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Synthetic weather files for dynamic simulations of future building energy demand in Finland

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Key questions

❖ How to bridge the temporal gap between climate model output and needs of climate impacts modelling?
<=> How to produce future hourly weather data for building energy related applications? – A Finnish example

❖ How large are the impacts of long term climate change on heating and cooling energy demand of buildings?

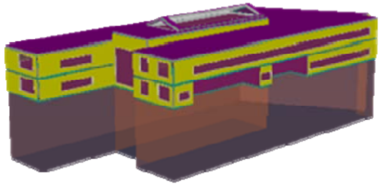
❖ How to assess these impacts?

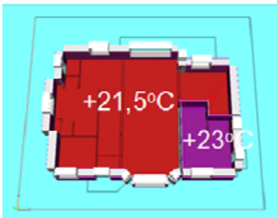
An extension of a work originally initiated by a **demand** of the Finnish Ministry of the Environment and conducted for the purpose of updating the **National Building Code of Finland**

Calculations of heating and cooling energy demand of buildings: two main methods

1. Heating and cooling degree-day sums

2. Building energy simulations
   i. thermal balance models for idealized buildings
   ii. dynamic building energy simulations for complex buildings





Input: Hourly meteorological data

- Heat transfer and air flows inside the building
- Time-variant heat loads from solar radiation, household appliances, lighting, etc.

Output: Key building performance indicators: energy demand, indoor temperature, humidity and air quality

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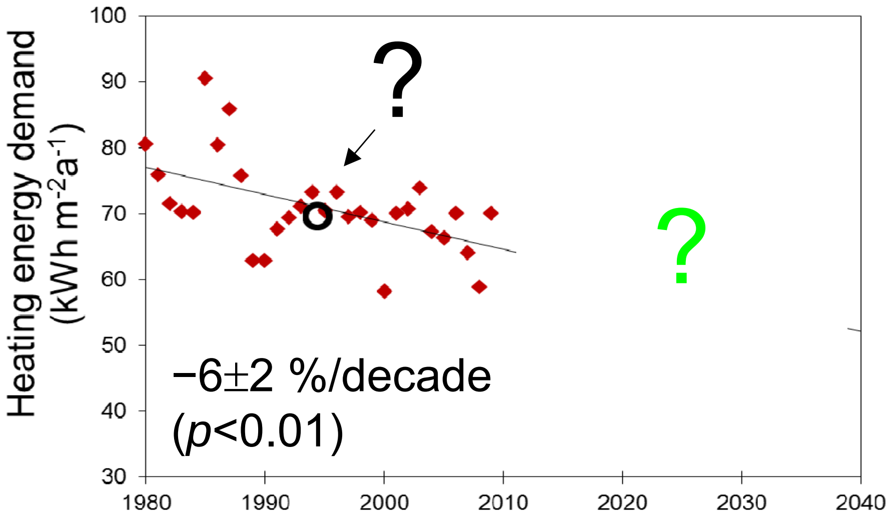
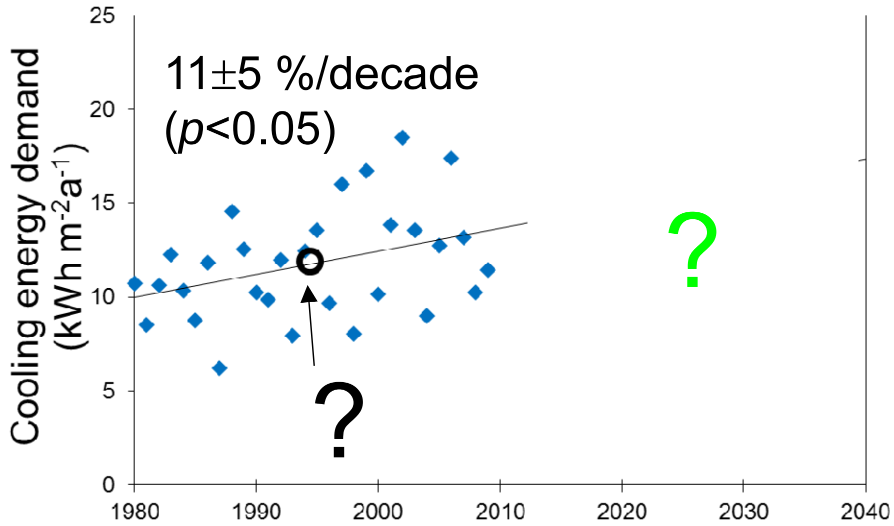
Recent decreases in heating and increases in cooling energy demand
based on dynamic building energy simulations*





Input: hourly data for

- Air temperature
- Solar radiation**
- Relative humidity
- Wind speed

⇐

◆ ◆ Actual observations during the 30-year period

OR

o Test reference year weather data

?

