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Developing the energy profile of mountainous areas

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ABSTRACT

The quantification of the increase of energy needs with altitude is undertaken in this paper, in an attempt to highlight the greater vulnerability of mountainous areas to energy poverty. Three different cases have been studied, namely, Austria, Switzerland and north Italy, by applying the method of degree days. The results show that in mountainous areas of little but not insignificant latitudinal variation, such as a country level or a large region within a country which is the usual scale in terms of energy policy, heating and cooling degree days can be predicted based only on altitude, with over 90% accuracy. For this reason, mathematical models – as simple functions of altitude – are suggested, estimating heating and cooling energy demand in a simple and reliable way. As an example, a typical residence at 1200 m in Switzerland has 2 times higher thermal energy needs and a longer heating period by 5 months, compared to the altitude of 200 m. Therefore, mountainous societies are more exposed to energy poverty compared to lowlands and energy policy measures (e.g. subsidies, taxes of fuel prices) should be adapted to their special needs.

1. Introduction

1.1. Energy poverty and energy demand in mountainous areas

Global energy demand is constantly increasing in recent years and is expected to grow by nearly one third between 2013 and 2040, along with the central World Energy Outlook scenario [14]. Moreover, despite the rapid drop in global oil prices between 2014 and 2015, and, on a smaller scale, in natural gas and coal prices, fossil fuel prices are expected to rise again in the future [15]. This trend leads to worsening the energy/fuel poverty problem, which is “the condition wherein a household is unable to access energy services at home, up to a socially and materially necessitated level” [6]. According to other approaches for the energy problem, it is claimed that energy/fuel poverty “is caused by a complex interaction between low income and domestic energy inefficiency” [12], or that energy poverty “has a strong correlation to how it is actually measured” [32]. The differences appearing in the various definitions of energy poverty have risen mainly “due to the lack of a universally accepted measure of what is the amount of energy needed to meet one's basic human needs” [30]. In any case, whatever is the way of measuring energy poverty, when fuel/energy prices are high, households living in energy inefficient dwellings and/or on low incomes may not be able to sufficiently meet their energy needs.

Apart from the economic-social aspect, energy poverty (along with the closely related problem of indoor air pollution) has evolved into a serious public-health problem, related to excess winter deaths, physical diseases, circulatory and respiratory problems and mental disability [4]. According to WHO [35], indoor air pollution was responsible for 4.3 million deaths, caused by strokes, ischaemic heart diseases, acute lower respiratory infections in children, chronic obstructive pulmonary diseases and lung cancers. As a result, indoor air pollution (as well as outdoor) has been characterized as the world's “largest single environmental health risk” [34].

The problem of energy poverty seems to be more intense in mountainous areas, compared to lowlands. A recent research showed that mountainous areas in Greece have common characteristics, such as lower temperatures, older building stock and lower incomes that make them highly vulnerable to energy poverty on an ongoing basis, compared to urban areas [22]. Moreover, the factor of isolation of mountainous areas and the high cost of remote energy grids has been noted in several references globally (e.g. Ref. [17]). For the case of Greece, Katsoulakos and Kaliampakos [21] report that gasoline and diesel oil prices in isolated mountainous

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regions, are about 5–7% higher, compared to the average prices in the country.

Recognizing the special features of mountain and lowland societies as well as the differentiation of their actual energy needs are the basic steps for a specialized energy policy. However, research on energy demand in mountainous areas mainly remains at a qualitative level. Some references with quantitative data have been detected in recent years but most of them are based on measurements of fuel consumption, focused mainly on poor or developing countries. For example, Bhatt and Sachan [2] studied the firewood consumption of households along an altitudinal gradient in India while a similar work was performed a few years later in another district of India [24]. Cai and Jiang [7] studied differences in energy consumption between remote, mountainous areas and urban areas in China. Quantitative results are also detected in other works, such as the work of Johnson and Bryden [18] about energy supply and use in an isolated rural village of West Africa, or that of Ahmed et al. [1] about energy consumption in Pakistan. Meng et al. [28] performed a questionnaire survey on living environment and on energy consumption in the west provinces of China, recording high thermal losses of buildings and increased energy needs. However, there is absence of systematic knowledge about quantitative calculation of energy demand in mountainous areas.

