

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 CO₂-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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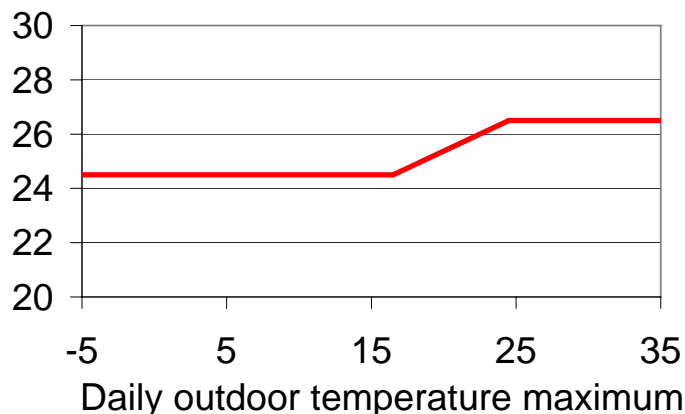
Thermal comfort requirements (overheating)

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

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

Potentially higher T-limit for non-cooled buildings

Indoor temperature: upper limit



(adaptive comfort model)

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Assumptions „warmer climate“

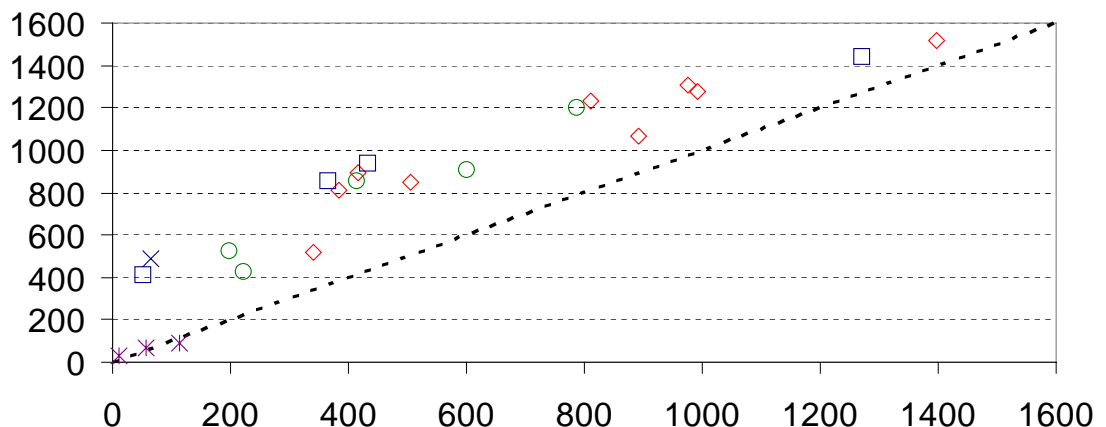
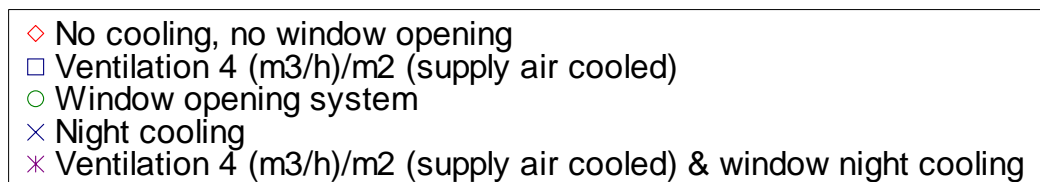
Change of mean temperature
(in urban environment)

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

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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:

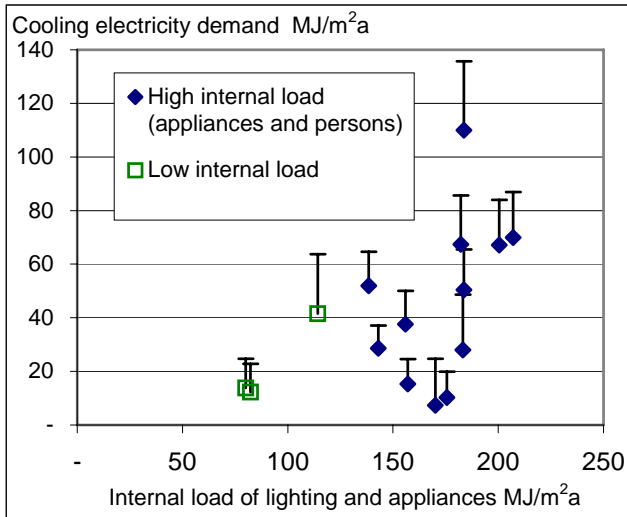
Buildings switch to non-acceptable comfort conditions

