Net Zero Energy Buildings - Calculation Methodologies versus National Building Codes

Anna Joanna Marszal[1*], Julien S. Bourrelle[2], Eike Musall[3], Per Heiselberg[1], Arild Gustavsen[2] and Karsten Voss[3]

[1] Aalborg University, Department of Civil Engineering, Sohngaardsholmsvej 57, 9000 Alborg, Denmark

[2] Norwegian University of Science and Technology, Department of Architectural Design, History and Technology, Alfred Getz vei 3, NO-7491 Trondheim, Norway

[3] Bergische Universität Wuppertal, Department of Architecture, Building Physics and Technical Services, Haspeler Straße 27, 42285 Wuppertal, Germany

[*] Corresponding Author, ajm@civil.aau.dk

Abstract

The international cooperation project IEA SHC Task 40 / ECBCS Annex 52 “Towards Net Zero Energy Solar Buildings”, attempts to develop a common understanding and to set up the basis for an international definition framework of Net Zero Energy Buildings (Net ZEBs). The understanding of such buildings and how the Net ZEB status should be calculated differs in most countries. This paper presents an overview of Net ZEBs energy calculation methodologies proposed by organisations representing eight different countries: Austria, Canada, Denmark, Germany, Italy, Norway, Switzerland and the USA. The different parameters used in the calculations are discussed and the various renewable supply options considered in the methodologies are summarised graphically. Thus, the paper helps to understand different existing approaches to calculate energy balance in Net ZEBs, highlights the importance of variables selection and identify possible renewable energy supply options which may be considered in calculations. Finally, the gap between the methodology proposed by each organisation and their respective national building code is assessed; providing an overview of the possible changes building codes will need to undergo in the coming years.

1. Introduction

Energy use in the building sector accounts for about 40% of world’s final energy use and 33% of direct and indirect greenhouse gas emissions [1]. This fact together with the issue of climate change and the growing energy resource shortage results in Net Zero Energy Buildings (Net ZEBs) being no longer perceived as buildings of a remote future, but as a realistic solution for the mitigation of the CO_2 emissions and/or the reduction of energy use in the building sector. In May 2010 at European level the European Commission and Parliament adopted the recast of the Directive on Energy Performance of Building [2] with “Nearly Zero Energy Building” as the future target for buildings:

> *“by 31 December 2020, all new buildings are nearly zero energy buildings as defined in Article 2(1a),*
>
> *after 31 December 2018, public authorities that occupy and own a new building shall ensure that the building is a nearly zero energy building (...)”*

The increasing number of Net ZEB demonstration projects [3-9] and research interest in the field at both national and international levels [10-13] highlights the growing attention given to Net ZEBs. Currently, the international discussions mostly focus on the lack of common understanding for this building concept [14-16]. Energy calculation methodologies are also part of these discussions where the actors attempt to agree on: how to account for the energy use, the energy generation and the building - grid interaction? Until now, the buildings were solely responsible for consuming energy. Net ZEBs are both energy consumers as well as energy producers, which interact with the national energy infrastructure. There is no agreed suggestion how to tackle this situation with respect to calculation methodologies and it appears that reaching a common agreement could be a challenging task.

Under the International Energy Agency (IEA) the implementing agreements Solar Heating and Cooling programme (SHC) and the Energy Conservation in Buildings and Community Services programme (ECBCS) a joint project Task 40 Annex 52: "Towards Net Zero Energy Solar Buildings" focuses one activity on investigating various approaches and/or methodologies for calculating energy in Net ZEBs. Organisations representing eight countries: Austria, Canada, Denmark, Germany, Italy, Norway, Switzerland and USA supplied their proposals for a Net ZEB energy calculation methodology. The actors from Germany and Austria delivered more than one methodology (2 x Germany and 3 x Austria) emphasizing the existence of multiple local approaches. All methodologies were assembled in order to study, recognize and understand different approaches for computing Net ZEB energy balance. As disposition for Net ZEBs are not explicitly included in any national building codes of the participating countries, the collected calculation methodologies merely reflect some of the common, known and applied practices in each country. They do not represent any national understanding of Net ZEBs calculation methodology.

