Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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

# Impact of climate change on thermal comfort, heating and cooling energy demand in Europe

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# What are we talking about

1. Impact of climate change (warmer climate) on thermal (dis-)comfort and electricity demand for cooling on the level of **individual buildings**
2. Impact of climate change in the **Swiss service sector** on final energy demand for heating and for comfort cooling
3. Application to **Europe**: Impact of climate change on relative $CO_2$-emissions (heating and cooling) in the **service sector**
4. Summary and conclusions

# 1. Impact of climate change (warmer climate) on thermal (dis-)comfort and electricity demand for cooling on the level of individual buildings

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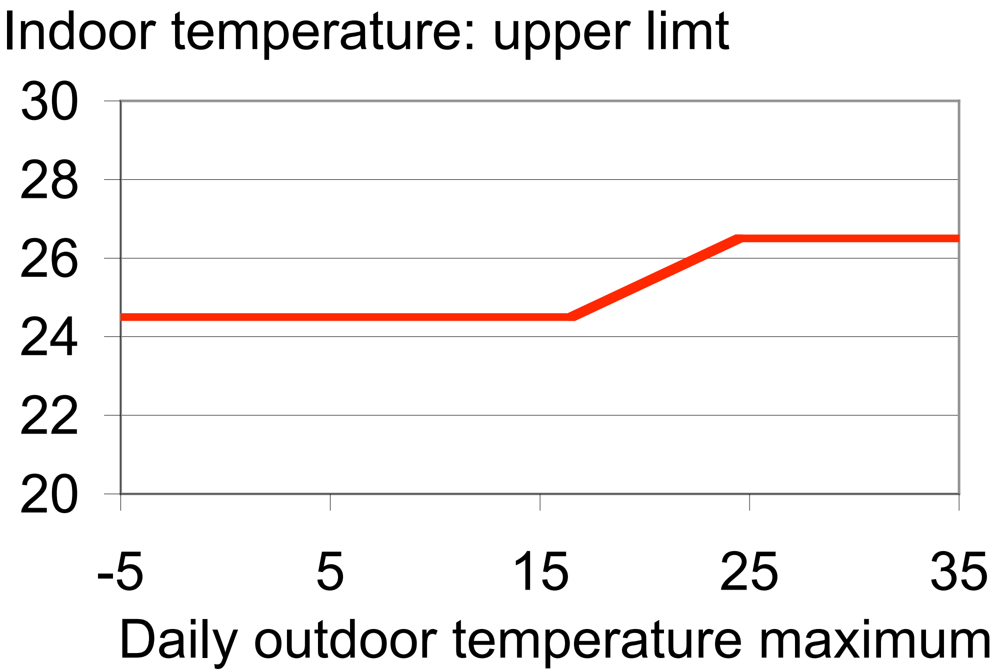
# Thermal comfort requirements (overheating)

Required: $T > T_{limit}$ less than 100 hours/year

Potentially OK: $T > T_{limit}$ less than 200 hours/year

Potentially higher T-limit for non-cooled buildings

(adaptive comfort model)

