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A method to account for the urban microclimate on the creation of 'typical weather year' datasets for building energy simulation, using stochastically generated data

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ABSTRACT

Predicting buildings' heating and cooling needs through dynamic simulation methods requires the input of hourly weather data, so as to represent the typical meteorological characteristics of a specific location. Hence, the so called 'typical weather years' (TWY), mainly deduced from multi-year records of meteorological stations outside the urban centres, cannot account of the complex interactions between solar radiation, wind speed and high urban densities which lead to the formation of the urban heat island effect and to higher ambient air temperatures. As the assumption that climatic parameters at a reference location of a meteo station are similar for a densely built up area can lead to miscalculations of the heating and cooling needs, the aim of this study is to present a computational method for assessing the urban climate's effect during the generation of typical weather data for dynamic energy calculations. In this vein, a typical 'urban specific weather dataset' (USWD), reflecting the microclimatic conditions in front of a building unit inside an urban district in the city of Thessaloniki, Greece is created based on microclimate simulations with the Envi-met model; it is then compared with a typical reference weather dataset (RWD), representing climatic conditions at a reference location of a meteo station. The results indicate that the proposed method can capture microclimate characteristics; higher dry bulb temperatures were reported during the year inside the urban canyon, compared to the corresponding values at the reference location, with indicative mean daily deviations up to 1.0 °C and 0.75 °C in February and July respectively. Wind speed, near the building façade is generally found lower than the corresponding values at the reference location, due to wind sheltering by neighbouring constructions. Given that climatic parameters strongly influence the output of energy simulations the proposed computational method provide a contribution for higher accuracy of building energy simulation in the urban context. Future work will involve energy performance simulations of a typical building unit with the generated USWD file so as to evaluate the urban climate's influence on energy needs.

1. Introduction

Today, residential and commercial buildings account for the 40% of the final energy use in European Union while heating represents the most important part of residential energy consumption. Aiming at the reduction of the energy demand of buildings, the Energy Performance Buildings Directive2002/91/EC has obliged all members of the EU to adopt a number of measures orientated towards innovations and practices in order to respond to the growing energy demand of the building sector. It has also imposed minimum energy performance requirements for new and existing building under major renovation, both for the residential and the tertiary sector [1]. Given the growing concerns about energy waste and its negative impact on the environment due to excessive CO2 emissions, there is an increasing interest towards accurate building energy simulation. The corresponding simulation tools are currently widely used by architects, engineers and designers in order to estimate building energy needs but also to investigate the potential of energy savings through measures that involve equipment, operational schedules or control strategies. The use of advanced Building Energy Simulation (BES) models may generally provide reliable estimates of building energy demand with simulation results fitting quite accurately with actual measurements [2].

When configuring the simulation, special attention should be given on the accuracy of the climatic dataset used as input for the calculation; as the IEA Annex 53 [3] pointed out, the weather file

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introduced in BES models, comprising of 8760 hours of various climatic values such as dry bulb temperature, dew point temperature, wind speed, solar radiation etc. will strongly influence heating and cooling loads calculations, systems dimensioning, energy production from solar panels etc. Given that long term real weather data, measured at a close distance from the respective study area are not always available, most of the corresponding BES models, adopt the so called 'typical weather files'; the latter are usually statistically processed and mainly derived from multiyear observations, issued by weather stations in the peripheral zones, outside the urban areas [4].

As a consequence, complex interactions between solar radiation, wind speed and the increased urban densities are ignored [5,6]; urban areas are usually characterized by higher ambient air temperatures and considerably different microclimate, compared to areas outside the city centres, which is usually referred as the urban heat island effect [7,8]. This differentiation is mainly attributed to extensive urban morphological changes comprising of: (i) the progressive substitution of vegetation and green areas with mineral surfaces, leading to a decrease of latent heat flux through evapotranspiration [9], (ii) the replacement of natural, permeable surfaces with mineral, rough materials such as concrete and asphalt, the thermal properties of which, contribute to large quantities of solar radiation stored and then re-emitted as long-wave radiation inside the urban districts [10], (iii) the low albedo of the urban construction materials, which increases the quantity of solar radiation absorbed by building envelopes and urban surfaces, causing thus, their higher surface temperatures (Tsurf), and severe intensity of long wave radiation emission [11] and (iv) the reduced opening to the sky, contributing to the entrapment of shortwave and long wave radiation inside the canyons inhibiting thus, the urban cooling [12]. As a result, when it comes to the energy performance simulation of an urban building, the assumption that the climatic conditions at a reference location of a meteo station (i.e. the airport area) are the same for a densely built up area can lead to inaccurate predictions of heating and cooling loads. This is not attributed to the altered solar radiation effects within the urban context that are usually treated sufficiently by advanced BES models, but to the fact that the complex urban geometry and surface materials strongly affect airflow, air temperature and relative humidity.

