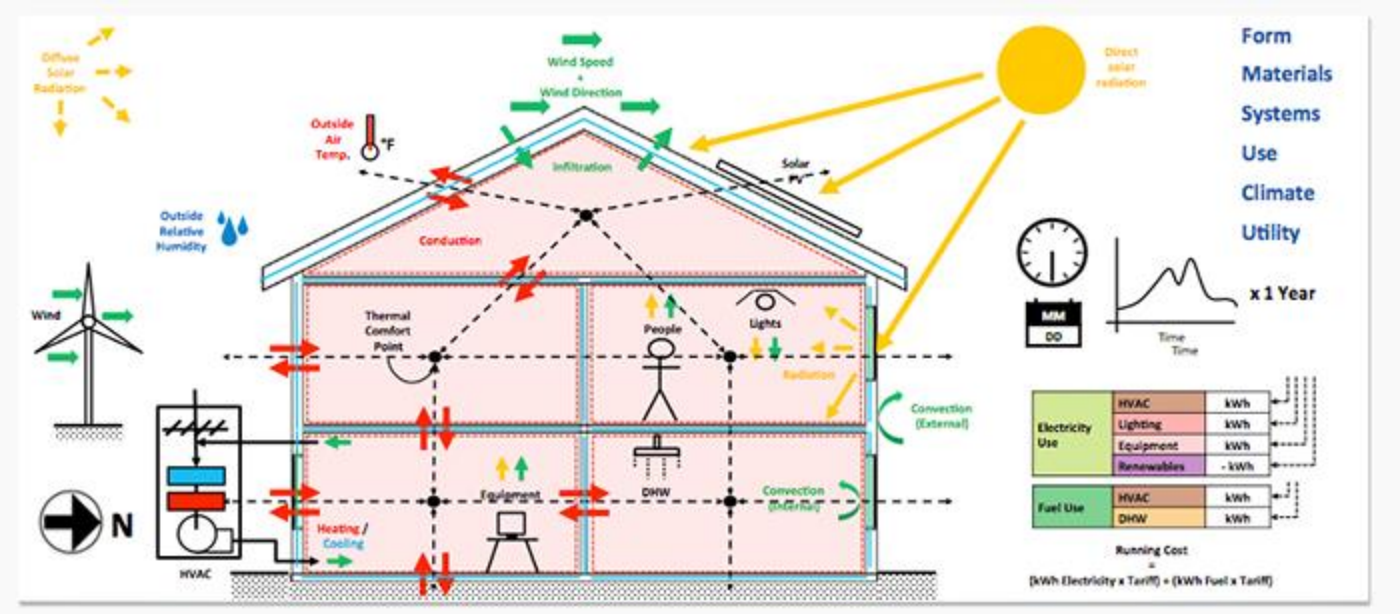
HØGSKOLEN I OSLO
OG AKERSHUS

Climate data for simulating buildings – Can we perfect it?

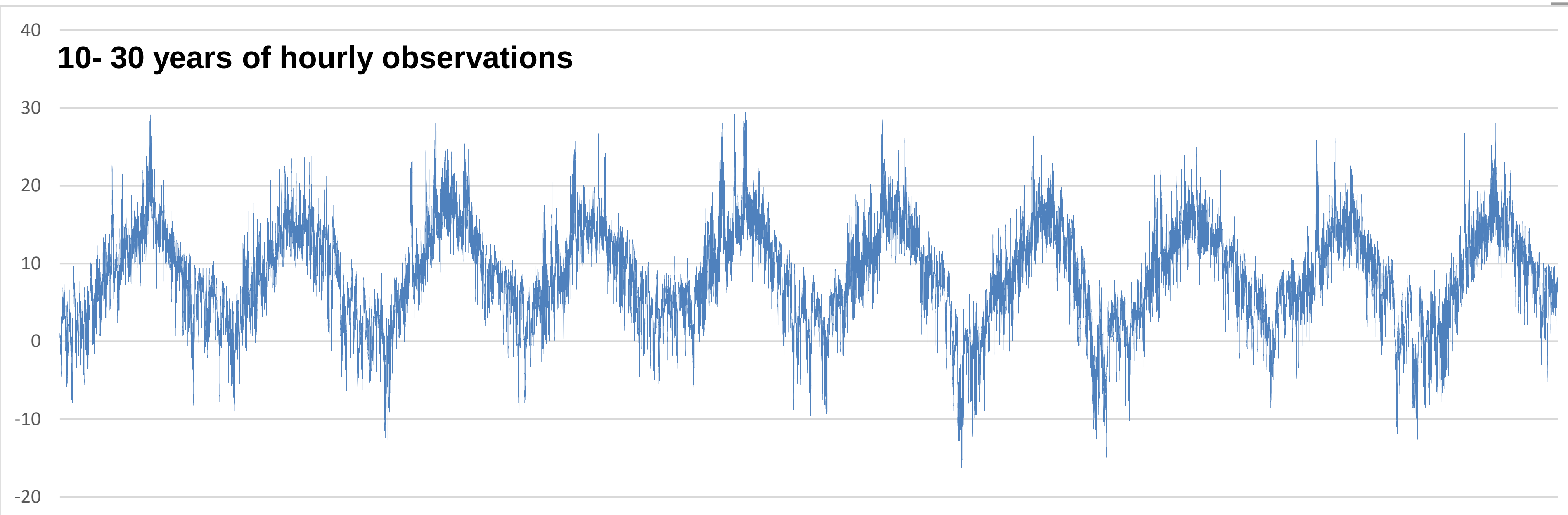


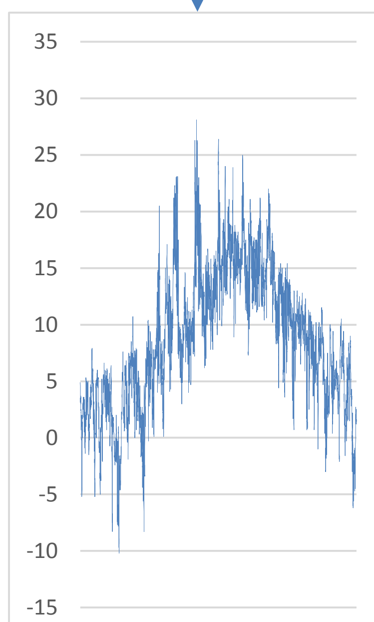
Peter G. Schild
Institutt for bygg- og energiteknikk

Background for the study
Climate data in energy simulation

Meteo parameters (e.g. EPW file format)

- Dry bulb temp.
- Dew point temp.
- %RH
- Pressure
- Horizontal infrared radiation
- Global horizontal solar radiation
- Direct normal solar radiation
- Diffuse horizontal solar radiation
- Global horizontal illuminance
- Direct normal illuminance
- Diffuse horizontal illuminance
- Zenith luminance
- Wind direction
- Wind speed
- Total sky cover
- Opaque sky cover
- Visibility
- Ceiling height
- Precipitable water
- Aerosol optical depth
- Snow depth
- Days since last snowfall
- Albedo
- Liquid precipitation depth
- Liquid precipitation accumulation period





Typical Meteorological Year (TMY)

Requirements for a perfect TMY file

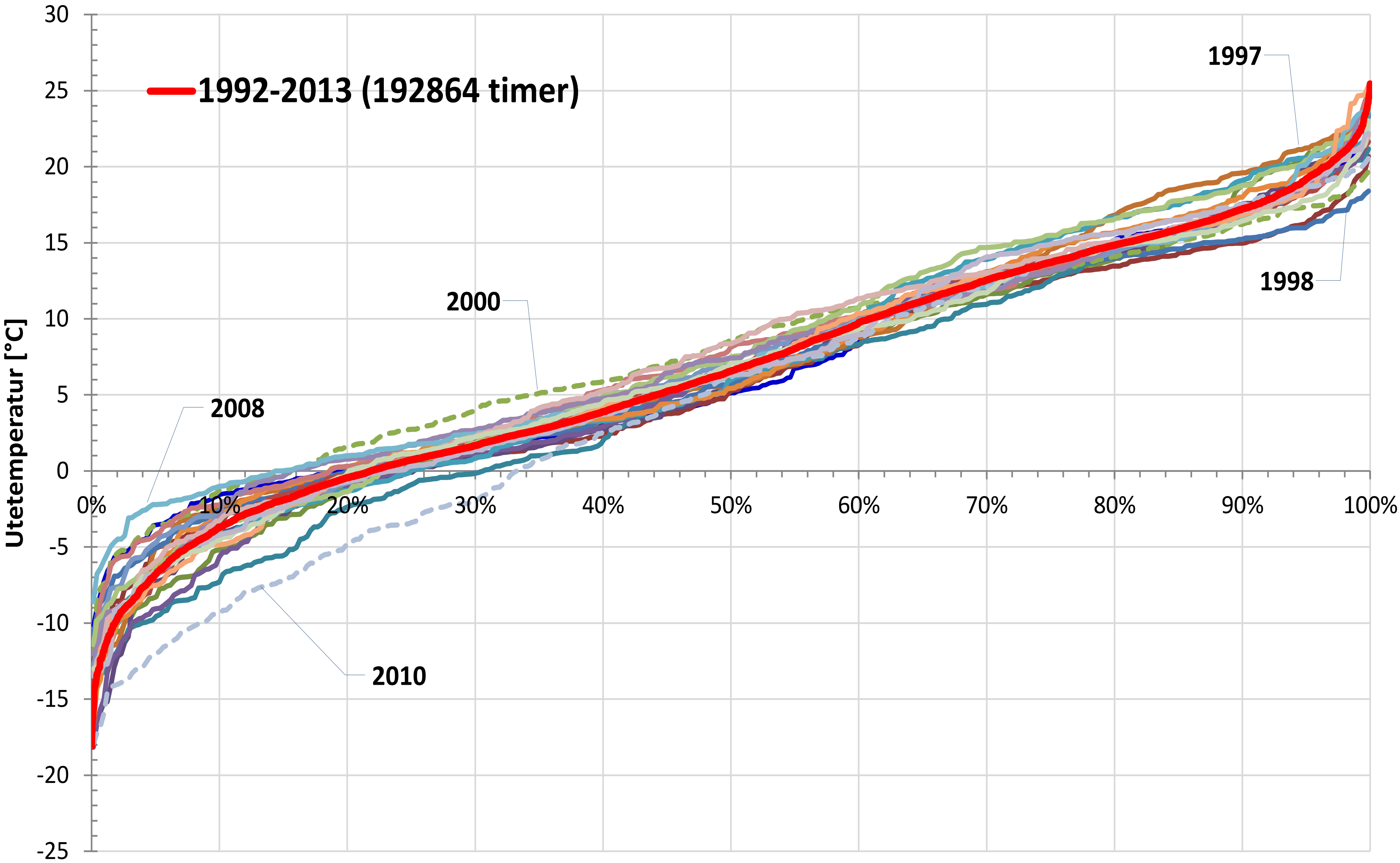
- **Unchanged CDF (cumulative distribution) for individual parameters.**
  This ensures that the peak and mean annual values are unchanged, and also ensures correct calculation of e.g. heat pump performance depending on outdoor temperatures, and the number of hours with indoor thermal comfort exceeds accepted bounds
- **Unchanged autocorrelation (power spectrum) for individual parameters.**
  This ensures that dynamic properties of the building and its systems are properly modelled, e.g. a sufficient number of very warm or cold hours occur together to heat up or cool the building's thermal mass. It also ensures that storage tanks experience realistic changes over time.
- **Unchanged correlations between parameters.**
  E.g. correlation between dry-bulb temperature and solar irradiance, or cloud cover, barometric pressure and precipitation and wind. This ensures that the building's energy balance, which is affected by all these parameters, is calculated with realistic boundary conditions.

