Nearly (Net) Zero Energy Building

APEC Energy Working Group

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PREFACE

Energy use in buildings worldwide accounts for over 40% of primary energy use and 24% of greenhouse gas emissions. Simply increasing energy supply will not solve the current energy supply and security situation and associated environmental problems. Given the challenges related to climate change and resource shortages, making residential and non-residential buildings more energy and resource-efficient while maintaining thermal comfort and cost-effectiveness represents and enormous opportunity to save money and reduce pollution.

Accounting for around 60 percent of world energy demand, the APEC region is a net energy importer and its demand for energy is on the rise. Recently, some APEC developed economies set the goal to achieve Nearly (Net) Zero Energy Building (NZEB) and already launched some research programs and accomplished successful demonstration projects. How to share the existing experiences and best practices of NZEB to promote this idea among APEC region is the main focuses of this project which will benefit both the new building construct work and existing building retrofit work in both developed and developing economies.

This project was funded by the APEC-Energy Working Group: 03-2013A- Nearly (Net) Zero Energy Building Project, the Expert Group on Energy Efficiency & Conservation managed the implementation of the project. The goal of this project is to enhance mutual understanding of APEC economy's latest progress in NZEB. The outcome of this project could be as a strong support for the APEC economies to promote NZEB in the future and also work as an important pillar for the existing APEC programs, which including APEC Energy Smart Communities Initiative (ESCI), APEC Smart Grids Initiative (ASGI) and APEC Low Carbon Model Town project (LCMT).

The project content includes：

- Exchanging each economy's latest policy and national goals to achieve NZEB in the future
- Comparison of different similar definition of NZEB
- Key findings and outcomes of the research programs in each economy
- The future revision plan of building energy code towards NZEB
- Related associations and alliances to promote NZEB
- Valuable experiences from the demonstration projects

Two workshops were held within the project, first APEC-Net Zero Energy Building workshop was held on October 30th to 31st 2013, 60 participants from 12 economies attended the workshop, the first workshop focus on policies and definitions, research programs and latest technology progress and how building codes upgrading influence the work of NZEB. 80

participants from 14 economies attended the second workshop on October 22nd to 23rd 2013, second workshop focus on monitoring results of pilot project and community and how to promote NZEB in the future in APEC region.

With the preparation of the report, the Project Overseer would like to support to initiate a boost for innovative NZEB among the APEC region - which will help to improve the efficiency and reduce the need for fossil fuel significantly, which will make great contribution to global climate change and emission reduction. The Project Overseer hopes that we can work together for that goal.

Although so many experts made great contributions to this report, it was prepared in a limited time; the Project Overseer will take responsible for the errors and mistakes in this report.

ACKNOWLEGEMENTS

The report was prepared according to the materials that the experts shared during the two workshops within this project, the Project Overseer would like to thank all the experts who attended the workshop during their busy schedule and share their valuable experiences on this topic.

The APEC-EGEEC economy delegates and nominated delegates in APEC economies participated the two workshops and shared their experiences during the Q&A session and the discussion session, which also give us a lot of comments and suggestions to finalize this report, we would like to thank them all.

After the preparation of the draft report, besides circulated it to EWG and EGEE&C members, we invited experts in this field to make a review of the report, we would like to thank all their contribution of time and suggestions on how to revise the report to benefit more APEC economies.

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KEY FINDINGS

Great opportunity exists now to catch and promote NZEB in APEC regions. The government agencies of APEC economies have set up long term goals for high-level policies as well as financial incentives to speed up the development of NZEB. Researchers from APEC economies are working on the definitions, technology roadmaps, building codes upgrading and demonstration projects of NZEB. Major institutes, societies and alliances have established stringent NZEB targets, which will lead the whole industry and all stake holders to move towards the future of NZE in buildings

1. Policy and Objective

   With regards to energy self-sufficiency, environment protection and pressure of climate change, some APEC economies had already issued policies and set up clear and aggressive long-term goals for NZEB.

Economy	Department	Year	Policy	Objective
Japan	MLIT,METI, MOE	2008	Action plan of ZEH and ZEB	Realizing ZEH and ZEB on average for all new buildings by 2030
Korea	MLIT and other 7 Ministry	2014	The Activation Plan of ZEB Corresponding to Climate Change	All new buildings are mandatory design to achieve NZE by 2025
The United States	Federal government	2007	Executive Order 13514	Buildings that enter the planning process in 2020 must be designed to achieve NZE by 2030
	Department of Energy	2007	Energy Independence and Security Act	Marketable NZEH by 2020; Commercial NZEB at low incremental cost by 2025

2. Financial incentives

   Corresponding financial and taxation policies together with the subsidy of pilot and demonstration projects have speeded up the development of zero energy building in some APEC economies.

Economy	Financial and Taxation Policy	Subsidy
Japan	-	Financial subsidy upper limit to 4 billion JPY.
Korea	15% floor-area ratio increase; lower property taxes; income tax exempted for enterprises; and so on.	50% cost of the equipment in renewable energy system; 15-50% cost of the passive method.

3. Definition

   The zero energy definition determines how to design and operate buildings to achieve the zero energy targets. It is also related to the government policies and incentives. Potentially, some definitions with similar content among APEC economies need to harmonize in the future.

Economy	Definition
Canada	Net zero energy housing, net zero energy building, A net-zero energy (NZE) home, A net-zero energy ready (NZER) home, A net-zero energy verified (NZEV) home
China	Nearly Zero Energy Building
Japan	Net Zero Energy Building, Zero-Energy Housing
Korea	Zero Energy Building: Low-rise Zero Energy Building, High-rise Zero Energy Building, Zero Energy Building Town
The United States	Zero-Net-Energy (site or source) Building, Net-Zero Energy (cost or emission) Building, Net Zero Energy Home, Energy Free Home

4. Research program and national research team

   Canada and Korea have set up national research teams. SNEBRN of Canada has 30 researchers from 15 Canadian Universities, 20 industrial and government partners and with participation of 100 grad students and 6.68 million C$ research funding for 5 years. This research network covers a broad range of topics about NZEB.

5. Building codes and standards
   Building codes and standards are the most fundamental and effective measures to promote NZEB development. Energy codes and standards play a vital role by setting minimum requirements for energy-efficient design and construction. Since 1970s to now, the building energy codes already make 50%-70% energy savings and still have a 70%-90% energy saving potential in the future. ASHRAE 90.1 and Title 24 of California in the United States have already set up goals to move to NZE step by step till 2020 and 2030.

6. Major institutes, societies and alliances have all established NZE or similar targets, most of them are more stringent than the federal (national) goal

Economy	Goal by institutes, societies and alliances
Canada	SNEBRN：facilitate widespread adoption of NZEB in Canada by 2030
China	Nearly Zero Energy Building Alliance: 30-30-30
The United States	AIA: carbon neutral buildings by 2030; ASHRAE: Vision 2020- net zero energy usage for all types of facilities by 2020

7. Demonstration projects
   Demonstration projects accomplished by NREL, SNEBRN, SHASE, KICT, CABR and companies and foundations cover almost all climate zones and major building types. The energy savings could reach to 50%-80% compared with the ordinary buildings. The market of NZEB is currently small, but it is booming as the technology roadmap becomes clear.

8. Industry

   High performance envelope and higher efficiency systems are needed to support the fast growth of NZEB development, in the future, the NZEB related industries will move into a fast track followed with the strong regulations.

9. Social & Energy & Environment Influence

   Net zero energy buildings emit GHG 70~80% less than existing buildings. In Korea, it is estimated that if zero energy buildings are built at the market penetration of 10% of the new construction annually, it will not only reduce GHG by 670,000 TCO2eq/year, energy reduction by 180,000 TOE/year, but also create additional cost 4.5 billion dollars and 500,000 jobs.

10. Obstacle and Barriers

    Long term NZEB targets together with clear milestones are needed in some economies. Significant funding is still needed for the technology research and building codes upgrades, to support the widespread of NZEBs by 2030. The incremental cost needs to be partially offset by government incentives in the near future and will be balanced by technology promotion, industry growth and marketization in the long term. Best practice demonstration projects need to be recognized and promoted, as it is one of the most effective ways to show the performance of NZEBs and verify the latest research achievements.

NOMENCLATURE & ABBREVIATIONS

GOVERNMENT ADMINISTRATIONS

CPUC	California Public Utilities Commission
DOC	Department of Commerce
DOE	Department of Energy
EERE	Office of Energy Efficiency &Renewable Energy
EPA	Environmental Protection Agency
KNSO	Korea National Statistics Office
MAF	Ministry of Agriculture and Forestry
ME	Ministry of Education
METI	Ministry of Economy, Trade and Industry
MF	Ministry of Finance
MFCS	Ministry of Future Creation and Science
MKE	Ministry of Knowledge Economy
MLIT	Ministry of Land, Infrastructure and Transport
MLTM	Ministry of Land, Transport and Maritime Affairs
MOE	Ministry of Economy
MS	Ministry of Safety
MTIE	Ministry of Trade, Industry and Energy
NASEO	National Association of State Energy Officials
NASA	National Aeronautics and Space Administration
NRCan	Natural Resources Canada
OACSIM	The Office of the Assistant Chief of Staff for Installation Management
SEO	The State and Territory Energy Office

LAWS AND REGULATIONS

ECL	Energy Conservation Law
EISA	Energy Independence and Security Act of 2007
EO13514	Executive Order 13514
NEP	National Energy Policy

CODES AND STANDARDS

AEDG	Advanced Energy Design Guides
BDCES	Building Design Criteria for Energy Saving
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CCREUB	Criteria for Clients on the Rationalization of Energy Use for Buildings
CCREUH	Criteria for Clients on the Rationalization of Energy Use for Houses
DCGREUH	Design and Construction Guidelines on the Rationalization of Energy Use for Houses

HASS	Heating, Air-Conditioning and Sanitary Standard
IECC	International Energy Conservation Code
IgCCTM	The International Green Construction Code TM
LEED	Leadership in Energy and Environmental Design

ORGANIZATIONS AND INSTITUTIONS

AIA	The American Institute of Architects
AIJ	Architectural Institute of Japan
ASHRAE	American Society of Heating Refrigerating and Air conditioning Engineer
ASRE	The American Society of Refrigerating Engineers
BFRL	Building And Fire Research Laboratory
CBC	Commercial Buildings Consortium
CMHC	Canada Housing and Mortgage Corporation
EPC	Economic and Planning Council
ERDC	The U.S. Army Engineer Research and Development Center
ETRI	Electronics and Telecommunications Research Institute
IBEC	International Bank for Economic Cooperation
ICC	International Code Council
IEA	International Energy Agency
IESNA	The Illuminating Engineering Society of North America
ILFI	International Living Future Institute
IPCC	the United Nations Intergovernmental Panel on Climate Change
KICT	Korea Institute of Civil Engineering and Building Technology
KIER	Korea Institute of Energy Research
KEMCO	Korea Energy Management Corporation
KEPCO	Korea Electric Power Corporation
NBI	The New Building Institute
NEEP	Northeast Energy Efficiency Partnerships
NFPA	The National Fire Protection Association
NIST	National Institute of Standards and Technology
NREL	National Renewable Energy Laboratory
NSERC	Natural Sciences and Engineering Research Council of Canada
NSTC	National Science And Technology Council
OECD	Organization for Economic Co-operation and Development
SBRN	Solar Building Research Network
SHASE	The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan
SNEBRN	Smart Net-zero Energy Buildings Strategic Research Network
USGBC	U.S. Green Building Council

TECHNICAL TERMS

AEO	Annual Energy Outlook
BEAP	Building Energy Assessment Professionals
BEE	Building Environmental Efficiency
BEMP	Building Energy Modeling Professionals
BEMS	Building Energy Management System
BEQ	Building Energy Quotient
CBECS	the Commercial Building Energy Consumption Survey
CEC	Coefficient of energy consumption
CI	Commercial Interiors
CS	Core and Shell
DIS	Data Item Set
EBC	Energy in Buildings and Communities
EBOM	Existing Buildings, Operations and Management
ECM	Energy Conservation Measures
ERS	Equipment Requirement Specification
ERV	Energy Recovery Ventilation
ESCOs	Energy service companies
EUI	Energy Use Intensity
EV	Elevators
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HEMS	Home Energy Management System
HW	Hot water
IEEE	Institute of Electrical and Electronics Engineers
IEQ	Indoor Environmental Quality
IOU	Investor Owned Utility
LPG	Liquefied Petroleum Gas
LCCM	Life Cycle Carbon Minus
ICT	Information Communication Technology
MEL	Miscellaneous Electric loads
MIF	Mortgage Insurance Fund
NC	New Construction
NOI	Net Operating Income
NZE	Net-Zero Energy
NZEB	Nearly Zero Energy Building
NZEH	Net Zero Energy Housing
NZER	Net-Zero Energy Ready

NZEV	Net-Zero Energy Verified
OA	Office Automation
PAL	perimeter annual load
PAS	Panel Approach system
PE	Professional Engineers
PTAC	Packaged Terminal Air Conditioner
PV	Photovoltaic
RSF	The Research Support Facility
SHC	Solar Heating and Cooling
SPVHP	Single Package Vertical Heat Pump
TFA	Treated Floor Area
VOC	volatile organic compound
ZCGH	Zero Carbon Green Home
ZEB	Zero Energy Building
ZEH	Zero Energy Homes
ZNE	Zero Net Energy

PROGRAMS

BBEES	Big Bold Energy Efficiency Strategies
BT	The Building Technologies Program
BTRD	Buildings Technology Research and Development
CBI	Commercial Building Initiative
CEESP	California Long Term Energy Efficiency Strategic Plan
EEAP	The Energy Engineering Analysis Program
EFHC	The Energy Free Home Challenge
FBI	Federal Buildings Initiative
SAI	The Solar America Initiative
SEEARP	State Energy Efficient Appliance Rebate Program
SETP	The U.S. Department of Energy Solar Energy Technology Program

SECTION I CANADA

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1 Policy, Objectives, Definitions

1.1 Building Status in Canada

Approximately one third of Canada's greenhouse gas (GHG) emissions are attributed to building energy consumption. Buildings also account for about 53% of Canada's electricity consumption (NRCan, 2006). They are largely responsible for the peaks in electricity demand associated with space heating, cooling, lighting and appliances.

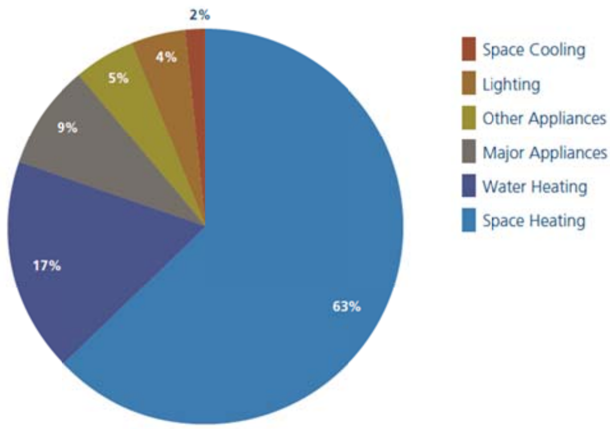

Figure 1.1 Residential Sector Energy Use in Canada (%)
Source: Background, Climate and The Solar Heating System

There are 13 million dwellings in Canada. These homes simultaneously represent a tremendous investment of resources and a commitment to maintenance and operating costs for years to come (Community Solutions 2007).

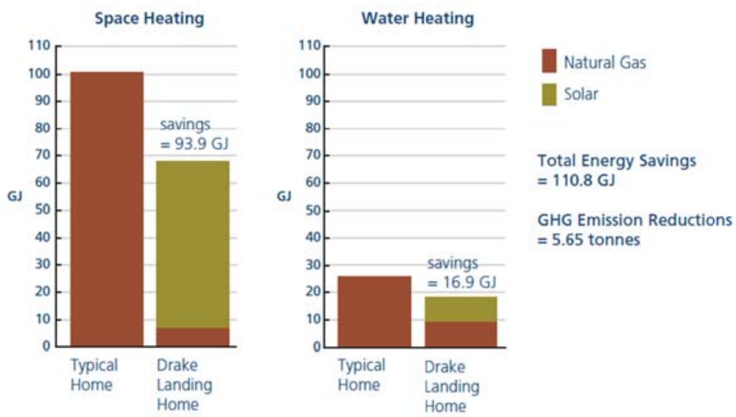

Figure 1.2 Home Energy Efficiency and Solar Energy
Source: Background, Climate and The Solar Heating System

Figure 1.2 shows representative results from a demonstration project of seasonal solar thermal storage in Okotoks, Alberta (Sibbitt 2011); as can be seen, over 90% solar thermal fraction was achieved by collecting solar energy and storing it in a borefield. The total energy consumption of commercial and institutional buildings accounts for 12% of Canada's secondary energy use and 11% of national GHG emissions (Office of Energy Efficiency, 2013). At Natural Resources Canada, it is recognized that the contribution that energy efficiency in the building sector can make towards Canada's economy, environment and society. Energy efficiency offers a proven pathway to generate substantial positive impacts – economic advantages for companies, higher employment, improved air quality, reduction in fuel consumption, lower utility bills, reduced pollution and GHGs, and enhanced competitiveness.

In 2012, electricity generation capacity in Canada reached 134 GW. Hydroelectricity is the primary source of electric power, accounting for 57 per cent of total capacity. Natural gas, coal, and nuclear plants provide most of the remaining supply, while non-hydro renewables such as wind, solar and biomass make up 5.5 per cent of capacity[1]. In Quebec (Canada's second largest province) hydroelectricity is the predominant energy source, while in Ontario (the largest province), much of the electricity is produced from nuclear plants as well as natural gas.

1.2 Definition

The term Net Zero Energy Housing (NZEH) rose out of the US Department of Energy's Zero Energy Homes research initiative that started in 2000. In 2006, Canada Housing and Mortgage Corporation's (CMHC) EQuilibrium™ Housing Pilot Demonstration Initiative set the challenge for Canadian homebuilders and developers (CMHC-EQ, 2007). "Net zero energy housing', as defined by CMHC, describes a home that produces as much energy as it consumes annually. This is done through a variety of means, including (Shawna Henderson, Chris Mattock. 2007):

- reducing energy loads through a climate-responsive, high-performance building envelope and use of energy efficient appliances and lights throughout the house
- increased use of passive solar cooling and heating techniques
- high-efficiency mechanical systems that match the lower energy requirements of the home
- space and water heating assisted by commercially available solar thermal systems and heat pumps
- electrical use offset by grid-connected commercially available photovoltaic (PV) systems

SNEBRN mainly uses the following definition of a net zero energy building: a net-zero energy building is defined as one that, in an average year, produces as much energy (electrical plus thermal) from renewable energy sources as it consumes (SNEBRN, 2013). The production of energy from renewables on-site is the most difficult to achieve, but in sunny climatic conditions present in most of Canada, building-integrated solar systems make this possible, particularly for houses.

IEA SHC Task 40 /EBC Annex 52 "Towards Net-zero Energy Solar Buildings", led by Canada, with much research activity by a SNEBRN team completed its 5-year international collaborative research in 2013, with both the first and final meetings held in Montreal at Concordia University. The Task produced two books on NZEBs – the first one led by Germany focusing on definitions and simplified calculation techniques for NZEBs (Voss et al. 2011); the second one led by Canada's NSERC Smart Net-zero Energy Buildings Strategic Research

[1] National Energy Board (2013). Canada's Energy Future 2013, Government of Canada.

Network (SNEBRN) is focused on modelling, design and optimization of NZEBs (Athienitis et al., in press).

According to the Net-Zero Energy Home Definition and Performance Metrics Project which is held by Net-Zero Energy Home Coalition (NZEH), the development of industry endorsed net-zero energy and net-zero energy ready definitions with quantifiable performance metrics are needed to be identified. As the only industry association in North America focused specifically on net-zero energy homes, the NZEH characterized the net-zero home in three metrics: A net-zero energy (NZE) home, A net-zero energy ready (NZER) home and A net-zero energy verified (NZE^V) home (Winkelmann S. W, 2012):

A net-zero energy (NZE) home is one that is designed and constructed to produce as much energy as it consumes on an annual basis.

A net-zero energy ready (NZE^R) home is one that is designed and constructed to deliver the same energy performance as a NZE home but has not yet installed the onsite renewable energy generation capacity needed to achieve NZE performance.

1. NZE^R must meet the same requirements as NZE, minus installation of the onsite renewable energy generation system.
2. Existing "Solar Ready" programs and guidelines such as those provided by NRCan and CanSIA will serve as the foundation for a solar option.

A net-zero energy verified (NZE^V) home is one that has been verified to produce as much energy as it consumes on an annual basis.

Voluntary standards for low-energy buildings using the principles of high insulation, good air tightness and heat recovery ventilation systems are increasingly popular, such as the R-2000 standard in Canada (NRCan, 2005). In current practice, the most common approach to ZEB is to use the electricity grid both as a source and a sink of electricity, thus avoiding the on-site electric storage systems. The term 'net' is used in grid connected buildings to define the energy balance between energy used and energy sold, the term 'net-zero energy' being applied when the balance is zero (Hernandez P, Kenny P. 2010).

At the present time, many countries including Canada are still working on a widely accepTable definition of NZEB. As reported by International Energy Agency Annex 52 Task 40 (Towards Net-Zero Energy Solar Buildings) from a recent literature review on ZEB definitions:' The Zero Energy/Emission Building is a complex concept thus the development of one ZEB definition applicable for all case is not a simple task." There are many parameters that need to be taken into account when defining Net-Zero Energy. For instance, what units of balance will we use; purchased energy, primary energy, energy cost, CO2 emission? Does embodied energy in the actual construction need to be accounted within the balance? What boundaries are we considering for the definition; site energy, building footprint, off-site supply, on-grid, off-grid.

While this approach could seem quite restrictive, The two most frequently cited definitions in current literature are ‘‘net-zero site energy’’ and ‘‘net-zero source energy’’, Net-zero site energy means that a site produces at least the same energy as it uses in a year, independent of the type of energy produced or used. In the 'net-zero energy source' definition, imported and exported energy are multiplied by a primary energy conversion factor, thus allowing for some flexibility in the use of heating fuels. For example, if electricity is being sold directly to the grid in a location where the electricity primary factor is high, the ‘net-zero energy source’ definition would allow the use of larger quantities of a heating fuel from a source with a smaller primary energy factor (Torcellini P, Pless S, Deru M. 2006).

1.3 Conclusion

Canada has taken many steps to perform research on solar and energy efficiency technologies and their integration to achieve cost effective, comfortable and marketable NZEBs. Research has been performed by the NSERC SNEBRN university-led research network, by CanmetENERGY and several demonstration projects – notably the EQuilibrium™ initiative have been carried out. There is strong support for NZEBs to become widespread by 2030.

2 Program & Findings

NSERC invests $816.6 million in all Priority Areas of Canada's S&T Strategy (2010-2011), among which 36% are focused on Environmental Sciences and Technologies, and Natural Resources and Energy. NSERC Smart Net-Zero Energy Buildings Strategic Network (SNEBRN) and many other programs receive significant attention.

2.1 Federal Buildings Initiative

The Federal Buildings Initiative (FBI) is a voluntary program that helps facilitate energy efficiency retrofit projects in buildings owned or managed by the Government of Canada. Developed and administered by Natural Resources Canada's Office of Energy Efficiency, it enables federal organizations to implement these projects through third-party energy performance contracts without necessarily using their own capital funds[1].

Many federal organizations have successfully completed a retrofit project because they are motivated and excited by the rewards of improved energy efficiency. This is a smart investment that pays off through important and tangible benefits including the following:

- Guaranteed energy savings – often more than 20 percent – which are retained after successful completion of the EPC;
- Low risk since the pre-qualified ESCOs assume virtually all risk;
- Private sector financing with no up-front costs;
- Turnkey implementation that takes advantage of the ESCOs engineering and energy management expertise;
- Healthier, more comfortable and productive working environments;
- Reduced greenhouse gas (GHG) emissions;
- A demonstrable contribution to sustainable development.

The FBI is working with representatives from numerous federal organizations to help them implement successful retrofit projects. To date, there have been over 80 retrofit projects, attracting $312 million in private sector investments and generating over $43 million in annual energy cost savings. These FBI projects have demonstrated on average a 15-20 percent energy savings and have also helped reduce the impact of operations on the environment – cutting GHG emissions by 235 kilotonnes.

Other levels of government, institutions and private sector firms also draw on the FBI's experience for help in designing their own energy efficiency programs.

2.2 The EQuilibrium™ Sustainable Housing Demonstration Initiative

EQuilibrium™ is a national sustainable housing demonstration initiative, led by CMHC that brings the private and public sectors together to develop homes, and eventually communities that are a model for sustainable living. EQuilibrium™ homes are designed to address occupant health and comfort, energy efficiency and renewable energy production, resource conservation, reduced environmental impact and affordability.

CMHC's EQuilibrium™ Sustainable Housing Demonstration Initiative offers builders and developers across the economy a powerful new approach to establish a reputation for building healthy and sustainable, quality homes that will meet the needs of Canadians now and well into the future[2].

The goals of the EQuilibrium™ housing initiative are to:

1) Develop a clear vision and approach to develop and promote low-environmental impact healthy housing across Canada.

2) Build the capacity of Canada's home builders, developers, architects and engineers to design and build EQuilibrium™ homes and communities across the economy;

3) Educate consumers on the benefits of owning an EQuilibrium™ home and achieve market acceptance of EQuilibrium™ houses and sustainable communities; and

4) Enhance Canada's domestic and international leadership and business opportunities in sustainable housing design, construction services and technologies.

To pursue this goal, CMHC invited Canada's builders and developers in May 2006 to submit their ideas for EQuilibrium™ demonstration homes. Seventy-two builder- and developer-led teams submitted expressions of interest. An evaluation committee of independent housing experts then chose 20 of the applicants to undertake an integrated design process and prepare and submit detailed proposals. On January 12, 2007, 18 teams submitted their final proposals, which were evaluated and ranked by a second independent committee. In 2007 CMHC announced the first 12 teams chosen to build and demonstrate their EQuilibrium™ projects. The vision for the EQuilibrium™ housing initiative was that of an active partnership between all levels of government and industry to ultimately achieve zero environmental impact homes. SNEBRN researchers were involved and played a key role in several of the EQuilibrium™ houses. The first house to be built, Ecoterra, was a prefabricated house in which SNEBRN, CanmetENERGY and the builder Alouette Homes collaborated to develop this project that is also an IEA Task 40 /EBC Annex 52 case study.

2.3 IEA SHC Task 40/EBC Annex 52

In October 2008, the International Energy Agency (IEA) approved the creation of a new five-year (ended on September 2013) international collaborative joint research initiative between the Solar Heating and Cooling (SHC) Implementing Agreement and the Energy in Buildings and Communities (EBC) Implementing Agreement, entitled "Towards Net-Zero Energy Solar Buildings" (SHC, 2013), with Canada assuming and funding the position of the Operating Agent. This R&D collaboration had a membership of 57 National Experts and an additional 25 regular participants and contributors from 19 OECD member countries. Three National Experts, two of which are NRCan staff – one being the Operating Agent Josef Ayoub, and the third being Dr. Athienitis, the Principal Investigator of the SNEBRN, represented Canada in this Task/Annex (NSERC, 2013); six doctoral students of SNEBRN also participated and played a key role in the completion of Volume 2 of the Task (Athienitis and O'Brien, 2014).

The objective of the Task was to study current net-zero, near net-zero and very low energy buildings and to develop a common understanding, a harmonized international definitions framework, tools, innovative solutions and industry guidelines. A primary means of achieving this objective is to document and propose practical NZEB demonstration projects, with convincing architectural quality. These exemplars and the supporting sourcebook, guidelines and tools are viewed as keys to industry adoption. These projects will aim to equalize their small annual energy needs, cost-effectively, through building integrated heating/cooling systems, power generation and interactions with utilities[4].

The planned outcome of the Task is to support the conversion of the NZEB concept from an idea into practical reality in the marketplace. The Task source book and the datasets will provide realistic case studies of how NZEBs can be achieved. Demonstrating and documenting real projects will also lower industry resistance to adoption of these concepts. The Task built upon recent industry experiences with net-zero and low energy solar buildings and the most recent developments in whole building integrated design and operation. The joint international research and demonstration activity addresses concerns of comparability of performance calculations between building types and communities for different climates in participating countries. The goal is solution sets that are attractive for broad industry adoption.

The Task produced two books mentioned in Chapter 1, with Volume 1 (led by Germany) covering definitions and simple calculations, while Volume 2 (led by Canada) is focused on modelling and design of NZEBs:

> *Net Zero Energy Buildings, 2011. Detail Green Books, Voss K. and Musall E. (Editors), Munich Germany. (ISBN: 978-3-0346-0780-3) – IEA SHC Task 40/ EBC Annex 52 sponsored publication.*
>
> *Athienitis, A. K., W. O'Brien, J. Ayoub, C. Kapsis, Y. Chen, V. Deslisle, S. Yip, J. Candanedo and S. Bucking et al. 2014. Modelling, Design and Optimization of Net-zero Energy Buildings, J. Wiley, in press (co-editors Athienitis and O'Brien).*

2.4 R-2000 Net Zero Energy pilot

The R-2000 Net Zero Energy pilot aims to recognize the builders and homes reaching net zero energy performance in Canada, and to pilot the next generation of NRCan's R-2000 Standard and EnerGuide Rating System in net zero energy applications. Drawing on NRCan's national systems and infrastructure - including its certified energy advisors, certification process and quality assurance protocols - will provide recognized metrics, objectivity, standardization and credibility to this emerging space. By focusing on off-the-shelf technology, the pilot is also aimed at advancing the commoditization of net zero energy homes in Canada. With the draft 2014 R-2000 Standard and the next generation EnerGuide Rating System (ERS) as the basis, NRCan will examine the best means for seamlessly incorporating the net zero energy offering into its suite of standards on a permanent basis moving forward. NRCan will also use this opportunity to explore possibilities surrounding net zero energy ready homes.

Key aspects are summarized below.

1. Build on national programs

The R-2000 Standard will form the basis for the pilot. R-2000 is an established national standard with the training, certification, house-testing, inspections and overall quality assurance that are an essential part to ensuring the integrity of net zero energy housing. The minimum envelope requirements of the 2014 R-2000 Standard will be applied in order to ensure the envelope and other long-term elements are well addressed before renewable energy technologies are used to reduce conventional energy use. Non-R-2000 builders can enter the pilot by using this process and this house to become R-2000 builders.

The pilot will label houses with a next generation ERS rating (0 GJ). This offers an opportunity for participants to use and feed into the next generation ERS process to ensure it addresses any outstanding issues that relate to net zero energy homes. The next generation ERS also includes an add-on service called the Efficient Living Assessment, which is a post-occupancy assessment that can be used to confirm as-operated performance.

With R-2000 certification, quality assurance will be provided for builders and homes that are attaining net zero energy home levels of performance. Each participating house must meet the established R-2000 and ERS criteria for the pilot and be certified and labeled accordingly. Using R-2000 and ERS avoids marketplace confusion in green labeling and provides continuity with the over one million Canadian homes that have been labeled using ERS to date.

2. Focus on energy performance and commoditization of net zero energy homes

The pilot will focus on energy performance, though it will also make use of the 2014 R-2000 Standard's five pick list categories: Indoor Air Quality, Energy Efficiency, Resource Management, Environmental Stewardship and Water Conservation. Since the pilot is looking to advance the commoditization of net zero energy homes, the approach will focus on homes that can be built today using technologies already available on the market that meet industry standards and regulations. Technologies will be limited to pre-engineered products and systems (e.g. versus custom mechanical systems). This will help ensure that the technologies can be modeled and provides some assurance with regard to their long-term performance.

Builders will have a first-to-market claim on this new Government of Canada certified level of recognition from NRCan. They will also play a key role in setting the requirements for labelling Net Zero Energy homes in Canada. NRCan will offer technical support and promotion as an in-kind contribution to each participant.

Pilot participants will also benefit from collaborating with leading experts to gain insight into design of homes using available, high performance building envelope products, technologies, and techniques that can be used to achieve net zero energy performance. Participants who are successful through the request for proposals process will also have access to modeling support from NRCan simulation experts for technologies that cannot be modeled using HOT2000.

This pilot will give participants an opportunity to demonstrate industry leadership with first-to-market, NRCan-recognized net zero energy homes built and certified under the quality assurance of R-2000. NRCan will also work with the pilot proponents to raise awareness about the pilot and its participants.

Timeline:

May 2013: NRCan presented research that demonstrates that an R-2000 home can achieve net zero energy home performance using commodity technologies and methods. The net zero energy cost optimization webinar also provided a cost ball-park, guidelines and starting point for pilot participants.

Fall 2013: Through a request for proposals process, 12 builders were invited to participate in the Pilot. A list of these builders is provided below.

Table 2.1 List of builders invited in R-2000 Net Zero Energy pilot

Avalon Master Builder	Calgary, AB	www.avalonmasterbuilder.com
Cornelis Grey Construction Inc.	Ottawa, ON	www.cgreyconstruction.com
Global Sustainable Solutions	Tay Township, ON	www.globalsustainablesolution.ca
Habitat for Humanity Manitoba	Winnipeg, MB	www.habitat.mb.ca
Habitat Studio & Workshop Ltd.	Edmonton, AB	www.habitat-studio.com
Insightful Healthy Homes Inc.	Vancouver, BC	www.insightful.ca
K&P Contracting	St John, NL	www.kp.nf.ca
Slingshot Residential Incorporated	Regina, SK	www.slingshotresidential.com
Sloot Construction Ltd	Arkell, ON	www.slootconstruction.com
Sonbuilt Custom Homes Ltd.	Vancouver, BC	www.sonbuilthomes.com
Sustainable TO	Toronto, ON	www.sustainable.to
Wrighthaven Homes Limited	Elora, ON	www.wrighthavenhomes.com

Spring 2014 to Spring 2015: Houses will be constructed and then go through the R-2000 verification and labeling protocol[5].

Summer 2015 to Fall 2015: Post-program analysis will be undertaken to allow NRCan to assess the feasibility of recognizing R-2000 net zero energy performance within its suite of standards as well as provide valuable lessons learned to interested builders for the future.

2.5 Affordable Net Zero Energy Homes

Recent Canadian demonstration projects by leading-edge builders have proven that Net Zero Energy (NZE) homes are technically feasible in Canada's cold but sunny climate. But current building approaches are complex, custom, and expensive, often adding $50-120K to the cost of a home. To make NZE homes more accessible to Canadians, CanmetENERGY has begun the Affordable Net Zero Energy Homes Project to explore ways to reduce the cost[6]. The project started in December, 2010 under the lead of NRCan.

The Affordable Net Zero Energy Homes project extends the Path to Net Zero initiative through an intensive evaluation and comparison of new and emerging approaches to the integration of renewable energy sources and energy conservation. As the graph in Figure 2.1 shows, the goal is to reduce the incremental costs associated with building Net Zero Energy homes to a level significantly lower than the $100-200K associated with the first Canadian prototype NZE homes, and the $90-120K associated with using second-generation practices.

To do this, the Affordable Net Zero Energy Homes Project will follow a four-step work plan:

1. Review best practices and define methodology. Review existing NZE housing practices, define the optimal market specifications to ensure archetypes and research results will be suitable for builder adoption, document existing and emerging technologies and practices, collect performance and costing data, and define the methodology and scope for technology assessment and optimization.
2. Assess technology and optimize performance. Model, analyze, and optimize the most

promising existing and emerging technologies.

3. Affordable technology integration. Based on the results of the first two steps, develop strategies for building affordable NZE housing.

4. Knowledge dissemination.

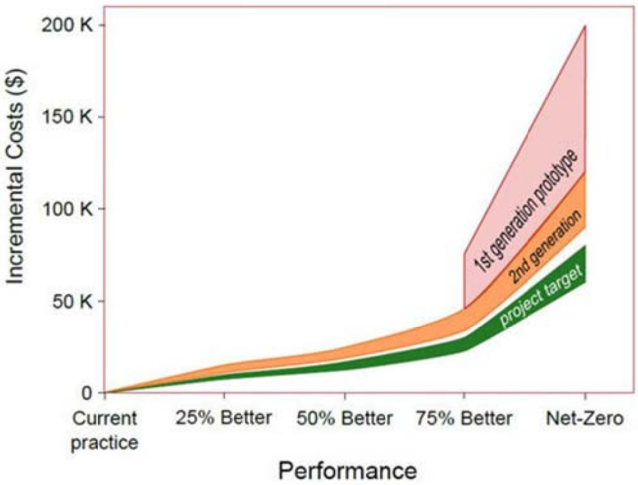

Figure 2.1 Technology pathways to achieve high performance, affordable housing

Based on the findings of steps 1-3, technology pathways to achieve high performance, affordable housing will be developed. Figure 2.1 shows the steps and the targets of the projects. The cost of a 5-7 kW photovoltaic system needed to build a net-zero energy house in many regions of Canada has dropped from about $50k in 2006 to about $15k in 2014. This rapid drop in price means that the cost increase to make net-zero an R2000 house that incorporates passive solar design should not be more than about $20k.

2.6 Conclusion

Integrating the research programs and the latest technologies, we conclude that Canada takes an integrated approach to development of net-zero energy houses and their widespread adoption by 2030. Significant funding was provided for the research on net-zero energy housing. While improving the energy efficiency of houses and buildings, the Canadian government still makes a lot of effort to make these houses and buildings affordable for many people. The major effort is through the NSERC SNEBRN university network led by Dr. Athienitis (and the previous NSERC Solar Buildings Research Network), by NRCan and by CMHC. In return, this greatly expands the influence in the population and accelerates the marketization of net-zero energy houses and building.

3 Building Codes and Standards

3.1 R-2000

R-2000 is a voluntary standard administered by Natural Resources Canada (NRCan) and is delivered through a network of service organizations and professionals across Canada. Developed in partnership with Canada's residential construction industry, R-2000 is one of the initiatives offered by NRCan's Office of Energy Efficiency. This initiative's aim is to promote the use of cost-effective energy-efficient building practices and technologies. Through the use of third-party evaluators and a government of Canada supported certification process homeowners are assured of real value and consistency.

The R-2000 Standard (R-2000)[7] is an industry-endorsed technical performance standard for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction. Houses built to the R-2000 Standard typically exceed the energy performance requirements of the current Canadian building codes and are recognized by meeting a high standard of environmental responsibility.

Since its introduction over 25 years ago, the R-2000 Standard has become the benchmark for energy efficient new home building in Canada. The Standard is continually upgraded to include new technologies as it becomes established in the marketplace furthermore it is flexible enough to apply to any type of home. Government and industry manage R-2000 technology through consultations. They involve researchers, home builders, product manufacturers and other housing experts.

The R-2000 Standard presents the criteria that a new house must meet to be eligible for R-2000 certification. The technical requirements of the R-2000 Standard include measures for the efficient use of energy, improved indoor air quality and better environmental responsibility in the construction and operation of a house (John Vandekleut, 2004).

The goal of the R-2000 Standard is to improve the energy efficiency of new houses without compromising either the interior or exterior environments. These technical requirements include both the performance goals and prescriptive measures that a house must meet to become eligible for R-2000 certification. The requirements are intended to give the builder flexibility in the selection of construction techniques, building products, mechanical equipment, lighting and appliances. The R-2000 Standard is periodically updated to ensure that R-2000 houses represent the leading edge of cost-effective housing technology (NRCan, 2012).

3.2 Evaluation Standards

3.2.1 ENERGY STAR

ENERGY STAR for New Homes is an initiative (in Ontario) to promote energy efficient home building backed by Natural Resources Canada and supported by progressive builders interested in offering a more energy efficient house to their customers[7].

3.2.2 R-2000 Certification

To be eligible for R-2000 certification, the house must comply with the rules and procedures established by Natural Resources Canada for plan evaluation, inspection, airtightness testing and issuance of an R-2000 certificate (NRCan, 2012).

Each R-2000 service organization is authorized to enforce NRCan's certification procedures. Service organizations shall adhere to minimum requirements set by Natural Resources Canada that include (NRCan, 2012): (a) R-2000 house application; (b) plan evaluation; (c) inspection; (d) airtightness testing; and (e) issuance of an R-2000 certificate. The R-2000 Procedures Manual provides additional information.

Homes that comply with the standard are issued a certificate by NRCan to the homeowner upon completion of the final inspection and tests. A central registry is maintained in Ottawa (Vanessa J, Richard K, 2014).

3.2.3 EnerGuide Rating System

An EnerGuide rating is a standard measure of a home's energy performance. Ratings are calculated by professional EnerGuide rating service energy advisors from information collected during the analysis of building plans and the results of the blower door test performed once the house has been built[8]. The final EnerGuide rating for a new home shows how energy efficient it is. The home's energy efficiency level is rated on a scale of 0 to 100. A rating of 0 represents a home with major air leakage, no insulation and extremely high energy consumption. A rating of 100 represents a house that is airtight, well insulated, sufficiently ventilated and requires no purchased energy on an annual basis (a net-zero energy house). A rating of 80 generally represents a house built to R2000 standard.

Table 3.1 Typical Energy Efficiency Ratings (EnerGuide)

Type of House	Rating
New House built to building code standards	65-72
New house with some energy-efficiency improvements	73-79
Energy-efficient new house (80 is R2000)	80-90
House requiring little or no purchased energy	91-100

A rating of 80 or higher is NRCan's goal for all new housing. The rating is determined by collecting detailed information about the home's energy systems, construction materials and assembly and inputting that information into an energy simulation modeling program developed by Natural Resources Canada. To factor out the influence of occupants habits (i.e., to measure the way the house itself uses energy, not the energy-using habits of its occupants), standard operating conditions are used in the rating.

3.3 Conclusion

R-2000 is the main Canadian (federal) voluntary building standard for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction. Though it is not developed specifically for net zero energy building, it ensures the development of energy efficient house with high levels of insulation and double-glazed low-e argon windows. The

Energuide rating is used to assess the relative an energy efficiency of a home, with 80 representing an R-2000 base house and 100 a zero net-energy house.

4 Networks & Organizations

4.1 NSERC Smart Net-zero Energy Buildings strategic Research Network (SNEBRN)

Natural Sciences and Engineering Research Council of Canada (NSERC) is a Canadian government agency that provides grants to University and College researchers for research in the natural sciences and in engineering. NSERC aims to make Canada a economy of discoverers and innovators for the benefit of all Canadians. The agency supports university students in their advanced studies, promotes and supports discovery research, and fosters innovation by encouraging Canadian companies to participate and invest in postsecondary research projects (see www.nserc.ca).

The NSERC Smart Net-zero Energy Buildings strategic Research Network (SNEBRN), funded for 2011-2016 under the strategic networks program of NSERC partly builds on a previous network: the NSERC Solar Buildings Research Network (SBRN), which completed its program at the end of 2010. SNEBRN brings together a total of about 30 researchers from 15 Canadian universities and over 100 graduate students (PhD and Masters) in an integrated effort to develop advanced concepts for net-zero energy buildings and communities. In addition there are about 20 partners from industry and government labs. Major partners include the CanmetENERGY Laboratory of Natural Resources Canada and a major utility in Quebec – Hydro Quebec. In addition to applied research, SNEBRN and SBRN played a key role in demonstration projects of NZEBs such as Ecoterra and Abondance under the EQuilibrium™ program conducted by CMHC.

The vision of SNEBRN is to perform the research that will facilitate widespread adoption in key regions of Canada, by 2030, of optimized NZEB energy design and operation concepts suited to Canadian climatic conditions and construction practices.

It aims to influence long-term national policy on the design of net-zero energy buildings and communities in association with our partners. **The main network goal** is to develop optimal pathways for achieving zero average annual energy consumption at both the building and neighborhood levels. This is achieved through combinations of dynamic building methods that integrate a number of technologies: building-integrated solar systems, high performance windows with active control of solar gains, short-term and seasonal thermal energy storage, heat pumps, combined heat and power technologies, and smart controls. The Network is organized into the following five Themes, each Theme having two internationally-recognized researchers as co-leaders:

1. Integrated solar and HVAC systems for buildings

2. Active building envelope systems and passive solar concepts.

3. Mid-to long-term thermal storage for buildings and communities.

4. Smart building operating strategies.

5. Technology transfer, design tools and input to national policy.

Source: NSERC Smart Net-zero Energy Buildings Strategic Research Network (SNEBRN) (www.solarbuildings.ca)

4.2 NRCan and CanmetENERGY (NRCan lab)

Natural Resources Canada (NRCan) is the ministry of Natural Resources of Canada. It seeks to enhance the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resources products. NRCan develops policies and programs that enhance the contribution of the natural resources sector to the economy and improve the quality of life for Canadians.Natural Resources Canada's CanmetENERGY is a leading government laboratory in clean energy research and technology development. With over 450 scientists, engineers and technicians it is Canada's main government lab in clean energy technologies[9].

