Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Centre for Energy Policy and Economics
Department of Management, Technology and Economics

# Energy ←→ Climate Change

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CCES-ClimPol, 13. 2. 2009

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## Overview

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- Summary
- Energy → Climate change (global )
  - Greenhouse effect
  - Energy system and greenhouse gazes ($CO_2$)
  - IPCC report
- Energy ← Climate change (local, CH)
  - Impact on energy demand
  - Impact on energy „production“ + renewables
  - Impact on energy transmission
  - Climate conditions and structure of energy system

# Summary: energy → climate change

- dT **very likely** anthropogenic GHG
- $CO_2$ (energy) > 80% all GHG
- dT : 2 ºC ← dCO2 : in 2050 < -50% and in 2100 < -80%
  4 ºC ← dCO2 : peak around 2060 and in 2150 = 2000





# Summary: energy ← climate change (CH)

## Energy demand (2050)

- Reduction heat demand (winter) -12%
- Increase electricity demand (summer) +6%

## Energy „production“ (2050)

- Reduction hydro (summer) -7%
- Cost increase thermal power plants ?
- Higher potential of renewables ?

Source: OcCC/Proclim, 2007 http://proclimweb.scnat.ch/products/CH2050/CH2050-report.html , chapter „Energie“

# Energy → climate change



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## Greenhouse effect

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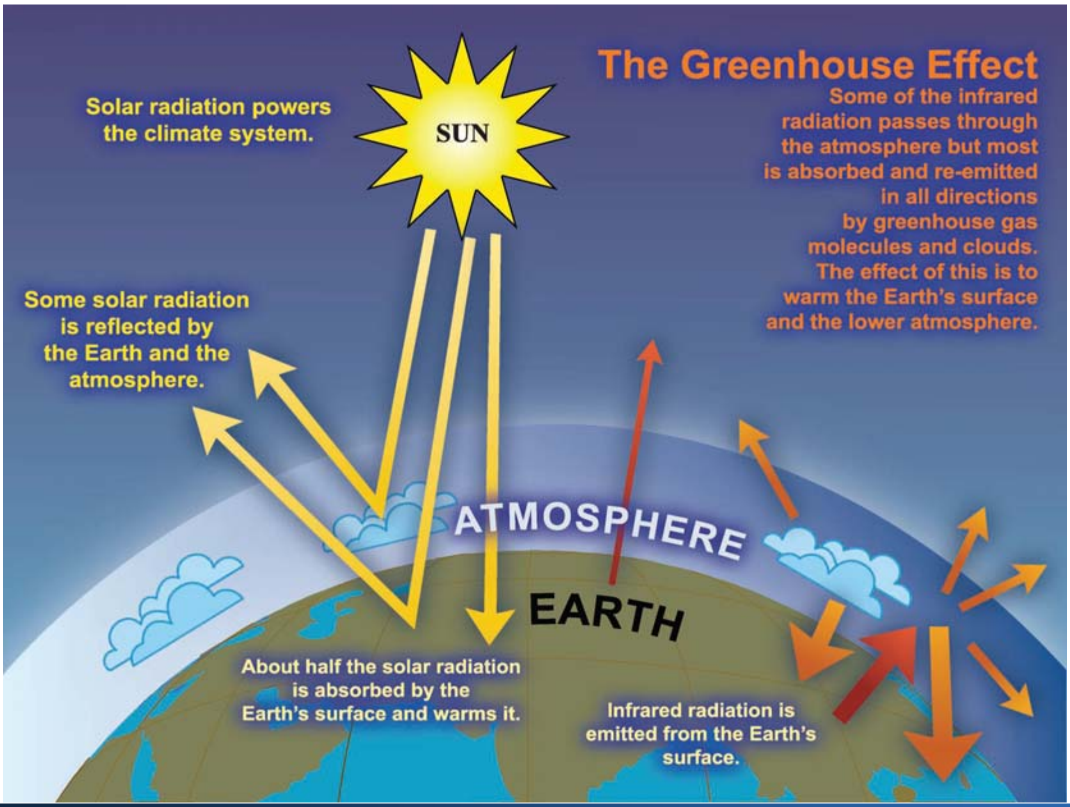


An idealised model of the natural green-house effect. (Source: IPCC, 2007)

**Effect:**
**-18 °C → +15 °C**

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# Carbon cycle

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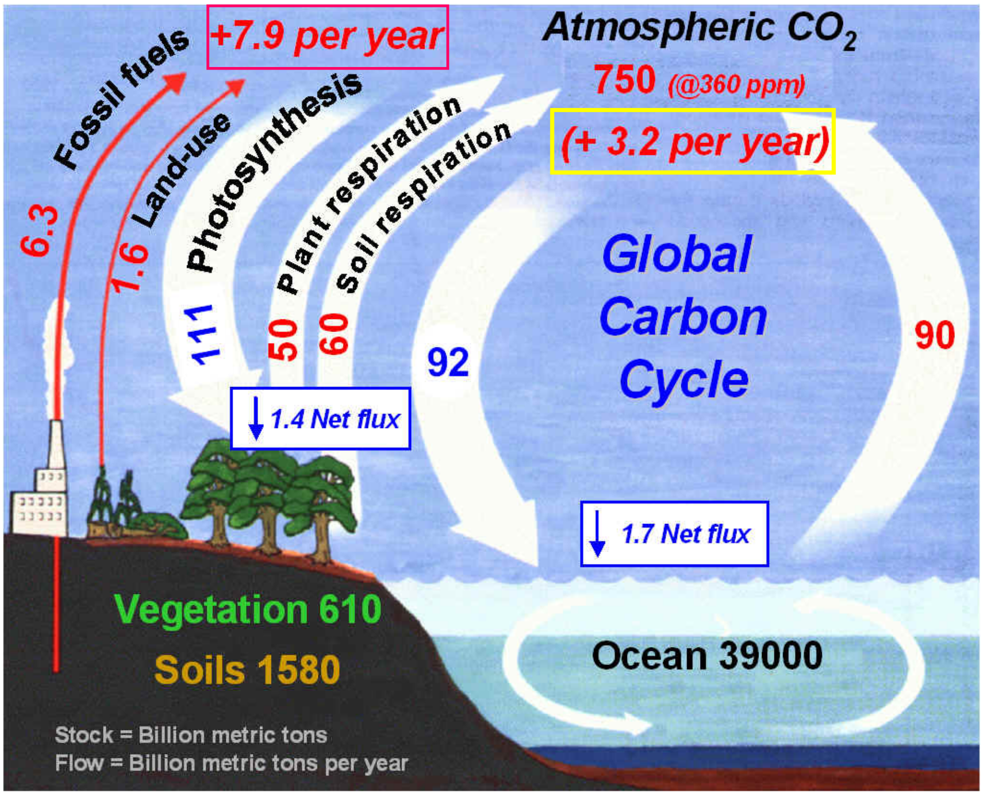