Historical development of TMY files

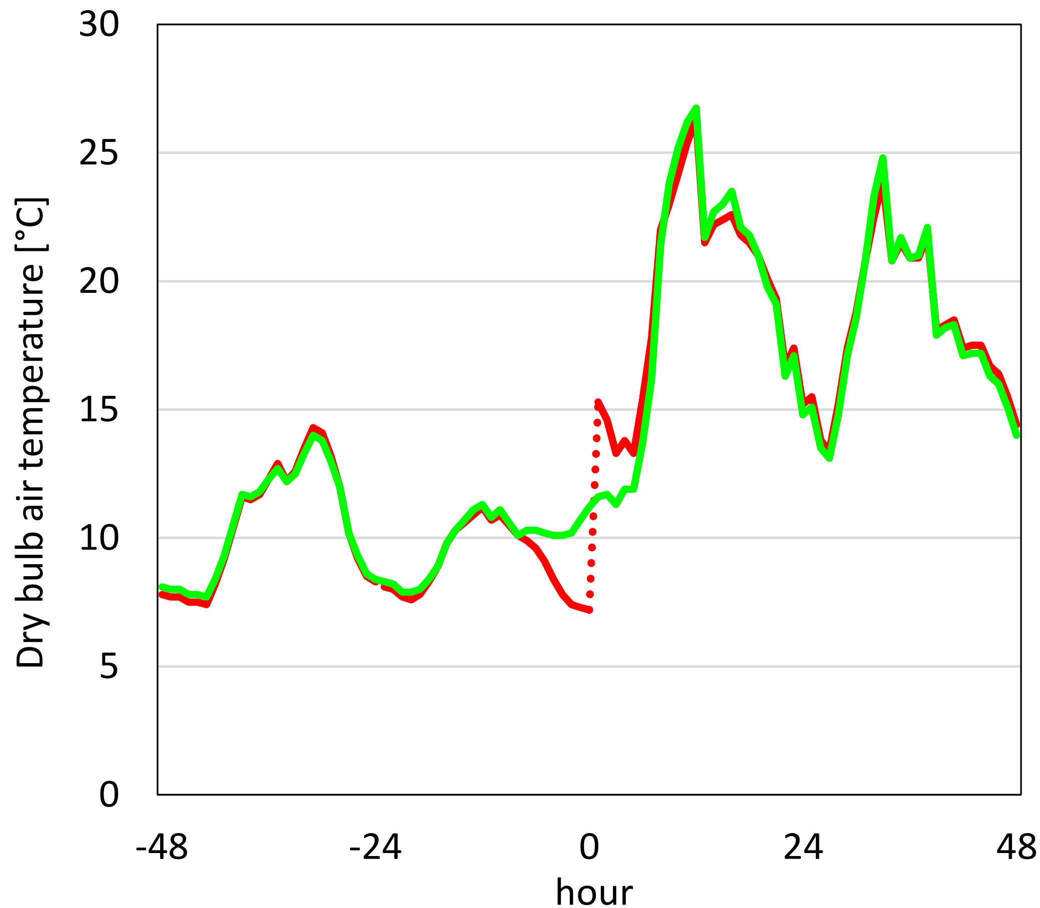
- 1970s: Select a whole year by successively eliminating years with most devaint monthy-mean temperatures
- 1978 on: Combine the 12 most typical months («SANIDA method»), Implemented in EN ISO 15927-4. Months are selected by Finkelstein-Schafer statistic.
- 1994: CDF-fitting used, maybe for the first time [DNMI, Skartveit & Olseth]
- 2011: Introduced differentiated weight factors for each month [Kalamees et al.]
- 2013: Improved method, omit years with Finkelstein-Schafer critical values <1% (not yet implemented in EN ISO 15927-4) [Pernigotto et al.]

Background for the study
Climate data in energy simulation
Problems with EN ISO 15927-4

Varighetskurver for årene 1992-2013
Blindern (data fra met.no)