CanmetENERGY manages science and technology programs and services, support the development of energy policy, codes and regulations, act as a window to federal financing and work with their partners to develop more energy efficient and cleaner technologies in the following areas:

- Buildings and Communities
- Clean Fossil Fuels
- Bio Energy
- Renewables
- Industrial Processes
- Oil Sands
- Transportation

CanmetENERGY works with the energy industry, academia and environmental stakeholders on cost-shared basis through in-house work and funding support.

4.3 Canada Mortgage and Housing Corporation (CMHC)

Canada Mortgage and Housing Corporation (CMHC) is a Crown corporation, of the Government of Canada, founded after World War II to provide housing for returning soldiers. After the war, a serious housing shortage and the return of large numbers of veterans led the government to create CMHC to promote the development of new housing by offering very low cost mortgages with small down payments and easy terms[10] [1]. It later built and/or funded urban renewal projects in Canada's cities.

One of the main functions of CMHC is to manage the federal Mortgage Insurance Fund (MIF), which was introduced in 1954 to provide protection to banks reluctant to enter the mortgage lending market (www.cmhc.ca) .Today its main function is managing providing insurance for residential mortgage loans to Canadian home buyers. This insurance protects mortgage lenders against mortgage defaults on mortgages for which insurance has been purchased (mandatory on loans with less than 20% down although lenders may require it on loans with more than 20% equity if they perceive additional risk of default). Besides mortgage insurance, the agency provides financing to housing projects and renovations, does housing market analysis and funds research into housing design and technologies along with the National Research Council. The mandate of CMHC, as Canada's national housing agency, includes facilitating accessibility to a "wide choice of quality, environmentally sustainable, affordable housing solutions."

4.4 Net-Zero Energy Home (NZEH) Coalition

The Net-Zero Energy Home (NZEH) Coalition is an incorporated, multi-stakeholder non-profit organization comprised of North American champions in advanced energy efficient residential construction and building products, the utility sector, research and development, and manufacturing and deployment of on-site renewable energy technologies. The Net-Zero Energy Home Coalition was formed in 2006 (Winkelmann S. 2012) and began formulating an action plan to involve other stakeholders and government in turning the vision into a reality. The Vision of the Net-Zero Energy Home Coalition is for all new home construction to meet a net-zero energy standard by 2030. New homes meeting a net-zero energy ready standard by 2020 will set the stage and prove out the practicality and viability for our 2030 Vision (Winkelmann S., 2012). This project's objective is to develop industry-endorsed net-zero energy (NZE) and net-zero energy ready (NZER) home definitions with quantifiable performance metrics. In so doing, a consistent platform is to be established to direct industry and government research, guide builders in creating and promoting their products, and form a foundation for developing training, verification and marketing tools.

4.5 Royal Architectural Institute of Canada

The RAIC is the main association of architects in Canada[11]. The RAIC is a voluntary national association representing professional architects, and faculty and graduates of accredited Canadian Schools of Architecture. The RAIC's mission is to promote excellence in the built environment and to advocate for responsible architecture.

Architecture Canada, in adopting the 2030 Challenge, is calling all design professionals to become actively engaged in reducing fossil fuel use in building construction and operation by a minimum 50% today, 60% in 2010, 70% by 2015, 80% by 2020, 90% in 2025 to arrive at carbon neutral by 2030. To achieve these reductions we need to pool our successes, flag our failures and educate each other to create a new era of environmentally responsive buildings.

4.6 Conclusions

Canada, through its research networks and alliances, plays a key role in international research collaborations on net-zero energy buildings. Students from colleges and universities in Canada have the opportunity to participate in NZEB research and competitions, as well as real projects and this has resulted in development of highly qualified personnel. Many of them participate in NSERC SNEBRN, CanmetENERGY many other institutions for NZEB research.

5 Demonstration Projects

An efficient and well-functioning housing sector enables the marketplace to be the primary vehicle to meet the shelter needs of Canadians. In Canada, the housing needs of some 80 per cent of Canadian households are being met through the marketplace. Most of pilot projects in Canada must consider economic factor, in other words, the pilot projects have to be able to accomplished and popularized in an affordable way, especially for residential projects. From this point of view, economic analysis of NZEBs and NZEH is necessary in Canada.

5.1 Economic Analysis

In Canada, housing is considered affordable if shelter costs account for less than 30 per cent of before-tax household income. The term "affordable housing" is often used interchangeably with "social housing"; however, social housing is just one category of affordable housing and usually refers to rental housing subsidized by the government. Affordable housing is a much broader term and includes housing provided by the private, public and not-for-profit sectors as well as all forms of housing tenure (ie. rental, ownership and cooperative ownership). It also includes temporary as well as permanent housing. In other words, the term "affordable housing" can refer to any part of the housing continuum from temporary emergency shelters through transition housing, supportive housing, subsidized housing, market rental housing or market homeownership.

For a sustainable housing project, it is important to consider all housing costs (initial, on-going and life-cycle), the impact of consumer values, as well as to understand the benefits and where these accrue.

NZEH coalition made a market research on net-zero energy homes during the industry survey in 2011. The opportunity was taken to ask additional questions during the industry survey. Below is a summary of the responses.

75% of the responders think that net-zero energy, as a brand, already developed some market recognition and strength or is there an opportunity to develop new branding around the concept of net-zero energy homes

Nearly 30% of the responders think that the net-zero energy home market segment will grow at a rate of 5%-10% over the next 5 years, and 6% of the responders thought this rate should be over 10%.

Figure 5.1 shows how much more are consumers willing to pay for the added value of net-zero energy homes. Figure 5-2 shows why consumers want net-zero energy homes.

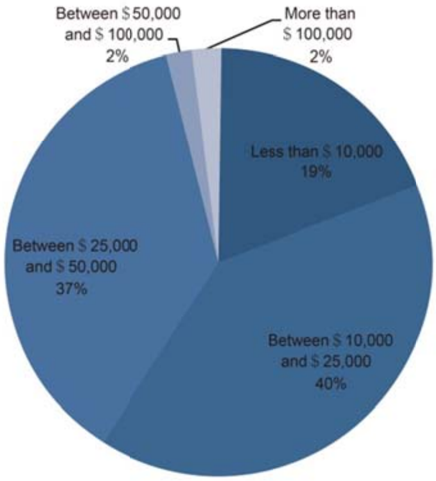

Figure 5.1 Additional value for net-zero energy home that consumers willing to pay

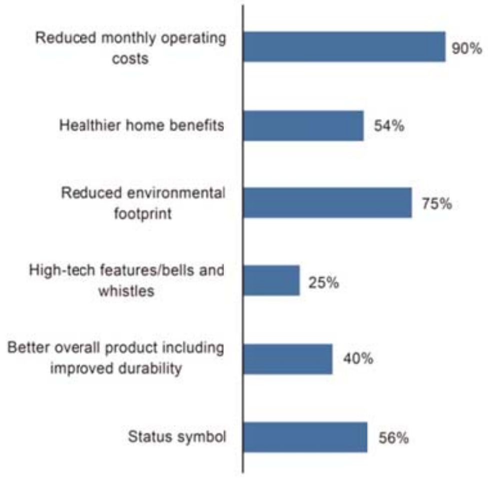

Figure 5.2 The reason that consumers want net-zero energy homes

Across Canada, most of the old existing housing stock was built with little consideration for energy efficiency. There is an opportunity to significantly reduce both energy use and greenhouse gas emissions through retrofit projects. Currently, residential buildings account for 17% of Canada's national energy requirements and 16 % of overall Canadian GHG emissions (CMHC, 2006).

For existing housing, retrofits in the $30,000 and $50,000 range were cost-effective when refinancing a mortgage. In many cases, the monthly energy savings outweigh the incremental increase in a mortgage payment. This Figure is over double the 'average' major renovation Figure of $12,000 reported in a CMHC study (CMHC, 2006).

A keynote presentation to the Affordable Comfort Institute's Summit on Carbon Neutrality in Summer 2007 estimated that four levels of retrofits were identified, moving from a 'general' energy efficient retrofit to a near zero or net zero energy retrofit as follows (Shawna H, Chris M. 2007):

- Low hanging fruit: costs about US$1500/home, saves 1,000 kWh and 100 therms annually
- Extensive retrofit: costs US$10,000/home, saves 4,000 kWh and 400 therms annually
- Deep retrofit: costs US$50,000/home, saves 7,000 kWh and 600 therms annually
- Deep retrofit + 3kW PV: costs US$75,000/home, saves 7,000 kWh and 600 therms annually and produces an additional 4,300 kWh/yr

5.2 The EcoTerra house

In an effort to encourage innovation, public knowledge, industry expertise, and public-private collaboration, the Canada Mortgage and Housing Corporation (CMHC) started the EQuilibrium™ Sustainable Housing Project Initiative (CMHC 2007). The initiative was an open design competition for builder- or developer-led teams to submit house designs that were both healthy and sustainable. Of the seventy-entries, the top 12 teams were selected to build their design.

Figure 5.3 ÉcoTerra house in Eastman, QC

The ÉcoTerra™ house, built by Alouette Homes, is a 240 m^2 prefabricated home that was assembled in September 2007 in Eastman, Quebec. The NSERC Solar Buildings Research Network, and in particular a team headed by Dr. Andreas Athienitis at Concordia University, led the energy system design of the house. The approach that was followed integrates the passive and active solar systems into the house design and optimizes energy efficiency technologies. The house includes an innovative building-integrated photovoltaic/thermal (BIPV/T) roof linked to a hollow core thermal storage system that is based on research carried out at Concordia University (Chen et al. 2010 a, b). ÉcoTerra™, the first of twelve CMHC EQuilibrium™ Demonstration Projects, uses energy collection and conservation features that are expected to enable it to consume less than 10% of the energy of a standard house of the same size on an annual basis (Athienitis et al., in press). The major features include:

- Building-integrated photovoltaic/thermal (BIPV/T) system which covers one continuous south-facing roof surface and simultaneously generates renewable electricity and heat.
- Passive solar design featuring high-performance windows, thermal mass and a highly-insulated and airtight building envelope.
- Ground-source heat pump system
- Waste-water and ventilation-air heat recovery systems
- Energy-efficient appliances
- The house demonstrates full architectural and envelope integration of an advanced solar energy system, as well as energy-saving measures, while maintaining occupant comfort.

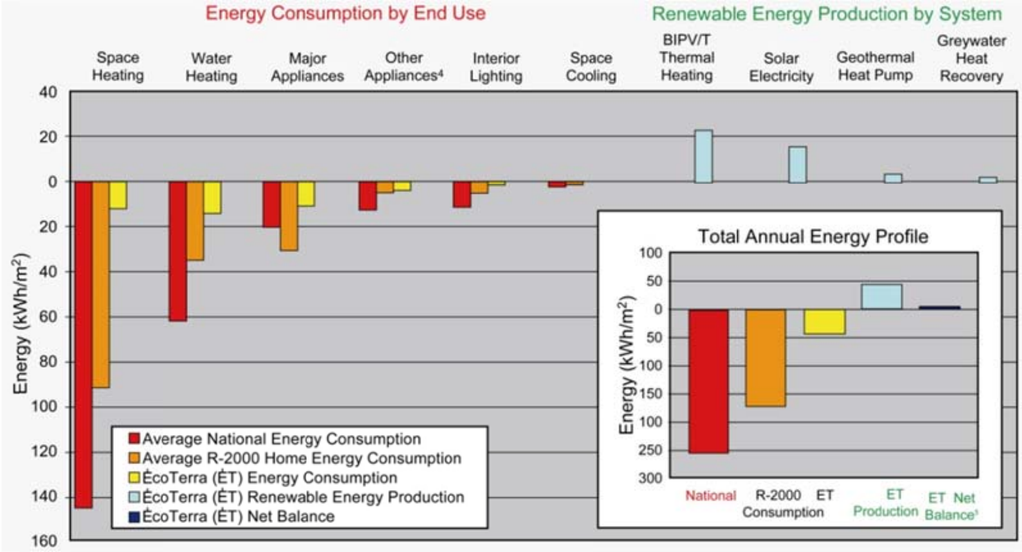

Figure 5.4 Annual energy consumption and production profiles of the ÉcoTerra house and other typical homes in Canada
Source: Case study of ÉcoTerra house in Canada

A redesign case study of the house is included in the book developed under the leadership of SNEBRN in IEA Task 40 (Athienitis et al. 2014). It shows that replacement of the low efficiency amorphous-Si PV system with a c-Si system covering the same area and having an efficiency in the range 15-18% and a few readily implemented energy efficiency measures will result in net-zero energy balance.

5.3 Drake Landing Solar Community

The Drake Landing Solar Community in Okotoks, Alberta, Canada has 52 detached energy-efficient homes. A solar thermal system with borehole seasonal storage is installed to supply space heating to the homes through a district heating network. Solar thermal energy is captured through 2293 m^2 of flat-plate collectors and stored in soil underground. The seasonal storage utilizes approximately 34,000 m^3 of earth. 144 boreholes with single u-tube heat exchangers are used to charge the earth and extract heat when needed. A short-term thermal storage consisting of 240 m^3 of water is used to interconnect the collection, distribution and seasonal heat storage subsystems (Sibbitt 2011).

Figure 5.5 The Drake Landing Solar Community (Sibbitt 2011)

This is the first system of this type designed to supply more than 90% of the space heating with solar energy and the first operating in a cold climate - 5200 heating degree-days and a design temperature of -31 C. The system has undergone detailed monitoring since it was brought into service in July. Monitored performance showed that a solar fraction of 97% in its fifth year of operation was achieved; this has demonstrated that high solar fraction systems of this type are technically feasible in a cold Canadian location (Sibbitt 2011). The ongoing monitoring and detailed simulation results are particularly valuable for learning from system designs such as this, where there is limited field experience. The success of the Drake Landing Solar Community project has led to the possibility of implementing similar but much larger systems, which offer opportunities for performance improvements and lower unit costs.

5.4 JMSB solar wall (BIPV/T) project

The John Molson School of Business (JMSB) building of Concordia University in Montreal, Canada uses a Building Integrated Photovoltaic/Thermal (BIPV/T) to collect heat and generate electricity from the sun using a single facade. This system is the first installation of its particular configuration and was led by the NSERC Solar Buildings Research Network (the Network on which SNEBRN built) and funded by the NRCan TEAM demonstration program. It is the world's first fully functional architecturally integrated BIPV/T façade that uses high-efficiency distributed air inlet technology with a 24.5 kWp photovoltaic (PV) is installed. Up to 75 kWp of heat by a 288 m^2 BIPV/T system will preheat up to about 15,000 cfm of fresh air. The construction was completed in 2008. The combined generation has an overall peak efficiency of about 60% (the rate of utilization of incident solar energy).

Figure 5.6 JMSB building façade with innovative solar façade system

SNEBRN currently performs research on BIPV/T technologies, semitransparent PV windows, thermal storage and predictive control to enable the design of net-zero energy office buildings.

5.5 The ECHO home

The ECHO house was designed as an entry to participate in the high-profile competition which was held by the U.S. Department of Energy - the Solar Decathlon. Team Ontario is a multidisciplinary team of students and faculty from Queen's University, Carleton University and Algonquin College. The team worked towards the 2013 competition for more than 3 years. In 2011 the team submitted a competitive proposal and in January 2012 they were notified that their bid was successful. After a 19-month design, construction and commissioning process, the

Team traveled to Irvine, California in October 2013 to participate in the competition.

Figure 5.7 Team Ontario's entry - ECHO house

At the end of the competition, the ECHO house has scored:

- First place in Engineering;
- Second place in Affordability;
- Tied for first place in Hot Water Draws;
- Tied for first place in Energy Balance;
- Sixth place overall

The house was entitled "ECHO": an Ecological Home for the next generation of young homeowners. The term also refers to the target demographic of the home: children of baby boomers sometimes referred to as "Echo Boomers". The house needed to appeal to a family with a young child, produce more energy than it uses over the course of a year in Ottawa, Ontario using only solar energy, and be as affordable as possible. The following Table lists some key design parameters of ECHO:

Table 5.1 Key design parameters of ECHO
Source: SNEBRN Newsletter Issue 2[14] (December 2013)

Conditioned floor space	87 m^2 (940 ft^2)
Exterior deck area	79 m^2 (850 ft^2)
Wall thermal resistance	9.7 m^2k/W (55hft^{2}F/Btu)
Solar photovoltaic (PV) capacity	7.8 kWp
Solar thermal array	12 m^2 (glazed flat-plate)
Heat pump COP	3.3
Heat pump capacity	5 kW (heating)
Predicted annual energy consumption (Ottawa)	7750kWh
Predicted annual energy production (Ottawa)	9850kWh
Estimated cost, parts and labor	USD $257,000

5.6 The Earth Ranger Centre (ERC)

The Earth Rangers Centre for Sustainable Technology is an advanced green building, certified

Gold under LEED for New Construction and Platinum under LEED for Existing Buildings: Operations and Maintenance. It is one of the most efficient buildings in Canada, using nearly 90% less energy than other buildings of its size. The ERC integrates innovative water, energy conservation and comfort strategies. The facility operates at less than 9 kWh per square foot, per year and generates 30% of its energy consumption on-site.

Figure 5.8 The Earth Rangers Centre[15]

The Centre is a showcase of sustainable building technology such as energy metering, smart automation and controls, innovative water and wastewater management, solar generation, green roofs, and geothermal heating and cooling. The original energy concept for the ERC was done by TransSolar[17], from Stuttgart Germany and Bautech developments. The original design provided a strong foundation of leading sustainable technologies including thermal mass, radiant heating and cooling, earth tube ventilation, on-site wastewater treatment and a green roof. Over the years, many of the technologies have been upgraded or integrated with new systems in order to continually stay at the forefront of the green building industry. The ERC has extensive energy, water and performance monitoring in place to manage the building on a day-to-day basis. These live data screens give access to how the Earth Rangers Centre is performing in real time.

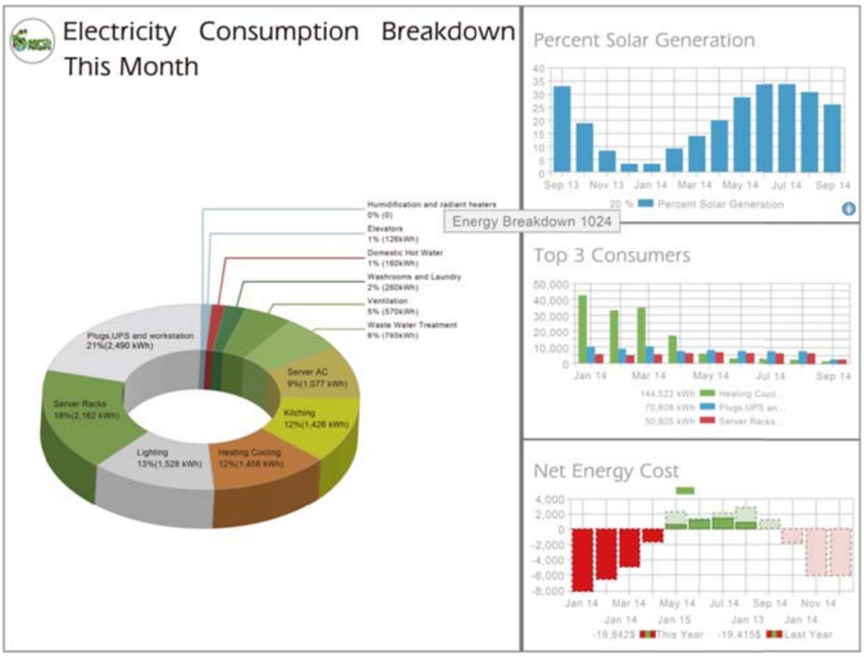

Figure 5.9 Power Monitoring for ERC[16]

5.7 S2E Technology's Smart Community Project – London, Ontario

The costs of many sustainable smart technologies have dramatically reduced in the last few years, making the concept of a Smart Community viable from technical and economic perspectives. The vision of S2E can be described as:

Put the living experience of people at the heart of communities by using proven, smart, sustainable technology to connect people, save them time and money, and allow them to more effortlessly care for themselves, their families, their communities, and their planet. This project is being developed to demonstrate the state of the art in Smart technology and Smart design for a multi-use community in London, Ontario. An exhaustive feasibility study to convert a conventionally designed mixed use community called Riverbend Village into a Smart Community was completed at the end of 2013.

- Located at Oxford St. and Kains Road in West London.
- 70 acres total
- 2,000 living units (High Rise, Medium Rise, and Townhomes)
- 150,000 sq. ft. of retail/commercial space
- 100,000 sq. ft. of office space
- Construction Period ~2015-2030

Figure 5.10 Strategy of the Smart Community Project

S2E and its partners investigated multiple technologies and designs that, when integrated, should create a community concept that is:

Livable, Healthy, Sustainable, Net Zero Energy, Net Zero GHG The Smartest Community in North America.

The feasibility research began in September 2013. s2e hired a team of over 50 engineers and scientists, and an additional 29 graduate students or Post-doctoral Interns worked full time on the project through the MITACS program. There were 11 universities collaborating in this research: it truly was a gathering of the best and brightest minds in Ontario. The team was very diverse and multi-disciplinary, bringing a holistic approach to the project development.

6 Conclusion

1. Background and Definition. Buildings account for about 53% of Canada's electricity consumption, space heating account for 63% of residential sector energy use. Begin from 2006, Canada Housing and Mortgage Corporation's (CMHC) EQuilibrium™ Housing Pilot Demonstration Initiative set the NZE challenge for Canadian homebuilders and developers. SNEBRN mainly uses the following definition of a net zero energy building: a net-zero energy building is defined as one that, in an average year, produces as much energy (electrical plus thermal) from renewable energy sources as it consumes. Even though there is no clear government objective on NZBE,the significant funding provided for the research will strongly support NZEBs to become widespread by 2030.

2. Research and promotion deployment. Through the work of NSERC SNEBRN, CanmetENERGY Lab of NRCan and industry leaders has achieved significant research outcome in NZEBs. While improving the energy efficiency of houses and buildings, the Canadian government still makes a lot of effort to make these houses and buildings affordable for many people. The major effort is through the NSERC SNEBRN university network, NRCan and CMHC. In return, this arrangement of collaboration greatly expands the influence in the population and accelerates the marketization of cost effective and comfortable net-zero energy houses and building.

3. Building Standards Upgrading. R-2000 is the main Canadian (federal) voluntary building standard for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction. Though it is not developed specifically for net zero energy building, it ensures the development of energy efficient house with high levels of insulation and double-glazed low-e argon windows. The Energuide rating is used to assess the relative an energy efficiency of a home, with 80 representing an R-2000 base house and 100 a zero net-energy house.

4. Networks and alliances. Canada, through its research networks and alliances, plays a key role in international research collaborations on net-zero energy buildings. Students from colleges and universities in Canada have the opportunity to participate in NZEB research and competitions, as well as real projects and this has resulted in development of highly qualified personnel.

5. NZEB demonstration. A demonstration program of near- net-zero energy homes was recently completed and the first house under this program – EcoTerra is briefly described. A house such as this was cost at least an extra $50k to build in 2007, but now with the rapid drop in the price of photovoltaic systems, it is possibly easy to build such a house in Canada based on the R2000 standard with a 5-7 kW system, adding only $15-20k to the price of an R2000 house.

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SECTION II CHINA

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1. Policy, Objectives, Definition

1.1 Policy

During the recent three decades, energy consumption in China has been increasing rapidly due to economic growth and development. With speeding modernization and urbanization, building energy consumption has steadily increased in China.

According to the statistical data, the share of building energy consumption in total energy consumption in China rose from 10% in 1978 to 30% and continues to maintain growth.

Compared with other industries, the sector of building will play a key role in energy consumption and become a prime objective for energy efficiency. Since 2006, The central government issues a series of measures about BEE to respond the challenge of rapid increasing building energy consumption owing to the increasing demand of more new buildings and household appliances, in the "Eleventh Five-Year Plan period", which Prof Shilei Lu made a clearly analysis in the paper <A review of building energy efficiency in China during "Eleventh Five-Year Plan" period >. The Main characteristics of Building energy efficiency development in China are: Development with the central government leading and top- down mode, Development in accordance with Chinese situation, Implementation of government enforcing, refining the technical standard system. The important fiscal incentive policies of building energy efficiency including: Special fund for energy efficiency of government office buildings and large-scale public buildings, Reward fund of energy efficiency retrofit for existing residential buildings in China's northern heating region, Special fund for demonstration of renewable energy application in building, Subsidy fund for building integrated photovoltaic (BIPV), Subsidy for city-level demonstration of renewable energy application, Financial subsidy for promotion of high efficiency lighting products.

But, at this stage, there is no clear government policy set the objective and development roadmap of NZEB.

1.2 Definition

China researchers start to discuss how to define NZEB in China, XU Wei and ZHANG Shicong analyzed the definition of NZEB and similar terms, they proposed that, according to the China situation, the energy calculation period should be one year, with the end-use energy as the performance indicator, the energy generated from the building and nearby renewable energy system are higher than the energy consumption of the building itself.

2. Research & Findings

Since the development for Net Zero Energy Building in China is still at the starting stage, universities and institutes are doing the majority of the researching work. Though most of the studies are still on the simulation and experiments, this will still be a powerful support and thus push the development of NZEB forward.

2.1 Energy supply concepts for ZERB in humid and dry climate

An energy supply concepts study for zero energy residential building (ZERB) in Shanghai (humid) and Madrid (dry) is conducted by Shanghai Jiao Tong University. During the study, two typical housing models are designed according to the real occupancy condition of two cities as well as life schedule, thermostats settings, etc. An energy analysis considering the annual balance of input from the grid and output from renewable power systems is provided for the ZERB. Indoor comfortable comparisons between two cities are also presented to show optimal design strategies for HVAC under different weather conditions. Primary energy payback time and CO2 emission reduction are presented to evaluate the performance of novel energy systems to show feasibility.

The first case of ZERB is a test apartment which will be built on the third floor of a green building in the campus of Shanghai Jiao Tong University (S Deng, 2009). Its indoor structure was designed according to China typical apartment for 2 adults and 1kid household. The second ZERB case Solar Decathlon Europe7 (SDE) that takes place in June 2010 in Madrid8 (Spain). The rendering design picture and passive design factors of two buildings can be seen in Figure2.1.

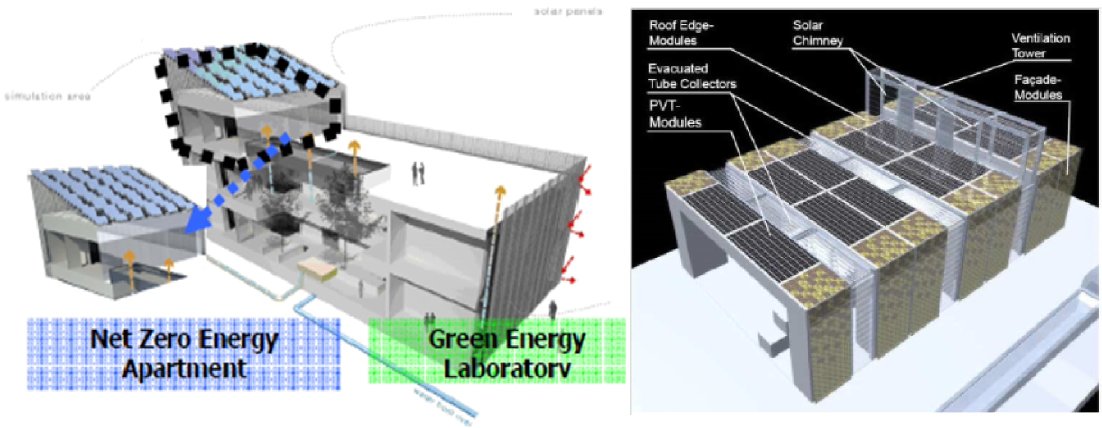

Figure 2.1 Design of the cases

(a) Concept design of the building 1; (b) Computer rendering of building 2

One weekly user profile is designed for the case (Figure 2.2 and Figure 2.3). The thermal and humidity gain profile is based on the building occupancy (2 people) and the electrical appliances of the house. Daily DHW demand corresponds to 50 litres/person with a 45°C set point temperature.

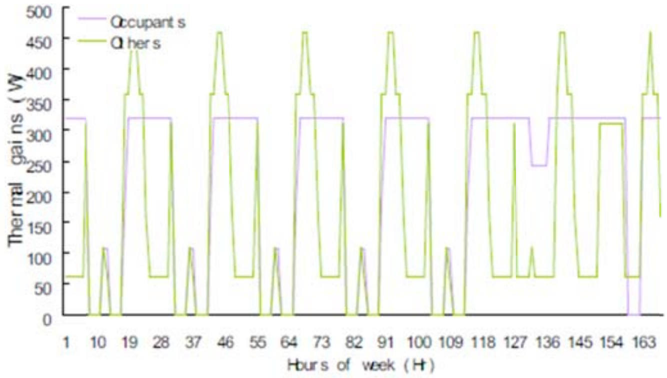

Figure 2.2 Thermal and humidity gains of building

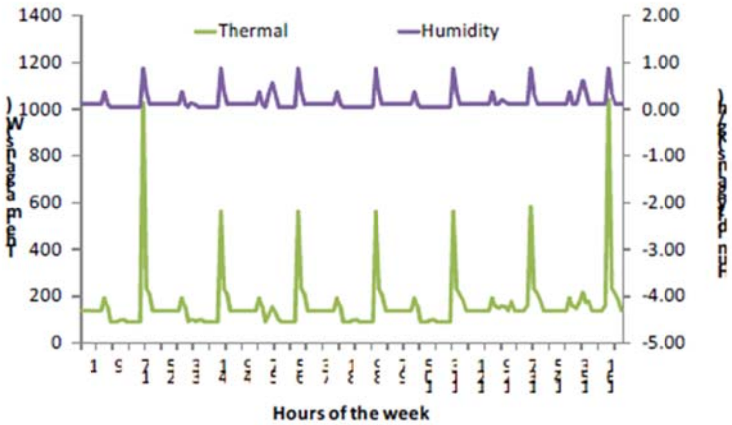

Figure 2.3 Thermal and humidity gains of building 2

The energy consumption of building 2 is smaller than building 1, not only because the better passive design (lower G value in window, etc.), but also because of novel active cooling technology, such as, radiant floor "free cooling". The electricity balance is positive for both climates in both cases, although it is less favorable in Shanghai since the electricity consumption is higher and the PV generation is lower.

2.1.1 Primary energy payback time

A life cycle analysis of the house has been done for the building 2 in order to calculate the primary energy payback time of the house for both climates. The total fossil primary energy necessary for materials and system technology (PV, solar thermal, HVAC…) has been estimated to 890 GJ. At the end of life, those materials can be either recycled or incinerated (thermally used) or put in landfills. The effective total primary energy needed for the house construction is then 610 GJ which gives 3026 kWh/m² (Figure 2.4).

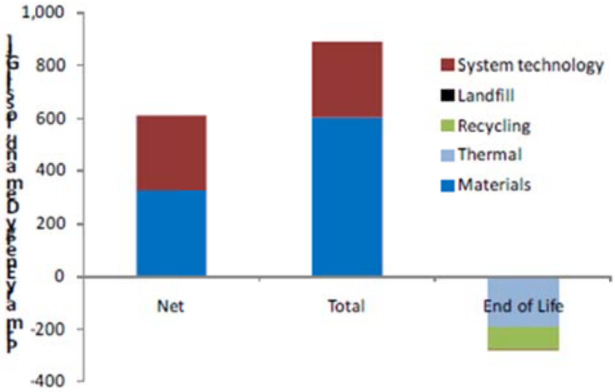

Figure 2.4 House primary energy demand

Based on this calculation result and the simulated energy demand during operation, the primary energy payback time can be calculated. The conversion factors of GEMIS have been used to consider the electricity mix generation of Spain and China. The primary energy payback times of building 2 for Madrid and Shanghai climates are 10.1 and 17.9 years, respectively.

2.1.2 CO_2 emission savings

Once the primary energy needed for the house has been recovered, the CO2 equivalent emissions savings during the rest of the house lifetime can be estimated. The conversion factors of GEMIS for Spain and China electricity mix have been used. The other conversion factor from one China research (Wang G, 2006) is also used as a reference. A house lifetime of 40 years has been used for the calculations.

Table 2.1 CO_2 emissions equivalent savings

	Madrid	Shanghai	
		GEMIS	MOST
CO_2 factor (kg/kWh_{el})	0.478	0.813	0.921
Total CO_{2eq} emissions saving	54745	75563	78838

The energy balance simulation result shows that the electricity generation of PV can meet the demands of two ZERB models in Shanghai and Madrid. Indoor comfortable results show that the temperature comfort can be met for two models under Shanghai and Madrid's weather. But humidity comfort demand need more customized energy concept's design schemes for different weather, such as, dehumidification device for Shanghai or humidification device for Madrid. Calculation results shows that primary energy payback time of ZERB in Madrid is 10.1 years and CO2 emission reduction is 54745 kg in building lifetime (Table 2.1).

2.2 Simulation Application in Evaluation of ZEB

Institute of Refrigeration and Cryogenics in Shanghai Jiao Tong University conducted a simulation application program on evaluating Zero Energy Building in terms of simulation-assisted design, simulation verification and simulation-assisted evaluation.

The whole life cycle of ZEB can be divided into 4 stages, including: preparation (manufacture and transport), construction, maintenance and demolition. The primary energy needed during the whole life time includes: embodied energy, operation energy and recycling energy.

- First stage: Supply load analysis as a guideline for the design of energy system.
- Experiment stage: Predict the test results via simulation. And update the simulation system based on the experiment verification.
- Final stage: Get performance data, which cannot be easily obtained through experiment under some external conditions, through verified simulation results.

A comprehensive analysis can be carried out based on the available data in terms of indoor comfort, energy balance and life cycle assessment (LCA). One should be note that the simulation is based on the typical Shanghai occupant's life style in the residential building and the main information for this life style. The weather data are from two typical meteorological year (TMY) files of data source: Chinese Standard Weather Data (CSWD) (China Meteorological Bureau and Tsinghua University, 2005) and Chinese Typical Year Weather (CTYW) (Zhang and Huang, 2008).

The case study is about a 93 m2 Zero Energy Apartment (ZEA) which is built on the third floor of a green building on the campus of Shanghai Jiao Tong University, as shown in Figure 2.5(a). The whole building 3D model is shown in Figure 2.6. The inside structure of apartment was designed and decorated according to the demand of a typical Chinese household, as illustrated in Figure 2.5(b).

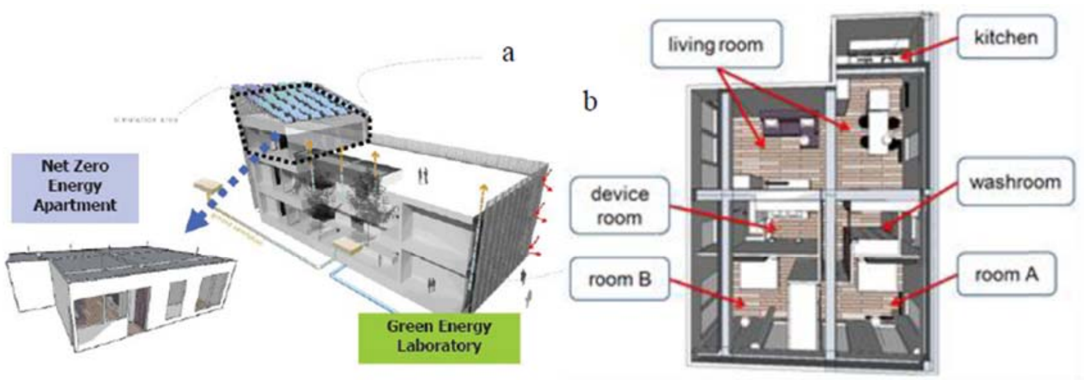

Figure 2.5 Architectural design: (a) ZEA; (b) inside structure

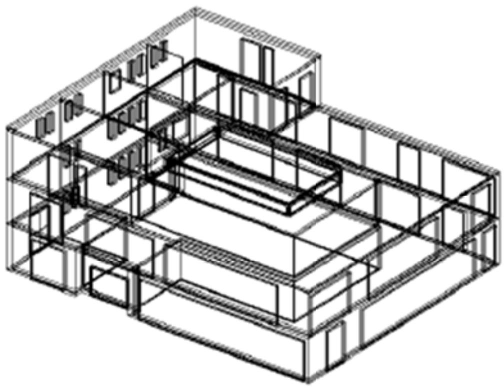

Figure 2.6 3D model of main body

Case information of the apartment:

Simulation software: EnergyPlus and DeST.

Simulating cooling load: 10.1 kW

Simulating heating load: 8.3 kW

Annual energy demand: 69.8(kWh/a) from EnergyPlus, and 78.5(kWh/a) from DeST.

It should be noted here that the load calculation is just for a comparison of passive design with the simplification model of an ideal energy system. Based on the calculated load, the energy system was designed for ZEA. Figure 2.7 shows the design concept of energy system in the ZEA, concerning the relationship among sources, devices and end user. The solar energy is applied as a main renewable energy source for cooling and heating and also electricity generation. The main devices are a solar collector (SC) loop and a hybrid heat pump which integrates a small scale LiBr absorption chiller with a conventional CO2 heat pump (HP).

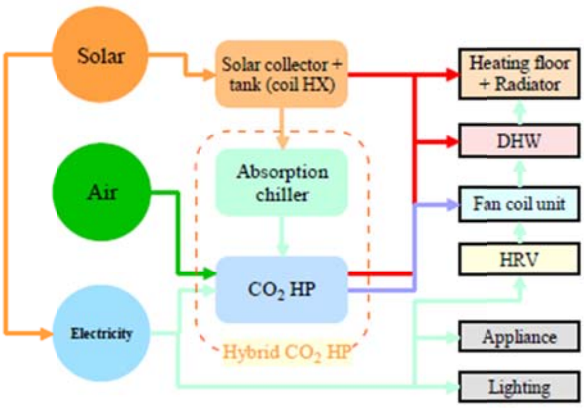

Figure 2.7 Design concept of energy system

Passive design of building has already been a mature technology and can be realized in a near-fixed process by simulation software, energy system design for ZEB may become the other focus regarding how to further improve total performance of ZEB. Energy system of ZEB, such as HVAC and DHW system, could be more efficient with the assistance of renewable energy. New configurations and system integration are needed to promote the system become more compact and reliable. As for power generation system, on-site self-supply or distributed energy systems will be depended on the smart control so that renewable energy could be easily integrated with the central grid network via smart meters. The case study shows possible applications in the evaluation of ZEB. Base on the experiment and simulation results, analysis regarding the indoor comfort and energy balance. The results show that the total electricity consumption can be reduced to the amount of 33.49kWh/m2 and it can be offset by a 24m2 PV array. In addition to the achieved energy balance for the goal of net zero, the indoor temperature can meet the comfortable request during the 94.38% time for the whole year.

2.3 Research on Design of ZERB for Tianjin Area

In recent years, China has achieved great success in energy efficiency by “3-step” plan, but still in the initial stage in basic research of zero energy building. Especially, the research of zero energy residential buildings in cold and severe cold region is almost in a blank state. Based on the above reasons, from the perspective of Tianjin climate feature and renewable energy potential use, a research on design of Zero-energy Residential Building for Tianjin area made a depth analysis on the influence factors of operational energy consumption in Tianjin residential building and on the basis of analysis conclusion developed a design guide of Tianjin zero energy residential building. From the guide of low energy design, by the integration and optimization of renewable energy applicable technologies, the thesis performed a research and practice of feasibility of Tianjin zero energy residential buildings.

Firstly, from the point of providing comfortable and healthy indoor environment for occupier, the research made a division of energy consumption season and period of Tianjin residential building, and developed four energy consumption seasons and periods of heating, cooling, ventilation and dehumidification in one year (Figure 2.8).

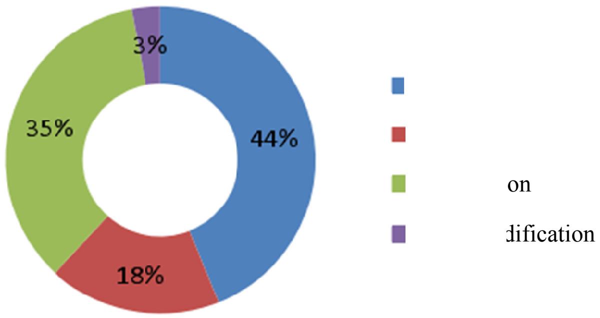

Figure 2.8 Energy consumption season and periods of heating, cooling, ventilation and dehumidification in one year

Secondly, from the perspectives of analysis on the worldwide samples of zero energy residential buildings and energy balance, the thesis prescribed the types of zero energy residential buildings in Tianjin district, and developed basic model applicable to the design of zero energy residential building in Tianjin by integrating Tianjin Building Efficiency Design Standard of Residential Building.

Thirdly using the energy simulation software Design Builder, the thesis made a simulation of inner and outer factors which influence the operational energy consumption of the basic model, and developed a series of guidelines such as the best orientation, shell fabric forms and thermal performance parameters, suitable window-to-wall ratio, window sun-shading forms and etc.

Fourthly, through the selection, integration and optimization of applicable renewable energy technologies in Tianjin, the thesis developed multi-energy providing system of Tianjin zero energy residential building experiment platform, made an analysis on the feasibility of Tianjin zero energy residential building, and made a preliminary evaluation.

Finally, the thesis established an indoor environmental monitor system of zero energy laboratory. Through the indoor environmental parameters record in one year, the thesis made an analytical judgment on indoor comfortable degree of zero energy lab without assistant cooling or heating sources and verified the reliability of low energy consumption design guide of zero energy residential buildings in Tianjin district.

2.4 Design-Build-Operate Energy Information Modeling (DBO-EIM) for Green Buildings

The concept of Building Information Modeling (BIM) has been gaining widespread interest in the building industry. It is recognized that BIM can potentially be used as an effective collaboration platform to reduce cost and effort during the Design-Build-Operate process. Similarly, green building concept is well accepted and its market is growing rapidly.

The "Design-Build-Operate Energy Information Modeling (DBO-EIM)" platform is proposed, advocating that a detailed whole building energy model:

(1) Created during the design phase to assist design decision making and to be used for code compliances;

(2) Modified during the construction and validated during the commissioning phases to become the as-built and well-tuned energy model;

(3) Continuously used during the operation phase to be integrated with building automation systems (BAS) to conduct advanced building controls to reduce energy consumption and improve occupant comfort.

The DBO-EIM is a "living" building energy information model that evolves through the entire building Design-Build-Operate process.

2.4.1 CSL case study for the design stage

Since the building construction has just been completed, all the models at this stage share the same assumptions on schedules and zone parameters based on ASHRAE 90.1-2007 energy standard (ASHRAE, 2007) and design specifications. The baseline model, and design alternative (DA) models are created for comparison purpose. Figure 2.9 shows the baseline and the PDC model in the DesignBuilder program.

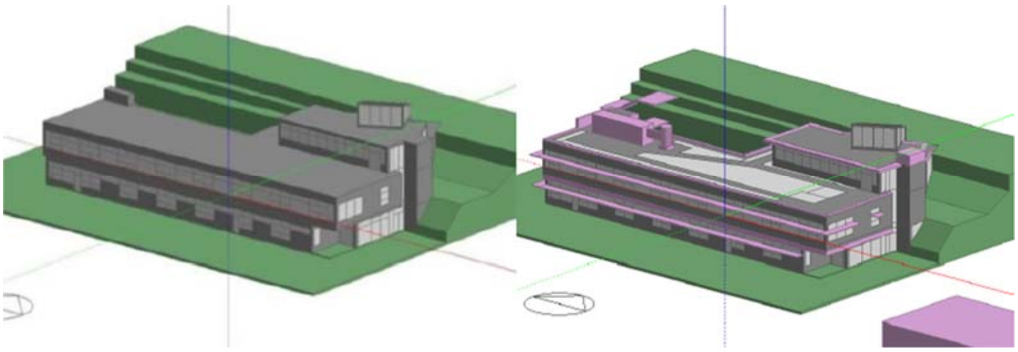

Figure 2.9 Baseline (on the left) and PDC (on the right) DesignBuilder models

Figure 2.10 shows the building cooling and heating design loads of different models given the same envelope design, the change of HVAC system does not influence cooling and heating design peak loads.