Figure 5. Pathways, pools, and fluxes in the global carbon cycle. Note that the actual numbers vary slightly with different estimates, and are used here only as guides to the levels of fluxes and pools. (King, 2008)

+ Rocks: 65'000'000



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# GHG emissions CH

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| Source/sink category | 2006 | 2006/1990 |
|---|---|---|
| | | |
| Energy | 43924 | 4.2% |
| Industrial processes | 3061 | -6.0% |
| Solvent, other product use | 238 | -49.0% |
| Agriculture | 5288 | -10.4% |
| Waste | 697 | -32.3% |
| Land use | -2230 | -13.3% |
| | | |
| Total | 50978 | 1.5% |
| | | |
| GHG emissions/removals by source and sink categories, in CO2 equivalent (GG) | | |
| Source: BAFU, 2008 | | |

**Shares of emissions (excl. land use) contributed by individual GHG:**
**$CO_2$ = 85%**, $CH_4$ = 7%, $N_2O$ = 6%, HFCs = 1% ($H_2O$ not considered! → ORF, 2009 ):

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# $CO_2$ emissions by energy transformation

Burning fossile fuels $C + O_2 \rightarrow CO_2$

- for heating, mobility, electricity production
- different emission factors:

| | |
|---|---|
| Coal | 0.095 t $CO_2$/GJ |
| Oil | 0.074 t $CO_2$/GJ |
| Gas | 0.056 t $CO_2$/GJ |



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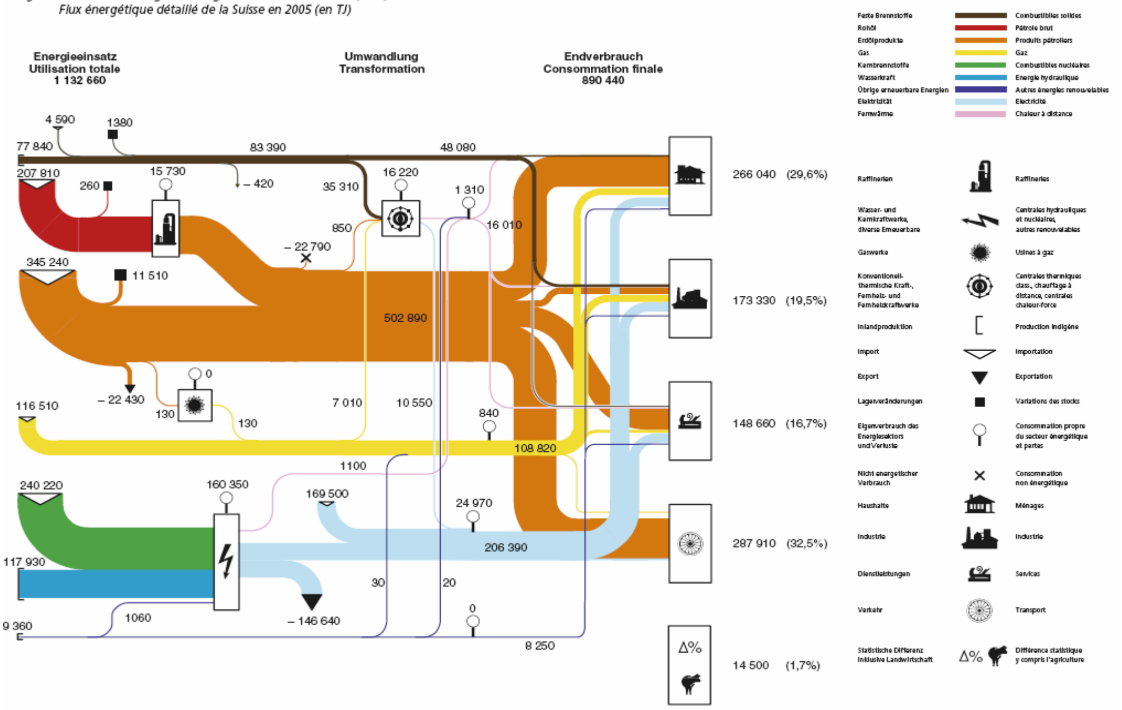
# Swiss energy system and system boundary (1)

*Fig. 5 Detailliertes Energieflussdiagramm der Schweiz 2005 (in TJ)*
*Flux énergétique détaillé de la Suisse en 2005 (en TJ)*




