Strategic Paths to the Future Energy System

Global versus Swiss Perspective(s)

Prof. Konstantinos Boulouchos
Institute of Energy Technology and Energy Science Center
ETH Zürich

Acknowledgement: F. Noembrini, C. Casciaro, S. Heinen, F. Frei

Presentation Content

- A set of challenges for the global energy system
  → Climate change mitigation of highest priority

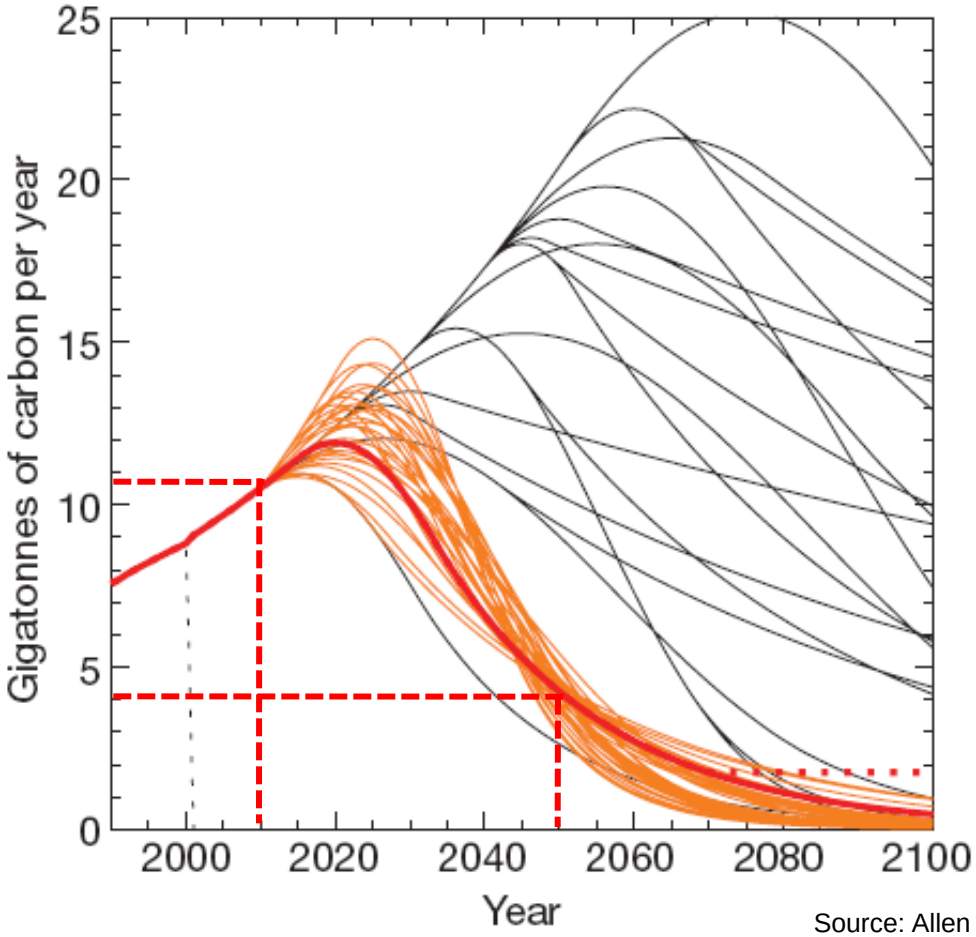
- A “mesoscale” technology view
  → Energy system structure, interconnections among sectors and relevant time scales

- Emphasis on the decarbonization of the transportation sector
  → Electricity will become the backbone of the future energy system

- Swiss Perspective(s): 2’000 W/cap vs. 1t CO_2/y/cap ?