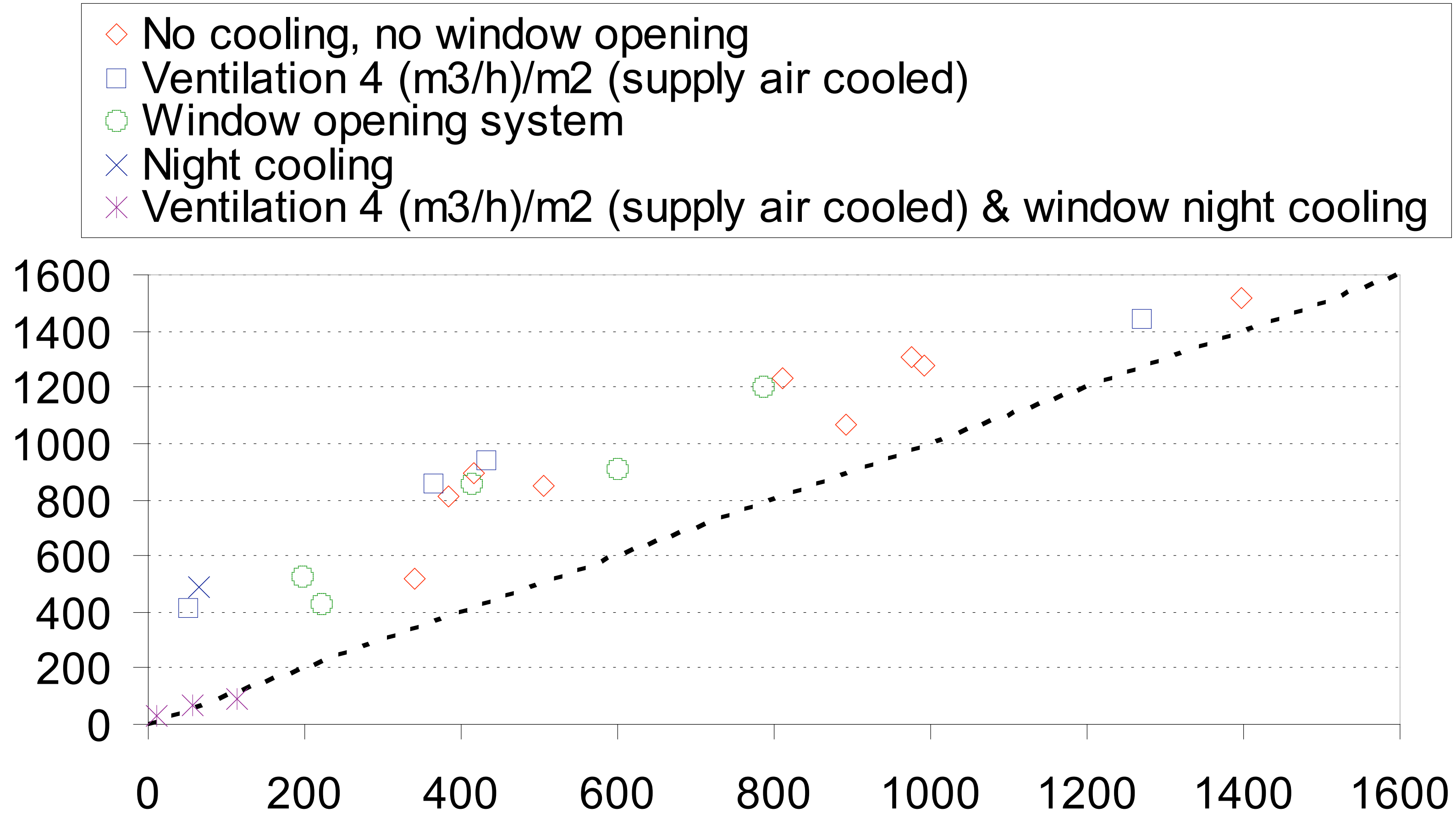


# Assumptions „warmer climate“

Change of mean temperature
(in urban environment)

- +2.5 °C during day
- +3.5 °C during night
- Not considered, but also very import:
  more frequent extreme events (heat waves)

# Impact of warmer climate on thermal (dis-)comfort (overheating)




**Warmer climate** Number of hours with indoor T above limit

**Today's climate** Number of hours with indoor T above limit

# Thermal (dis-)comfort (overheating)

## “Moderate zone” (north of alps)

Huge variations depending on building design and technology

- **Internal loads**, glazing proportion, thermal mass
- **Use of “free cold”**
- **Insulation increases thermal discomfort** (sic! overheating)

Jakob et al. 2006

Impact of **warmer climate** **large**:

**Non-linear threshold** behaviour:
=> Buildings switch to non-acceptable comfort conditions
=> Impact of productivity, complaints

**Discomfort as driver for more cooled (office) space**

# Thermal (dis-)comfort (overheating)

Huge variations depending on building design (thermal mass, envelope and building technology)

- Strong impact of **internal loads**, impact of **glazing proportion**
- **Use of "free cold":** (controlled) window opening or cooling (separated from ventilation)
- Insulation increases thermal discomfort (sic! overheating)