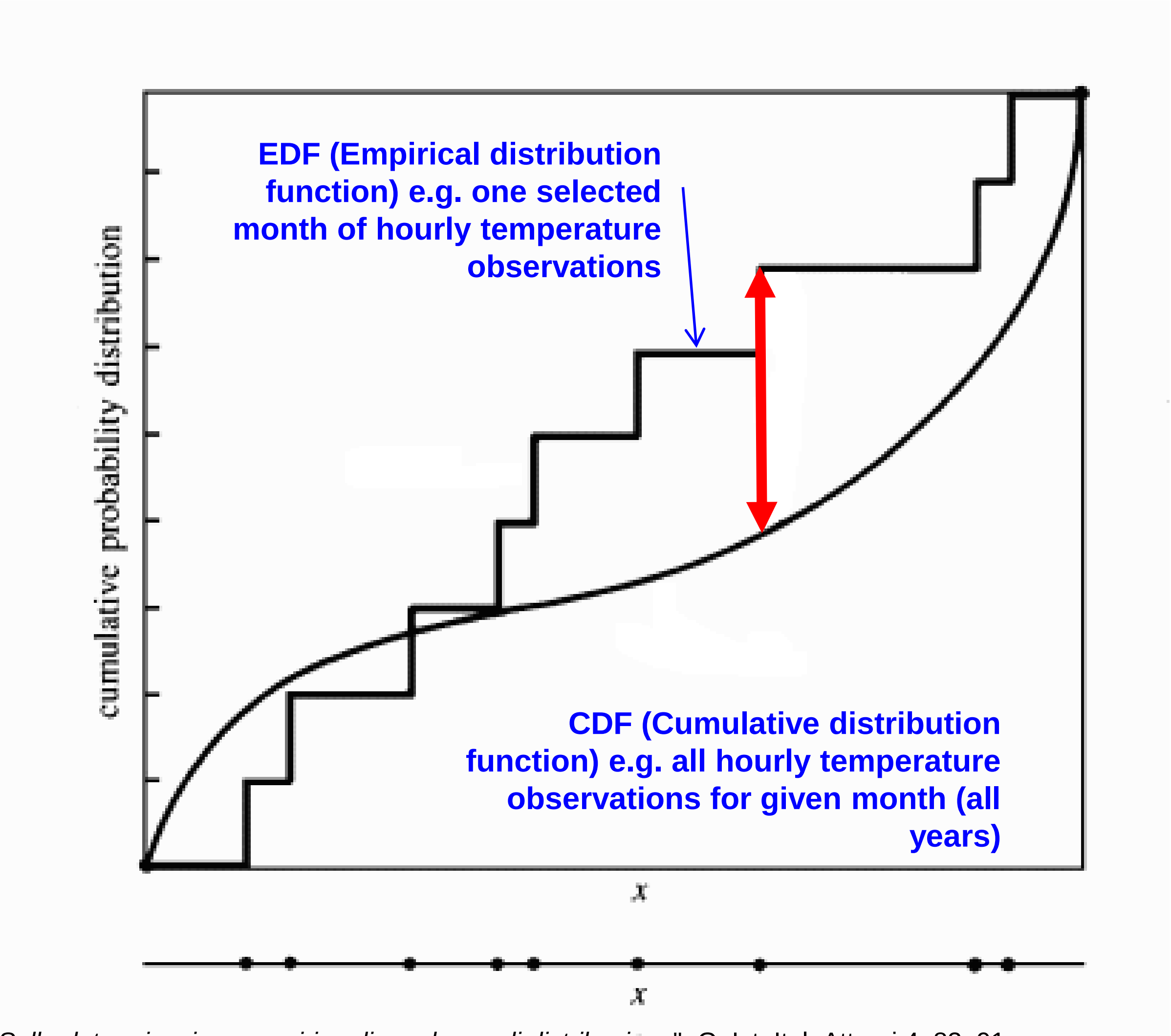


Traditional method – month joint



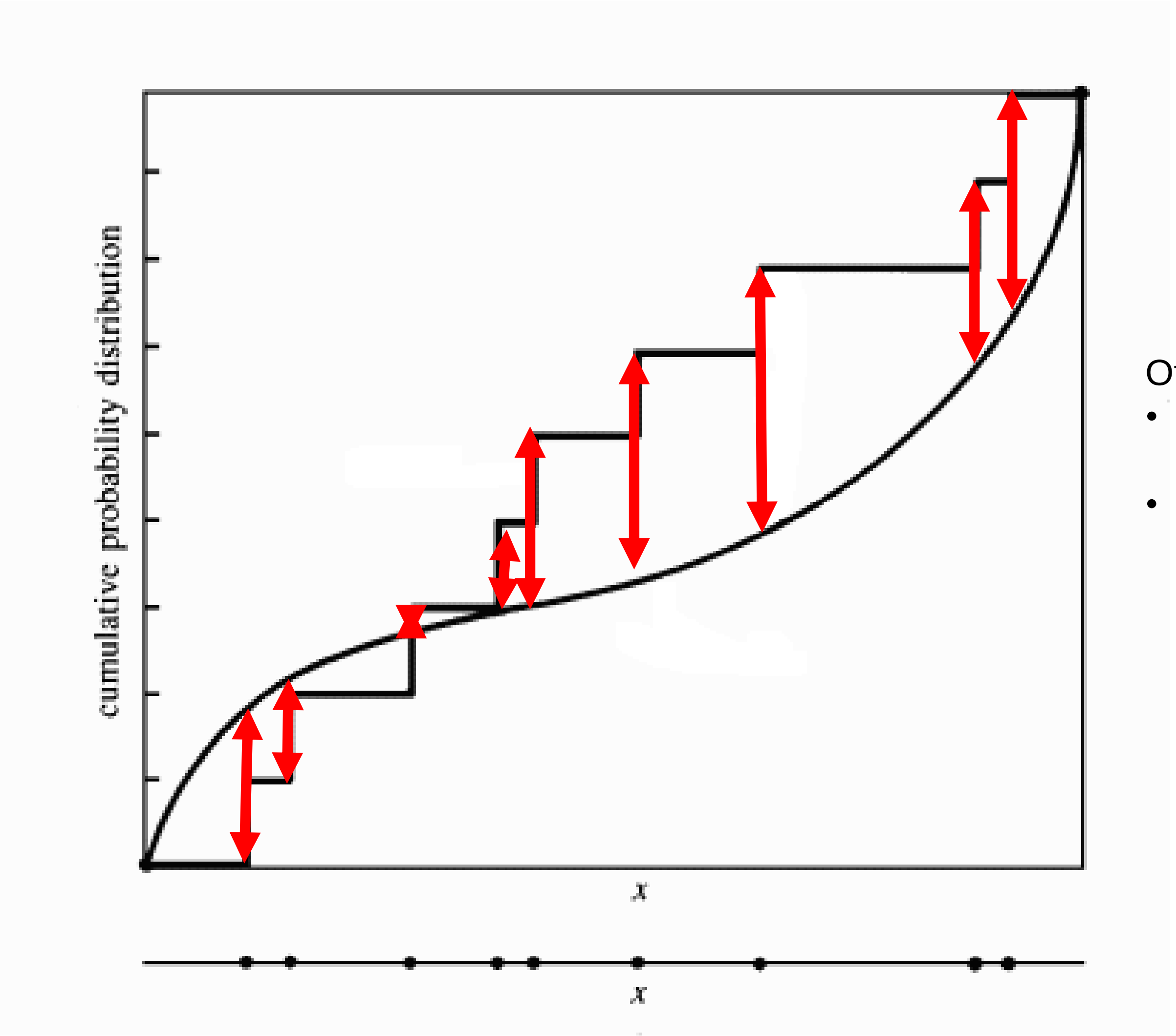
Example of join made by standard Sandia method in summer. Climate data taken from Sola airport, Norway. The join is 31st May 2006 and 1st June 2008. After both smoothing and CDF-fitting (green line) the difference in max-min temperatures is 18.9°C (p=99.9% value from observations is 18.2°C) and difference in day-mean temperatures is 9.1 °C (p=99.9% value from observations is 7.6°C).

Nonparametric* goodness-of-fit tests (* distribution-free)



Kolmogorov A (1933). "*Sulla determinazione empirica di una legge di distribuzione*". G. Ist. Ital. Attuari 4: 83–91.
Smirnov N (1948). "*Table for estimating the goodness of fit of empirical distributions*". Annals of Mathematical Statistics 19: 279–281. doi:10.1214/aoms/11777302

Finkelstein-Schafer goodness-of-fit test

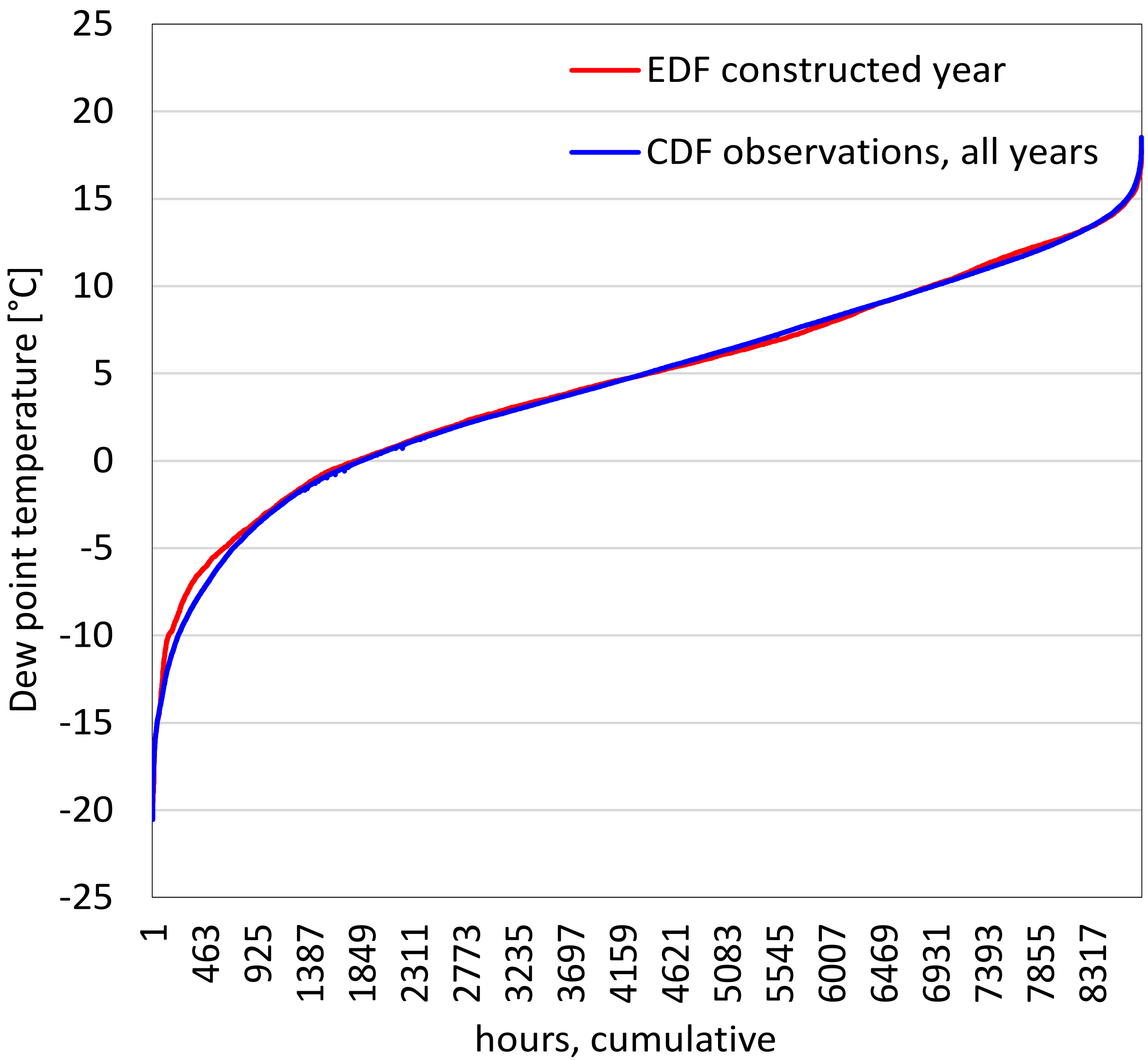


Other GoF tests:

- Cramér–von Mises (1952)
- Anderson–Darling (1954)

J.M. Finkelstein and R.E.Schafer (1971). «*Improved goodness-of-fit tests*», Biometrika, v.58, n.3, p.641