- Strategic Technology and Research Areas

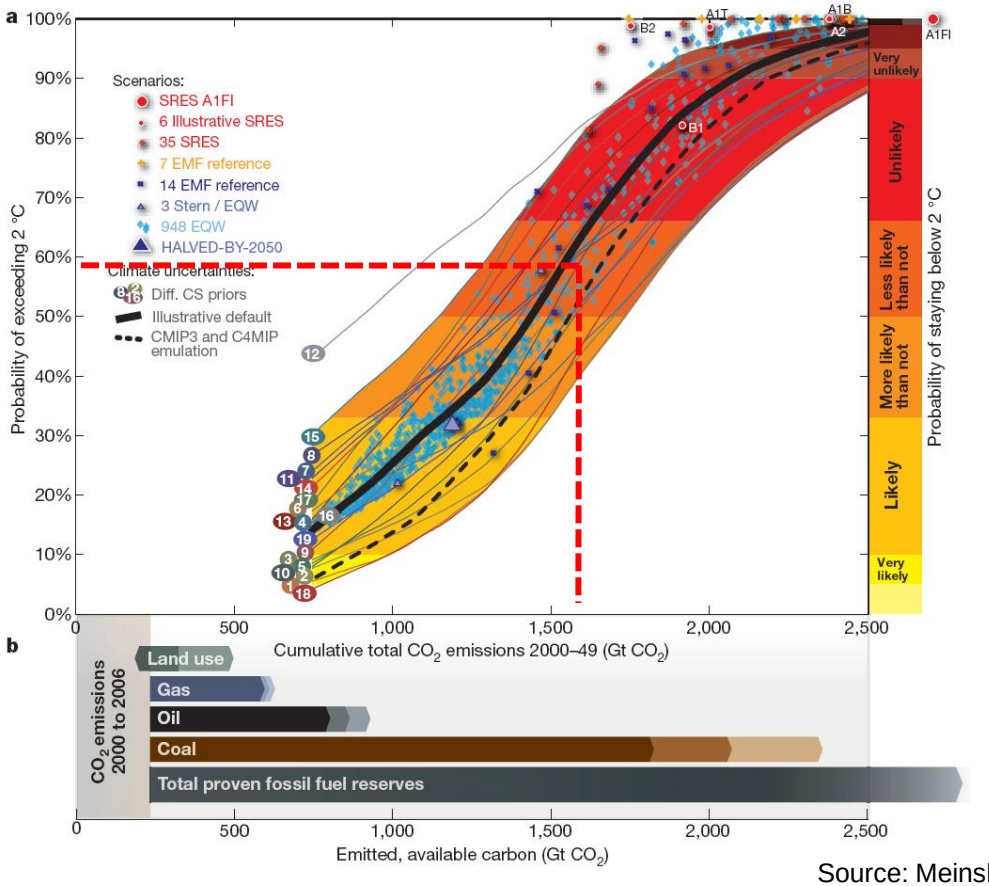
Global warming caused by cumulative carbon emissions and reduction trajectory for 2°C-target



- Red curve only viable scenario in order to keep:
  - CO_2-concentration below 450 ppm
  - CO_2-equiv. concentration below 500 ppm
- Reduction trajectory for 2°C-target implies:
  - less than 50% of 2010 CO_2-emissions in year 2050
  - stable level of long-term annual CO_2-emissions at no more than 20% of 2010 level

