SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

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Towards Net Zero Energy Solar Buildings

Net Zero Energy Solar Buildings
SHC Position Paper

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Aim of Position Paper

The aim of this Position Paper is to present the current status of the various research and pathways in designing and constructing net-zero energy buildings (NetZEBs). It is written to provide general information on this topic to policy and decision makers who may be in positions to facilitate the market uptake of NetZEB practices. The information therein draws from the work of the 82 National Experts from the 19 member countries that participated in the Task/Annex and have contributed so much knowledge to advancing this field.

Executive Summary

Worldwide, over 40% of primary energy use and 24% of greenhouse gas emissions are accounted by in buildings. Given the global challenges related to climate change and resource shortages, much more is required from the building sector than incremental improvements in energy efficiency.

Recently, a prominent vision touted by so many stakeholders in the building sector proposes the so-called “net zero energy” buildings (NetZEBs) - buildings whose energy consumption are fully offset by renewable energy generated on site. Whether focused on new or existing buildings, achieving net zero energy involves three fundamental steps: optimize passive building design; maximize energy efficiency to minimize the building’s demand; then explore on-site renewable energy generation to cover the remaining energy needs. There are a number of definitions and strategies to achieving net-zero energy, but for NetZEBs to become mainstream in the market, there is a need for a wide consensus on clear definitions, and agreement on the measures of building performance that could inform “zero energy” building policies, programs and industry building practices, as well as design tools, case studies and demonstration projects that would support industry adoption.

The joint IEA SHC Task 40/ EBC Annex 52: “Towards net Zero Energy Solar Buildings” was inaugurated in October 2009 for a 5 year period to enlighten this field of research to encourage market acceptance of NetZEBs.

Introduction and Relevance

Over 40% of primary energy use and 24% of greenhouse gas emissions[1] are attributed to worldwide energy use in buildings. Energy use and emissions include

[1] IEA *Promoting Energy Efficiency Investments – case studies in the residential sector* ISBN 978-92-64-04214-8. Paris. 2008

both direct, on-site use of fossil fuels as well as indirect use from electricity[2], district heating/cooling systems and embodied energy in construction materials.

Given the global challenges related to climate change and resource shortages, much more is required from the building sector than incremental improvements in energy efficiency. Recently, a prominent vision touted by so many stakeholders in the building sector proposes so-called "net zero energy" buildings (NetZEBs)[3]. Although this term had to encompass several meanings that are poorly understood, several IEA countries have adopted this vision as a long-term goal of their building energy policies[4]. However, to mainstream market adoption of NetZEBs, what is needed is a wide consensus on clear definitions and agreement on the measures of building performance that could inform "zero energy" building policies, programs and industry building practices, as well as design tools, case studies and demonstrations that would support industry adoption.

What is known about achieving "zero" in buildings? The first strategy is to reduce energy demand through suitable architectural design and improved building envelopes. Measures for achieving this depend on climate and building type and include insulation, improved glazing and daylighting, airtight building envelopes and natural ventilation as well as active or passive shading for control of solar gains. Improving the efficiency of energy systems and services through better heating, cooling and ventilation systems, controls and lighting is the corresponding strategy for efficient use of the energy supplied. The so-called "Passive House" reflects these concepts for cold and moderate climates. However, to reach "zero" use of fossil fuels or zero-carbon emissions require intensive utilization of renewable energy concepts including solar heating, solar cooling, solar PV, biofuels or other clean energy generation sources.

The "net zero" option: Zero energy buildings (ZEBs) are not a new concept. An area of focus has been autonomous building energy options. With existing technology, this "off-grid" approach has been and still is a technical, economic and ecological challenge for most applications[5]. For example, seasonal and daily variations of demand and supply, at most locations worldwide, result in costly over-sizing of energy supply systems. As well, autonomous buildings require expensive thermal storage systems that can embody large amounts of energy relative to the small energy stored and efficient, long-term electrical storage is still not solved. Furthermore, most of these so-called ZEBs do require some "imported" energy for backup and high power density loads, such as cooking.

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[2] Note: In most countries, indirect emissions are not counted as emissions from the building sector but from the industry (power plants). This means the environmental footprint of building related energy use is often underestimated.

