
1 Introduction

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1.1 Why another book on net zero energy buildings?

This book is the principal output of a major international research project under the auspices of the International Energy Agency (IEA) Solar Heating and Cooling (SHC) and Energy in Buildings and Communities (EBC) Technology Collaborating Programs joint *SHC Task 40/EBC Annex 52: Towards Net Zero Energy Solar Buildings* [1]. The focus of the project was to examine the performance in use of net-zero energy buildings (Net ZEBs) across the globe in order to understand the strengths and weaknesses of the design solution sets adopted. The fundamental contribution of the part of the project described in these pages was this examination of many different built and functioning buildings and the general lessons about Net ZEBs that can be drawn.

At heart therefore, this book is an examination of 30 case studies. These projects all aimed to equalize their small annual energy needs, cost-effectively, through building integrated heating/cooling systems, power generation and interactions with utilities. These buildings had to meet strict criteria for inclusion in this analysis, beyond merely being labeled by their designers or promoters as “green” or “energy positive” or “net-zero energy.” The most important among these criteria was the insistence that a minimum of one full year of metered performance data was available for analysis. In addition, the research team sought to identify buildings whose architecture and combinations of technologies formed “solution sets” which could potentially be useful exemplars for other design teams seeking to build a net-zero energy buildings.

The world of modern architecture has flirted for the past fifty years with idea of bioclimatic design and autonomous architecture. Too often these have been one-off exercises serving only a research agenda, and not integrated into the mainstream of architecture or society. As such, they have been incredibly useful learning vehicles, but have found little acceptance outside of a small world of academics and research scientists. The underlying concept of a Net ZEB is that it should be widely accepted and it should connect to community and national energy grids.

The buildings in this study, while excellent exemplars, cannot be copied or adopted without careful analysis of each new design situation. The analysis in this book is directed to assisting the readers’ understanding of the circumstances of each exemplar and of their design and performance constraints in order that designers of future Net ZEBs will not require the same level of fundamental analysis undertaken in these buildings. The buildings documented here are pioneers in their society or circumstances.

They incorporate measures and technologies that are at the leading edge of technical innovation for their time and are all to that extent repeatable. The goal of this book is to reduce the impression of risk for the new investor. Documenting not just the technology, but also the success of that technology in real buildings is intended to assist those investing in new buildings to understand how best to apply the technology themselves.

The book eschews presentation of the data in a catalog of case studies. The approach has been to examine as carefully as possible the lessons that can be drawn from these individual cases. The complete case study data collected for the analysis is however available online in a standardized database format to enable the reader to extract their own information [2]. No particular building type has been focused on: the list includes both single family residential and commercial/institutional buildings. It is conventional in a book of this type to ascribe other broader world-view rationales for the writing. It is clear for example that this book is arriving at a time when in much of Europe and in the USA governments are setting or have set ambitious goals for new buildings to be designed to be net zero energy by 2030: in the USA within the Energy Independence and Security Act of 2007 (EISA 2007) and, at the European level within the “recast” Directive on Energy Performance of Buildings (EPBD).

The EISA 2007 supports a goal of net-zero energy for all new commercial buildings by 2025 and notes a longer term goal of net-zero for all U.S. commercial buildings by 2050 [3], whereas the EPBD proposes “nearly zero” energy buildings from 2020 for all new buildings [4]. It is our belief that this book will provide one of the tools to enable designers to achieve and even exceed these political goals.

It is not our intention to repeat the rationales or catalog government approaches of these or other government initiatives. Rather, it is anticipated that the reader picked up this book in the full understanding of this international, and their own local context, and wants to learn from those who have built what works and what does not work among the many candidate design techniques and technologies to be found in the many text books describing Building Physics, Bioclimatic Architecture, or low energy Environmental Systems Design.

1.2 What is a net zero energy building?

1.2.1 IEA SHC Task 40/EBC Annex52: Towards net zero energy solar buildings

Over 82 national experts from 19 different countries have been directly involved in this IEA research collaboration for over a 5-year period (October 2008 – September 2013). Their goal was to support the conversion of the Net ZEB concept from an idea into practical reality in the marketplace. This source book and the associated datasets provide realistic case studies of how Net ZEBs can be achieved. Demonstrating and documenting real projects has the ultimate goal of lowering industry resistance to adoption of these concepts.