Source: Allen Myles R. et al., nature08019, Vol 458, 30 April 2009, p. 1163-1166

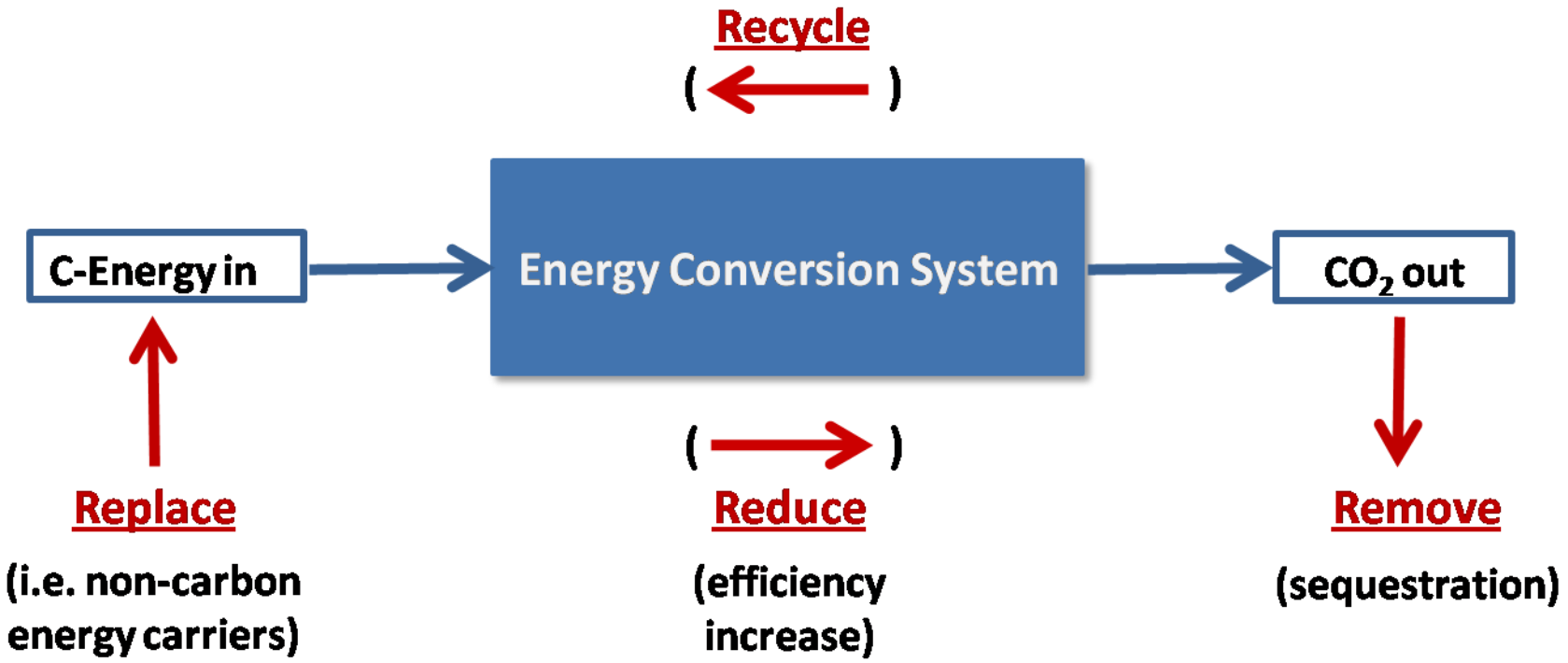
The probability of exceeding 2°C warming versus CO_2 emitted in the first half of the twenty-first century and fossil fuel reserves