In this context, the aim of this study is to present a computational method so as to create typical weather datasets that account for the influence of local, site specific surroundings and the respective microclimatic conditions. The proposed methodology is depicted in Fig. 1. More precisely, two typical hourly weather files are generated:

- A reference one, corresponding at a reference location of a meteo station.
- An urban specific weather dataset, reflecting microclimate conditions inside an urban study area.

A stochastic generation procedure is carried out for the creation of both datasets; the detailed analysis of the corresponding process is presented in Section 3. It has to be underlined that the generated 'reference' weather file could be theoretically used for every study area inside the city (hence, no specific microclimatic conditions of the district are considered) while the 'urban specific' weather dataset is only site specific, representing microclimatic conditions of the analysed study area.

The two datasets are generated so as to be representative of climatic conditions for a long time period, and not just for a single calendar year (see Section 3). In order to account of local microclimate conditions in the latter climatic file, the Envi-met non hydrostatic microclimate model [13] is applied. Finally the major climatic variables of the two datasets, that strongly influence buildings' energy performance, are intercompared so as to identify the impact of the urban morphology on the urban climate parameters.

2. Overview on the methods for 'typical weather years' generation

The use of a 'typical weather file' for BES has arisen from the need to compromise accuracy and computationally efficient simulations. To date, several procedures regarding the acquisition of typical weather data have been reported in the literature. One of the most commonly used hourly data format file for BES is the Typical Meteorological Year format, created by the U.S. National Renewable Energy Laboratory in 1978 for 248 locations using long-term observations of solar radiation and weather data from the 1952–1975 [14]. Later updates, in the early 1990 s, introduced the TMY2 format derived from measurements during 1961–1990 [15], while the current TMY3 data sets cover 1020 sites across the US using data from 1976–2005 or 1991–2005 [16]. The 'typical year' is composed of 12 'Typical Meteorological Months' [17], selected from different years and concatenated so as to form a single year [18]. A detailed description of the creating process of a TMY is presented in [19]. A similar compilation procedure, based on long-term measurements (usually 20 years), is applied for the Test Reference Year (TRY), a technique developed by Chartered Institution of Building Services Engineers (CIBSE) [20]. Finkelstein-Schafer statistics are estimated for each month and each climatic variable in order to define the typical months which are then aggregated to form a complete year; yet, there are two major differences with the TMY technique: (a) only the mean value of dry bulb temperature and wind speed and the global solar radiation are taken into account, instead of the 9 variables considered in the TMY method, (b) all three variables are equally weighted whereas on the TMY technique, the global radiation is considered to be more critical, having the highest weight factor. Another technique for generating hourly weather dataset is the Weather Year for Energy Calculation method (WYEC), initially proposed by [21]. It relies again on the definition of 12 representative months in order to form a complete year; still, there are two important differences in comparison with the previous techniques: individual months are only selected if the average monthly dry bulb temperature has a difference of ± 0.2 °C. After the initial selection, in case abnormalities or extreme events are found, individual days or hours can be adjusted so as to lead the monthly mean values to come closer to the respective long term values. The complete procedure of creating hourly weather values with this technique along with the corresponding further improvements were described by [22] and [23]. Finally, a different approach is proposed in the Example Weather Year (EWY) method, introduced by [24]. A complete year is now defined, the monthly mean weather values of which, contain the least abnormalities in comparison with the long-term observations. Thus, a whole representative year instead of representative months is sought. More precisely, monthly mean values of global and diffuse radiation, daily mean wind speed, mean, maximum and minimum dry bulb temperature and their standard deviation from the long-term mean are estimated; The years that contain monthly means that differentiate more than standard deviation from the corresponding long-term mean are rejected and the last remaining year would become the example year chosen [20,25].

3. Methodology for climate data generation

As already mentioned, the current study aims to present a computational method for the generation of typical weather years that account for the influence of local surroundings and the respective, site specific microclimatic conditions. Based on the previously mentioned techniques, when aiming at the generation