Impact of **warmer climate** "moderate zone" (north of alps) **large**:

- Buildings with good or medium thermal comfort
  => Non-linear threshold behaviour:
  Buildings switch to non-acceptable comfort conditions
  => Impact of productivity, complaints

**Discomfort as driver for more cooled (office) space**

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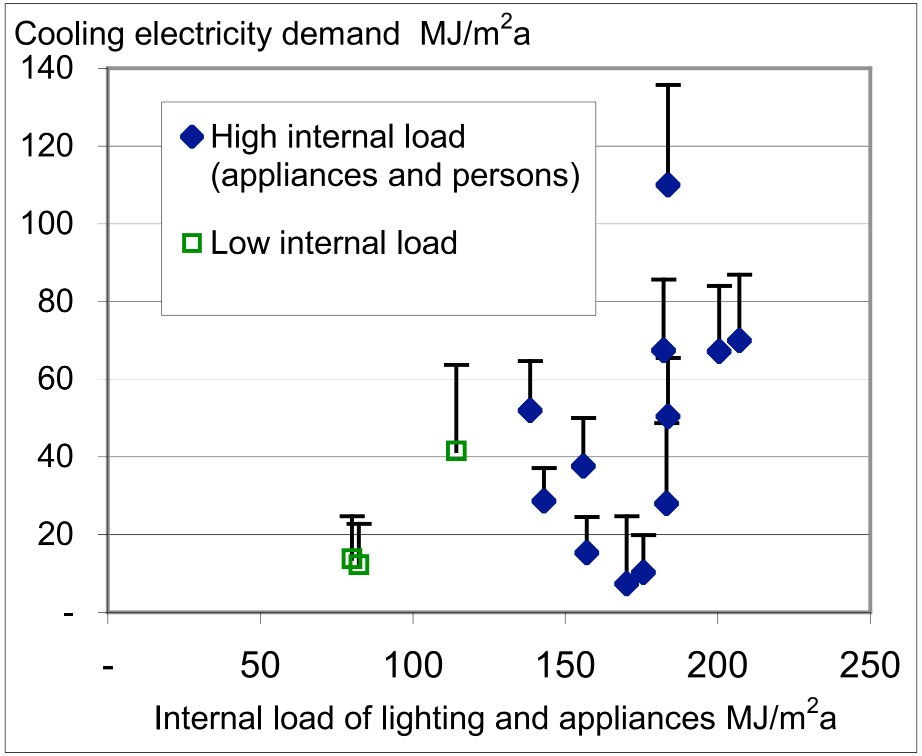
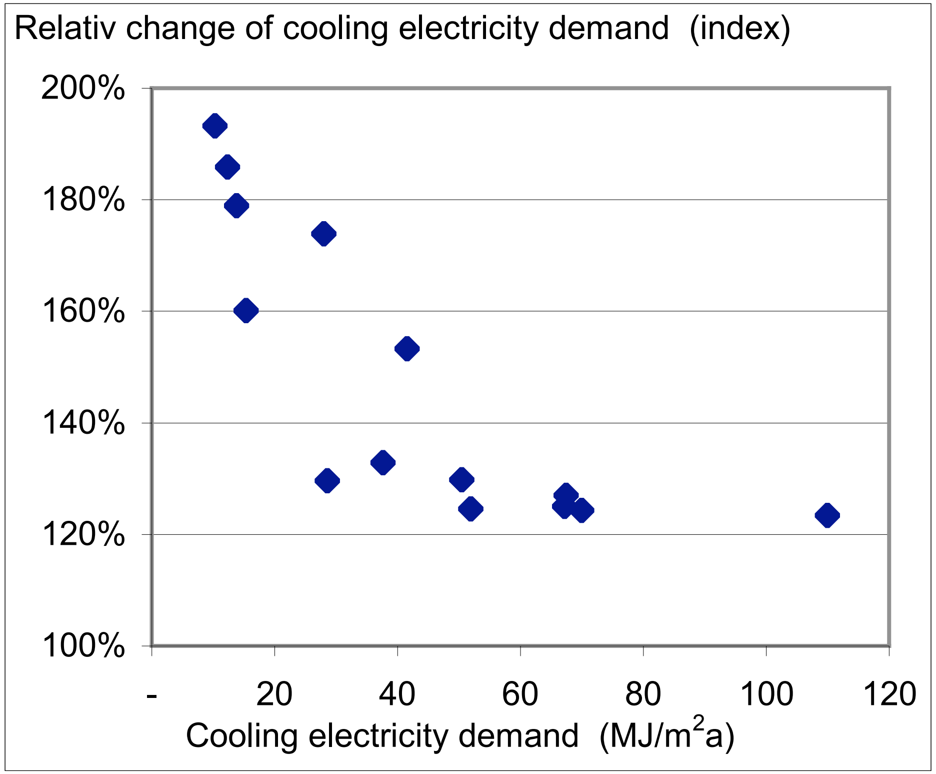
# Sensitivity of cooling electricity demand regarding warmer outdoor temperatures