The research team examined the many variations on the theme of Net Zero Energy that could be found in the literature as well as in the different participating countries. The goal was to discover a common language, and common performance metrics for what at first seems a simple concept: *a Net ZEB is an energy grid-connected building which on an annual basis contributes as much energy to the grid(s) to which it is connected as it*

draws from the grid(s). It is not an autonomous building standing alone and separate from a community. Rather, it is an integral part of that community, and its energy grids. An energy grid could be a part of a local or national electricity grid. Equally, it could be a district heating or cooling system. A further corollary of this derivation in this project is that the required on-site generation is from renewable energy sources – solar, bio-fuels, wind and so on. Merely creating a building with an on-site fossil fuel fired electricity generator is not creating a building that fits the net-zero definition adopted in this research. An associated goal of this IEA work was to develop a clear definition and international agreement on the measures of building performance that could inform “zero-energy” building policies, programs and industry adoption.

However, a viewing this simplistic description reveals a number of variants – each of which has a place, depending on the type of analysis contemplated. The research team was able to identify and classify these different variants, but not to develop a single internationally applicable definition, because not would satisfy all of the participants nor their country-specific needs. The issues that arise are concerned with: mismatch of time of peak use and time of peak generation; definition of time scales for the analysis – one year, or a lifetime; definition of boundaries – where to place the energy generation, on site, or near site.

The definitions work was the subject of a separate research task within the overall research framework. The research output from this work has produced a number of key outputs clarifying and documenting these definitions including a source book published by DETAIL Green Books [5]. The Net-Zero Energy Balance tool developed in this work is also used in this book to document each building in a consistent manner. Other participants in the IEA task worked on documenting and developing tools for use in the design and analysis of Net ZEBs. Their work was published in a second source book by Ernst und Sohn (a Wiley Brand) [6].

1.2.2 Target audience: Designers and their clients

The purpose of this book is to provide an easy to read guide to the principles and benefits of ultrahigh performance buildings. These buildings are targeted at producing at least as much energy as they consume on an annual basis. They are therefore performing at a far more extreme level than typical buildings in a particular climate or location. To this extent, they are radical departures from the normal practice of most designers at present. The goal is to transform standard architectural practice from its past reliance on energy consumption to a mixed consumption and generation mode of operation. This requires a paradigm shift on the part of much architectural practice. It is not our intention to suggest that all architects need to change. Rather as researchers we have sought to learn from those willing to experiment – those who push the boundaries of standard practice.

The structure, the content and the analysis in the book is therefore aimed at informing the interested designer. Within its pages there should be sufficient information for the designer who wishes to work on a net zero energy building to understand:

- What is the mix of skills required in the design team to achieve a Net Zero outcome?
- What are the important design priorities in the architectural form and planning?
- What are the passive energy design approaches which are appropriate for the climate, location, and society and building type?

- What are the significant energy efficiency techniques and technologies for the climate, location, and society and building type?
- And what are the energy generation technologies that might convert a low energy building into an energy positive building?

Crucially important in all this analysis is the energy use information from real buildings. While it is anticipated that most building owners and investors will not read this book from cover to cover, and are unlikely to be interested in the design principles it is expected that they will be highly interested in the functional details. Do these buildings deliver? Are they really low energy? Do they deliver the claimed superior comfort? Are users really much happier than in conventional buildings? The packaging of this design guide on the basis of real data should deliver on this client need.

Designers require simple solutions and low risk design concepts If Net ZEBs are to become standard practice, then design practice needs to change. The lessons of all these buildings are that they are the results of quite intensive collaborations. Design teams are adamant this intensity of collaboration is hugely important. They are also atypical of current practice. Often these design teams have met well prior to any architectural concept sketch and established a set of parameters and constraints for the building. Style is part of this. Function is part of this. Cost is an essential element. None takes precedence. The conventional notion of an architect developing a design and handing it over to an engineer to make it work is abandoned. The engineer is a part of the design process from the outset. No design phase has an engineer or analyst adding 'heating and cooling and lighting energy consuming services'.

However, the level of analysis and design team involvement observable in the case study buildings is not thought feasible for every building. This is one of the purposes of this book: to simply and thus make feasible in everyday practice this advanced building design process. The design team that works together often, and works on similar buildings in similar climates will learn what works and then be able to apply and develop the design ideas more than the examples in this book. This is a far simpler process than has had to be undertaken for these pioneer buildings. It is also a far lower risk. Design teams in our litigious society cannot afford to take risks: dissatisfied clients sue; court cases discourage new clients. The purpose then of the design analysis in this book is to simplify the process from that of the experimental exploratory designs presented in the case studies to the level where standard practices, offering standard design fees might feasibly be able to deliver high performance Net ZEBs.

