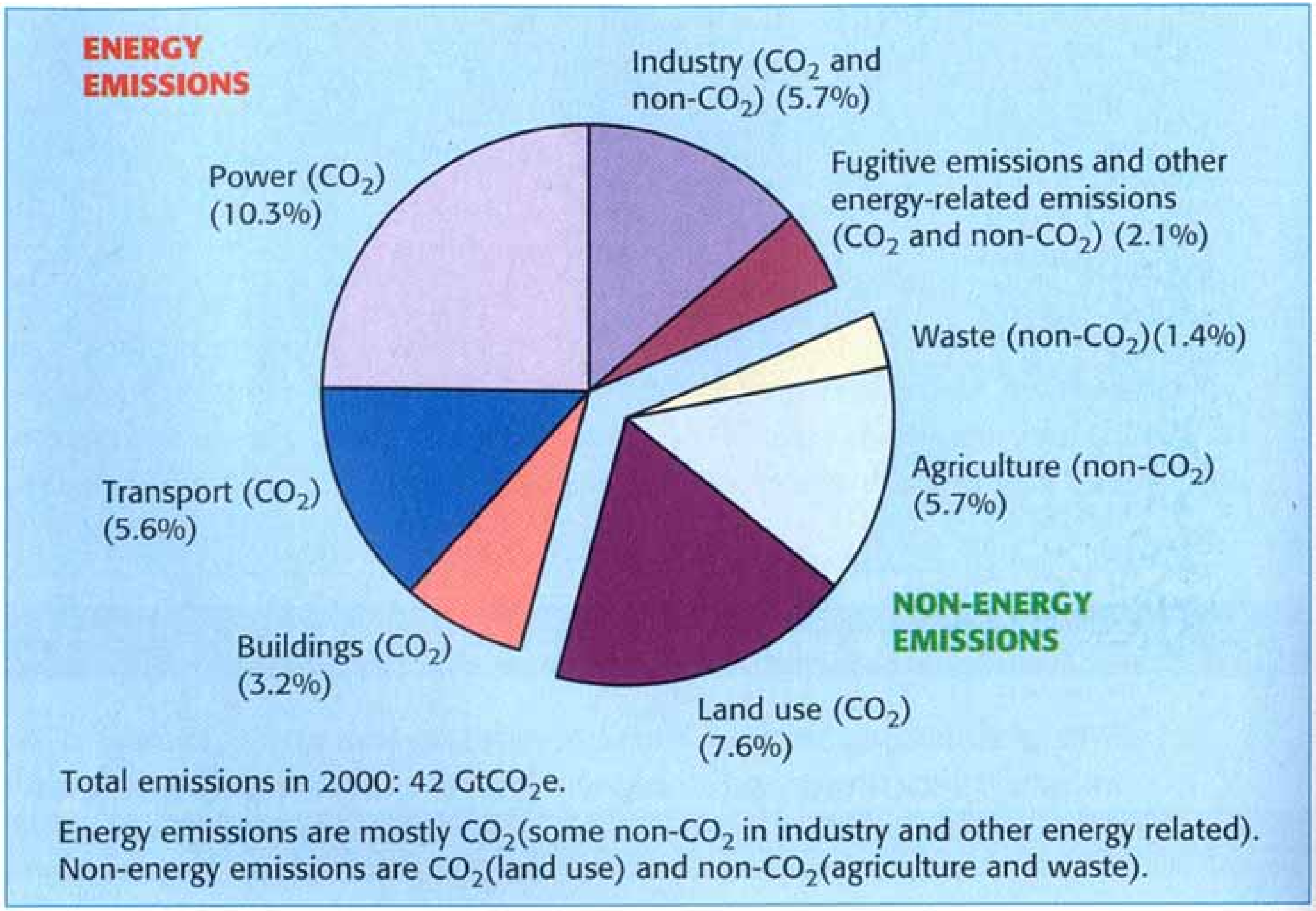


Per capita CO_2 emissions – Regional distribution



Source: Holtsmark (2006)

Sources of the greenhouse gas emissions in 2000



Source: WIR (2006), according to Stern Review

Life cycles of energy-relevant technologies/infrastructures

Years (order of magnitude, approximation)

Electric power-plants		Vehicles		Fuel and road infrastructure	Heating devices		Buildings	
Fossil	40	Cars	10	50-100	Burners	15	Renovation	40
Nuclear	60	Ships	30		Heat pumps	25	New ones	100
Hydro	100	Trucks	20					

Survival rates of CO_2 in atmosphere: ~100-150 years!

Individual Transportation – Effective Energy Use

number of cars worldwide:
Today: 900 millions
2100: 4-5 billions!