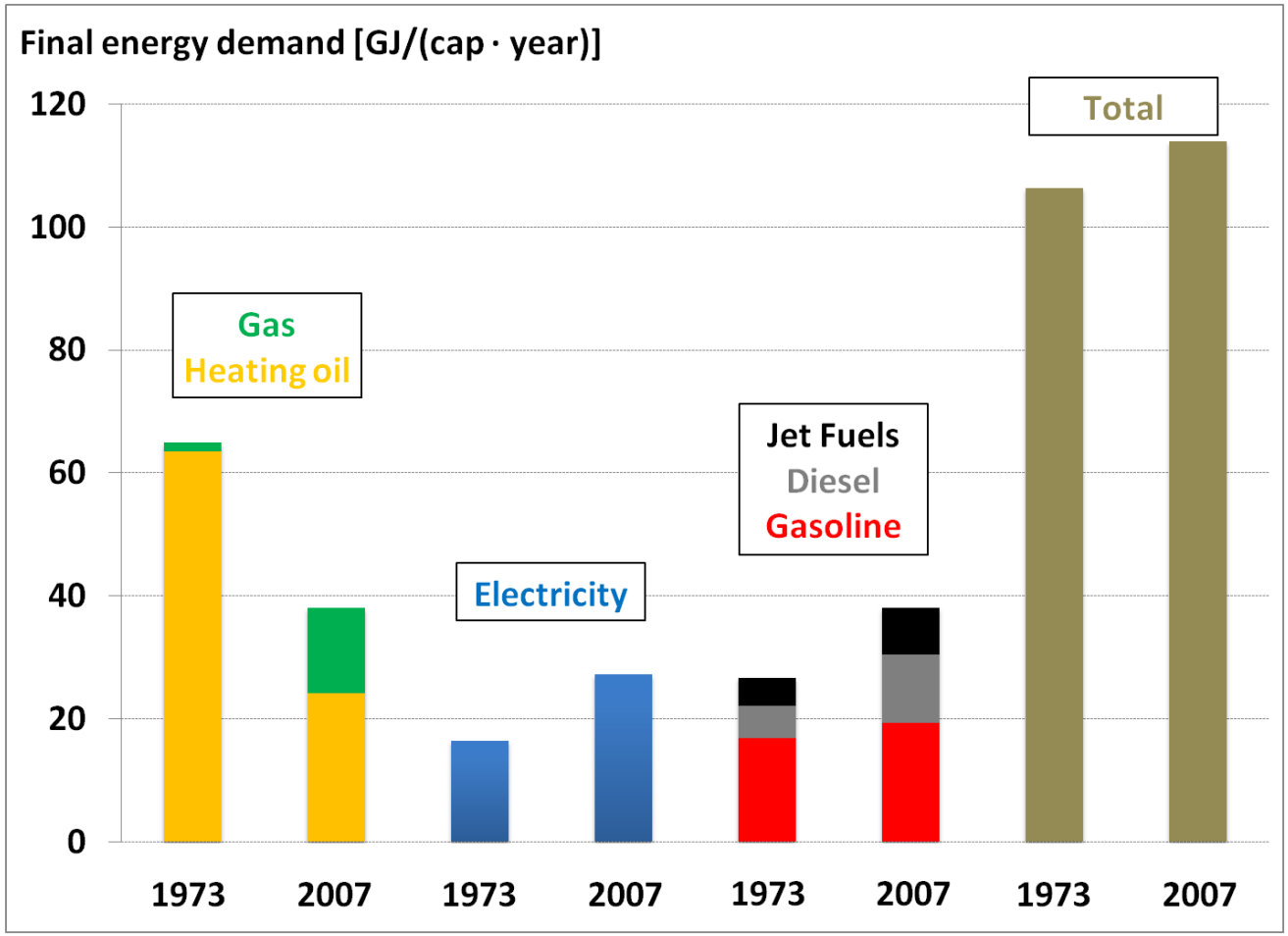
- 1‘500 Gt CO_2 cumulative emissions from 2000 to 2050 are upper limit for 50%-probability of complying with the 2°C-target
- Combined oil and gas proven reserves would release about this CO_2 amount, while total proven fossil reserves are twice the target emissions level!

Source: Meinshausen M. et al., nature08017, Vol 458, 30 April 2009, p. 1158-1163

The four R's – strategy towards decarbonization



Structure of the final energy demand in Switzerland



Data source: BFE and BFS, 2009

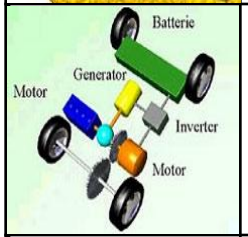
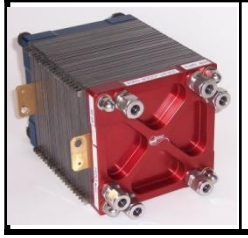
Providing the missing links among sectors

- Efficient ways to decarbonize the heat sector → electrically driven heat pumps and ambient/solar heat

- Paths towards decarbonisation of the (short/medium range) transportation → electricity is on the long-term by far the best option compared to hydrogen or biofuels, in terms of primary energy demand and scalability correspondingly

- Electricity will therefore emerge as the backbone of the future global energy system (input portfolio for primary energy sources, output portfolio for energy services)

Technical options for the future powertrain

	Evolution of the **Otto engine** Evolution of the **Diesel engine** } Downsizing, direct injection with high variability, flexible high charging, variable valves, flexible geometries, combined exhaust gas aftertreatment
	Evolution of the IC-motor (Diesel, Otto) **PLUS** **new fuels** (biogenous, gas/liquid, synthetic/H_2-enriched reformates)
	Increasing **hybridization** (mild, full,...) on IC-engines as „Range Extender" and finally extensive **electric operation**
	Conversion to hydrogen and fuel cells