http://www.bfe.admin.ch/themen/00526/00541/index.html?lang=en

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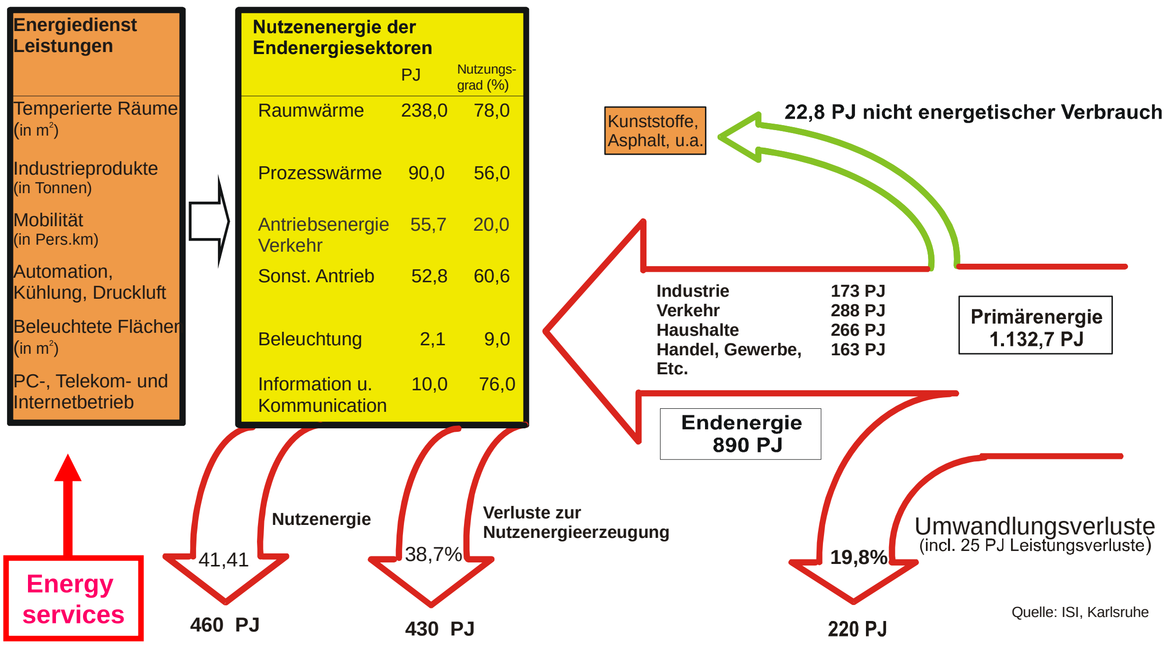
# Swiss energy system and system boundary (2)

## Energiefluss-Diagramm für die Schweiz 2005




Quelle: ISI, Karlsruhe



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# Swiss energy system and system boundary (3)

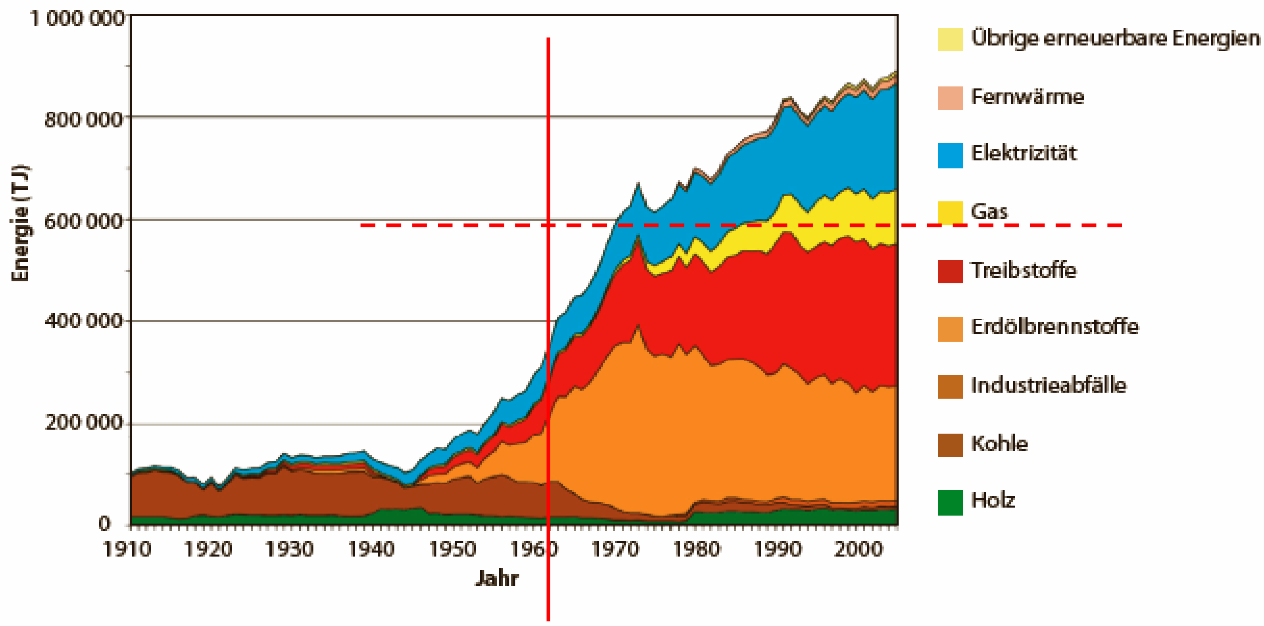



Abbildung 1: Energieverbrauch in der Schweiz, aufgeteilt nach den verschiedenen Energieträgern (1 TJ = 0.3 GWh). (Quelle: BFE Gesamtenergiestatistik 2005)

# Swiss energy system and system boundary (4)

System boundary

- Country border

  „Grey“ energy/$CO_2$ (embodied energy/$CO_2$) not considered (→ Jungbluth et al., 2007)

  Relevance? Global dimension!
- ± Commercial energy only

  → passively used solar energy not considered
- Dimensions considered: physical/technical, economic mainly.