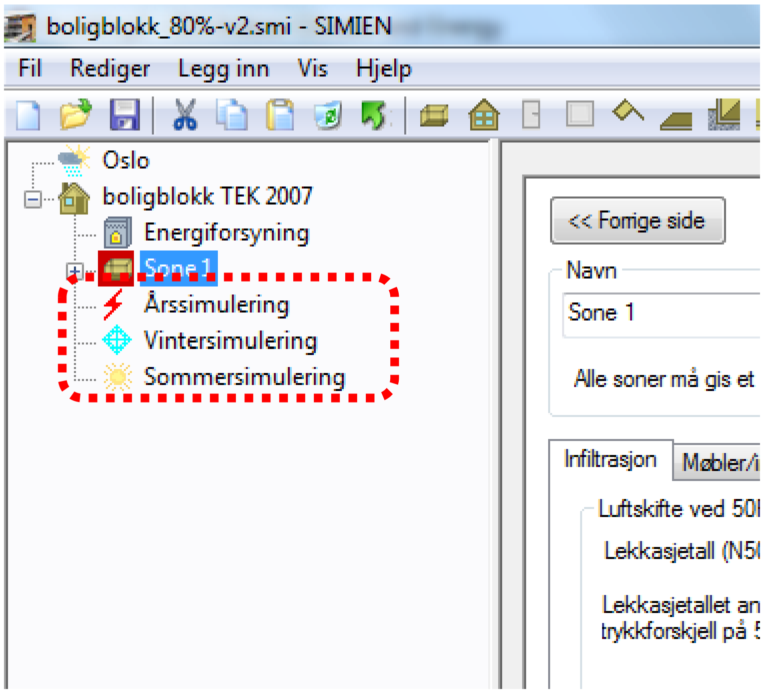
Problemer med FS goodness of fit test



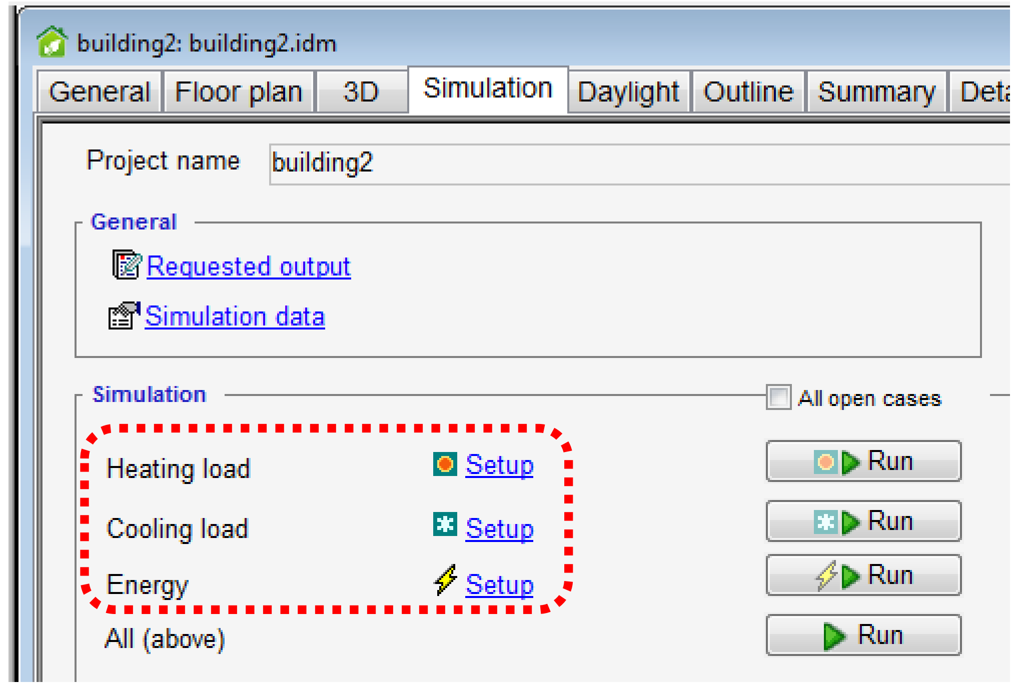
FS-statistic exceeds (by factor 1.03) critical value for a=1%.

Therefore deemed very poor fit according to FS-test !

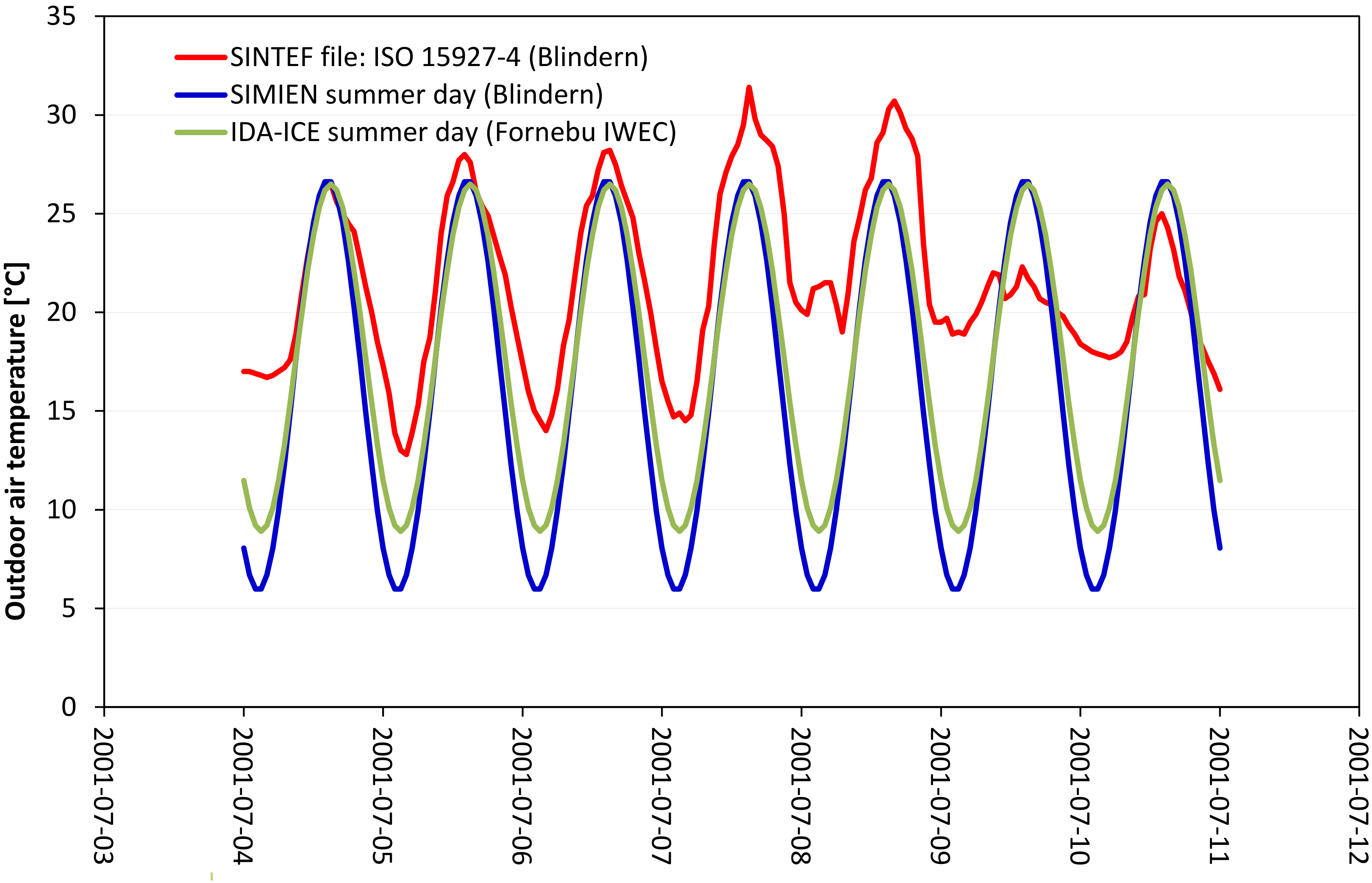
SIMIEN GUI



IDA-ICE GUI



Sammenligning av klimadata i SIMIEN "Sommersimulering" og Byggforsk konstruert år



Background for the study

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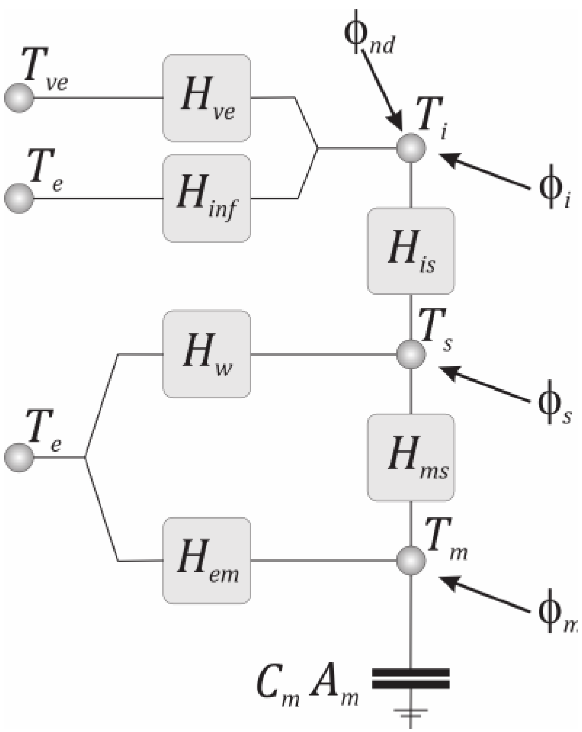
Improvements