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

But → ⟹ **Compare**

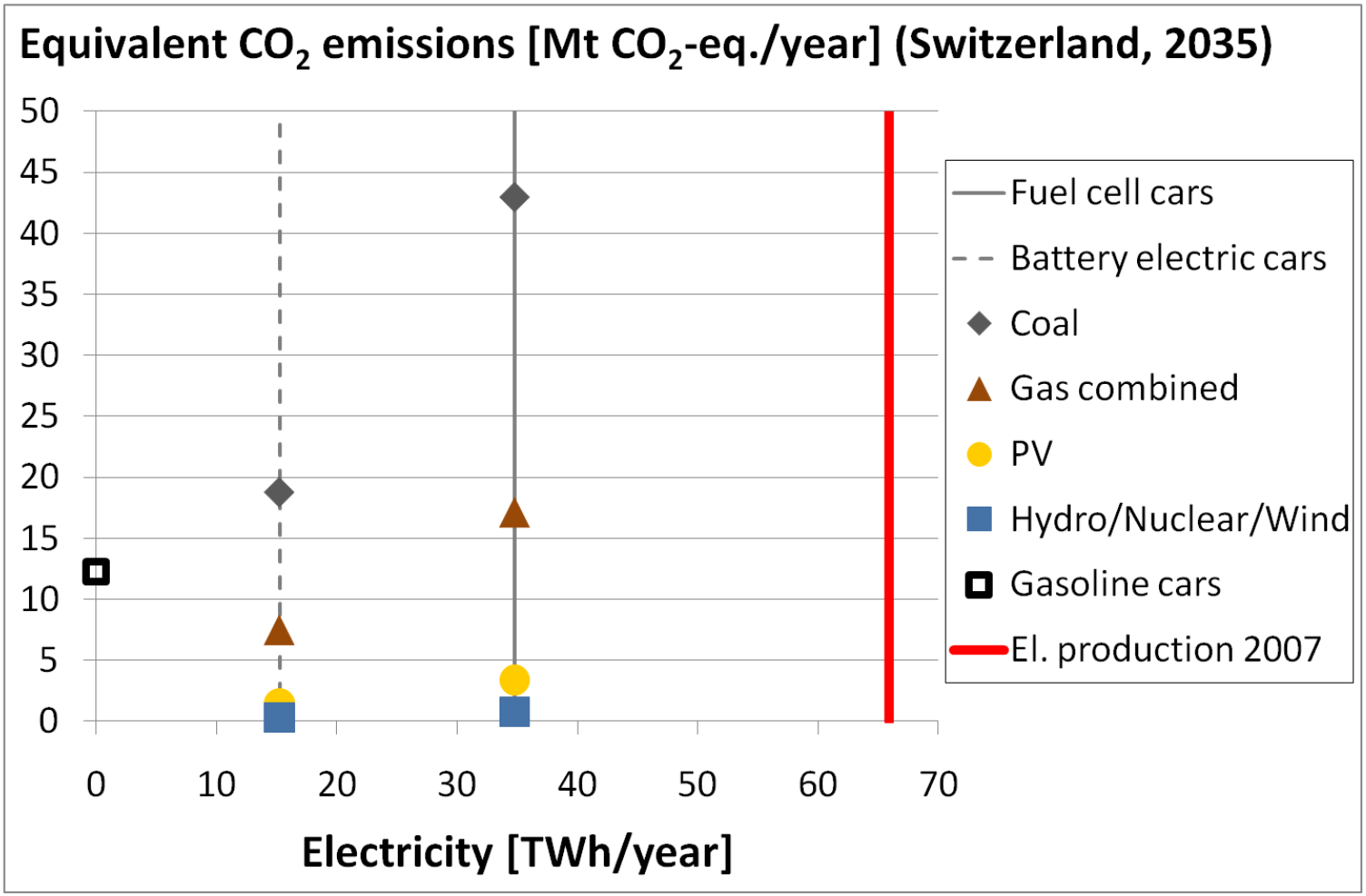
sun $\xrightarrow{\text{PV}}$ electric propulsion — efficiency ~ 10%

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

!