=> Impact of productivity, complaints

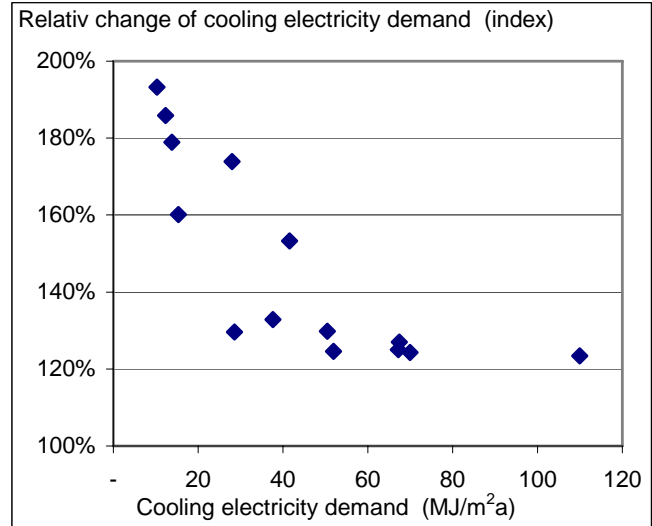
Discomfort as driver for more cooled (office) space

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



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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

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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)

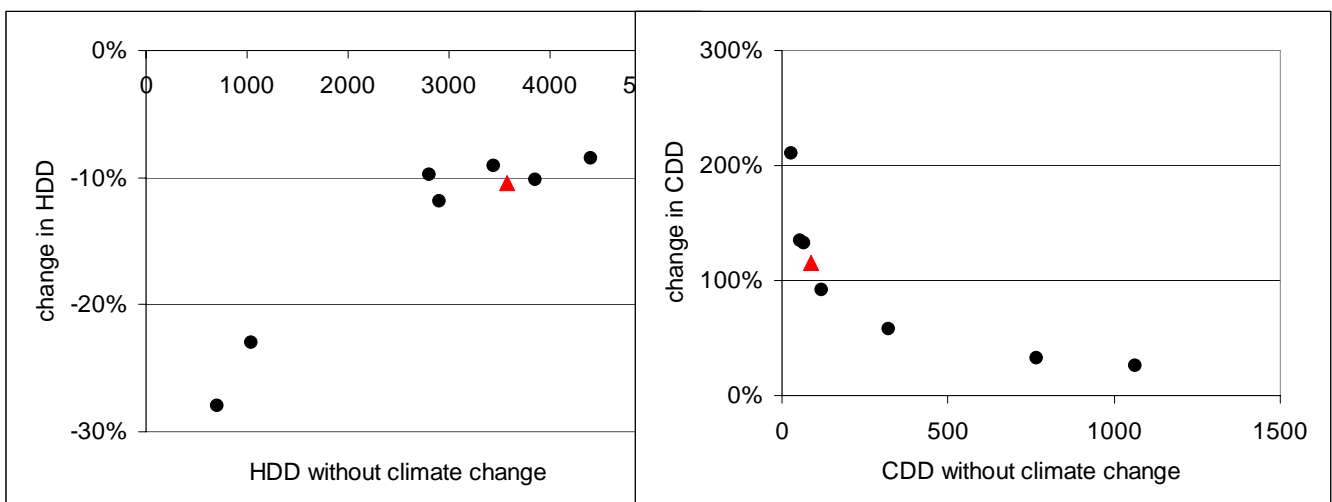
- +1 °C in the months from September to May
- +2 °C from June through August
- → Change of heating degree days (HDD)
- → Change of cooling degree days (CDD)