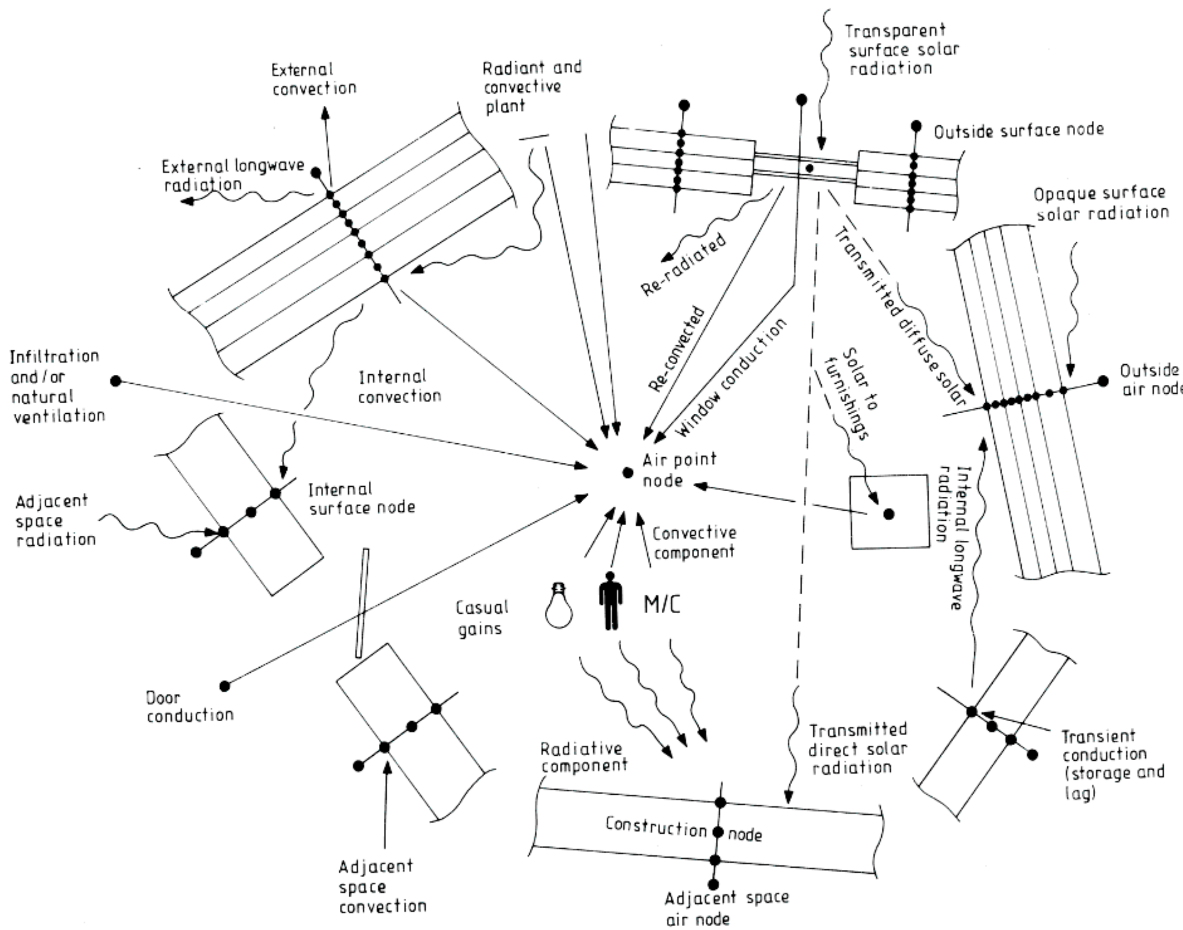
Algorithm basics

- No longer use FS-statistic critical values.
  Distribution specific critical values calculated on the fly using new algorith.
- No longer use FS-statistic weight factors.
  Calcumate RMS for perturbations in integrated energy model instead
- Stochastic method: Trial different year subdivisions (always 12 subdivisions, but different start/end days)
- Force use of periods for peak heating and cooling
- CDF fitting
- Test for temperature jumps between joined periods

Choice of lumped system model

Detaljeringsgrad – Modellering av termisk masse





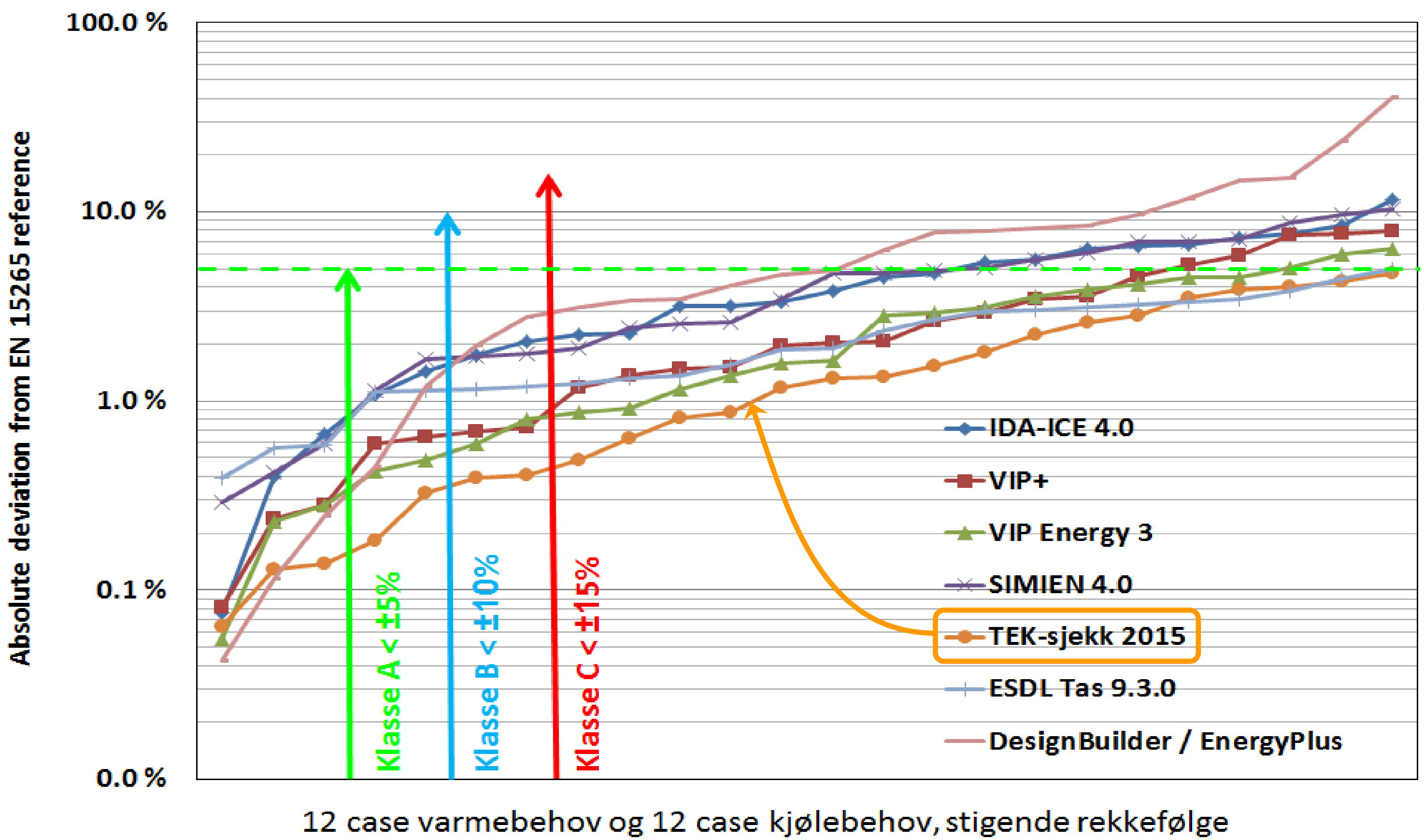
1 masse-node pr sone
"Simple hourly method"
ISO 13790 / TEK-sjekk

→

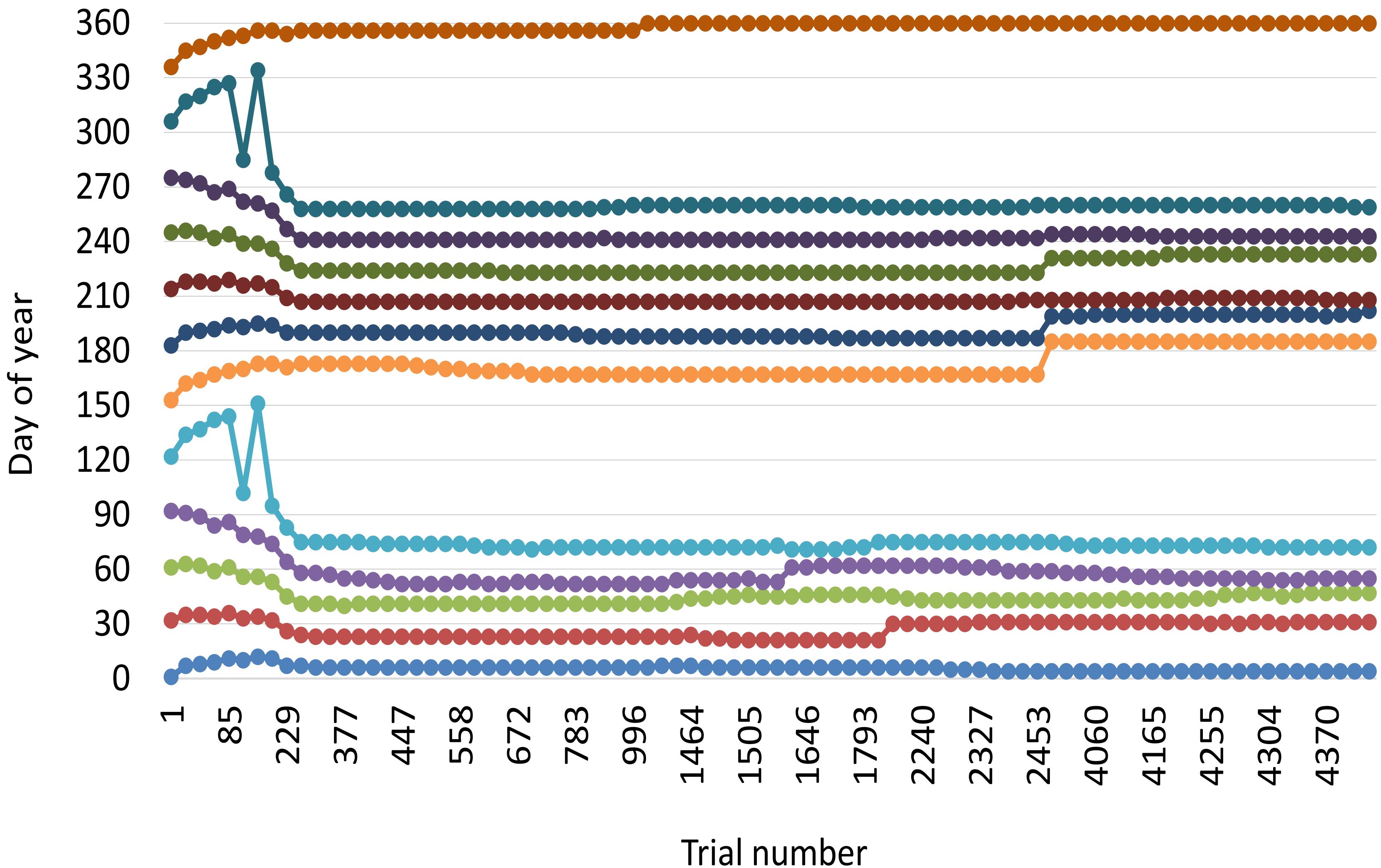
Flere noder pr vegg
"Detailed dynamic"
IDA-ICE

