Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 48 (2014) 796 – 805
Energy Procedia

SHC 2013, International Conference on Solar Heating and Cooling for Buildings and Industry
September 23-25, 2013, Freiburg, Germany

The influence of measured/simulated weather data on evaluating the energy need in buildings

Daniela Ciobanu[a], Elena Eftimie[a], Codruta Jaliu[a]

[a]*Renewable Energy System and Recycling Department, Transilvania University of Braşov, Braşov, 500036, Romania*

Abstract

In evaluating the thermal energy demand in buildings by using TRNSYS software, weather data are necessary to optimise the implementation location of a new building. The weather data are obtained from in-field measurements, using a weather station, or by using simulated data obtained using the dedicated software, e.g. METEONORM.

The paper aims at investigating the influence of measured/simulated meteorological data on an accurate evaluation of the thermal energy demand in buildings. Further on, the paper discusses a case study for a building in Transilvania University of Brasov, located in a mountain, urban area.

Selection and peer review by the scientific conference committee of SHC 2013 under responsibility of PSE AG

Keywords: Weather data; direct solar radiation; space heating demand; METEONORM; TRNSYS

1. Introduction

The main climatic parameters, with significant influence in the design of solar energy conversion systems are the solar radiation, wind speed, temperature and humidity. Among these, solar radiation is the main input parameter, both in the design of solar energy conversion and in improving energy efficiency in (passive) buildings. Solar radiation is a driving force in optimizing a series of solar energy applications such as photovoltaic systems, solar collectors for heating and domestic hot water, solar air conditioning climate control in buildings and passive solar devices.

Under these circumstances, the use of accurate weather data (solar radiation, ambient temperature and wind speed) is an

Corresponding Author Tel.+40268413000
E-mail address: eftimiem@unitbv.ro

Selection and peer review by the scientific conference committee of SHC 2013 under responsibility of PSE AG
doi:10.1016/j.egypro.2014.02.092

important issue in the design and correct dimensioning of solar systems and in the correct determination of the solar energy gains.

Unfortunately, not every site has recorded weather data; therefore, it becomes necessary to use estimation models or software for generating weather data. However, it is important to note that the predictions of climatological models are always subjected to uncertainty due to limitations of knowledge on the climate system, pollution and available computing resources [1], [2].

Although weather data generators are proper tools for the sites with no local weather stations, the quality of the generated data is influenced by the site geographical conditions, the recording time and the climate changes due to weather variability [3].

The latest version of METONORM software includes meteorological data from 8725 weather stations, but only 1217 of them contain data on global solar radiation (385 for Europe) [2]. The weather data for a site that is not available in the software database the weather data will be interpolated based on the data from the nearest stations. In this case, the accuracy of the generated data depends on the accuracy of the measurements recorded in the stations chosen from the database, and the distances to these weather stations [3], [4], [5], [6], [7].

Thus, the meteorological data coming from local weather stations are available only for a limited number of sites, but the weather files are usually based on past observations. In this case, the fact that the actual weather conditions in a particular year can be very different from the configuration indicated by long-term data is not taken into account [7]. Besides, uncertainties of the generated data can be caused by the assumptions regarding the microclimatic conditions, and the results must take into account the particular issues arising from urban climatology.

Thus, the correct evaluation/estimation of the solar radiation data is important in calculating the building energy demand, either by using traditional methods or dedicated software as TRNSYS.

In this context, the paper proposes a comparative analysis of meteorological data values recorded with a local weather station and weather data generated by METEONORM software, and evaluates the impact of the differences identified between the two sets of weather data on the building heating / cooling demand. The paper presents the energy demand determined for a building by using the TRNSYS software. In order to calculate the energy demand, the TRNSYS software needs accurate weather parameters as input data. These data can be simulated using METEONORM software or can be added after in-field measurements and data refining. The influence of these two data types is presented for a case study for mountain urban area in a temperate region (Brașov, Romania) and the results prove the need to use databases containing in - field data collected over at least one year, but preferably more. The case study presented by this paper shows by differences up to 30% between the values of heating demand calculated with measured and generated weather data during February, March, April and October, while the most significant differences in the cooling demand were obtained in July, August, when it may exceed 40%.