A well-known index of energy demand is degree days. Therefore, an effective methodological tool for approaching the issue of energy needs with respect to altitude is the study of the variation of degree days with respect to altitude. A few references dealing with the issue of degree days' correlation with altitude have been detected. Büyükalaca et al. [5] demonstrated that heating degree days increase versus altitude for the case of Turkey whereas no correlation between them was found for the case of cooling degree days. Matzarakis and Balafoutis [27] calculated heating degree days for the case of Greece and indicated that higher altitudes have higher heating requirements. Borah et al. [3] calculated HDD (heating degree days) and CDD (cooling degree days) for different climatic zones in North-East India and showed that warmer climatic zones (at low altitudes) have higher annual CDD values, so higher demand for cooling, whereas colder climatic zones (at high altitudes) present higher HDD values and higher heating demand.

The first systematic approach on the issue was presented by Katsoulakos and Kaliampakos [21] who highlighted the vital role of altitude in heating and cooling degree days for the case of Greece, supplemented with specific quantitative data. The results of this work showed that heating degree days are linearly related to altitude with a coefficient of determination (R^2) of 86%, while they are less correlated to other variables examined (latitude, longitude, solar radiation and distance from the sea). Cooling degree days proved to be statistically correlated only with altitude while not following a discrete trend line – noting that the linear model also gives a good coefficient of determination (R^2), equal to 78%. Following the above work, Katsoulakos and Kaliampakos [23] verified the crucial role of altitude in heating/cooling degree days, through an energy optimization model performed for the case of Greece.

As arising from literature review, it is not widely understood that mountainous areas are hardest hit by the energy poverty problem. The research field concerning heating and cooling energy demand in mountainous areas is most often based on empirical findings, such as the lower temperatures and the higher thermal loads. Yet, there are sporadic references showing that higher altitudes present higher HDD values and, therefore, higher thermal energy needs but the quantitative specification of the increase is still missing.

Therefore, there is a knowledge gap concerning the quantification of the impact of altitude on energy needs and, subsequently, on the energy poverty problem. Through this research, the increase of energy needs with respect to altitude is quantified, revealing the greater vulnerability of mountainous areas to energy poverty and pointing out the need for a specialized energy policy in mountainous regions. Three developed mountainous regions have been studied, namely the countries of Austria and Switzerland and the region of north Italy, in order to extend the conclusions to real-scale cases, since there is also a serious lack of knowledge about energy demand variations within developed areas. In the context of the theoretical framework developed, mathematical models determining heating and cooling degree days, and therefore energy demand, are provided for the cases under study, transforming the outcomes into useful energy policy tools.

1.2. Mountain policy framework in Europe

According to Nordregio [29], the majority of mountainous or hilly countries have some type of mountain policy or a policy line for relevant matters, presenting main differences though, from one country to another. In general, four different types of mountain policies can be identified throughout European countries, as stated by Nordregio [29]:

- Countries without any energy policy, involving countries with no mountains at all (e.g. Denmark, Malta, Estonia, Netherlands Latvia, Lithuania), countries with very few or low mountains (e.g. Luxembourg, Ireland, Belgium) and countries which are mountainous, as a rule (e.g., Greece, Slovenia, Norway).
- Countries where mountain policies/measures refer to a specific domain, which is usually agriculture, tourism and environment (e.g. Portugal, Hungary, Slovakia).
- Countries where mountain policies/measures refer to a broader domain of development, including agriculture, other economic fields (tourism), environment and public infrastructure (e.g. Germany, Austria, Spain).
- Countries where mountain policies/measures refer to a total, integrated development. In some countries, such schemes appeared before the 1970s, where particular domains of development began establishing (e.g agriculture) and certain tools began applying, such as mountain laws and mountain funds. For the time being, three countries have an official mountain policy: Switzerland, France and Italy. There are some others, as well, such as Romania and Bulgaria, which tend to approach the main line of the above integrated mountain policies, not being supported though by an official legislation.

Regarding the first of the three regions examined, Austria is included in the third category of mountain policy, with a fairly integrated policy for several schemes (e.g. for agriculture by 1960, for global development by 1975). Specifically, in 1979, the Federal Chancellery introduced the “Mountain Area Special Initiative”, which was later renamed as the “Initiative for Endogenous Regional Development”, in 1985. Austria is one of the few cases wherein legislation addresses precisely mountain agriculture and not agriculture, in general, with the example of the “Mountain Farmers' Special Programme”, which was introduced in 1972.

Switzerland and Italy are included in the fourth category of mountain policy, with a fully integrated policy for mountain areas. The Swiss “LIM” (Law on Investment in Mountain Regions) was ratified in 1974 while the current Italian “Mountain Law” was enacted in 1994. Besides, Italy includes further long-standing mountain schemes, as mountain special features have been acknowledged since 1948 and “Mountain Communities” have been established since 1971.