* The IDA Indoor Climate and Energy (IDA-ICE) program

** Diffuse on a horizontal surface and direct normal to the solar beam

Jylhä et al. (2015a)

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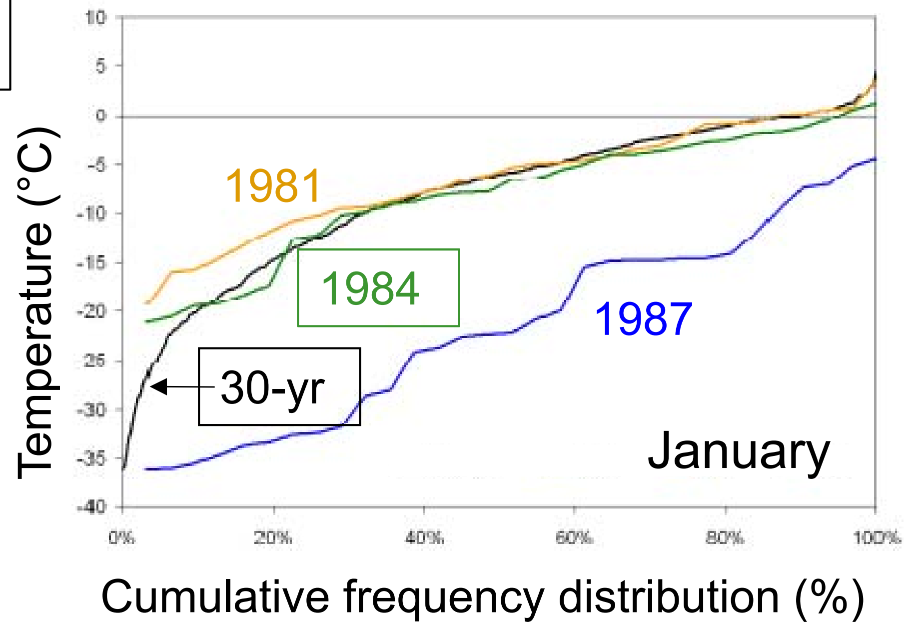
Hourly test reference year weather data in the recent past climate

= Observed data from 12 months that originate from different calendar years during the 30-year period

Objectives

- To represent as typical as possible weather conditions during 365 days
- To be suitable for estimates of average recent energy demand of buildings
- To serve as a baseline for developing future synthetic hourly weather files



Selection

- ❑ Comparison of cumulative frequency distributions of daily means
- ❑ Several climate variables are taken into account simultaneously
- ❑ More emphasis for those variables that have the largest impact on the energy demand

In the climate of Finland: more weight for temperature (in all seasons) and solar radiation (in May-Aug) than for relative humidity and wind speed

Kalamees et al. (2012)

Development of synthetic hourly weather files for the future (1/2)

Objective: to represent typical climate conditions prevailing around the years 2030, 2050 and 2100, assuming three different emission scenarios

The hourly weather observations for the selected 12 months
+
Multi-mean estimates from a wide set of climate models (CMIP3)

Downscaling of temperature, solar radiation, humidity & wind

Goals:

- Minimized influence of climate model biases
- Realistic diurnal cycles and day-to-day fluctuations of weather
- Statistics of the pseudo weather to be consistent with the model-based projections of the climatic changes

Development of synthetic hourly weather files for the future (2/2)

Delta-change methods for the various climatic variables:

- Future changes in monthly means:
  from climate models
- **Temperature***
  Percentage changes in standard deviation was supposed to be almost similar in daily (from models) and hourly time scales
- **Solar radiation***
  Observed partition between the global, direct and diffuse radiation based on > 260 000 in-situ recordings in Finland in 2000-2009
  => Projected changes in global solar radiation were primarily applied to direct radiation, and only secondary to diffuse radiation*
- **Relative humidity****
  Changes in saturation deficit & an iteration algorithm*
- **Wind speed****
  Separately for zonal and meridional components

*Jylhä et al. (2015b) **Lehtonen et al. (2014)

