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Implications of weighting factors on technology preference in net zero energy buildings

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ABSTRACT

With the current movement towards Net Zero Energy Buildings (Net ZEBs) decisions regarding energy carrier weighting factors will have implications on which technologies could be favoured or disfavoured, and therefore adopted or not adopted, in the building sector of the near future. These implications should be taken into consideration by policy makers when developing legislation and regulations addressing the building sector. A parametric analysis was conducted on six buildings in Europe of different typologies and climates in order to assess how different weighting factors would impact the choice of technical systems to be installed. For each combination the amount of PV capacity necessary to achieve a net zero balance has been calculated and used as the main indicator for comparison; where less PV area means more favourable condition. The effect of including a solar thermal system is also discussed. With the current European national weighting factors, biomass boiler is largely the preferred solution, frequently achieving the balance with PV installed on the roof, while gas boiler is the most penalized. The situation changes when strategic weighting factors are applied. Lower weighting factors for electricity and district heating, e.g. reflecting national targets of increased penetration of renewables in such grids, would promote the use of heat pump and district heating, respectively. Asymmetric factors aimed at rewarding electricity export to the grid would facilitate the achievement of the zero balance for all technologies, promoting cogeneration in some cases. On the contrary, low weighting factors for electricity, e.g. reflecting a scenario of high decarbonisation of the power system, prove quite demanding; only few technical solutions would be able to reach the balance within the available roof area for PV, because of the low value credited to exported electricity. In this situation, the preferred solution would be heat pumps combined with solar thermal. In addition, the choice of weighting factors and the resulting favoured technologies will determine the temporal matching of load and generation. While all-electric solutions tend to use the grid as seasonal storage, other solutions will have a yearly net export of electricity to the grid to compensate for the supply of other (thermal) energy carriers. Therefore, it is important to consider the implications for the electricity grid resulting from the choice of weighting factors.

1. Introduction

The need to reduce greenhouse gas emissions and use of depleting fossil energy resources highlights the importance to improve the performance of buildings, one of the major contributors of carbon dioxide emissions and energy consumer sectors. Within this context, the EU Directive on Energy Performance of Buildings (EPBD) requires all new buildings to be nearly Zero Energy Buildings (nearly ZEB) by 2020 [1]. However, despite the current emphasis, a clear definition of the ZEB concept is still lacking. The International Energy Agency (IEA) project ‘Towards Net Zero Energy Solar Buildings’ [2] has been focusing on the multisided nature of Net ZEBs, listing its characterizing aspects and the several options available to policy makers when establishing a (national) Net ZEB definition

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[3–5]. The wording 'Net' is used in the mentioned literature, and adopted in this article, to emphasize the fact that buildings are connected to energy grids with which they exchange energy. The annual balance (whether zero, nearly zero, or positive) is therefore given by a net accounting of energy imported from and exported to the grids. In addition to assessing the balance, significant effort has been carried out to characterize Net ZEBs temporal matching of load and generation, and consequently the interaction of the building with the energy grids leading to the proposal of several indexes [5–10].

Generally, a Net ZEB is obtained by energy conservation and efficiency measures coupled with renewable energy generation. Each Net ZEB definition includes a specific methodology to calculate the building energy balance; see Sartori et al. [5] for detailed discussion. Marszal et al. [6] and Voss et al. [11] present a comprehensive overview of the calculation methodology options available. In particular it is important which metrics is adopted to express the balance (e.g. primary energy, carbon emissions) and which conversion factors are applied to the various energy carriers. In Sartori et al. [5] the term weighting factor is introduced, because it includes political/strategic factors that are actually not a real conversion between final and primary energy, but more a way to express the relative 'weight' of an energy carrier compared to the others. In this article the term "weighting factor" is therefore adopted.

Choice regarding the weighting factors may lead towards a reduced number of feasible or favoured building energy system solutions,[1] as shown in Beerepoot and Beerepoot [12] and Sartori et al. [13]. Sartori et al. [13] assessed the implications that a specific definition (both for primary energy and carbon equivalent emission) with defined weighting factors has on the investigated heating systems for typical Norwegian houses. Kurnitski et al. [14] investigated the energy performance and cost optimality of different construction and technical systems, reporting the lowest total primary energy consumption for heat pump, based on Estonian current national weighting factors. In Ecofys [15] a large number of building energy systems are analyzed (together with building envelope and ventilation system variants) for different building types and climates; but the weighting factors are fixed. To the best of our knowledge, no study has systematically investigated the influence that different weighting factors have on the choice of energy systems for a range of building types in different climates.