[3] Another ambitious approach was formulated with the 2000-W-Society and the resulting energy demand limits for buildings: Zimmermann, M., *Althaus, H.-J., Haas, A.: Benchmarks for sustainable construction – A contribution to develop a standard*, Energy and Buildings, 37, 2005.

[4] CA, DE, UK, USA, NL, NZ

[5] Goetzberger, A., et. al., *The Self-Sufficient Solar House Freiburg*, Advances in Solar Energy, vol. 9, p.1-70, 1994

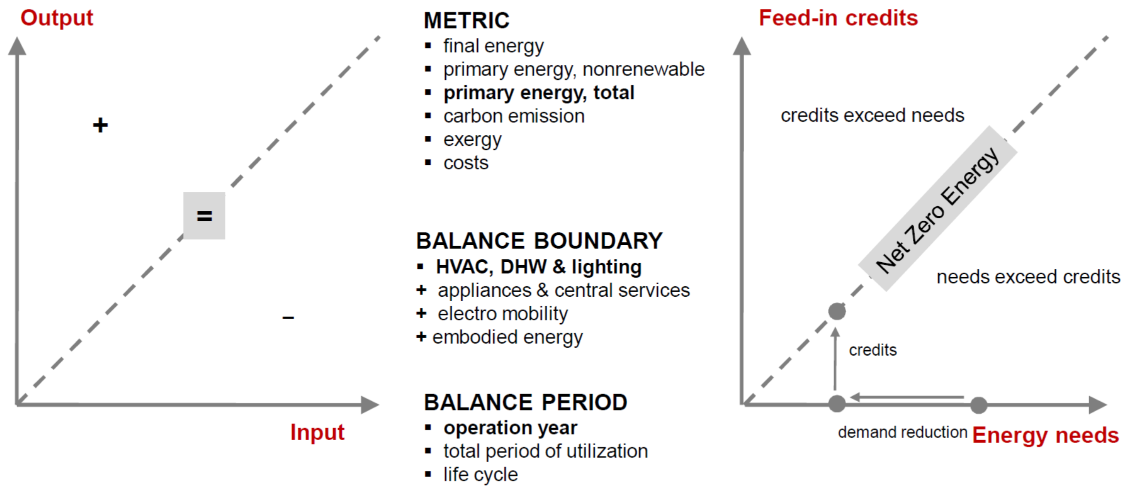
Addressing the limitations of autonomous buildings, while still achieving “zero”, leads to utility-connected solutions that optimize energy generation, distribution and storage. This “net zero” approach (for new and existing building retrofits) still incorporates on-site renewable energy but the focus is on achieving an annual balance of energy supply and demand economically through interactions with electricity grids and other utilities such as community energy systems. To minimize impacts to grids by reducing the mismatch of supply and demand, the NetZEB approach requires a very high level of energy-efficiency, smart controls, load management and on-site solar energy utilization.

Status of the Technology/Industry

The convergence of the need for innovation and requirements for drastic reductions in energy use and greenhouse gas emissions in the buildings sector is transforming the way buildings and their energy systems are conceived and built. Since the early 1990s the idea of net-zero energy buildings has been gaining widespread acceptance as a technically feasible long-term goal for the buildings sector - becoming part of the energy policies of several countries.

The recast of the of the EU Directive on Energy Performance of Buildings (EPBD), set the framework and boundaries for new buildings to achieve “nearly zero energy” targets by the end of 2020. For the Building Technologies Program of the US Department of Energy, the strategic goal is to achieve “marketable zero energy homes in 2020 and commercial zero energy buildings in 2025”. On a state level, California has committed to making all new commercial buildings and 50% of existing commercial buildings net-zero by 2030. While case studies have clearly shown that net-zero energy buildings could be created using existing technologies and practices, most experts agree that a broad scale shift towards net-zero energy buildings will require clear policy frameworks and significant adjustments to prevailing market structures.