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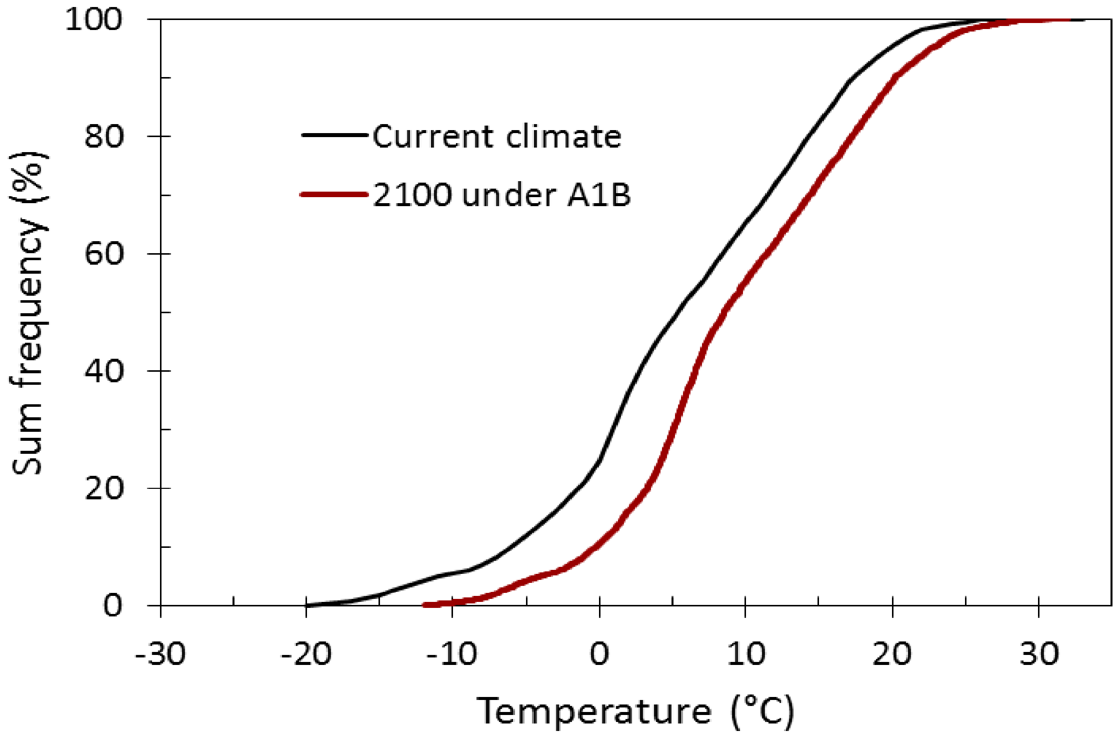
Anticipated future climate in southern Finland