Nomenclature

EnBH_avg	monthly average of direct energy on horizontal plane
EnDifH_avg	monthly average of diffuse energy on horizontal plane
EnGH_avg	monthly average of global energy on horizontal plane
MPD	mean percentage difference
Tavg_mesured_Brasov	monthly average ambient temperature measured in Brașov
Tavg_ METEONORM _Brasov	monthly average ambient temperature provided by METEONORM
Wavg_measured_Brasov	monthly average wind speed measured for Brașov
Wavg_ METEONORM _Brasov	monthly average wind speed provided by METEONORM
Q_heat_Measured_Data	energy need for heating using measure data
Q_heat_METEONORM_Data	energy need for heating using METEONORM data
Q_cool_Measured_Data	energy need for cooling using measured data
Q_cool_METEONORM_Data	energy need for cooling using METEONORM data
HVAC	heating, ventilation and air conditioning system
PPD	Predicted Percent of Dissatisfaction

2. Equipments and computational methods

2.1. Geographical and climate description

Braşov city is located in eastern-central Romania at 25°36' East longitude and 45°39' Northern latitude. Situated in the Braşov basin, in Carpathians internal curvature, Braşov urban area is about 790 m above the sea level. Braşov has a temperate continental climate specific to the transition between temperate oceanic and continental climate. This region exhibits some typical features regarding topology, climatology and environment. The build-up area is low in comparison with the one of the neighbouring mountains, which circles the basin area [10].

In terms of geographical aspects, Braşov is the junction of three major natural units: Eastern Carpathians, Southern Carpathians and Transylvanian Plateau, resulting in a pronounced complexity and diversity of geological and geomorphologic features, reflected in climate, water, soils, vegetation and fauna [11], [12]. Mountain terrain covers about 40% of Braşov region, the rest being low and hilly land. The juxtaposition of mountain massifs and depression creates altitudinal and clinometric contrasts.

On the outskirts of Braşov Region is a series of low-rise mountains (with a maximum altitude of 1200 m) as a border, which, together with the high mountains surrounding the basin, act as a barrier that limits the wind speed.

General features of the regional climate are strongly modified by local physical and geographical conditions. The influence of mountainous terrain provides a subdivision of the general climate and the climatological phenomena natural setting. Thus, Braşov Basin is characterized by a climate with excessive variations - high thermal amplitude, frequent temperature inversions, early and late frosts; the rainfall is affected by the surrounding mountains, and the wind regime is also dependent on local orographic characteristics.

The interaction between local characteristics and general climate creates favourable conditions for the thermal inversion phenomenon. From the temperature point of view, the effect of Braşov basin consists in increasing the radiative cooling processes over the night, and, also, of the daily heating processes [11], [12], [13].

2.2. Meteorological data

To provide the necessary information about the weather, meteorological equipment was used. The meteorological data measurement was carried out with a Delta-T local weather station, positioned on the roof of Product Design and Environment Department (Romania). The weather station has a modular structure, the data sets been collected since October 2005 and comprising the following parameters: global solar radiation [W/m^2], diffuse solar radiation [W/m^2], air temperature [^{o}C], wind speed [m/s], wind direction [degrees], relative humidity [%], rainfall [pluviometric mm], sunshine duration. The weather station is equipped with an environmental data logger (Delta-T Logger), which initiates the readings, controls the sensors and stores data related to 10 minutes range.

2.3. Methods used

Exponential growth that both the hardware and the software have had in the last decade has made possible the development of software packages and applications that generate and process large volumes of data. In this way it is possible to generate maps with weather information (air temperature, wind speed and direction, solids or liquids precipitation) from anywhere in the world, available online, anytime, anywhere for a user connected to the Internet.

One of the software products used in the data forecast was developed by METEOTEST' [14]. METEONORM uses an empirical method for calculating solar radiation on horizontal and arbitrarily oriented surfaces that are situated in any location. The method consists in composing databases and interpolation algorithms in a predetermined scheme.

The average monthly data for the weather stations are stored in the METEONORM database, while the hourly data are generated accordingly, when needed. The average monthly values (over 10 years) for the cities and other locations are obtained by interpolation, and the hourly values are generated based on them [14]. In the case of locations that are not in the vicinity of predefined ones, the following parameters should be known: location name, altitude and geographical coordinates, the time zone, type of soil and other optional information like: location abbreviation, internal reference time, etc.