This paper investigates the influence that different weighting factors, both currently used factors and strategic ones, may have on the selection of different building energy systems. A parametric analysis is conducted on a variety of buildings and technical system configurations in several countries, using the size of photovoltaic (PV) system required to reach the zero balance of either primary energy consumption or CO_2 emissions for comparison. Additionally, the temporal match between load and generation in the various cases is analyzed.

2. Methodology

A parametric analysis was performed on six European case studies of different typologies and climates to assess the impact of policy decisions, namely the weighting factors, on the technologies that may be favoured or discouraged. These cases represent typical Net ZEBs designed in Europe and were chosen as required information and data were available to the authors. In this paper the impacts of the weighting factors were investigated. The paper refers to different choices in the weighting factors as "weighting options", while different building energy systems are called "technical solutions". The combination of the two is addressed as "combination" in the following of this paper.

2.1. Calculation tools

The calculation method adopted in this paper is the balance between load and generation, as described in Sartori et al. [5]. This consists of the annual balance between on-site energy generation, and energy demand, i.e. all consumption purposes such as heating, cooling, domestic hot water, ventilation, auxiliaries, built-in lighting and plug loads, including the system efficiencies. The energy demand was treated as given input when evaluating the different combinations. Data for energy demand and generation for each case study were obtained from simulations using appropriate tools fulfilling current national regulations according to the buildings location. In this way, it was possible to evaluate the expected impact of simulation tools widely used in the different countries. Both primary energy and carbon equivalent emissions were analysed using simulated monthly data. These represent the most common calculation methodologies applied in building codes as indicated by [6]. Finally, all case study results were collected and compared using the "Net ZEB evaluation tool", an excel based tool developed within the above mentioned IEA project, freely downloadable together with its user manual [2].

The two German case studies "Die Sprösslinge" and "Kleehäuser" were calculated with the Excel based tool "EnerCalC" [16]. EnerCalC enables a building characterisation in terms of its energy use (usable energy, final energy and primary energy) and shows energy performance requirements for a building to be balanced in accordance with the German calculation regulation DIN V 18599. Furthermore, the program enables simplified static primary energy and carbon emission balancing in monthly resolution and provides information for designing the respective building as a Net ZEB according to the balance methodology of the above mentioned IEA evaluation tool. A breakdown of different energy uses (heating, cooling, ventilation, domestic hot water, lighting) is possible as well as the input of monthly loads for additional consumers (e.g. appliances, IT, central services).

The calculations for "EnergyFlexHouse" were performed with the Danish calculation tool Be10 [17], which is the official tool for building compliance with the energy requirements in the Danish Building Regulations. Be10 is a steady-state calculation tool based on mean monthly calculations. Be10 is mainly based on EU standards EN 13790, 15316 and 15193-1 and includes calculation of energy production from Solar Thermal (ST) collectors and PV but not Combined Heat and Power (CHP).

The Spanish case study "Circe" was mainly calculated with the tool "Calener GT", which is the official software tool provided by the Spanish government to perform the energy certification process. The tool is used for big tertiary buildings and is based on hourly simulations to determine the energy use (heating, cooling, ventilation, domestic hot water, lighting and auxiliary). Calener GT leaves equipment and appliances energy use outside the balance and some form of on-site renewable energy are considered in a simplified way. Details of Calener GT compared with other energy performance evaluation systems can be found in Cubi and Salom [18]. The monthly energy generation from renewables were computed with other tools based on hourly simulation: TRANSOL [19] and PVSyst [20].

The Swedish case studies "Glasbruket" and "Väla Gård" were calculated using VIP Energy [21] which is a dynamic calculation tool, validated with: IEA-BESTEST, ASHRAE-BESTEST and CEN-15265. The tool is widely used in Sweden and to some extent in other Nordic countries. Simulations are based on hourly time step to determine the energy use (heating, cooling, ventilation, domestic hot water, lighting and auxiliary). VIP Energy enables to model

[1] Combination of heat (co)generation system, w/o solar thermal, and PV system.