Medium-class PKW

SUV

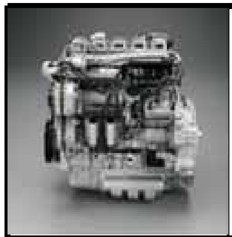
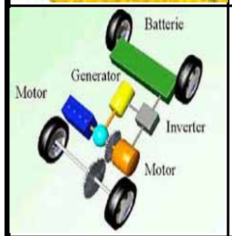
„Optimized“ car

(weight and powertrain)

e.g. full hybrid resp. fuel cell (well-to-tank losses included)

	Medium-class PKW	SUV	„Optimized“ car
Powertrain efficiency in driving cycle	**17%**	**10%**	**25%**
Vehicle weight	1300 kg	2500 kg	900 kg
Capacity utilization	1.6 persons/car	1.6 persons/car	1.6 persons/car
Useful mass	130 kg	130 kg	130 kg
Useful-to-overall weight ratio	**0.10**	**0.052**	**0.14**
Effective energy use	**1.7%**	**0.5%**	**3.6%**

Technology paths for the future cars power train

	Evolution of conventional IC engines (high-tech)
	Evolution of conventional IC engines (high-tech), plus new biogenic fuels
	Gradual hybridization (mild, full, plug-in, full-electric)
	Hydrogen-fuel cells (quite unlikely to happen: high electricity demand, new infrastructure, costs)

2000 → **2050**

Biofuels: yield per hectare (in appropriate regions)

RME	**1‘520 l*/(hectare·a)**
Bio-Ethanol	**1‘670-2‘320 l*/(hectare·a)**
BTL (2nd generation)	**3‘900 l*/(hectare·a)**

Example Germany: max 3.5 millions hectares available;
with 50% bioethanol and 50% BTL ?
fossil energy substitution and CO_2-savings of about 15-20% possible