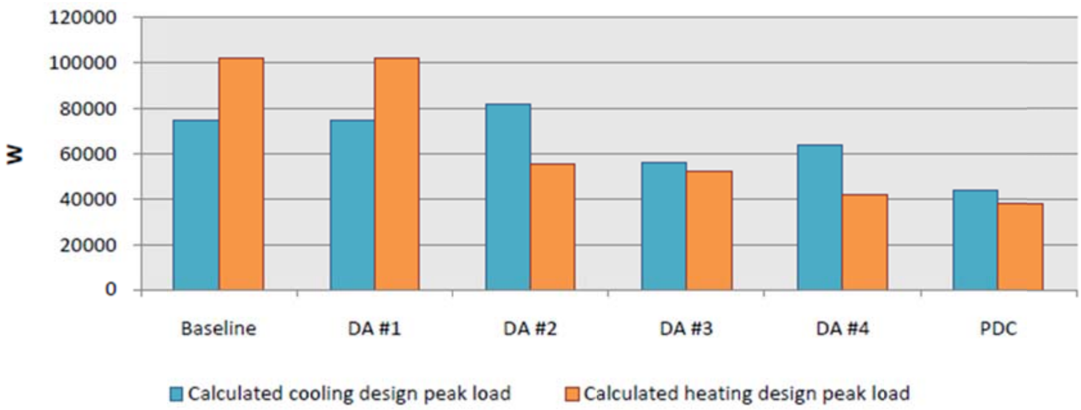

Figure 2.10 Calculated building cooling and heating design loads

The models with different envelope designs (the DA#1 and the DA#3) are compared. Given the same HVAC #1, the CSL PDC envelope can result in 24.8% reduction in cooling design load and 49.2% reduction in heating design load comparing to the baseline envelope design.

Figure 2.11 shows the annual EUI of all the models and the predicted on-site PV electricity generation (conditioned floor area is 1775.9m2). With the same baseline envelope design, the models with different conventional HVAC systems result in similar annual energy consumptions. By comparing the DA #1 and the DA #3, with the same HVAC #1, the improvement of building envelope design shows a 28.3% reduction in HVAC energy consumption and a 12.0% reduction in total energy consumption.

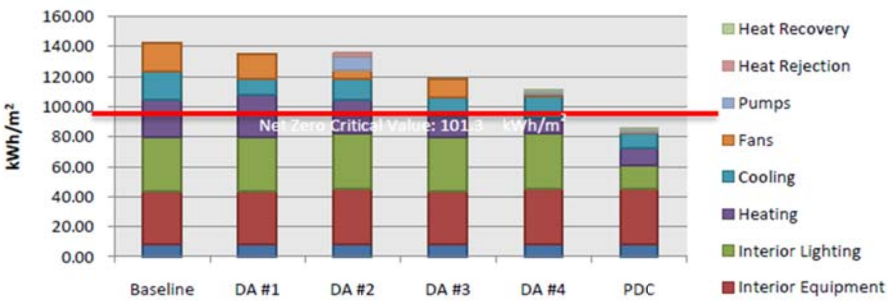

Figure 2.11 Annul EUI and the predicted on-site PV electricity generation

At the design stage, the detailed models are built following the DBO-EIM framework. The current work is the foundation of the overall DBO-EIM framework, which illustrates the process of building energy modeling process, as well as the decision making process based on the energy performance of different system design strategies. Results show that the CSL PDC model can meet the net zero site energy objective.

In future work, the model will be validated in actual projects and tuned on the basis of the as-built and commissioning results. The building control model will be developed based on the schema. The overall DBO-EIM framework will then be complete and continuously used in the CSL. The performance of the total DBO-EIM will be evaluated by both objective and subjective methods.

3. Building Codes and Standards

3.1 Introduction

China adopted building energy standards in stages, starting with an energy design standard for residential buildings in the Heating Zone in north China in 1986, and revised in 1995. This was followed by a standard for tourist hotels in 1993, and then standards for residential buildings in the Hot-Summer Cold-Winter Region in central China in 2001 and the Hot-Summer Warm-Winter Region in south China in 2003. A national energy efficient design standard for public buildings (similar to commercial buildings) was adopted in 2004 and revised in 2014. Preceding these national or regional standards, there have been also local standards in major cities, such as Beijing, Shanghai, Wuhan, and Chongqing.

From an institutional point of view, China has benefit of a centralized Ministry of Housing and Urban-Rural Development (MOHURD) responsible for regulating a building industry that over the past decade has built roughly half of the new construction of the entire world. Under the MOHURD, there is a network of Construction Commissions in the major cities and provinces to oversee building construction, including the granting of building permits and enforcement of building codes, as well as a parallel network of building research institutes to provide technical expertise and support to the MOHURD and the building industry. Within the MOHURD, building energy standards fall under the jurisdiction of the Department of Standards and Norms. However, the technical development of building energy standards is the responsibility of the Department of Science and Technology, in collaboration with building research institutes, universities, and industry representatives. For example, for the current residential and public building standards, Code Compilation Committees were organized under the leadership of the China Academy of Building Research. Local governments can choose to either comply with the national codes or adopt more stringent local codes.

The Chinese government has prioritized certain areas of building energy code development, based on relative energy consumption and other factors. For example, code development activities have focused more on residential than public buildings, more on the northern part of China than on the south, and more on new rather than existing buildings

China’s current building energy standards in both public and residential buildings are mainly focused on the building envelope and HVAC systems, excluding other important building components such as lighting, electric power and hot water systems. In other words, Chinese building energy codes aim to improve the thermal performance of the building envelope and the HVAC energy efficiency--the two factors widely believed to have the greatest influence on building energy efficiency in China

3.2 Climate Zones

China’s building energy standards identify five climate zones, including (1) severe cold, (2) cold, (3) hot summer and cold winter (HSCW), (4) temperate, and (5) hot summer and warm winter (HSWW), presented in Figure 3.1 and Table 3.1.

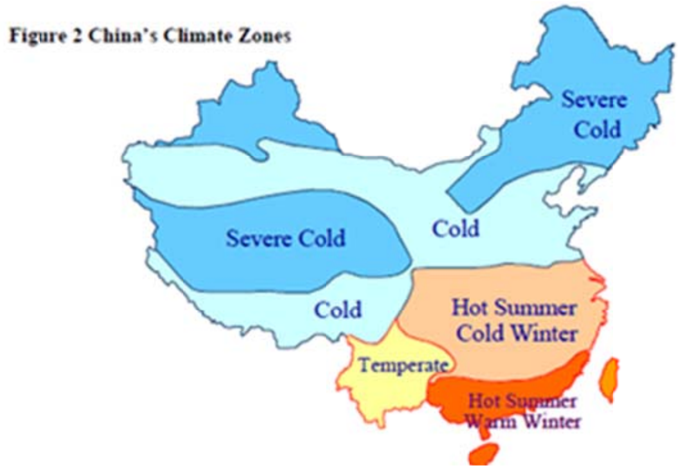

Figure 3.1 China's Climate Zones
Source: Lin, 2008; Huang and Deringer, 2007

Table 3.1 Mean Temperatures in Architectural Climate Zones
Source: Source: Lin, 2008; Huang and Deringer, 2007

Climate Zone	Mean Temperature in			
	Coldest Month	Hottest Month	HDD°18	CDD°18
Severe Cold	≤-10℃		3800-8000	
Cold	-10-0℃		2000-3800	100-200
HSCW	0-10℃	25-30℃	60-1000	50-300
HSWW	＞10℃	25-29℃	>600	>200
Temperature	0-13℃	18-25℃	600-2000	≤50

3.3 Design Standard for Energy Efficiency in Public Buildings（2014）

New construction is the main driver of China's commercial building energy use. From 1996 to 2008, the total floor space of commercial buildings increased from 2.8 billion m^2 to 7.1 billion m^2. Currently, approximately 0.5 billion m^2 of new commercial building floor space is built every year. China issued its own standards for commercial (public) buildings (GB50189) in 1993, with an initial emphasis on reducing energy consumption in hotels. After that, the standards were revised to include other commercial building types. The last update, in 2005, mandated that commercial buildings be 50% more efficient than a baseline defined by 1980s building characteristics. The new 2014 update anticipates that new commercial construction will be 65% more efficient than the previous baseline.

To quantify the energy performance of the new Chinese commercial building standard (GB50189), the researchers from CABR and LBL developed a Chinese office reference building and used it to compare implementation of measures in the 2014 standard with measures in the 2005 standard. While the absence of a building standard in the 1980s makes it difficult to evaluate whether the 2014 update will save 65% over the baseline, this analysis allows evaluation of whether the 2014 standard will be 30% more efficient than the 2005 standard.

The simulated reference building performance is shown in Figure 3.2. Overall, the new standard has significantly improved energy performance compared with the 2005 version. Buildings in north China (e.g., Beijing) enjoy a 27% improvement due to energy savings from heating, cooling, lighting, plug load, etc. The performance improvement in transition (e.g., Shanghai) and warm (e.g., Guangzhou) climates are 23% and 24%, respectively. To calculate the Chinese national average values, the researchers used weighting factors for office buildings in the north, transition, and south climate regions. On average, the new Chinese standard demonstrates an overall 25% energy savings over the 2005 version.

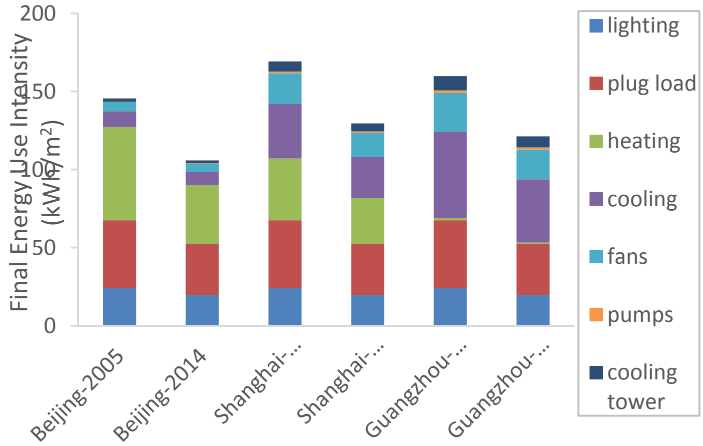

Figure 3.2 Energy performance of Chinese office reference buildings

4. Network & Organizations

4.1 China Committee of Heating Ventilation and Air Conditioning

China Committee of Heating, Ventilation and Air-conditioning (CCHVAC) was founded in 1978， which is the largest organization in this area in China. CCHVAC have the task and responsibility exactly similar as ASHRAE. CCHVAC held China HVAC&R Conference every two years, the number of people attending the China HVAC&R Conferences increased from 168 to 1620 from 1978 to 2014. CCHVAC have a broad international cooperation with ASHARE, REHVA, SHASE.

On Oct 25th 2012, CCHVAC and REHVA held an international workshop on Nearly Zero Energy Building together. After the workshop, within the CCHVC, a research group on NZEB was established, the group now is working on the following topics:

- China National Technology Roadmap to Achieve NZEB
- Key Performance Index of residential building and commercial building towards NZEB in different Climate Zones
- NZEB Certification methodology

On August 13th 2014, with the support from Ministry of Housing and Urban-Rural Development, CCHVAC held the 1st China Nearly Zero Energy Building Conference, with 300 participants and 14 speakers sharing the latest research result on NZEB topic. During this conference, China Academy of Building Research issued Performance Criteria of Passive Nearly—Zero Energy Building In China.

Figure 4.1 China Nearly Zero Energy Building Conference

4.2 China Nearly Zero Energy Building Alliance

On July 11th 2014, leading by China Academy of Building Research, together with other 30 co-founders, China Nearly Zero Energy Building Alliance was established. The alliance was established as an outcome of CABR nearly zero energy building. The alliance was comprised of research institute, building envelope and HVAC equipment manufacturers, energy system integration companies and real estate developers, with the goal to promote nearly zero energy building in China.

Figure 4.2 China Nearly Zero Energy Building Alliance

5. Demonstration Projects

Take the consideration of booming status of NZEB in China, Ministry of Housing and Urban-Rural Development kick-off an investigation of China nearly zero energy building on May 2014. The investigation was led by China Academy of Building Research, in which 12 projects are studied, including 3 residential building and 9 public building. Take a view from the climate zone, 2 projects locate in the severe cold zone, 6 projects locate in the cold zone, 2 projects locate in the cold winter/ warm summer zone, 2 projects locate in the warm winter/ hot summer zone. The project list could be found in Table 5.1.

Table 5.1 Project name list

No	Project Name	Type	m^2	Location	Climate Zone
1	Xingfubao Passivehouse	Public	4520	Wulumuqi	Severe Cold
2	Chen Neng	Residential	7800	Harbin	Severe Cold
3	CABR Net Zero Energy Building	Public	4025	Beijing	Cold
4	Exhibition Center of China-Singapore Eco-Center	Public	3467	Tianjin	Cold
5	R&D Center of Hebei academy of building	Public	14120	Shijiazhuang	Cold
6	UNIDO International Solar Energy Center for Technology Promotion and Transfer Headquarters Building	Public	13976	Lanzhou	Cold
7	Velux China Headquarter	Public	2014	Langfang	Cold
8	Riverside Program	Residential	28050	Qinghuangdao	Cold
9	Landsea Brooke Project	Public	2445	Huzhou	Hot summer/ Cold winter
10	Germany/Hamburg House	Public	3150	Shanghai	Hot summer/ Cold winter
11	Meijing Home	Residential	8078	Nanan	Hot summer/ Warm winter
12	Longde International Ecological Kindergarten	Public	3400	Dongguan	Hot summer/ Warm winter

The energy consumption and heating and cooling load limits could be found in Table 5.2

Table 5.2 Energy consumption and heating and cooling load limits

No	Project Name	Design Criteria		
		Primary Energy Consumption	Heating load （W/m^2）	Cooling Load （W/m^2）
1	Xingfubao Passivehouse	105	12	10
2	Chen Neng	120	10	10
3	CABR Net Zero Energy Building	25	45	30
4	Exhibition Center of China-Singapore	125	50	55
5	R&D Center of Hebei academy of building	100	--	--
6	UNIDO International Solar Energy Center for	32	100	80
7	Velux China Headquarter	34	--	--
8	Riverside Program	102	10	15
9	Landsea Brooke Project	69	8.1	21.6
10	Meijing Home	120	5	40
11	Longde International Ecological Kindergarten	--	--	--

5.1 China Academy of Building Research Nearly Zero Energy Building

Among all the building that was designed and constructed to achieve nearly zero or net zero. The one located in China Academy of Building Research is the most famous one.

With the objective of concentrated display of the accomplishments of the basic research and international joint research during the 11th Five Year Plan, leading the building energy efficiency work to a higher level, from January 2013 to June 2014, under the umbrella of US-China Clean Energy Research Center, US and China experts jointly research, design, construct the Nearly Zero Energy Building of China Academy of Building Research

The Building is an office with the area of 4,025m^2, which addresses the fundamental issues about the building energy efficiency in China. The design principle is "passive building, proactive optimization, economic and pragmatic". CABR demo building can be considered as an innovative Chinese attempt to achieve Nearly Zero Energy Building with affordable cost. The experience acquired from CABR project will be valuable input to the development of future Chinese standard and roadmap toward NZEB. 28 world leading building environment and energy technologies are utilized in this building to achieve the energy target **"zero fossil fuel for heating in winter, 50% cooling energy reduction in summer, 75% lighting energy reduction"**.

On July 11th 2014, Secretary Moniz from DOE of the States and Minster Wan Gang of Ministry of Science and Technology of China took the opportunity to tour the CABR cutting-edge Nearly Zero Energy Building and launched the opening ceremony of this building.

Figure 5.1 Opening ceremony of CABR-NZEB during CERC board meeting

Figure 5.2 CABR Nearly Zero Energy Building

6. Conclusion

- Energy consumption in China has been increasing rapidly due to economic growth and development. With speeding modernization and urbanization, building energy consumption has steadily increased in China. Since 2006, the central government issues a series of measures about BEE to respond the challenge of rapid increasing building energy consumption owing to the increasing demand of more new buildings and household appliances, but at this stage, there is no clear government policy set the objective and development roadmap of NZEB.
- Some researchers are starting to find the technical feasibility and technology roadmap of NZEB, but due to the imbalance of economy development, huge climate and working/living habit in different area， more deep research programs are expected to get funded in the future.
- With the last 30 years updated of building energy codes, the building now in China are 65% energy efficiency compared with 1980s. In the future, more regular upgrade of building energy codes are expected.
- China Committee of Heating, Ventilation and Air-conditioning and China Nearly Zero Energy Building Alliance played an important role in the promotion of NZEB in China.
- During the last 3 years' effort, there are now 12 demonstration projects in China which was built with the objective to achieve nearly zero energy. The energy reduction potential are 80%-90% compared with ordinary building nowadays.

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SECTION III JAPAN

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1. Policy, Objective, Definition

1.1 Building energy status in Japan

Japan's energy consumption has been steadily expanded especially in the commercial/ residential sector since the 1970's oil crises period, largely due to convenience-thriving and energy-needing lifestyles. Energy efficiency has long been paid much attention in Japan, especially after the Great Eastern Japan Earthquake in 2011, it has been considered as a matter of energy security from national level. Today, the increasing building energy consumption has attracted more attention for Japanese government on energy efficiency promotion. Figure 1.1 shows a transition of Final Energy Consumption and energy consumption in buildings during the period of 1990-2011. The percentage of total energy consumption in commercial and residential sector in 2011 is 1.33 times higher than it was in 1990, among which the commercial sector is 1.41 times higher than it was in 1990 and the residential sector is 1.25 times higher. The graph on the left shows that the building sector increasing faster than the transportation and industrial sector. Therefore, strengthened energy efficiency measures are called for mostly in the commercial and residential sectors.

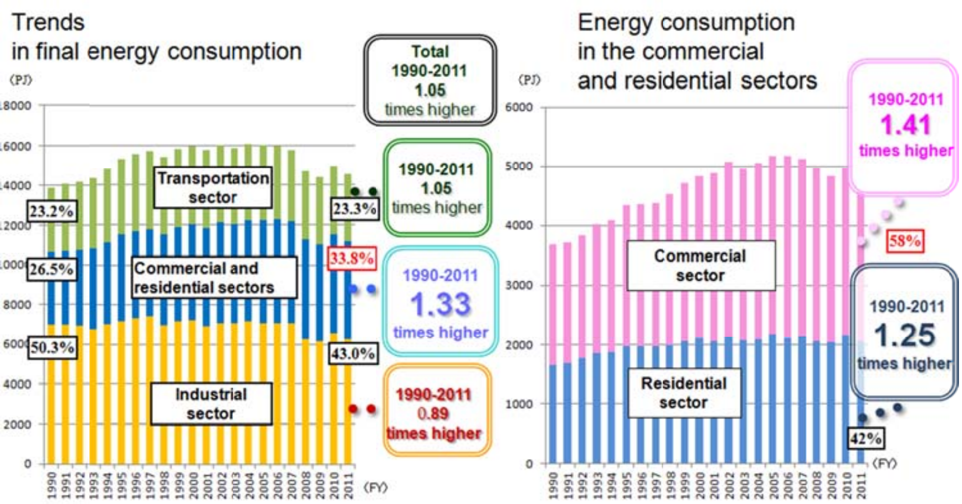


Figure 1.1 Transition of Final Energy Consumption and energy consumption in Buildings

1.1.1 Energy consumption in commercial section

Of the total energy-originated CO_2 emissions in 2005, the commercial sector accounts for about 20%, which increased 43.9% compared with 1990. This proportion declined 11% by the year 2010 with a CO_2 emission reduction in about 26 million to 28 million tons of CO_2.

Figure 1.2 lists out different energy sources that consumed in various kinds of non−residential buildings. These kinds of energy resources combination occupy a considerable rate as for the whole Japan. The combination of electrical power and gas, LPG is a very common way in Tohoku district and different kinds of public buildings. In office, electrical power is used in a larger proportion compared with other building types and accounts for 30% of the total.

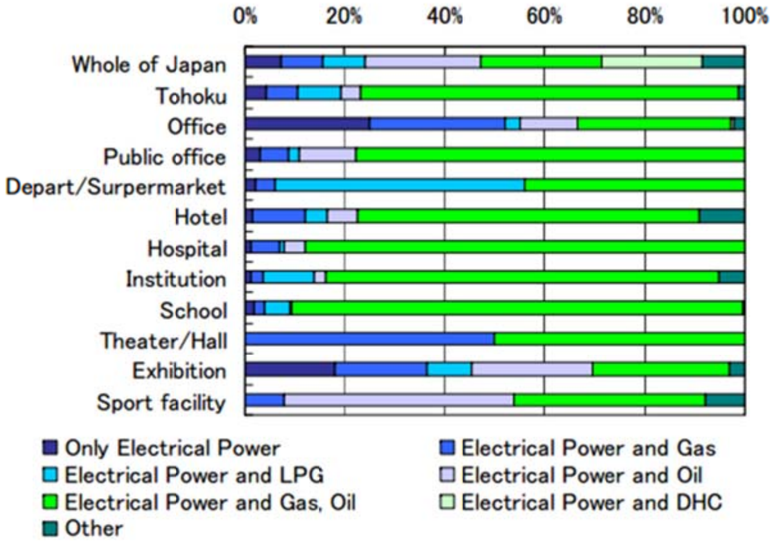


Figure 1.2 Sources of energy consumption in commercial buildings

As for the private Offices and public offices with similar building functions, energy consumption of public offices is about 40% lower than private offices.

1.1.2 Energy consumption in residential section

The energy consumption in residential sector per household is at a relative low level comparing with the US and EU countries. Heating and air conditioning account for nearly 30% of energy consumption in homes (Figure 1.3).

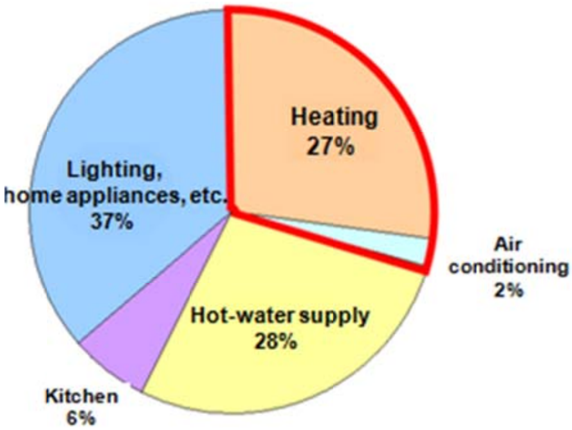


Figure 1.3 Energy consumption in homes

Source: Handbook on Energy & Economic Statistics in Japan

Figure 1.3 shows energy consumption data per household in each economy. This plot illustrates that Japan's energy consumption per household is approximately 41% and 55% less than the equivalent EU and US respectively, especially in space heating and cooling which have been reduced by improving the buildings' thermal insulation and air tightness.

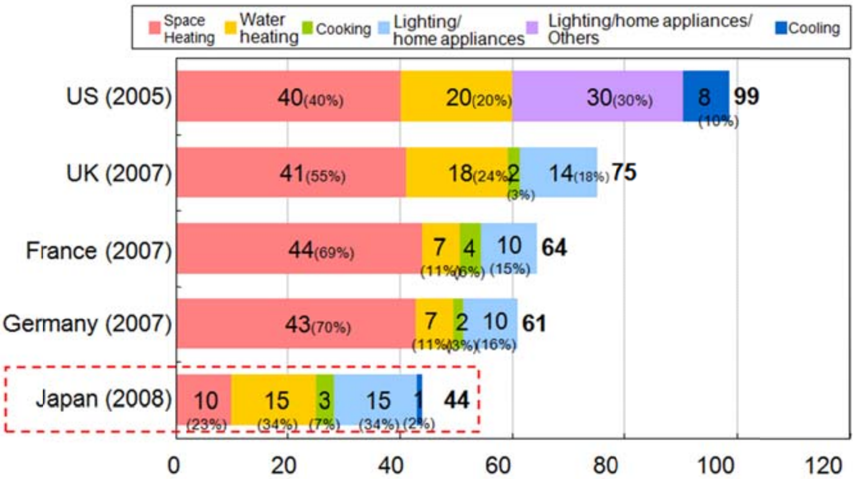


Figure 1.4 Energy Consumption per Household (GJ/household, year)
Source: Sep. 2010 Report of Jyukankyo Research Institute Inc.

1.2 Energy Conservation Law

In Japan, energy efficiency was connected strongly with energy security and cover a wide variety of industries. Today, energy efficiency is also a matter of mitigating climate change and the Japanese government tries to make energy efficiency everyone's responsibility. The Japanese government believes that energy efficiency policies for each sector should be complemented with policies to promote lifestyle changes and that the general awareness has to be increased. Japan has achieved a lot of success regarding nationwide energy efficiency improvements over the last 30 years; however substantial improvements are still required. Other nations use Japan's effective energy conservation laws as examples or guidelines to form their own.

The Law of Rational Use of Energy (or Energy Conservation Law, ECL) was enforced in Japan in 1979 after the second oil crises and has subsequently been revised several times. Since then ECL has developed and enhanced energy efficiency policies for the industrial, transportation and commercial sectors [ACEEE, 2010b]. There are four major areas addressed by the ECL. Groups targeted in each area are (Figure 1.5):

- Housing and buildings: building owners/developers and managers
- Factories, etc: Managers of factories and workplaces
- Equipment and appliances: producers and importers of equipment and appliances
- Transportation: transport companies

Figure 1.5 Authorities for Energy Conservation Law in Building sector

ECL forms the basis of Japan's policy to conserve energy. It is designed to be comprehensive so as to cover various items from buildings to equipment and appliances. Within ECL, there are several sections that apply to the building sector, including Criteria for Clients on the Rationalization of Energy Use for Buildings, and the Design and Construction Guidelines on the Rationalization of Energy Use for Houses. The first applies to non-residential and the second to residential buildings. Although these standards are defined as voluntary, there are numerous aspects that are enforceable.

In order to achieve energy efficiency performance, more stringent regulation is highly needed. Figure 1.6 explains the recent revision in the Energy Conservation Law in 2008.

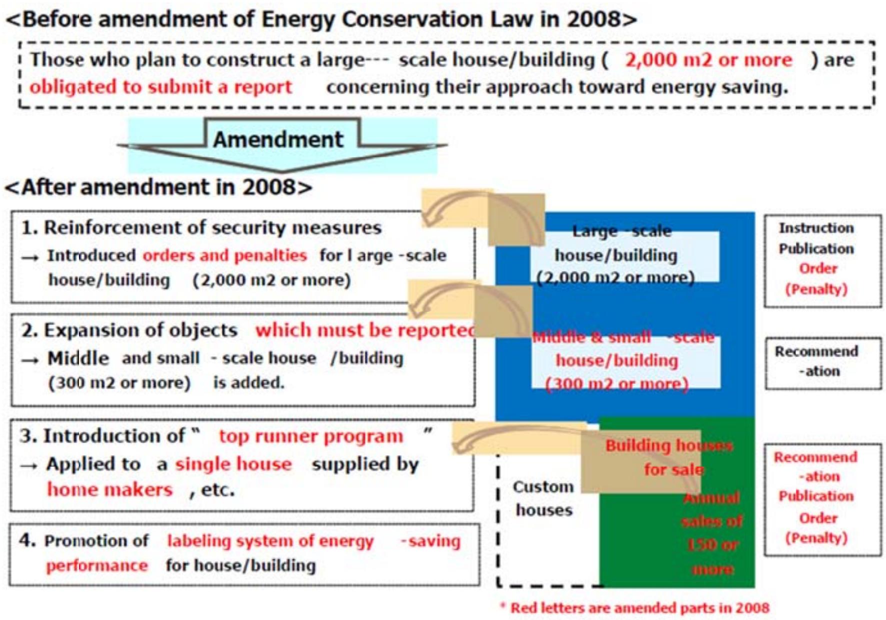


Figure 1.6 Revision of Energy Conservation Law

1.3 Action Plan and Roadmap of ZEH and ZEB

In Japan, a "**Committee on Realization and Generalization of ZEB**" was organized and a report published in 2009 in order to examine the roadmap to realization and generalization of Zero Energy Building (ZEB). Focusing on the trends of final energy consumption, the building sector accounts for more than 30% and its share has been increasing rapidly compared with that in other sectors, so energy saving in this sector is becoming most important. By introducing energy saving measures for buildings, this committee proposed to **realize ZEB as the standard for new buildings by 2030**.

the 4th Assessment report of the United Nations Intergovernmental Panel on Climate Change (IPCC) concluded that global warming, which today calls for an urgent response, is "very likely" to have been caused by an increase in the atmospheric concentration of CO_2 that has accompanied the mass consumption of fossil fuels. To prevent global warming, the Japanese government **set a mid-range target to reduce CO_2 emissions by 25% by 2020 (compared to 1990)**. In order to achieve this goal, higher energy saving measures of new buildings and energy saving renovation of existing building in the business & residential sector is definitely needed.

Ministry of Land, Infrastructure and Transport (MLIT), Ministry of Economy, Trade and Industry (METI) and Ministry of Economy (MOE) published the roadmap for ZEH and ZEB by 2030, eventually aim the realizing Life Cycle Carbon Minus (LCCM) building to reduce CO_2 emissions throughout the housing lifecycle: construction, living, demolition, reuse and etc.

Achieving Zero Energy needs comprehensive cooperation and a step-by-step development roadmap. Figure 1.7 shows a development process of NZEB in Japan. Taking the traditional building energy consumption as reference point which consumes 2030MJ/m^2/year，the access to ZEB pass through Passive Design, High Performance Equipment, to High Performance System, the primary energy consumption reduced and reduced, and the action plans became more and more clear.

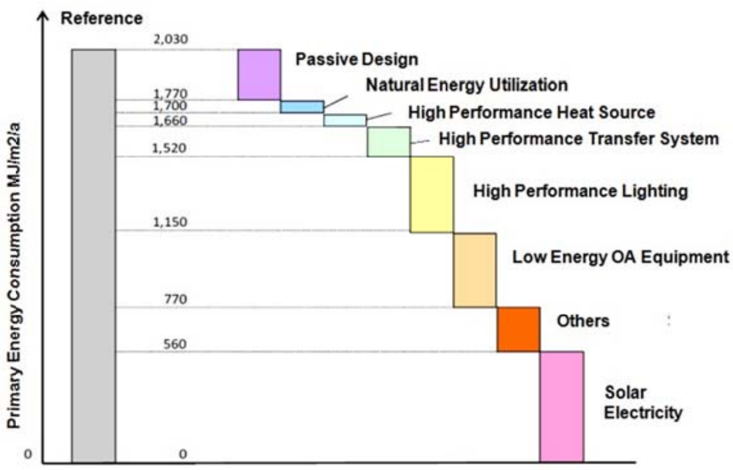


Figure 1.7 Primal energy saving for each technology to realize ZEB

1.3.1 Action plan of ZEH

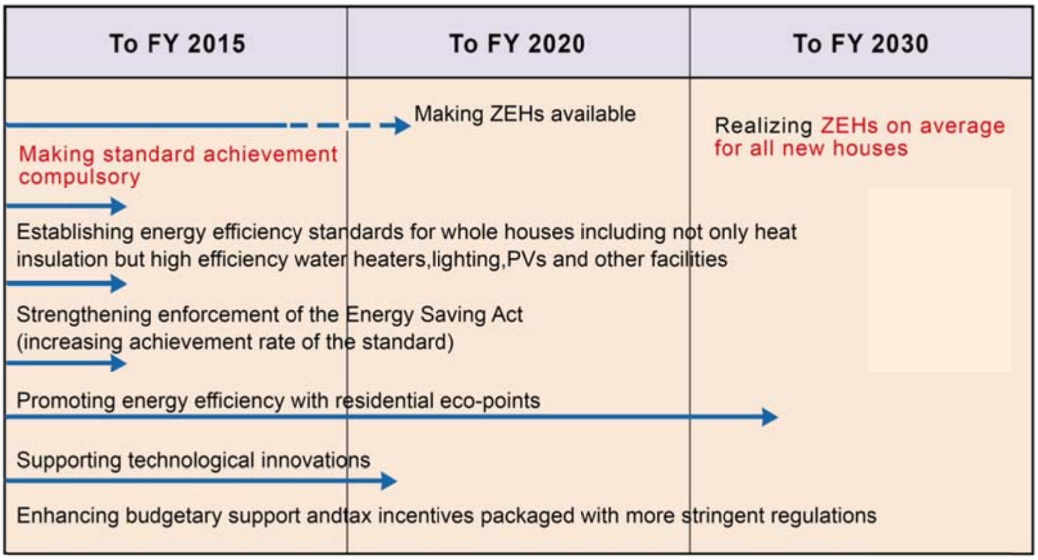
Future targets of achieving Net Zero Energy House (ZEH) are as below (Table 1.1):

- To make ZEH the standard for new single houses by 2020.
- To double the number of renovating energy-efficient houses by 2020.
- To realize ZEH for new single houses on average by 2030.

The further action plans can be also concluded as:

- ◆ Establish energy efficiency standards for whole houses including not only heat insulation but high efficiency water heater, lighting, PVs and other facilities
- ◆ Strengthening enforcement of the Energy Saving Act
- ◆ Promoting energy efficiency with residential eco-points
- ◆ Supporting technological innovations
- ◆ Enhancing budgetary support and tax incentives package with stringent regulations

Table 1.1 Action plan of ZEH



1.3.2 Action plan for ZEB

For ZEB, as is shown in Table 1.2, future targets are as below:

◆To realize ZEB for new public buildings, etc., by 2020.

◆To realize ZEB for new buildings on average by 2030.

The further action plans can be also concluded as:

- ◆ Enhancing energy efficiency standards under the Energy Efficiency Act
- ◆ Introducing labeling for building evaluating energy efficiency
- ◆ Supporting technological innovations
- ◆ Enhancing budgetary support and tax incentives package with stringent regulations

Table 1.2 Action plan of ZEB

To FY 2015	To FY 2020	To FY 2030
Making standard achievement compulsory	Realizing ZEBs in new public buildings (e.g., schools)	Realizing ZEBs on average for all new buildings
Enhancing energy efficiency standards for buildings under the Energy Efficiency Act.		
Introducing labeling for buildings evaluating energy efficiency		
Supporting technological innovations		
Enhancing budgetary support and tax incentives packaged with more stringent regulations		
Promoting area-		
Standardizing and diffusing control interfaces for lighting, air conditioners, and data specs for energy efficiency in small and medium-sized buildings		

The Ministry of Economy, Trade and Industry, Ministry of Environment, and Ministry of Land, Infrastructure, Transport and Tourism, jointly established the Council for promoting Housing and Living for Low - Carbon Society to study compliance with energy saving standard of new housing and buildings by 2020 and released an interim report and schedule on July 10.

Based on the issues below, requirements are imposed gradually in the order of large buildings, medium - sized buildings and small buildings.

Issues to be solved for meeting the requirements:

- Clarification of need and grounds of regulations on housing and buildings
- Consideration of balance with energy saving regulations on housing and buildings in other sectors and countries
- Careful consideration to medium - sized and small builders ad carpenters
- Study based on opinions that traditional wooden houses would not be built if the compliance with energy saving standard is imposed

Promotion of improvement of measures related to new construction, enhancement of existing stock and future human resources development to realize low - carbon society. Figure 1.8 shows the schedule towards Compliance with Energy Saving Standard of New Housing and Buildings.

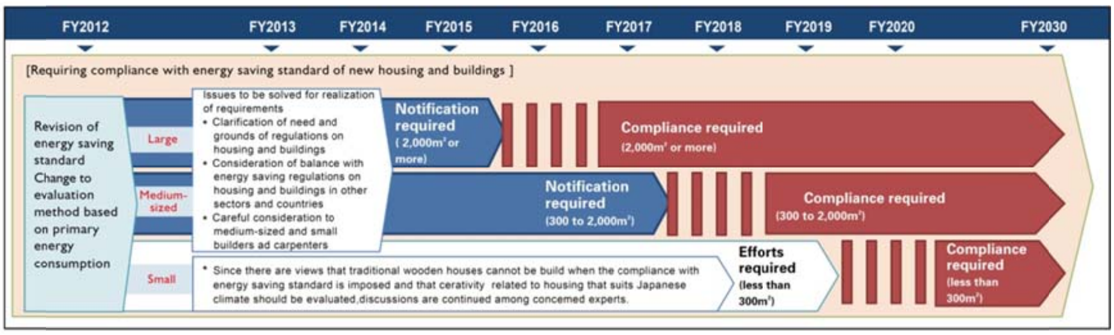


Figure 1.8 Schedule towards Compliance with Energy Saving Standard of New Housing and Buildings

Improvement of measures related to new construction for now is seeking for the support for zero energy housing/support for model CO_2 saving housing and buildings/certification and support of low - carbon housing and buildings, etc. The enhancement of existing stock can be realized by focusing on renovation into energy - efficient housing and buildings/promotion of performance of building materials and equipment based on advanced building materials and equipment programs. Future human resources development can be depended on finding support for medium - sized and small builders and carpenters to acquire techniques for energy - saving construction (5 years from 2012 to 2016)/study of evaluation method of traditional wooden houses (Figure 1.9). Figure 1.9 shows the detail of the roadmap of future building energy efficiency policies.

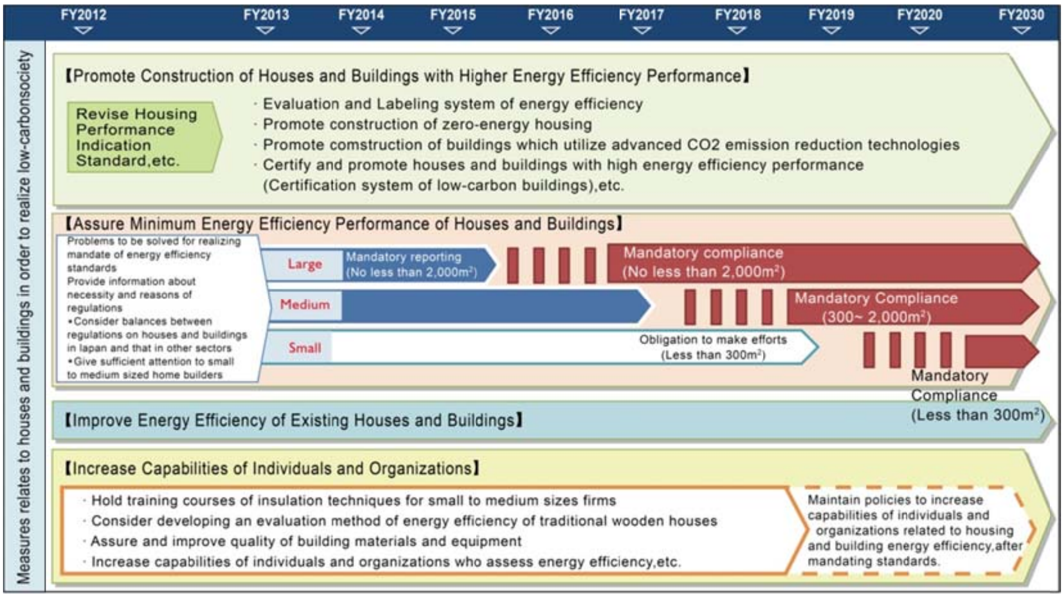


Figure 1.9 Roadmap of future building energy efficiency polocies

It's important to develop a fair and reliable method to evaluate the energy efficiency performance of buildings. The new Energy Efficiency Standards (2013) evaluated by primary energy consumption was published to assure minimum energy efficiency performance. Promote construction of houses and buildings with higher energy efficiency performance can be realized in the following two ways:

- Certify and promote houses and buildings with high energy efficiency performance (Certification system of low-carbon buildings)
- Labeling and information provision of energy efficiency

1.4 Other Energy Saving Policies

In the residential and commercial sectors, MLIT, METI and MOE established "**Promotion committee of housings and lifestyle toward a low-carbon society**" and currently consider from a broad standpoint and summarize implementing policies.

Besides, the government urges development which can contribute to realizing energy conservation and low-carbonization regarding lifestyle and work style, aiming for the improvement of comfort and intellectual productivity.

Policies for promotion of net ZEB, especially policies for energy conservation, achieving higher efficiency and grid stabilization, are shown in Figure 1.10.

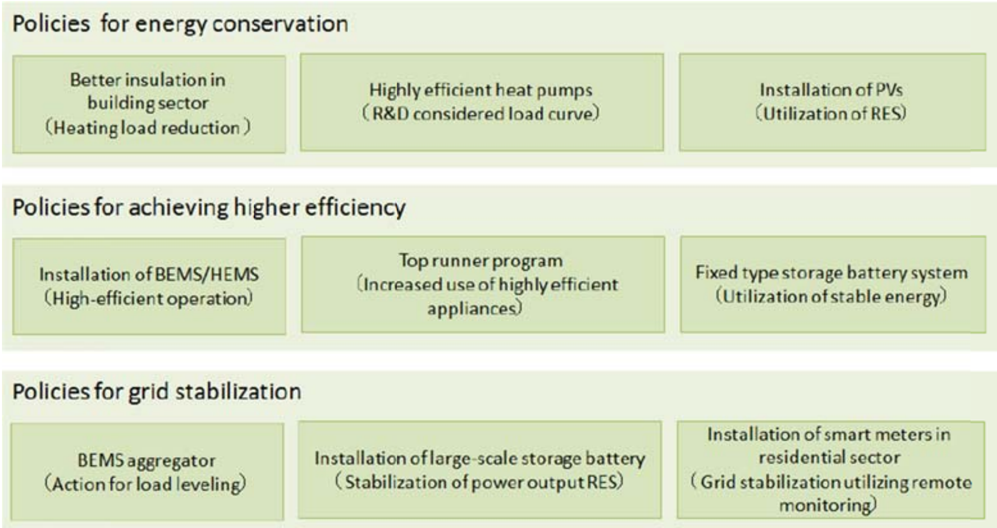


Figure 1.10 Environment and energy policies related to net ZEB

With the purpose of widespread deployment of highly efficient technologies and renewable energies which contribute to realizing a low-carbon society, the government provides preferential treatment in financial services and tax breaks (Figure 1.11). In addition the government urges investment from private sector through launching the leading-edge project by urban area and disseminating information on its best practices in effective utilization of energy.

	Policy	Verification & development	Impact of penetration (excluding energy)
Subsidy for highly efficient equipment	Widespread deployment of CO2-free technologies	Verification of energy performance/ Power system stabilization	Lower cost due to increased penetration
Enhancement of institution	Labeling program/ Preferential treatment in tax system or interest rate/ Enhancement of energy-saving standard	Development of energy statistics/ Development of next-generation energy standard	Increase of asset value
Promotion of leading-edge project	Network for district heating and cooling/ Utilization of unused energy sources/ Utilization of distributed generation	Verification of economic feasibility and penetration	Regional activation and decarbonization

Figure 1.11 Impacts coming from policies

Also a movement has started to promote the realization of zero energy school buildings as in a brochure titled "Toward Zero Energy School Buildings" jointly published by MLIT and the Ministry of Education, Culture, Sports, Science and Technology in March 2012.

According to IEEJ, the milestones for the energy saving policies can be concluded as:

Within 3 years:

- Introduce renewable energy and enhance energy efficiency to the maximum extent for the next 3 years
- Restart nuclear power plants, once their safety is assured by the NRA (Nuclear Regulatory Agency).

Within 10 years:

- Establish the best long-term mix of power sources.

1.5 Subsidy policies

From 2011, some financial subsidy program came up related to realization of ZEB, at the very beginning, subsidy are direct goes to high performance equipment, since high adiabatic of building itself is of equal important for realization of ZEB, subsidy scale extents to measurements or design to ensure certain level of building itself.

Energy saving property should achieve higher energy efficiency above the requirements of energy saving law, then within 1/3 to 2/3 of equipment costs could be covered by subsidy.

Financial subsidy for cost of high performance system adoption is also available for new and renovation and additional civil buildings, subsidy upper limit is **4 billion JPY.** One of the following items is required for the subsidy.

1) In case of new, renovation and additional civil buildings, primary energy consumption should reduce at least 30% compared with energy saving standard at that time.
2) In case of renovation civil building, primary energy consumption should reduce at least 30% for the past 3 years.
3) One of the 4 basic elements* for ZEB realization should be introduced.
4) Measurement equipment, control system, monitor equipment and operation data record and analyze equipment should be adopted.
5) One of system control technology* should be introduced,

6) Complete manage mechanism for energy consumption data monitoring, record, analyze and evaluation, reporting of heat source, pump, lighting system and other energy consumption equipment.

Note*:

1. The 4 basic elements in item (3) for ZEB realization include:
   a. Improve thermal performance of building envelope
   b. reduce indoor heat generation
   c. installation of high performance equipment （lighting, air conditioning, ventilation, hot water, cool storage）

d. installation of energy generation system

2. System control technology in item (5) refers to:

   a. System control equipment

   b. Auto control system according to the occupancy

   c. Load control

   d. Co-control system among buildings

   e. Tuning among operation

Above 1/3 subsidy principle, upper limit of a single project subsidy is **500 million JPY**. In case of energy consumption reduction is 40% and 50%, subsidy could go up to 1/2 and 2/3 specifically. Table 1.3 lists the subsidy objects of the project. There are 71 projects have applied for this subsidy in 2015, and 17 of them saving up to 40% energy consumption, 10 up to 50%.

Table 1.3 Subsidy project of the program*

Building Type	Subsidy Object
Hotel	Hotel, motel, inn
Hospital	Hospital, nursing home, welfare house
Shop	Market, store
Office	Office, library, museum, post office
School	School, college, university
Cafeteria	Restaurant, canteen, cafeteria
Meeting Place	gymnasium, theatre, cinema

* Financial Program proposed by METI

There exists special funding for School in Japan. Besides adoption of various high technologies, high performance equipment are necessary for realization of zero energy school, which will results high initial cost for investigation. There are some government supportive subsidies are available for the following events.