Firstly, this paper aims to give a general explanation of the "known practice" for energy calculations of Net ZEB in each of the eight countries. The calculation methodologies represent the approaches from various location worldwide, thus the main focus will be put on exposing the similarities between the methodologies as well as highlighting the unique features of each methodology. Secondly, the paper presents the overview of the "gap" between the delivered "known practice" and the respective national building code/standard in each country.

2. Method

The methodologies for calculating energy associated with Net ZEBs are very different across the world. Therefore, the first step in this activity was to collect the various approaches respecting different perspectives of the problem. Within the IEA SHC Task 40 / ECBCS Annex 52 participants representing various organizations from eight countries supplied their "known practices" on energy calculation for Net ZEBs. All methodologies were analysed and merged together into one interactive excel-spreadsheet. Within this spreadsheet, a sheet dedicated to input data is linked to all the calculation methodologies, each having dedicated single sheet. The spreadsheet permits to test the energy performance of a building against each calculation methodology by entering data only once, easing the comparison of the methodologies.

The excel spreadsheet was distributed among all eight participants in order for them to become familiar with it and test known national Net ZEB projects against the other methodologies. Finally, the participants explained the differences between the "know practice" for energy calculation of Net ZEBs and their national building code.

3. Net ZEB calculation methodologies

This chapter provides an overview of the different calculation procedures with an emphasis on their similarities and peculiarities. As the general framework for energy is similar in each methodology, the aim here is not to present a complete description of each calculation methodology.

The study of the methodologies shows that the most accepted energy balance takes place between the energy use of a building and the renewable energy generation. This approach is favoured within all eight countries. However, within its first methodology proposed by the German representatives the balance is based on the building grid interaction, i.e. the energy delivered to the building from the utility grid has to be offset by the energy feed back to the grid. As for the period of the energy balance, all eight countries calculate it on an annual basis. Again the second Germany approach applies a month as the basis for the balance. The methodologies are not so unanimous on other issues related to the energy balance e.g. the type of energy use included or the unit of the balance. In nine out of eleven proposals (American, 3 x Austrian, Canadian, Danish, 1x German, Norwegian and Switzerland) the energy balance includes both the energy related to the building (heating, cooling, ventilation, lighting, pumps and fans, other technical service systems) and related to the users (DHW, cooking, appliances, lighting). The analysis of the methodologies indicates that primary energy is the most favoured metric for the balance (ten out of eleven methodologies). However, some other possibilities are also used e.g. delivered energy, CO_2 credits or energy costs. Furthermore, some methodologies include more than one unit for the energy balance, e.g. Germany, USA.

The calculation proposals represent the approaches from various locations worldwide. Thus, almost all of the methodologies present a set of unique features. For example, the American methodology is based on the hierarchy of renewable supply options created by the National Renewable Energy Laboratory (NREL) [17]. The Canadian methodology applies the Canada EnerGuide® Rating for Houses and EGH* rating system. The Swiss methodology accounts the embodied energy in the energy balance. In that case, there is a set limit of 25 kWh/m^{2}a for the embodied energy under which it is neglected in calculation but over which the difference between the actual embodied energy and the limit is taken into consideration in the calculations. The Danish proposal, aside the calculation of energy performance, indirectly evaluates also the indoor climate in the building by having a special output called "penalty for overheating". This special output represents the electricity demand of a fictive cooling system with a fixed efficiency of 2 that turns on automatically if the indoor temperature is above 26°C. The only way to control the cooling system is simply by trying to avoid the indoor temperatures above 26°C. The one German methodology focusing on the balance between imported and exported energy, gives the building owner the possibility to invest in an off-site windmill and to include part of the energy generated by the windmill into the energy balance of the building. Two of the Austrian proposals consider in the energy balance the effort of the whole energy production on-site.