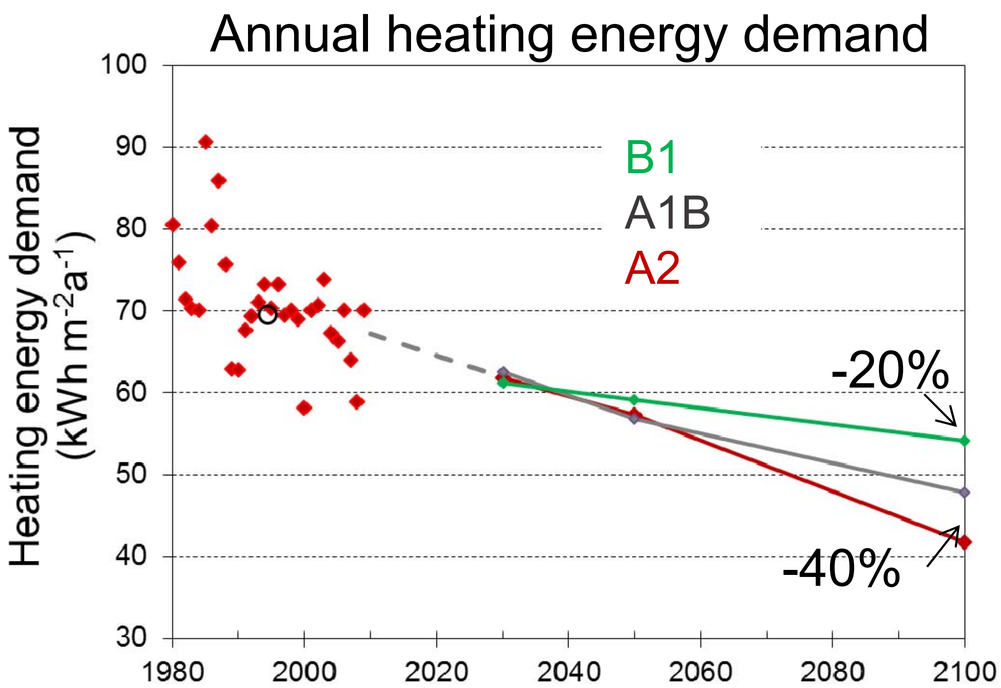


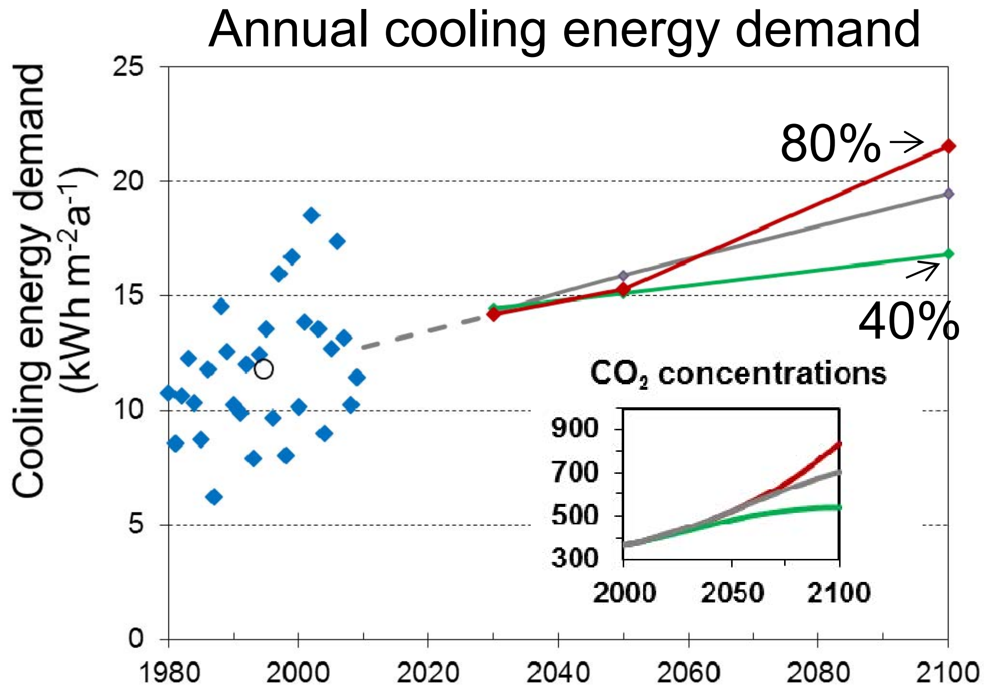
Cumulative frequency distribution of hourly temperature

- Stronger warming of low rather than high temperatures

- **Monthly mean temperatures**: ~3ºC higher in winter, 1.5–2ºC higher in summer by 2050 (relative to 1980-2009)
- **Variability in daily mean temperature**: 10-15% smaller in Oct - Apr by 2050
- **Solar radiation**: less in winter and spring, slightly more in late summer/early autumn
- **Wind speed**: slight increases in Nov - Feb
- **Relative humidity**: small rises in all seasons except summer

Future building energy demand of a typical detached house





Note the different vertical scales!

Comparisons to the traditional degree day-sum method:

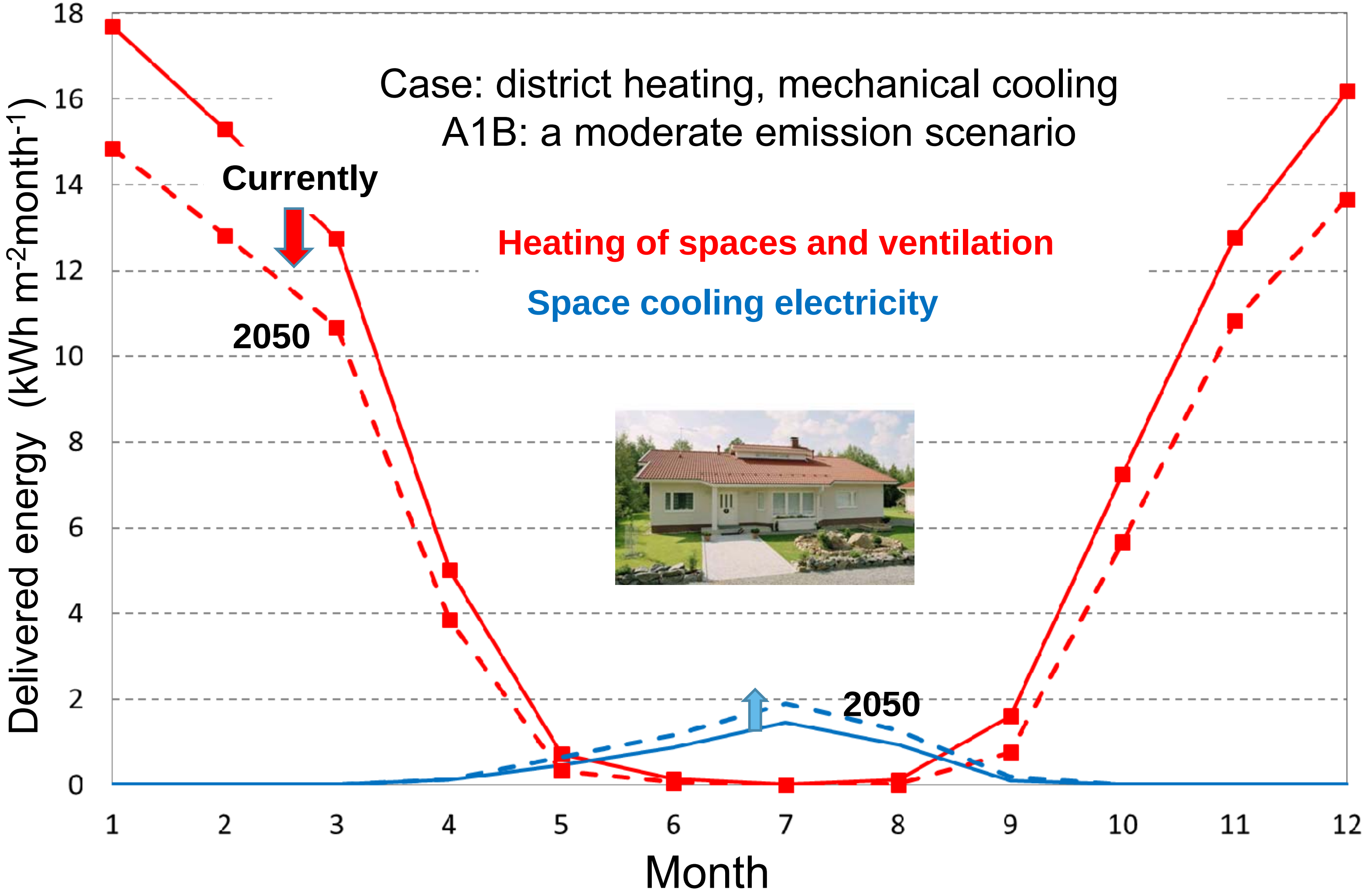
HDD: almost the same percentage decreases

CDD: much larger increase: 230% vs 65% (here) by 2100 under A1B

✓ The CDD method ignores time variations in solar heat load => not accurate enough

The annual building energy demand of a typical detached house in Finland is assessed to decrease by 10% by 2050

Due to climate change alone: projected reductions of 15-18% in heating energy demand, but increases in cooling energy demand by 28-34%



Jylhä et al. (2015a)

Concluding remarks

- **Synthetic weather files** for simulations of future building **energy demand** aim to represent typical future climate conditions
    - Those constructed for Finland are freely available
- In Finland, decreases in heating energy demand dominate over increases in cooling energy demand.
- The absolute changes in building **energy consumption** also depend on the heating and cooling systems used.
    - For the increases in cooling energy demand not to be materialized as rises in energy consumption, further development and implementation of **energy-efficient cooling systems** and **passive cooling solutions*** are needed.

*e.g., orientation, shading and size of the windows

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For more details

Kalamees *et al*. 2012:
Development of weighting factors for climate variables for selecting the energy reference year according to the EN ISO 15927-4 standard. *Energy and Buildings*, 47, 53-60. doi:10.1016/j.enbuild.2011.11.031

Jylhä *et al.* 2015a:
Energy demand for the heating and cooling of residential houses in Finland in a changing climate. *Energy and Buildings*, 99, 104-116. doi:10.1016/j.enbuild.2015.04.001

Jylhä *et al.* 2015b:
Hourly test reference weather data in the changing climate of Finland for building energy simulations. *Data in Brief*, doi:10.1016/j.dib.2015.04.026

Lehtonen *et al*. 2014:
The projected 21st century forest-fire risk in Finland under different greenhouse gas scenarios. Boreal Env. Res., 19, 127–139.

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Thank you
for your attention!

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