- **Subsidy for public school equipment installation**: Provide for large scare renovation project of public school, such as installation of PV system. (Ministry on Education, Culture, Sports, Science and Technology)
- **Investment support for CO_2 emission saving leading project**: Provide for CO_2 saving leading program of house and building (Ministry of Land, Infrastructure, Transport and Tourism)
- **Regional renewable energy utilization**: PV electricity generation for self-usage subsidy program (Ministry of Economy, Trade and Industry)
- **Financial support for necessary basic design**: Provide for renovation projects and super eco school project of existing public school towards nearly zero energy school (Ministry on Education, Culture, Sports, Science and Technology)

1.6 Definition

Japan has continued its efforts to promote buildings featuring energy resource protection and global warming prevention since the oil crisis in the 1970's although such buildings have been defined differently, for example, "energy-efficiency building", "environmental-harmonious building", "green building", "low-carbon building" or "sustainable building". In response to the policy trends described above, the economy launched an effort to promote net zero energy buildings using renewable energy technology in 2009.

1.6.1 Net Zero Energy Building (NZEB)

NZEB (Net Zero Energy Building) has become recognized to be important for energy conservation and global warming prevention. For the current stage, definition and evaluation method of NZEB is not so clear that design method of NZEB is not yet established. According to the definition given by SHASE, NZEB is defined as:

"A building that consumes zero or nearly zero energy on an annual net basis by reducing primary energy consumption in the building as a result of enhanced energy efficiency performance of the building and facilities, neighboring buildings, on-site utilization of renewable facilities, networking of buildings, on-energy, and so on"

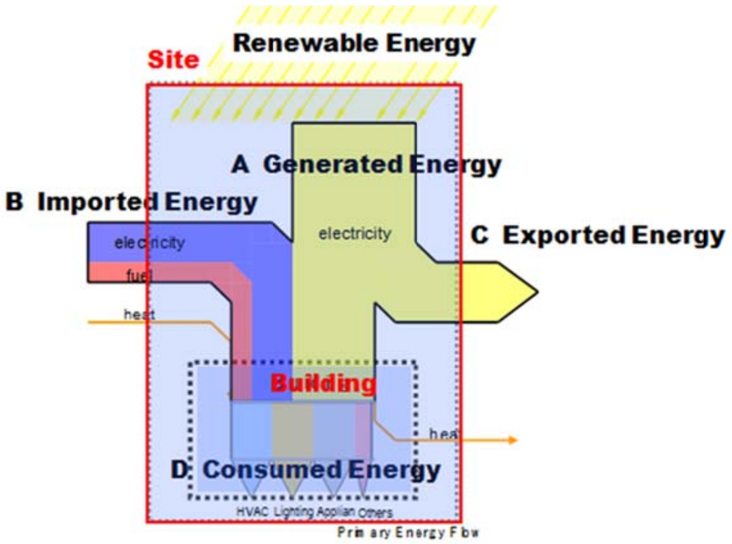


Figure 1.12 Primary Energy Flow of Net Zero Energy Building

Figure 1.12 explains the boundary of NZEB definition in Japan with on-site renewable sources. For a Net Zero Energy Building, the amount of generated energy should compensate or surplus the consumed energy in annual calculation. Renewable energy is on-site generation from on-site renewables, like solar, bioenergy, wind, etc.

The energy saving calculation has also been proposed by a method of Demand and Supply Side (Figure 1.13) in which A stands for Low Energy Buildings and B stands for Low Energy Infrastructure.

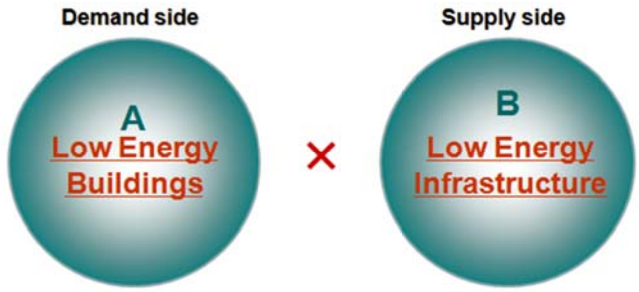


Figure 1.13 Energy Saving by the method of Demand and Supply Side

If: A*B=1.0*1.0=1.0 It is Reference Building

If: A*B=0.7*0.7=0.49 It is 50% Energy Saving Building

If: A*B=0.5*0.5=0.25 It is 75% Energy Saving Building

The balance of annual energy generation and consumption is an important measurement of NZEB. Figure 1.14 shows an energy consumption process from Reference Building to Zero Energy Building. It choose the average level of building energy consumption in Japan as Reference Building and the low energy building consumes 45% less of energy per year. Net Zero Energy Building adopts Renewable Energy while keep on reducing the building energy consumption.

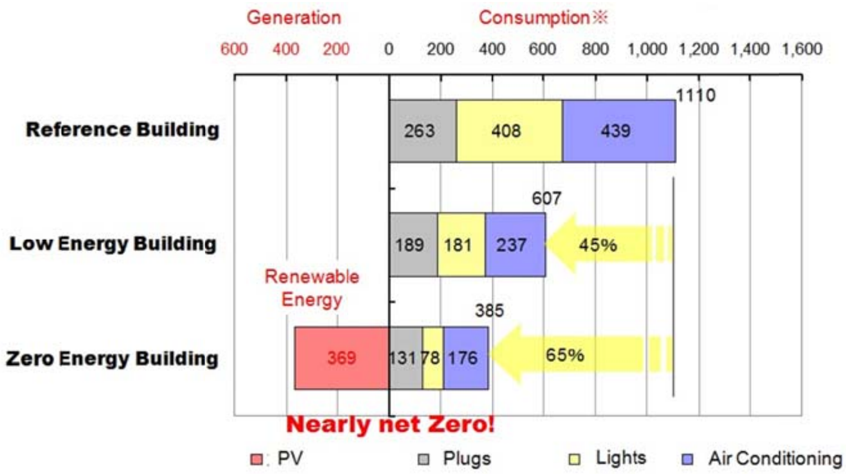


Figure 1.14 Annual Primary Energy Consumption and Generation

1.6.2 Sustainable Building

According to the definition by the Architectural Institute of Japan (AIJ), which is the most frequently referred in Japan, A sustainable building is one which is designed(AIJ, 2005, "Architecture for a Sustainable Future", Tokyo: IBEC):

1) To save energy and resources, recycle materials and minimize the emission of toxic substances throughout its life cycle

2) To harmonize with the local climate, traditions, culture and the surrounding environment

3) To be able to sustain and improve the quality of human life while maintaining the capacity of the ecosystem at the local and global levels.

1.7 Conclusion

1. Comparing with other developed countries, building energy consumption in Japan is at a relative low level and thus possesses 30% of the total energy consumption .Building in Japan are designed to be self- sufficiency in energy and the development of Zero Energy Building is put on the agenda. Since the establishment of Energy Conservation Law (ECL) in 1979, the set of minimum energy efficiency raised and raised after several revisions and series of relevant action plans were also proposed and taken into effect.

2. The Japanese government has provided great support on developing Net Zero Energy Building. Following with the series of clear policies, the mid-range targets have been set on building CO2 emission:

   - Reduce CO2 emissions by 25% by 2020 (compared to 1990).
   - Compliance with energy saving standard of new housing and buildings by 2020

   Financial subsidies for cost of high performance system adoption are also available for existing, new, renovation and additional civil buildings. In 2011, the government initiated financial subsidy programs with an upper limit of 4 billion JPY. This greatly put the development of NZEB forward.

3. From researching the definition of NZEB in Japan, a clear developing route can be concluded as: Low Energy Consumption Building--Sustainable Building-- Net Zero Energy Building-- Zero Energy Building. The ZEB definition raised by SHASE is widely accepted in Japan and corresponding action plans are also taken into effort:

   For Net Zero Energy House (ZEH)

   - To make ZEH the standard for new single houses by 2020.
   - To double the number of renovating energy-efficient houses by 2020.
   - To realize ZEH for new single houses on average by 2030.

   For Net Zero Energy Building (ZEB)

   - To realize ZEB for new public buildings, etc., by 2020.
   - To realize ZEB for new buildings on average by 2030.

2. Program & Findings

2.1 Research Programs

Joint program of MLIT and METI was established to promote zero-energy housing, introduce housing systems that contribute to zero-energy housing and assist small and medium-sized builders' effort for zero-energy housing.

2.2 Technologies to Realize ZEB

Due to continue efforts in building energy efficiency improving and CO_2 emission reducing, annual CO_2 emissions and energy consumption could be reduced by 35-65% even with existing technologies as shown in Figure 2.1.

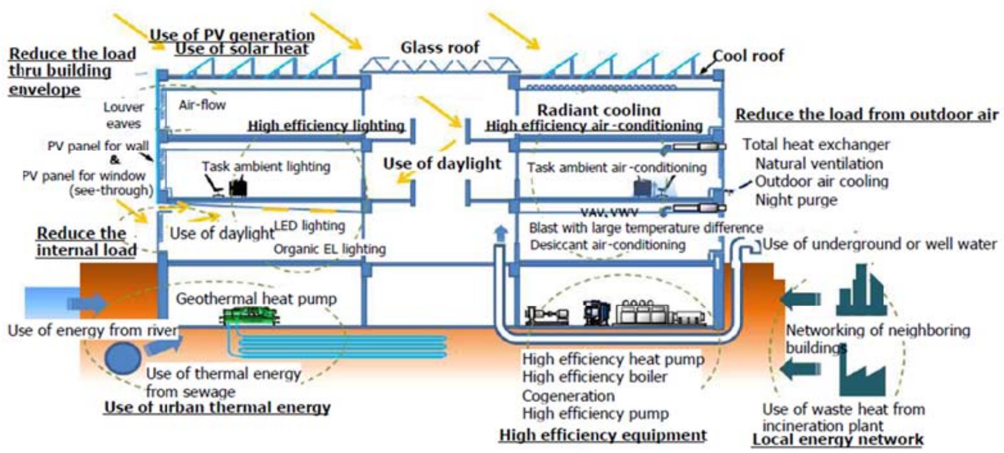


Figure 2.1 Technologies for realizing ZEB

Therefore, to realize ZEB (100% reduction), progress in individual technologies and its effectively combination, integrated control as well as comprehensive design are especially essential. Design method of NZEB can be summarized into 3 aspects and 9 points, as shown in Figure 2.2.

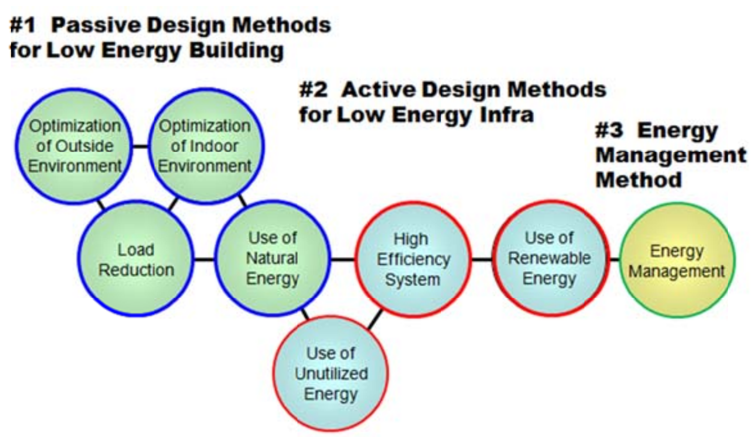


Figure 2.2 Design methods of NZEB

1. Minimize building load (passive design) to reduce energy consumption

   Measurements such as high insulation material for building envelope, high performance window system, natural ventilation and effective lighting system could be considered.

2. Introducing of high efficiency equipment and renewable energy system to enhance energy efficiency such as high efficiency heat pump, high efficiency boiler or pump.

3. Intelligent building management system to optimize the operation of subsystem for energy conservation and efficiency improving.

Specifically, advanced technologies can be described by the following 9 aspects

1. Optimization of Outside Environment

   1.1 Location of Building: Ventilation, Location of Building

   1.2 Outside Environment Planning: Green and water, Surface Material

2. Optimization Indoor Environment

   2.1 Thermal Environment: Temperature, Humidity, Radiation

   2.2 Lighting Environment: Optimization of illumination

   2.3 Air Quality: Outside Air Volume

3. Load Reduction

   3.1 Shading of Sunlight: Tree, Building Shape

   3.2 Insulation of Envelope: Window Surface, Pair Glass, Double Skin, Roof Greening

   3.3 Reduction of Inner heat: Waiting Power, Clouding

4. Use of Natural Energy

   4.1 Natural Lighting: Top light, light shelf, Light Duct

   4.2 Natural Ventilation

   4.3 Earth heat Using: Earth Tube, Geo-HP

   4.4 Solar Heat Using: Passive and Active

5. Use of Unutilized Energy

   5.1 Temperature Difference: Ground Water

6. High Efficiency System

   6.1 Lighting: LED、Natural Lighting, Task & Ambient Lighting

   6.2 HVAC: High Efficiency Equipment

   6.3 Heat Source: High Efficiency System

   6.4 Electricity: High Efficiency Trans

   6.5 Others: HW Supply system

   6.6 Control: Blind Control, Task & Ambient Control

7. Resource and Material

    7.1 Resource

    7.2 Materials

    7.3 Waste

8. Use of Renewable Energy

    8.1 PV

    8.2 Wind Power

    8.3 Biomass

9. Energy Management

    9.1 BEMS (Building Energy Management)

    9.2 LCEM (Life Circle Energy Management)

    9.3 Visualization

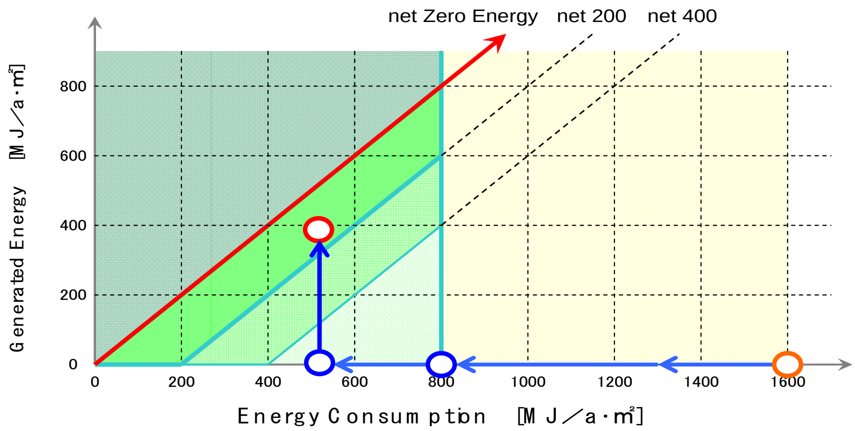


Figure 2.3 Approach to realize ZEB

Since long-term efforts of zero emission of building, building energy consumption level has improved a big step. In conception of zero energy building, energy consumption and generation amount should balance as red line shown in Figure 2.3. It is known from investigation that some of Japanese building has on-site primary energy consumption amount between 600 to 1200MJ/(a.m^2) which is in the range of green and light blue in Figure 2.3.

2.3 Analysis of the potential to realize ZEB

The potential for ZEB will increase by networking neighboring buildings, and using solar panels for façades, etc. With the use of low energy consumption OA equipment, high-efficiency lighting, heat source equipment, natural energy, photovoltaic power generation and many other high efficiency measurements, low-rise buildings with three floors or less will achieve ZEB, and buildings of even around 10 floors will be able to reduce emissions by about 80%.

2.3.1 Government Building

It is known from calculation that a 2-floor government building with primary energy consumption 360MJ/(m^2.y) could realize NZEB if 70% of roof area was covered by PV panel. For a high-floor public building, take Tokyo industry university for example, if 0.7-0.8MWh/(y.m^2) could be generated by PV panel per kW which corresponds to primary energy 600MJ/(y.m^2), to realize NZEB, primary energy consumption of this building should be within 600 MJ/(y.m^2).

To balance energy consumption and generation towards NZEB, it is required that primary energy consumption of government public building should be ranged from 400-600MJ/(m^2.y), which is 50-70% less than ordinary public buildings. Therefore, the installation of PV panel is essential necessary. Energy generation from PV panel should be 100 to 500 MJ/(m^2.y)

2.3.2 School

Different from commercial or residential buildings, primary energy consumption per m^2 of school facilities tends to lower. It is much easier to realize nearly zero energy building without sacrifice indoor environment comfortable.

Energy consumption of school is summarized as follows.

Characteristic of Energy utilization

- Cooling period is short
- Utilization of class room become flexible with the movement of students
- Less operation or maintenance engineer
- Include sports center and equipment.

Characteristic of energy consumption

- Energy consumption of lighting accounts for big amount
- Heating consume much more energy than cooling

Characteristic of architecture

- High ceiling
- Low-rise building accounts for large percentage
- Spatial continuity
- High window-well ratio

Design method for zero energy school is much more the same as zero energy building, but the combination of different sub-system or technology should be emphasized on considering of above characters

According to above characteristics, reduction of energy consumption is suggested to follow the orders below.

1) primary energy consumption on lighting system

2) primary energy consumption on heating and cooling system

3) primary energy consumption on ventilation

On the other hand, classroom indoor environment should be insured; as public shelter, energy storage system or energy production system should be guaranteed and effective when disaster happens.

2.3.3 Private-Sector Buildings

Many private sector buildings pay great effort in realization of ZEB, from investigation of 9 private sector buildings, it is found that primary energy consumption of these buildings ranges from 600 to 1300MJ/(y.m^2), which is 40-60% lower than building energy saving standard. Efforts on load reduction, high efficiency equipment and building energy management system installation provide great advantage for ZEB realization of private-sector building.

2.4 Conclusion

This chapter summarized research programs and technology progress for realization of ZEB, especially analyzed the potential towards NZEB of different building types. With the Importance of NZEB in energy conservation and global warming prevention, Joint program of Ministry of land, infrastructure, Transport and Tourism and Ministry of Economy, Trade and Industry made efforts to promote zero-energy buildings a serious programs have been carried out towards ZEB.

Due to continue effort for building energy saving, many government, private –sector building in Japan have achieved 40%-65% energy saving with normal technologies. But to realize zero energy consumption, three design methods has been reached agreements, and PV panel installation on sustainable house made it much more closer for ZEB.

1) Passive design (building load reduction)

2) High performance equipment installation and on-site renewable energy utilization

3) Energy Management System on optimize utilization of multiple system.

Different from other countries, emergency disaster is more frequent in Japan, specific technology is required such as anti-seismic, for buildings towards NZEB for both commercial and civil buildings. School facility is specifically required in energy self-supportive, anti-seismic and environment education function for children and its role as disaster refuge.

3. Building Codes and Standards

3.1 Overview

Japan has developed a set of building energy standards under the Energy Conservation Law among which one covers commercial buildings and the other two cover houses (Table 3.1). Criteria for Clients on the Rationalization of Energy Use for Buildings (CCREUB) is a mixture of performance and prescriptive energy codes for commercial buildings. There are two building energy standards related to residential buildings: (1) Design and Construction Guidelines on the Rationalization of Energy Use for Houses (DCGREUH), issued by MoC in 1980; and (2) Criteria for Clients on the Rationalization of Energy Use for Houses (CCREUH), issued by MITI and MoC in 1980, and later revised in 1992 and 1999.

Table 3.1 Structure of the Building Energy Codes in Japan
Sources: CCREUB 1999, DCGREUH 1999 and CCREUH 1999

	Commercial	Residential	
	CCREUB	DCGREUH	CCREUH
Building Envelope	1. Heat loss through the building envelope	1. Thermal insulation 2. Thermal performance of the building envelope 3. Thermal performance of windows and doors	1. Maximum annual heating and cooling loads by climate zone 2. Standards for equivalent clearance areas by climate zone 3. Condensation control
HVAC	2. Air conditioning and heating 3. Mechanical ventilation (except for air conditioning and heating)	4. Ventilation plans 5. Heating, cooling and hot water supply plans 6. Airflow plans	4. Ventilation volume 5. Prevention of indoor air contamination from heating and hot water systems 6. Planned operation of heating and cooling systems 7. Ventilation routes for heat dissipation
Lighting	4. Lighting	Not Applicable (N.A.)	N.A.
Hot water	5. Hot water supply	(See 5. Heating and cooling, and hot water supply plans	N.A.
Other	6. Lifting equipment	7. Information on building operation and maintenance (" how to live")	N.A.

There are totally six climate zones in Japan. Climate zones I and II are located in northern areas with cold winters and hot summers, and climate zones V and VI are located in southern areas with warm winters and hot summers. The energy code for commercial buildings references three climate zones: ordinary, cold and tropical. Most areas in Japan fall into the ordinary zone. The energy codes for residential buildings or houses also provide values adjusted for regional and climate differences for insulation-related indictors. However, there are six climate zones in the residential energy codes (Figure 3.1).

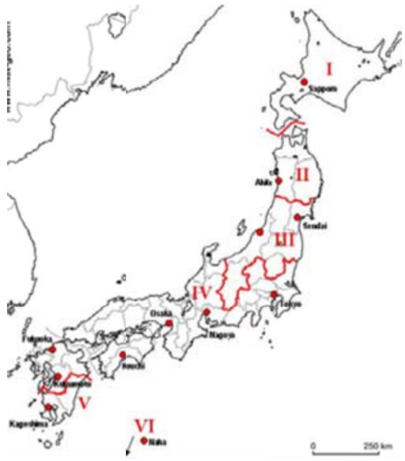


Figure 3.1 Residential Climate Zones in Japan

The history of the building energy standards in Japan can trace back to 1979 when the first energy conservation law was published (Table3.4). Ever since the Energy Conservation Law established in 1979, the Building Energy Standard was established in the very following year according to the law. Since no obligation was taken on building owners by that time, the standard was similar to recommendation. And after several times of revision, like in 1992 (S55 Standard), 1993 (H4 Standard), and 1999 (H11 Standard), the levels of the standard were enhanced step by step (Figure 3.2). The standard became mandatory in 2009 except small buildings and housings.

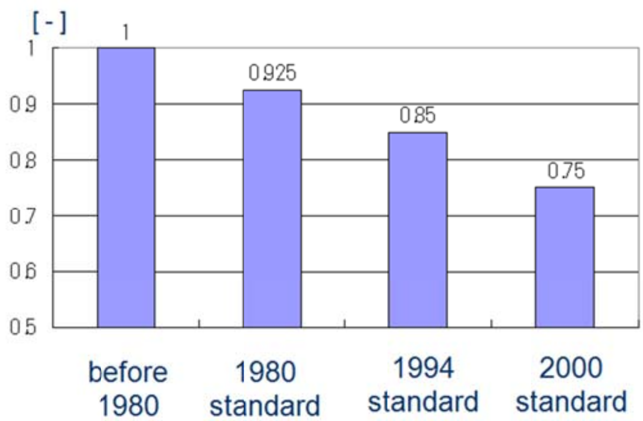


Figure 3.2 Energy comparison of the amount of energy consumption of buildings by each energy efficiency standard

The percentage of newly built houses that satisfy the 1999 energy efficiency standard is shown in Figure 3.3. From 2008 to 2011, the percentage of newly built houses' satisfactory rose from 18% to nearly 50%. This can be attributed to the high attention and powerful execution of the Japanese government.

Figure 3.3 Percentage of newly built houses that satisfy the 1999 energy efficiency standard

3.2 Energy Codes for Commercial Buildings - Criteria for Clients on the Rationalization of Energy Use for Buildings (CCREUB)

The CCREUB covers insulation of the building envelope as well as heating, ventilation and air conditioning (HVAC), lighting, water heating, and lifting equipment (Table 3.2).

Table 3.2 Essential Features of the CCREUB
Source: *CCREUB 1999*

Section Number and Title	Selected Provisions
1.Heat loss through building envelope	(1) Orientation of outer walls and layouts of the rooms should be considered in site planning, (2) Building materials with high thermal insulation properties should be used in the outer walls, floors and other parts of the building envelope, (3) Measures for windows & tree planting be used to limit solar heat gain.
2. HVAC	(1) The load characteristics of rooms and other factors should be taken into consideration in the design of HVAC systems, (2) Ducts, piping and other equipment designed for high heat retention should be considered in the building plans, (3) A proper control method should be adopted for HVAC equipment, and (4) A high-efficiency heat source should be used.
3.Mechanical ventilation	(1) A plan to reduce energy losses from air ducts should be included in the design, (2) Mechanical ventilation equipment should have proper controls, (3) Energy-efficient equipment should be used for ventilation.
4. Lighting	(1) Energy-efficient lighting should be used, (2) Lighting equipment should have proper controls, (3) Lighting equipment should be installed in a manner that facilitates easy maintenance and management, and (4) The arrangement of lighting equipment, the level of luminance, and the selection of room shape and interior finish should be properly determined.
5.Hot water supply	(1) Shorter piping routes and thermal insulation of piping should be considered in plumbing design, (2) Hot water supply equipment should have proper controls, and

	(3) The heat source system should be energy efficient.
6.Lifting equipment (elevators)	(1) Lifting equipment should have proper controls, (2) Drive systems should be energy efficient, and (3) The installation plan for the required transport capacity should be properly designed.

Some of provisions of the CCREUB are relatively general, although others include specific values or calculation methodologies.

The CCREUB has requirements for specific building envelope components by climate zone. The specific components selected receive different scores depending on their impact on energy efficiency. The CCREUB also employs two energy indicators to measure energy performance of a building. The perimeter annual load (PAL) is for the energy performance of the building envelope, and the coefficient of energy consumption (CEC) for the energy performance of the building equipment.

$$\text{PAL}=\frac{\text{Annual space conditioning load in the perimeter zone [MJ/year]}}{\text{Area of perimeter zone [m]}}$$

For the performance of the building equipment, Coefficient of Energy Consumption (CEC) is an important coefficient which is defined as:

$$\text{CEC}=\frac{\text{Annual energy consumption [MJ/year]}}{\text{Annual thermal load or reference consumption [MJ/ year]}}$$

- CEC/AC : CEC for Air-conditioning
- CEC/V: CEC for Ventilation
- CEC/L: CEC for Lighting
- CEC/HW: CEC for Hot water supply
- CEC/EV: CEC for Elevators

3.3 Energy Codes for Residential Buildings (Houses)- Design and Construction Guidelines on the Rationalization of Energy Use for Houses (DCGREUH)

The DCGREUH is a set of prescriptive building energy codes for residential buildings (houses). During the DCGREUH, thermal insulation and thermal performance were prescript in details and the maximum heat transfer coefficient of the openings from colder areas to hotter areas are also listed out (Table 3.3). Details on design and construction measures are also provided in

Table 3.3 Maximum Heat Transfer Coefficients (U-values) of Windows and Doors by Climate Zone

Source: DCGREUH 1999

Unit: watts/m^2℃

Climate Zone					
I	II	III	IV	V	VI
2.33		3.49	4.65		6.51

In the coldest zones (I and II), windows must generally have triple-glazed glass, or double-glazed glass and a storm window. Double-glazed windows are required in zones III to V.

In contrast to the residential building codes of other APP countries, Japan's residential building energy code also provides instructions regarding the operation and maintenance of the house, including the following:

- Open combustion heating systems should be equipped with a device to prevent incomplete combustion,
- Proper measures should be taken to prevent moisture condensation in an open heating system,
- Proper ventilation is needed when significant amounts of chemical substances, offensive odors and vapors are generated inside the house.
- Filters on ventilation systems and heating and cooling equipment should be cleaned regularly.
- Rooms must be ventilated by windows when there is a small difference between the inside and outside temperature, except during the heating season.

Under the Energy Conservation Law, owners of large houses and buildings must provide local authorities with reports on maintenance every three years.

3.4 Latest Building Energy Standard

In April 2013, the whole standard was revised and primary energy consumption is needed as criterion index, in addition to envelope performance. The differences of the old Standard and the new one are concluded in Table 3.4.

Table 3.4 Comparison of the old standard and the 2013 new building energy standard

Old Standard	New Standard
There are 5 criterion indices for each equipment and it is not an index for whole building performance.	New index: PAL and Primary energy consumption of 5 equipment (AC, V, L, HW and EV).
Calculation methods have not been updated for about 30 years and some newly technique cannot be evaluated.	New calculation method is developed, which can estimate the energy consumption more accurately.
The values for the PAL and CEC depend on the building type.	Criterion value is defined according to types of room.

Concerning future basic direction and its procedure, the "Committee for the Promotion of Housing and Lifestyles Contributing to the Creation of a Low Carbon Society" was established by METI, MLIT and MOE with experts and practitioners in housing energy and environmental areas, discuss promotion policy of Energy Efficiency / CO_2 Efficiency concerning manner of housing and lifestyles. With the presentation of Mid-term summary (Draft) and Progress schedule (Draft), the new Building Energy Standard focuses more on developing a fair and reliable method to evaluate the energy efficiency performance of buildings. The following compliance to the standard will be mandatory:

Promote construction of houses and buildings with higher energy efficiency performance

- Labeling and information provision of energy efficiency
- Promote construction of zero-energy homes
- Promote construction of houses and buildings which utilize advanced CO_2 emission reduction technologies
- Certify and promote buildings with high energy efficiency performance

Assure Minimum Energy Efficiency Performance of Houses and Buildings

Evaluation by primary energy consumption index, problems to be solved for realizing mandate of energy efficiency standards are discussed during this revision:

- Provide information about necessity and reasons of regulations
- Consider balances between regulations on houses and buildings in Japan and that in other sectors and in other countries
- Give sufficient attention to small to medium sized home builders

Improve Energy Efficiency of Existing Houses and Buildings

- Support energy efficiency renovations of existing houses and buildings
- Promote improvement of building materials and equipments by top-runner standards
- Consider evaluation and labeling system of energy efficiency of existing houses and buildings.

Increase Capabilities of Individuals and Organizations

- Hold training courses of insulation techniques for small to medium sized firms
- Consider developing an evaluation method of energy efficiency of traditional wooden homes
- Assure and improve quality of building materials and equipments
- Increase capabilities of individuals and organizations who assess housing and building energy efficiency

Throughout the history of the Building Energy Standard, the Japanese government has taken a lot of effort in promoting energy efficiency with increasingly stringent demanding. Table 3.5 lists out the development history and the future of Building Energy Standard. As is scheduled, until 2020, compliance to the standard will be mandatory for all buildings and housings. BRI developed the on-line calculation tool for the new energy standard and certification system of low-carbon buildings.

Table 3.5 History and Future of the Building Energy Standard

1979	The Energy Conservation Law was established.
1980	The Building Energy Standard was established according to the law. No obligation was taken on building owners. So the standard was similar to recommendation.
1992	The standard for housings was revised owing to the Gulf War.
1993	The standard for buildings was revised as well as for housings.
1999	The levels of the standard were enhanced because of the Kyoto Protocol.
2009	Reporting on the standards was mandatory except small buildings and housings.
2013	The whole standard was revised. Primary energy consumption is needed as criterion index, in addition to envelope performance.
……..	
2020	Compliance to the standard will be mandatory for all buildings and housings.

3.5 Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)

Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) is a green building rating system developed by the Japan Sustainable Building Consortium to assess the "environmental efficiency" of buildings. CASBEE is a tool for assessing and rating the environmental performance of buildings and built environment.

CASBEE was developed according to the following policies:

1) The system should be structured to award high assessments to superior buildings, thereby enhancing incentives to designers and others.

2) The assessment system should be as simple as possible.

3) The system should be applicable to buildings in a wide range of building types.

4) The system should take into consideration issues and problems peculiar to Japan and Asia.

CASBEE is a method for assessing and rating the environmental performance of buildings, ranked in five grades: Excellent (S), Very Good (A), Good (B+), Fairly Poor (B-) and Poor (C). The first assessment tool, CASBEE for Office, was completed in 2002, followed by CASBEE for New Construction in July 2003, CASBEE for Existing Building in July 2004 and CASBEE for Renovation in July 2005.

CASBEE is unique to Japan for its introduction of an innovative concept: it evaluates a building from the two viewpoints of environmental quality and performance (Q=quality) and environmental load on the external environment (L=load) when evaluating the environmental performance of the building and defines a new comprehensive assessment indicator, the Building Environmental Efficiency (BEE), by Q/L (Figure 3.4). CASBEE comprises the four basic tools, tailored to the building lifecycle, and expanded tools for specific purposes. These are called collectively as the "CASBEE Family".

3.6 Top Runner program

The "Top Runner program" which is applied to household appliances, equipment and automobiles. It is a mandatory program for companies (manufacturers and importers), to fulfill the efficiency targets within 3 to 10 years, which encourages competition and innovation among the companies without increasing market prices. Companies make efforts toward those goals, so the program has contributed to improving energy efficiency of consumer electronics and automobiles in Japan. "Top Runner Program" is implemented in about 70% of the energy consumption in households (Figure 3.4).

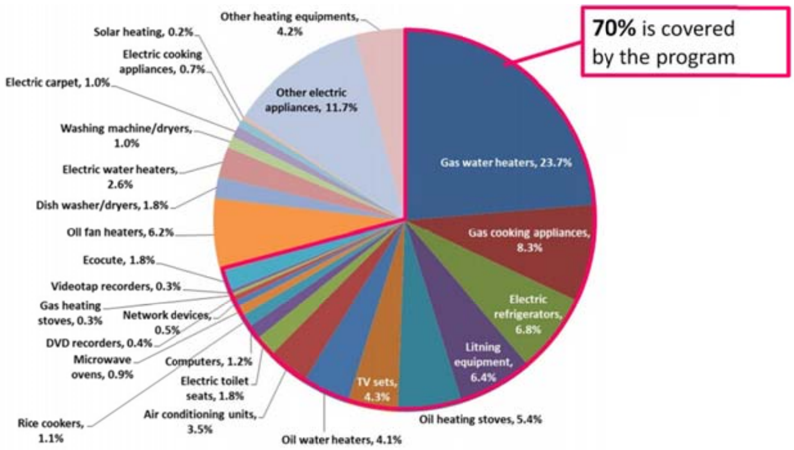


Figure 3.4 Energy consumption level per household in 2009, 34,905MJ/Year
Source: Atsushi Fukuda. IEA HPP Workshop, 2013

3.7 Conclusion

This chapter summarized Codes and Standards towards NZNB in Japan. There are three building energy codes so far. One refers to commercial buildings and the other two cover residential houses.

1. As the part of Energy Conservation Law, the three building energy codes (CCREUB, DCGREUH and CCREUH) also promote with the revision of the Law. The latest 2013 Standards is reinforced by regulating new calculation method with refinement models, which made the estimation of energy consumption become more accurately, thus clarified the road to NZEB.
2. As the most authoritative assessment in Japan, CASBEE is a tool for assessing and rating the environmental performance of buildings and built environment. It is also a voluntary program being implemented by local governments, with training for the assessors and third party assessment.

4. Networks and Organizations

4.1 SHASE

The society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE) is a major organization for heating, air-conditioning and sanitary engineering in Japan with a history of over 80 years. It was established in 1917 as Heating and Refrigeration Association and changed its organization name to the Society of Domestic and Sanitary Engineering in 1927 and then to The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan in 1962. It is also the only scientific society in the field of air-conditioning and sanitary engineering in Japan with more than 20,000 members all over the world.

SHASE develops the science of building mechanical service system and environmental engineering including heating, ventilation, air-conditioning and sanitary engineering through:

- Education: Organizing symposiums, technical meetings, training courses and technical tours.
- Publication: Issuing journals, technical papers, research reports, etc.
- Research: Conducting, supporting and promoting research and investigation
- Collaboration: Cooperating and collaborating with international relevant societies
- Standard: Setting HASS (Heating, Air-Conditioning and Sanitary Standard)
- Qualifying examination: Qualifying "Building Service Engineer" in Japan
- Awards: Giving prizes for contribution to the fields

SHASE has also contributed a great effort on pushing the development of NZEB forward, Figure 4.1 depicts the vision for 21th Century of SHASE in Japan.

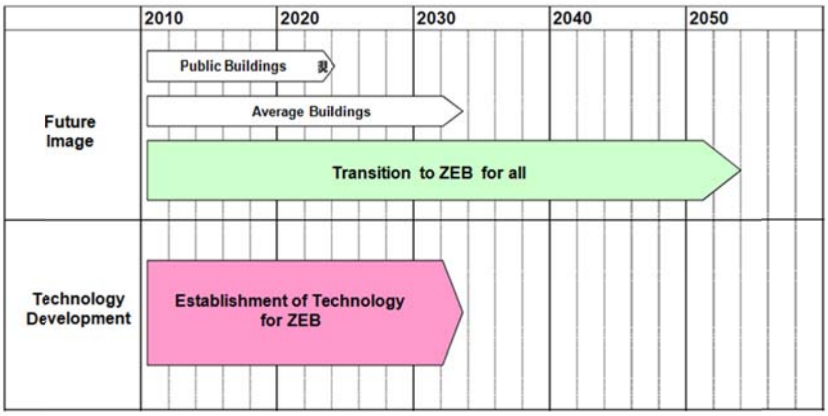


Figure 4.1 Vision for 21th Century of SHASE* in Japan (2012)

4.2 Committee for the Promotion of Housing and Lifestyles Contributing to the Creation of a Low Carbon Society

For the Promotion of Housing and Lifestyles Contributing to the Creation of a Low Carbon Society, joint establishment of the "**Committee for the Promotion of Housing and Lifestyles**

Contributing to the Creation of a Low Carbon Society" by METI, MLIT and MOE with experts and practitioners in housing energy and environmental areas, discuss promotion policy of Energy Efficiency / CO_2 Efficiency concerning manner of housing and lifestyles.

The establishment shows the directions of future measure to improve energy efficiency in housing and buildings:

Discussion to mandate compliance with the building energy standard until 2020 and its process

- Revision of method to evaluate energy saving performance
- Promotion to prevail Zero-Energy Housing and Buildings
- Establish certification of Low-Carbon Buildings

Installing renewable energy

Promotion to install solar energy generation, solar thermal, earth thermal which have large room for utilization in housing and buildings field.

Reducing CO_2 emissions through lifecycle in total

By prevailing LCCM Housing, and so on, reduce CO_2 emissions through lifecycle from construction to maintenance control, abolishment and recycle, etc.

4.3 Committee on Realization and Generalization of ZEB

Agreed by Ministerial Conference on Economic Measures in 2008, **Committee on Realization and Generalization of ZEB** was established by Ministry of Economy, Trade and Industry to launch an effort toward the realization of ZEB.

This committee played very important role in development of ZEH/ZEB. In 2012, meeting organized by this committee was launched. Development of ZEB all over the world and the necessity of ZEB in Japan and its orientation was deeply discussed, especially relation between energy saving and ZEB, ZEB and disaster relief were clarified.

4.4 School ZEB Promotion Measure Committee

School ZEB Promotion Measure Committee are conducted by Ministry on Education, Culture, Sports, Science and Technology, and Ministry of Land, Infrastructure, Transport and Tourism. This committee is endeavors to the realization of zero energy of school.

4.5 Conclusion

1. Committees, organization and network in related to zero energy building in Japan are facing with different field. There are mainly 5 committees, which may include houses, schools, equipment promotion and standards making, all of these were supported by either government or private companies to promote the realization of zero energy buildings. Along with the internationalization, committees in Japan are also working on developing NZEB with international cooperation.
2. Committees in Japan most come from universities, construction/ electrical companies, and many research institutes. They are endeavored to standards code, laws, policies making, technology innovation and popularization, like SHASE, they provide great support on

developing NZEB. The vision for 21th Century of SHASE depicts stage development target of NZEB in Japan:

- Realize NZEB in public buildings by 2020
- Realize the promotion of average building energy status to NZEB by 2030
- Realize the target of NZEB for all buildings by 2050

5. Demonstration Projects

5.1 Overview

In Japan, the Ministerial Conference on Economic Measures discussed "accelerating the realization of zero emissions buildings" in a joint session in April 2009. In response to the session, the METI established a Committee on Realization and Dissemination of Zero Energy Buildings (ZEBs) to launch an effort toward the realization of ZEBs. This committee has launched several programs to promote NZEB development.

In this chapter, 9 typical buildings designed as zero energy buildings including government, private-sector buildings and residential houses, distributed in different climate zones were analyzed, and their current energy consumption level and potential towards ZEB were analyzed, 4 of them were introduced from technologies in use and CO2 emission or energy consumption point of view.

Table 5.1 gives an overview of recent typical buildings designated as zero energy (buildings A to G). Although most of them are government facilities or research centers located in suburban areas, they also include super-high-rise buildings in urban areas and buildings in cold climate areas. The energy-efficient technologies used in these buildings can be roughly divided into passive and active methods. Also, an energy management approach has been developed in recent years. Among renewable energy technologies, photovoltaic (PV) power generation technology using PV panels is the mainstream.

These buildings only consume energy between around 700 and 1300 MJ/ m^2 ・year in on-site primary energy consumption unit terms, which is equivalent to 35% to 65% of that of Japanese standard office buildings (2000 MJ/m^2 ・year). Among the buildings, even the one with the highest on-site primary energy production generates as little as 300 MJ/m^2・year.

Table 5.1 Overview of Typical Japanese Buildings designated as Zero Energy

Building		A	B	C	D	E	F	G
Location		Mie	Tokyo	Tokyo	Aichi	Tokyo	Tokyo	Sapporo
Type of building		Government facility	Research center	Research center	Research center	Office	Office	Office
Structure & number of stories		SRC, 4	RC, 5	S, 3	S, 8	SRC, 22	SRC, 27	SRC, 8
Site area (m^2)		14,800	5,200	69,400		3,000	,80,000	860
Building area (m^2)		3,800	2,200	3,300	5,700	2,200	4,600	770
Gross floor area (m^2)		9,500	9,000	5,500	43,000	51,800	104,000	7,000
Major energy efficiency technology	Passive	Exterior louvers, Roof greening, Natural ventilation	Eaves & louvers	Veranda space, Natural ventilation, Use of daylight	Light shelf, Natural lighting, Natural ventilation	Double-pane low-E windows, Natural lighting	Double-skin façade, Roof greening, Natural ventilation Natural lighting	External insulation, Minimum window area + low-E
	Active	Automatic lighting control, Floor-mounted air diffusers, Radiation cooling/heating	Task ambient air conditioning, Ductless air conditioning	Personal air conditioning Task ambient air conditioning Desiccant air conditioning Ground heat use, Solar heat use	Chilled water storage exhaust heat recovery system, Free cooling	Task ambient radiation air conditioning, Desiccant air conditioning, LED lighting Blind lighting	LED lighting Desiccant air conditioning Radiation air conditioning	Natural lighting devices, Building thermal storage, Radiation heating/cooling Free cooling, Outdoor air cooling
	Other		Visualization	Visualization	BEMS	Smart BEMS PC power saver	BEMS, Visualization	
Renewable energy technology		Solar	Solar	Solar	Solar	Solar	To be installed	None
Onsite primary energy MJ/m^2year	Consumption	649	982	1,310	756	900	1009	878
	Generation	42	7	301	97	16	0	0
	Note	Actual 2008	Actual 2012	Actual 2011	Actual 2010	Planned	Planned	Actual 2010
Offsite effort				CDM		CDM		
Completion		Jan.2007	Oct.2011	Spt.2010	Apr.2010	May 2012	Spt.2011	Jun.2006
Remarks		Suburban	Suburban	Suburban	Suburban	Urban	Urban	Cold climate

The 45°lines depicted in Figure 5.1 represents net zero energy. Currently, a net energy consumption between 600 and 1000 MJ/m^2・year may be a reasonable level to be achieved. The Figure also shows the trial calculation for school buildings described in the School ZEB Promotion Measure Committee's Guideline stated above. As shown in the graph, the possibility of realizing school ZEBs is relatively high, due to its self-quality summarized in chapter 2

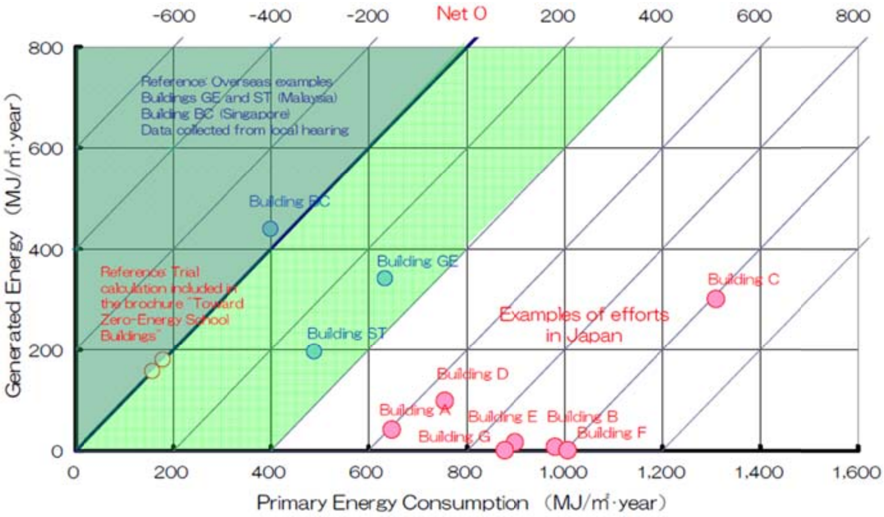


Figure 5.1 Primary Energy Map of Typical Buildings designated as Zero Energy (A to G) in Japan

5.2 Demonstration Projects

5.2.1 Shikajima Technology Research Center

Building in Figure 5.2 is a normal office building located in Tokyo, with a site area of 2202 m^2 and floor area of 8812m^2, 5 floors above the ground and 2 underground, 18m-high. The construction started from April.2010 and completed in Oct. 2011. The building was designed with a multiple conception of low environment load, comfortable indoor environment; technologies such as duct, raised floor were introduced.