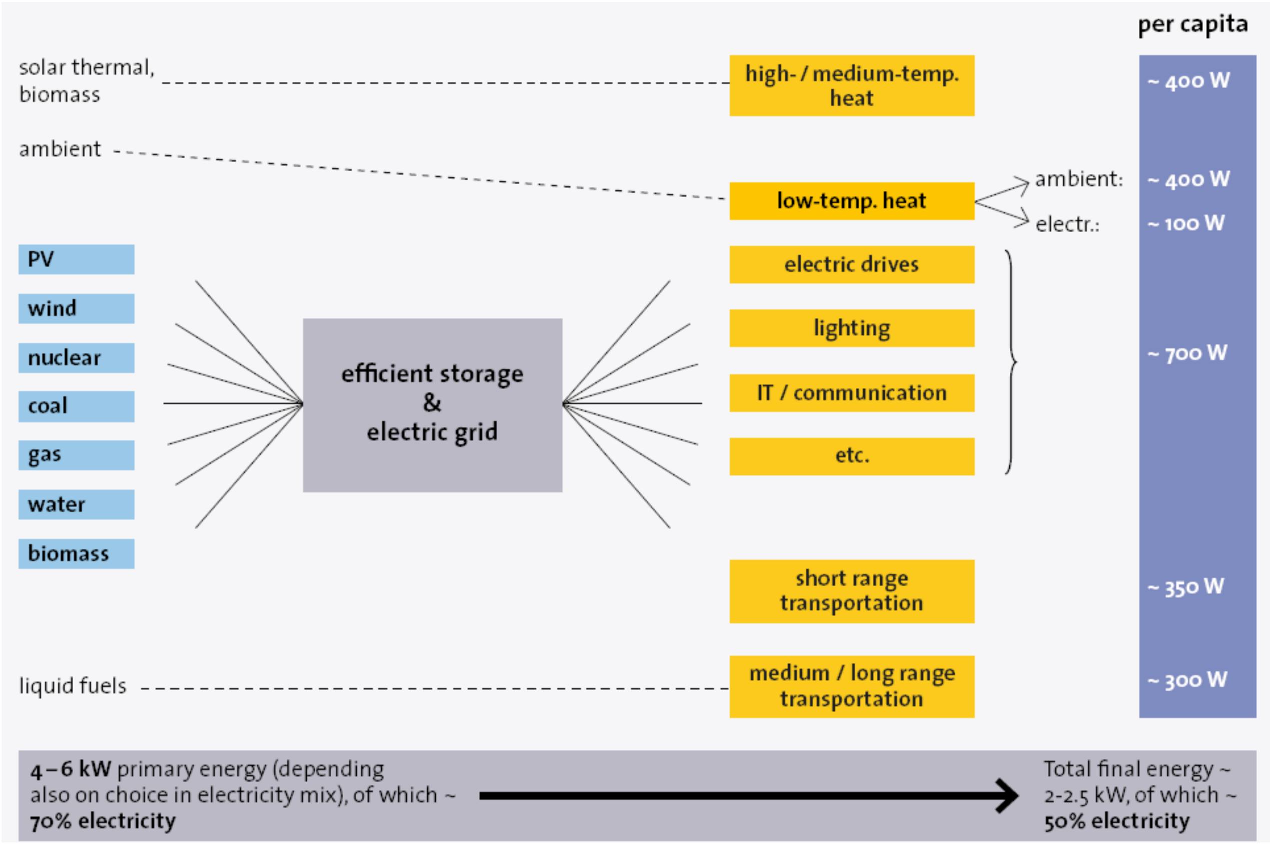
⇒ **Compare:**

sun $\xrightarrow{PV}$ electric propulsion — efficiency ~10%

sun $\xrightarrow{\text{Photosynth.}}$ biofuels $\xrightarrow{\text{Converter}}$ propulsion — efficiency ~ 0.1%

Source: Shell, SSM Lucerne 2006, VDI-Nachrichten

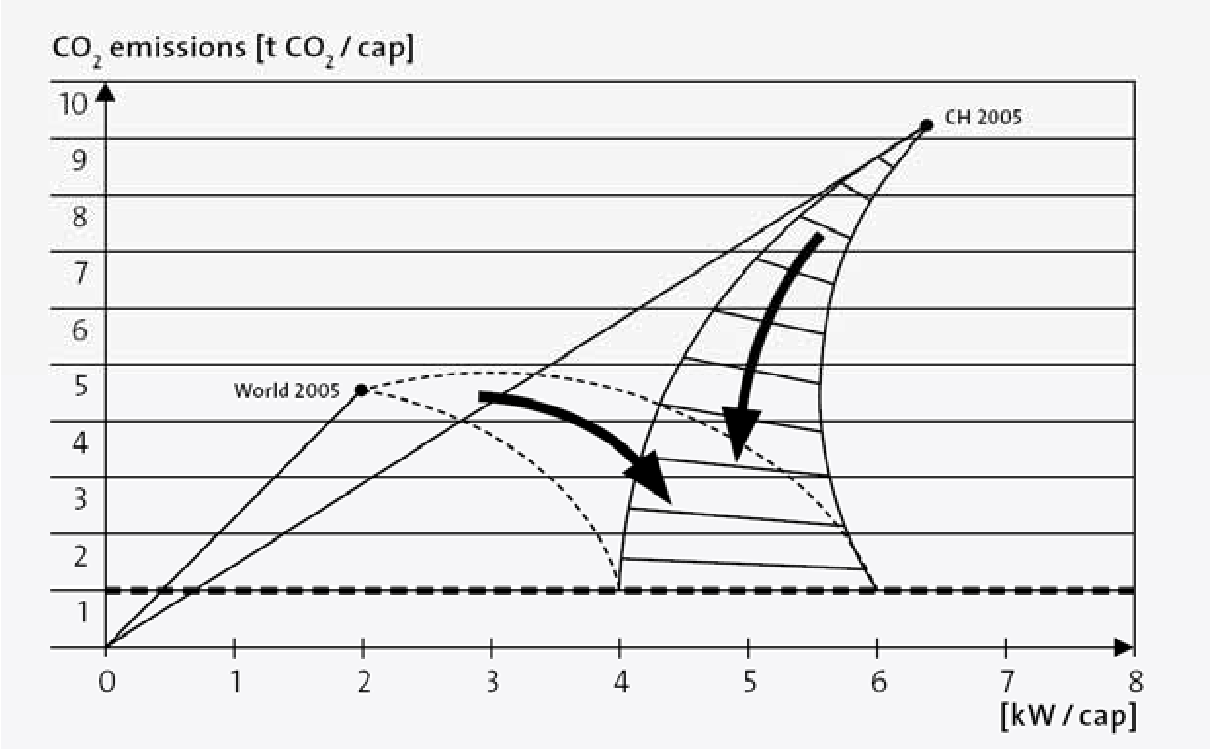
Electricity as the backbone of the future energy system



Source: Energy Strategy for ETH Zurich, ESC 2008

The strategic climate-relevant goals for the future energy system can be reached through a combination of increases in the efficiency of the entire conversion chain together with a significantly higher proportion of low-CO_2 electricity in the entire energy mix.