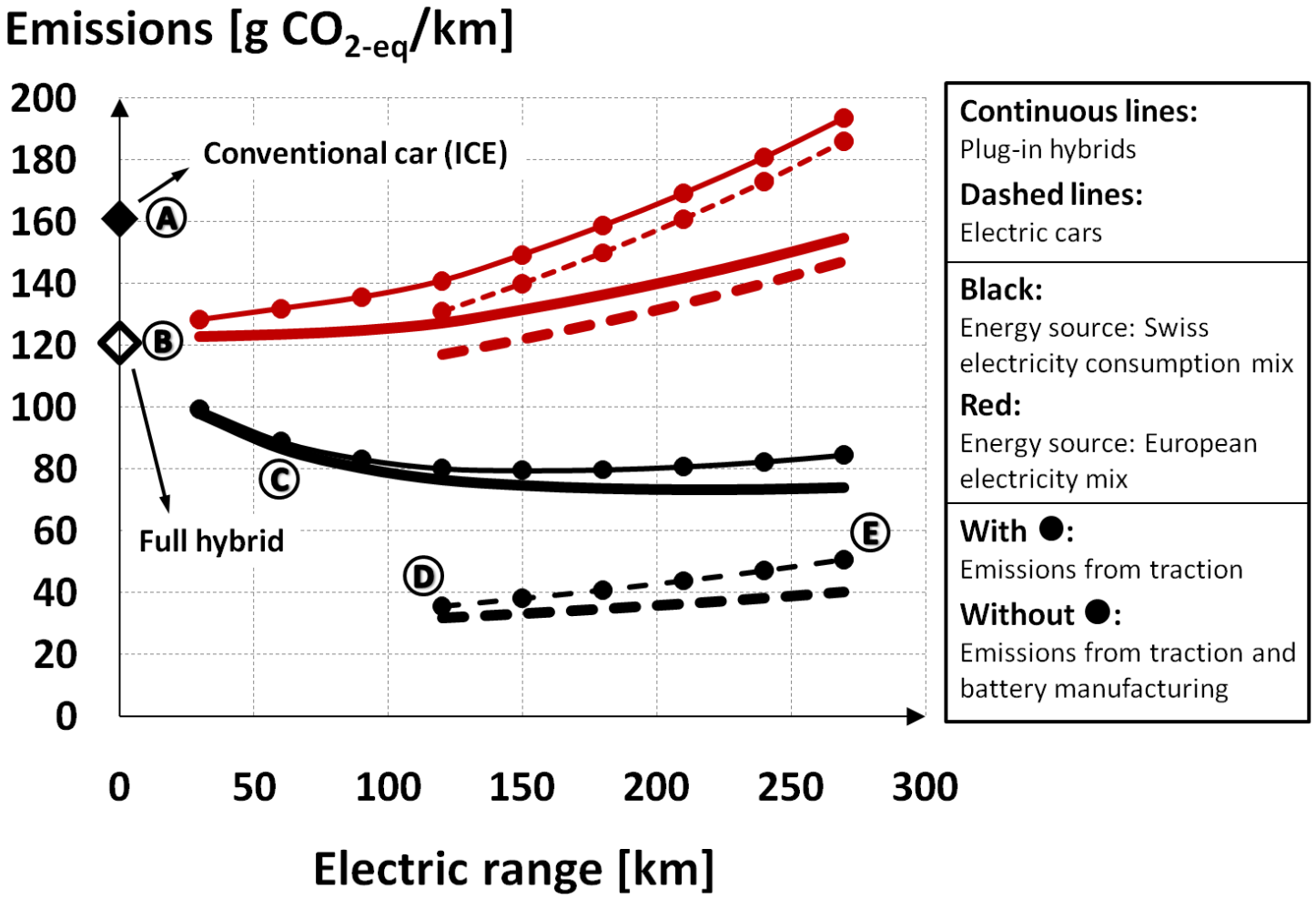
Source: Shell, SSM Lucerne 2006, VDI-Nachrichten