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

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

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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)



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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:

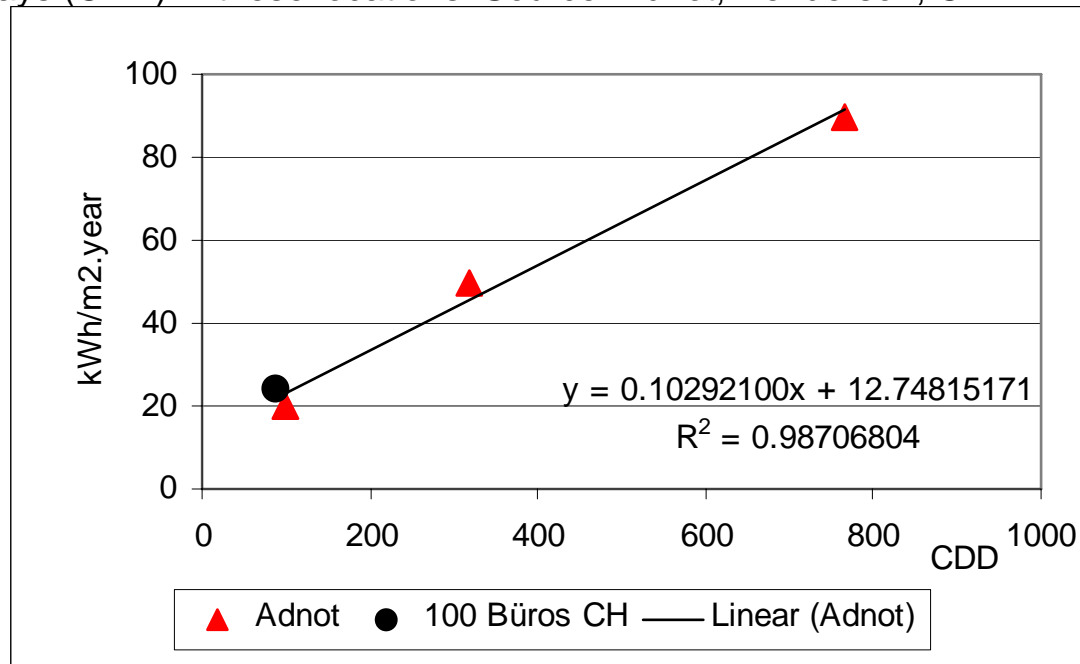
1. Increase of floor area with air conditioning (cooling)

- → 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_c².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



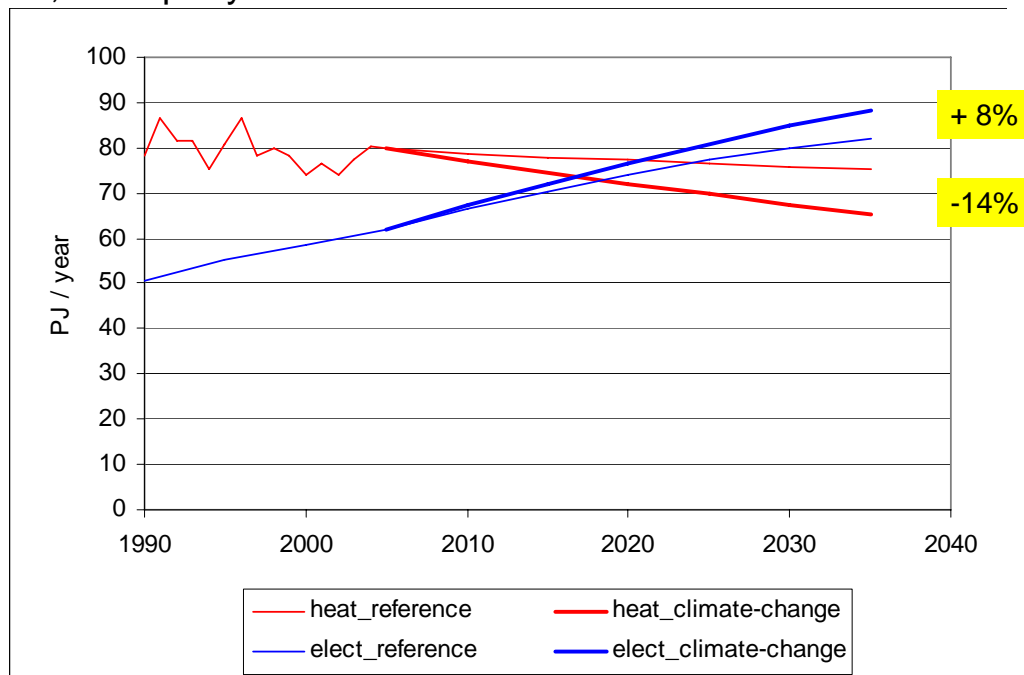
Impact on cooling energy demand (2)