The energy demand can be calculated using either specialized software for building energy simulation (TRNSYS) or a classical method. In the second case, the building heating demand is calculated by taking into account a constant temperature which is far below the actual recorded value, leading to an over-sized solar thermal system. In case of using the computerized tool, the building energy demand can be evaluated for various options before deciding to implement one of them.

TRNSYS (Transient System Simulation Program) is a software used in the energy simulation based on a modular system [16]. The software library contains standard equipment for heating, ventilation and air conditioning, renewable energy components and newly emerging technologies. This simulation package is already used for 25 years in analysing and dimensioning the HVAC systems, in the multi-zone air flow analysis, in power simulation, solar system design, buildings thermal behaviour, analysis of control schemes, etc.

3. Results and discussions

3.1. Radiative parameters for Braşov urban area

Solar radiation represents the main climatic factor that determines variations of other climatic factors. Considering the functionality of the solar energy systems, the incident beam has the main influence.

At this stage, based on the specific climatological and geographical conditions of Braşov urban area, an analysis of the characteristics of solar radiation for Braşov urban area is proposed, as a prerequisite for a feasible technical dimensioning and for the economic evaluation of the installations using this energy type. Thus, the following annual average values of the solar energy were recorded during 2006...2011 for Braşov urban area:

- The average monthly global energy varies during the year between 23 kWh/m^2 (in December) and 172 kWh/m^2 (in July);
- The average monthly direct energy varies during the year between 9 kWh/m^2 (in December) and 103 kWh/m^2 (in July);
- The diffuse energy represents 40% (in July) and 60% (in December) from the global energy;
- The annual global energy is 1148 kWh/m^2, the annual direct energy is 629 kWh/m^2 and the annual diffuse energy is 519 kWh/m^2 (annual energy diffuse is ≈ 45% of global energy).

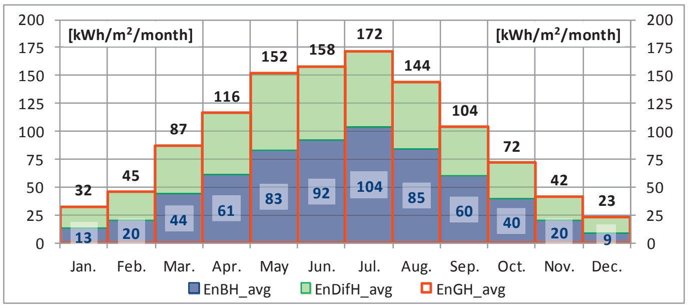

Fig. 1. Average monthly energy during 2006 – 2011

3.2. Comparative analysis of the real weather data and data generated with METEONORM

Renewable energy systems' designers need certain basic data to determine the reliability of a particular system in a certain place. In order to meet their needs, new software applications were developed, providing primary input data, which, in the case of a solar panel, refer to:

- the site geographical coordinates;
- the declination, altitudinal, hourly, azimuth angles and the tilted angle of a solar collector or PV panel;

- data and diagrams that show the solar energy potential (direct radiation, diffuse radiation, hours of daylight), wind potential (wind speed and direction as well as its density), hydropower potential of the region.

The meteorological data provided by METEONORM for Braşov site are presented in Fig. 2 (daily global radiation and sunshine duration). Since no weather station is located in Braşov, the data is obtained by interpolating the meteorological parameters for Sibiu (112 km), Râmnicu Vâlcea (113 km), Târgu Mureş/Vidrasa (127 km), Galaţi (190 km), Buzău (111 km) and Caransebeş (261 km).