Validation results for energy models (EN 15265)

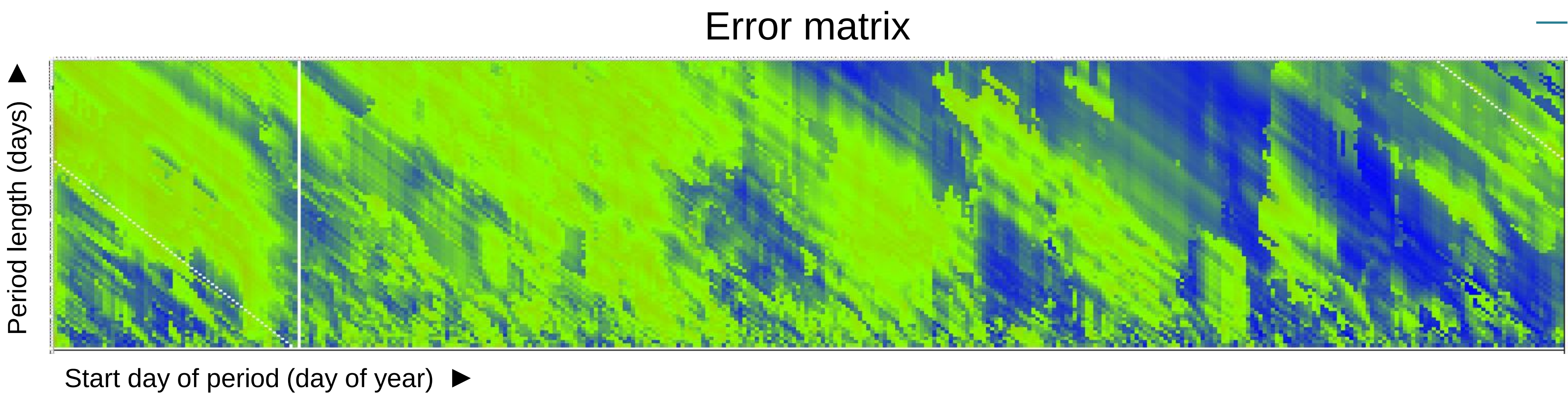
- TEK-sjekk validert til beste klasse (A), dvs. innenfor ±5% avvik på varme eller kjølebehov,
  med gjennomsnittlig 1.2% avvik i gjennomsnitt for test-casene gitt i EN 15265.
- SIMIEN validert til klasse C , dvs. innenfor ±15% , beregner noe høyere oppvarming og kjøling.