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



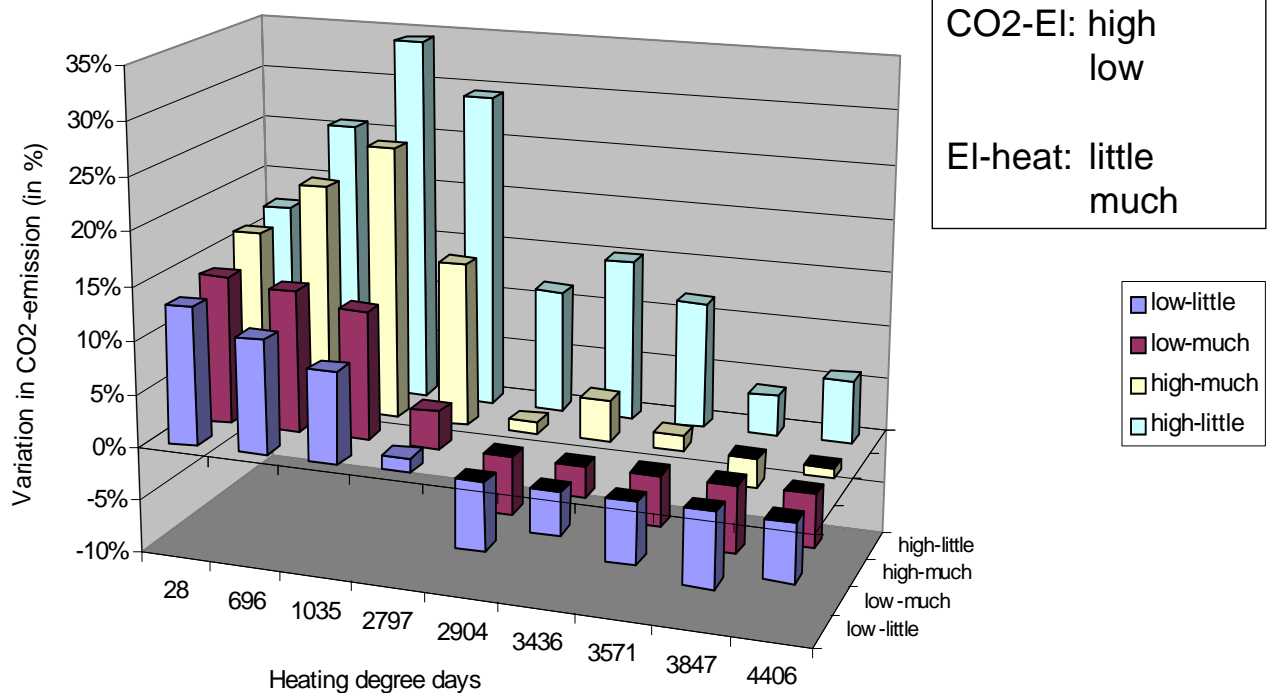
3. Application to Europe: Impact of climate change on relative CO₂-emissions (heating and cooling) in the service sector

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**
- CO₂-content of electricity
 - 100% coal fired power plants = **high**
 - 90% CO₂-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



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 m² cooled floor area

Net effect in final energy

- Decrease in northern regions, increase in southern regions

Net effect on CO₂

- Largest increase (in relative and absolute terms) in warm climate with high CO₂-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 CO₂ reduction targets?

We remember gratefully our friend

George Henderson

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