Impact in absolute values (represented as error bars) (MJ/m²a)




Relative change, 100%=demand with today's climate



# Cooling electricity demand

Impact of **warmer climate** **large**:

- In absolute terms:
  buildings with already high cooling load
- In relative terms:
  buildings with low cooling demand in today’s climate

# Cooling electricity demand

Huge variations depending on building design (envelope and building technology)

- Strong impact of **internal loads**, impact of glazing proportion
- **Separation of** ventilation and cooling **needs**
- **Use of "free cold":** (controlled) window opening, ground coupled or hybrid (wet) heat exchanger, night ventil.
- **Smart control** (by-pass of chiller, demand-related operation)
- **Type** and performance of **chiller** (e.g. dynamic dT)

Impact of **warmer climate** **large**:

- In relative terms: low cooling demand bldg in today's climate
- In absolute terms: bldgs with already high cooling load

# 2. Impact of climate change in the Swiss service sector on final energy demand for heating and for comfort cooling

# Assumptions „climate change scenario“

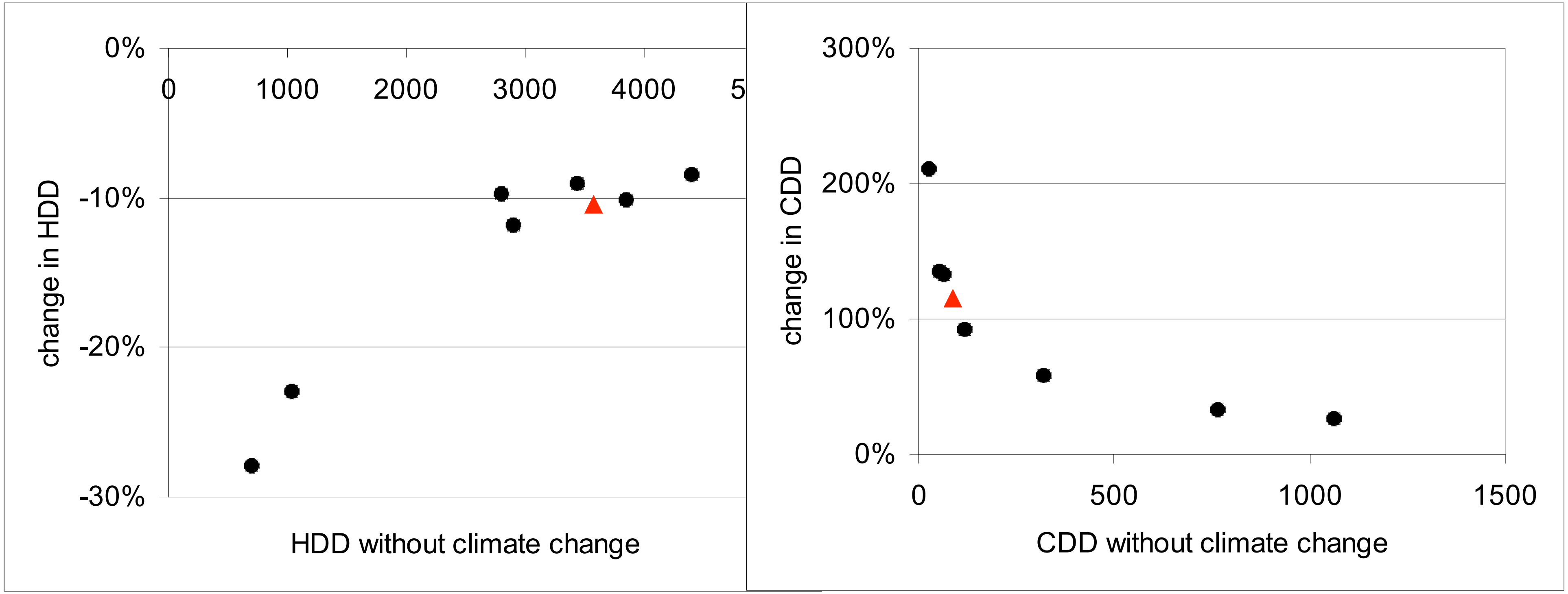
Change of mean temperature (2035)

