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A data base for European climatic data for energy potentials and mapping

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Abstract

Climatic data may be very important for determining the use of heating and cooling of buildings. At the same time, they are the basic for determining the ground temperature in the different locations, as well as for determining the potential of using geothermal energy.

For promoting the diffusion of GSHP (Ground Source Heat Pumps), a tool for sizing these systems will be carried out in the H2020 research project named "Cheap-GSHPs". The paper presents the set up of a consistent data base of weather conditions for the tool which will be used by both expert technicians and also non expert users.

The sets of data have been collected by the TRY data base of Energyplus files (EPW) as well as some weather files of Meteonorm. The different locations have been labelled in terms of DD for heating and cooling as well as by the Köppen -Geiger scale. The work presents a classification of weather conditions in Europe, in order to help the user in selecting the weather conditions which are closest to the location of interest. The data base will be used in the selection tool which will be developed in the second step of the H2020 project.

Keywords - Weather conditions, Climate definition, Degree-Days, Mapping, GSHP

1. Introduction

Weather is the state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy. Most weather phenomena occur in the troposphere, just below the stratosphere. Weather refers, generally, to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over longer periods of time [1]. As well known, for energy uses in buildings weather conditions play an important role. For this reason, it is important to define the proper boundary conditions in terms of the different parameters affecting energy and comfort in buildings, which may be different from case to case depending on the particular problem. In this work, particular attention has been paid to the ambient air and how to define in a simple way the climate.

Atmospheric temperature is a measure of temperature at different levels of the Earth's atmosphere. It is governed by many factors, including incoming solar radiation, humidity and altitude. When discussing surface temperature, the annual atmospheric temperature range at any geographical location depends largely upon the type of biome, as measured by the Köppen climate classification, which has been recently updated [2] (see Fig. 1).

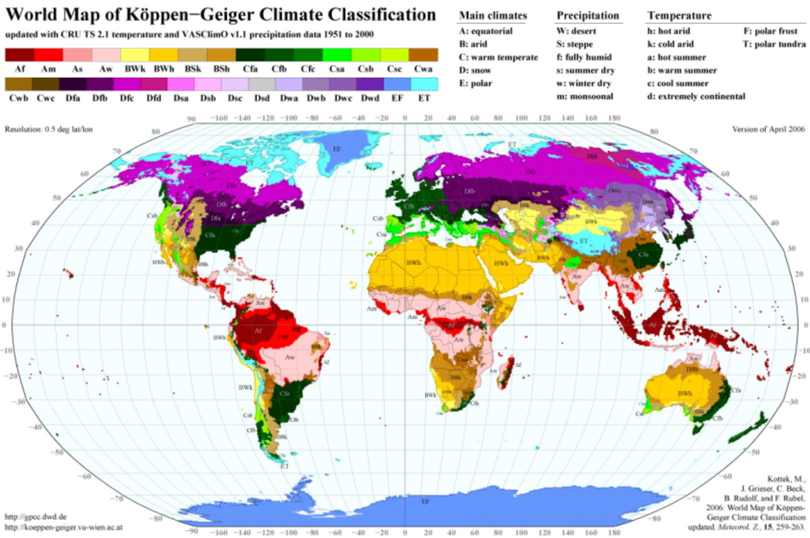

Fig. 1 Updated Köppen -Geiger map classification [3].

Nowadays climatic data are available for most of the climates. Among the different ways to define the weather conditions, the Köppen -Geiger scale and the Degree-Days (DD) have been used as parameters.

Degree-days are a tool that can be used in the assessment and analysis of weather related energy consumption in buildings. They have their origins in agricultural research where knowledge of variation in outdoor air temperature is important [4], and the concept is readily transferable to building energy. Weekly or monthly degree-day figures may be used within an energy monitoring and targeting scheme to monitor the heating and cooling costs of climate controlled buildings, while annual figures can be used for estimating usual costs.