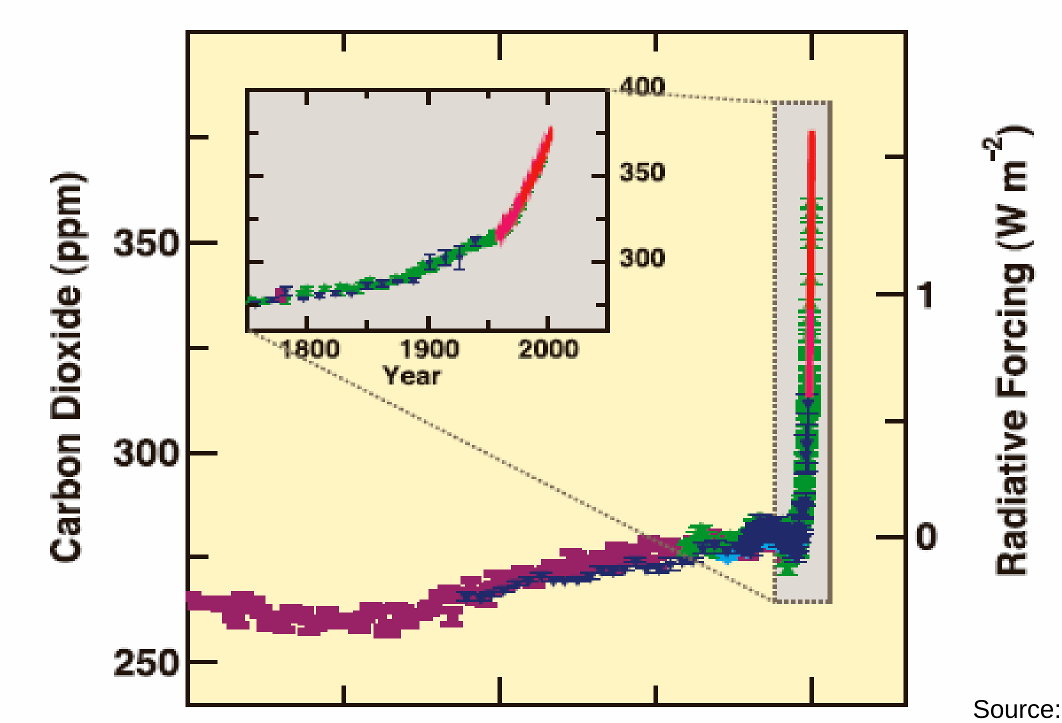


**IPCC**: Intergovernmental Panel on Climate Change = The IPCC is a scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Programme (UNEP). www.ipcc.ch (**2007 Nobel Peace Prize)**

**OcCC**: The Advisory Body on Climate Change (OcCC) was appointed in 1996 by the Swiss Government. Its role is to formulate recommendations on questions regarding climate and global change for politicians and the federal administration. www.occc.ch

**ProClim**– ProClim- is the Swiss forum for climate and global change issues. It seeks to facilitate both integrated research activities and the necessary linkages among scientists, policy-makers and the public at home and abroad. www.proclim.ch