- +1 °C in the months from September to May
- +2 °C from June through August
- → Change of heating degree days (HDD)
- → Change of cooling degree days (CDD)

“Business as usual” improvement of buildings, heating and air conditioning systems,

No specific adaptation measures, except increase in cooled floor area!

# Relative variation of HDD and CDD due to the assumed climate change in 2035 in function of HDD and CDD without climate change (typical locations in EU)



# Impact on heating energy demand

Apply formula used for correction of annual variation of heating degree days (HDD) to variation of HDD due to climate change:

- $H\_{CC} - H\_{2005} = H\_{2005} * a * (HDD\_{CC} / HDD\_{2005} - 1)$

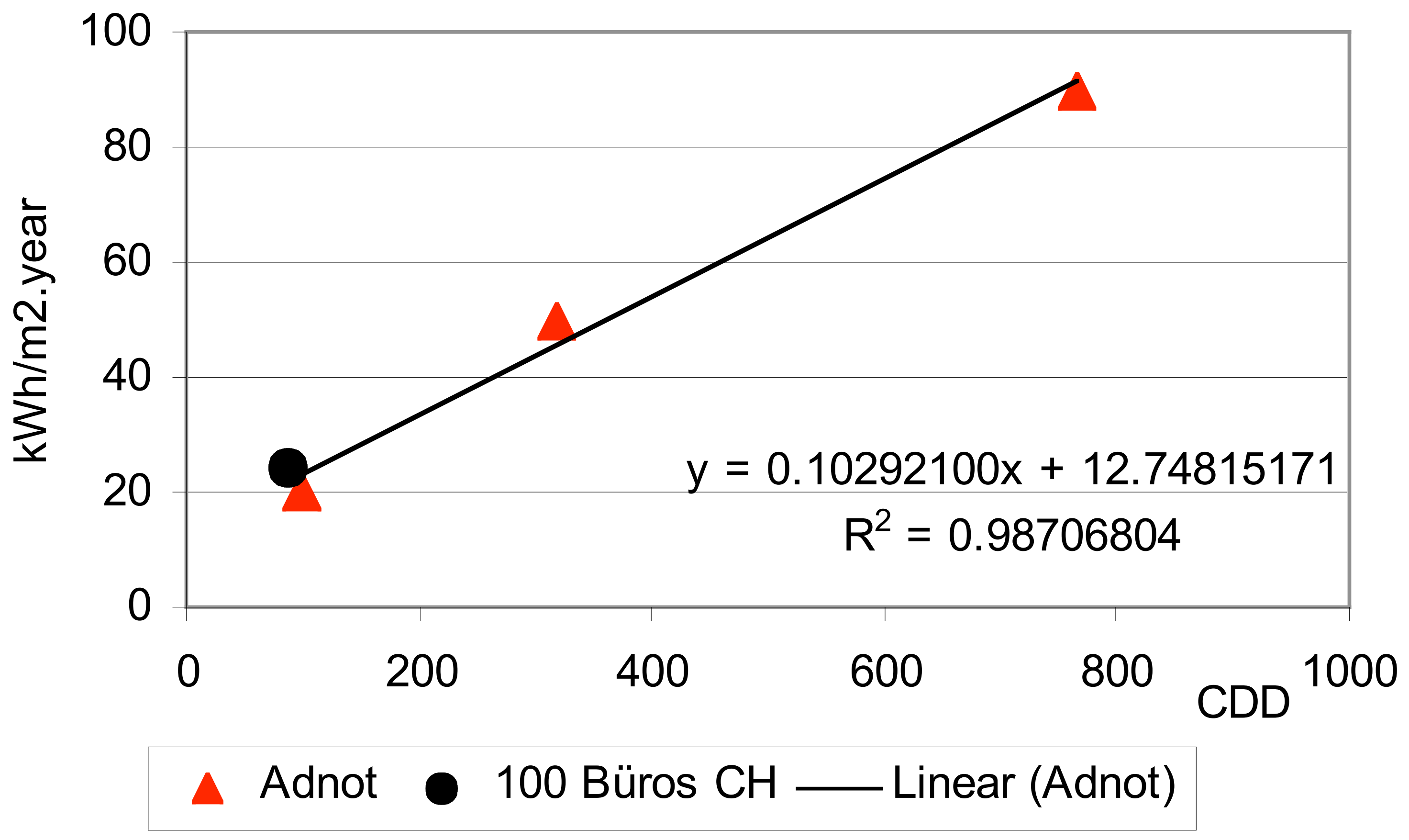
# Impact on cooling energy demand (1)