Clients want guaranteed performance In normal building practice, the client is the person or institution risking their resources. In such circumstances, it is only the rare client, with other motives than the delivery of the building itself, who is prepared to invest in a technology or building design approach that has not been shown to work elsewhere. The energy performance of a building is typically a relatively small expense compared to the initial investment. Achievement of Net ZEB performance requires careful investment. There is a risk that the return on investment may take many years to break even. The case studies in this project have all examined this question within very different societies and financial structures. In some cases they were experimental projects where there was additional funding for the experiment. In other cases the extra funds were

essentially part of the promotional budget of the firm interested in ensuring that their building matched the future proof image they wished to project. Yet others were interested to invest a little more upfront in order sell their buildings as modern or advanced and thus seek a rental or sales premium relative to the rest of the market.

The goal of this book is to enable even the most timid of investors to understand the technologies and design approaches that must be invested in order to achieve Net ZEB performance. When this average investor is able to quantify or understand how small the added risk of investment is in net-zero energy performance compared to the already substantial risk they are undertaking in investment in a building, then Net ZEBs will be mainstream. The purpose of including real energy data in this book, along with local energy costs and the total investment cost per square meter is to provide data that the investor understands. The family investing their life savings in a house, or the institution considering how best to make a return on constructing an office building share this same interest: what will the added expenditure on net zero energy performance, if there is any, return in the way of performance.

1.3 Structure of this book

Chapter 2 focuses on addressing the unique combinations of energy efficiency measures and renewable energy sources, forming a “solution set,” required to reach pre-defined zero energy performance for a specific climate and building typology. It describes a general methodology based on fundamental principles of designing high performance buildings for comparing while building Net ZEB solution sets for cold, moderate and hot climates. The methodology constructs the solution sets in four steps by: selecting and characterising buildings according to their type of use and regional climate conditions; identifying the combinations of compatible energy efficiency and energy supply measures applied to the selected buildings; assessing the delivered energy of the primary energy and the Net ZEB performance (balance); and delineating these solution sets according to the chosen type of building and climate conditions.

Chapter 3 displays the collected data from the thirty (30) case studies by listing the various measures undertaken to reach the zero-energy balance. It provides summary description of these measures presented in frequency histograms according to building type, design challenges, technology requirements and climate type. The intent is to document as much information as necessary to allow informed determination of the kind of measures that can be adopted to enable buildings (residential and non-residential) reach the net-zero energy targets in different climates.

Chapter 4 shifts the discussion towards design of Net ZEBs from an architectural perspective. It complements the energy-focused analysis undertaken in the accompanying chapters to integrate the ideas that architects consider when design these buildings. In this context discussions on building design are extended to include the impact of Net ZEBs on the surrounding landscape.

Chapter 5 introduces the monitoring of Net ZEBs and a discussion on post occupancy behavior. It is one thing to design a Net ZEB, but unless it is monitored for its performance in real-life situations it may not meet its design objectives. In this chapter the issue of comfort is presented from the points of views of building managers and occupants along with the energy performance of the 30 case studies. Descriptions of two

protocols for monitoring building energy performance and indoor air quality are also provided, with a detailed discussion of the energy and IEQ monitoring systems at the EnerPos building on Reunion Island.

Chapter 6 examines the lessons learned based on feedback from the building designers, architects, engineers and Net ZEB occupants. It presents observations, anecdotes and experiences gathered from a series of selected face-to-face interviews with the design team and occupants of seven case study buildings and present some recommendations regarding future designs.

This book was written primarily by country experts participating in Subtask C of the IEA SHC Task40/EBC Annex 52. Subtask C, entitled *Advanced Building Design, Technologies and Engineering* was focused on: developing whole building net-zero energy solution sets for cold, moderate and hot climates with exemplary architecture that would be the basis for national demonstration projects; documenting Net ZEB design options in terms of market application; and developing guidelines and tools for industry adoption of integrated designs and concepts. Subtask C participants settled on carefully selected 30 high quality Net ZEB case studies to form a greater understanding of practical and technical challenges on building Net ZEBs. Members of Subtask C were a diverse group of researchers from universities, national research centers, and the building industry.

Readers are encouraged to explore the products of the five-years of in-depth studies by the 82 IEA SHC Task/EBC Annex researchers world-wide on the Web site task40.iea-shc.org/publications.

References

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