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A cooperative net zero energy community to improve load matching

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ABSTRACT

The work reported here addresses load matching improvement in Net Zero Energy Buildings (Net-ZEBs). The related relevant literature shows that currently research work is mainly focused on improving the load matching of individual buildings. In this paper the concept of a Cooperative Net Zero Energy Community (CNet-ZEC) is introduced, extending discussion to the enhancement of load matching at a wider community level. Both building and community levels are compared in order to assess the work proposed here, through the analysis of three distinct scenarios where five Net-ZEBs work individually or in community.

The results presented here were obtained through a detailed simulation based on 1-min resolution stochastic load profiles and recorded weather data. The results indicate that over the period of a year the CNet-ZEC has the potential to increase the electrical demand covered by onsite electricity generation up to 21% and the on-site generation that is used by the building up to 15%. The following elements are considered by the CNet-ZEC in order to produce those results: (i) demand heterogeneity of the buildings integrating the community; (ii) the higher number of controllable devices; and (iii) the potential higher amount of energy available to satisfy the community demand.

1. Introduction

1.1. Background and motivation

Buildings are a main topic in European Union's (EU) energy efficiency policy, as nearly 40% of final energy consumption and 36% of greenhouse gas emissions are in houses, offices, shops and other buildings [1]. Therefore it is mandatory to improve the energy performance of European building stock to: (i) reach European Strategy for Energy and Climate Change objectives [2], and (ii) meet the longer term objectives of EU climate strategy to restrict global warming due to human-related CO_2 emissions to less than 2 °C [3].

In Europe, a legal framework is already in place aimed at improving the energy efficiency of buildings, which includes the directive 2010/31/EU on the energy performance of buildings [4]. Regarding Net Zero Energy Buildings (Net-ZEB), that directive targets 31st December 2020 as the horizon when all new buildings shall be nearly Net-ZEBs. Similar policies were also adopted in other developed countries, e.g. USA and Canada [5,6].

Although several different definitions of Net Zero Energy Buildings are found in the literature, there is a common understanding that the Net-ZEB concept regards a building that, over a certain period of time (typically one year), has a neutral energy balance (i.e. it produces as much energy as it consumes from the supply grid) when certain energy efficiency measures are implemented. Once the renewable energy produced on-site is governed by the availability of the respective primary energy source, there is often a mismatch between the local generation and the Net-ZEB demand [7]. This mismatch might impose a negative impact on the performance of the electrical grid at high penetration levels of the Net-ZEB concept, such as voltage fluctuations [8].

The importance of taking into account the match between the Net-ZEB's on-site energy production and its demand is highlighted by new policies encouraging self-consumption of on-site generation. For example, Portugal approved new legislation for distributed generation allowing self-consumption and the exporting of surplus energy [9]. In Germany, between 2009 and 2012, there was a special rate for self-consumed electricity, besides the traditional feed-

