Technical Report 13-19

2001–2010 Danish Design Reference Year

- Reference Climate Dataset for Technical Dimensioning in Building, Construction and other Sectors

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Reference Climate Dataset for Technical Dimensioning in Building, Construction and other Sectors

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Yearly average air temperature 2001 - 2010
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Abstract

This report presents the Danish Design Reference Year based on observed data from 2001 – 2010. In various sectors - i.e. building and construction, energy, etc. - the climate and weather usually plays a part in a given project. The Danish Design Reference Year dataset is a collection of data series for eleven specific parameters, that each represents a typical year in Denmark. The uses of the dataset may vary from simulations to statistical analysis, graphical overviews etc.

The Danish land areas have been sectionalized into five to six climatological zones depending on the parameter, each characterized by distinct diurnal and yearly variations. The dataset consists of observed data from one station located within and representing each zone.

The parameters included in the dataset are temperature, relative humidity, wind speed and direction, atmospheric pressure, global radiation, cloud cover, soil temperature, sea temperature, diffuse irradiance and illuminance. The time resolution is hourly except for soil temperature where the resolution is daily values.

In addition to the complete Danish Design Reference Year dataset, a subset specifically selected to be used for energy performance calculations for obtaining a building permit is included.
Preface

This report presents the collective Danish Reference Year dataset, previously published in the two distinct reports in Danish language only:


Both projects were funded by the Danish Energy Agency, and the process involved the following collaborators:

- Danish Energy Agency
- Danish Meteorological Institute
- Danish Building Research Institute, Aalborg University
- Technical University of Denmark

1. Introduction

The Danish Design Reference Year (DRY) was last published in 1995 [3], presenting various climate data from the period 1975 – 1989. It is well known, that the climate of Denmark has since changed, hence the need for an updated reference dataset.

The purpose was – and still is – to produce a dataset from climate data, designed specifically to be used as input data for computer simulations of technical dimensioning i.e. in the energy and construction sector.

As part of this, a new dataset to be used for energy performance calculations for obtaining a building permit [4] is presented. Given the general rule that similar conditions apply for all locations in Denmark, it was decided that one dataset should represent the whole Denmark in this regard. This dataset should best represent most of the population in Denmark, and datasets from the three stations Holbæk Flyveplads, DMI and Sjælsmark were chosen.

In 2012 the project “Solar Resource Assessment in Denmark” [5] resulted in the above mentioned report [1], presenting an updated DRY dataset aimed at the solar energy sector in Denmark, including the parameters global radiation, relative humidity, temperature, wind speed, diffuse irradiance and illuminance. The project was funded by the Danish Energy Agency.

It was since expanded in 2013 with more parameters - still funded by the Danish Energy Agency – and published in a separate report [2], with a supplementary dataset consisting of the parameters wind direction, atmospheric pressure, cloud cover, sea temperature and soil temperature.

The present report presents the collective DRY dataset from the two reports. It is a collection of hourly (for ten parameters) and daily (for one parameter) climate data, spanning one calendar year for all eleven parameters and various locations across the country. It is constructed from monthly data from assorted years during the period 2001 – 2010, resulting in a complete calendar year of data.

Where the previously used DRY dataset consisted of data from two locations in Denmark, the updated dataset presented in this report has been expanded to cover five to six climatological zones in Denmark, each characterized by distinct diurnal and yearly variations. The zones each represent the climatological variations in a given area of Denmark for each of the eleven parameters, making it possible to tune the derived calculations depending on location.

The present report contains the following information on the DRY dataset:

- station metadata
- maps with zonal sections and station positions
- time series plots
- tables with simple statistical information
- attached .csv files with the hourly (daily) dataset
2. Data
The dataset consists of observations from the DMI station network, and has undergone a series of calculations and quality control procedures to meet specific requirements for the DRY dataset.

Parameters
The dataset include one year of hourly data for the following parameters:

- temperature (°C)
- relative humidity (%)
- wind speed (m/s)
- wind direction (°)\(^1\)
- atmospheric pressure (hPa)
- global radiation (W/m\(^2\))
- cloud cover (%)
- sea temperature (°C)
- diffuse irradiance (W/m\(^2\))
- illuminance (lux)

and one year of daily data for:

- soil temperature (°C)

Since diurnal variations in soil temperature in 1m depth are negligible, only daily mean values are included in the dataset for this parameter.

Interpolated values
Missing and/or erroneous values have been replaced with interpolated values from the nearest stations, which ensure complete time series. Interpolated values are clearly flagged, see section 18.