A degree-day is computed as the integral of a function of time that generally varies with temperature. The function is truncated to upper and lower limits that are appropriate for climate control. The function can be estimated or measured by one of the following methods, in each case by reference to a chosen base temperature:

- Frequent measurements and continuously integrating the temperature deficit or excess;
- Treating each day's temperature profile as a sine wave with amplitude equal to the day's temperature variation, measured from max and min, and totaling the daily results;
- As above, but calculating the daily difference between mean temperature and base temperature;
- As previous, but with modified formulae on days when the max and min straddle the base temperature.

Analysis techniques typically use the degree-day. Degree-days provide a means to compare energy performance in buildings under different conditions. Analysis techniques also use degree-days to produce empirical models of consumption [5].

Heating degree-day (HDD) is a measurement designed to reflect the demand for energy needed to heat a building. It is derived from measurements of outside air temperature. The heating requirements for a given structure at a specific location are considered directly proportional to the number of HDD at that location. A similar measurement, cooling degree-day (CDD), reflects the amount of energy used to cool a home or business.

Heating degree-days are defined relative to a base temperature, i.e. the outside temperature above which a building needs no heating. The most appropriate base temperature for any particular building depends on the temperature that the building is heated to, and the nature of the building (including the heat-generating occupants and equipment within it). The base temperature is usually an indoor temperature of 18-19°C, which is adequate for human comfort (internal gains increase this temperature by about 1-2°C).

Recent publications by the CIBSE [6] and The Carbon Trust [7] [8] provide a current view of the theory and application of heating degree-days [9].

Action Energy, run by the Carbon Trust, has published “Degree-days for energy management – a practical introduction”. The guide (Good Practice

Guide 310) gives an introduction in to the use of degree-day analysis and is intended for those who are responsible for energy management but who are not familiar with the degree-day technique [10].

A key issue in the application of degree-days is the definition of the base temperature, which, in buildings, relates to the energy balance of the building and system. This can apply to both heating and cooling systems, which leads to the dual concepts of heating and cooling degree-days.

The document of CIBSE [6] replaces previous guidance. It provides a detailed explanation of the concepts described above, and sets out the fundamental theory upon which building related degree-days are based. It demonstrates the ways in which degree-days can be applied, and provides some of the historical backdrop to these uses.

Calculations using HDD have several problems. Heat requirements are not linear with temperature, and heavily insulated buildings have a lower "balance point" [11]. The amount of heating and cooling required depends on several factors besides outdoor temperature: building insulation, amount of solar radiation, number of electrical appliances running, amount of wind outside, and comfort temperature of the occupants. Another important factor is the amount of relative humidity indoors; this is important in determining how comfortable an individual will be. Other variables such as precipitation, cloud cover, heat index, building albedo, and snow cover can also alter a building's thermal response.

Another problem with HDD is that care needs to be taken if they are to be used to compare climates internationally, because of the different baseline temperatures used as standard in different countries.

Although cooling degree-days are published, the methodology is not well developed and many times it is not recommended to be used in connection with cooling or air-conditioning of buildings [9]. Another important item is the latent load, which is difficult to estimate based on CDD and can be relevant in the overall cooling energy demand of the building.

Some of these items are discussed in [12]. In this work, a robust database has been set up and a suitable definition of the weather conditions has been faced. The weather definition here presented will be used as a base for a freeware tool for sizing the Ground Source Heat Pumps (GSHP) in the frame of the H2020 project Cheap-GSHPs.

2. Methods

The data base of climatic conditions of METEONORM and ENERGYPLUS have been analyzed in order to produce a suitable set of data. Locations of both database have been selected to create a properly wide European database.

Due to the different climatic data, the database has to be built up in terms of synthetic values which can be easily understood by expert and non expert users. For this reason two main parameters have been chosen.

The first parameter is the Köppen -Geiger scale; this parameter helps the non expert user to check which climate can be mostly similar to the current location. Figure 2 shows the cities which have been introduced in the database.The second parameter is the degree day (DD) for heating (HDD) and cooling (CDD). This parameter shows an expert user if the location requires mostly heating or cooling or both.