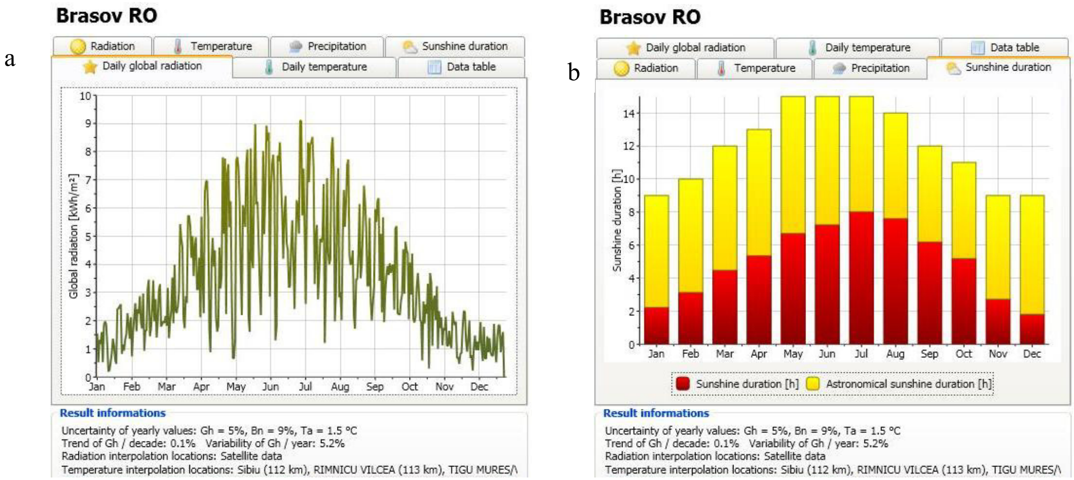

Fig. 2. Results obtain from METEONORM 7 software for Braşov Region, daily radiations (a) and sunshine duration (b)

For the comparative analysis of the meteorological parameters recorded with the Delta-T weather station and the values for the same parameters generated using METEONORM (for the Braşov site), monthly values of the solar energy, air temperature and wind speed are presented.

The variation of the solar radiation is outlined in Fig. 3 and the results show that the percentage difference ranges between 0..55%; during the warm seasons, in March - September, the percentage difference is below 10%, while the highest differences were recorded during winter: January - 34.3%, February - 46.1 %, and December - 55%. The use of generated weather data can introduce approximations and generates over-assessment of energy needs for heating and cooling, thus over-sizing and significantly higher initial costs.

The comparative analysis of average monthly temperature variations leads to the conclusion that the generated data underestimate the real values, the highest differences between the real and the generated values being recorded for January ($-4.2^{0}C$ compared with the real value of $-2.03^{0}C$), February ($-2^{0}C$ compared with the real value of $-0.42^{0}C$) and December ($-2.7^{0}C$ compared with the real value of $-0.37^{0}C$).

The monthly values of wind speed, generated in METEONORM software have big errors relative to the real recorded values (see Fig. 4). The lowest percentage error is registered in June (73%), while the highest value is obtained in November (157%).

The previous results highlight the conclusion that the combination of radiative, dynamic, and even the economic and geographic factors contribute in individualizing Braşov climate and providing its own climatological characteristics.

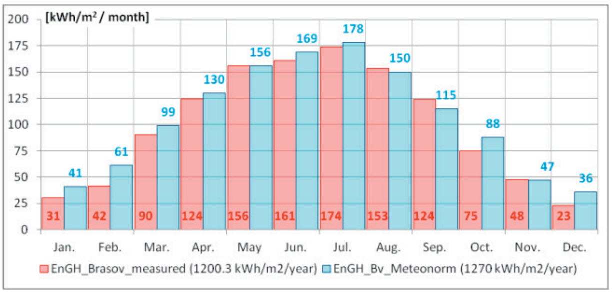

Fig. 3. The average monthly values of the global energy

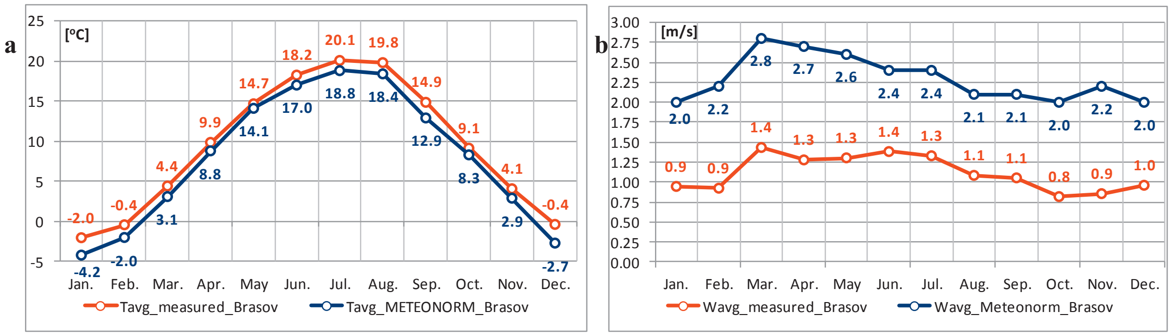

Fig. 4. The average monthly weather data obtained by processing real data and the data generated in the METEONORM software (air temperature (a), wind speed (b))

3.3. Space heating demand

Based on a case study, the chapter explores the implications of using two meteorological databases on the values of a building heating and cooling demand and, therefore, on the procedures for sizing solar-thermal systems. The differences identified between the weather data used in building energy simulations can lead to significant differences in the values of the solar energy captured on surfaces, especially when the captured energy is calculated on an inclined surface. Therefore, the source of meteorological data should be carefully selected [4], [6], [7].