The reference year
As described above, the dataset contains one year of hourly or daily data. The dataset is not measured continuously throughout a specific year; rather it is constructed from monthly data from different years. Each month has been selected with the climatological premises in mind, that it should exhibit typical climatological variation. This means no extremes, yet some variation is indeed tolerated.

The reference year is constructed from twelve typical months during 2001 – 2010 and is shown below.

<table>
<thead>
<tr>
<th>month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
</table>

Zones
In the same way that the reference year must represent a typical climatological year, each parameter must also exhibit typical climatological variations across the country. Consequently, Denmark has been sectionalized into five to six climatological zones depending on the parameter, each characterized by distinct diurnal and yearly variations, i.e. coastal areas might have very different diurnal variation than inland areas in spite of similar monthly averages.

The dataset consists of observed data from one station located within and representing each zone. When choosing a station to represent each zone, two main criteria needed to be fulfilled: firstly the location of the station should best represent the climatology in the zone and secondly the regularity of the observations should be as high as possible.

\(^1\) 0° is quiet, 360° is wind from north, 90° is wind from east etc.
3. How to use the dataset

Using the dataset for a given location, one needs to determine – for each parameter – in which zone the location is situated. This can be done by inspecting the maps for each parameter in the following sections. When the zones are determined, the corresponding stations can be looked up in the station tables.

As an example, assume a building project in Hillerød needs to assess the corresponding datasets for temperature, wind speed, atmospheric pressure and global radiation for that specific location:

Looking through the maps and tables in the following sections, the zones and stations can be presented:

<table>
<thead>
<tr>
<th>parameter</th>
<th>zone</th>
<th>station name</th>
<th>station no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>5</td>
<td>Holbæk Flyveplads</td>
<td>6156</td>
</tr>
<tr>
<td>wind speed</td>
<td>4</td>
<td>Holbæk Flyveplads</td>
<td>6156</td>
</tr>
<tr>
<td>atmospheric pressure</td>
<td>4</td>
<td>Holbæk Flyveplads</td>
<td>6156</td>
</tr>
<tr>
<td>global radiation</td>
<td>5</td>
<td>Sjælsmark</td>
<td>6188</td>
</tr>
</tbody>
</table>

After downloading the dataset, the data series can easily be assessed in the files:

- DRY_temperature_hourly_6156.csv
- DRY_wind_speed_hourly_6156.csv
- DRY_pressure_hourly_6156.csv
- DRY_global_radiation_hourly_6188.csv
4. Temperature

Data
The temperature dataset consists of hourly mean values from six stations.

Stations and zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>Station name</th>
<th>Station no.</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Esbjerg Lufthavn</td>
<td>6080</td>
<td>55.528065</td>
<td>8.563086</td>
<td>Westcoast of Jutland</td>
</tr>
<tr>
<td>2</td>
<td>Flyvestation Karup</td>
<td>6060</td>
<td>56.293420</td>
<td>9.113890</td>
<td>Inland parts of Jutland</td>
</tr>
<tr>
<td>3</td>
<td>Horsens/Bygholm</td>
<td>6102</td>
<td>55.868000</td>
<td>9.786903</td>
<td>Eastcoast of Jutland</td>
</tr>
<tr>
<td>4</td>
<td>Tystofte</td>
<td>6136</td>
<td>55.246502</td>
<td>11.328447</td>
<td>Coastal parts of Sealand and Funen plus Lolland-Falster, Langeland and Møn</td>
</tr>
<tr>
<td>5</td>
<td>Holbæk Flyveplads</td>
<td>6156</td>
<td>55.735783</td>
<td>11.603472</td>
<td>Central parts of Funen and Sealand</td>
</tr>
<tr>
<td>6</td>
<td>Nexø Vest</td>
<td>6197</td>
<td>55.055748</td>
<td>15.095350</td>
<td>Bornholm</td>
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</table>

![Temperature map](image.png)

Ver.: 20130603 1331

Yearly average 2001-2010 (°C)
Time series

Statistics

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<th>mean</th>
<th>max</th>
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<td>13.9</td>
<td>25.3</td>
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</tr>
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</table>
5. Relative humidity

Data

The relative humidity dataset consists of hourly mean values from six stations.

Stations and zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>Station name</th>
<th>Station no.</th>
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<td>Bornholm</td>
</tr>
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</table>

Relative humidity

Yearly average 2001-2010 (%)
Time series

Relative humidity [%]

Station 6060

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<tr>
<th>Station</th>
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<th>Apr</th>
<th>May</th>
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Station 6136

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Station 6156

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Station 6197

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Statistics
7. Wind speed

Data
The wind speed dataset consists of hourly mean values from five stations.