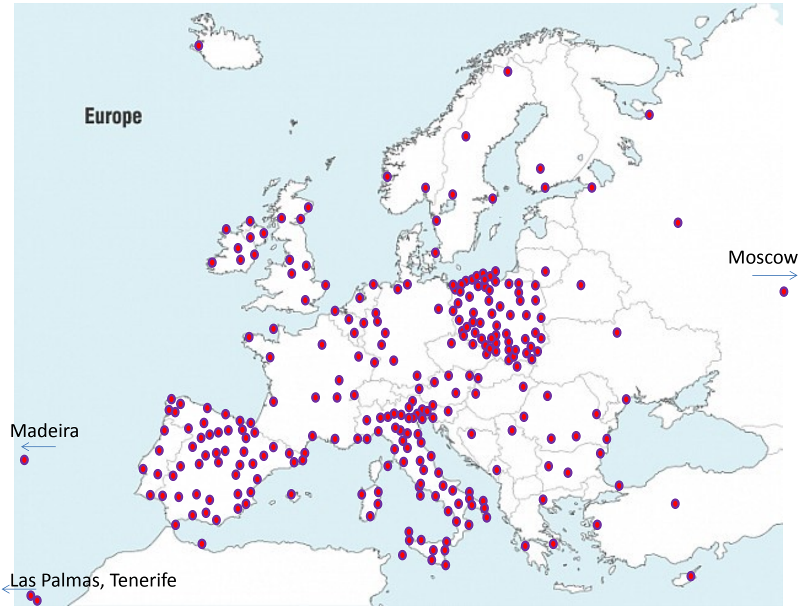

Fig. 2 Climatic data used in the present work.

3. Köppen -Geiger scale

Based on the definition of the updated Köppen -Geiger scale, looking at the climatic conditions in Europe, the following groups have been considered:

- Bsk: arid, summer dry, cold air
- BWk: arid, desert, cold air
- Cfa: warm temperature, fully humid, hot summer
- Cfb: warm temperature, fully humid, warm summer
- Cfc: warm temperature, fully humid, cool summer

- Csa: warm temperature, summer dry, hot summer
- Csb: warm temperature, summer dry, warm summer
- Dfb: snow, fully humid, warm summer
- Dfc: snow, fully humid, cool summer

It has to be underlined that the definition of a location is not an easy task, since the available database [3] is defined by latitude and longitude and in many places (especial mountain areas) the climatic conditions may change drastically.

The cities grouped into these categories have been further analyzed to check also how to make simpler information to non expert users who can later use the information of climatic conditions of a certain location. For this purpose, based also on the values of the HDD and CDD, the following macro-groups have been defined (see Fig. 3):

- Dry climates, including BWh and Bsk
- Mild warm climates, including Csa, Csb, Cfa
- Mild cold climates, including Cfb and Cfc
- Cold climates, including Dfb and Dfc

A further analysis has been carried out for each country in order to see whether there were differences in the climatic conditions depending on particular conditions. Fig. 4 shows the overall results listing the climatic conditions per Country from the warmest climates to the coldest climates. This result can give a quick overview to people what can be expected in a certain country in terms of climatic conditions and hence as potential for heating and/or cooling.

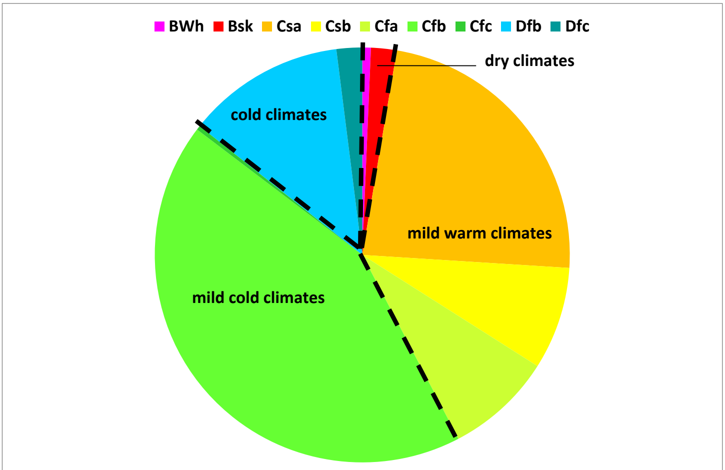

Fig. 3 Sudivision of climatic conditions based on the Köppen -Geiger scale for the different locations of Europe.