Two factors:

1. Increase of floor area with air conditioning (cooling)
   - → ad-hoc assumptions (no second summer 2003!)
   - CH: 50% of no cooling → partial cooling

     50% of partial cooling → fully air conditioned
   - Other countries → see paper
2. Increase of specific electricity demand
   - $EI_{\_CC} - EI_{\_2005} = 0.102921 * (CDD_{\_CC} - CDD_{\_2005})$ , in kWh/ $m_c^2$.a

Electricity demand for cooling, in kWh/m2.year, of office buildings in London, Milano and Sevilla (= Adnot) in function of the Cooling Degree Days (CDD) in these locations. Source: Adnot, Henderson, CEPE



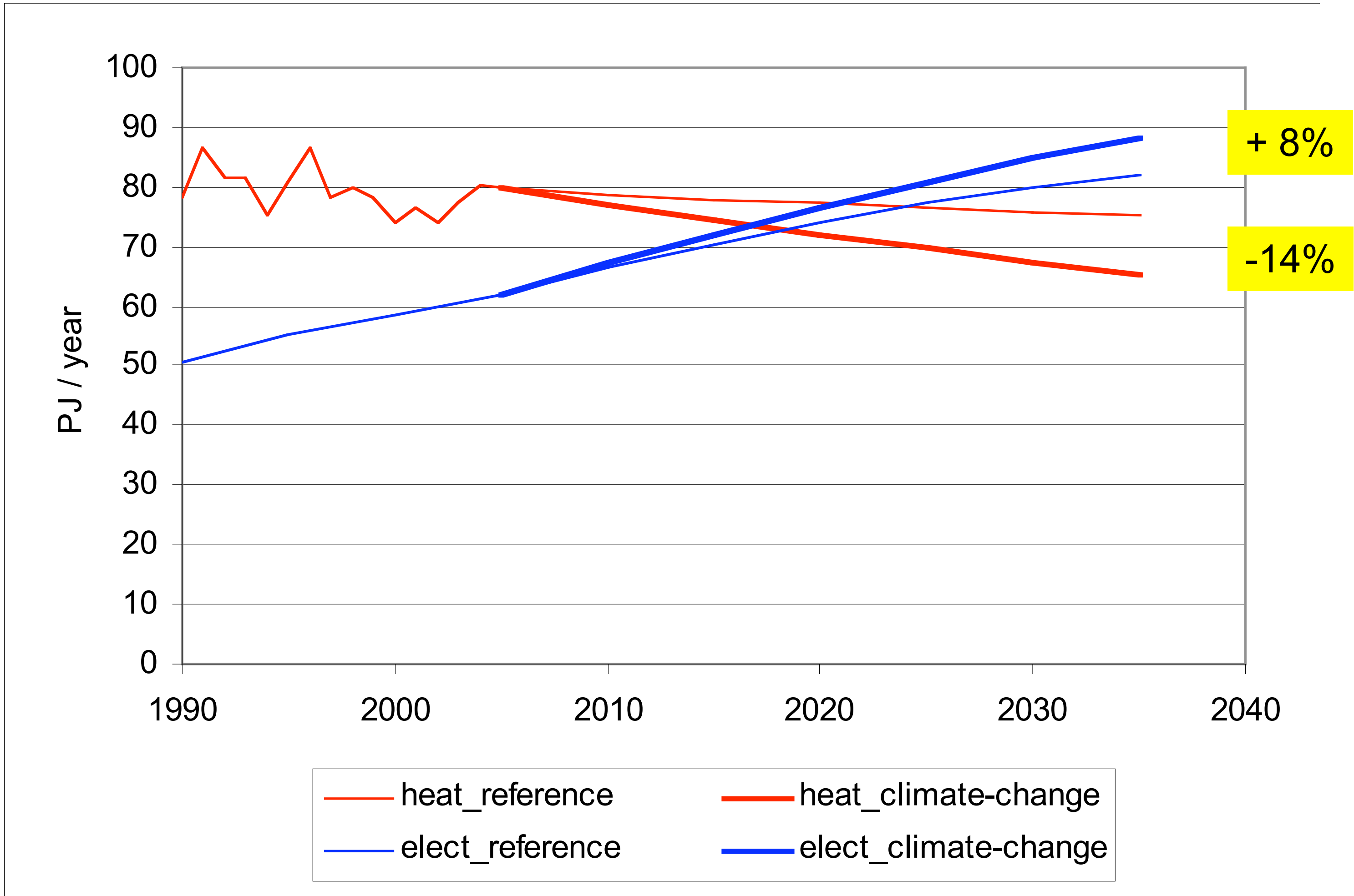
# Impact on cooling energy demand (2)

In Switzerland in the year 2035, increase due to climate change relative to reference scenario (no temperature increase): + 115% (EU regions see paper)

Relative importance of the two factors in Switzerland:

- Increase of cooled floor area = 60%
- Increase of specific electricity demand = 40%

# Heating energy demand and total electricity demand in the reference scenario with constant mean temperatures and in the climate change scenario, in PJ per year. Source: CEPE



# 3. Application to Europe: Impact of climate change on relative $CO_2$-emissions (heating and cooling) in the service sector