Figure 5.2 Front sight of the building

5.2.1.1 Main technologies

Ductless air conditioning system was developed and installed to reduce energy consumption during transmission process. Wooden fiber cement board was utilized to achieve a good performance of sound, air and view effect without air flow root obstruction.

Due to indirect lighting from ceiling to bookshelf, results from simulation shows that the lighting method could achieve a much less the same visual effect (300Lux) as general lighting system therefore, electrical consumption on lighting sector could reduce 60% by this method..

Figure 5.3 Ductless system by using flat-slab

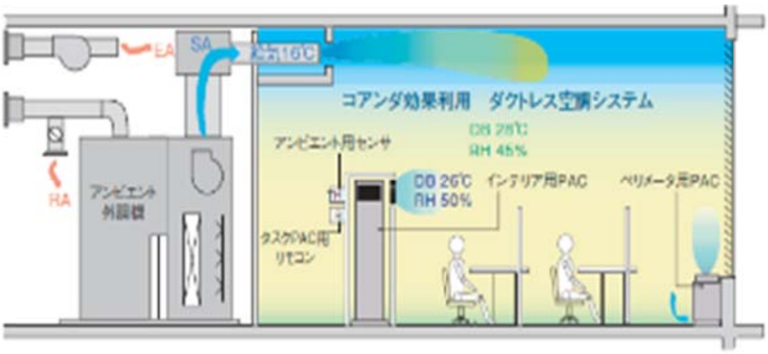


Figure 5.4 Interior Space combined with functions of Architect, Facilities and Construction

5.2.1.2 CO_2 emission

BEE (CASBEE) score of 83 has achieved which is regarded as the highest among the economy at that time. A third Certification has achieved as well. 60% of CO_2 reduction achieved compared with average CO_2 emission level of buildings in Tokyo in 2005.

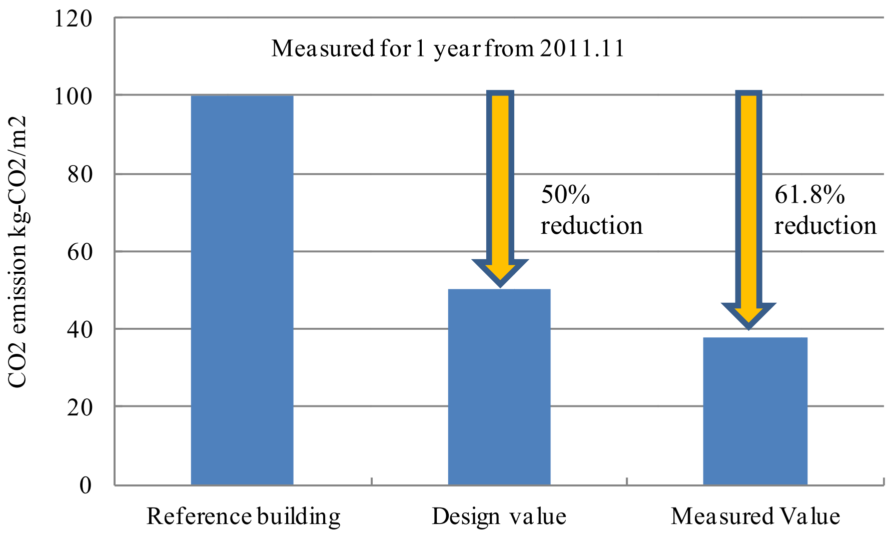


Figure 5.5 CO_2 emissions through the year

5.2.2 SHIMIZU Building

Consider a further development, and to improve the ability for disaster resist, a super environmental friendly SHIMIZU building was constructed from April. 1st 2009 to May 15th 2012.This building was a combination of BCP and eco, eco represents Energy saving and CO_2 emission decreasing, while BCP refers to a safe and reliable, self-energy production and conservation strong building.

Figure 5.6 Photo of SHIMIZU building

5.2.2.1 Introduction

Location: Tokyo

Site area: 3000 m^2

Floor area:51800 m^2.

Construction: Reinforced Concrete

Floor: 22 floor above, 3 under ground, 1 tower on the roof

Construction period: 2009.4.1 ---2012. 5.15

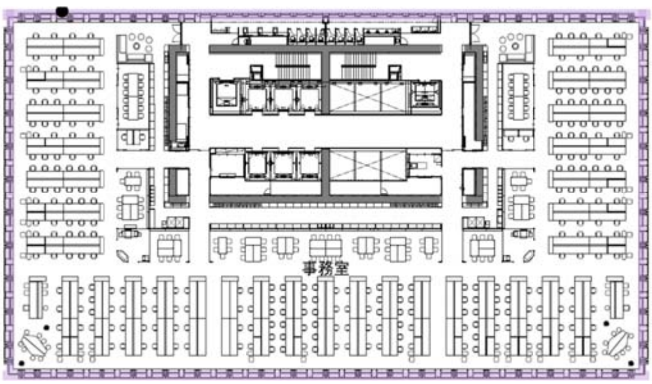


Figure 5.7 Plan of typical floor

5.2.2.2Advanced technology

1. hybrid envelope system

Outside flame is designed of deep eagle type, with PV panel, Low-E glass, anti-seismic panel integrated on the envelop system which is connected with RC steel of building elevator, performs as anti-seismic system of the super high-rise building. Polycrystalline silicon solar panel and thin film solar cell with an total area of 2000 m^2 were installed. Electrical production is about 84000kWh per year which accounts for total electric consumption of lighting system with yearly round operation.

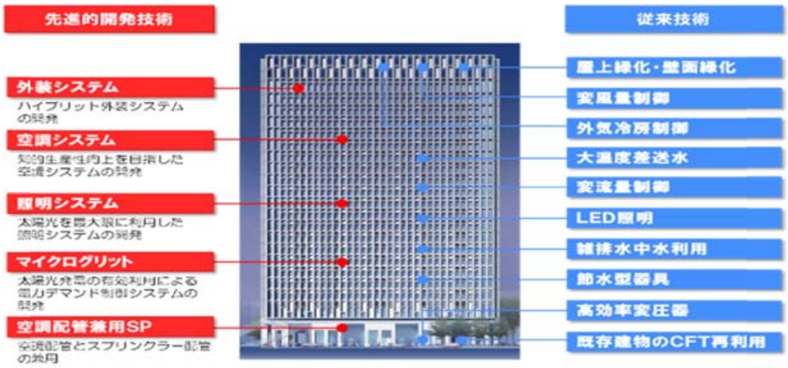


Figure 5.8 Technologies adopted in the building

2. Task and ambient radiation system

Radiation cooling and personal air supply system are adopted as heating and cooling system. In cooling period, room temperature was cooled by cold water flow inside pipes of roof radiation system. Humidified air was supply to the room from adjustable air outlet under floor according to one's requirement. Due to this system and operation mode, 30% of energy could be saved compared with traditional air conditioning system.

3. Task and ambient lighting system

Ceiling lighting with LED was introduced into the building, a desk lamp with approximately 300 Lux was supplied on each station in case of weak lighting. Two measures could effectively ensure a lighting level of 700 Lux. Linkage control among day lighting, window blind and LED lighting system were adopted to reduce energy consumption without sacrificed lighting comfort. It is confirmed that approximately 90% of electricity were saved per year from this sector.

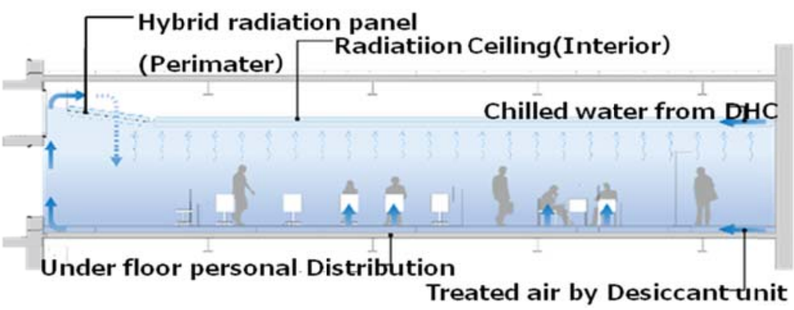


Figure 5.9 Radiation Figure Radiation H/C & Task/Ambient lighting system

5.2.2.3 CO_2 emission

After almost 7 months operation from August 2012 to Feb. 2012, CO_2 emission of the building is approximate 55kg-CO_2/(y m^2.), about 20kg-CO_2/(y m^2) was saved compare to 99kg CO_2/(y m^2) in 2005, which means 60% of CO_2 emission was reduced. It is expected to reduce up to 70%

5.2.3 Kawaga office building

This is a government office building located in Mie ken, Japan. The building was constructed with anti-seismic and waterproof design. Executive room with an open ceil for lounge and events was designed under PC construction. Front view of the building is shown in Figure 5.10

5.2.3.1 Introduction

Floor area: 9534m^2,

Floor: 4

Construction: Reinforced Concrete (RC), Precast Concrete (PC)

Completed: Jan. 2007.

Figure 5.10 Front view of the building

Figure 5.11 Top view of the building

5.2.3.2 Main technology

Main technologies is shown in Figure 5.12 .such as roof green with recycled wood, top light system for day lighting, open ceiling for natural ventilation, recycled wood louver to import daylight, floor heating for heating and radiation ceiling system for cooling PV system and yearly electrical heat storage system.

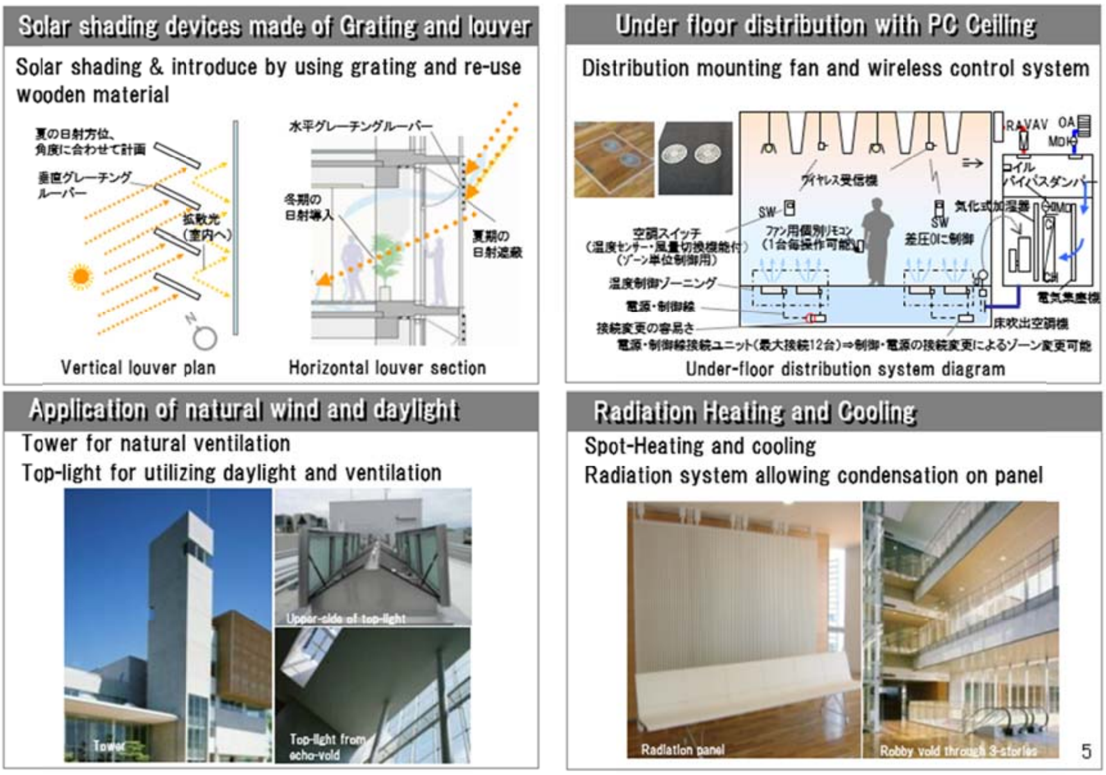


Figure 5.12 Technologies adopted in the building

5.2.3.3 Energy Consumption

Yearly CO_2 emission is plotted in Figure 5.13. It is known from the Figure that approximately 626 MJ/(m^2,y) primary energy was consumed according to the measurement in 2007. 23% of the energy reducing was contributed by main installed technologies (louver, PV, Control lighting, natural ventilation et al.). Energy consumption in 2011 was measured as 607MJ/(m^2,y), about 50% of energy was saved comparing with general office building with average energy consumption of 1261MJ(m^2,y).

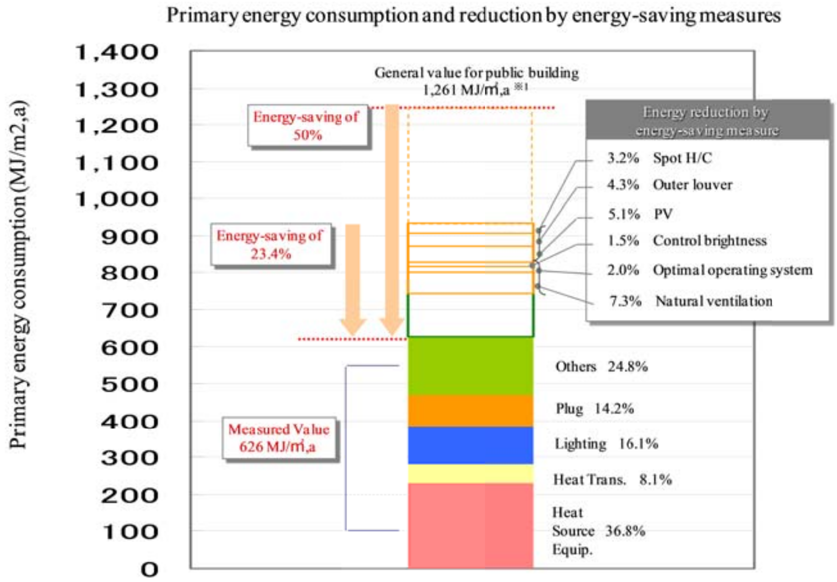


Figure 5.13 CO_2 emission

5.2.4 Kimobetsu Nearly Zero Energy House

Figure 5.14 Front view of the residential house

Figure 5.15 Technologies and monitor system of the residential house

This building is regarded as the world first Near Zero Energy public house, which was produced by Prof. Katunori Nagano, Hokkaido University

5.2.4.1 Introduction

This public house located in Kimobetsu town, Hokkaido University, it is 2 floor-building for 2 families, with an area of around 300 m^2.

5.2.4.2 Main technologies

1) Super high ambient technologies: Q value=0.58W/(m^2.K)

- Basic insulation + external insulation （Styrofoam）
- Highest performance window system in the world<1.0）
- Earth tube+ high efficiency sensible heat recovery type ventilation equipment

2) High performance equipment

- GSHP system
- High performance CO2HP water heater
- High performance LED lighting

3) High efficiency PV system（4 kWp, installed on the roof）

4) Low temperature radiation heating. Passive solar

- 1F floor heating+2F radiator
- Heat storage system

5.3 Conclusion

This Chapter summarized recent typical buildings designated as zero energy. Although most of them are government facilities or research centers located in suburban areas, they also include super-high-rise buildings in urban areas and buildings in cold climate areas. Technologies used in these buildings can be roughly divided into passive and active design. 3 pilot projects including government office, private-sector buildings are precisely present in technologies, CO2 emission and the following 5 characteristics are achieved.

- ◆ The essential strategies for achieving nZEB are a combination of passive design: mitigating heat load, active design: using renewable energy and effective energy management
- ◆ High performance envelop, natural ventilation, daylight, LED lighting and solar shading technologies are required for load reducing.
- ◆ High performance HVAC system as well as heat pump system, heat storage system, PV panel are necessary for active design.
- ◆ The importance of self-sufficiency of energy are emphasized in realization of NZEB
- ◆ BEMS is important for building, performance evaluation, analyze, especially for system optimization.

6. Conclusion

1. Comparing with other developed countries, building energy consumption in Japan is at a relative low level and thus possesses 30% of the total energy consumption. Japanese governments pay a lot attention on energy saving and energy efficiency has been lifted to the height of national energy security, especially after the Great Eastern Japan Earthquake in 2011, building in Japan are designed to be self- sufficiency in energy and the development of Zero Energy Building is put on the agenda. Since the establishment of Energy Conservation Law (ECL) in 1979, the set of minimum energy efficiency raised and raised after several revisions and series of relevant action plans were also proposed and taken into effect.

2. Definition and action plan. From researching the definition of NZEB in Japan, a clear developing route can be concluded as: Low Energy Consumption Building--Sustainable Building-- Net Zero Energy Building-- Zero Energy Building. The ZEB definition raised by SHASE is widely accepted in Japan and corresponding action plans are also taken into effort:

   For Net Zero Energy House (ZEH)

   - ◆ To make ZEH the standard for new single houses by 2020.
   - ◆ To double the number of renovating energy-efficient houses by 2020.
   - ◆ To realize ZEH for new single houses on average by 2030.

   For Net Zero Energy Building (ZEB)

   - ◆ To realize ZEB for new public buildings, etc., by 2020.
   - ◆ To realize ZEB for new buildings on average by 2030.

3. Energy saving property should above level of energy saving law, then within 1/3 to 2/3of equipment costs can be covered by subsidy. In 2011, the government initiated financial subsidy programs with a upper limit of 4 billion JPY. New, renovation and additional civil buildings with an energy consumption reduction of 30%, or construction with complete operation data, or with detailed system introduction that can require for the subsidy. This promise Japan abundant operating data and experiments thus can greatly put the development of NZEB forward.

4. Networks and Organization’s positive impact. Committees, organization and network in related to zero energy building in Japan are taking active effort in participating NZEB development. The various fields which include houses, schools, equipment promotion and standards making were supported by either government or private companies to promote the realization of zero energy buildings. They are endeavored to standards code, laws, policies making, technology innovation and popularization, like SHASE, they provide great support on developing NZEB. The vision for 21th Century of SHASE depicts stage development target of NZEB in Japan which is much more ahead of national target:

   •Realize NZEB in public buildings by 2020

•Realize the promotion of average building energy status to NZEB by 2030

•Realize the target of NZEB for all buildings by 2050

Along with the internationalization, committees in Japan are also working on developing NZEB with international cooperation.

5. Pilot demonstrations intensive study. Most of the NZEB pilots in Japan in the investigation are large-scale commercial or federal buildings. NZEB demonstrations in Japan for the current stage are mainly from government and enterprises support. The development of NZEB can be considered as the extension of sustainable building. This made Japan a perfect work on the integrity of the building energy study, either in term of technological design, or sequential study, like operating data record, and performance analyze. The precious data record and experiences may give a major push on the subsequent marketization process.

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SECTION IV KOREA

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1. Policy，Definition，Objective

1.1 Building energy status in Korea

Korea has the world’s thirteenth largest economy, with a gross domestic product (GDP) of US$1.4 trillion in 2007 (IMF, 2008). Due to its limited domestic energy resources, Korea imports almost all of its coal, oil and natural gas. It is the world’s second largest importer of coal, and one of the largest importers of oil and natural gas as well (EIA, 2008a). Korea’s final energy consumption was estimated at 182.6 million TOE in 2008.

Among the various parts of energy consumption, according to *Energy Survey Report* (2011), Korea Energy Economics Institute, 21.2% of Korea primary energy was consumed by the building sector, compared to 56% by the industrial sector and 22.8% by the transportation sector. Of the 21.2 quads consumed in the building sector in 2011, household accounted for 56% and commercial and public buildings accounted for 44%, as is shown in Figure 1.1.

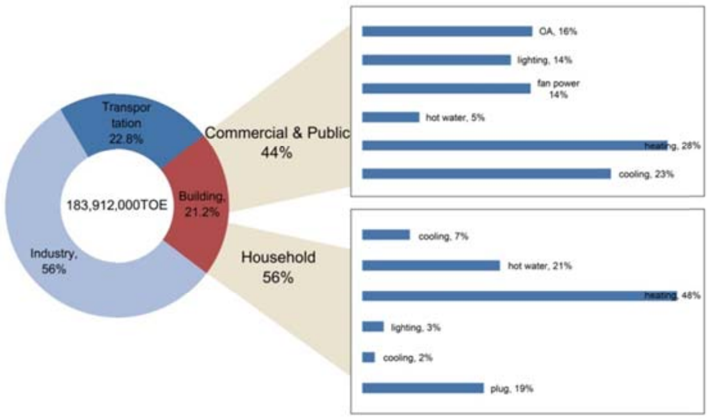

Figure 1.1 Energy Consumption in Korea

Korea’s construction industry has more than doubled from 1995 to 2009, as shown in Figure1.2. Meanwhile, the energy consumption in building sector is rising steadily in Korea (Figure 1.3). Without increasing energy efficiency, as a result of the continuous increase of buildings and the energy use equipment, the energy consumption of building will reach 50% by 2050, according to *IEA 2013，IPCC 2014*.

Figure 1.2 Construction Orders in Korea (million $)（KNSO，2010）

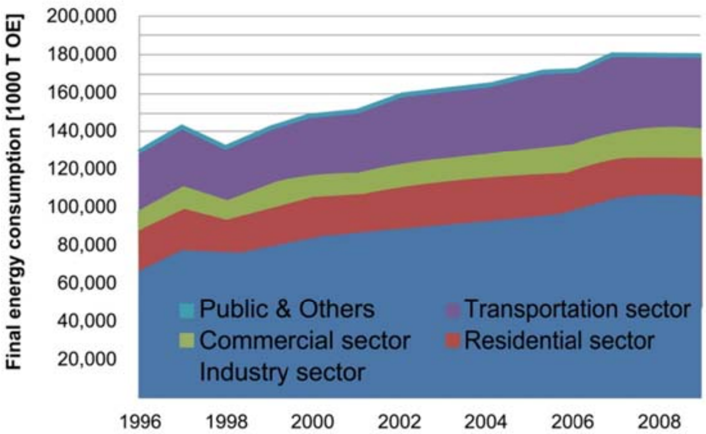

Figure 1.3 Energy consumption of Korea is rising steadily

Korea was the 9th biggest source of CO_2 emissions in the world. In 2006, Korea emitted 515 Mt carbon dioxide (EIA, 2008b). The total greenhouse-gas emission of Korea was about 620 million ton CO_2 in 2007. Total CO2 emissions between 1990 and 2007 rose by 4.3% per year and CO_2 emissions in building sector comprises about 22.6% of total CO2 emissions of Korea, as shown in Figure 1.4.

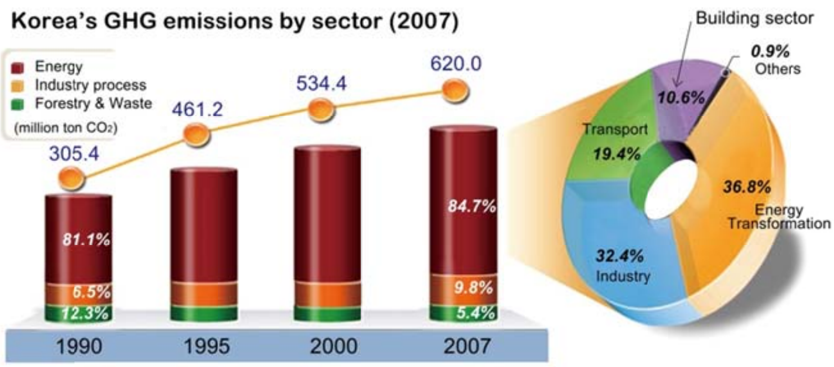

Figure 1.4 Korea's GHG emissions by sector (2007)

In order to create new technologies and new industries in response to demand for energy, climate change, and reducing greenhouse gas emissions, there is great need to promote zero energy building market as soon as possible.

1.2 Policy & Objective

The earlier energy efficiency performance is improved, the better greenhouse gas reduction effect there will be considering the accumulation.

According to Presidential Conference on Green Growth hold on November 5th, 2009, Korea tries to reduce 80% of cooling/heating energy in building sector by 2017. The detailed plan is shown in Figure 1.5.

Figure1.5 Detailed plan of ZEH in Korea

Moreover, on July 17 2014, Ministry of Land, Infrastructure and Transport issued **The Activation Plan of ZEB Corresponding to Climate Change** on the 11th General Meeting of the Presidential Advisory Council on Science and Technology (PACST), which is chaired by President PARK Geun-Hye.

This plan clearly analyzes the barriers and obstacles of ZEB promotion setting up the future roadmap step by step. The plan also shows the corresponding financial policy and subsidy for pilot projects, work distribution and calculation of the expected social, environment and economy effect.

1.2.1 Objective

According to the Plan, Korea plans to develop a pioneer project with new approach and create a market and at last achieve gradual obligation of zero energy building and set a series of objectives in stages. The strategy shown as Figure 1.6.

- (Foundation 2014~2016) Set imperative foundation such as institutional basis and technology to activate the pilot project, so as to verify the development of technology and economy efficiency.

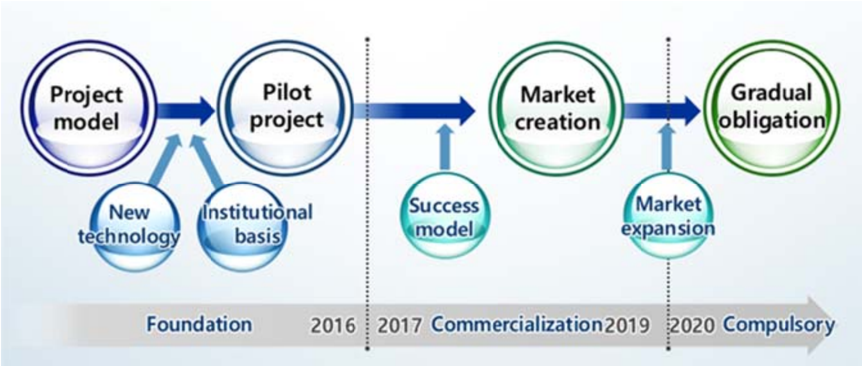

Figure 1.6 Strategy of Korea ZEH Plan

- （Research and Development, ~2017）Promote the localization of building materials and improvement of material energy information system through technology development and market expansion. Reduce the proportion of imported building materials in Zero Energy Building construction from 20%~30% now to 0% in 2017.
- (Commercialization, 2017~2019) On the basis of the success model, guide the market creation and expansion, and widespread commercialization. Secure the marketability by continue in developing renewable energy technologies, and strengthen the energy designing criteria to meet passive design standards. Compulsory passive design for residential buildings by 2017, and non-residential buildings by 2020.
- （Compulsory, 2020) Compulsory ZEB for small-scale public buildings such as resident centers, post offices and schools by 2020, and obligation of ZEB will begin to implement in all new buildings gradually from 2025.

At the same time, the government will set ZEB Service Centre and launch building material information system to provide support in ZEB technology consult and performance certification. Meanwhile, promotion of ZEB is on the basis of building material technology development and domestic demand.

1.2.2 Difficulties and Obstacles

Although there is great need to reduce the energy consumption of buildings, the actual promotion of ZEB has many difficulties and obstacles.

- The ZEB market in Korea is relatively difficult to form due to its low energy costs and high construction costs in comparison with other developed countries.
- The construction costs of ZEB will be over 30% higher than general buildings. Nonetheless, the subsidy or government support is lacking, and this affects the enthusiasm of the developers.
- Regardless of Korea's strength in ICT based new technologies and materials, it is difficult to create businesses due to low demand on Korea's ZEB market. The government should support new building material industries to be dominated on the basis of zero energy building by standards and regulations.

- Even before the issue of the Plan, the government has already been providing subsidies for the use of renewable energy systems such as solar and geothermal. However, there are no subsidies for applying the "passive" technologies, which prevents significant amount of energy loss leading to decrease in energy demand.
- The limited variety of passive technology building materials produced in Korea, due to its low demand, leads to use of high cost imported products.
- The quantity of Korea's pilot projects is relatively small compared with Europe and the United States.

1.2.3 Supportive Measures: Financial and Taxation Policy

Because of the incremental cost of zero energy building，Korea issued corresponding financial and taxation policy to offset it to activate the development of zero energy building.

- The building floor-area ratio will increase by 15% on the basis of the existing standard in order to offset parts of the additional construction cost of ZEB.
- Zero energy building could get lower acquisition and property taxes (15%, for 5 years).
- Attract the public's attention by provide subsidy and fund support for successful pilot projects.
- Support existing buildings green remodeling projects by reducing its interest through housing funds.
- For enterprises producing zero energy building structure components (such as: external thermal insulation, high performance windows), part of the income tax shall be exempted.
- After the zero energy building development to a higher stage, lead the additional construction cost of zero energy buildings down to less than 10%, and withdraw this part of the additional cost through energy consumption reduction.

1.2.4 Pilot Project Plan and Subsidy

Given the technology and economic factors, in order to carry out the ZEB act as soon as possible, on the realistic level three pilot projects will be implemented gradually. The Low-rise Zero Energy Building pilot project will start in 2014, the High-rise Zero Energy Building pilot project will start in 2015, and lastly the Zero Energy Building Town pilot project will start in 2016. The pilot project will be selected through recruiting, considering energy self-sufficiency rate, design factors, etc. Detailed information is shown in Table 1.1.

In order to attract the public's attention and accelerate activation of ZEB, Korea government provides subsidy and fund for pilot project as follows:

- Renewable Energy

Buildings that use renewable energy (solar, geothermal and other renewable energy facilities) could preferentially get 50% the cost of the related equipment subsidies.

- Passive Technology

For buildings adopting passive design to decrease the energy consumption of buildings (such as: high efficiency heat insulation equipment, windows, etc.), provide subsidy through giving allowance on project payment (15% in residential building and 50% in public building).

- BEMS(Building Energy Management System)

For buildings to adopt intelligent control system, through the analysis of real-time monitoring and statistics of energy consumption, reduce the cost of the energy by more than 10% with the most efficient control of the building.

- Fund Support

Residential buildings could get low interest loan (2% for 3years) support from residential building fund.

Table1.1 Pilot Project Promotion Plan

	Non-government	government	Pilot cities	
Low-rise ZEB	Residential(consolidation and the newly building of residential building)	Public(Small-scale business facilities)	New cities like Sejong City	2014~
High-rise ZEB	Residential Building	Public(Schools and parks)		2015~
ZEB Town	Smart zero energy town			2016~

The following is **economic analysis of a pilot project**.

Table1.2 shows the general condition of the building and Table 1.3 shows every part of the pilot project subsidy.

Table1.2 The general condition of the pilot building

	Items	**Details**	**Comment**
General condition of building	Ground size	4257 m^2	
	size	12514 m^2	
	FAR	230%	ceiling（law:250%; regulation:200%）
	General construction cost	13,000 million KRW	
	number	110 units	7 floor

Table1.3 Economic analysis of pilot project (Low-rise)

	Economic analysis	cost(million KRW)	Comment
Additional cost	Passive（high efficiency heat insulation equipment）	4100	
	Renewable energy（solar and geothermal energy）	900	
	BEMS cost	200	
Subsidy of pilot project	Housing sales profits after FAR increase	4000~7600	national average（10 million KRW/3.3m^2）Seoul average（18million KRW/3.3m^2）（FAR increases by 15/100）
	Renewable subsidy（50%）	450	priority
	Low interest subsidy (2% 3year)	450	
	Subsidy for passive mode	600	15% in residential building, 50% in public building
	Subsidy for BEMS	100	50% of equipment cost

For a 12514m^2 low-rise pilot building, the additional cost of zero energy construction is 40% more (5,200 million KRW) compared with the 13,000 million KRW general construction cost. The subsidy is 5,600 million KRW in total. That is to say, the subsidy can completely offset the incremental cost with additional incentive.

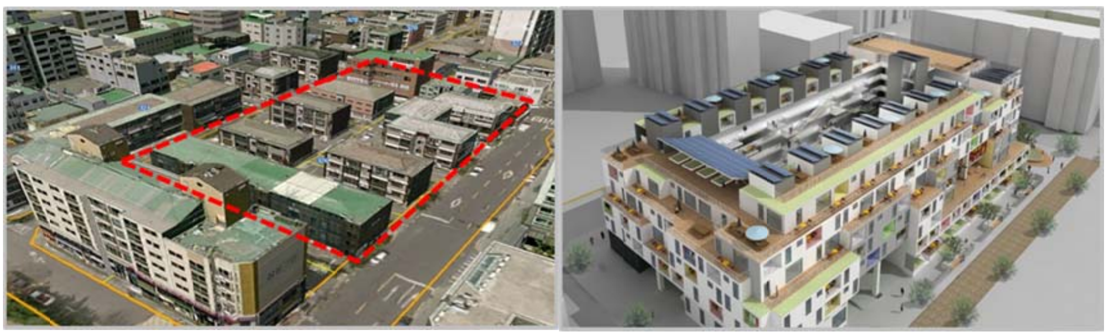

Figure1.7 Present and future of Reconstruction

1.2.5 Work Distribution and Plan

From 2014 to 2017, seven ministries of Korea and the local governments will work together in the promotion of Zero Energy Building, including Ministry of Land, Infrastructure and Transport, Ministry of Trade, Industry and Energy, Ministry of Agriculture and Forestry, Ministry of Future Creation and Science, Ministry of Finance, Ministry of Safety, Ministry of Education.

Table1.4 Work distribution and Plan in Korea

Work distribution and Plan			
	Work Distribution	Ministry	Implementation Period
Core technology research and development	Core technology research and development (ICT, building materials technology development, zero energy wooden town, zero energy town)	MFCS, MTIE MLIT, MAF	2014 ~
	Market based type zero energy building and zero energy town promotion(TEST - BED)	MLIT	Residential buildings, ~2017 Town,2016~
ZEB Codes Establishment and Upgrading & Capacity Building	Loosen building standards (ready to review policy)	MLIT, Local government	2014~
	Tax levy reduction (income tax, property tax and corporate tax, etc.)	MS,MF	2015~
	Allowance to increase profits on the basis of cost (public building)	MLIT	2014~
	Set the ZEB service center	MF,MLIT	2014~
	Building material performance information system	MLIT	~2017
	Standard revision of garden law	MLIT	2015~
Subsidies of pilot project	Subsidy of renewable energy	MTIE	2015~
	Subsidy of residential building fund	MF, MLIT	2015~
	Subsidy of ‘passive technology’ and BEMS	MF, MLIT	2015~
Promotion of pilot project	Recruit and select object	MLIT	Low-rise,2014~ High-rise,2015~ Town 2016~
	Energy infrastructure	ME,MTIE, MLIT	2015~

1.2.6 Expected Effects

The expected new housing constructions in Korea is 4,000,000m^2 per year, including 400,000 single family houses and 3,600,000 multi-family houses (apartments). Zero energy buildings (not including electricity use) emit GHG 70~80% less than existing buildings. It is estimated that if zero energy buildings are built in 10% of the area permitted for building annually, it will not only reduce GHG by 670,000 TCO2eq/year, energy reduction by 180,000 TOE/year, but also create 50,000 jobs with additional cost of USD 4.5 billion.

1.3 Definition

In Korea, "Zero Energy Building" is defined as "A building that maximizes thermal insulation performance to minimize energy consumption, and uses renewable energies to provide energy self-sufficiently."

To accomplish zero energy buildings as soon as possible, Korea develops three kinds of zero energy buildings as follow:

- Low-rise Zero Energy Building

A building that can provide energy required in cooling, heating, lighting and ventilation self-sufficiently within the corresponding site.

- High-rise Zero Energy Building

A building that can provide energy required in cooling and heating within the corresponding site. It need to maximize the renewable energy system installations to provide the energy required in cooling and heating self-sufficiently, and the shortages can be covered by other renewable energy installations from nearby schools, parks, etc.

- Zero Energy Building Town

It is to expand the range of zero energy from individual buildings to district units, and enforce the development targeting new towns and municipalities.

It is to utilize the use of recent technologies, such as Information & Communication Technologies, and linked with governmental R&D to aim for actualization of the avant-garde smart zero energy city.

1.4 Conclusion

- Korea has accomplished the Top-Level Design from the central government of research and development，extension and marketization of Zero Energy Building. On July 17, 2014, Ministry of Land, Infrastructure and Transport, cooperating with other six Ministries, issued **The Activation Plan of ZEB Corresponding to Climate Change** to achieve the goal of mandatory design of all new buildings by 2025. In the plan, work distribution and plan in stages is determined, mainly in four directions: core technology research and development, ZEB codes establishment and upgrading & capacity building, subsidies of pilot project and promotion of pilot project.
- Korea financial policy and project subsidy of ZEB already formed a comprehensive system, including FAR increase and lower taxes. The building floor-area ratio could increase by 15%. Zero energy building could get lower acquisition and property taxes (15%, for 5 years). Buildings using renewable energy could preferentially get 50% the cost of the related equipment subsidies. Government provides allowance on project payment to buildings that adopt passive mode (residential building 15% and public

building 50%). The support measures including FAR increase and tax benefit and direct subsidy of pilot project could completely afford the additional cost of ZEB.

- ZEB in Korea is defined as 'A building that maximizes thermal insulation performance to minimize energy consumption, and uses renewable energies to provide energy self-sufficiently'. Under the current technology level, three kinds of pilot projects will be demonstrated gradually, including 'Low-rise ZEB', 'High-rise ZEB' and 'ZEB Town'.

2. Program & Findings

2.1 Background

The research of Zero energy building is mainly leading and financed by Ministry of Land, Infrastructure and Transport, cooperating with Ministry of Trade, Industry and Energy.

The technology includes ICT, building materials technology development, zero energy building town and so on. Technologies of Zero energy building is shown in Figure 2.1.

These technologies are under researched by three different academies: KICT takes passive construction techniques; ETRI takes energy management and monitoring technology; KIER assumes for new renewable energy supply system technology.

➢ KICT(Korea Institute of Civil Engineering and Building Technology)

Korea Institute of Civil Engineering and Building Technology (KICT) is a government-sponsored research institute responsible for establishing government policies and performing R&D. The institute focuses on the development of low-carbon and low-energy green homes and ecological urban technologies to ensure environmentally-friendly construction, while also studying techniques to address disasters such as floods, earthquakes, building fires, and events that are related to public safety.

Figure 2.1 Key Technology in Zero energy building

➢ **ETRI(Electronics and Telecommunications Research Institute)**

The major work of ETRI contains the follows:

a) Creation, development and dissemination of knowledge and technology required for the development in the field of information, telecommunications, electronics, broadcasting and related convergence technology

b) Information security and standardization of information, telecommunications, electronics, broadcasting and related convergence technology, training professionals in the field of science and technology

c) Technical consulting and providing technical information for the industry in the field of Information, telecommunications, electronics, broadcasting and related convergence technology

d) Cooperation with domestic and foreign institutions in the field of Information, telecommunications, electronics, broadcasting and related convergence technology

➢ **KIER(Korea Institute of Energy Research)**

Since the founding in 1977, the KIER has had focused on energy technology R&D which is closely related with our living standards and national security while overcoming the challenges we have faced as a resource poor economy.

KIER's R&D areas include improving efficiency and securing environment-friendly way in use of limited conventional energy resources such as oil, coal as well as natural gas and exploring new energy sources such as solar, wind and water as well as its commercialization.

2.2 Research Programs

The three agencies have set several brand-making projects aimed at creating value for nation, society, and citizenry, including low-carbon, zero energy and eco-housing estate, etc. Detail information of these projects is shown in Table 2.1.

Table2.1 Research programs of the three agencies

Project name	Project Leader	Schedule	Budget	Type of Revenue	Keywords
Development of Low/Zero Carbon Green Home	Cho, Dong-Woo	Jul.2009~ Oct. 2012	USD 7 million	Government Funding	Green-home, Low/Zero Carbon, Passive System, High-rise, Apartment
Demonstration of External System of Zero-Energy Residential House	Kang, Jae-Sik	Dec.2008~Oct.2013	USD 9.9 million	Government Funding	Zero-energy, Envelope, VIP, Exterior Insulation, Residential House
Development of Construction Technology of One Day Housing	Lim, Seok-Ho	Jan.2011~Dec. 2011	USD 3.5 million / USD 0.5 million (2011)	Basic Government Funding	Unit Modular, BIM, One Day Housing, 3R (Reuse, Reduce, Recycle) materials.
Technology on Developing Eco-Housing Estate Against Urban Climate Changes	Kim, Hyeon-Soo	Jan.2008~Dec. 2012	USD 1.8 million / USD 0.3 million(2011)	Basic Government Funding	Climate Change, Green Infrastructure, Low Impact Design
Research for Stabilization and Optimization of pH Decrease Technology for Recycled Aggregate	Lee, Sea-Hyun	Mar.2010~Aug.2011	USD 0.2 million	Government Funding	Recycled Aggregate, Alkalinity, Construction Waste
Development of Smart Energy Management System	Pack, Koun-Grow	2010~Mar. 2013			
Passive Solar Integrated Design Aid System	Lee, Euy-Joon	Jan.1998~Dec.1999			
Design Technology of a Super-Low-Energy Office Building	Park, Sang-Dong and Suh, Hang Suk	1994 ~ 1998			

2.2.1 Development of Low/Zero Carbon Green Home

2.2.1.1 Objective

The objective of this project is to build the world-best CO_2-low/zero green home for high-rise apartments by developing the vacuum thermal insulation window and external thermal insulation system and by applying the renewable energy system and energy monitoring management system.

Objectives in 2011

- To achieve Low Carbon Green Home in high-rise apartment buildings
- To reduce heating energy demand by 80% compared to existing apartment houses
- To develop the HEMS-HAN linked green home energy management platform

2.2.1.2 Construction of Zero Carbon Green Home

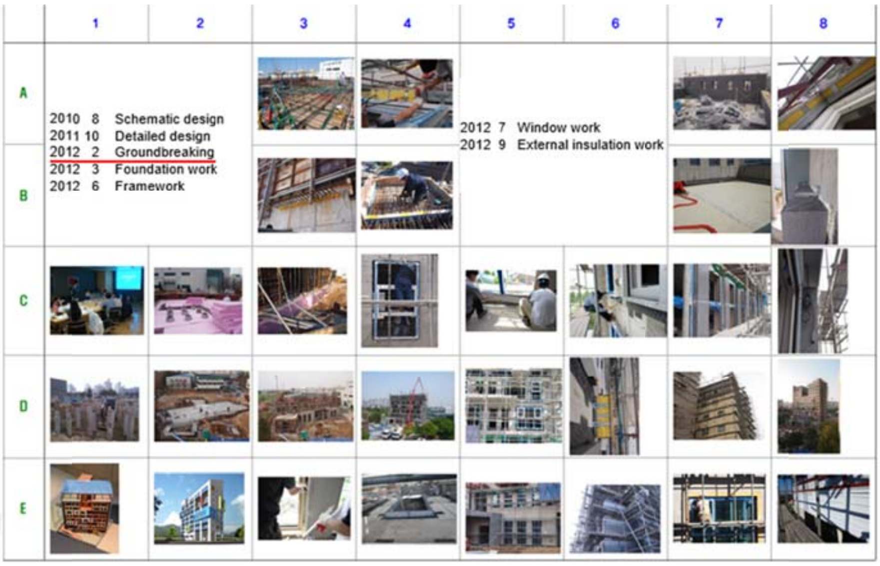

Figure2.2 Construction progress of the ZCGH (a)

Figure2.2 Construction progress of the ZCGH (b)

The construction progress of ZCGH lasts more than one year from February 2012 to March 2013 with a total cost of $3.5 Million. That is to say, the average construction cost of ZCGH is $ 1640 per square meter.

2.2.1.3 Energy Monitoring of Zero Carbon Green Home

The ZCGH energy monitoring system used technologies such as the wall-pad. Researchers can monthly analyze energy consumption, CO_2 emission and costs in each unit, and compare energy consumption between occupant's unit and average of 15 units in building, along with comparison between this monthly data and last year's monthly data and so on.

Figure2.3 Energy monitoring

2.2.1.4 Research Overview and Results

This study aims at developing Low Carbon Green Home technology with a heating energy demand of 15 kWh/p ^{5}year and a primary energy of 120 kWh/p ^{5}year by 2012, and eventually at providing Zero Carbon Green Homes in Korea.