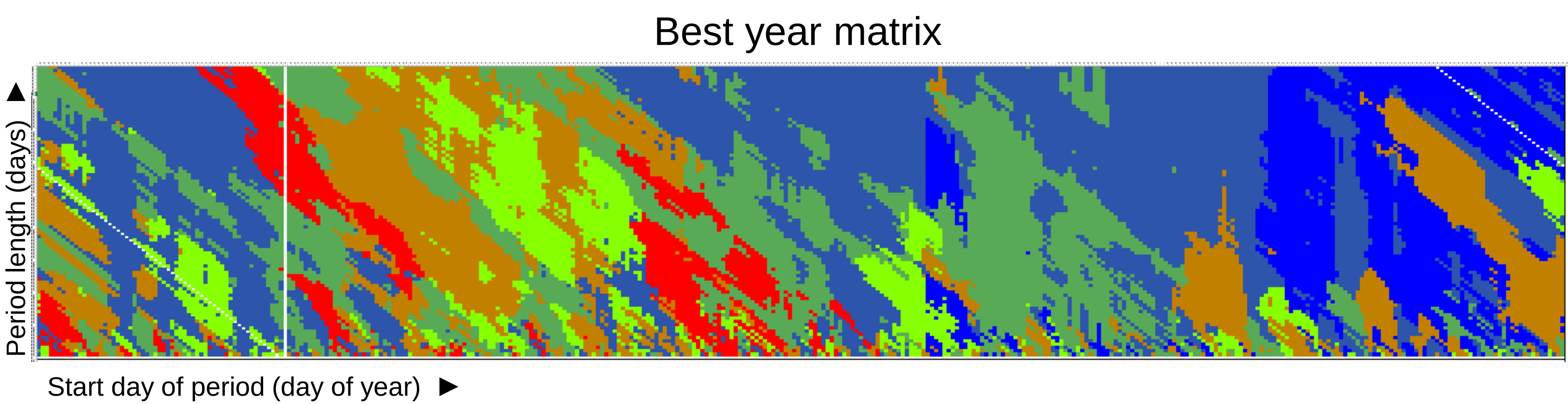


Stochastic search

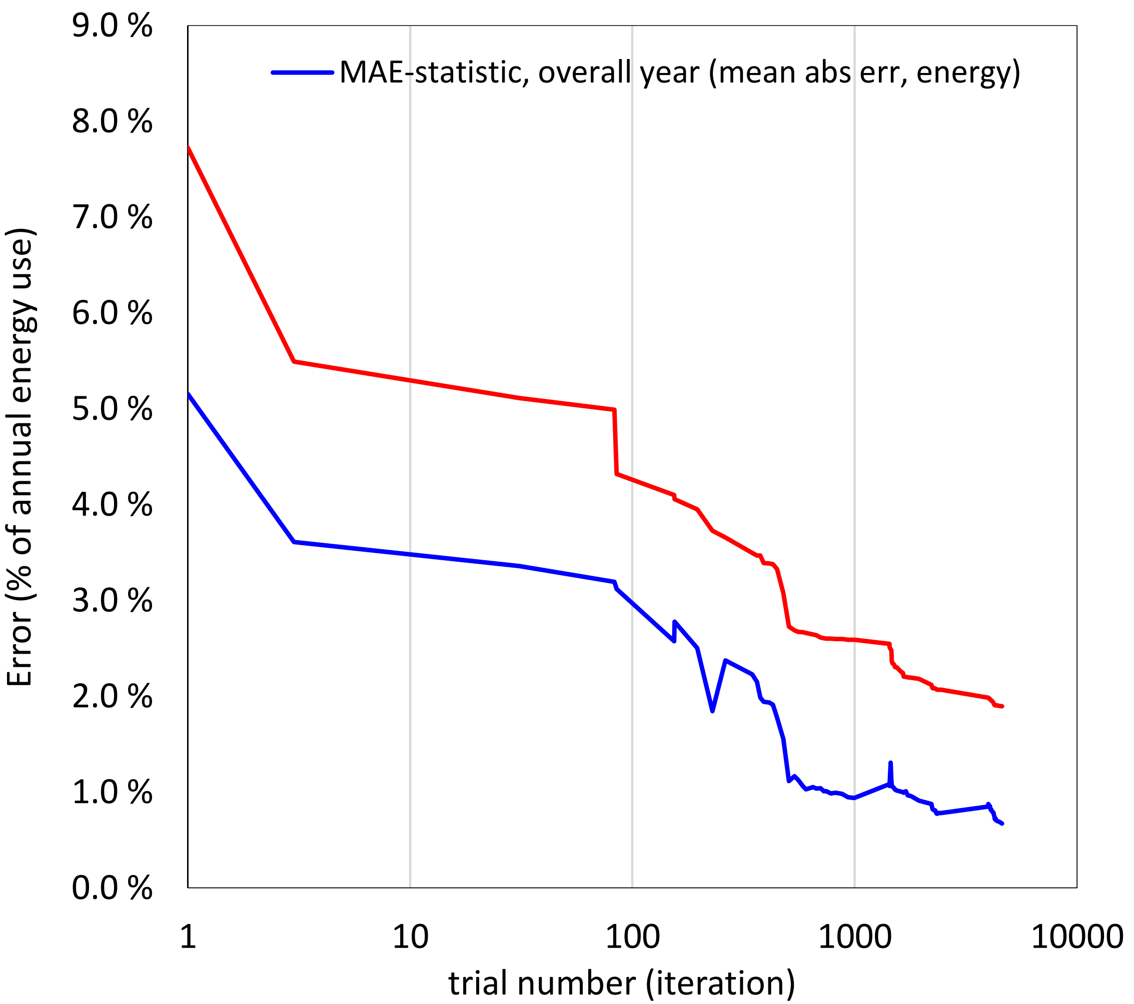


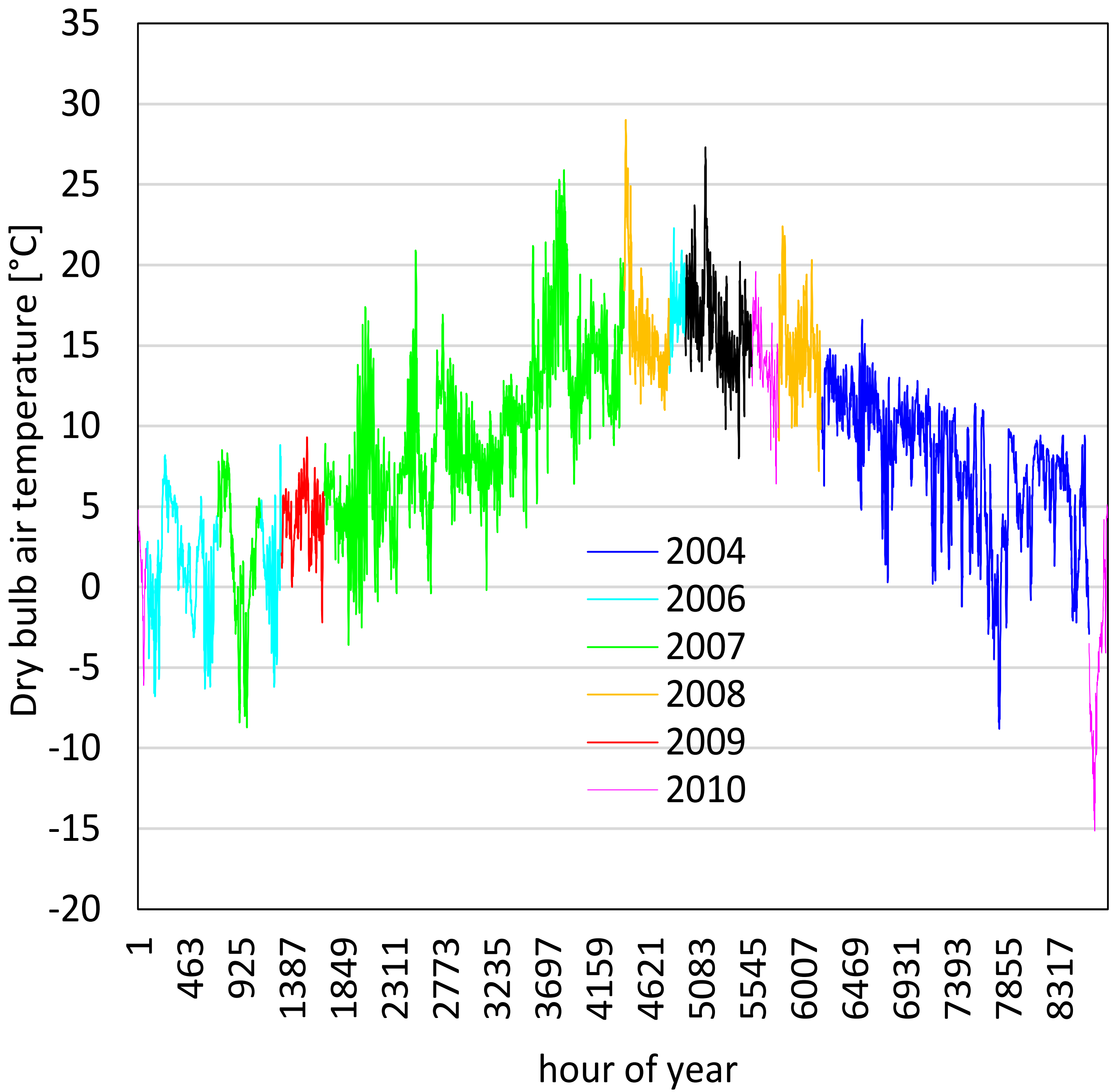
Precalculated matrix of period errors





Stochastic search cont.





35
30
25
20
15
10
5
0
-5
-10
-15
-20
Dry bulb air temperature [°C]
2004
2006
2007
2008
2009
2010
1
463
925
1387
1849
2311
2773
3235
3697
4159
4621
5083
5545
6007
6469
6931
7393
7855
8317
hour of year

Background for the study

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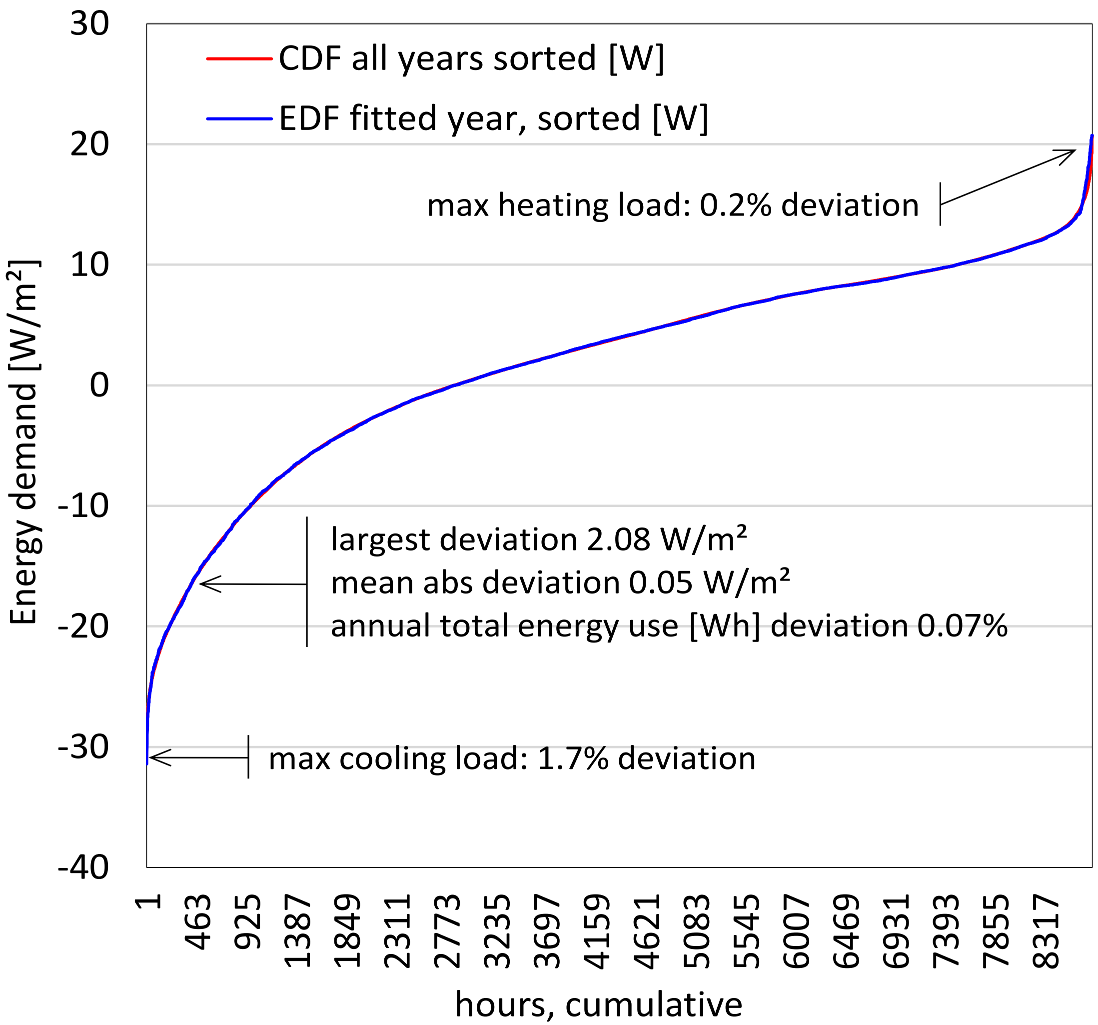
Problems with EN ISO 15927-4

Improvements

Results



CDF all years sorted [W]
EDF fitted year, sorted [W]
max heating load: 0.2% deviation
largest deviation 2.08 W/m²
mean abs deviation 0.05 W/m²
annual total energy use [Wh] deviation 0.07%
max cooling load: 1.7% deviation
Energy demand [W/m²]
30
20
10
0
-10
-20
-30
-40
1
463
925
1387
1849
2311
2773
3235
3697
4159
4621
5083
5545
6007
6469
6931
7393
7855
8317
hours, cumulative