To emphasize the importance of using measured weather data in designing solar thermal energy systems, finally the paper proposes the space heat demand calculation for a certain building. Thus, a transient analysis software (TRNSYS) is used; TRNSYS software uses as default database for weather data the METEONORM data [16]. The calculation is done using weather data generated by software METEONORM for the nearest location to Braşov and measured weather data (implemented into TRNSYS subroutines). The comparative analysis leads to the conclusion that, where a site has a weather station, it is recommended the use of measured weather data for solar renewable energy system design.

The simulation carried out for Braşov weather data uses the Type 99 component (see Fig. 5), which allows using a custom weather data file, and reads the data provided at regular time intervals [15].

The building to be simulated energetically is designed to allow studying viable solutions for comfortable and healthy indoor environment by using renewable energy sources and increasing energy autonomy [10], [14]. The optimized architectural shape allows natural air circulation between the two floors, benefiting from full natural ventilation (see Fig. 6). The radiant floor provides the building thermal comfort. The building is used as office space, the ground floor having a capacity of 12 seats, and the floor being arranged as a meeting hall (about 30 seats). The building total area covers 261 m^2.

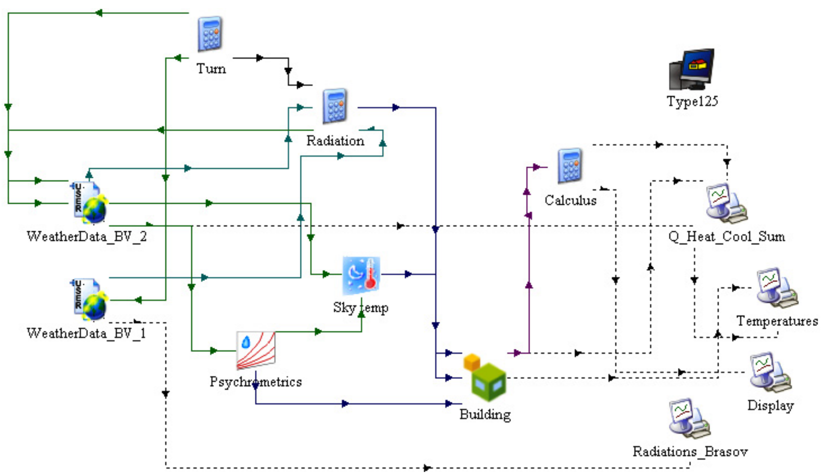

Fig. 5. TRNSYS model for the heating demand calculus

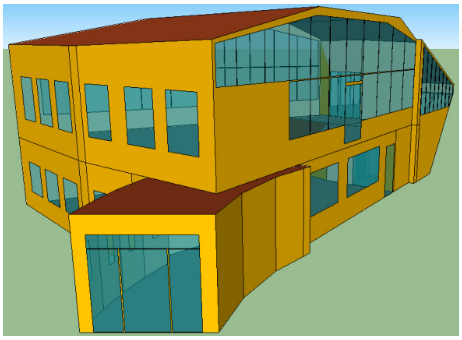

Fig. 6. The house geometric model

The 3D model is built at 1:1 scale, each surface being modelled according to the type characteristics: window, door, adjacent wall, ceiling, floor, etc. Thus, the file contains accurate data regarding the floor surface, the percentage of fenestration, etc. for each area. Further, the building 3D model is imported in the Simulation Studio file, where the links to the weather data components are established, and the output data are settled down, either for visualisation or further processing [10], [14]. The information regarding the materials used in the building construction, the structural components thickness, the heat transfer coefficient, the coefficient of thermal conductivity, etc. is input data in the module TRNBuild. The materials used are of the latest generation, with increased heat resistance. The building is insulated outside with a layer of 10 cm expanded polystyrene. Thus, the building is characterized by reduced energy consumption, fitting successfully into the category of low energy buildings. Another input data for the TRNBuild module is the building occupancy degree or the working program, i.e. from Monday to Friday, between 7.30 and 19.30. Each area in the building can be described by different working regimes, heating and cooling programs and temperatures, etc. The example presented in the paper takes into account the same program for the electronic equipment (computers, laptops, printers, etc.) as for the working staff.