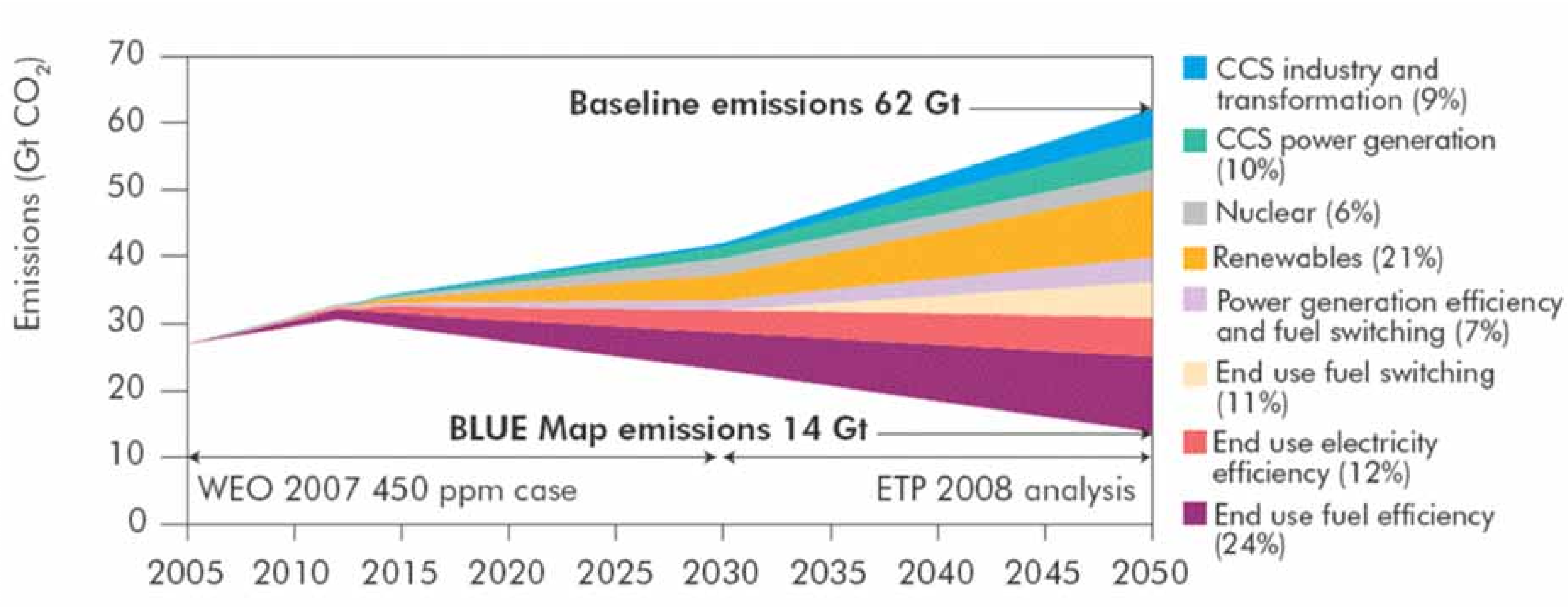
Plausible primary energy range for 1 CO_2/Cap in year 2100, depending on electricity generation mix (fossil/nuclear/solar/wind/water)



1 t CO_2 per capita can be realized towards the end of the 21st century in Switzerland and worldwide by the complete exploitation of realistic efficiency potentials and the targeted decarbonization of all energy sectors to the greatest possible extent.

Source: Energy Strategy for ETH Zurich, ESC 2008

Comparison of the World energy Outlook 2007 450 ppm case and the BLUE Map scenario, 2005-2050



Source: ETP Report, OECD / IEA, 2008

How can all this be accomplished?

- Sensible resources must get a clear “price tag”
  (for climate change, air/water/land pollution, non-renewable energy)
  ® research on energy and environmental economics

- Decision making mechanisms (individual/institutional) need to be understood and aligned to the overarching strategic goals
  ® social science research

- Technology breakthroughs are necessary for a dramatic increase in efficiency and maximal, environmental-friendly utilization of renewable energy carriers incl. energy storage for intermittent electricity
  ® natural science and technology research

Conclusions and Outlook

1. First priority of a global energy strategy for the 21st century must be climate change mitigation
   ® **1 t CO_2/cap**! (most other challenges can be met in parallel, if this goal is achieved)

2. The transformation path will include
   a) a drastic increase of overall energy efficiency
   b) a coordinated switch from fossil-nuclear to dominantly renewable energy carriers (photovoltaics being the champion)

3. The optimal energy system will be characterized by
   a) gradual decarbonization first of the heat sector and second of short-range transportation through electrification
   b) a high-share of „CO_2-free“ electricity (around 50%) in the final energy mix.

4. A transformation to a sustainable energy system within 50-100 years is possible. It will however require consistent and thoughtful action as well as all available organizational, economic and intellectual capabilities, humanity has available.