One of the core technologies for Low/Zero Carbon Green Homes is the super insulation wall and window. Super insulation material and high performance external insulation system to be applied to roofs and walls in high-rise apartment buildings have been developed, along with the vacuum insulation glazing and high performance window system (K value of 0.8W/p ^{5}K or less).

The second core technology is the system that can incorporate renewable energy, which will be applied in the form of photovoltaic system and biomass heating system in apartment buildings. Renewable energy technology has been selected to meet the current heating and electric power needs of Low/Zero Carbon Green Homes.

The third one is to develop users' energy management interface technology by monitoring energy and operating to maximize reduction of users' energy consumption in apartment buildings.

With these research results combined, the design draft reflecting passive technology and photovoltaic system was evaluated. This draft predicts at least 80% reduction in heating energy demand and 85% reduction in electric energy use compared to the existing apartment houses. A demonstrative project to verify and monitor energy performance was completed by the end of 2012 in the form of a real 8-story apartment building. These results were contributed to support the government-driving green home supply project, to reduce the heating and cooling cost by over 50% (return on invest around 10 years), to reduce the energy cost by 1 trillion won, to reduce the CO_2 emissions by 2.5 million tons/year based on one million units.

2.2.2 Demonstration of External System of Zero-Energy Residential House

2.2.2.1 Objective

For a zero-energy housing it is important to make an external wall system having high energy efficiency to save energy consumption. This project is to develop materials and components for external walls of zero-energy housing such as IR/UV absorbing films for glazing and vacuum insulation panels, etc. The project has also been conducted as a model project in convergence and integration technologies among industries.

Objectives in 2011:

- Demonstration Project for Zero-energy green home
- Application methods of IR/UV absorbing materials for glazing
- Development of key components of vacuum insulation panels

Figure 2.4 and 2.5 show PAS and Test bed construction.

Figure 2.4 U-value 0.15 W/m2K Panel Approach system (PAS)

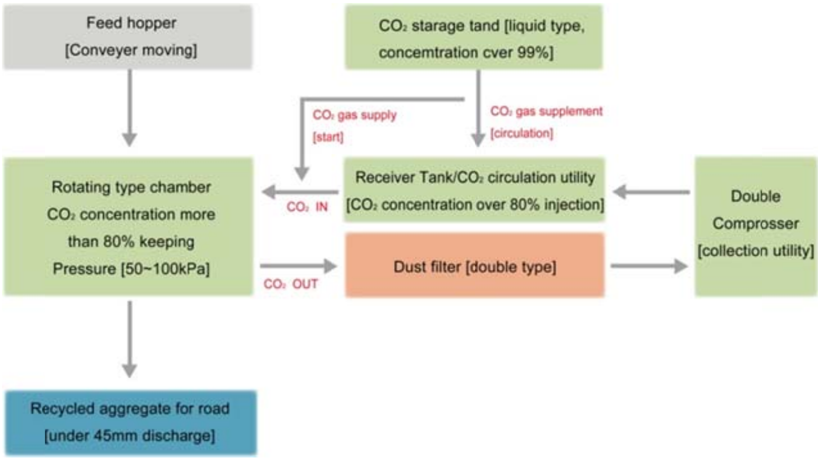

Figure 2.5 Test bed construction process

2.2.2.2 Research Overview and Results

This project is a part of government-supported projects to improve the nation's energy efficiency. It will contribute to reduce energy consumption and CO2 emission by developing; exterior insulation system & vacuum-insulation materials for claddings, light-regulating smart windows. Three sub-projects titled as ‘The exterior module development and the demonstration project for reduction of energy loads’, ‘Development a of IR/UV absorbing advanced materials & Glass coating’ and ‘Development of a strategy and a business model for implementation of architectural vacuum-insulation panels’ have been carrying out, and pilot projects and its' field test are under monitoring.

The expected outputs and products of this project are 'PAS/DIS wall technology', 'SI Door model', 'IR/ UV Absorption prevention material & Mass Production skill', 'Vacuum-Insulation material & Module structure technology', and etc. and they are expecting to be applied to a construction project for multi-story apartment housing.

If the outputs are applied successfully into the housing market, they can save the construction costs by USD 1 billion annually and the national target of 30% reduction of CO2 emission in the building sector will be accomplished by 2030.

2.2.3 Development of Smart Energy Management System

Because of the shortage for energy demand and supply, the ‘smart energy management system’ used to manage energy efficiency of residential and commercial building attracted wide attention. The system is result of the project ‘Development of efficient building energy platform’ and ‘Development of Green Home Energy Management Platform’, which are supported by Ministry of Knowledge Economy and Korea Evaluation Institute of Industrial Technology.

2.2.3.1 Advantage of the technology

Advantage of the technology is that it can manage and monitor large-scale residential areas and realize long-distance control almost building, so as to optimize the power supply.

The technology can be used homely to collect the energy consumption, including temperature of household equipment, humidity, energy consumption of illumination, boiler, air conditioning, and so on. And this provide the conditions for centralized and unified management.

In addition, this technology can be used in the central management and analysis of the many kinds of environmental sensor information as the building energy consumption information, and the temperature, humidity, illumination, online testing and so on. Through the cross analysis of building's energy consumption patterns and weather information, users could provide optimistic service for buildings and hotels.

2.2.3.2 Results

The technology has been widely applied in project COEX and ETRI 12 and manage the energy of the two projects in a long-distance.

In the smart home area, it is also used in the project 'Zero-carbon Green Home' and Sumsung's project.

On the other hand, ETRI has applied 24 patents according to the technology, including

SCI papers and 40 papers. Additionally, ETRI participates in domestic and international

Standards establishment.

(Source: www.etri.re.kr, In Korea)

2.3 Key technologies

Zero energy building technology in Korea shown in Figure 2.6 can be divided into three aspects in general:

- Passive Technology

  External insulation, high performance glazing three layer low-e glass, thermal bridge breaker

- Active Technology

  Solar energy system, ground source heat pump system

- BEMS

Monitor the illumination, cooling, heating power real-time and collect data through measurement. Analyze the preferred control strategy according to the real-time monitoring of gas consumption and renewable energy.

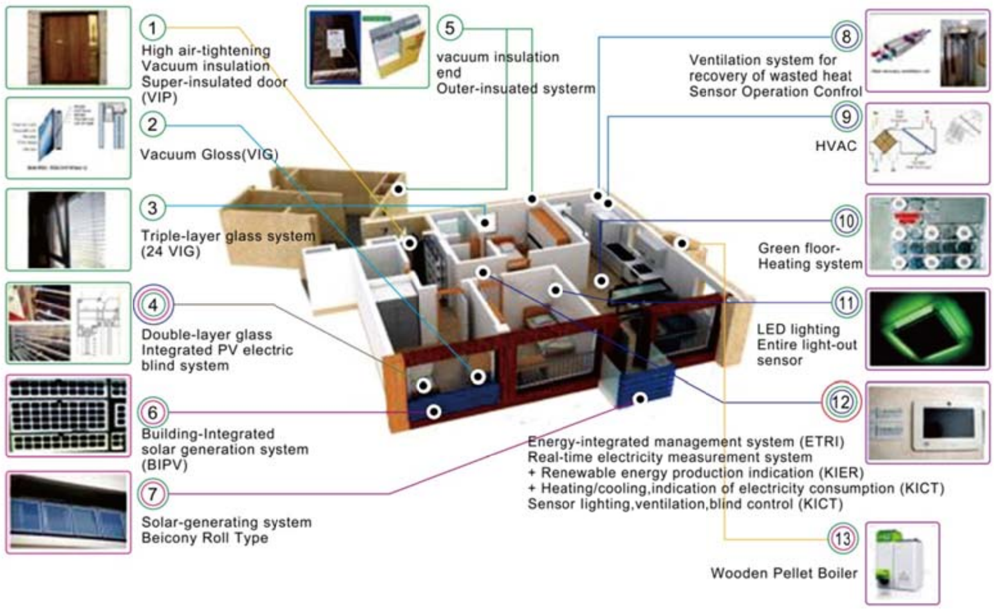

Figure 2.6 Zero energy building technology in Korea

2.4 Conclusion

- Based on the Top-Level Design of ZEB, Korea has formed a national research team including three academies, which are KICT, ETRI and KIER. KICT mainly concentrates on passive construction techniques; ETRI focus on energy management and monitoring technology; KIER mainly does research on new renewable energy supply system technology.
- The three agencies have set eight projects, including building materials technology development, zero energy building town, smart management system and so on, with USD 0.2~9.9 million USD budget for each project.

3. Building Codes and Standards

Building energy codes help ensure that new buildings use energy efficiently, and this can reduce building energy use by 50% or more compared to buildings designed without energy efficiency in mind. This is important because buildings typically last 30-50 years, and it is much less expensive and time-consuming to design for energy efficiency than to retrofit a building later.

3.1 Governing System of Building Energy Conservation in Korea

Korea has established a relatively complete system of building energy standards and specifications by the year 2014, which is shown as Figure 3.1.

Under the leading of Korea's government, MKE (Ministry of Knowledge Economy), cooperating with MLTM (Ministry of Land, Transport and Maritime Affairs),set relevant standards along the different development direction.

For example, Ministry of Knowledge Economy concentrates on 'Rational Energy Utilization Act' while Ministry of Land, Transport and Maritime Affairs makes 'Building Code'. The codes are divided into two connected kinds according to its application objects of existing stock building and new building.

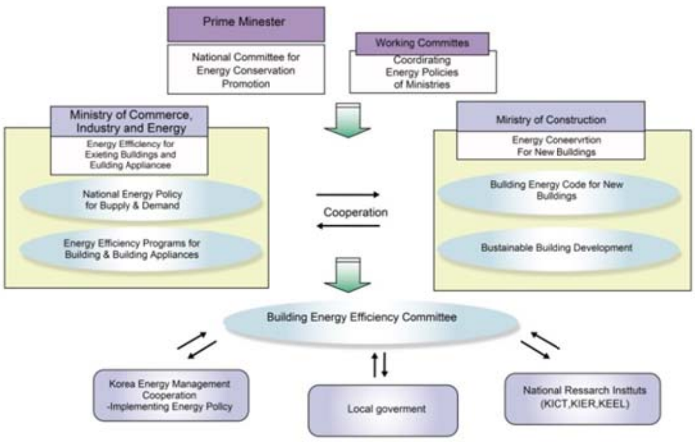

Figure 3.1 System of building energy standards and specifications

Korea has published a series of energy efficiency policies,which are divided into four categories according to its applicable objects.

Table 3.1 Energy efficiency policy in Korea

New buildings	Building energy code (building design criteria for energy saving)
	Building energy certification system
	Green building certification system
Existing stock buildings	Building energy management standard
	Construction guideline of integration calorimeter for APT
	Guideline for energy saving of public institute
Energy use equipments	Energy standards & labeling
	Minimum energy performance standard
	High energy efficiency equipment certification system
	Energy conservation assistance law
	Voluntary agreement (V/A) for existing buildings
	Energy use report system
	Renewable energy obligation system for public institute

3.2 History of the Building Energy Standard

In the oil crisis of the 1970s, Korea government issued the rational national law for energy efficiency and conservation. In 1977, Korea issued its first mandatory building standard on insulation thickness, followed by building energy standards for several types of building in the next two decades. These standards covered offices, hotels, hospitals and residential buildings.

The separate energy standards for respective building types were integrated into the Building Design Criteria for Energy Saving (BDCES) in 2001, which is mandatory for all types of buildings where high energy consumption is expected.

A new clause in the code called "Relaxed Zoning Restrictions on Building Size" also provides further incentives for maximum implementation of energy saving technologies, as is seen in Table 3.2.Buildings exceeding the standards in the code are allowed to be built larger than the standard zoning restrictions would otherwise allow.

Meanwhile, Korea is gradually tightening up design standards. The thermal transmittance criteria has become lower and lower from 1980. The government is promoting high performance building: The thermal performance of windows have been strengthened over 2 times compared to the levels in 2009. The maximum heat transmission of building envelope components will be strengthened in phases.

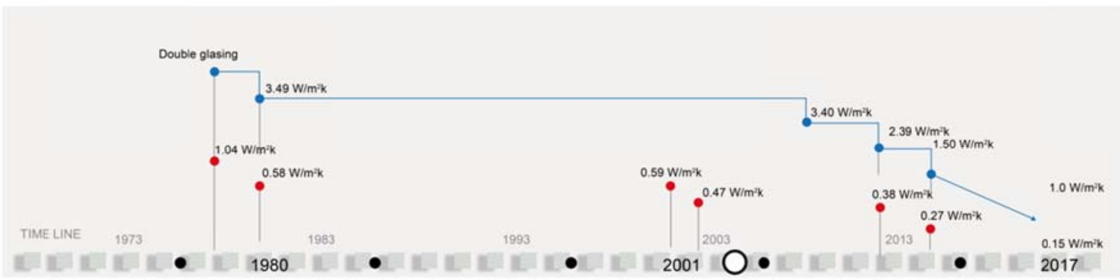

Figure3.2 Historical Transition of Thermal Transmittance Criteria in Korea

Table 3.2 Maximum Heat Transmission (U-factor) of Building Envelope Components by Region

Building Element			Overall Heat Transfer Value		
			Central	South	Jeju Island
Wall	Exposed to the outside air		0.47	0.58	0.76
	Semi-exposed to the outside air		0.64	0.81	1.10
Ground Floor	Exposed To the outside air	Floor heating	0.35	0.41	0.47
		Other than floor heating	0.41	0.47	0.52
	Semi-exposed to the outside air	Floor heating	0.52	0.58	0.64
		Other than floor heating	0.58	0.64	0.76
Roofs over the Top Floor	Exposed to the outside air		0.29	0.35	0.41
	Semi-exposed to the outside air		0.41	0.52	0.58
Side Walls in Multi-family Housing			0.35	0.47	0.58
Middle Floor in Multi-family Units	Floor heating		0.51	0.81	0.81
	Other than floor heating		1.16	1.16	1.16
Windows and Doors	Exposed to the outside air		3.84	4.19	5.23
	Semi-exposed to the outside air		5.47	6.05	7.56

Table3.3 Comparison of the Maximum Heat Transmission

U-Value Climate Area		Wall(W/m^2K)			Roof(W/m^2K)			Floor(W/m^2K)			Window(W/m^2K)		
		Upper	Lower	Jeju	Upper	Lower	Jeju	Upper	Lower	Jeju	Upper	Lower	Jeju
79.09.15~80.12.31		1.05			1.05			1.05			Double glazing		
81.01.01 ~84.03.26		0.58			0.58			1.16			3.49 or Double glazing		
84.03.27 ~87.07.20		0.58		1.16	0.58		1.16	0.58		1.16	3.49 or Double glazing		
87.07.21 ~01.01.16		0.58	0.76	1.16	0.41	0.52	0.76	0.58	0.76	1.16	3.37	3.60	5.81
01.01.17 ~08.07.09	Direct	0.47	0.58	0.76	0.29	0.35	0.41	0.35	0.41	0.34	3.84	4.19	5.23
	Indirect	0.64	0.81	1.10	0.41	0.52	0.58	0.52	0.58	0.64	5.47	6.05	7.56
08.07.10 ~11.01.31	Direct	0.47	0.58	0.76	0.29	0.35	0.41	0.35	0.41	0.46	3.40	3.70	4.40
	Indirect	0.64	0.81	1.10	0.41	0.52	0.58	0.52	0.58	0.64	4.60	5.30	6.30
11.02.01 ~13.10.1	Direct	0.36	0.45	0.58	0.20	0.24	0.29	0.30	0.35	0.35	2.39	2.69	3.40
	Indirect	0.49	0.63	0.85	0.29	0.34	0.41	0.43	0.50	0.50	3.19	3.69	4.30
Present	Direct	0.27	0.34	0.44	0.18	0.22	0.28	0.23	0.28	0.33	1.50 (2.10)	1.80 (2.40)	2.60 (3.00)
	Indirect	0.37	0.48	0/64	0.26	0.31	0.33	0.35	0.40	0.47	2.20 (2.60)	2.50 (3.10)	3.30 (3.80)

3.3 The Latest Standards towards ZNB

3.3.1 Building Design Criteria for Energy Saving (2008)

3.3.1.1 Overview

The BDCES is a prescriptive-based building energy standard. It contains four main sections: "Construction Design," "Machinery Design," "Electric Facility Design" and

"Renewable Energy Facility Design". Each section outlines "mandatory items" and "Recommended items." In addition, there are "Supplementary Rules" mandating that multipurpose buildings be approved for each relevant purpose.

Table 3.4 Essential Features of the BDCES

Section	Description
1. General Information	Purpose,application scope,terminology
2. Energy Saving Design Criteria	Mandatory / Recommended
2.1 Construction part	Heat transmission of building envelope element,Dew condensation prevention and sealing, Layout, Ventilation, Natural lighting, etc
2.2 Machinery part	Design specification & efficiency standard HVAC, Thermostats Ventilation equipment, Sanitation facilities, etc
2.3 Electric Facility part	Electric power supply, Power equipment lighting equipment Control equipment Standby energy loss, etc
2.4 Renewable energy part	Installation of renewable technology
3. Report of energy saving plan	1) General items, 2) Mandatory items, 3)Energy Performance index
4. Supplementary provision	Relaxed zoning restrictions on building size, Supplementary rules

Each section contain both 'mandatory items' and 'recommended items'.

3.3.1.2 Application

The building envelope requirements in the BDCES, such as insulation material standards, are mandatory for all new buildings. More detailed provisions regulate large new buildings6, including:

- Apartment/condominium buildings with over 50 households
- Education/research or office buildings greater than 3,000 square meters
- Hotels/motels and hospitals over 2,000 square meters
- Public bathhouses and swimming pools over 500 square meters
- Wholesale/retail stores (e.g. department stores) with a centralized cooling/heating system and over 3,000 square meters
- Performance halls, town halls and stadiums with total floor area over 10,000 square meters.

3.3.1.3 Implementation

The Ministry of Land, Transport and Maritime Affairs (MLTM) developed the building energy codes. Local government building officials execute the codes as part of the building permitting process for new buildings. The property owner must fill out an energy-saving worksheet and submit it to local governmental offices to obtain a building permit. The worksheet should be signed by three licensed professionals, including an architect, mechanical engineer and electrical engineer. The energy-saving worksheet may be reviewed either by the local office or by KEMCO. However, the local office has the responsibility for approving the energy-saving worksheet (Lee, 2006).

Each building must satisfy all mandatory items and reach at least 60 points for both mandatory and recommend items combined to comply with the standard (PNNL Country Report, 2009).

3.3.2 Building Energy Rating System in Korea

With many years' accumulation of research, MLTM (Ministry of Land, Transport and Maritime Affairs) issued the first edition of building energy certification standards in 2001. MTIE (Ministry of Trade, Industry and Energy) released a new version of building energy certification standard in 2013 (MTIE bulletin 2013-34, 2013.5.20).

Application:

- Applied to apartments(2001~) and office buildings(2010~)
- Applied to residential and non-residential buildings(2013~)
- Mandatory to new apartments and buildings in public sector(2013~)

3.3.2.1 Calculation Method

In the standard the whole building energy consumption needs to be converted into "**primary energy** "to be evaluated. Evaluation is based on the calculated energy requirements- heating, cooling, hot water, lighting, and ventilation.

Calculation method is shown in equation 3.1.

$$source\ energy\ consumption\ per\ unit\ floor\ area = \frac{heating\ energy}{heating\ area} + \frac{cooling\ energy}{cooling\ aera} + \frac{hot\ water\ energy}{hot\ water\ supply\ aera} + \frac{lighting\ energy}{lighting\ aera} + \frac{ventilation\ energy}{ventilation\ aera}$$

Comments:

- Residential building without refrigeration equipment (except public houses as dormitory and single-family detached homes), exclude the refrigeration energy consumption evaluation project.
- Renewable energy production is included in energy efficiency certification evaluation by reflected in energy consumption amount.
- source energy consumption per unit floor area=energy consumption per unit floor area ×Primary energy conversion ratio

Primary energy conversion ratio in Korea is shown in Table 3.5:

Table3.5 Primary energy conversion ratio in Korea

	Primary energy conversion ratio
Fuel	1.1
Electric	2.75
Area Heating	0.728
Area Cooling	0.937

3.3.2.2 Rating Grade

Annual primary energy requirements per area of each grade are shown in Table 3.6.

Table 3.6 Rating Grade

Grade	Annual primary energy requirements per area (kWh/m^{2}year)	
	Residential	Non-residential
1+++	~ 60	~ 80
1++	60 ~ 90	80 ~ 140
1+	90 ~ 120	140 ~ 200
1	120 ~ 150	200 ~ 260
2	150 ~ 190	260 ~ 320
3	190 ~ 230	320 ~ 380
4	230 ~ 270	380 ~ 450
5	270 ~ 320	450 ~ 520
6	320 ~ 370	520 ~ 610
7	370 ~ 420	610 ~ 700

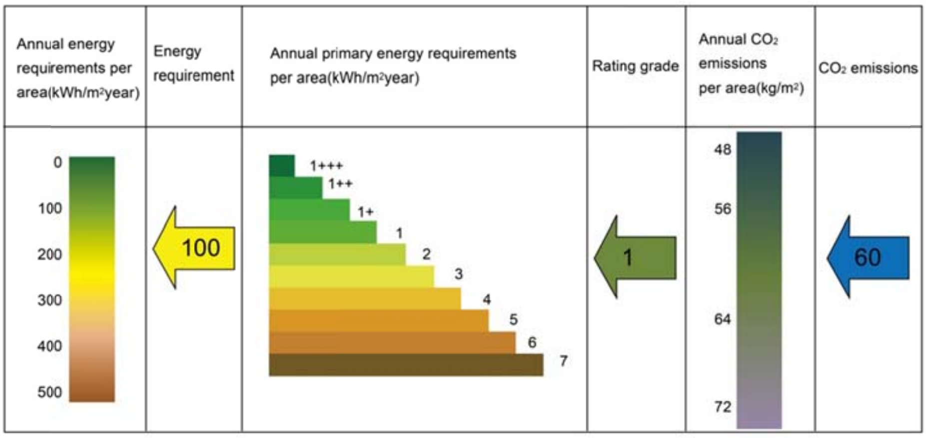

Figure 3.3 Building Energy Rating system

Under the existing certification system. When a building's energy consumption rate reach to Grade 1 or higher, it belongs to zero energy building.

3.4 Direction of Future Development

Korea also developed other related standards, such as "Supportive Code of Green Building", "Public Authority Energy Rationalization Promotion Regulation" and "Building Energy Saving Design Standard" and so on.

The Korea government will strengthen energy efficiency standards to match passive house level minimizing household energy consumption with **high-tech thermal insulation techniques.** Meanwhile, Korea government plans to continue to distribute

high efficient equipment, LED lamps and renewable energy system through various energy saving policies. All newly constructed houses after 2017 should reduce heating and cooling energy use by 90%; in addition, the Korea government has established the goal of a zero-energy house level design for 2025.

The government has also launched policies to promote energy efficiency in existing buildings.

In 2007, the government mandated that energy audits should be conducted every five years for buildings where annual energy use is over 2 thousand tons of oil equivalent (ktoe). Buildings deemed energy efficient under the voluntary Korean Energy Efficiency Rating can be exempted from this requirement (IEA, 2006).

In the future, it is expected that the government will likely adopt a performance-based building energy code which will limit energy use per unit area in new buildings, and set higher insulation standards over time (Lee, 2006).

3.5 Conclusion

- Korea had already set up a completely management system of building energy efficiency, with the close cooperation of several ministries and local governments.
- Building energy saving standards is gradually strengthened from 2011. The heat transmission requirement of building envelope components now is 25% as of the beginning.
- Under the existing building energy efficiency certification standard, energy consumption of the zero energy building is not equal to net zero, but nearly zero. When a building's energy consumption rate reaches up to Grade 1 or higher according to the building energy certification standard, it is considered as zero energy building.

4. Demonstration Projects

In order to achieve the national goal of greenhouse gas reduction and active the market of zero energy building, Korea government develops several pilot projects. The most representative three will be introduced below.

4.1 Zero Carbon Green Home Project

4.1.1 Project introduction

The ZCGH(Zero Carbon Green Home) is built in early 2013 within KICT (Korea Institute of Civil Engineering and Building Technology), which is located in the northern suburbs of Seoul, with the aim to reduce heating energy by more than 80% and electricity energy by more than 85%.

The ZCGH building has an increased construction cost of less than 20% compared with conventional residential buildings and its payback period is expected to be around 10 years. For passive technology, it applied high performance windows and an external insulation system; and for active technology, heat recovery ventilation system, and renewable energy technology such as rooftop photovoltaic system and a pellet boiler.

The environmental aspect of ZCGH is considered as well as design techniques with long life expectancy and reusable materials are applied.

Figure 4.1 Zero Carbon Green Home

4.1.2 Design of ZCGH

The ZCGH building is eight stories high and houses 15 households, which can be categorized in four types based on the standard household area of 84 m^2. The mean WWR (window to wall area ratio) of the ZCGH building was designed to be 40%.

Figure 4.2 shows the typical floor plan for zoning of thermally separated spaces of the ZCGH building. For the households' heating space, an exterior insulation system is used, and the heating is not provided in the elevator hall and in the staircase room. Unheated spaces are separated with expansion joints from heated spaces. On the exterior surfaces of the windows, in order to block the insolation, electrically operated exterior blind system is installed.

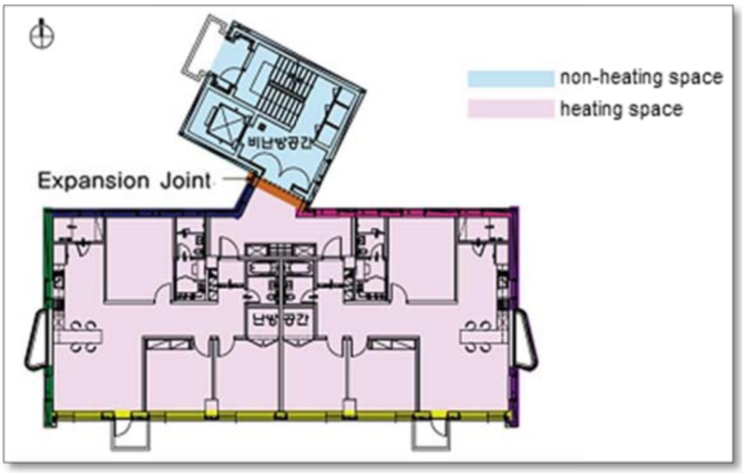

Figure 4.2 Plan for Zoning of thermally separated spaces

Analysis for energy-efficient elevation design including orientation, window area ratio, overhang, cross-ventilation, thermal bridge, mass forms and so on.

For the insulation, the thermal transmission coefficient is lower than 0.15 W/ m^2K, which is 3 times improved compared to that of conventional apartments; and for the windows, it is 0.80~1.0 W/m^2K, around 2.5 times improved. The heat recovery ventilation system has 81% efficiency with a fan power of 0.45 kWh/m^2.

The installed photovoltaic system, shown in Figure 4.3, has a capacity of 36 kWp, with 120 solar modules of 300 Wp each. The installed rooftop area takes up 204.3 m^2, with an expected annual power generation of 45,000 kWh. It is expected to save 85% of power on those 15 households, with 3,000 kWh/year saved per household.

Figure 4.3 ZCGH photovoltaic panel

4.1.3 Energy analysis of ZCGH

- Heating energy supply amount analysis

For the heating energy analysis during the winter, the amount of heating energy consumption of six households in Case 1 was measured for the month of January, 2014, as shown in Figure

4.4.

Figure 4.4 Heating energy use of each unit

Based on the hot water consumption amount for one month to each of the households, it was calculated the per unit area per households. The mean monthly per unit area heating energy consumption amount induced for each household was 4.38 kWh/m^2·month. Depending on the size and location of the households, there was a difference in the heating energy consumption. Unit 302 consumed more energy than the other households, though it has the least area, with energy consumption of 5.88 kWh/m^2·month. Units 701 and 802, which have more exposed area than other units, are found to have used somewhat higher level of heating energy, relatively.

- Used pellet amount analysis result

The comparison of ZCGH energy consumption amount with that of conventional apartment is shown in Table 4.1.

Table 4.1 Energy consumption comparison with conventional multi-housing buildings

Division	Energy consumption (kWh/year)	Heating cost (KRW/unit·year)	Notes
Conventional apartments	9,088	632,000	Gas(LNG) boiler
ZCGH	1,884	126,000	Pellet boiler (heating period)
Annual reduction	7,204	506,000	80% reduction

In order to conduct a heating energy consumption analysis of ZCGH, the amount of pellets consumed was measured during the previously conducted measuring period. For the measured one-month period, the pellet use was about 1,800 kg, when the used energy amount was 9,419 kWh, and the mean unit area energy consumption amount of 15 households was 10.4 kWh/m^2·month.

This means that, during the winter heating period from December through February, each of the households of the demonstration home uses 1,884 kWh/year (360 kg/year). About 80% of the annual energy consumption amount (9,088 kWh) of a conventional apartment was saved.

- Photovoltaic electricity generation analysis

As shown in Figure4.5, the electricity generated by the photovoltaic system of ZCGH was measured for a year from January, 2013 -2014.

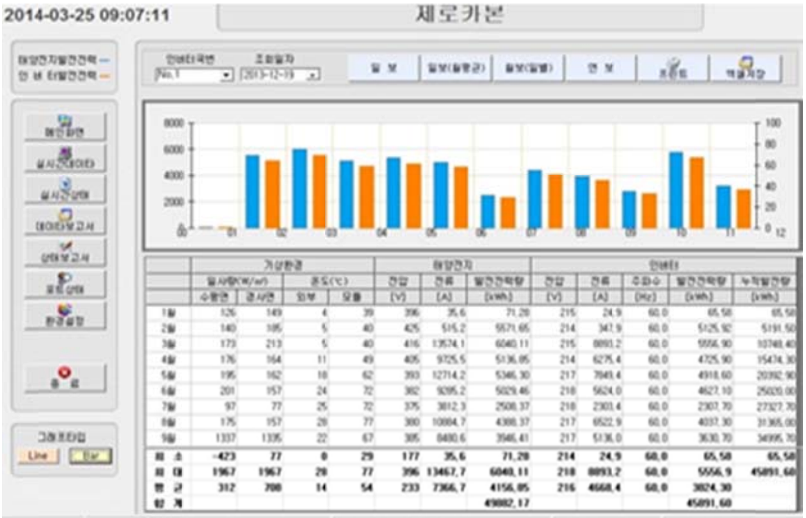

Figure 4.5 Electricity Generated by PV System

The total electricity amount generated was about 50,000 kWh; and the final electricity amount, considering the 8% energy loss from the inverter, was about 46,000 kWh. The monthly mean amount generated was about 5,500 kWh, with the maximum amount in March and a relatively lower amount during the summer rainy season. This is equivalent to 255 kWh of power generated per month per household, which is about 85% of the one-month use of conventional apartments (300 kWh), allowing a saving of more than 90% of the monthly electricity bill .

4.1.4 Economy analysis of ZCGH

The comparison of ZCGH heating cost and electricity cost with that of conventional apartment is shown in Table 4.2. Monthly electricity cost is increasingly reduced gradual promotion system of advance rise step by step in Korea.

8-story (15 units) ZCGH saves 80% of heating costs, over 90% of electricity costs and 85% of total cost compared to conventional apartments.

Table 4.2 Heating and electricity cost comparison with conventional multi-housing buildings a year

Division	Heating cost (KRW/ unit·year)	Electricity cost (KRW/unit·year)	Total cost
Conventional apartments	632,000	530,000	1,162,000
ZCGH	126,000	48,000	174,000
Annual reduction (saving ratio)	506,000 (80%)	482,000 (91%)	988,000 (85%)

Around 80% of heating energy was saved compared to those of existing apartments by applying passive technologies, and around 85% of electric energy was saved by applying PV system.

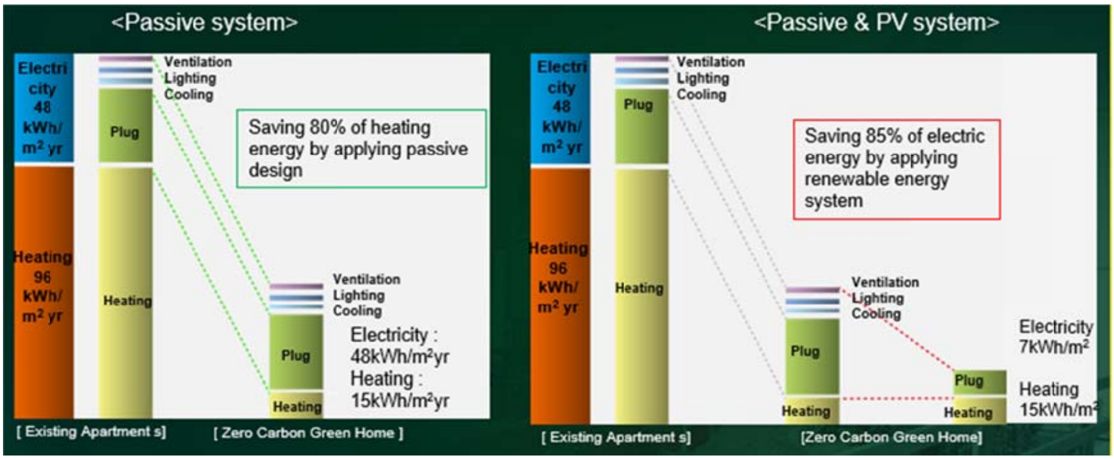

Figure 4.6 Energy Saving of Zero Carbon Green Home

4.1.5 Conclusion

Zero Carbon Green Home was established successfully with the integration of Passive System and Renewable Energy Systems.

"Zero Carbon Green Home" project minimizes energy loss, develops passive core technologies, maximizes energy supplies through renewable energy systems and optimizes the management of a Zero Carbon Green Home. It verifies the performance of core technology applied through energy monitoring and evaluation in a Zero Carbon Green Home occupied under normal conditions. In addition, this project will present a Green Home prototype that provides a strong social and economic rationale for use as well as provides a means to disseminate related technologies.

In summer, with the use of external blinds and cross ventilation, in addition to the highly-insulated building envelope, the indoor temperature can be reduced.

In winter, high performance windows and highly-insulated walls resulted in minimum heat loss, showing stable indoor air and floor temperature of 20℃.

ZCGH saves 80% on heating, and 85% on electricity compared to conventional apartments.

4.2 Green Tomorrow

4.2.1 Project introduction

Located in Giheung area 1026-1, Yongin, Gyeonggi Province, the Samsung Green Tomorrow house is a zero energy house that is meant to showcase a wide array of state-of-the-art green building strategies. The construction was from January 2009 to October 2009, and the 676 sq. meters building includes two parts, with a 276 sq. meters PR Room and a 400 sq. m Display Room .In September 29, 2009, Green Tomorrow achieved the first LEED Platinum rating for any building East Asia.

Fiure 4.7 Overhead view of Green Tomorrow

"Green Tomorrow" is one of the long-term commitments to making the world a better, sustainable place to live by minimizing the burden on nature while taking into full account of human convenience. Figure4.8 shows the building appearance and the inner design.

Figure 4.8 The appearance and the inner design

4.2.2 Energy Efficient Technology

Green Tomorrow is not just for showing the concept of green superficially. It is the practical residential building which has integrated diverse sustainable design strategies.

It mainly includes the three points:

Table 4.3 Energy Conservation Measures

Zero energy	Zero emission	Green IT
Maintaining the overall annual energy balance '0' or '+'	Maintaining the lifecycle CO2 with '0'	Optimizing an IT technology based on sustainable energy, and providing convenience
Passive design	Sustainable materials	Energy Management System
Active design	Water efficiency	Home Network
New and renewable energy	Waste reduction and recycling	RFID Based Technology

As a collection of 68 energy efficiency technologies, Green Tomorrow will become a Zero Energy Building combined with zero energy consumption, zero carbon dioxide emissions and network technology in the future. Meanwhile, with the continuous upgrading technology, the environment-close building could advance automatically.

Figure 4.9 The fuel induction solar cell and roof greening

Among the home's innovative technologies are a sophisticated energy distribution system that communicates with the grid, a high-performance facade that reduces energy consumption, daylight sensors, heat pumps, radiant floor heating, high-efficiency lighting and 163 square meters of rooftop photovoltaic panels.

The building also contains all other green building strategies such as dual flush toilets, waterless urinals and a grey water system that reduces water consumption. Low-VOC materials and improved ventilation rates ensure a healthy interior.

- **Interior Design of Green Tomorrow**

Integrated with green technologies, follows its overall sustainable design concept. Well maintained natural elements in the exterior are permeated in interior space. Reused, recycled, rapidly renewable, and low-emitting materials were used for interior materials, furniture, and interior accessories of Green Tomorrow, under the sustainable design concept, "Again and

Again."

Figure 4.10 Green Interior Design

➢ **Retrofit Design**

Retrofit Design is a design technique that brings retrofit technology into public application for easy maintenance and replacement of Architectural, Mechanical & Electrical equipment and components during operation.

Figure 4.11 Retrofit Design

➢ **Phase Change Material Cooling Sheet**

Phase Change Material is a functional material which is able to use latent energy while the material changes its phase from liquid to solid and to liquid. It absorbs heat when the room temperature is over the setting temperature(26℃), and it emits stored heat when room temperature is under the setting temperature to maintain the constant room temperature.

Figure 4.12 Phase Change Material
(Source: http://www.greentomorrow.co.kr/)

4.3 Seoul Energy Dream Center

As Korea's first and largest energy autonomous building, the Seoul Energy Dream Center aims to teach the importance of energy conservation and sustainability through various programs and experiences.

Figure 4.13 Seoul Energy Dream Center exterior

Figure 4.14 Seoul Energy Dream Center -2zone

The Seoul Energy Dream Center has been designed to reduce the average energy consumption by 70%. The remaining 30% comes from renewable energy sources, such as sunlight and geothermal heat. Operated independently from the electric power grid, the facility is the nation's first and largest energy autonomous building.

- Sunlight: The building harnesses solar energy through its 624 rooftop solar panels and 240 panels in the front. The surplus energy from the panels are sold to the Korea Electric Power Corporation (KEPCO).

- Geothermal heat: Geothermal power is extracted through 37 wells dug 50m deep. Consistent temperature range of 10~20 degrees Celsius year round provides heating in the winter and cooling during the summer.

- The overall slick design of the building reflects up to 60% of the sunlight.

4.4 Conclusion

- Pilot project is an important action to promote ZEB of Korea. The leading research institutes and large enterprises with social responsibility has achieved successive demonstration effect in the small-scale, high-rise residential buildings and exhibition buildings.
- Technologies used in ZEB to realize zero energy building mainly consists of three parts: Passive technology (high performance windows and an external insulation system); Active technology (heat recovery ventilation system, renewable energy technology); and Energy Monitoring and Management system (BEMS).
- The pilot project can reduce the average energy consumption by 70~85% compared to existing buildings. The remaining 20~30% could come from renewable energy sources, such as solar energy and geothermal heat.

5. Conclusion

1. Due to its limited domestic energy resources, Korea had accomplished the Top-Level Design from the central government of research and development， extension and marketization of Zero Energy Building. On July 17, 2014, Ministry of Land, Infrastructure and Transport, cooperating with other six Ministries, issued The Activation Plan of ZEB Corresponding to Climate Change to achieve the goal of mandatory NZE design of all new buildings by 2025. In the plan, work distribution and step by step plan is determined. The plan also made clear financial policy and project subsidy support of ZEB, which could completely afford the incremental cost of ZEB.

2. ZEB in Korea is defined very clearly as ‘A building that maximizes thermal insulation performance to minimize energy consumption, and uses renewable energies to provide energy self-sufficiently’. Under the current technology level, three kinds of pilot projects will be demonstrated gradually, including ‘Low-rise ZEB’, ‘High-rise ZEB’ and ‘ZEB Town’.

3. According to the Top-Level Design of ZEB, Korea has formed a national research team including three agencies, which are KICT, ETRI and KIER. KICT mainly concentrates on passive construction techniques; ETRI focus on energy management and monitoring technology; KIER mainly does research on new renewable energy supply system technology. The three agencies have set eight R&D projects, including building materials technology development, zero energy building town, smart management system and so on, with USD 0.2~9.9 million USD budget for each project.

4. Building energy standards is gradually upgrading. The heat transmission requirement of building envelope components now is 75% energy efficiency as of the beginning. Under the existing building energy efficiency certification standard, energy consumption of the zero energy building is not equal to net zero, but nearly zero. When a building’s energy consumption reaches up to Grade 1 or higher according to the building energy certification standard, it could be certified as zero energy building.

5. Demonstration project successfully accomplished by the leading research institutes and large enterprises with social responsibility had achieved great social-economy-environment effect in the small-scale, high-rise residential buildings and exhibition buildings, which could reduce the average energy consumption by 70~85% compared to existing buildings. The remaining 20~30% could come from renewable energy sources, such as solar energy and geothermal heat. Technologies used in ZEB to realize zero energy building could be category into three parts: Passive technology (high performance windows and an exterior insulation system); Active technology (heat recovery ventilation system, renewable energy technology); Energy Monitoring and Management system.

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SECTION V THE UNITED STATES

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1. Policy , Objective, Definition

1.1 Building energy status in the US

As the world's largest economy, the U.S.'s energy consumption decreased by 2% to 97.8 quads between 2008 and 2010. Meanwhile, the U.S.'s carbon dioxide emissions decreased 3% over the same period. According to *2011 Building Energy Data Book* (2012), energy the U.S. consumed in 2010 represented 19% of global consumption— following China, became the second largest share of world energy consumption by any economy.

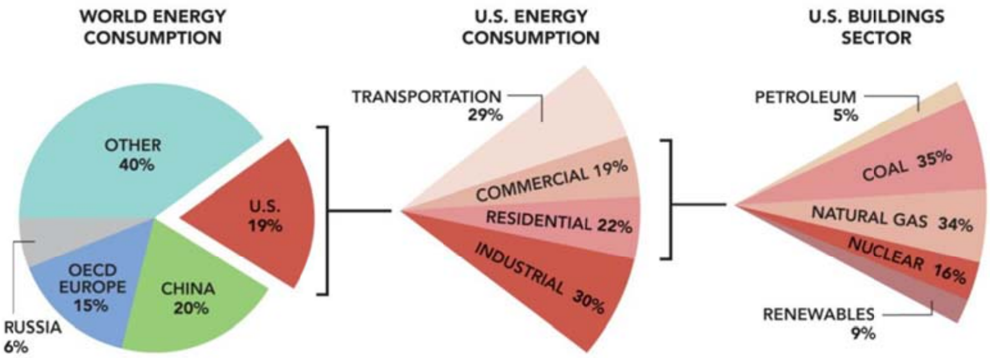


Figure1.1 Energy consumption in existing building

Among the various parts of energy consumption, according to *2011 DOE Energy Building Data Book (2012)*, 41% of U.S. primary energy was consumed by the buildings sector, compared to 30% by the industrial sector and 29% by the transportation sector. Of the 39 quads consumed in the buildings sector in 2010, homes accounted for 54% and commercial buildings accounted for 46%, as is shown in Figure 1.1. Of the energy sources used by the U.S. buildings sector, 75% came from fossil fuels, 16% from nuclear generation, and 9% from renewables.

U.S. buildings have come to represent an increasing portion of the economy's carbon dioxide emissions—40% in 2009, compared to 33% in 1980; yet, the fast growth rate of global emissions means that emissions from U.S. buildings have become a declining percentage of the global total—8.5% in 1980, compared to 7.1% in 2009. Driven by economic expansion and population growth that require more and more facility space each year, energy use in the US commercial sector is expected to grow by 1.6% per year. This is resulting in an energy impact that is increasing faster than all of the energy conservation measures being taken and retrofits being made to buildings.

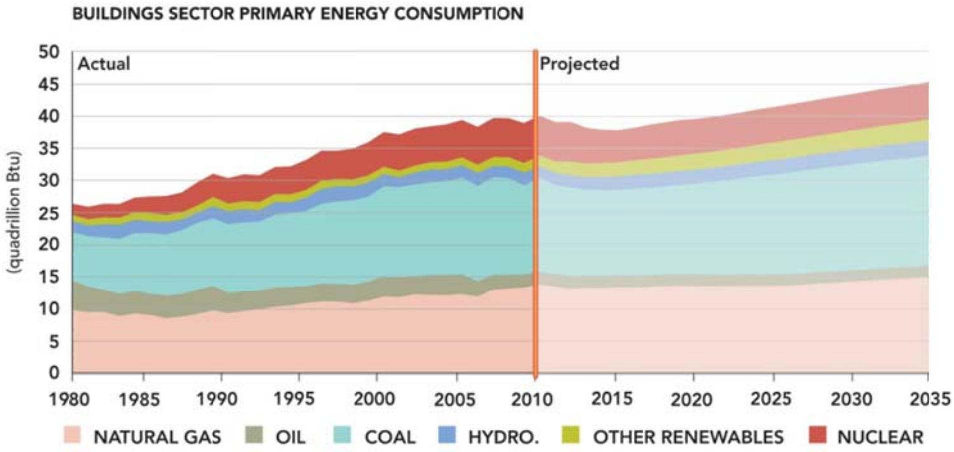


Figure1.2 Buildings sector primary energy consumption

Space heating, space cooling, and lighting were the dominant end uses in 2010, accounting for close to half (49%) of all energy consumed by the buildings sector. Primary energy consumption in the residential sector increased 24% from 1990 to 2009. Commercial floor space and primary energy consumption grew by 58% and 69%, respectively, between 1980 and 2009. Energy Information Administration (EIA) projects that this growth will stagnate due to the recession until 2016, as is shown in Figure 1.2, steady growth is predicted through 2035. Total primary energy consumption is expected to reach more than 45 quads by 2035, a 17% increase over 2009 levels, with a 13% increase in residential sector and a 22% increase in commercial sector. This growth in buildings sector energy consumption is fueled primarily by the growth in population, households, and commercial floor space, which are expected to increase 27%, 31%, and 28%, respectively.

