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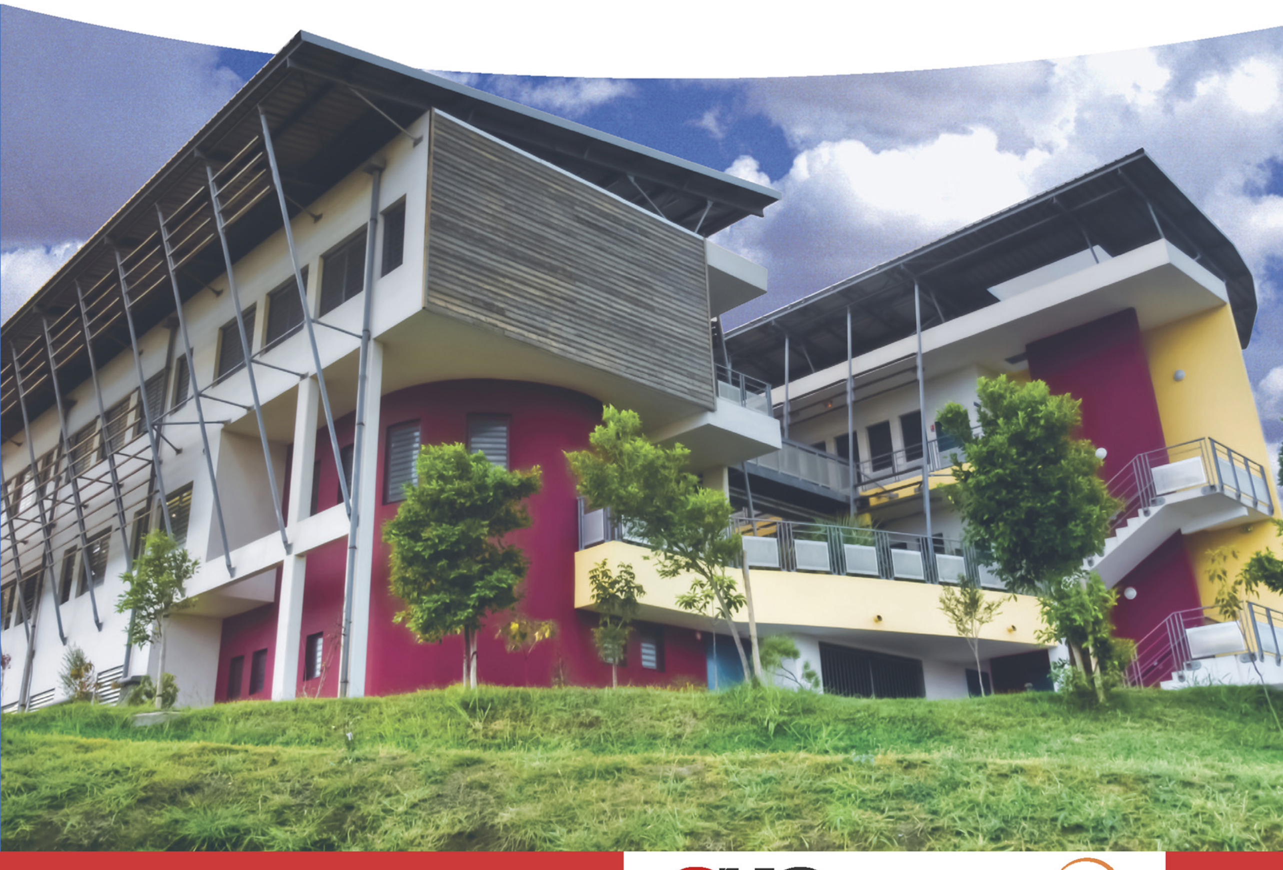
Solution Sets for Net Zero Energy Buildings

Feedback from 30 Net ZEBs worldwide



SHC
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

EBC
Energy in Buildings and Communities Programme

Edited by
François Garde
Josef Ayoub
Daniel Aelenei
Laura Aelenei
Alessandra Scognamiglio

Solution Sets for Net Zero Energy Buildings

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Cover:
ENERPOS: a French Net Zero Energy Building (Net ZEB) and one of the first Net ZEBs designed in the tropics thanks to an efficient passive design using cross natural ventilation and building integrated PV roofs that produce electricity. ENERPOS is located on Reunion Island (France).
(Photo: Jerome Balleydier)

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Josef Ayoub is a Senior Energy Science and Technology Planning Advisor at the Department of Natural Resources Canada, at the CanmetENERGY technology research center in Varennes, Quebec. He participates in several departmental portfolios under the Government of Canada's Program on Energy Research and Development in the technology areas of integration of renewable distributed energy resources into net zero energy buildings. He is the former Operating Agent of the IEA SHC Task 40 EBC Annex 52 ("Towards Net-Zero Energy Solar Buildings") (2009–2013) and the Former Network Manager of the Canadian NSERC Smart Net Zero Energy Buildings Strategic Research Network (2011–2014). He was also Canada's delegate to the Executive Committee of the IEA Photovoltaic Power Systems Program (2005-2012), and is presently Canada's Alternate Delegate to the Executive Committee to IEA International Smart Grid Action Network.