Stations and zones

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Wind speed

Yearly average 2001-2010 (m/s)

Ver.: 20130603 1331
## Time series

![Wind speed (m/s)](image)

### Statistics

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8. Wind direction

Data

The wind direction\(^2\) dataset consists of hourly mean values from five stations.

Stations and zones

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<th>Station no.</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
<th>Area</th>
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<td>8.214873</td>
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<td>55.055748</td>
<td>15.095350</td>
<td>Bornholm</td>
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\(^2\) 0° is quiet, 360° is wind from north, 90° is wind from east etc.
9. Atmospheric pressure

Data

The atmospheric pressure dataset consists of hourly mean values from six stations.

Stations and zones

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Atmospheric pressure

Yearly average 2001-2010 (hPa)

Ver.: 20130531.0904
Time series

Atmospheric pressure [hPa]

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10. Global radiation

Data
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Stations and zones

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Global radiation

Yearly sum 2001-2010 (MJ)
Time series

Global radiation [W/m²]

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11. Cloud cover

Data
The cloud cover dataset consists of hourly mean values from six stations.

Stations and zones

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Cloud cover
Time series

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21/34
12. Soil temperature

Data

The soil temperature dataset consists of modelled daily mean values from six stations.

Model

Since soil temperature in 1m depth changes slowly, the soil temperature is modelled as daily values. The temperature is modelled from measurements of soil temperature in 30 cm depth.

The climatological zones are identical to those of air temperature.

The model is chosen by the Danish Building Research Institute and is described in *Varmetab fra fjernvarmeledninger*, by B. Kvisgaard og S. Hadvig, 1980 [6] by the formulas:

\[ T_D = T_{mean} + (T_{30f} - T_{mean}) \cdot e^{(-D\sqrt{\pi/(\alpha\tau))}} \]

where

\[ T_{30f} = T_{30cm} \text{ at time } \tau - D\sqrt{\tau_0/(4\alpha\tau)} \]

and

- \( T_D \) soil temperature in 1m depth\(^3\)
- \( T_{mean} \) yearly mean temperature in 30 cm depth
- \( T_{30cm} \) temperature in 30 cm depth
- \( D \) depth
- \( \tau \) time in seconds after Jan. 1. 00:00
- \( \tau_0 \) period in seconds (\( \sim 3,15 \cdot 10^7 \text{s} \))
- \( \alpha \) soil temperature conductivity \((8,0 \cdot 10^{-7} \text{m/s})\)

\(^3\) Since the soil temperature in 30 cm depth is input to the model, a depth of 70 cm has been used.
## Stations and zones

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### Soil temperature

- Zone 1: Silstrup
- Zone 2: Års Syd
- Zone 3: Horsens/Bygholm
- Zone 4: Tystofte
- Zone 5: Holbæk Flyveplads
- Zone 6: Nexø Vest

**Map:** Ver.: 20130603 1331
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### Soil Temperature (°C)

- **Jan**: 3.0, 2.6, 2.8, 3.0, 3.2, 3.0
- **Feb**: 3.1, 2.4, 2.4, 3.1, 3.5, 3.2
- **Mar**: 2.3, 2.9, 2.4, 2.9, 2.8, 2.3
- **Apr**: 2.3, 4.3, 4.4, 4.4, 4.4, 4.7
- **May**: 6.8, 10.3, 8.4, 11.6, 11.6, 11.6
- **Jun**: 10.3, 12.0, 10.9, 15.0, 15.0, 15.0
- **Jul**: 12.4, 16.2, 14.5, 14.8, 14.8, 14.8
- **Sep**: 13.5, 15.9, 10.7, 14.3, 14.3, 14.3
- **Oct**: 10.8, 11.5, 6.3, 11.7, 11.7, 11.7
- **Nov**: 6.6, 13.3, 4.7, 9.0, 9.0, 9.0
- **Dec**: 4.9, 10.5, 2.0, 6.0, 6.0, 6.0

### Time Series

- **Station 6197**: Time series for soil temperature from Jan to Dec.
- **Station 6166**: Time series for soil temperature from Jan to Dec.
- **Station 6136**: Time series for soil temperature from Jan to Dec.
- **Station 6156**: Time series for soil temperature from Jan to Dec.
- **Station 6197**: Time series for soil temperature from Jan to Dec.
13. Sea temperature

Since the dataset for sea temperature is measured in harbour basins, there are no zonal sections. The dataset from the harbour basins does not represent climatological variations in sea temperature, rather it describes the temperature variations within each basin.

Data

The sea temperature dataset consist of hourly mean values from six harbour basins.