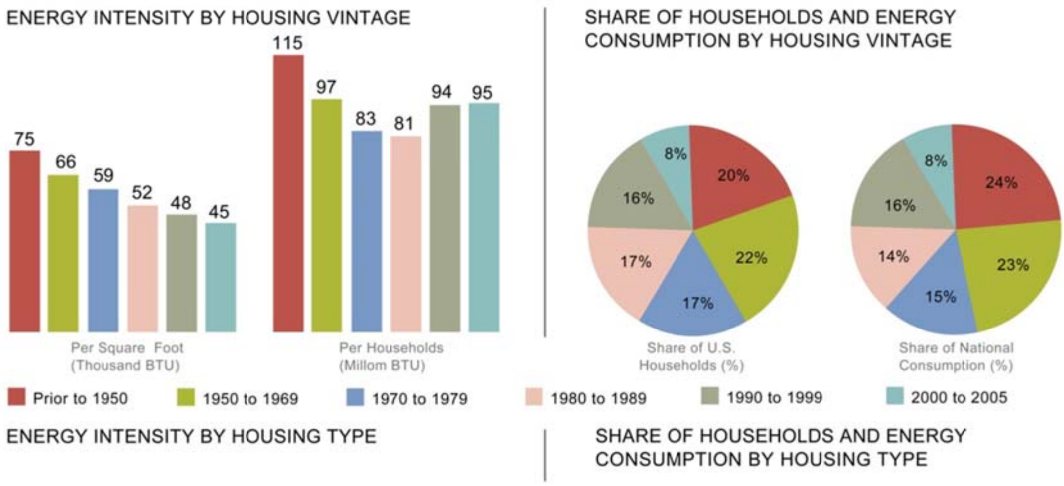


Figure1.3 Energy intensity in residential buildings

Since the energy consumption of building cause more and more attention, for now, Net Zero Energy Building (NZEB) is starting in rapid developing stage.

1.2 Federal Buildings

The Federal government owns approximately 445,000 buildings with total floor space of over

3.0 billion square feet, in addition to leasing an additional 57,000 buildings comprising 374 million square feet of floor space. These structures and their sites affect our natural environment, our economy, and the productivity and health of the workers and visitors that use these buildings[1].

With the goal of achieving zero-net-energy, the federal government enacted the Executive Order 13514. Executive Order 13514 (NARA, 2007) is an executive order titled Federal Leadership in Environmental, Energy, and Economic Performance that U.S. President Barack Obama issued on October 5, 2009.

"Zero-net-energy building" is defined in Executive Order 13514 as "**a building that is designed, constructed, and operated to require a greatly reduced quantity of energy to operate, meet the balance of energy needs from sources of energy that do not produce greenhouse gases, and therefore result in no net emissions of greenhouse gases and be economically viable**".

This executive order mandates federal buildings and leases to meet Energy Efficiency Guiding Principles. The timeline and means for achieving the stated goal of zero-net-energy federal buildings can be summarized as follows:

- As of 2020, all planning for new Federal buildings requires design specifications that achieve Zero-Net-Energy use by 2030.
- Zero-Net-Energy goals are to be incorporated into the process of buying or leasing new government properties.
- At least 15% of existing federal buildings and leases need to meet the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* by 2015[2].

1.3 Commercial and residential buildings

The Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL) have developed extensive resources and conducted wide-ranging research on energy efficiency, renewable energy technologies and the development of net zero energy commercial and residential buildings (Hootman T, 2012). Its Office of Energy Efficiency &Renewable Energy (EERE), leads the U.S. Department of Energy's efforts to develop and deliver market-driven solutions for energy-saving homes, buildings, and manufacturing; sustainable transportation; and renewable electricity generation. The program that funded by DOE make great contribution to zero energy building, which could be find in Figure 1.4.

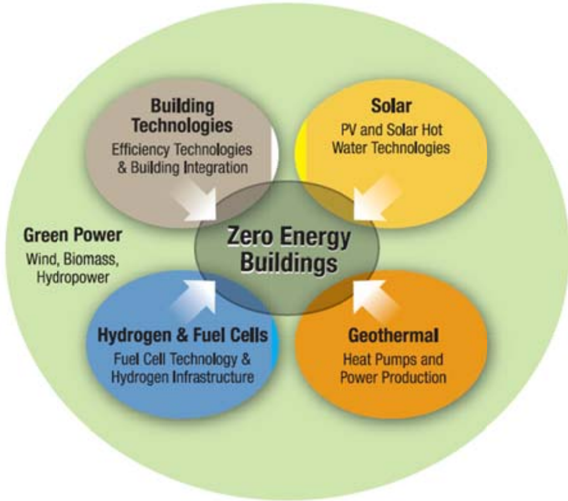


Figure1.4 EERE Programs Contributing to ZEB
Source: National Energy Policy Development Group, National Energy Policy, May 2001.

President Bush's National Energy Policy (NEP) in 2001 calls for "reliable, affordable, and environmentally sound energy for America's future." In order to achieve this vision, the President's plan has defined several objectives including increasing energy conservation, relieving congestion on the Nation's electricity transmission and distribution systems, and establishing energy efficiency and environmental protection as national priorities (NEPDG, 2001).The implementation of the President's NEP is a top priority for EERE which plays a critical role in achieving the NEP's goals of improving the energy efficiency of residential and commercial buildings as well as improving the energy-consuming equipment in these buildings, which could be find in Figure 1.5. Building Technologies Program Structure and Building Technologies Strategic Goal could be find in Figure 1.6 and 1.7.

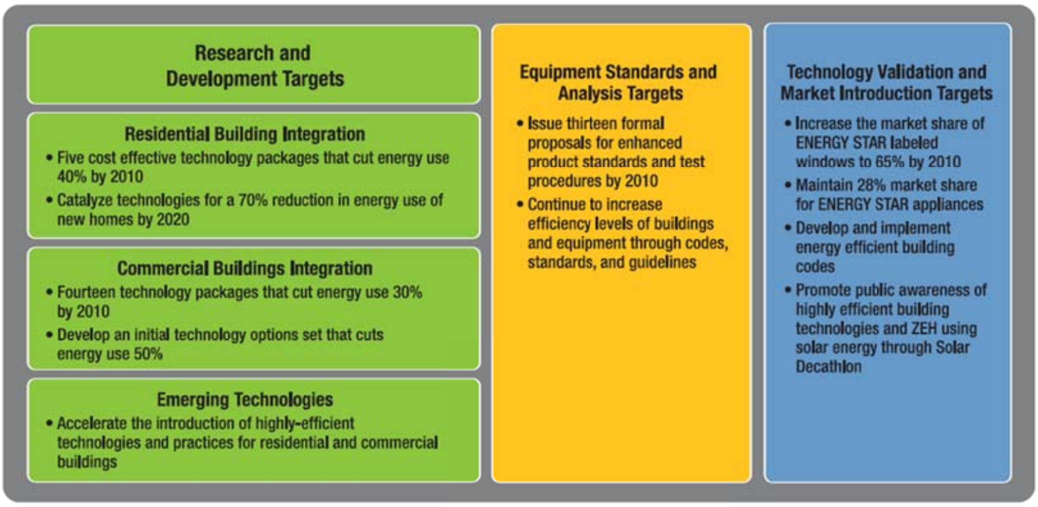
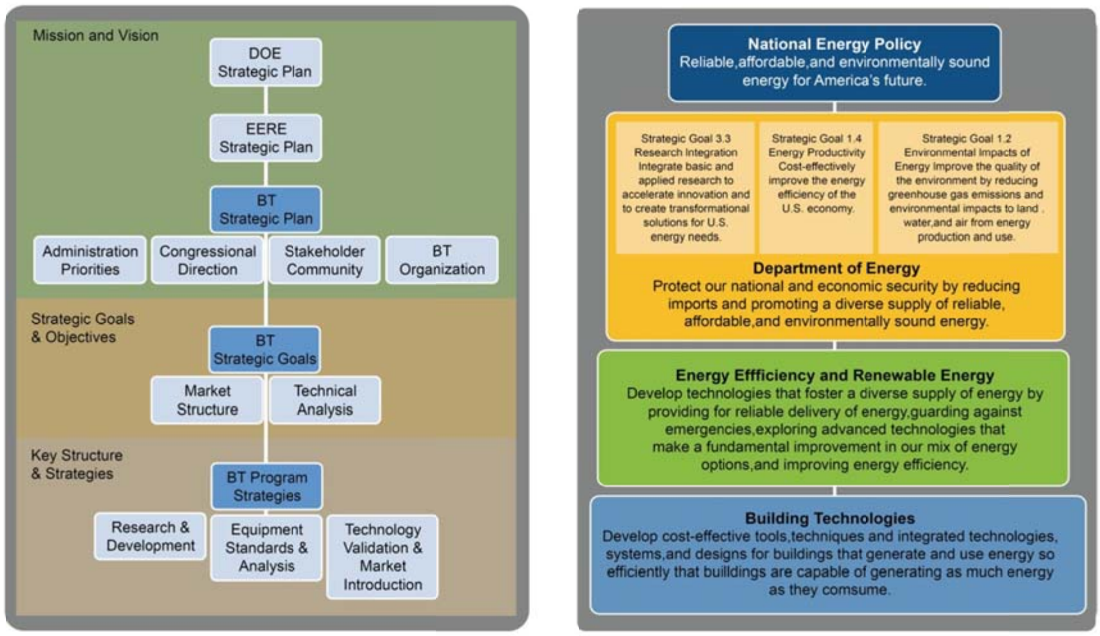


Figure1.5 Research and Development Target



l Cascade

The objectives align with the **Energy Independence and Security Act of 2007 (EISA 2007)**, which authorizes DOE to host industry-led Commercial Building Energy Alliances and to establish the Net-Zero Energy Commercial Building Initiative, included establishing specific goals that calls for (Cassidy R, Schneider J W, 2011) ：

- Net zero energy use in all new commercial buildings constructed by 2030
- Net zero energy use in 50% of the United State commercial building stock by 2040
- Net zero energy use in the entire United States commercial building stock by 2050

Two milestones for NZEB have also been defined by the DOE for residential and commercial buildings. The priority is to create systems integration solutions that will enable:

- **Marketable Net Zero Energy Homes （NZEH）by the year 2020**

--Building America Program, to develop net zero energy homes that consume at 50% to 70% less energy than conventional homes.

- **Commercial Net Zero Energy Buildings （NZEB）at low incremental cost by the year 2025**

--Aims to achieve marketable net zero energy buildings by 2025 through an array of public and private partnerships to advance the development and adoption of high performance buildings.

With this technological support, DOE further announced a serious of webinars on marketing and sales solutions for zero energy ready homes, building stronger more efficient homes, Energy Free Home Challenge (EFHC) and more.

The **Energy Free Home Challenge (EFHC)** is opened to teams around the world in 2010[4]. This green building competition will encourage both design innovation and cost reduction, by requiring design entries to meet 'zero net energy' and 'zero net cost' criteria. The purposes of this competition can be concluded as follows (Al-Beaini, 2010):

- **A 'zero net energy' home** produces at least as much energy as it purchases over the course of a year, regardless of the time and form of the energy consumed or produced.
- **A 'zero net cost' home** is no more expensive than a traditional home of comparable size and comfort, must have a payback period less than 30 years.

The overarching goal of the competition is to develop affordable, high- performance homes that can be mass-produced at a large scale, and are able to meet occupant needs in harsh climate[3].

1.4 California Zero Net Energy buildings

California has long been a leader in efforts to improve building energy efficiency, both at the time of construction and upon a major remodel or equipment replacement. Efforts have included advanced building codes and appliance standards, a wide variety of incentive programs, design and installation training, and public outreach. California's per capita energy consumption is among the lowest in the economy and has remained relatively constant since 1974, in sharp contrast to the rest of the economy.

California's residential sector relies most heavily on natural gas for energy. To further decrease building energy consumption and promote the penetration of **Zero-Net-Energy** (ZNE) buildings, California government has release and adopted a series of policies on ZNE buildings.

California has a policy goal of achieving **zero-net-energy building** standards by 2020 for low-rise residential buildings and by 2030 for commercial buildings.

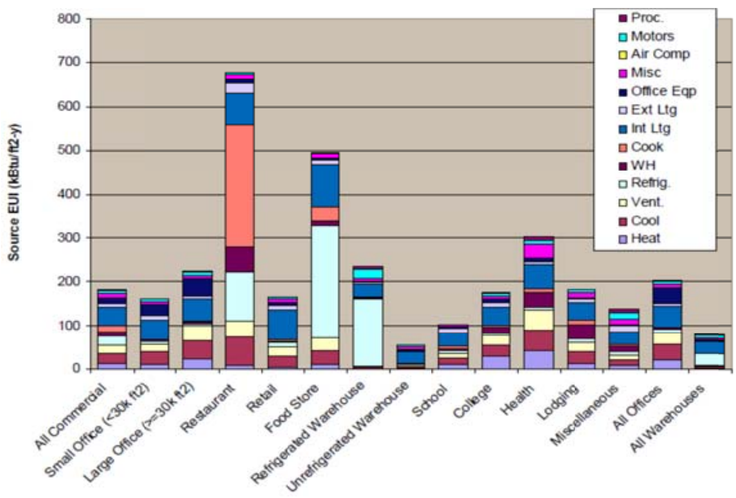


Figure1.8 California buildings site energy consumption by end use
Source: CEUS, AEC

CA Executive Order B-18-12 was signed by Governor Brown in April of 2012, it calls for all new state buildings and major renovations to reach the targets (CEC, 2013):

1) Any proposed new or major renovation of State buildings larger than 10,000 square feet use clean, on site power generation
2) 50% of new facilities beginning design after 2020 to be Zero Net Energy.
3) 100% of new State buildings & major renovations beginning design after 2025 to be Zero

Net Energy

Additionally, new buildings or major renovations larger than 10,000 square feet must earn the "Silver" level of LEED certification and incorporate on-site renewable energy if economically feasible.

As part of this planning approach, the California Public Utilities Commission (CPUC) has used the following conceptual diagram depicted in Figure1.9 which represents the diffusion of the zero net energy concepts across the market.

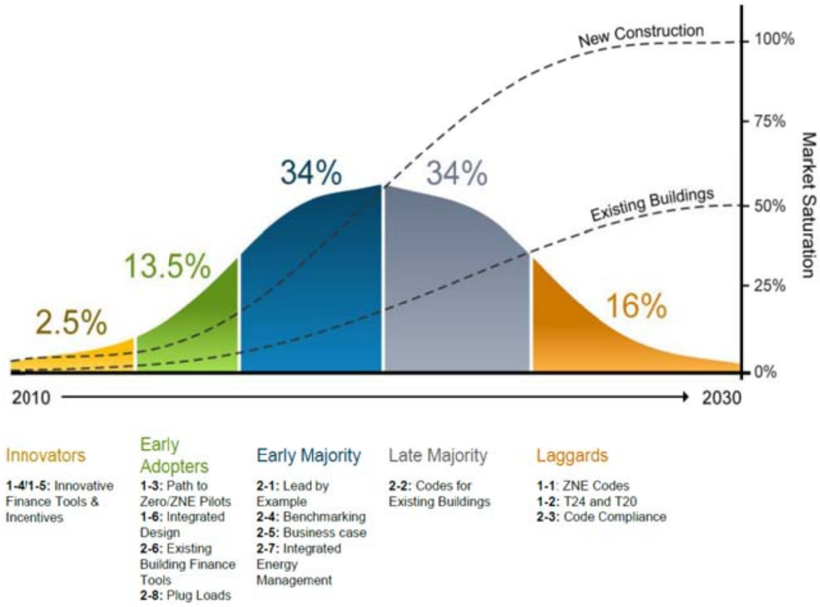


Figure1.9 Conceptual Market Diffusion for Zero Net Energy Targets

Source: Net Zero by 2030

As major building owners and managers of public building portfolios, state and local governments can lead by example by becoming early adopters of advanced technologies and energy management practices. Indeed, the relatively high number of public ZEBs indicates the level of public sector commitment and market-leading capacity. Demonstration projects, public procurement policies, and public facility management practices can prove performance, generate a body of data, enhance industry capacity, and provide education and awareness-raising opportunities.

The goal of 50 percent of existing buildings achieving ZNE by 2030 is significantly more challenging than achieving 100 percent ZNE in new construction. A study conducted for the U.S. Department of Energy （Figure 1.10） lists the depth of energy savings required by building type to achieve ZNE within the footprint of the building (assuming solar installation to create the required renewable energy) (Crawley, 2007). The study indicates that achieving ZNE in warehouses should be simple; doing so in hospitals and labs would be extremely difficult. On average, a two–thirds reduction in energy use is required to approach ZNE goals.

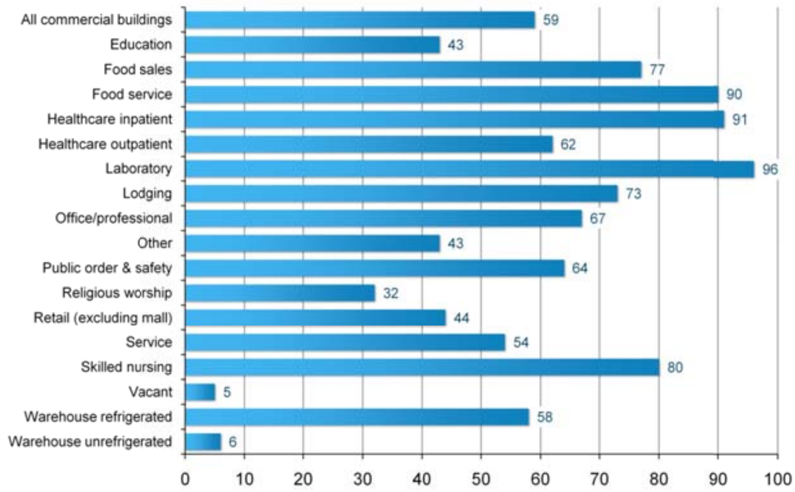


Figure1.10 Need 60%to 70% decrease in energy consumption of commercial buildings

Published in 2008 and updated in 2011 by the California Public Utilities Commission, **the California Long Term Energy Efficiency Strategic Plan (CEESP)** outlines energy goals and efficiency strategies for key market sectors (commercial, residential, etc.) and crosscutting resource (such as heating, ventilation, and air conditioning (HVAC), codes and standards, research and technology)[4]. In order to guide long-term changes in the market by reducing barriers to the adoption of energy efficiency measures—market transformation—the Plan embraces four specific programmatic goals, known as **the Big Bold Energy Efficiency Strategies (BBEES)** (CPUC, 2008):

- All new residential construction in California will be zero net energy by 2020
- All new commercial construction in California will be zero net energy by 2030
- Heating, Ventilation and Air Conditioning (HVAC) will be transformed to ensure that its energy performance is optimal for California‘s climate
- All eligible low-income customers will be given the opportunity to participate in the low income energy efficiency program by 2020.

Unlike traditional regulatory approaches, the Plan identifies near-term, mid-term and long-term milestones to move the state towards these BBEES,which could be find in Figure 1.11.

ZNE Commercial Buildings				
Strategies	Near Term 2009-2011	Mid Term 2012-2015	Long Term 2016-2020	2021-2030
Establish a long-term progrsssive path of higher minimum codes and standards.	Establish one-or two-tiered voluntary EE building standards.	Adjust the code on a triennial schedule on a fixed trajectory to ZNE by 2030.	RD&D and Title 24 updates	RD&D and Title 24 updates
Broaden Title 24 to address as many energy end uses as possible	Adopt broader codes and standards to include plug loads and whole building approaches including metering and data management automated diagnostic systems:and sub-metering for tenant-occupied space.	Develop and adopt progressively broader and deeper codes and standards	Develop and adopt progressively broader and deeper codes and standards	Develop and adopt progressively broader and deeper codes and standards
Establish a "Path to Zero" Campaign to create demand for high-efficiency buildings	Convene leading building industry associations to plan and conduct campaign.	Conduct Campaign	Conduct Campaign	Conduct Campaign
Develop Innovative financing tools for ZNE and ultra-low energy new buildings.	Develop and pllot innovative financing tools.	Implement most effective funding mechanisms.	Expand Implementation of funding mechanisms.	On-going expansion of these options.

Figure1.11 Implementation plan and timeline

To help California's commercial buildings sector achieve the goals described in the California Long Term Energy Efficiency Strategic Plan, involvement of stakeholders outside of investor owned utilities (IOUs) is definitely required. The ZNE Action Plan developed by ZNE stakeholders is a way to operationalize the zero net energy goals of the Strategic Plan for the commercial sector, which includes:

- Strategies - An overview of the strategy and why it is important to focus on these activities now.
- Progress to Date (2010-2012) - A graphical depiction of milestone progress, based on percent complete in the action plan.
- Action Plan (2010-2012) - Identifies the milestones to achieve the strategy and has specific activities, is time bound and is aligned with champions in the industry.
- Priorities for The Future (2013–2030) - Additional actions that were identified via stakeholders as potential strategies/milestones to include in an update to the Strategic Plan.

1.5 Other states ZNE buildings

Besides California, many other states have also taken effort in setting policies to promote the energy efficiency in new constructions and existing buildings with extraordinary achievements.

1.5.1 The Energy Trust of Oregon: a Path to Net Zero Pilot Program

The Energy Trust of Oregon offers a Path to Net Zero Pilot program of enhanced energy incentives for owners achieving exceptional levels of energy savings and those aiming for net zero energy use. The pilot program was immediately fully subscribed with 15 projects, including four schools or college facilities, four multi-unit residential buildings, three community centers/event spaces, two government/ municipal buildings, one retail space, and one office building[5]. Of these projects, seven are recently constructed or are nearing completion.

1.5.2 The Massachusetts Zero Net Energy Buildings Task Force

Buildings in Massachusetts consume 54 percent of energy in the commonwealth (MZNEBTF, 2009). At the direction of Governor Deval Patrick and under the leadership of Energy and Environmental Affairs Secretary Ian Bowles, the Massachusetts Zero Net Energy Buildings Task Force convened for the first time in July 2008 to begin deliberations to transform the building sector, by creating a pathway toward zero net energy buildings in the Commonwealth.

Building on the Commonwealth's leadership to advance energy efficiency and employ cutting-edge design and clean energy technologies, the Task Force was charged with making recommendations that will:

- Allow the state to issue specifications for the first, state-owned zero net energy building by January 1, 2010;
- Lead to the specification of an interim standard for state-owned construction that is significantly more stringent than the Massachusetts LEED Plus benchmark;
- Put the private sector on a path toward (1) broad marketability of zero net energy commercial and residential buildings by 2020 and (2) universal adoption of zero net energy practices for new commercial and residential construction by 2030.

Upon its formation, the Zero Net Energy Buildings (ZNEB) Task Force reached two initial conclusions. First, recognizing that, even by 2030, achieving the zero net energy performance goal may be infeasible for some buildings, the broader objective should be to reduce energy loads to the minimum practical level, produce onsite as much of the required energy as reasonable from renewable resources, and purchase locally generated renewable energy to satisfy remaining needs. Second, the extended lifetime of a typical building dictates that the absolute magnitude of potential energy reductions associated with the existing building stock will be far greater than those associated with new buildings alone, so developing recommendations that do not address the energy performance of existing buildings would result in a significant missed opportunity for reducing the overall energy needs, and carbon footprint, of the state.

1.6 Army Net Zero Initiative

As the largest single consumer of energy and oil in the world, the U.S. military has also begun a transition to efficient and renewable energy. The US Army's Net Zero Energy initiative, which started in 2010, means that they will aim to produce as much energy (and water, and waste) as they use. Cost and reliability are the primary reasons, but cutting carbon pollution is one of the outcomes (ASA, 2013).

Under the Army's Net Zero Initiative, the goal for Net Zero Energy pilot installations is to produce as much energy on the installation as they use annually. Energy reduction and efficiency are addressed first, followed by energy recovery, cogeneration and production of on-site power with preference given to the generation of renewable energy. Key best practices documented to date include:

- Conduct thermal building envelope analysis
- Reduce energy use through energy management control systems

- Hire resource efficiency managers
- Pursue alternative financing mechanisms
- Conduct energy master planning

The initiative is not imposed on individual bases from the top down. One hundred installations responded that they wanted to be net- zero, and the Department of Defense selected 17 for a nationwide pilot program. A site specific assessment helps to tailor any changes to current processes, while ensuring that mission requirements are not compromised while reducing cost.

The cornerstone of the Army's Net Zero Initiative is the Net Zero Hierarchy, comprised of five interrelated steps: reduction, re-purpose, recycling and composting, energy recovery, and disposal. And building of energy projects is the last of the interrelated steps of the Net Zero Hierarchy, which is to be implemented after all the waste mitigation strategies have been fully exercised. The goal is for these interrelated steps to be integrated into the installation's long-term planning efforts, including its master plan, while also evaluating the benefits of installation management actions and projects on a number of variables, including cost.

Figure1.12 Net zero hierarchy

The EISA calls for GSA's Office of Federal High-Performance Green Buildings to conduct an annual demonstration project on the green features of Federal buildings, including monitoring and data collection to study their impact on energy use and operational costs. The goal is to ensure that the Federal government learns from its experiences in green building and applies those lessons to current and future programs.

A number of overarching actions were taken over the past year in support of the Net Zero Energy pilot installations. The Energy Engineering Analysis Program (EEAP) conducted Energy Assessments at the pilot installations to identify energy inefficiencies and wastes in representative buildings, and to propose energy-related projects that could meet its Net Zero Energy goals. The assessment included a Level I/Level II study of energy conservation opportunities including an analysis of building envelopes, lighting, ventilation air systems, controls, and appliances.

Fort Bliss' Residential Community Initiative contractor completed a residential mock billing program and moved to live billing in November 2012 resulting in one third of homes conserving enough energy to qualify for rebates. Currently Fort Bliss's annual saving is $4.8 million

The U.S. Army Engineer Research and Development Center (ERDC) demonstrates a new technology with the support of the Office of the Assistant Chief of Staff for Installation Management (OACSIM) and the Installation Technology Transition Program at Fort Drum. The technology enables rapid, high-resolution detection of building envelope energy losses.

The Army issued a policy in FY2013 to expand the Net Zero approach to all permanent Army installations. All installations will be directed to evaluate the feasibility of and then implement, to the maximum extent practicable and fiscally responsible, policies, procedures, and new technology that advances them to meet their Net Zero goals.

Figure1.13 Net Zero Pilot Installations

1.7 Definition

Net-zero energy buildings (NZEB) have been the subject of research initiatives for institutions and scholars to pay attention to in recent years. And there is still lack of a definition for Net-zero energy buildings which can reach broad consensus. Though sharing the same goals of reducing building energy consumption in a renewable and compensating way, there are still some subtle differences existed in the net zero energy building definitions.

1.7.1 Zero-net-energy building in Executive Order 13514

In Executive Order 13514, "Zero-net-energy building" is defined as "a building that is designed, constructed, and operated to require a greatly reduced quantity of energy to operate, meet the balance of energy needs from sources of energy that do not produce greenhouse gases, and therefore result in no net emissions of greenhouse gases and be economically viable".

1.7.2 Net-Zero Energy Building by DOE

DOE described the NZEB definition in its BT program report: "A net-zero energy building is a residential or commercial building with greatly reduced needs for energy through efficiency gains (60 to 70 percent less than conventional practice), with the balance of energy needs supplied by renewable technologies." (DOE, 2013)

1.7.3 Zero Net Energy project by CPUC

The CPUC has defined “Zero Net Energy” at the level of a single “project” seeking development entitlements and building code permits in order to enable a wider range of technologies to be considered and deployed, including district heating and cooling systems and/or small-scale renewable energy projects that serve more than one home or business (CEC, 2013). Zero net energy is a general term applied to a building with a net energy consumption of zero over a typical year. To cope with fluctuations in demand, zero energy buildings are typically envisioned as connected to the grid, as is depicted in Figure 1.14, exporting electricity to the grid when there is a surplus, and drawing electricity when not enough electricity is being produced.

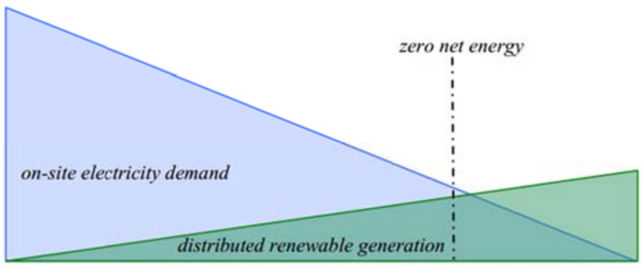


Figure1.14 Zero Net Energy defined with electricity demand

The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.

1.7.4 Zero Net Energy by NBI

Besides the definitions that proposed in the governments’ policies and national program reports, many other institutes also present definitions according to their research work. NBI’s Zero Net Energy (ZNE) definition is one that has been widely used (CEC, 2011):The amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.

1.7.5 NZEB Definition by ASHRAE

ASHRAE defined NZEB as:A building that annually use no more energy from the utility grid than is provided by on-site renewable energy sources.

1.7.6 Term definition by NREL

NREL and DOE published “Zero Energy Buildings: A Critical Look at the Definition” (Paul Torcellini,2006) in 2006 with the attempt to reach a common definition, or even a common understanding, of what the term “zero energy building” means. A zero energy building can be defined in several ways, depending on the boundary and the metric. Different definitions may be appropriate, depending on the project goals and the values of the design team and building owner.

Each definition uses the grid for net use accounting and has different applicable renewable energy sources. The definitions do apply for grid independent structures. For all definitions, supply-side ZEB can be used if this resource will be available for the life of the building. Off-site ZEBs can be achieved by purchasing renewable energy from off-site sources, or in the case of an off-site zero emissions building, purchasing emissions credits. In support of DOE’s

ZEB research needs, the following definitions refer to ZEBs that use supply-side options available on site. For ZEBs that have a portion of the renewable generation supplied by off-site sources, these buildings are referred to as "off-site ZEBs."

- **Net Zero Site Energy**: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
- **Net Zero Source Energy**: A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
- **Net Zero Energy Costs**: In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- **Net Zero Energy Emissions**: A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

1.7.7 Comparisons of different definitions

The key challenge of making definition is how to keep common sense definition of ZNE intact and meaningful while being applicable to all buildings in the near future.

The zero energy definition affects how buildings are designed to achieve the goal. It can emphasize energy efficiency, supply-side strategies, purchased energy sources, utility rate structures, or whether fuel-switching and conversion accounting can help meet the goal. There is no "best" definition of net-zero energy buildings, nor is there a "best" method for accounting for energy use. Each has its merits and drawback, and building teams should select the appropriate approach for each project to align with the client's goals. The pluses and minuses comparisons of different definitions are listed in Table 1.1.

Table1.1 Comparisons of different definitions

Definition	Pluses	Minuses
Net Zero Site Energy:	•Easy to implement •Verifiable through on-site measurement •Conservative approach to NZEB •No externalities affect performance, can track success over time •Easy for the building community to understand and communicate	•Requires more PV export to offset natural gas •Does not consider all utility costs (can have a low load factor) •Not able to equate fuel types •Does not account for non-energy differences between fuel types
Net Zero Source Energy:	•Able to equate energy value of fuel types used at the site •Better model for impact on national energy system • Easier NZEB to reach	•Does not account for non-energy differences between fuel types •Source calculations too broad •Source energy use accounting and fuel switching can have a larger impact than efficiency technologies • Does not consider all utility costs
Net Zero Energy Costs:	•Easy to implement and measure •Market forces result in a good balance between fuel types •Allows for demand- responsive control •Verifiable from utility bills	• Not reflect impact to national grid for demand •Requires net-metering agreements such that exported electricity an offset energy and non-energy charges •Highly volatile energy rates make for difficult tracking over time
Net Zero Emissions:	•Better model for green power Accounts for non-energy differences between fuel types (pollution, GHGs) •Easier NZEB to reach	
ZNE Ready Building	•Meet the same high efficiency Energy Use Intensities (EUIs)	•Lack on-site renewables.
Zero Net Electric Building	•Meets EUI by building type and climate zone •Reflect best practices for highly efficient buildings	•Relevant measurement standard need a further completement
Net Positive Building	•Produces more renewable energy on-site than consumed over a typical year.	
Zero Net Energy Community	Provide a community-scale renewable energy source	Each building in the community should be ZNE Ready Building

1.8 Conclusion

1. 41% of U.S. primary energy was consumed by the buildings sector, compared to 30% by the industrial sector and 29% by the transportation sector. Total primary energy consumption is expected to reach more than 45 quads by 2035, a 17% increase over 2009 levels, with a 13% increase in residential sector and a 22% increase in commercial sector. Since the energy consumption of building have a rapid increasing tendency and cause more and more attention, long term bold goal and mid-term action plan are issued by federal government and states: for federal buildings, as of 2020, all planning for new Federal buildings requires design specifications that achieve Zero-Net-Energy use by 2030; for commercial buildings and residential buildings, marketable net zero energy homes by the year 2020 and commercial net zero energy buildings at low incremental cost by the year 2025.

2. The zero energy definition affects how buildings are designed to achieve the goal also have a relationship with the government subsidy potentially, Executive Order 13514,DOE,CPUC,NBI,ASHRAE,NREL all have the definition of NZEB or similar terms. The key challenge of making definition is how to keep common sense definition of ZNE intact and meaningful while being applicable to all buildings in the near future.

2. Program & Findings

The U.S. had implemented numbers of research programs at all levels, from nation-wide to industrial alliance, which including technical potential, cost-affordable, roadmap of different type of building in different climate zones and also the financial solutions for NZEB.

2.1 Buildings Technology Research and Development Vision Agenda

The U.S. government published a research agenda for Net –Zero Energy, high-performance green buildings in 2008. Sponsored by the Buildings Technology Research and Development (BTRD) Subcommittee, Co-Chairs Shyam Sunder, (Director BFRL/NIST/DOC) and Jerry Dion, (Building Technologies/ EE&RE/DOE), together with a large circle of Federal government departments, conducted a series of activities to identify R&D priorities and opportunities; develop long-range, interagency R&D plans; coordinate with other NSTC subcommittees; coordinate R&D implementation plans. The main purpose can be concluded as (NSTC, 2008):

- Provide R&D guidance aimed at supporting advances in buildings technology and related infrastructure, with a particular focus on enabling the energy efficient, automated operation of buildings and building systems
- Provide R&D guidance to enable sustainable renewal of the nation's physical infrastructure, improve construction productivity, enhance disaster resilience of buildings, and benefit human health and productivity

The document describes the BTRD goals and the R&D objectives by which they are to be achieved. The goals and objectives focus on net-zero Energy, water and materials use, indoor environmental quality, performance measurements and metrics, and barriers to the adoption of these new technologies by the buildings sector. The plan also includes a description of current Federal programs in support of the research agenda.

Through the interagency Buildings Technology Research and Development Subcommittee of the National Science and Technology Council, have defined an R&D vision for the technologies required for buildings of the future- Enable designs of new buildings and retrofits of existing buildings that over the life cycle:

- Produce as much energy as they consume (net-zero energy) and significantly reduce GHGs.
- Double the service life of building materials, products, and systems and minimize life cycle impacts
- Halve the use of domestic water, maximize water recycling and rainwater harvesting, and minimize storm water runoff.
- Achieve breakthrough improvement in indoor occupant health, productivity, and comfort.

The report Federal Research Agenda for NZE High Performance Green Buildings, focuses on the development of new technologies, protocols, and practices at the building site, unless they apply as well to groups of buildings or communities. Among the 6 Goals for Effective Energy, Water, and Resource Use in Buildings, Goal 1 and Goal 2 are extremely focused on development of measurement and strategies for net zero energy buildings:

Goal 1: Develop the enabling measurement science to achieve net zero energy, high-performance green building technologies.

a. Develop rigorous metrics that enable high-performance building goals to be predicted, assessed, monitored, and verified and new energy-efficient technologies, products, and practices to be developed.

b. Enable widespread adoption of high-performance goals by developing practical tools and processes to address the complex interactions of building components and systems throughout the building life cycle.

Goal 2: Develop net zero energy building technologies and strategies.

a. Develop building envelope materials, components, systems, and construction techniques to minimize building energy loads.

b. Develop ultra energy-efficient components and subsystems that minimize energy and satisfy building needs.

c. Develop supply-side technologies that, when coupled with energy efficiency, can achieve net zero energy buildings and communities.

Goal 3 to Goal 6 are focused on promotion of building materials and waste collection considering life cycle environmental impacts. These can be found in the report of Federal Research Agenda for NZE High Performance Green Buildings.

2.2 Technical Potential for Achieving NZEB in Commercial Sector

NREL conducted a research to assess the technical potential for zero-energy building (ZEB) technologies and practices to reduce the impact of commercial buildings on the U.S. energy system. The final report "Assessment of the Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector" was published in December, 2007.

This assessment characterizes commercial building energy performance in the context of the U.S. Department of Energy (DOE) BT program long-range vision for ZEBs (Long N. 2007). The BT program has set a goal of developing market-viable low- and zero-energy buildings, and this assessment was conducted to determine the technical potential of that goal for the commercial buildings sector. We use the term technical potential to refer to "maximum technology" scenarios that are used to estimate what is possible in the sector, and therefore do not include cost and economic analyses such as assessing market penetration or projecting how the sector might evolve. NREL researchers focused on evaluating sets of known technologies and practices and modeling the system interactions with detailed engineering calculations.

For the assessment, NREL used EnergyPlus to produce a data set of energy performance metrics for commercial building prototypes in various subsectors and climates. We used the information gathered from these data sets to:

- Determine what can be achieved with current and emerging technologies in the context of meeting the goal of net-zero energy use.

- Determine the technical potential for energy savings in the sector.
- Identify where additional technology R&D is needed to meet BT's programmatic goals.

In the final report, the program ends up with a series of conclusions:

2.2.1 ZEB Opportunities in Commercial Buildings

The simplest way to express the opportunities for ZEBs in the sector is to determine the percentage of total floor area, or the total number of buildings, that could meet the ZEB goal. Based on a ZEB definition that uses net site energy use of zero or less, the results show that by using known technologies and practices with projected performance levels for 2025:

- 47% of commercial floor area could reach ZEB
- 62% of buildings could reach ZEB

These results indicate that the ZEB goal is not too aggressive and can be achieved for large segments of the commercial sector.

2.2.2 Programmatic Factors for Meeting the ZEB Goal

The programmatic requirements of buildings (architectural program elements) can be considered as the major factors that influence the ability of buildings to reach the ZEB goal.

Plug and Process Loads

Meeting the ZEB goal is easier for lower non-HVAC&L energy use. It is suggested that the ZEB context differs from the traditional approach to energy-efficient design in that non-HVAC&L loads must be considered rather than treated as fixed, or unregulated, and therefore largely ignored.

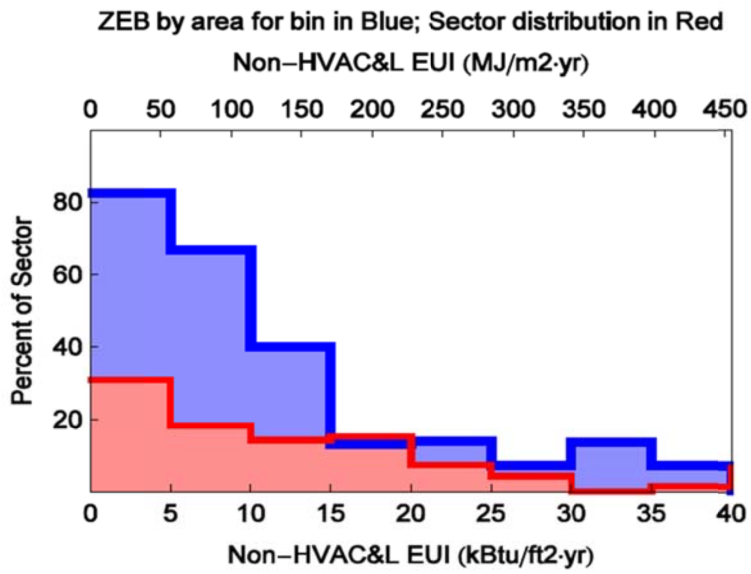


Figure2.1 Percentage of floor area that can reach ZEB as a function of non-HVAC&L EUI: Max Tech Scenario

Number of Floors

Single-story buildings offer a large amount of roof area per usable floor area for PV power-generating capacity and can be more easily daylight.

Building Floor Area

Overall building size is not necessarily a good way to distinguish which parts of the sector should be the focus of ZEB research.

Location

Greater cost savings were seen in the West North Central and East South Central census divisions and lower cost savings were found in the West South Central and Pacific divisions.

Solar resource

The relationship between improving solar production (e.g. by increased efficiency or area) and the ability of commercial sector buildings to reach the ZEB goal.

2.2.3 Technologies and Practices for Meeting the ZEB Goal

Way to explore the importance of efficiency measures is to calculate the percent savings needed to meet the ZEB goal based on the available on-site production from PV power systems. For the sector as a whole, the results indicate that 59% savings over 90.1-2004 is needed to reach the ZEB goal for the PV power systems modeled (20% efficient modules on one-half of the roof area). Results for the savings required in different subsectors are plotted in Figure 2.2. Offices need 67%, warehouses 6%, educational facilities 43%, and retail needs 45% savings to reach ZEB. Very high levels of savings (greater than 90%) would be needed to reach ZEB for high-intensity subsectors such as food service, inpatient health care, and laboratories.

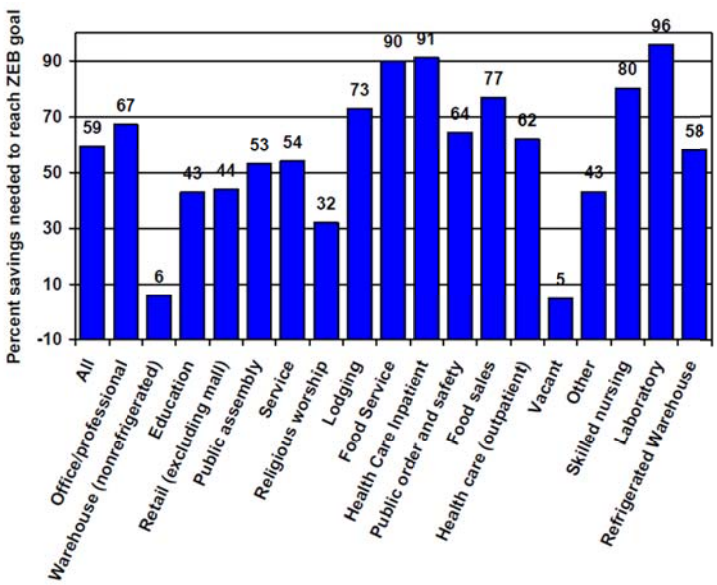


Figure 2.2 Percent savings from efficiency needed to reach ZEB
Source: Long N, 2007

2.3 A Cold-Climate Case Study for Affordable Zero Energy Homes

The project of Cold-Climate Case Study for Affordable Zero Energy Homes, supported by the U.S. Department of Energy's Building America Program, is a case study in reaching zero energy within the affordable housing sector in cold climates (Norton P, 2006). The design of the 1200 square foot, 3-bedroom Denver zero energy home carefully combines envelope efficiency, efficient equipment, appliances and lighting, and passive and active solar features to reach the zero energy goal. The program will detail the construction of the home including passive and active solar features, super-insulated walls, ceiling, and floor, and efficient equipment.

The goal of the U.S. Department of Energy's Building America program is to create commercially viable zero energy homes by 2020. This project is a case study in reaching that goal within the affordable housing sector in cold climates. Zero energy is especially important in this sector where increasing energy cost can take a high toll on homeowners with limited economic resources. A zero energy home guarantees long term energy cost stability for the homeowner.