The flexibility of TRNSYS software allows analysing different heating programs in order to determine an optimal program, by considering the building thermal behaviour. The variation of the PMV and PPD thermal comfort parameters throughout the simulation period (one year or 8760 hours) enables setting up the optimal heating temperature at 21^0C during the working hours, while for the night periods, and on Saturdays and Sundays, the temperature is set up at 18^0 C.

The values of monthly and annual energy demand for heating the building are outlined in Fig. 7. The following data are obtained for the chosen working program:

• in the case of the simulations based on measured meteorological data, the total energy is 28132 kWh / year, or 107 kWh/m^2/year.
• using the METEONORM database for Cluj Napoca city, the total energy is 22 615 kWh / year, i.e. 86 kWh/m^2/year.

Observations

1. The METEONORM database of TRNSYS software contains weather data only for 7 areas in Romania (Bucharest, Cluj Napoca, Constanta, Craiova, Galati, Iaşi and Timişoara). The weather data is available for 369 cities from 35 countries in Europe, 67 locations in 3 countries from North America (excluding USA), and 227 sites from 43 countries in Asia.

2. The limited numbers of sites for which TRNSYS software offers weather data leads to the conclusion that the simulation of energy demand in buildings that are not located in one of these areas, should be made based on one of the following methods: a). by using a database from nearby areas, which will increase the uncertainty of the weather data used in simulation; b). by using databases recorded in weather stations from the area for which the simulation is performed; but in this case, the need to develop consistent weather data files formats supported by TRNSYS arises (version recommended).

3. It should be also noted that the use of METEONORM databases disregards weather changes from year to year [2]. It is envisaged that solar variability is manifested by an increase in solar activity followed by a lull. Intensification of solar activity has implications in the atmospheric dynamics, occurring at soil level by increasing the temperature gradient and appearance of extreme weather events. The periods of high solar activity are also characterized by the increase in the global solar radiation. The analysis of spatial measurements of global solar radiation presents a cyclic solar activity with a period of about 11 years, with variations of ~ 0.1% in the solar activity (even at shorter periods than 11 years). Nowadays, we are facing a period of increased solar activity whose maximum is estimated to be in 2013 [8], [9].

It has to be noted that the METEONORM database from TRNSYS does not contain weather data for Braşov city, and the use of geographic coordinates for their generation is not possible (it is not possible to use weather data for sites that are not included by METEONORM database contained by TRNSYS). It can be noticed, if the METEONORM database from TRNSYS is used for building simulation, this is not the same used for the comparison of the climate and for the comparison of the building energy needs. This is also a reason to recommend the use of recorded weather data and the developing of weather data files in formats supported by TRNSYS (observation 3). Therefore, the heating needs simulation was performed using the weather data of the closest city to Braşov available in the database - Cluj Napoca, for which METEONORM software generates weather data.

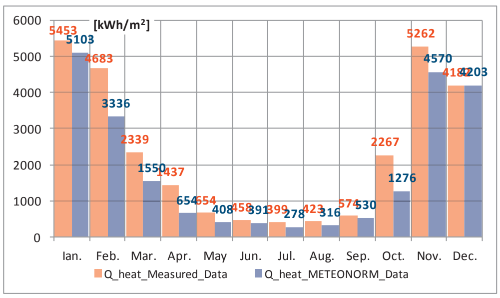

Fig. 7. Energy needs for heating the building

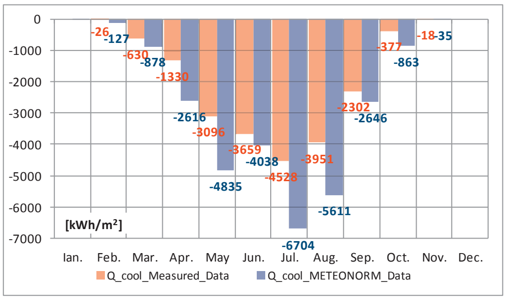

Fig. 8. Energy demand for cooling the building

The values contained in Fig. 7 highlight a need for heating the building even in summer. This need occurs due to the days with low temperatures (even below 10 ° C), days that are exceptions from traditional summer days.