# Application to some regions in the EU

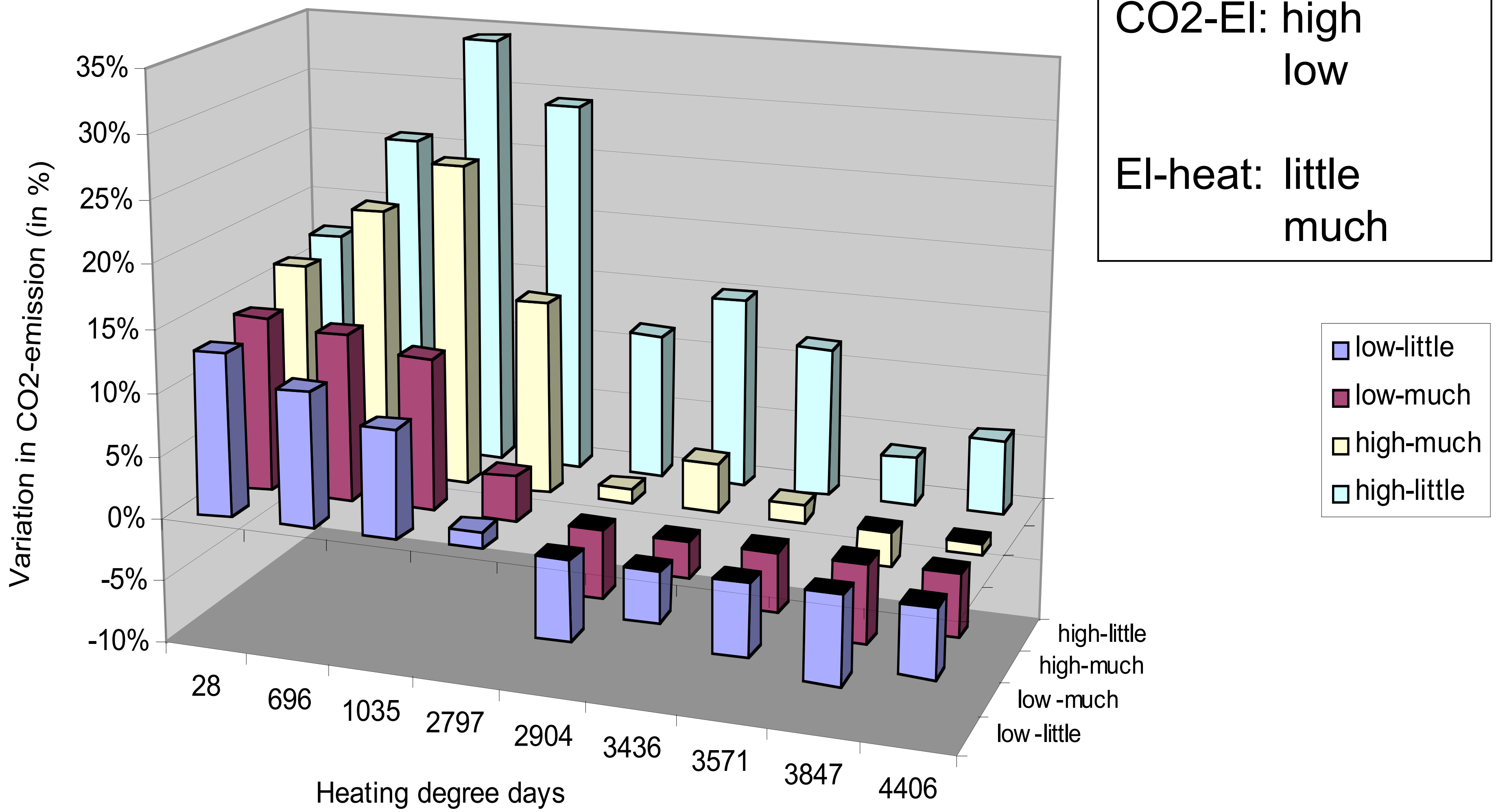
Very simplified sensitivity exercise:

- Heating degree days and cooling degree days (location)
- Fuel mix for heating / heating system
  - 10% electric resistance/ohmic heating = **little**
  - 50% electric resistance/ohmic heating = **much**
- $CO_2$-content of electricity
  - 100% coal fired power plants = **high**
  - 90% $CO_2$-free power plants = **low**

# Changes in relative CO2 emission from heating and cooling due to climate change in different locations (characterised by HDD), in percent

CO2-EI: high
low

EI-heat: little
much



# 4. Summary and conclusions (1)

## Temperature increase

- Decrease in HDD → reduction of heating energy demand
- Increase in CDD → increase of cooling energy demand due to two factors:
  1. increase in thermal discomfort → increase cooled floor area
  2. Increase in energy demand per $m^2$ cooled floor area

## Net effect in final energy

- Decrease in northern regions, increase in southern regions

## Net effect on $CO_2$

- Largest increase (in relative and absolute terms) in warm climate with high $CO_2$-intensity of electricity

# 4. Summary and conclusions (2)

In temperate and cold climate:

+100% (and more) increase in energy for cooling

→ More and new policy measures needed:

- Planning of new buildings (and refurbishment) considering future temperature increase
- Double strategy: avoid conventional mechanical cooling (if possible) and improve cooling concepts

- But, don't forget heating demand!

# 4. Summary and conclusions (3)

Impact of climate change should be taken into account in defining $CO_2$ reduction targets?

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# We remember gratefully our friend

# George Henderson

# who inspired us to do this paper and contributed substantially to a first version of this paper