To date the basic definitions, boundary conditions, measurement metrics and other components of a robust net-zero energy regulatory framework are deficient or missing in most countries. The work of the Task/Annex suggests that an appropriate framework for driving NetZEBs is elaborated in the graph below (Contributions from Subtask A led by K. Voss)):



However, despite the emphasis on the goals, the definitions remain in most cases generic, but the basic steps to achieving net-zero targets are clear: *make the building as energy-efficient as possible through integrated design and energy-saving technologies, add renewable energy on-site and ensure optimal building performance over time.* Policymakers who wish to support the broad diffusion of net and near zero energy building's will need to determine what kind of regulatory framework is most appropriate for their jurisdictions.

Potential

The world economy is becoming increasingly obstructed by energy cost, energy availability, and energy-related environmental regulations. Many countries are looking to shore up their energy supply structure and identify measures to address energy demand issues. On a global scale, buildings (both residential and commercial) account for 35% to 40% of total final energy consumption. With the continued challenge of climate change, more countries are implementing measures that will reduce energy consumption and GHG emissions. The global acceptance of green-build and the increasing deployment of energy efficiency retrofits for commercial and public buildings provides an important pathway for increasing energy security, reducing – or even decreasing – energy demand, reducing GHG emissions, and reducing demand for new energy production and distribution facilities. Energy efficiency retrofits can also be used by commercial building owners and tenants to support greening and green marketing efforts[6].

Around the world, green building is accelerating as it becomes viewed as a long-term business opportunity. Fifty-one percent of the architects, engineers, contractors, owners and consultants anticipate that more than 60% of their work will be green by

[6] Navigant Research, Energy retrofits for Commercial and Public Buildings, press release: https://www.navigantresearch.com/research/energy-efficiency-retrofits-for-commercial-and-public-buildings

2015, up from 28% of firms in 2012[7]. And the growth of green is not limited to one geographic region or economic state - it is spreading throughout the global construction marketplace.

The goal of net-zero may have been once considered an unattainable, far-reaching and expensive proposition, only available to the most technically advanced projects, but now it is within the realm of possibility[8] for the new-build and retrofit markets. The process of achieving net zero energy for an existing building is somewhat similar to that of deep energy retrofits, but with additional considerations: adopting a whole-building analysis process that delivers much larger energy cost savings – sometimes more than 50 percent reductions[9]. Navigant Research forecasts that global revenue for energy efficiency commercial building retrofits will grow from $68.2 billion in 2014 to $127.5 billion in 2023.

Net-zero energy has been achieved in a number of new and, while more challenging, existing buildings. The main differences for achieving net zero energy for existing buildings are that orientation, site configuration and systems are 'predetermined and for the most part fixed'[10]. Nonetheless, the overwhelming consensus about achieving net-zero energy is most likely to be feasible in:

- Low energy Single family homes (new and retrofitted) with appropriately roof orientation and low energy demands;
- Sub-tropical and moderate climate zones, where the use of natural convection and shading strategies could offset most of the building's energy load;
- Low-rise buildings (residential and office) (one- to three-story). It becomes more difficult to achieve the net-zero energy target in buildings with more than three floors due to limited roof area and the use of elevators[11]; and
- Buildings with low plug process loads.

Current Barriers

A key requirement of NetZEBs is the need for rigorous design and operation of a building as an integrated energy system that must have good indoor environment suited to its function. If NetZEBs are to become standard building practice, then the design practice needs to change from the traditional linear process to an integrated design approach, bringing together the architects, structural, electrical and mechanical engineers, general contractors and other stakeholders to bear down on

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[7] McGraw Hill Construction, World Green Building Trends: Business Benefits Driving New and Retrofit Market Opportunities in 60 countries, SmartMarket Report, 2013.

[8] C. Carmicahel, K. Managan, Reinventing Existing Buildings: Eight Steps to Net Zero Energy, Rocky Mountain Institute, Johnson Controls, May 2013.

[9] Ibid.

[10] Ibid.

[11] C. Carmicahel, K. Managan, Reinventing Existing Buildings: Eight Steps to Net Zero Energy, Rocky Mountain Institute, Johnson Controls, May 2013.

the design process. The design of smart NetZEBs requires the following three key approaches[12]:

1. An integrated approach to energy efficiency and passive design.
2. An integrated approach to building design and operation. Optimized NetZEBs need to be designed based on anticipated operation so as to have a largely predictable and manageable impact on the grid;
3. A building design optimizes for solar harvesting. The concept of solar optimization requires optimal design of building form with equatorial facing façades and roofs for conversion to solar electricity, useful heat and daylight."