In order to calculate the energy demand for cooling, the temperature when cooling becomes active is set up at the value of 24 ° C (Fig. 8).

Thus, it can be stated that both heating and cooling are needed during the transition periods, from April to May, and from September to October, due to the high external temperature changes during the day. Heating is needed in the nights and mornings, while the space cooling is required in the afternoons and evenings.

Energy simulations lead to the following conclusions:

- The climatological characteristics of the area chosen for the solar systems implementation influence the equipment behaviour and performances, requiring a deeper analysis of the area specific meteorological parameters. This analysis is required for a proper and accurate sizing of solar thermal systems and for their energy simulation.
- The solar radiation is the main input parameter in the design of solar thermal and photovoltaic systems, and, if possible, it is recommended to use the databases containing in-field weather data measured at the weather stations situated in the implementation area. Therefore, it is recommended to use the component Type 99 in the simulation process, which allows the introduction of a custom weather data file (this component reads the data provided at even time intervals).
- Referring to the presented case study, the difference between the yearly heating need, calculated using METEONORM database, and the value obtained based on the recorded weather data, is ≈ 20%. Therefore, the use of the data generated by METEONORM software leads to an **under-sized solar thermal system for space heating**; however, when designing a system for **space cooling, an over-sized system** can be achieved by using the METEONORM data, the difference between the yearly cooling demands calculated using generated and recorded data being of 42%.

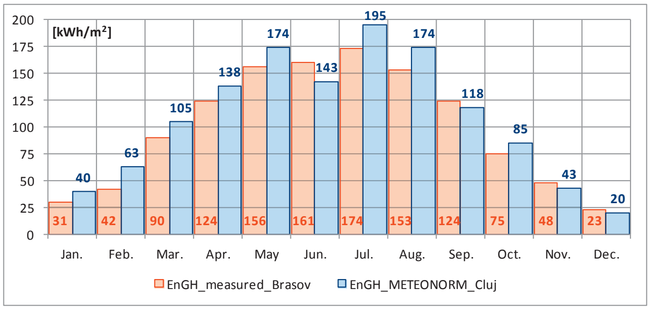

Fig. 9. The average monthly values of global energy - Comparison between recorded weather data for Braşov and generated weather data for Cluj Napoca

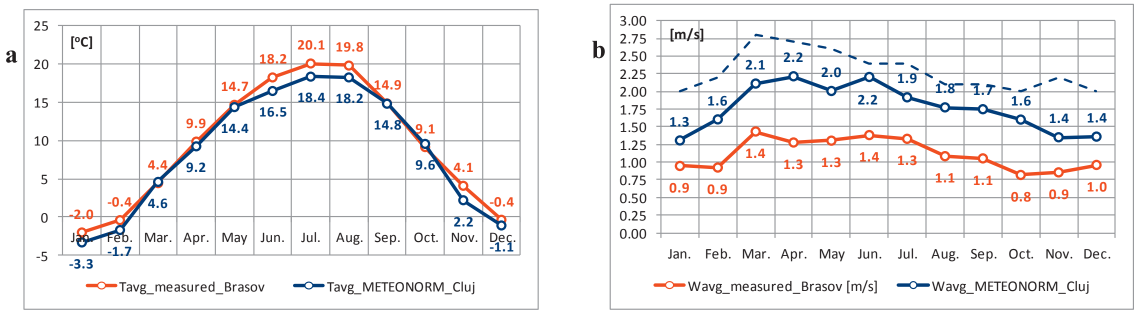

Fig. 10. The average monthly weather data obtained by processing real data and data generated by METEONORM software (a.air temperature, b.wind speed) - Comparison between recorded weather data for Braşov and weather data generated for Cluj Napoca

Therefore, the set of meteorological parameters (solar radiation, air temperature, wind speed) has an important influence on the demand for space heating and cooling. The differences between the values generated through the two methods are due to the significant differences between the recorded weather data for Braşov and the generated data for a city close to Braşov, for which TRNSYS software contains the METEONORM meteorological database, in this case, for Cluj Napoca.