Background for the study

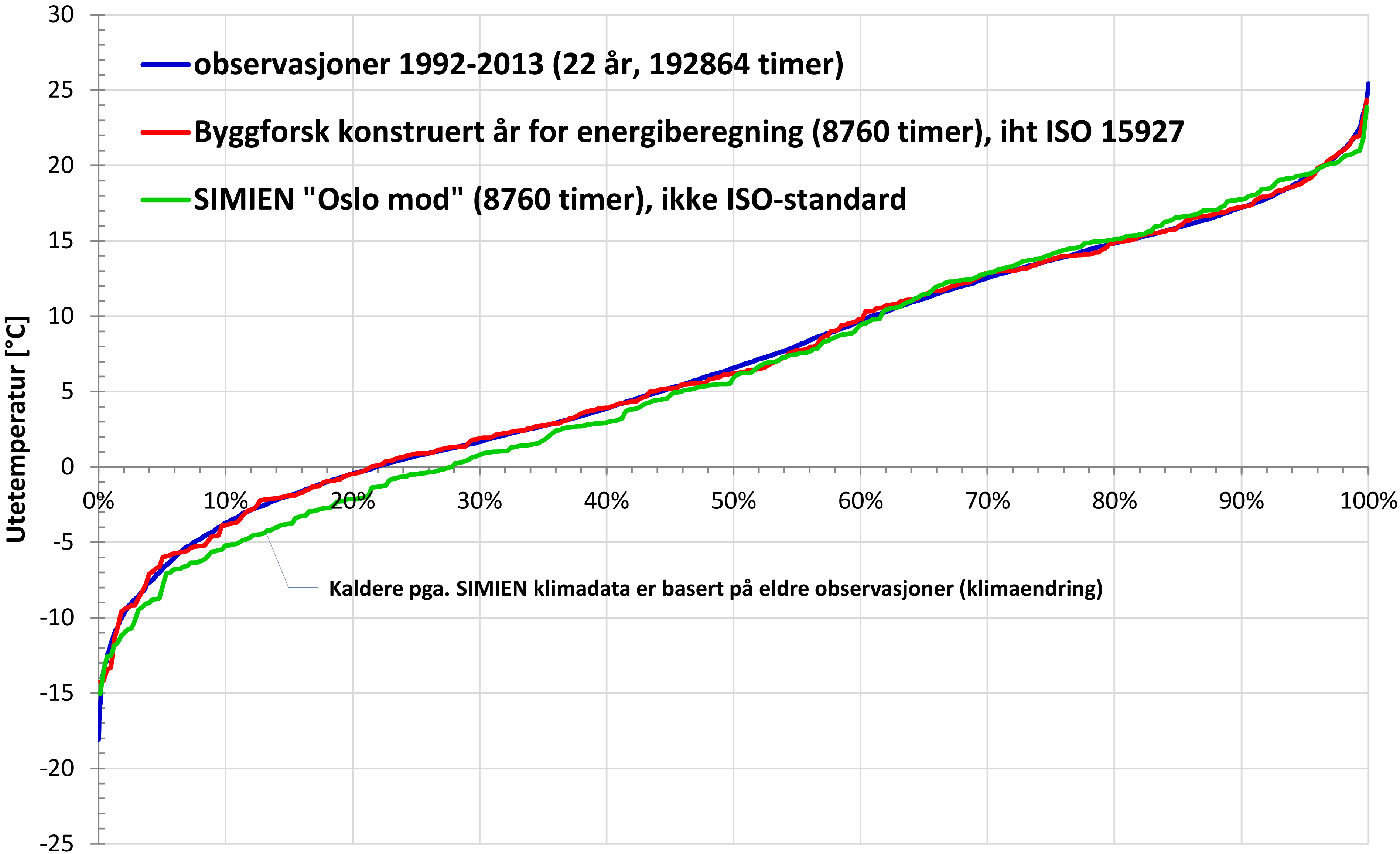
Climate data in energy simulation

Problems with EN ISO 15927-4

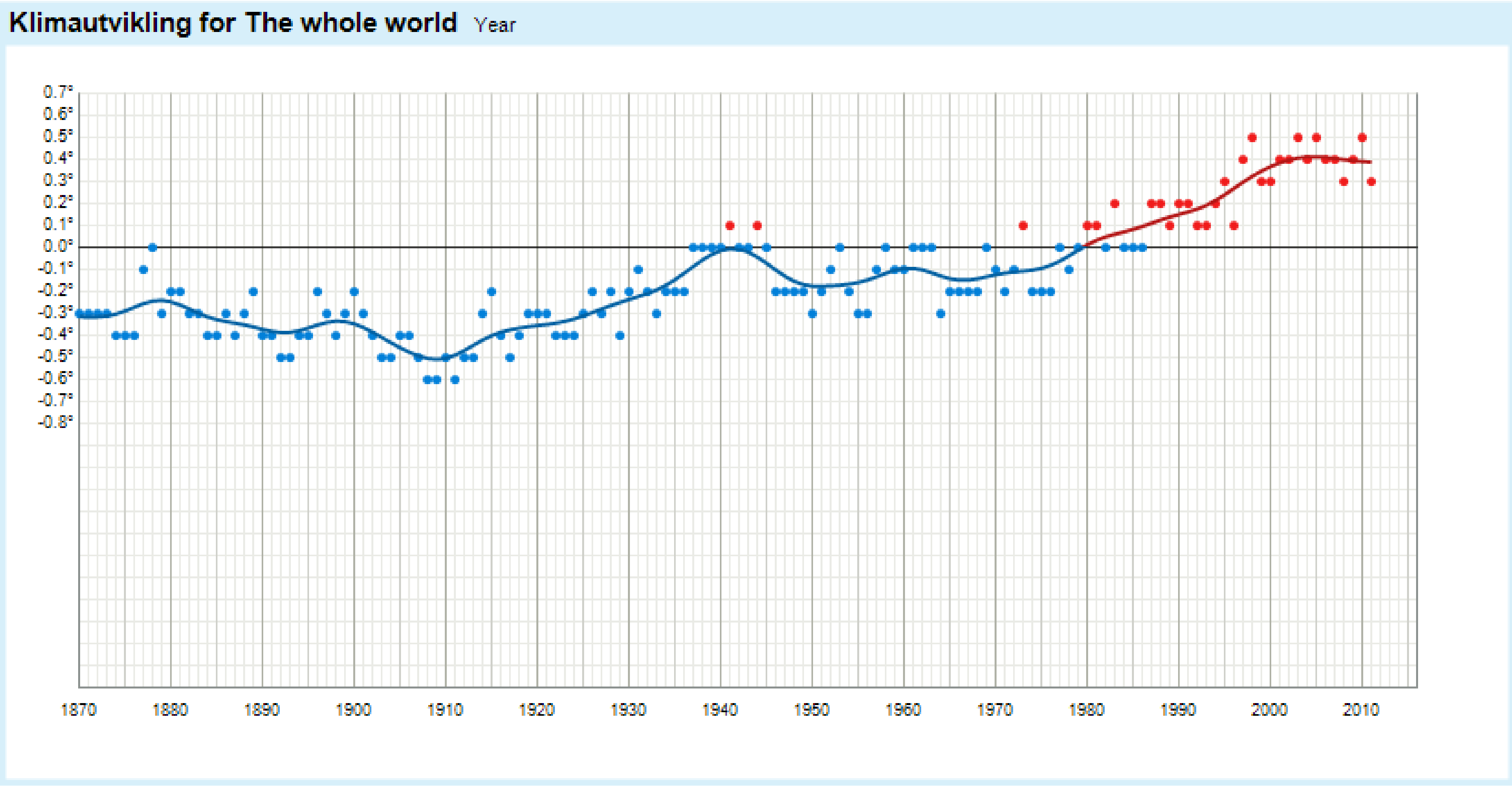
Results

Climate change

Comparison of climate data sources
- day mean temperatures



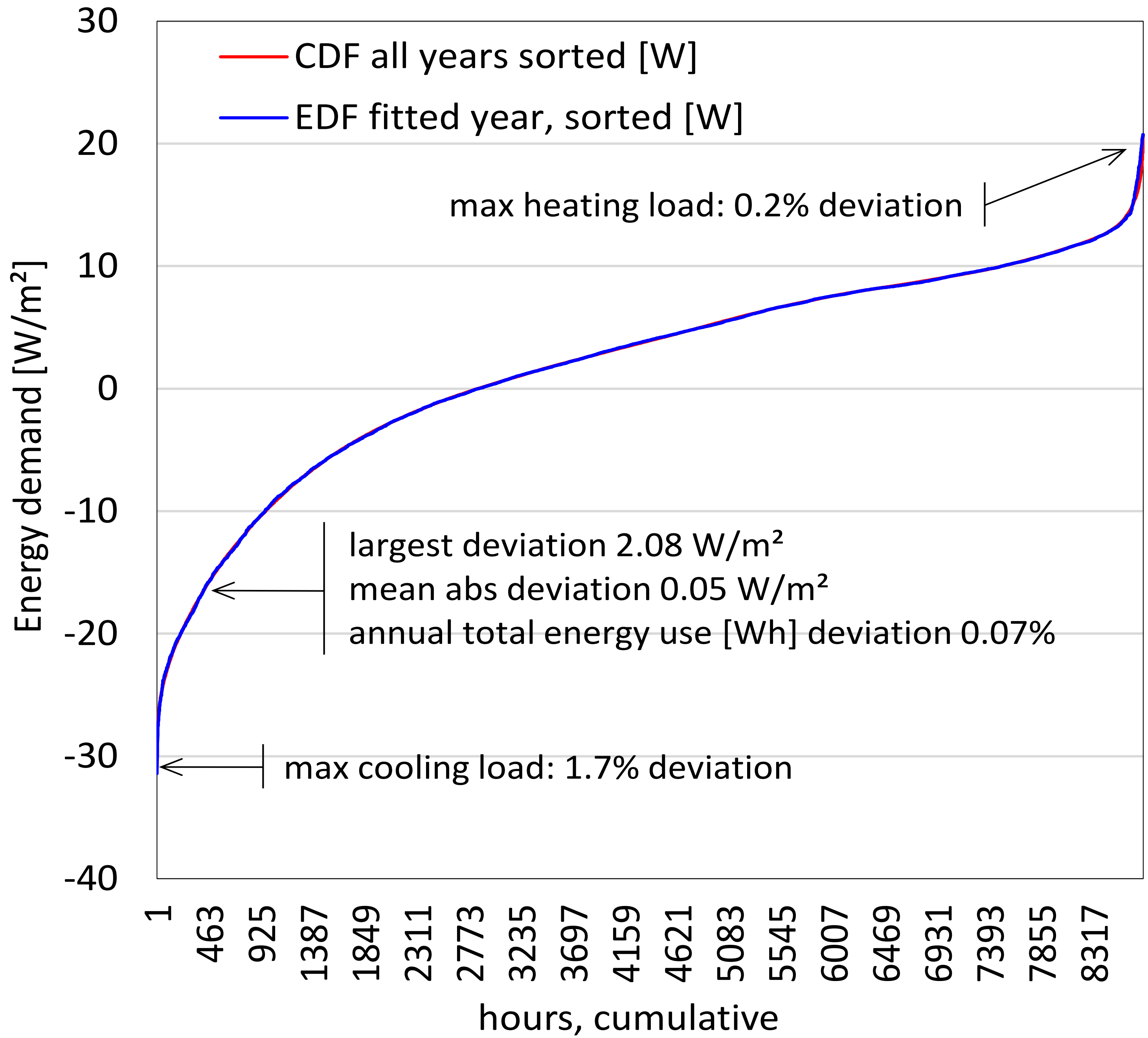
Global temperatur



Conclusion

The new method is a significant improvement upon EN ISO 15927-4, not least for plant-sizing.

It will be used at SINTEF Byggforsk to generate the next edition of Norwegian TMYs in EPW-format.



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Energy demand [W/m²]
hours, cumulative
30
20
10
0
-10
-20
-30
-40
1
463
925
1387
1849
2311
2773
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