3.1. Summary of energy supply options

The following chapter summarises the renewable energy supply options suggested in the various energy calculation methodologies. Fig. 1 presents the five supply options (I-V) ordered following the location of the energy supply option with respect to the building. In their calculation approaches, certain organisations highlight the importance of a hierarchy of supply options (i.e. that certain types of supply are preferable over others). However, no such hierarchy has been agreed upon and thus, the diagram presented here limits itself to order the supply options based on geographical parameters, i.e. the centre of the graph represents those options where the supplied energy is transformed into a useful form closest to the building. Some supply options presented here are fiercely debated internationally.

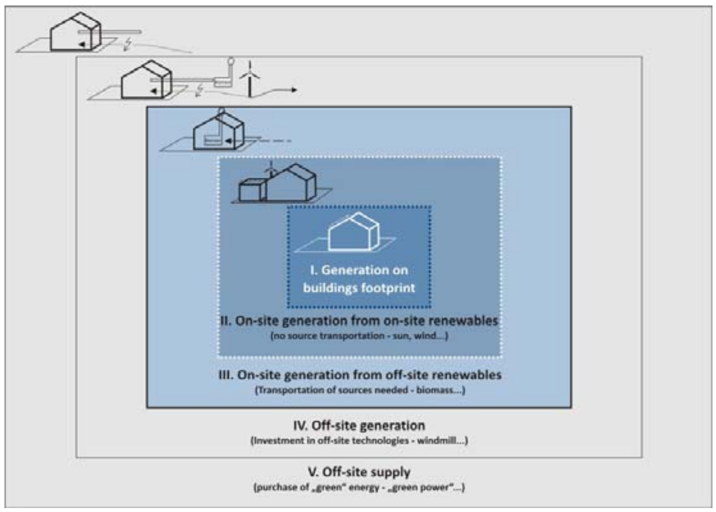

Fig. 1. Overview of current renewable energy supply options linked to common international practice for energy calculation methodologies for Net ZEBs.

Description of presented supply options:

I. Generation on building footprint: The generation of usable forms of energy takes place within the building footprint by transforming renewable energy reaching the building without effort, i.e. no effort is needed to transport the renewable energy to the building footprint (sun, wind, etc.).

II. On-site generation from on-site renewables: Same as I. but with generation taking place on the building site (i.e. the ground owned by the building owner which is directly adjacent to the building footprint).

III. On-site generation from off-site renewables: Renewables are supplied from outside the building site but the generation of usable forms of energy takes place on the project site, i.e. energy carriers need to be transported

IV. Off-site generation: Investment from the building owner in renewable energy generation plants located outside the project site. The energy produced by the plant is included in the energy balance of the building.

V. Off-site supply: Purchase of green energy from the grid.

4. Gap between methodologies and national building codes

As mentioned earlier, in those eight countries the concept as well as the calculation methodology of Net ZEB are yet not included in the building codes, thus there often exists a “gap” between the supplied “known practices” and the building codes. This chapter attempts to give an overview of those differences for the countries which provided the relevant information.

Norway

The proposed Net ZEB calculation methodology is in general in line with the building code having two differences. First, the metric used in the building code is final energy whereas the proposed methodology includes three metrics: the final energy, primary energy and emissions. Second, according to the building code the renewable electricity generated on-site is only accountable for compensating the annual electric specific load, while in the proposed methodology excess feed-in electricity is accounted for achieving the zero balance. Furthermore, no national scheme currently exists to regulate electricity feed-in tariffs, thus in each case the tariffs have to be agreed with the local electricity provider.

Switzerland

The major difference is the fact that the Swiss building code focuses only on the heating demand requirements as the Net ZEB methodology includes as well the demand for domestic hot water (DHW) and total electricity use. In the first step the DHW demand and electricity are based on fixed values depending on the building type given by the national Swiss code. The proposed Net ZEB calculation methodology is in line with the building code by computing the energy balance on the annual basis.