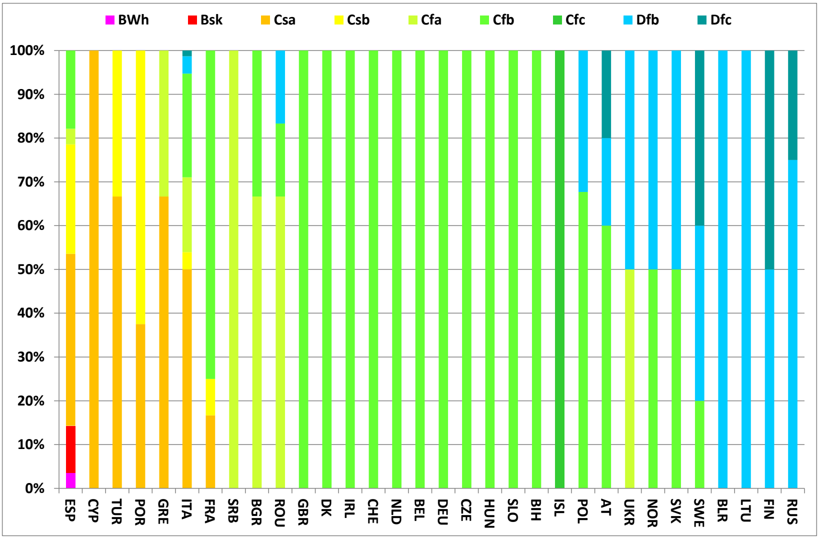

Fig. 4 Subdivision of climatic conditions based on the Köppen -Geiger scale for each Country considered within Europe.

4. Degree-Days for heating and cooling

As for the DD for heating and cooling, among the different definitions and set of conditions which are proposed in literature, the following equations have been used for the calculations

$$HDD = \Sigma_{\mathrm{i}} (18 - t_{ext,i}) \qquad \text{if } t_{ext,i} < 14 \qquad (1)$$
$$CDD = \Sigma_{\mathrm{i}} (18 - t_{ext,i}) \qquad \text{if } t_{ext,i} > 20 \qquad (2)$$

where $t_{ext,i}$ is the average external temperature for each day and the sum is extended all over the year.

Based on the calculated DD for heating and cooling for each location included in the combined ENERGYPLUS and METEONORM database, an analysis has been set in order to check the values of the HDD and CDD of the locations corresponding at the Köppen -Geiger classifications for the European climate. Among the different scales, due to the limited values of BWk (only two locations in Canary Islands) and of Cfc (only Reykjavik), the statistical analysis has been carried out only for the climates Bsk, Cfa, Cfb, Csa, Csb, Dfb, Dfc. As shown in Fig. 5, the average values of the HDD (orange circles) and CDD (blue circles) for each climate are shown as well as the standard deviation (bars around the mean values). In the same figure the minimum (yellow squares) and maximum (red squares) HDD values as well as the minimum (light blue squares) and maximum (dark blue squares) CDD values are also reported for each climate.

