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The suitability of high resolution downscaled seasonal models for the energy assessment of the building sector

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ABSTRACT

The present work attempts to provide more accurate estimate of HDD and CDD and investigates the suitability of high resolution downscaled seasonal climatic forecasting models for assessing and accurately estimating the energy demands of buildings. The analysis has been established through a series of indices for estimating heating (HDD) and cooling degree days (CDD) using interpolated hourly data which were produced from the model output. The work has considerable potential to provide refined inputs for assessing building sector-specific vulnerability to climate change: energy supply and demand.

In this work the application of the above mentioned methodological approach in the assessment of the energy performance and requirements of buildings on Greece are presented, for a period and with a forecast horizon of 6 months. The ARW-WRF model has been set up and validated to produce downscaled climatological fields for Greece, forced by the output of the CFSv2 model, with a horizontal spatial resolution of 5 km × 5 km. The data, that covered all Greek regions and climatology zones according to the existing building regulations code and the region elevation present a very reasonable correlation with data published in previous studies.

1. Introduction

The socioeconomic impacts of climate change on buildings and infrastructures make the need for resilience and adaptation measures urgent and critical. Climate impacts vary across the EU depending on the location, the seasonal patterns, the territorial settings (e.g. urban/rural/coastal), the existing adaptive capacity and resilience, and the level of economic development of each region. Climate related impacts, such as an increased frequency of extreme weather events or changing air temperatures have denoted effects on energy production, distribution and demand, especially for anthropogenic activities.

The Mediterranean region is generally acknowledged to be a very sensitive region to climatic pressures (e.g. IPCC AR4 report: http://https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf, UNEP/MAP: http://www.unepmap.org/index.php and http://www.eea.europa.eu/data-and-maps/data-providers-and-partners/united-nations-environment-programme-mediterranean) being located at the intersection of the desert climate of Africa and the European continental climate. The complicated topography and strong sea-atmosphere interactions give rise to many small scale features and local patterns which require particular consideration and the application of downscaling modelling frameworks. The economic activity in the majority of the Mediterranean countries is heavily influenced by the climate conditions and climate deviations from normality are expected to significantly influence the lives of millions of exposed people. As current estimates (JRC PESETA I (2009) and PESETA II (2014) projects: http://ftp.jrc.es/EURdoc/JRC55391.pdf and http://peseta.jrc.ec.europa.eu/) put climate impact costs to the order of billions of Euros, the detailed analysis of the costs and benefits of adaptation will be an extremely useful decision support tool in deriving timely and accurate actions.

Climate change is expected to impact directly on energy demands of residential and commercial sectors as their heating and cooling needs are highly connected to temperature conditions and variations. Weather-related factors play an important role in affecting electricity consumption. For many years, utility companies and the electric power industry have been interested in the relation between energy consumption and climate, and have developed empirical weather normalization algorithms aimed at improving load forecasting subject to variations in regional climate. Many of the studies that have investigated the sensitivity of electricity

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consumption to weather have focused on short-term load forecasting. According to International Energy Agency data in 2004, one third of all energy used is consumed by households, and in temperate regions, more than half of this energy is used for heating. Space cooling is currently a much less important energy use but it is growing rapidly both in high income countries and in emerging economies, such as India and China. Heating and cooling are also an important energy use of commercial and service sector. Numbers of studies [1–5] have attempted to predict residential and commercial building energy consumption. The general relationship between temperature change and heating and cooling related requirement is also connected to anticipated changes in heating and cooling degree days [6].

According to Eurostat the annual energy consumption for a Greek household is equal to 61 GJ (Giga Joule) or 1.46 Toe (equivalent oil quantity). Greek households consume 30% more energy than Spain, almost the double energy of Portugal and equal amount of energy with Netherlands and more energy than Belgium or Czech Republic, countries which are much colder than Greece (Fig. 1). The building sector in Greece demands 36% of the total energy consumption. Buildings increased their energy consumption 24% during the period 2000–2005 reaching the amount of $3.58 \times 10^{+17}$ J (8.54 Mtoe). The mean household in Greece has 80 m^2 area with 2.8 habitants whereas the respective household in Netherlands has 100 m^2 area with 2.4 habitants. It is more convenient to compare the energy consumption in m^2 or m^3. The energy in Greek households refers mostly to thermal uses. The thermal energy consumption of a household in Greece is more than Denmark, Germany or even Great Britain. In addition, the energy consumption in Greek offices is bigger with a great difference from other European countries [7].