# IPCC: $CO_2$-concentration since 10000 years

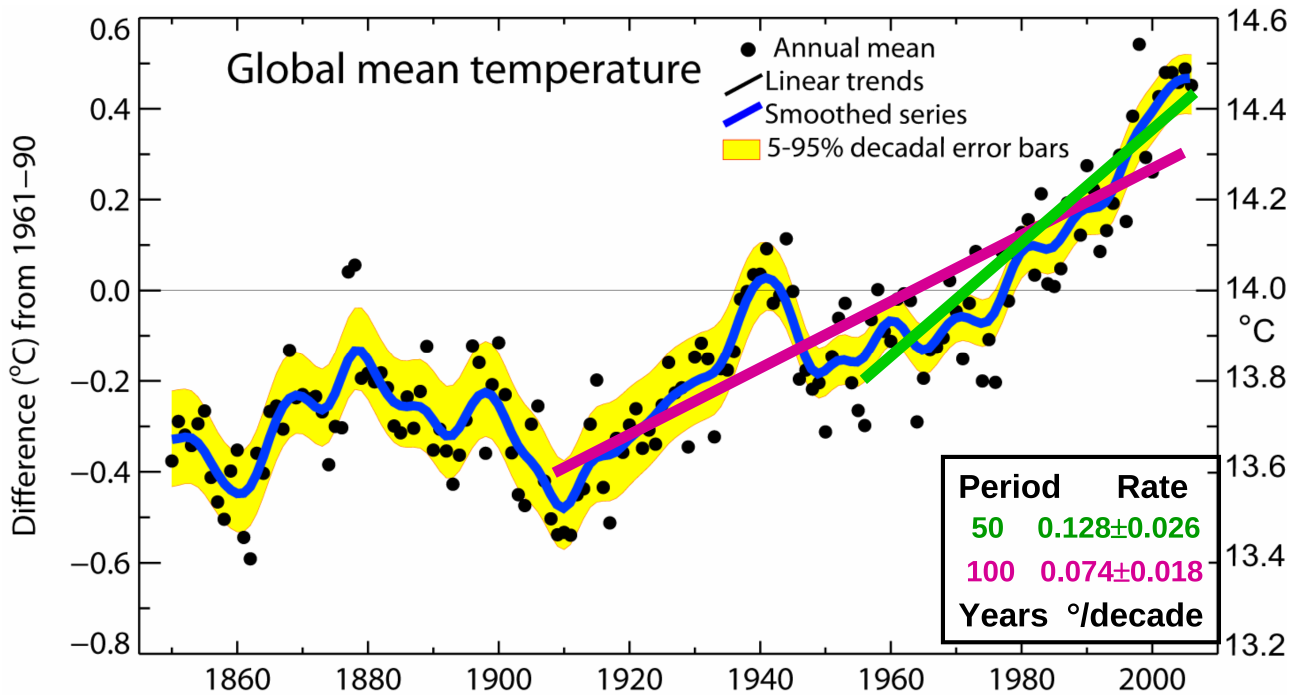



Source: IPCC, 2007/2, p. 3





# IPCC: Evolution of global mean temperature




Source: IPCC, 2007/3, p.235

## IPCC: $CO_2$-emissions und temperature increase

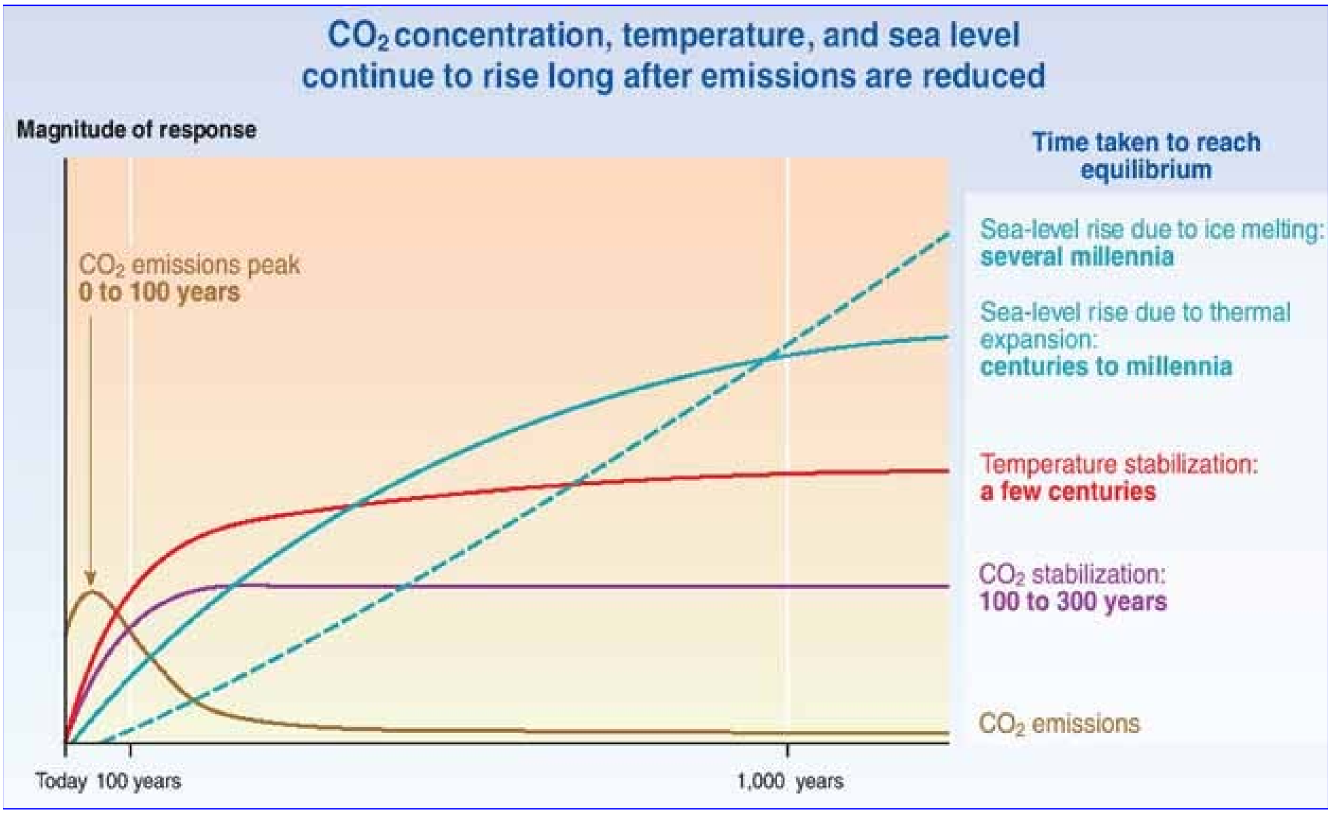
Most of the observed increase in global average temperatures since the mid-20th century is **very likely** due to the observed increase in anthropogenic GHG concentrations.

Source: IPCC, 2007/2, p. 10

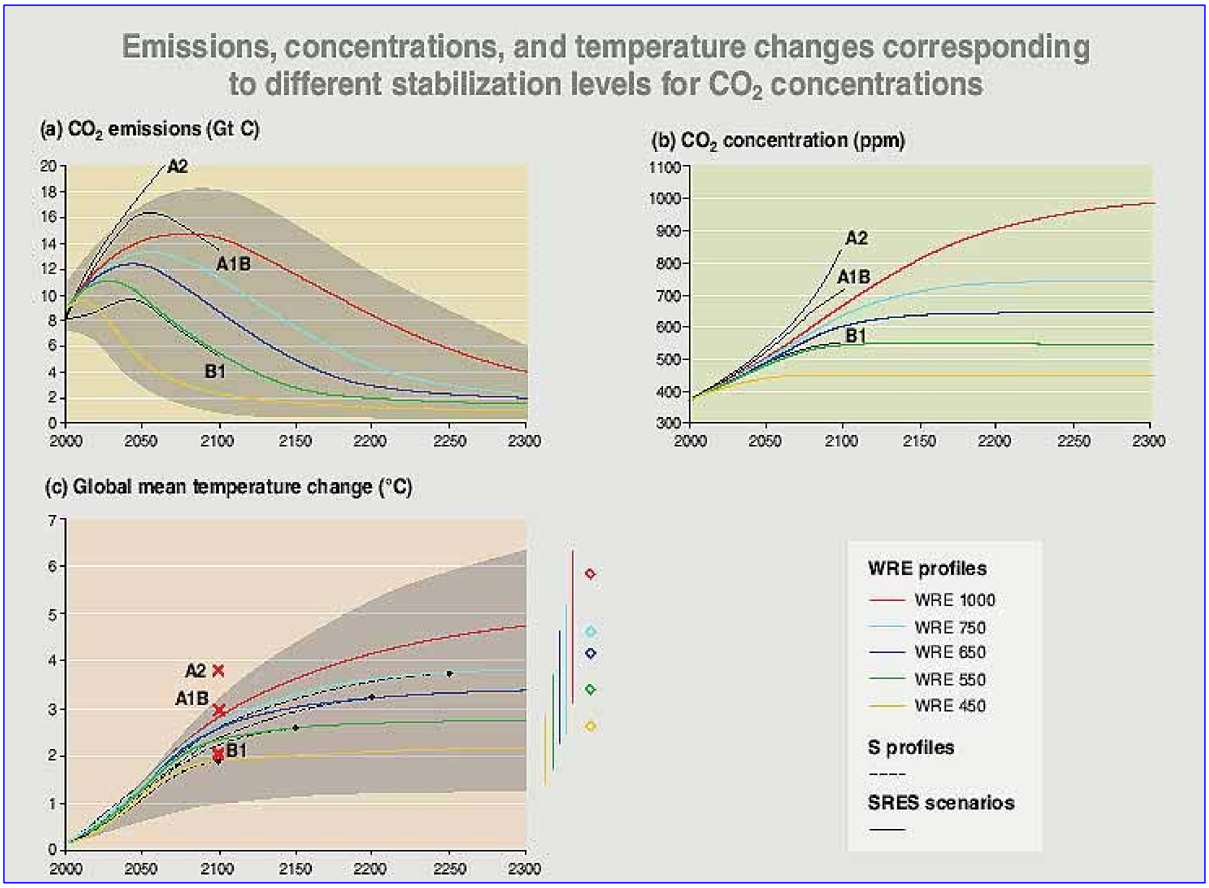
| | |
|---|---|
| "Virtually certain" | > 99% probability |
| "extremely likely" | > 95% probability |
| "Very likely" | > 90% probability |
| "Likely" | > 66% probability |

$CO_2$-emissions from fossil fuels represent in CH > 80% of all greenhouse gases ($CO_2$-equivalent)






Quelle: E. Jochem, 2006




Quelle: Jochem, 2006 (see also ADAM, 2007, p.27)