Electricity demand and CO_2 emissions for different options

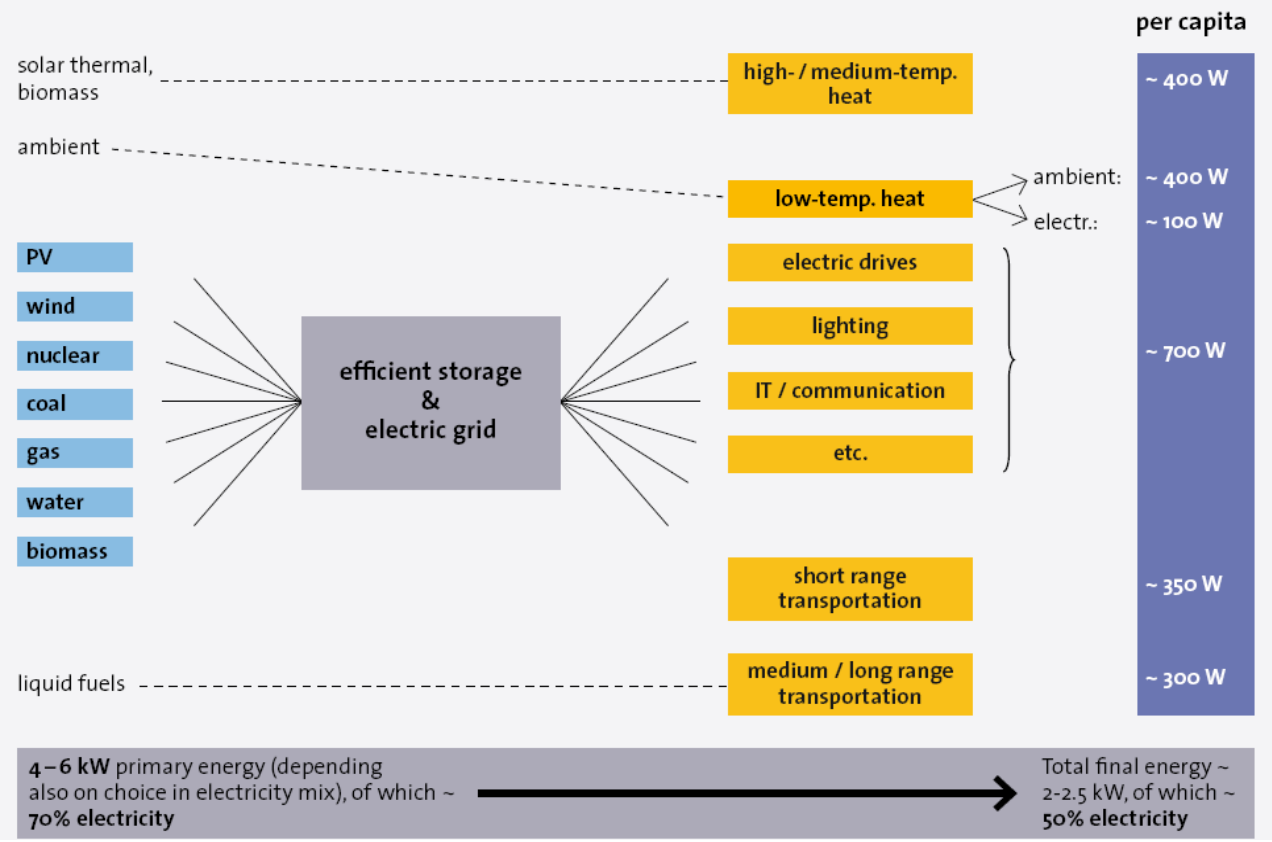


Source: Energy Navigator, ETH-LAV, 2008

Towards Electrification?