In the middle of the energy, economic and environmental crisis period, accurate calculation of energy requirement is more than urgent. The precise estimation of the building related climatic parameters, such as heating and cooling degree days, can result in considerable improvement of the energy requirements in buildings and the cost benefit analysis of viable economic alternatives (e.g. heating, cooling, hot water, and lighting) for example by using passive or thermal insulation. The innovative element of this work is the application of a very high resolution downscaled regional model that would improve the knowledge base and modelling capacity for minimizing the uncertainty surrounding several key factors that influence the climate impact on building energy requirements.

The present work establishes a consistent and extensive bottom-up framework for assessing building sector-specific vulnerability to climate change: energy supply and demand. More specifically, it elaborates on the above mentioned concept targeting the application of downscaled seasonal models for estimating energy performance of buildings in Greece. The modelling system has been tested for two different simulation periods, up to 6 months in the future, with very high spatial resolution that provides an improved assessment of heating and cooling degree days.

2. Literature review of degree days

The commonly used method for the correlation of climate change with the buildings energy consumption is the concept of degree days (DD). This method can be applied to heating and cooling systems for a better management of environmental, economic and energy crisis. The heating degree days (HDD) or cooling degree days (CDD) are usually calculated from the application of simple calculations in order to define the difference of ambient air temperature with a pre-defined base temperature.

Similarly, a heating or cooling degree hour (HDH–CDH) is the difference between a specified base temperature and the average ambient air temperature for the hour. The energy needs in the building sector for cooling and heating are proportional to the number of CDD and HDD, respectively. Due to the heat urban island phenomenon in large cities different energy needs appear for the same type of building even between adjacent areas of the city. It is also advisable to take into account local weather conditions data and not an average database throughout the city. Many different data sets and methodologies have been developed and applied for the evaluation of degree days. The following mentioned equations and the notation of the variables have been directly adopted from the researchers in order to keep stable the symbols and the meaning on purpose.

The estimation of energy consumption for simulating energy behaviour of buildings either use data derived from the monthly average dry bulb temperatures, according to the ISO 13790 method [8], the heating and cooling degree-days at various base temperatures, according to the variable-base degree-days method [9,10] or,

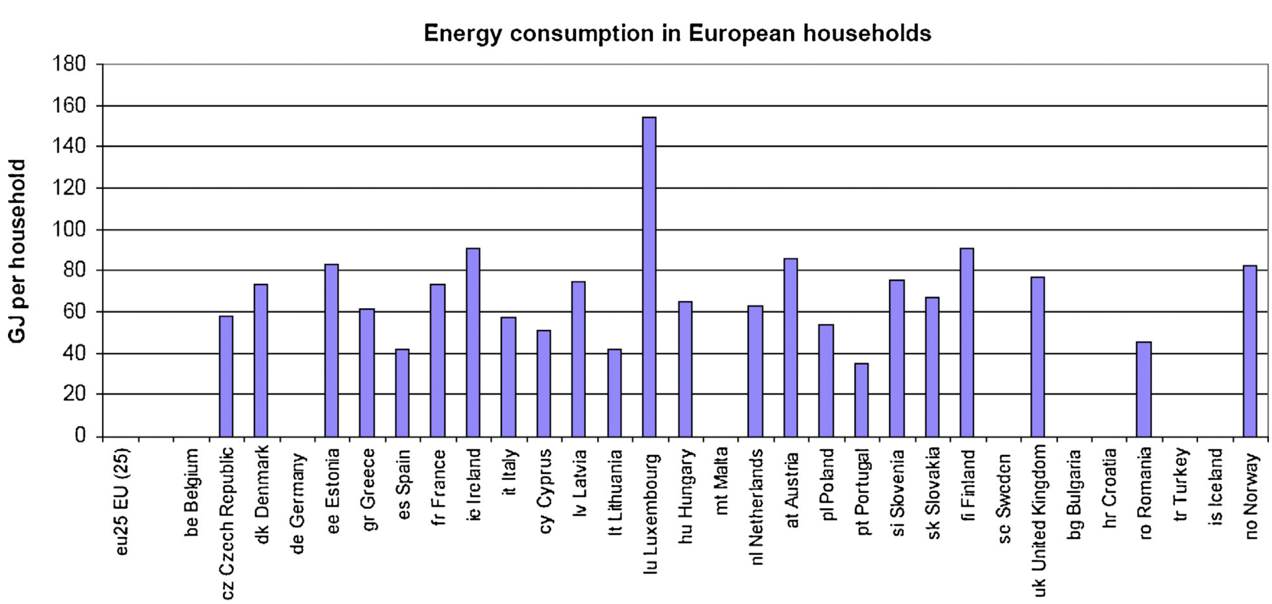

Fig. 1. Eurostat: energy consumption in households and number of households combined [1].