Germany

To date, no national, standardized methodology for balancing energy of Net ZEB exists in Germany. Hence, the current used practice focuses on the annual balance of energy delivered to the building and energy feed into the grid. Some actors include all consumption sectors, others exclude appliances and plug loads thereby addressing the building service technology only. Although widely applied, this methodology is not in line with the current building code.

The second German methodology reflects the official building regulation “Energieeinsparverordnung EnEV 2009”. The building code addresses all energy consumption for HVAC, DHW and lighting on a monthly level. On-site generated PV electricity can be subtracted from the on-site electricity load up to the limit of the monthly consumption. Surplus feeding in of electricity is neglected and considered as part of the grid. So, monthly excesses electricity can´t be balanced with demands of other months. It is not viable to balance non-electrical demands (gas or wood pellets) with self generated PV electricity and moreover to integrate other consumption sectors in the energy balance. A Net ZEB is not feasible considering this framework.

Austria

The proposed Net ZEBs calculation methodologies are not in correspondence with the national building code. First, since the building code defines only the methodology for calculating the energy demand of the building fully neglecting the possible on-site renewable energy generation issue. Therefore, in the supplied methodologies the methods for calculating the energy balance have no legal foundations. Secondly, the building code uses the final energy as the metric whereas the proposed methodologies are based on the primary energy. Furthermore, the delivered methodologies take into consideration the total energy demand of the building including household appliances. However, building code focuses for residential buildings only on the demand for heating, domestic hot water and auxiliary and for non-residential additionally on lighting and cooling.

Denmark

It can be said that generally the proposal for Net ZEB calculation methodology is in line with the national building code. There are two major differences: (1) types of energy use included in the energy balance, (2) the definition of the building site. For the first one, the energy performance framework for residential buildings in the building code covers the total demand for heating, ventilation, cooling and domestic hot water. The supplied calculation proposal goes a step further and takes also into account the energy for the household appliances and lightning in the energy balance. For the second difference, the renewable energy generation in the Net ZEB calculation proposal can take place within buildings footprint and on site that is directly adjacent to the building. However, in the building code the buildings site includes also the common area that is owned and shared between a cluster of buildings i.e. 10 residences that are constructed close to each other and share a common renewable system on a common site around the buildings.

Italy

It can be noticed, that the energy calculation proposal addressing Net ZEB generally is in line with the national building code. It is although recognized that the latter neglects some important aspects. In fact both the calculation procedures are based on primary energy and address heating, DHW, cooling, lighting and auxiliaries, neglecting e.g. the energy use for ventilation and appliances. With reference to the application of on-site energy generation, the building code takes into account possible PV and cogeneration systems in the balance. In spite of similarities the "known practice" clearly adopts the energy balance between the energy use and the electricity generation, the building code is ambiguous if the balance is between the delivered and feed-in energy or energy use and the electricity generation.

5. Discussion

The supplied Net ZEB calculation methodologies give a significant insight on different possibilities for writing the balance of Net Zero Energy Building. Most favoured is the balance between energy use and renewable energy generation. However, by adopting this balance a number of questions arise e.g. energy use refers to calculated energy demand or actual, measured energy consumption? What type of energy use is included in the balance: only the building related or as well the user related? How to include the building – grid interaction? Therefore, some researches state that for the Net ZEBs the balance between delivered and feed in energy more useable one and eliminates all the issues of how the energy is used in the building. Until now, the unambiguous answer, which balance is the right one maybe one is usable for designing phase and the second for the monitoring data, does not exist?