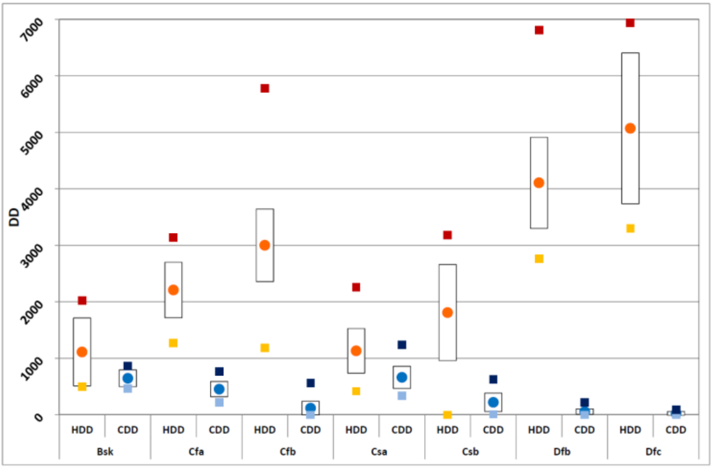

Fig. 5 Average values (circles), standar deviation (bars), minimum and maximum values (squares) for the HDD (red, yellow and orange) and for the CDD (blue) for the considered Köppen -Gaiger categories in Europe.

The statistical analysis for HDD and CDD has been also applied to the macro-groups defined in section 3 (dry climates, mild warm climates, mild cold climates, cold climates). Results are shown in Fig. 6 for the average values of the HDD (red circles) and CDD (blue circles); the standard deviation (bars around the mean values) is also reported. In the same figure the minimum (yellow squares) and maximum (red squares) HDD values as well as the minimum (light blue squares) and maximum (dark blue squares) CDD values are also reported for each main climatic subdivision.

As can be seen in Fig. 5 and Fig. 6, the simplified classification is easier to understand and shows a more evident trend in the increase of HDD and decrease in CDD when passing from dry climates to cold climates.

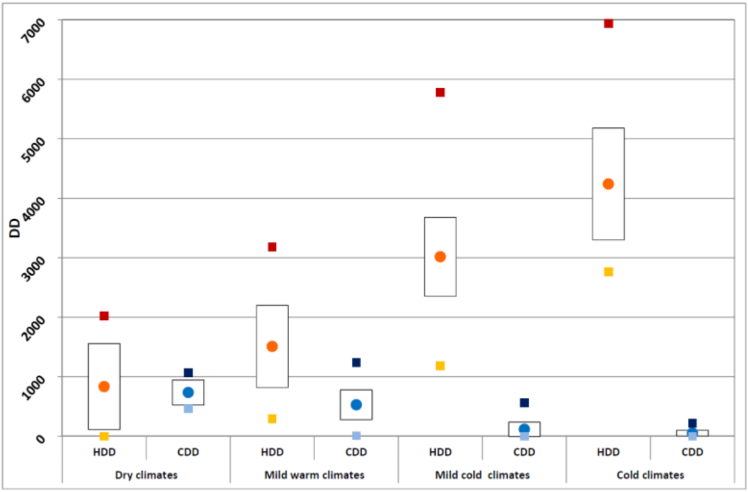

Fig. 6 Average values (circles), standar deviation (bars), minimum and maximum values (squares) for the HDD (red, yellow and orange) and for the CDD (blue) for the macro-subdivisions of climatic conditions in Europe: dry climates, mild warm climates, mild cold climates, cold climates.

5. Conclusions

The climatic conditions of Europe have been analysed based on the data base of ENERGYPLUS and METEONORM. For each location the Köppen - Geiger scale as well as the HDD and the CDD have been evaluated. The climatic conditions have been further subdivided in four macro-groups: dry climates, mild warm climates, mild cold climates and cold climates. This subdivision may be easier to understand and can give directly information on the main need for heating and/or cooling. As a matter of fact the Köppen - Geiger scale is well known at scientifical level, but it may be difficult to understand for non-expert persons, who can easier understand a less detailed scale.

In any case, the HDD and CDD are necessary for technicians in order to measure the potential for heating and cooling. Based on HDD and CDD the energy needs of buildings can be estimated, as shown in [12], based on some standardized heating/cooling profiles. Moreover the HDD and CDD coupled with the macro-groups (dry climates, mild warm climates, mild cold climates, cold climates) are quite efficient in order to give a more detailed information about the location.

The climate data base will be later used for a freeware tool whose aim is to get easier access to the GSHP. Moreover the database will be also used to draw maps of potentials for the energy needs of buildings and the possible use of the GSHP.

Acknowledgment

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