The important difference between the two values of the heating demand (≈ 20%) is due to the big differences between the recorded meteorological parameters and the generated ones, during the cold period (January-May and October-December). Thus, the differences can reach 31% for the average monthly solar radiation, 60% for the average monthly air temperature, and up to 90% for the average monthly wind speed (see Fig. 9 and Fig. 10).

The difference between the two values of the yearly cooling demand during the warm period (measured and generated) is 42%; the difference between the measured and generated values of the solar radiation is ≈ 11%, of the air temperature goes below 10% and of the wind speed ranges between 40% and 70% (see Fig. 9 and Fig. 10).

4. Conclusion

Taking into account the results of the energy demand simulation using TRNSYS software, the following conclusion can be stated: sizing of solar-thermal systems for space heating or cooling can be made using climatological data from the weather stations located in the area of implementation. The weather data generated by specialized software cannot take into account all the geographical parameters and climatological conditions of each area. Besides, if the solar energy conversion systems have to be implemented in an urban environment, the weather data generation methods should take into account the specific conditions of this kind of site (urban pollution can lead to a lower solar radiation).

Acknowledgements

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/89/1.5/S/59323 and National Grant EST IN URBA 28/10.1012.

References

[1] Remund J., Müller S. C. Trends in global radiation between 1950 and 2010, Eurosun 2010, Graz, Austria, 2010.

[2] Remund J., Müller S.C.Solar Radiation and Uncertainty Information of Meteonorm 7 26th European Photovoltaic Solar Energy Conference and Exhibition,2011 4388 – 90

[3] Radhi H., A comparison of the accuracy of building energy analysis in Bahrain using data from different weather periods, Renewable Energy, 2009:34, 869–75

[4] Botpaev R., Obozov A., Orozaliev J., Budig C., Vajen K. Comparison of meteorological data from different sources for Bishkek city, Kyrgyzstan Proc. EuroSun 2008, Lisbon (PT), 2008.

[5] McLeod R. S., Hopfe C. J., Rezgui Y., Application and limitations of regional and future predictive climate data in Passivhaus design, Proceedings of Building Simulation 2011: 12th Conference of International Building Performance Simulation Association, 2011, 2415-22

[6] McLeod R. S., Hopfe C. J., Rezgui Y., A proposed method for generating high resolution current and future climate data for Passivhaus design Energy and Buildings, 2012:5, 481–93.

[7] Mahdavi A., Leinich V., Orehounig K., 261: Implications of varying weather data sets for predictions of thermal performance of buildings, PLEA 2008 – 25th Conference on Passive and Low Energy Architecture, Dublin, 22nd to 24th October 2008

[8] Gray L. J.,. Beer J, Geller M., Haigh J. D., Lockwood M., Matthes K., Cubasch U., Fleitmann D., Harrison G., Hood L., Luterbacher J., Meehl G. A., Shindell D., B. van Geel, White W., Solar influences on climate, published 30 October 2010.Copyright 2010 by the American Geophysical Union. Reviews of Geophysics, 48, RG4001 / 2010, 8755 - 1209/10/2009RG000282, Paper number 2009RG000282

[9] Haigh J., Solar influences on Climate, Imperial College London Grantham Institute for Climate Change Briefing paper No 5, February 2011

[10] Şerban C., Vişa I., Eftimie E., Coste L., Energy Simulation of a Building in Braşov Urban Area, Proceedings of 26th European Photovoltaic Solar Energy Conference and Exhibition, Hamburg, Germany, September, 2011.

[11] Marcu V. , The climatic features of Braşov tourist area, Proceeding of the International Conference BIOATLAS, Transilvania University of Braşov, Romania, 2010, 127-38.

[12] www.meteoromania.ro - The National Meteorological Administration.

[13] Eftimie E., Estimating Clear Sky Solar Radiation Using Linke and Ångström Turbidity Coefficients in Romania. Journal of Energy and Power Engineering 5, USA, 2011, 29-41,.

[14] http://www.meteotest.ch

[15] Şerban, C., Eftimie, E., Coste, L., Simulation Model In Trnsys Of A Solar House From Braşov, Romania, Renewable Energy and Power Quality Journal, 2011:9

[16] Klein S.A.,et al., TRNSYS 16, A transient System Simulation Program, University of Wisconsin Solar Energy Laboratory, Madinson, USA, 2006.