Fig. 1. presenting possible renewable supply options depicted by the different calculation proposals brings our attention to the question: how and where the renewable energy is produced. It can be noticed that the variety of possible options is wide, but none of the delivered Net ZEBs calculation methodologies explores all known options and even none of existing Net ZEB does it [9]. Moreover, some of the proposed methodologies even do not yet address the issue of various supply options. The opinions are divided, one claim that only building footprint and site should be used, others accept the

possibility of buying carbon credits in the carbon market in order to offset the energy use of a building. Even, the recent recast of the Directive on Energy Performance of Building [2] gives unclear answer to the above mentioned questions by stating:

> *"(...) energy from renewable sources, including energy from renewable sources produced on-site or nearby"*

6. Conclusion

This paper presented an overview of existing energy calculation methodologies for Net ZEBs together with the gap between these methodologies and national building codes. It also discussed which variables and what types of renewable supply options are taken into consideration in these calculations. From the information presented, it may be seen that some discrepancies exist between the different energy calculation approaches to Net ZEBs. Notably, how the different supply option are understood as pertaining to renewable or non-renewable energy supply option, i.e. how a "green grid" is taken into consideration. Finally, the paper provides some insight on how the international community sees Net ZEBs and how building codes might evolve to adequately include this type of building.

Acknowledgments

The work presented in this paper has been largely developed in the context of the joint IEA SHC Task40 / ECBCS Annex52: *Towards Net Zero Energy Solar Buildings*. The authors would like to thank all participants of Subtask A and especially: Sonja Geier, Igor Sartori, Monika Hall, Assunta Napolitano, Shanti Pless, José A. Candanedo, Søren Østergaard Jensen for supplying the proposals for the Net ZEB calculation methodologies and the overview of the "gap" between the "known practice" and the building code/standard.

References

[1] International Energy Agency (IEA), Energy Technologies Perspectives: Scenarios and Strategies to 2050, OECD/IEA, 2008, Paris.

[2] The Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, Official Journal of the European Union, 53 (2010)

[3] The Bolig+ project http://www.boligplus.org/

[4] Villa Åkarp http://greenlineblog.com/2009/02/villa-karp-a-positive-net-energy-house-in-malm-sweden/

[5] The International Energy Agency (IEA) Net Zero Energy Buildings Database http://iea40.buildinggreen.com/index.cfm

[6] M. Noguchi, A. Athienitis, V. Delisle, J. Ayoub, B. Berneche, Net Zero Energy Homes of the Future: A Case Study of the ÉcoTerraTM House in Canada, Renewable Energy Congress, Glasgow, Scotland, July 2008

[7] The Active House project http://www.activehouse.info/

[8] M. Heinze, K. Voss, Goal: Zero Energy Building - Exemplary Experience Based on the Solar Estate Solarsiedlung Freiburg am Schlierberg, Germany, Journal of Green Building 4 (4), Glen Allen, USA, 2009

[9] E. Musall, T. Weiss, A. Lenoir, K. Voss, F. Garde, M. Donn, Net Zero energy solar buildings: an overview and analysis on worldwide building projects, EuroSun conference 2010, Graz, Austria, 2010 – under review

[10] The IEA SHC Task 40 / ECBCS Annex 52 'Towards Net Zero Energy Solar Buildings (NZEBs)' http://www.iea-shc.org/task40/index.html

[11] The Strategic Research Centre on Zero Energy Buildings http://www.zeb.aau.dk/

[12] The Research Centre on Zero Emission Buildings (ZEB) www.zeb.no

[13] Zero Carbon Hub http://www.zerocarbonhub.org/

[14] A.J. Marszal, P. Heiselberg, (2009), A literature review of Zero Energy Buildings (ZEB) definitions, DCE Technical Report no. 78 ISSN 1901-726X, Aalborg University, Denmark http://vbn.aau.dk/da/publications/a-literature-review-of-zero-energy-buildings-zeb-definitions_da50db00-eaf6-11de-b63d-000ea68e967b.html

[15] I. Sartori, I. Graabak, T.H. Dokka, Proposal of a Norwegian ZEB definition: Storylines and Criteria, Renewable Energy Research Conference 2010, Trondheim, Norway, 2010.

[16] P.A. Torcellini, D.B. Crawley, Understanding zero-energy buildings, ASHRAE Journal 48, (2006) 62-69

[17] D. Crawley, S. Pless, P. Torcellini, Getting to net zero, ASHRAE Journal 51, (2009) 18-25