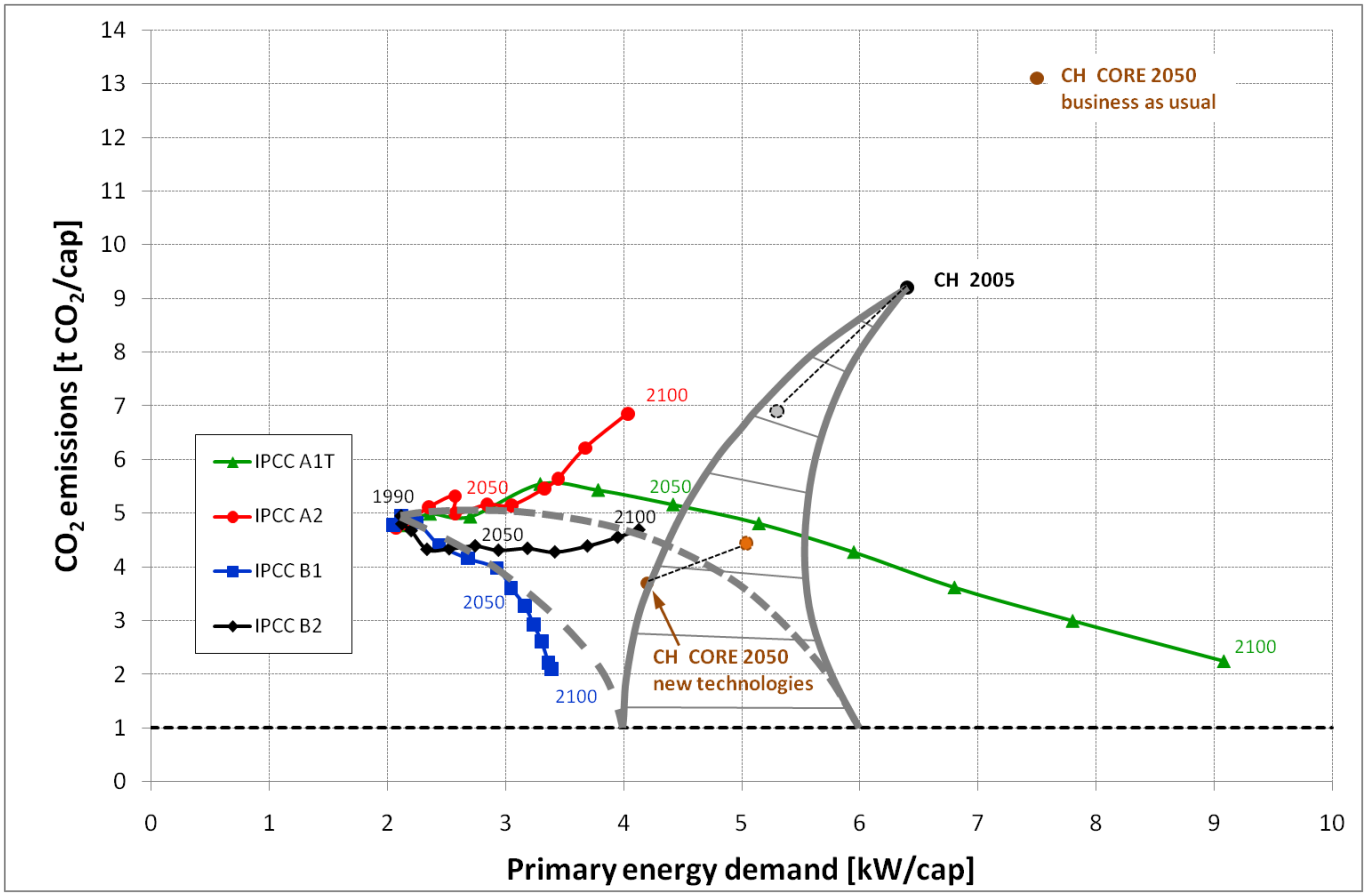
Electricity as the backbone of the future energy system



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.

Source: Energy Strategy for ETH Zurich, ESC 2008

IPCC and Swiss scenarios: CO_2 emissions vs. energy demand



Source: IPCC; BFE, Konzept der Energieforschung des Bundes 2008 bis 2011

Key technology and research areas

- Intelligent tools & processes for optimizing demand side management
- Instruments and measures for increased efficiency of electricity-based services to the end customer
- Cost-efficient storage of intermittent renewable electric energy (in particular solar and wind) → emphasis on electrochemistry
- Nanostructured materials for efficient photons capture and charge transmission as well as manufacturing processes for new generation, affordable PV-systems
- Advanced Nuclear Power Plants
- Robust methods for capturing, even better for recycling, CO_2
  a) from concentrated emissions sites
  b) from the atmosphere at low concentrations

Summary

- From a global point of view, climate change mitigation is an even bigger challenge than (future) scarcity of fossil fuels
- In terms of our overarching strategy, decarbonization is therefore the dominant issue → 1t CO2/y/cap is a much more robust and meaningful target than 2‘000 W/cap
- Key to a successful transformation path (both global and regional will be the simultaneous decarbonization of the electricity and the transportation sector
- For that to happen it will take not less than several decades and it will require
  - coherent policy effort (costs)
  - a careful selection of (and cooperation in) mission critical research and technology areas