The key challenges/barriers for NetZEBs to overcome are summarized in the table below (contributions from A. Athienitis, Subtask B Co-Leader) for each of the five major building subsystems, where the current situation is contrasted with the expected characteristics of NetZEBs.

BUILDING SYSTEM DESIGN & OPERATION	CURRENT BUILDINGS	SMART NetZEBs
Building fabric/envelope	Passive, not designed as an energy system	Optimized for passive design and integration of active solar systems
Heating, ventilation and air conditioning (HVAC)	Large oversized systems	Small HVAC systems optimally controlled, integrated with solar systems, combined heat and power, seasonal storage and district energy
Solar systems/renewable generation	No systematic integration – an afterthought	Fully integrated: daylighting, solar thermal, photovoltaics, hybrid solar, geothermal systems, biofuels linked with smart micro grids
Building automation systems	Building automation systems not used effectively	Predictive building controls to optimize comfort and energy performance; online demand prediction / peak demand reductions
Design and operation	Design and operation of buildings typically considered apart	Design and operation of buildings fully integrated and optimized together subject to satisfying comfort

[12] A. Athientis and W. Obrien (eds.), 2015, Modeling*, Design and Optimisation of Net-Zero Energy Buildings*, Ernst & Sohn, Berlin, Germany.

Actions Needed

Net zero energy describes buildings whose energy consumption is fully offset by renewable energy generated on site. Whether focused on new or existing buildings, achieving net zero energy involves three fundamental steps: optimize passive building design; maximize energy efficiency to minimize the building's demand; then explore on-site renewable energy generation to cover the remaining energy needs.

The responsibility for achieving NetZEBs requires considerable challenges for all sectors of the building community. To make Net ZEBs a reality, designers will need the tools to design and apply better integrated equipment, manufacturers will need to produce high efficiency equipment and develop the know-how to integrate them into buildings, and both will have to carefully monitor occupants; needs and provide comfortable living conditions[13].

The industry needs to: 1.) develop pathways to fully integrate equipment and renewable energy technologies to optimize their value the building; 2.) deploy ultra-high efficiency equipment and systems that minimize energy use in all seasons; 3.) develop more refined tools for architects, engineers and manufacturing companies for properly sizing and selecting appropriate HVAC equipment in NetZEBs; 4.) enhance building automation systems and controls to achieve better comfort control with less energy; 5.) improve building design and selection of low-emitting materials and furnishings along with advanced air filtration and treatment technologies to allow for better control of indoor air quality; 6.) set standards for measuring the performance of integrated systems within the building; and 7.) train employees in new construction techniques and quality control procedures[14] .

A number of market-oriented initiatives should be pursued to encourage adoption of NetZEB technology and also to support NetZEB marketing activities. The four main priorities include: 1.) building certification (plaque, label or certificate that could be displayed prominently in the building) that could serve to inspire building owners and designers; 2.) accreditation of professionals; 3.) virtual dashboards that highlight energy flows and consumption of a given NetZEB; and 4.) available information (publications, handbooks, guidelines, other) to motivate NetZEB practitioners.

Finally, the research community should galvanize its efforts in building envelopes - including the integration and optimization of renewable energy technologies, mechanical equipment, lighting services, water and space heating and all related controls in support of market uptake of NetZEB projects.

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[13] ASHRAE Vision 2020: Producing Net Zero Energy Buildings, A Report from the American Society of Heating, Refrigeration and Air-Conditioning Engineers, January 2008.

[14] Ibid

Acknowledgement

The content of this paper builds upon the concepts developed in the context of the joint IEA (International Energy Agency) SHC (Solar Heating and Cooling Program) Task 40 and EBC (Energy in Buildings and Communities Program) Annex 52: Towards net Zero Energy Solar Buildings, involving the participation of 82 national experts and Regular Participants from 19 member countries from October 2009 To September 2013 (http://task40.iea-shc.org/).