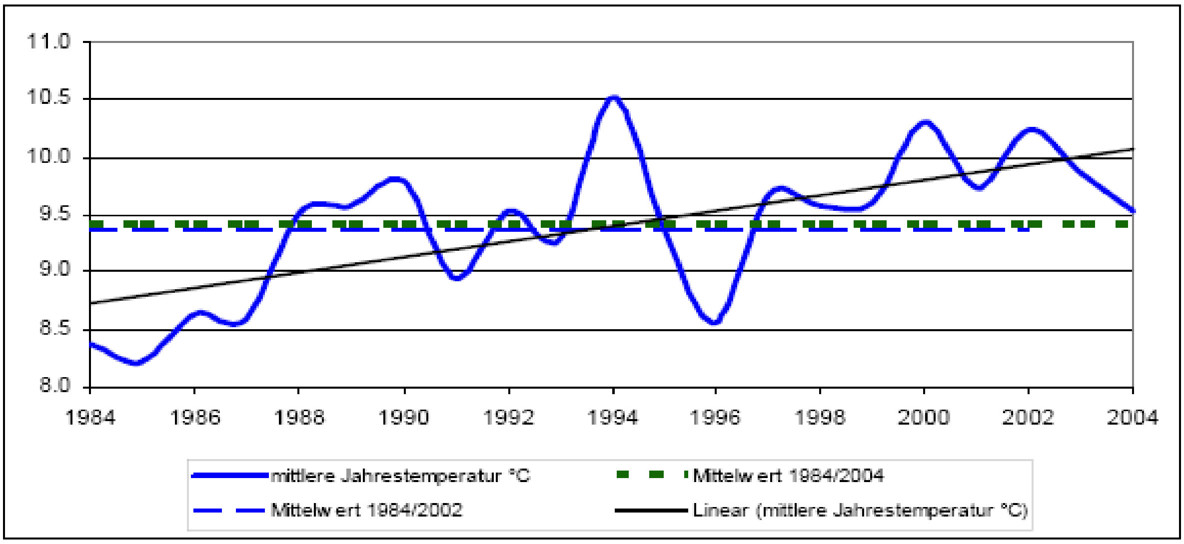


# Energy ← climate change

Source: OcCC/ProClim, 2007, chapter „Energy“

# Mean annual temperature in Switzerland

Entwicklung der mittleren Tagestemperaturen, 1984-2002




Source: Hofer, 2007





# Scenario assumptions

Increase until 2050

- +1.5 ºC in winter
- +2.5 ºC in summer
- Insolation: +5%
- No second „summer 2003“ in the coming years

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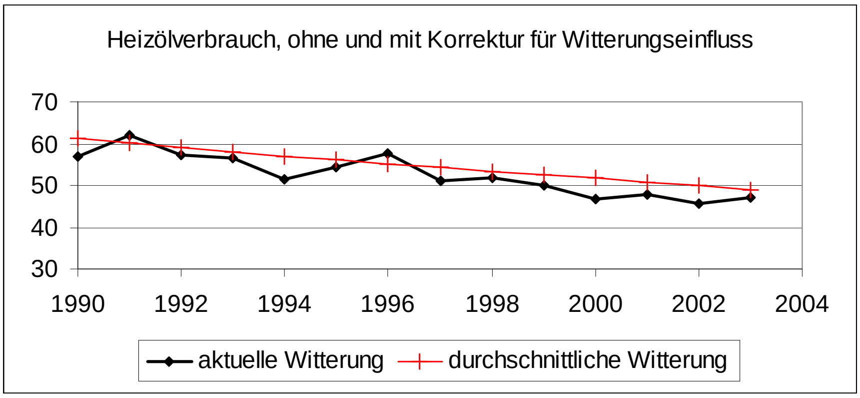
# Impact on heat demand

Heat demand (room heating + preparation of warm water)

- +1.5 ºC in den Wintermonaten → -15% heating degree days (HDD)




- -15% HDD → -11% heat demand → -6% $CO_2$ emissions
  (Source: BFE (2007), own calculations)



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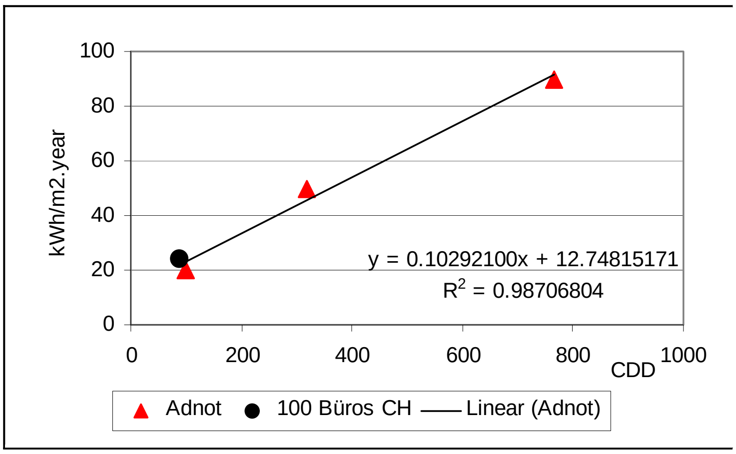
# Impact on electricity demand (1)

Example: electricity demand for cooling / air conditioning) in the service sector

- +2.5 ºC in summer → +150% cooling degree days (CDD)




Source: Aebischer et al., 2007

- +150% CDD → + 70% electricity demand for cooling/a.c.

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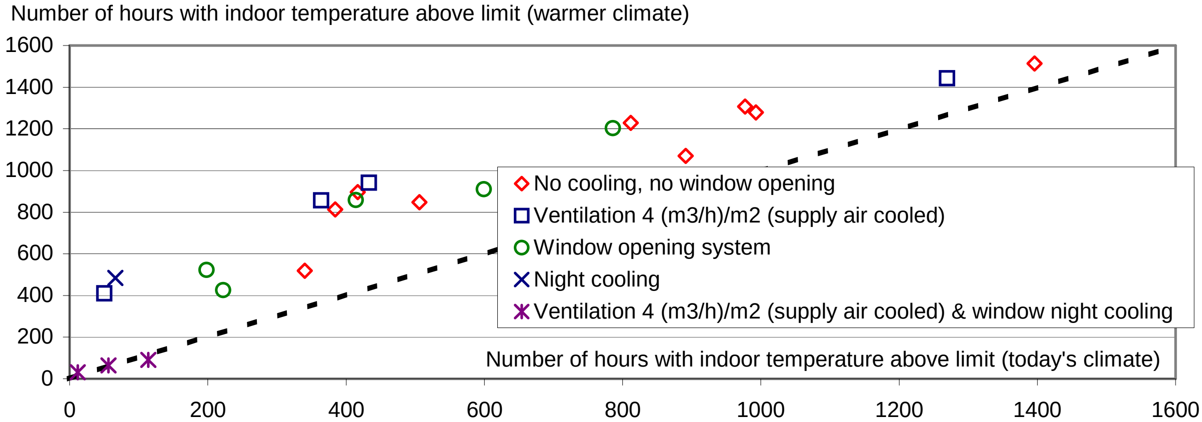
# Impact on electricity demand (2)

- +2.5 ºC in summer → uncomfortable, decrease of productivity




Source: Aebischer et al., 2007

- uncomfortable, decrease of productivity → increase of floor area with a.c.: + (70-100)% electricity for a.c.