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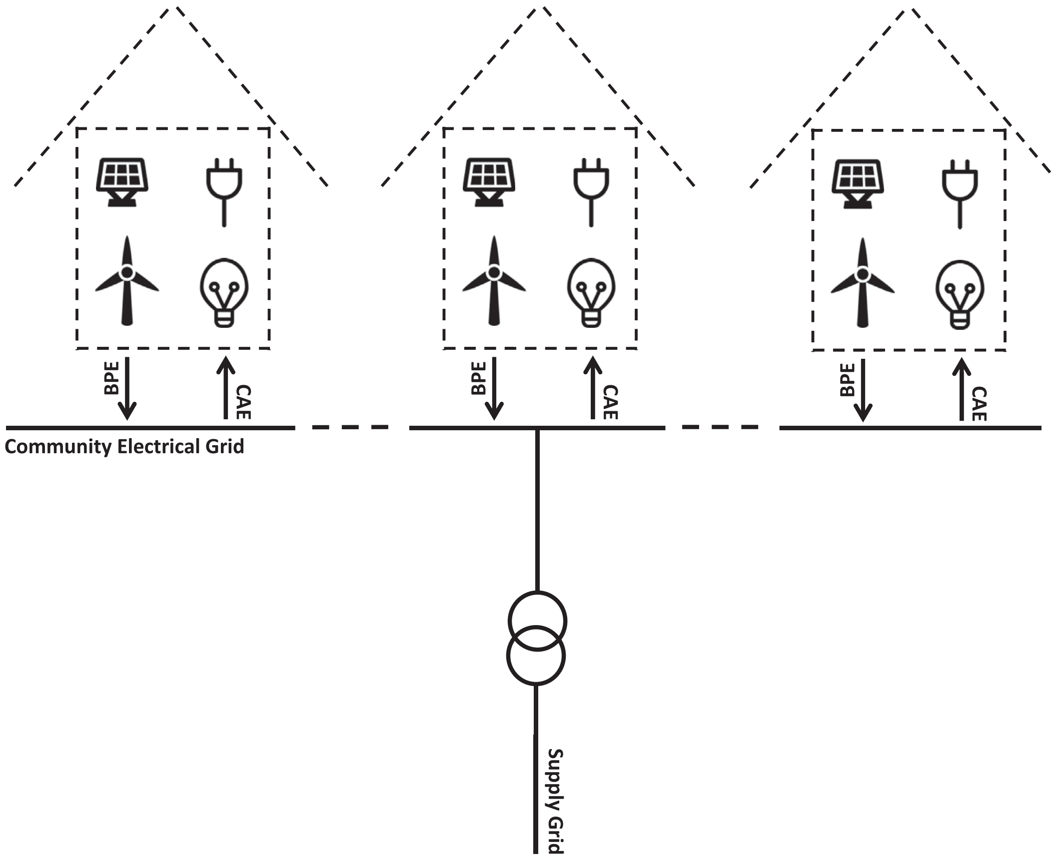

Fig. 1. Cooperative Net Zero Energy Community: general overview.

Table 1
Summary description of scenarios used.

Scenario	Level	Description
1	Building	This is the baseline scenario. Buildings work individually and their electricity demand profile is not modified by the DSM method.
2	Building	In this scenario buildings act independently, as in scenario 1. However, the electricity demand profile of a specific building is modified by the application of the DSM method without taking into consideration the demand profile of other buildings. The operating times of the controllable devices are shifted by the DSM method to periods that maximize load matching of the particular building.
3	Community	All buildings work as a cooperative net zero energy community. The DSM method is applied to shift the operating times of all controllable devices to periods that maximize CAE consumption.

in tariffs. This special rate was abandoned because feed-in tariffs had become so low by 2012 that they provided a natural support for self-consumption [10]. In all electricity markets that lack net-metering or feed-in support, and where retail prices are higher than wholesale prices, a high match between production and consumption is automatically promoted [11].

1.2. Current options to improve load matching

The number of studies on load matching improvement has increased rapidly in recent years. These studies often refer to load matching as self-consumption and are mainly focused on buildings with Photovoltaic (PV) systems. Three different approaches have been studied to improve load matching: 1) energy storage [12–30]; 2) Demand Side Management (DSM) [31–35]; and 3) a combination of energy storage and DSM [36–43]. Improvement rates reported in the literature are promising but defined in distinct conditions (e.g. size of the on-site energy generation system, storage capacity, and time-resolution used on the simulation), which makes the comparison between different studies difficult and sometimes highly subjective.

Energy storage approaches use solid state batteries [19–30], hydrogen storage tanks [14], and thermal storage [12] [13] [15–18]. Solid state batteries and hydrogen storage tanks are each used to improve self-consumption by storing surplus generated energy and later allowing the consumption of this stored energy to reduce the imports when the on-site generation from renewable sources is insufficient to meet the building's demand. Regarding the thermal storage, it is normally used to anticipate the energy consumption of a certain electrical device (e.g. air-conditioner, electrical water tank or heat pump), using the thermal properties of the device itself or the respective building to reduce the import of energy later.

While there is no single definition for DSM, a common concept is that it relates to a range of measures to improve the energy system from the demand side [44]. Literature reports that methods based on DSM normally improve load matching by rescheduling the demand of electrical devices (e.g. washing machines, clothes dryers, and dishwashers) to periods with a generation surplus