Dr. Laura Aelenei is a senior researcher at the Energy Efficiency Unit of National Energy and Geology Laboratory and Invited Professor of Energy Efficiency studies at the Master of Energy and Environment Engineering at the Faculty of Sciences of the University of Lisbon (FCUL). She is a Civil Engineer, holding a Master Degree on Buildings Rehabilitation and a PhD in Civil Engineering (heat and mass transfer, fluid dynamics through building ventilated envelope systems). She is involved in several national and international research projects as participant or coordinator and participated

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Dr. Daniel Aelenei is a professor of building physics and building technical services at the Department of Civil Engineering and senior researcher at Center of Technology and Systems (CTS) of the "Universidade Nova" of Lisbon, Portugal. He is responsible for graduate and postgraduate courses and for supervision of dissertations in energy efficiency of buildings. He studied civil engineering at the Technical University "Gheorghe Asachi" of Iasi, Romania, and in 2004 achieved his PhD at the "Instituto Superior Técnico" of University of Lisbon, Portugal, in the field of passive cooling design and technologies for housing. He is active participant in the Cost Action TU1403 ("Adaptive Façade Network") and in the IEA EBC Annex 67 ("Energy Flexible Buildings") and has participated in the IEA SHC Task 40 EBC Annex 52 ("Towards Net-Zero Energy Solar Buildings").

Dr. Alessandra Scognamiglio is a researcher in the Photovoltaic Systems and Smart Grids Unit at the ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development). She holds a PhD in Technologies for Architecture and Environment from the Second University of Naples Luigi Vanvitelli, 2010, a Master in Architecture from the University of Naples Federico II, 1998, and is a licensed architect (Naples, 1998). Her main fields of activity are: Building Integrated Photovoltaics (BIPV), Photovoltaics and sensitive landscapes, Net Zero Energy Buildings and Smart Cities. Since 2003, she has been a teacher at the Italian National Institute of Architecture for a post graduate master course in "Designer of sustainable architectures." She is participating in European projects aimed at the development of special photovoltaic components for buildings. She is also involved in several IEA research collaborations, particularly: 2008–2012 IEA SHC Task 41 *"Solar Energy and Architecture"*; 2008–2013 IEA SHC Task 40-EBC Annex 52 *"Towards Net Zero Energy Solar Buildings,"* 2013–2017 IEA SHC

Task 51 *"Solar Energy in Urban Planning,"* and since 2015 in the IEA PVPS Task 15, "*Enabling framework for BIPV acceleration*". Since 2008 she has been topic organizer of the European Photovoltaic Solar Energy Conference (EUPVSEC) focusing on Photovoltaics and Architecture. She is an active member of the COST RELY action TUI 401 "Renewables and Landscape quality."

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IEA Solar Heating and Cooling Programme

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency. Its mission is "*to enhance collective knowledge and application of solar heating and cooling through international collaboration to reach the goal set in the vision of solar thermal energy meeting 50% of low temperature heating and cooling demand by 2050*".

The members of the IEA SHC collaborate on projects (referred to as "Tasks") in the field of research, development, demonstration (RD&D), and test methods for solar thermal energy and solar buildings.

A total of 57 projects have been initiated, 49 of which have been completed. Research topics include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54)
- Solar Cooling (Tasks 25, 38, 48, 53)
- Solar Heat or Industrial or Agricultural Processes (Tasks 29, 33, 49)
- Solar District Heating (Tasks 7, 45, 55)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56)
- Solar Thermal & PV (Tasks 16, 35)
- Daylighting/Lighting (Tasks 21, 31, 50)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42).

In addition to the project work, there are special activities:

- SHC International Conference on Solar Heating and Cooling for Buildings and Industry
- Solar Heat Worldwide – annual statistics publication
- Memorandum of Understanding – working agreement with solar thermal trade organizations
- Workshops and seminars.

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For more information on the IEA SHC work, including many free publications, please visit www.iea-shc.org

Foreword

This work was produced in the context of a joint collaboration between approximately 75 national experts from 19 nations in Europe, North America, Oceania, and Southeast Asia of the International Energy Agency (IEA), under the framework of the IEA Solar Heating and Cooling (SHC) and Energy in Buildings and Communities (EBC) Technology Collaboration Programs. The joint SHC Task 40/EBC Annex 52 (T40A52) "Towards Net-Zero Energy Solar Buildings" sought to study current net-zero, near-net-zero and very low energy buildings and to develop a common understanding of a harmonized international definitions framework, tools, innovative solutions, and industry guidelines to support the conversion of the Net ZEB concept from an idea into practical reality in the marketplace. This Task/Annex pursued optimal integrated design solutions that provided good indoor environment for both heating and cooling situations. The process recognized the importance of optimizing a design to meet the functional requirement, reducing loads, and designing energy systems that pave the way for seamless incorporation of renewable energy innovations, as they become cost effective. To achieve these results, the National Experts met twice annually at a hosting member country to coordinate the R&D activities and advance the work plan comprised of the following four major activities:

1) **Subtask A** dealt with establishing an internationally agreed understanding on Net ZEBs based on a common methodology. This was done by reviewing and analyzing existing Net ZEB definitions and data with respect to the demand and the supply side; studying grid interaction (power/heating/cooling) and time-dependent energy mismatch analysis; developing a harmonized international definition framework for the Net ZEB concepts considering large-scale implications, exergy, and credits for grid interaction (power/heating/cooling); and, developing a monitoring, verification and compliance guide for checking the annual balance in practice (energy, emissions, and costs) harmonized with the definition;
2) **Subtask B** aimed to identify and refine design approaches and tools to support industry adoption. This was done by conducting work along four major R&D streams: (i) in documenting and analyzing processes and tools currently being used to design Net ZEBs and under development by participating countries; (ii) assessing gaps, needs, and problems to inform simulation engine and detailed design tool developers of priorities for Net ZEBs; (iii) qualitative and quantitative benchmarking of selected tools; and (iv) selecting four case study buildings to conduct a detailed analysis of simulated/designed vs. actual performance, and proposing the redesign/optimization of these buildings;
3) **Subtask C** focused on developing and testing innovative, whole building net-zero solution sets for cold, moderate, and hot climates with exemplary architecture and technologies that would be the basis for demonstration projects and international collaboration. This was achieved by documenting and analyzing current Net ZEBs designs and technologies, benchmarking with near Net ZEBs and other very low energy buildings (new and existing), for cold, moderate, and hot climates considering sustainability, economy, and future prospects using a projects database, literature review, and practitioner input (workshops); developing and assessing case studies

and demonstration projects in close cooperation with practitioners; investigating advanced integrated design concepts and technologies in support of the case studies, demonstration projects, and solution sets; and developing Net ZEB solution sets and guidelines with respect to building types and climate, and to document design options in terms of market application;

4) **Subtask D** was crosscutting work that focused on dissemination to support knowledge transfer and market adoption of Net ZEBs on a national and international level. This was accomplished by establishing a Net ZEB web page within the IEA SHC/EBC Programmes' framework and a database that can be expanded and updated with the latest projects and experiences; transferring the outputs (reports, sourcebooks, guidelines, other) to national policy groups, industry associations, utilities, academia, and funding programs; participating in national and international workshop, seminars, and industry exhibitions highlighting the results and activities of the Task/Annex contributing high-quality technical articles and features in journals to stimulate market adoption; and, establishing an education network of highly qualified people that will continue the work in the field in their future endeavors.

I am pleased to present the research results of Subtask C compiled in this volume of work entitled "*Solution Sets from Net Zero Energy Buildings: Feedback from 30 Net ZEBs worldwide*" as a major accomplishment in this field of research. Building energy design is currently going through a period of major changes driven largely by three key factors and related technological developments: (i) the increasingly widespread adoption in most OECD member countries and by influential engineering societies, such as ASHRAE, of net-zero energy as a long-term goal for new buildings; (ii) the need to reduce the peak electricity demand for buildings through optimal operation; and (iii) the need to efficiently integrate advanced energy technologies into buildings, such as photovoltaic/thermal systems, windows with semitransparent photovoltaic glazing, controlled shading/daylighting devices, and integrated thermal storage. This body of work encapsulates the many and varied lessons learned of designing, building and operating net-zero energy buildings by government research organizations, international and regional research centers, academia, and industry. I am confident this book will find many interested readers.

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Josef Ayoub: The Government of Canada provided partial funding for this work under two major programs: the Program of Energy Research and Development (PERD), a federal inter-departmental program operated by the Department of Natural Resources Canada, supported the position of the Operating Agent for five years to coordinate the work and lead this international network of researchers; and the recently ended Canada's Climate Change Action Plan EcoENERGY Innovation Initiative (EcoEII), aimed at supporting energy technology innovation to produce and use cleaner energy more efficiently. Both the PERD and the EcoEII programs funded the R&D work and the participation of all National experts from Canada in the IEA SHC Task 40 EBC Annex 52.

Laura Aelenei**:** The National Laboratory of Energy and Geology supported the work and participation of this National expert in the IEA SHC Task 40 EBC Annex 52. Laura Aelenei thanks in particular the Director of Energy Laboratory, Doctor Helder Gonçalves for his permanent support and encouragement to accomplish this work.

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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 building.

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.

Solution Sets for Net Zero Energy Buildings: Feedback from 30 Net ZEBs worldwide. First Edition.
Edited by François Garde, Josef Ayoub, Daniel Aelenei, Laura Aelenei, and Alessandra Scognamiglio.