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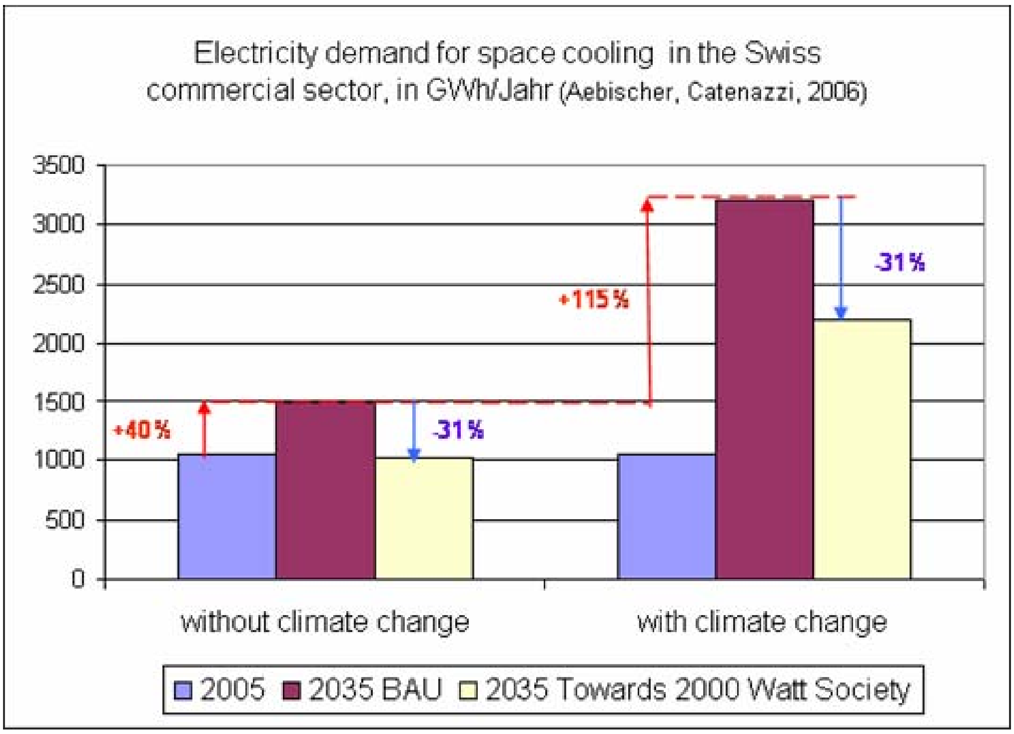
# Impact on electricity demand (3)



# Impact on electricity production

Hydro

- Less precipitation (summer), more evaporation, more frequent flood → -7% water and electricity production (pumped-storage power stations not affected)

Thermal power plants (nuclear power stations)

- Higher water temperature of rivers reduces cooling capacity (due to smaller $\Delta T$ and $T_{max}$ for river temperature)

  Example: in summer 2003, during two months -25% electricity from nuclear power stations → -4% annual electricity production