Stations

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14. Diffuse irradiance

Diffuse horizontal irradiance is composed of the indirect radiation part of the global radiation, i.e. the radiation that is backscattered from the atmosphere, clouds etc.

The Technical University of Denmark has developed the method used to model the diffuse irradiance from the global radiation, see [7].

Data

The diffuse irradiance dataset consists of hourly mean values from six stations.

Stations and zones

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Diffuse irradiance

![Map of Denmark with stations and zones indicated]
Time series

![Diffuse irradiance (W/m²) for stations from January to December]

Statistics

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15. **Illuminance**

Modelled values of solar illuminance are presented below. The correlation between illuminance and global radiation is a function of the water content of clouds. The values have been calculated by The Danish Meteorological Institute [1, 8].

**Data**

The illuminance radiation dataset consists of hourly mean values from six stations.

**Stations and zones**

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<th>Zone</th>
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<th>Station no.</th>
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![Illuminance map](image)
Time series

Statistics

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</tbody>
</table>
16. Data for Building Permit Calculations
A dataset to be used for energy performance calculations for obtaining a building permit [4] is included.

Given the general rule that similar conditions apply for all locations in Denmark, it was decided that one dataset should represent the whole Denmark in this regard. This dataset should best represent most of the population in Denmark, and datasets from the three stations Holbæk Flyveplads, DMI and Sjælsmark were chosen.

This specific dataset is a subset of the DRY dataset, and thereby does not introduce any new data.

Data
The dataset consists of hourly mean values for the parameters temperature, relative humidity, wind speed and direction, atmospheric pressure, global radiation, cloud cover, diffuse irradiance and illuminance and daily values of soil temperature.

Stations

<table>
<thead>
<tr>
<th>Station name</th>
<th>Station no.</th>
<th>Latitude (°)</th>
<th>Longitude (°)</th>
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<td>11,603472</td>
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<tr>
<td>DMI</td>
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<td>12,562150</td>
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<td>Sjælsmark</td>
<td>6188</td>
<td>55,876457</td>
<td>12,412090</td>
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</tbody>
</table>
17. Quality Control

The quality control has been performed on all data in the dataset. The general method is described below, followed by a description of special cases of quality control for cloud cover and sea temperature.

**General method**

The dataset has been scrutinized on two levels:

1. A spatial control for daily, monthly and yearly data, performed by a contour mapping of Danish land area

2. A visual control of the time series from each station

Erroneous values have been replaced by interpolated values from nearby stations, to make sure the dataset is complete.

**Special cases**

In addition to the general quality control, some special cases of quality control had to be performed for cloud cover and sea temperature, as described below.

**Cloud cover**

In the cloud cover dataset, some values were missing, and the following values have been replaced:

<table>
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<tr>
<th>station no.</th>
<th>station name</th>
<th>period</th>
<th>replaced with values from</th>
</tr>
</thead>
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<td>6049 Hald vest</td>
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<td>6184 DMI</td>
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</table>

For station 6193 Hammer Odde Fyr all data in the months January 2009, February 2009 and November 2010 have been replaced with values from January 2008, February 2008 and November 2009 respectively.

**Sea temperature**

For station 30336 Københavns Havn all data in November 2010 have been replaced with values from November 2008.
18. Format

The collective dataset attached to this report consists of two zip-files.

a. The DRY dataset (TR13-19_DRY.zip)
   b. The building permit dataset (TR13-19_building_permit.zip)

a. The DRY Dataset

The DRY dataset is attached as a zip-file containing a csv-file for each station and parameter in the format:

**DRY_<parameter>_hourly_<statid>.csv**

- Hourly values for <parameter> and <station number>
- format:
  - Station number
  - Timestamp in UTC\(^4\) format yyyymmddhh
  - Value
  - Quality index (1100 indicates an observed value, 1000 indicates an interpolated value)

**DRY_soil_temperature_daily_<statid>.csv**

- Daily values for soil temperature and <station number>
- format:
  - Station number
  - Timestamp in UTC\(^2\) format yyyymmdd
  - Value
  - Quality index (1100 indicates an observed value, 1000 indicates an interpolated value)

b. The Building Permit Dataset

The dataset for obtaining a building permit contains a csv-file for each parameter in the same format as in “a. The DRY Dataset”.

---

\(^4\) Universal Time, Coordinated: In Denmark, UTC+2 hours corresponds to summer time (daylight savings time) and UTC+1 hour otherwise.
References


[4] *Danish Building Regulations 2010 (BR10)*, Ministry of Economic and Business Affairs, Danish Enterprise and Construction Authority, Copenhagen 2010


[8] Please contact Kristian Pagh Nielsen, DMI, for more information on illuminance calculations.