# Impact on potential of (new) renewable energy sources

Wind power

- Wind velocity? → ±
- Extreme events → locally, temporary interrupt

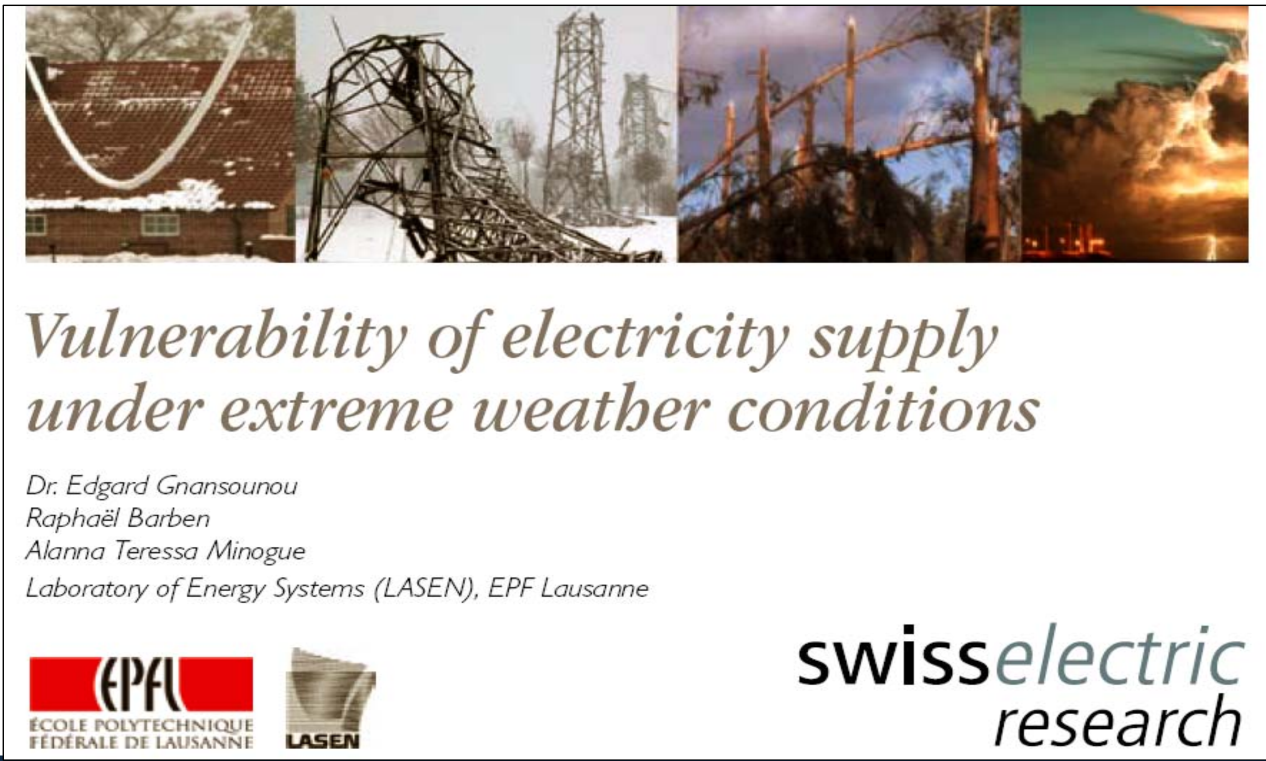
Biomass

- Increase of forest area → increase of potential
- Extreme events, e.g. Lothar → peaks in supply

Solar energy

- Possibly increase of isolation → possibly increase of potential

# Impact on electricity transmission



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# Financial aspects (1)

Energy demand

- Heating: reduction in energy costs and in capital costs (smaller boilers)
- Cooling: increase in energy costs and in capital costs (a.c. units) → adaptation costs

  – or avoid → mitigation costs

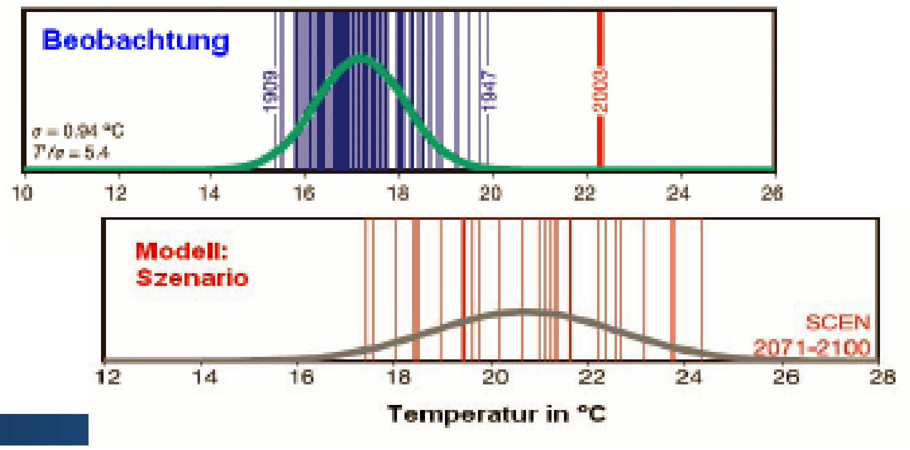
# Financial aspects (2)



## Electricity production and transmission

- Reduction in output and in income (ceteris paribus!) of hydro power stations
- Adaptation to more frequent extreme events, e.g. in cooling systems of thermal power stations and in transmission lines → adaptation costs

In the second half of the century a summer'03 will not be an extreme event anymore (Schär et al., 2004)



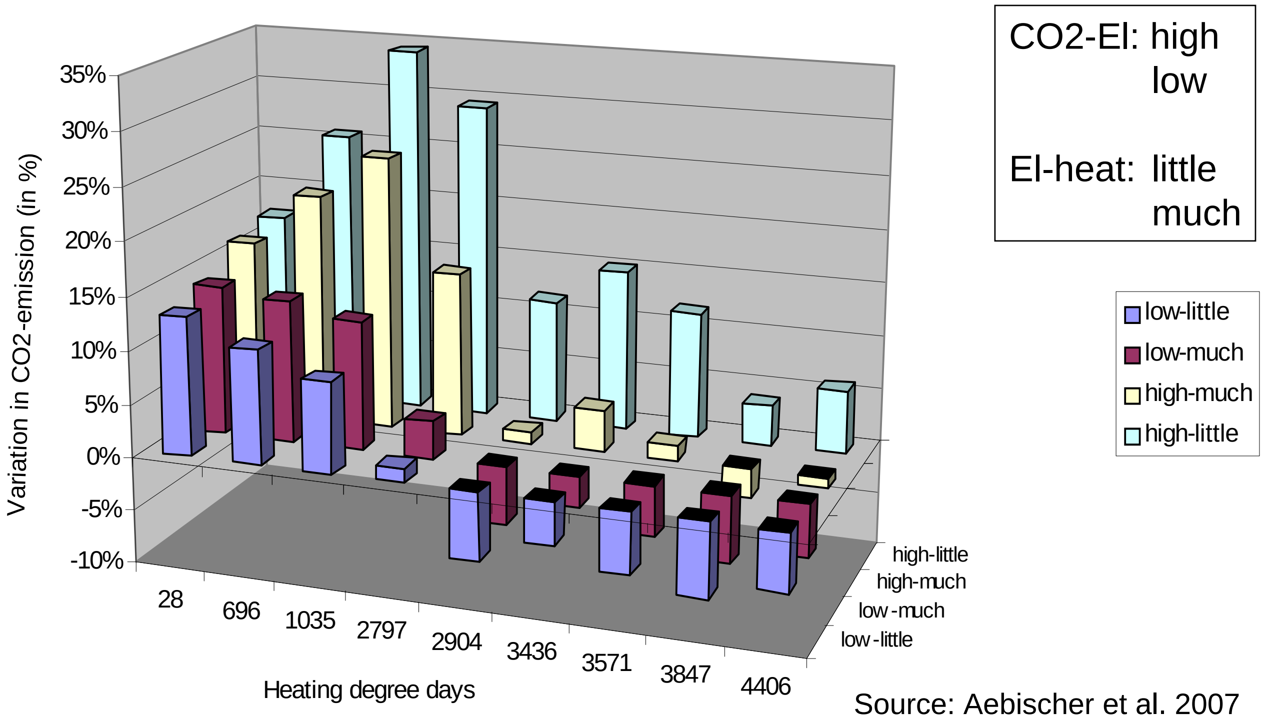





# Impact on $CO_2$ emissions in Europe

CO2-El: high
low

El-heat: little
much




Source: Aebischer et al. 2007

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