Figure2.3 The NREL/Habitat Zero Energy Home

Technology used in the final design:

- **Ventilation System:** An energy recovery ventilation (ERV) with efficient electronically commutated motors.
- **Space Heating:** Natural gas in the home, reducing the required PV array size by 1.1 kW and to take a hybrid approach to space heating.
- **Water Heating System:** A natural gas tankless water heater works as a backup to the solar system. Unlike tank water heaters, the tankless system uses no heating energy when the solar water tank is at or above the 115 degree F hot water delivery temperature, although it may use electricity in standby. The disadvantage of using the tankless system is the added cost compared to a tank system.
- **Photovoltaic System Sizing:** The BA Benchmark includes assumptions that we used to estimate the MELs and size the 4kW PV system. These assumptions are based on the best available nationwide studies of energy use. So the home's PV system is sized with the assumption that it will be occupied by a "typical" American household. If the actual household and weather are typical, the home will achieve zero energy. If the household or weather is atypical, the home may not achieve zero energy or may be a net producer.

2.4 Feasibility of Achieving NZE&NZC Homes

Sponsored by the United States Government, a program aiming at zero energy and zero net cost in buildings was completed in 2009. The final report "Feasibility of Achieving Net-Zero-Energy Net-Zero-Cost Homes" was also supported in part by the California Energy Commission in September, 2009. The authors in the report conducted a survey of the most progressive home energy‐efficiency practices expected to appear in competition design submittals.

The Energy Free Home Challenge （EFHC） has two focus: zero net energy and zero net cost. Zero net energy refers to achieving a net zero draw of grid electricity and any non‐renewable fuel (such as natural gas or heating oil). The home's primary fuel consumption and grid electricity consumption will be converted to a common unit, summed, and compared to its net renewable energy production; the two must cancel one another out. Net zero cost refers to zero additional cost above a traditional home of comparable size and comfort when evaluated over a 30‐year mortgage. In other words, the ''green premium" must pay for itself in energy savings within 30 years. The overarching goal of the competition is to develop affordable, high performance homes that can be mass‐produced within communities and are able to perform in harsh climates (the competition is set in Illinois). To ensure that the established rules are challenging, yet reasonable, this report seeks to refine the competition goals, and explore their feasibility through case studies, cost estimation, and energy modeling.

It is believed that the cost of electricity generated by home generation technologies will continue to exceed the price of US grid electricity in almost all locations. Strategies to minimize whole house energy demand generally involve some combination of the following measures:

- optimization of surface (area) to volume ratio;
- optimization of solar orientation;
- reduction of envelope loads;
- systems based engineering of high efficiency HVAC components;
- on‐site power generation.

A "Base Case" home energy model was constructed, to enable the team to quantitatively evaluate the merits of various home energy efficiency measures. This Base Case home was designed to have an energy use profile typical of most newly constructed homes in the Champaign‐Urbana, Illinois area, where the competition is scheduled to be held. The model specifies the most significant details of a home that can impact its energy use, including location, insulation values, air leakage, heating/cooling systems, lighting, major appliances, hot water use, and other plug loads. EFHC contestants and judges should pay special attention to the Base Case model's defined "service characteristics" of home amenities such as lighting and appliances.

In the end, the program discussed the possibility of feasibility of net zero energy and net zero cost:

- **Feasibility of Net Zero Energy**

The question of whether net zero energy is technically possible is easily answered: it is certainly possible. Using extensive energy efficiency measures and large solar arrays will reach zero energy, but may not come close to achieving net zero cost.

- **Feasibility of Net Zero Cost**

Given that net zero energy must be achieved, zero net cost remains a significant challenge for entrants. This report provides cost estimates for various scenarios, trading in various efficiency improvements to determine how much solar (or other electricity generation technology) would be required. The author have also explored projections for future cost reductions and have determined that, while solar is expected to become less expensive as the industry expands, the installed costs will not decrease enough in the short - term to make net zero cost easily achievable. Significant innovations in energy efficiency will likely be necessary.

2.5 Roadmap to Zero Net Energy Public Buildings

Created for Northeast Energy Efficiency Partnerships' (NEEP) High Performance Buildings Project, the Road map to Zero Net Energy Public Buildings was published in the fall of 2011.The program was completed in collaboration with a group of regional building energy stakeholders and outlines key steps the public sector can take to facilitate the eventual broad adoption of zero net energy building practices throughout the Northeast and Mid-Atlantic states (Coakley S, 2012).

Intermediate-term Steps to Facilitate Zero Net Energy Public Sector Buildings shows that NEEP recommends be taken in the next 10-15 years to make zero net energy public buildings a widespread practice across the region. These are followed by a series of "critical next steps" that we suggest must be taken now to pave the way to a future where all new buildings consume only as much energy as they produce.

In the next 10-15 years, the region should take steps in the following four areas to facilitate zero net energy buildings (ZNEBs):

- **Information and Education**

Decision makers will need more and better information that is reliable and readily understood on how buildings perform with respect to energy use. Critical information includes: Techniques for achieving substantial energy use reductions and the estimated costs and benefits of those measures; Actual energy performance of individual buildings, which could be generated by the implementation of building energy rating and disclosure programs.

- **Building Energy Codes**

Energy codes will need to incorporate the changes: Progressively lower energy use over the next 20 years so that codes are eventually strict enough to facilitate ZNEBs; Focus on outcome-based rather than prescriptive requirements to allow for innovative approaches to lowering energy use; Require continuous commissioning to ensure that buildings are performing as expected; Address all energy used in the building including plug loads, i.e. the energy consumed by devices plugged in to electrical outlets.

- **Finance**

A price on carbon pollution would be effective in two ways as a means to create a financial incentive: It would provide a direct financial motivation for consumers to use less energy and to demand more efficient buildings; The revenues from a carbon assessment could be funneled into programs to subsidize investments in building energy efficiency projects.

- **Utility Regulation**

State regulators and energy offices should work with their program administrators to: Create rate mechanisms that fully decouple cost-recovery from volumetric sales; Remove barriers to net-metering to promote greater use of on-site renewable energy; Provide performance incentives to utilities that effectively help their customers reduce consumption.

Critical Next Steps

In order to achieve the intermediate-term changes, NEEP has identified five critical next steps.

Step 1. Develop a "Path to Highest Performance" Information Campaign

Step 2. Promote the Continued Development of Exemplary Public Buildings

Step 3. Prioritize Measurement and Reporting of Public Building Energy Performance

Step 4. Implement Stretch Building Energy Codes

Step 5. Create a Revolving Loan Fund or Similar Mechanism to Provide Capital for Energy Investments

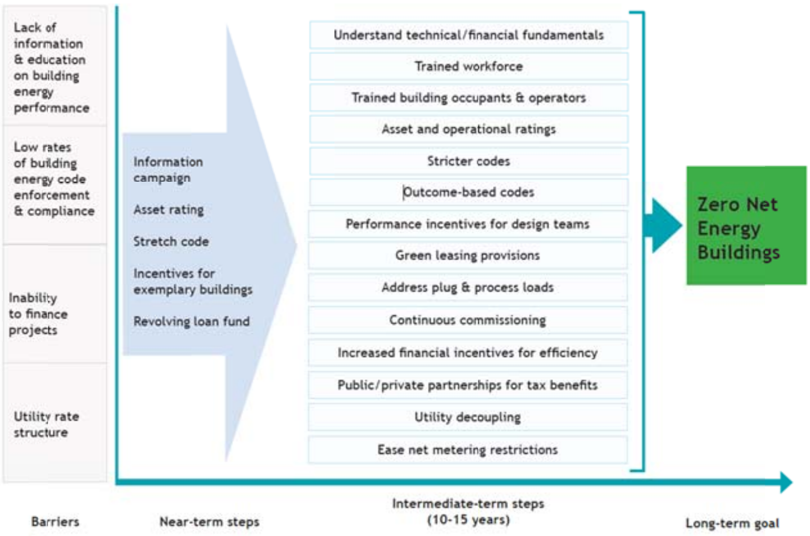


Figure2.4 Barriers and Solutions to ZNEBs

2.6 Net Zero and Living Building Challenge Financial Study

The District of Columbia (the District) is a leader in green building implementation. According to the 2012 Green Building Report, the District has more green buildings than other large U.S. cities on a per capita basis. While District policies have been a driver of high performance building development in the private sector, ambitious new goals will require the District to make another leap forward. To advance the industry into the next era of green design, the District of Columbia's Department of the Environment sought to understand the costs and benefits associated with net zero energy, net zero water, and Living Buildings.

New Building Institute (NBI) teamed up with the International Living Future Institute (ILFI) and Skanska to conduct this study on two purposes: First, to investigate costs, benefits and approaches necessary to improve building performance in the District of Columbia from LEED Platinum to zero energy, zero water and Living Building status. Second, to advise District government on policy drivers related to deep green buildings and to analyze the opportunities for the District to offer incentives to advance most rapidly toward zero energy, zero water and Living Buildings.

NBI and ILFI determined the most appropriate energy efficiency and renewable energy strategies for the buildings, while Skanska determined the anticipated premium costs for the various energy strategies employed. The work included four categories of tasks:

- Determining a starting Energy Use Intensity (EUI) in kBtu/SF /year for each building to be used as a point of comparison for evaluating building efficiency performance;
- Analyzing the building characteristics and estimating the energy profiles of the reference buildings;
- Establishing a net zero energy budget by calculating available solar energy production on site;
- Applying Energy Conservation Measures (ECMs) and onsite renewable energy strategies to the reference buildings.

Costs for getting to zero are difficult to distinguish from overall project costs. The team conducted an analysis to identify incremental cost premiums for deep energy and water conservation as well as for photovoltaic and water reuse systems that would bring a project to net zero. The cost premium for energy efficiency was approximately 1-12% depending on building type. This raised to 5-19% for net zero energy. The analysis made clear that if the owner has sufficient tax appetite, tax credits and renewable energy credits make the return on investment approximately 30%, whereas the return on investment for energy efficiency alone was in the range of 5-12%.

Table 2.1 Cost premium range

	Energy Conservation Measures	Net Zero Energy (Renewables with ECMs)
Office New Construction	1-6%	5-10%
Multifamily New Construction	2-7%	7-12%
Office Renovation	7-12%	14-19%

A new policy framework is required if the building industry is to embrace net zero and Living Buildings at scale. To accelerate adoption, this research suggests the District develop a comprehensive roadmap that addresses all of the following issues over time and illustrates a clear pathway to the District's aggressive 2032 goals. The roadmap should consider these key recommendations from the study：Define net zero，Consider community-level approaches，Encourage transition to outcome-based energy codes，Establish new and modify existing financial incentives to encourage deep savings，Address limitations of the grid and acknowledge the changing role of utilities.

2.7 The Net-Zero Energy Commercial Building Initiative

This initiative aims to achieve market-ready, netzero energy commercial buildings by 2025. American Recovery and Reinvestment Act funds were used to accelerate and expand partnerships with major companies that design, build, own, manage, or operate large portfolios of buildings and that commit to achieving exemplary energy performance. This funding helped expand the number of partnerships from 23 to about 75 through a competitive process.

CBI also includes a National Laboratory Collaborative on building technologies, concentrating the efforts of fi ve National Laboratories—Argonne, Lawrence Berkeley, Oak Ridge, and Pacific Northwest National Laboratories, and the National Renewable Energy Laboratory—on the net-zero energy goal, and the Commercial Building National Accounts, which conducts cost-shared research, development, and deployment for new building technologies among major national companies. The website offers commercial reference building models, advanced energy design guides, energy simulation software, and a high-performance building database.

Ongoing R&D activities in support of the CBI include: Commercial Lighting Solutions, Building Envelope R&D, Commercial Building Energy Alliances, Commercial Real Estate Energy Alliance, Retailer Energy Alliance, Hospital Energy Alliance, Commercial Buildings Key Publications, Building America, High Performance Green Building Partnership Consortia.

2.8 Conclusions

1. Building energy consumption can be reduced by about 60%-70% by using a broad array of currently accessible and cost-effective technologies. The ZEB goal is not too aggressive and can be achieved for large segments of the commercial sector and residential buildings. Achieving net zero is not only a matter of design, it requires technical support, as well as careful attention to operations and maintenance (O&M), together with occupancy patterns and loads.

While net zero buildings are possible in most of the buildings with today’s technologies, the balance of cost and benefit became an important factor that effect its popularization and application. If the owner has sufficient tax appetite, tax credits and renewable energy credits make the return on investment approximately 30%, whereas the return on investment for energy efficiency alone was in the range of 5-12%.

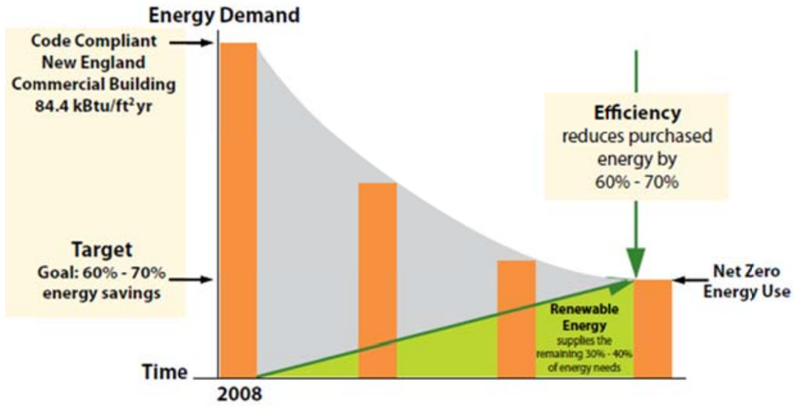


Figure 2.5 Approach for achieving net zero energy buildings
Source: Russell R, Sunder S, & Domich P. 2008

2. The United States is on a leading road towards zero energy building and the further step to zero energy building can be concluded as (Baum M, 2007):

- Create a detailed roadmap for each R&D goal in partnership with key stakeholder organizations.
- Engage key stakeholders – universities, research institutions, standard and code development organizations, professional societies, and private sector companies – to implement the R&D agenda.
- Publicize the Federal performance requirements for purchases and procurements.
- Evaluate successes and lessons learned.
- Organize follow –on workshops, conferences, and planning forums.
- Refine the research agenda.

3. If a local government would like to promote the NZEB with a specific roadmap, the roadmap should consider：Define net zero energy building，Consider community-level approaches，Encourage transition to outcome-based energy codes，Establish new and modify existing financial incentives to encourage deep savings，Address limitations of the grid and acknowledge the changing role of utilities.

3. Building Codes and Standards

Building codes and standards for energy conservation are the most basic and powerful measures of improving building energy efficiency and promoting NZEB development. Energy codes and standards play a vital role by setting minimum requirements for energy-efficient design and construction. They outline uniform requirements for new buildings as well as additions and renovations. As the forerunner among the APEC economies, the US has done a lot of work on making, implementing and upgrading building energy codes and stands.

Energy codes specify how buildings must be constructed or perform, and are written in mandatory, enforceable language. States or local governments adopt and enforce energy codes for their jurisdictions. Energy standards describe how buildings should be constructed to save energy cost-effectively. They are published by national organizations such as the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). They are not mandatory, but serve as national recommendations, with some variation for regional climate. States and local governments frequently use energy standards as the technical basis for developing their energy codes. Some energy standards are written in mandatory, enforceable language, making it easy for jurisdictions to incorporate the provisions of the energy standards directly into their laws or regulations. Energy use targets of building energy codes are also proposed by authoritative institutes and organizations to illustrate the developing blueprint.

3.1 ANSI/ASHRAE/IESNA Standard 90.1

ANSI/ASHRAE/IESNA Standard 90.1, Energy Standard for Buildings except Low-Rise Residential Buildings (2013), is published as a consensus standard to provide minimum requirements for the energy-efficient design of new and renovated or retrofitted buildings. It offers, in detail, the minimum energy-efficient requirements for design and construction of new buildings and their systems, new portions of buildings and their systems, and new systems and equipment in existing buildings, as well as criteria for determining compliance with these requirements. It is an indispensable reference for engineers and other professionals involved in design of buildings and building systems.90.1 is adopted by reference by the National Fire Protection Association (NFPA), so if a locale adopts NFPA, it adopts 90.1. The International Code Council has also developed a single set of regulatory documents for use by states and other locales. The 2012 IECC has two paths within its chapter 5. The first is to comply with 90.1-2007. Or one can follow the prescriptive requirements of the rest of Chapter 5.

Standard ASHRA 90.1 has been a benchmark for commercial building energy codes in the United States and a key basis for codes and standards around the world for more than 35 years. 90.1 is written in a code intended language as minimum requirements so it does not necessarily provide exemplary or state-of-the-art design guidance. ASHRAE Standard 90.1 is on continuous maintenance and is republished on a three year cycle. The current version is 90.1-2013[6].

The 2013 edition has been expanded to include new features and more detailed requirements, as well as incorporating changes from more than 100 addenda. The upgrading aspects include (ASHRAE, 2013):

- Revised, stricter opaque element and fenestration requirements at a reasonable level of cost-effectiveness
- Improvements to daylighting controls, space-by-space lighting power density limits, and thresholds for top-lighting
- Revised equipment efficiencies for heat pumps, packaged terminal air conditioners (PTACs), single package vertical heat pumps and air conditioners (SPVHP and SPVAC), and evaporative condensers
- Improved requirements for expanded use of energy recovery, small-motor efficiencies, and fan power control and credits
- Improved equipment efficiencies for chillers
- Clarifications for the use of prescriptive provisions when performing building energy use modeling, and revisions to enhance capturing daylighting when performing modeling calculations

3.2 ASHRAE Advanced Energy Design Guides (AEDG)

The ASHRAE Advanced Energy Design Guides (AEDG) are a series of publications designed to provide prescriptive recommendations for achieving 30% energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1 in eight U.S. climate zones. They are developed by a committee of experts and undergo peer review but are not developed through a consensus process. They show a way, but not the only way, to achieve 30% savings.

The first step in the process toward achieving a net zero energy building which is defined as a building that, on an annual basis, draws from outside resources equal or less energy than it provides using on-site, renewable energy sources. The Guides have been developed in collaboration with these partnering organizations[7]: The American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IES), the U.S. Green Building Council (USGBC), and the U.S. Department of Energy (DOE). The New Building Institute (NBI) participated in the development of the initial Guide.

As 90.1 gets more stringent, the standard will eventually surpass the energy savings recommended in the 30% AEDGs[8], however, they will remain excellent tools for energy-efficient design of buildings for quite some time. These guides provide a good starting point for anyone looking for a prescriptive, simple way to improve their energy efficiency and remain a good resource due to the information contained in the how-to tips. Each of the AEDGs (except the Small Office guide) lists the average savings as compared to 90.1-2004, additional AEDGs at 50%.

Advanced Energy Design Guides (AEDGs) are currently planned to be a series of guides that provide 30% energy reduction guidance, 50% energy reduction guidance, and 70% energy guidance. The committee recommends that the 70% energy reduction guides scheduled for completion by 2015 be modified to become net zero energy design guides. These guides would offer strategies that provide design guidance for 70% energy savings and strategies for on-site renewable energy concepts that result in NZEBs.

3.3 ASHRAE Standard 189.1-2011

ASHRAE Standard 189.1-2011, Standard for the Design of High-Performance, Green Buildings except Low-Rise Residential Buildings, is intended for buildings that wish to exceed the minimum requirements of Standard 90.1.

The purpose of this standard is to provide minimum requirements for the siting, design, construction, and plan for operation of high-performance green buildings to (a) balance environmental responsibility, resource efficiency, occupant comfort and well being, and community sensitivity, and (b) support the goal of development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This standard provides minimum criteria that:

a) Apply to the following elements of building projects:

1. New buildings and their systems
2. New portions of buildings and their systems
3. New systems and equipment in existing buildings

b) Address site sustainability, water use efficiency, energy efficiency, indoor environmental quality (IEQ), and the building's impact on the atmosphere, materials, and resources.

The provisions of this standard do not apply to single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes) and manufactured houses (modular), or buildings that use none of the following: electricity, fossil fuel, or water (ASHRAE, 2011). This standard is a compliance option of the International Green Construction CodeTM (IgCCTM).

When the new versions of Standards 90.1 and 189 are issued, the AEDGs and other energy-related documents need to be updated.

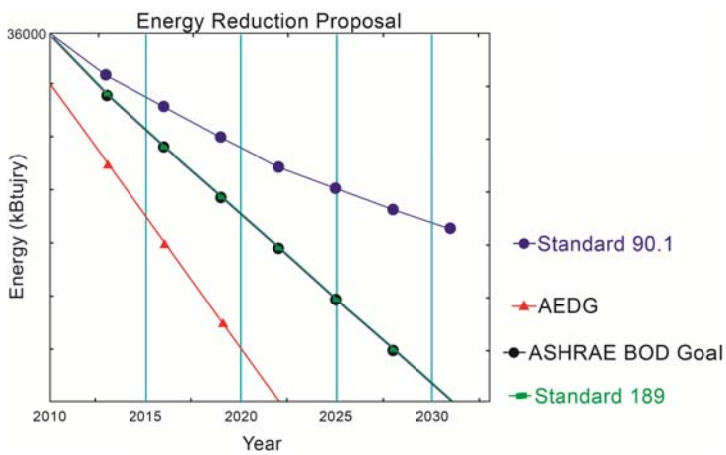


Figure3.1 Comparisons of different standards in energy reduction proposal
Source: ASHRAE, 2008

3.4 International Energy Conservation Code (IECC)

The IECC is typically published every three years, though there are some exceptions. In the last two decades, full editions of the MEC came out in 1989, 1992, 1993, and 1995, and full editions of the IECC came out in 1998, 2000, 2003, 2006, 2009 and 2012.

The IECC can be categorized into two general eras: 2003 and before, and 2004 and after. This is because the residential portion of the IECC was heavily revised in 2004. The climate zones were completely revised (reduced from 17 zones to 8 primary zones in 2004) and the building envelope requirements were restructured into a different format. The code became much more concise and much simpler to use. These changes complicate comparisons of state codes based on pre-2004 versions of the IECC to the 2009 IECC.

3.5 California's Building Energy Efficiency Standards

California's energy code is considered to be one of the most aggressive and best enforced energy code in the United States, and has been a powerful vehicle for advancing energy-efficiency standards for building equipment. Many specifications are performance-based, offering flexibility for designers. The code also stands out because it includes field verification requirements for certain measures and reports high compliance rates overall. The most recently adopted 2013 code (CEC, 2012), effective January 1, 2014, is mandatory statewide and exceeds 2012 IECC standards for residential buildings and meets or exceeds ASHRAE/IESNA 90.1-2010 for commercial buildings.

The Energy Commission's energy efficiency standards have saved Californians more than $74 billion in reduced electricity bills since 1977. The California Energy Commission has partnered with the State wide Codes & Standards Program to provide training and resources for building officials. California's building energy code can help save energy, keep our air cleaner and offset the need to build new power plants. We understand it can be quite technical and difficult to navigate new standards, especially when time and resources are limited.

California's Building Energy Efficiency Standards are updated on an approximately three-year cycle. The 2013 Standards will continue to improve upon the current 2008 Standards for new construction of, and additions and alterations to, residential and nonresidential buildings. The 2013 Standards has come into effect on January 1, 2014.

The Title 24 (part 6) Building Energy Efficiency Standards (CEC, 2012) upcoming triennial update cycles will need to address ZNE in response to the policy goals for 2020. Codes and Standards are the most important push mechanism available for implementing policy goals. Each update of the standards makes them more stringent and moves the needle towards higher efficiency. Title 24 also provides for the adoption of "reach codes," which are higher level than the base code and typically become the precursor to base code in the subsequent update. Achieving ZNE will necessitate some renewable generation but this can only be required in code if analysis determines that this meets standard cost effectiveness criteria. The 2013 standards have been adopted and are going into effect as of Jan 1, 2014 (CEC, 2013). Typically the standards' stringency increases at the rate of 12-15% in each cycle.

A newly constructed residential building built to the prescriptive requirements of the 2013 Standards will use 25% less energy for lighting, heating, cooling, ventilation, and water heating than one built to the prescriptive requirements of the 2008 Standards. For nonresidential buildings, there will be a 30% reduction in energy use (CEC, 2012a).

The Major changes of the Standards for 2013 can be concluded as follows (CEC, 2013):

- The first Standards update designed to put newly constructed homes on a path to achieve California's Zero Net Energy goals by 2020.
- The first Standards update to establish a photovoltaic compliance option, which allows a portion of the energy generated by a solar electric system to count toward meeting the energy budget in the performance Standards.
- Wall insulation requirements for residential buildings are increased to prevent heat transfer and reduce HVAC loads.
- Process equipment installed in grocery stores, commercial kitchens, data centers, laboratories, and parking garages is now covered by the Standards.
- All 3/4-inch and larger residential hot water pipes must be insulated to avoid wasting water and energy, and reduce the time it takes to get hot water to where it is needed.

The 2013 standards update codes for lighting, space heating and cooling, ventilation, and water heating. These standards add approximately $2,000 to the new residential building construction costs. Estimated energy savings to homeowners, however, is more than $6,000 over 30 years. In total, these standards are estimated to save 200 million gallons of water (equal to more than 6.5 million wash loads) and avoid 170,500 tons of greenhouse gas emissions a year.

The significant changes to the Building and Standards code are the first update since California's energy agencies agreed upon a Zero-Net Energy goal: all new residential buildings by 2020 and new nonresidential buildings by 2030. The 2016 and 2019 Building Energy Efficiency Standards will move the state even closer to the Zero-Net Energy goal.

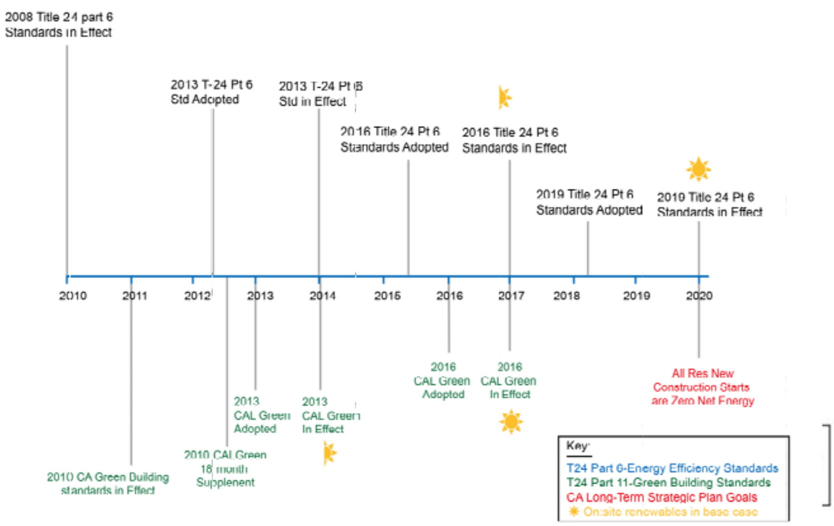


Figure3.2 Further path in residential

Source: IEPR workshop (CEC, 2011)

"These new Title 24 standards will help California buildings function beautifully and economically. The most effective way to optimize building performance is during construction," said Commissioner Andrew McAllister who oversees the Energy Commission's energy efficiency division. "Standards are a foundational part of California's long-term goals for meeting our energy needs, conserving resources and protecting the environment."

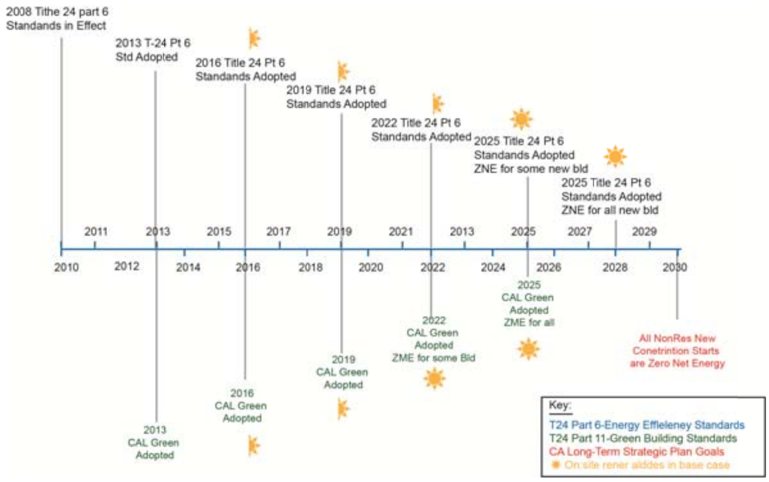


Figure3.3 Further path in commercial

Source: IEPR workshop (CEC, 2011)

3.6 Evaluation Standard

3.6.1 Energy Star Portfolio Manager

ENERGY STAR[9] is a U.S. Environmental Protection Agency (EPA) voluntary program that helps businesses and individuals save money and protect our climate through superior energy efficiency.

Energy Information Administration Commercial Building End-Use Consumption Survey (CBECS) (2012) shows a 14% increase in the number of buildings and a 22% increase in floor space since 2003, the building status can be evaluated in Energy Star Portfolio Manager calculates an EUI for a building based on like building types, climate, size, occupancy and loads.

Certain property types can also receive a 1–100 ENERGY STAR score, which compares the building property to similar properties nationwide. A score of 50 represents median energy performance, while 75 means your building is a top energy performer.

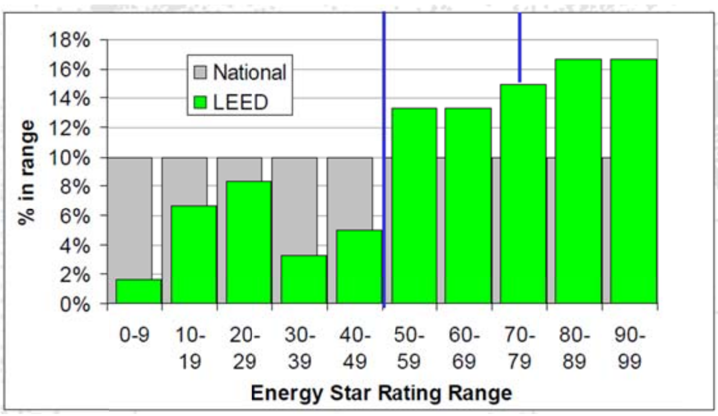


Figure3.4 Energy Star Ratings and LEED

Source: Frankel M. 2008

3.6.2 LEED

LEED, or Leadership in Energy & Environmental Design, is a green building certification program that recognizes best-in-class building strategies and practices[10]. A select committee of building design and performance professionals familiar with the Energy Star and European Union labeling programs created the Workbooks and established program criteria. To receive LEED certification, building projects satisfy prerequisites and earn points to achieve different levels of certification. Prerequisites and credits differ for each rating system that provides information on a building's energy use, and teams choose the best fit for their project.

Buildings participated in a range of USGBC LEED programs covers four certifications: New Construction (NC); Existing Buildings, Operations and Management (EBOM); Core and Shell (CS); and Commercial Interiors (CI). Existing buildings often cross into several LEED categories depending on the extent of the retrofits or renovations. USGBC is encouraging ongoing certification in EBOM to reflect continuous improvement and energy tracking. The reasons for projects pursued and obtained a LEED rating. Some possible reasons for this are:

1. LEED provided a set of target criteria on a variety of environmental areas.
2. In most cases, the building renewals were a one-time occurrence for the owner. With LEED providing a pre-made framework, there was no incentive to explore or establish independent criteria. The owners perceived a strong value to the third-party certification and market recognition of the label.
3. NBI’s search more easily found projects that accomplish LEED or other green/energy ratings due to their higher public and industry news profiles.
4. Building owners, operators and design professionals more readily respond to requests for information because they have LEED submittal reports and are interested in the exposure for their work.

3.6.3 The Home Energy Score

The Home Energy Score is a national rating system developed by the U.S. Department of Energy. The Score reflects the energy efficiency of a home based on the home’s structure and heating, cooling, and hot water systems. The Home Facts provide details about the current structure and systems. Recommendations show how to improve the energy efficiency of the home to achieve a higher score and save money.

The Home Energy Score allows homeowners to compare the energy performance of their homes to other homes nationwide. It also provides homeowners with suggestions for improving their homes' efficiency.

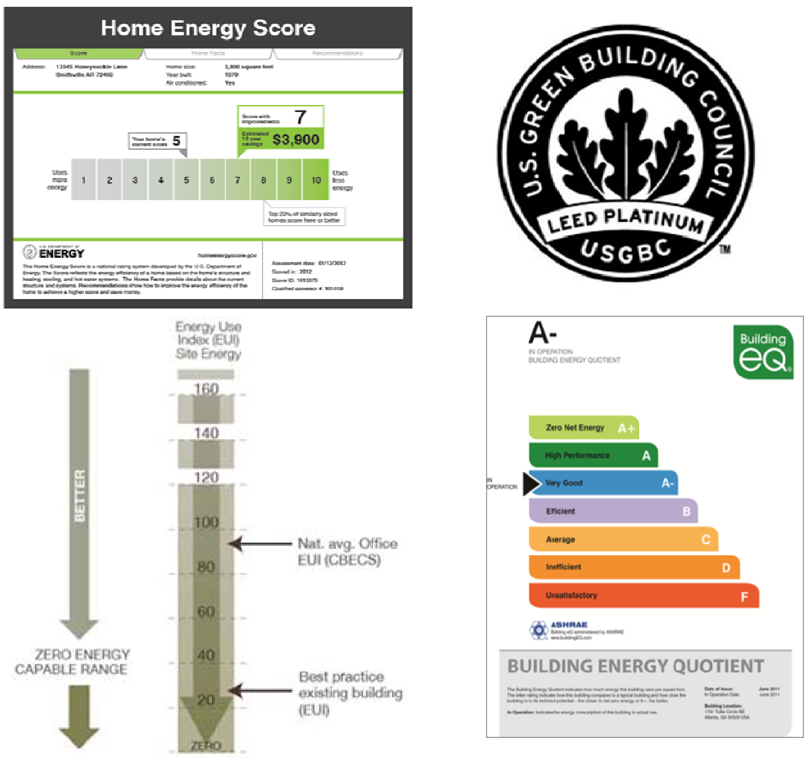
The process starts with a Home Energy Score Qualified Assessor[11] collecting energy information during a brief home walk-through. Using the Home Energy Scoring Tool, developed by the Lawrence Berkeley National Laboratory, the Qualified Assessor then scores the home on a scale of 1 to 10. A score of 10 indicates that the home has excellent energy performance. A score of 1 indicates the home needs extensive energy improvements. In addition to providing the Score, the Qualified Assessor provides the homeowner with a list of recommended energy improvements and the associated cost savings estimates.

3.6.4 Building Energy Quotient

Building Energy Quotient (bEQ)[12] is a building energy rating program that provides information on a building's energy use. Only select individuals can submit completed workbooks to ASHRAE for review and receive ASHRAE issuance of a building rating.

- Professional Engineers (PE) licensed in the jurisdiction where the rated building is located
- ASHRAE Building Energy Modeling Professionals (BEMP)
- ASHRAE Building Energy Assessment Professionals (BEAP)

Two separate workbooks, one evaluating As Designed potential and the other assessing In Operation performance, form the foundation of bEQ. bEQ rests on ASHRAE methodologies and standards and the experience of qualified practitioners. These characteristics distinguish bEQ and assure owners that they are receiving reliable and consistent results and recommendations. bEQ was further enhanced and validated using ASHRAE's broad technical resource network consisting of building energy modeling experts, energy assessors and representatives from utilities, government, and the advocacy community.



3.6.5 HERS

Home energy rating systems. Also known as HERS, these compare the energy efficiency of a home to a computer-simulated reference house. The rating involves analysis of the home's construction plans and at least one on-site inspection. This information is used to estimate the home's annual energy costs and give the home a rating between 0 and 100. The higher the score, the more efficient the home.

3.7 Conclusion

1. Building codes and standards for energy conservation are the most basic and powerful measures of improving building energy efficiency and promoting NZEB development. Energy codes and standards play a vital role by setting minimum requirements for energy-efficient design and construction.

2. ASHRAE 90.1 and related standards works as the Model Code as US building energy codes, together with Title 24 of California, all have a clear goal to achieve NZE step by step. The 2016 and 2019 Title 24-Building Energy Efficiency Standards will move the state even closer to the Zero-Net Energy goal.

3. The building energy evaluation standards, including Energy Star Portfolio Manager, LEED, The Home Energy Score, Building Energy Quotient, HERS, which will make revision according to the building energy design codes, all have a positive impact on the promotion of NZEB.

4. Networks & Organizations

4.1 The American Institute of Architects (AIA)

The American Institute of Architects (AIA) 2030 Commitment is a voluntary program for AIA member firms and other entities in the built environment that asks these organizations to make a pledge, develop multi-year action plans, and implement steps that can advance AIA's goal of carbon neutral buildings by the year 2030. Architects are confronting the fact the buildings are the largest single contributor to the production of greenhouse gases and almost half of the total annual production.

Because of their leadership role in the built environment, architects are in an ideal position to alter the construction industry's actions, In order to reach AIA's goal of carbon neutral buildings by 2030, there is a crucial need for design experts to apply their experience, innovations and talents to current practices that will lead to significant reductions in the use of natural resources, non-renewable energy sources, and waste production. To promote the regeneration of natural resources will require a multiple-year effort and we strongly encourage architecture firms nationwide to join us in this endeavor."

Participating firms commit to the following steps in recognition of the AIA 2030 Commitment:

1. Within two months of the commitment date, establish a team or leader to guide the development and implementation of the firm's plan.

2. Within six months of signing the commitment, the firm will implement a minimum of four operational action items from the list provided. These actions will be undertaken while the long-term sustainability plan is in development.

3. Within one year of signing the commitment, the firm will develop a sustainability action plan that will demonstrate success toward the AIA's 2030 goals.

4. Make the sustainability action plan and annual progress reports available publicly by providing them to the AIA for posting on the website and subsequent dissemination.

4.2 The American Council for an Energy-Efficient Economy (ACEEE)

The American Council for an Energy-Efficient Economy (ACEEE), a nonprofit organization, acts as a catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviors. We believe that the United States can harness the full potential of energy efficiency to achieve greater economic prosperity, energy security, and environmental protection for all its people. ACEEE was founded in 1980 by leading researchers in the energy field. Its mission can be concluded as[13]:

- Conducting in-depth technical and policy analyses
- Advising policymakers and program managers
- Working collaboratively with businesses, government officials, public interest groups, and other organizations
- Convening conferences and workshops, primarily for energy efficiency professionals

- Assisting and encouraging traditional and new media to cover energy efficiency policy and technology issues
- Educating consumers and businesses through our reports, books, conference proceedings, press activities, and websites

Since 1980, ACEEE has accomplished a great deal and has become known as America's leading center of expertise on energy efficiency. ACEEE's reputation is based on the high quality, credibility, and relevance of our work, as well as our bipartisan approach. ACEEE's thorough and peer-reviewed technical work is widely relied on by policymakers, business and industry decision-makers, consumers, media, and other energy professionals.

4.3 American Society of Heating and Air-Conditioning Engineers (ASHRAE)

ASHRAE[14] is a global society advancing human well-being through sustainable technology for the built environment. The Society and its members focus on building systems, energy efficiency, indoor air quality, refrigeration and sustainability within the industry. Through research, standards writing, publishing and continuing education, ASHRAE shapes tomorrow's built environment today. ASHRAE was formed as the American Society of Heating, Refrigerating and Air-Conditioning Engineers by the merger in 1959 of American Society of Heating and Air-Conditioning Engineers (ASHAE) founded in 1894 and The American Society of Refrigerating Engineers (ASRE) founded in 1904.

ASHAE's mission is to advance the arts and sciences of heating, ventilating, air conditioning and refrigerating to serve humanity and promote a sustainable world. As for NZEBs has become a hotly debated trend, ASHRAE Standard 90.1, Energy Standard for Buildings except Low-Rise Residential Buildings, is published as a consensus standard to provide minimum requirements for the energy-efficient design of new and renovated or retrofitted buildings. 90.1 has become the basis for building codes, and the standard for building design and construction throughout the United States. 90.1 has recently been approved by DOE as the minimum standard to be met by all states in the U.S.

ASHRAE published < *ASHRAE Vision 2020*>: Develop guidance and strategy for the development of energy-related products, the conducting of research in renewable energy systems, and the sequencing of the various identified activities that will produce net zero energy usage for all types of facilities by 2020. ASHRAE's vision, as articulated in the report, is that the building community will produce market- viable net zero energy buildings (NZEBs) by the year 2030.

While it is acknowledged that NZEB technology is still developing, there are components of that body of knowledge whose aspects should be included in ASHRAE standards and guidelines. These include methods of testing for NZEBs. Additionally, the scopes of Standards 90.1 and 189P should be expanded to include

plug loads, cooking equipment, and refrigeration loads. ASHRAE's Board of Directors has approved Energy Use targets for its code-intended standards:

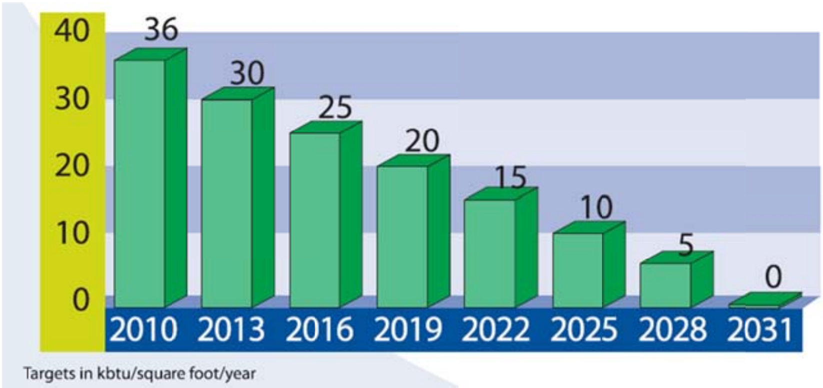


Figure4.1 Energy use target of ASHRAE 90.1

4.4 International Code Council （ICC）

The International Code Council (ICC) was established in 1994 as a non-profit organization dedicated to developing a single set of comprehensive and coordinated national model construction codes. The founders of the ICC are Building Officials and Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International, Inc. (SBCCI). Since the early part of the last century, these non-profit organizations developed three separate sets of model codes used throughout the United States. Although regional code development has been effective and responsive to our economy's needs, the time came for a single set of codes. The nation's three model code groups responded by creating the International Code Council and by developing codes without regional limitations; the International Codes. The International Code Council (ICC), which develops Standards relative to NZE, including the IgCC and IECC.

4.5 Zero Energy Commercial Buildings Consortium (CBC)

The Zero Energy Commercial Buildings Consortium (CBC)[15] is a public/private entity working with the DOE to develop and deliver technologies, policies, and practices to aid the industry in realizing economically viable net zero energy buildings by 2030. This initiative supports the measures set forth in the 2007 Energy Independence and Security Act. The CBC, created in 2009, is open to membership across the industry; as of late 2011, more than 500 organizations had joined. CBC addressed the need for a coordinated, broad-based industry/ government effort to move the entire commercial sector over time, both new buildings and existing stock, to "net-zero" levels of energy performance. The effort must be sufficient in scale to influence the more than $600 billion that commercial building owners spend each year on new construction, renovation, and energy.

In early 2011, the CBC published two reports focused on challenges and recommendations for the advancement of net zero energy building practices. The first, "Next Generation Technologies Barriers and Recommendations," describes barriers to achieving net zero energy related to key building systems, as well as recommendations for system improvements that would accelerate the transition to net zero energy. The second, "Analysis of Cost & Non-Cost Barriers and Policy Solutions", analyzes barriers due to market and policy conditions and provides policy, financing, and other recommendations to address these barriers(Hootman, 2012).

Recognizing that transforming the energy performance of commercial buildings is one of the quickest and most cost-effective ways to slow greenhouse gas (GHG) emissions, while also reducing the impact of rising and increasingly volatile energy prices, several leading organizations prepared the first draft of the Commercial Buildings Initiative Action Plan and convened a series of meetings, starting in October 2006 and culminating in a one-day public workshop in December 2007 with support from the U.S. Department of Energy.

4.6 New Buildings Institute (NBI)

New Buildings Institute (NBI)[16] is a nonprofit organization working to improve the energy performance of commercial buildings. It focused on providing the building industry resources and research for improved energy performance in commercial buildings and worked collaboratively with commercial building market players— governments, utilities, energy efficiency advocates and building professionals—to remove barriers to energy efficiency, including promoting advanced design practices, improved technologies, public policies and programs that improve energy efficiency. NBI also developed and offered guidance to individuals and organizations on designing and constructing energy-efficient buildings through **Advanced Buildings®** suite of tools and resources.

Ever since its establishment in 1997, NBI has become a trusted and independent resource providing guidance and project management services to energy efficiency advocates and commercial building professionals. Among its funders and project partners are the Energy Foundation, U.S. Green Building Council, American Institute of Architects, U.S. Department of Energy, Environmental Protection Agency, and leading electric utilities and public benefits administrators. NBI has released a first-of-its-kind research paper on the current status of net zero energy buildings in the U.S. market. The newest report, "Getting to Zero 2014 Status Update: A look at the projects, policies and programs driving zero net energy performance in commercial buildings" (2014) can be downloaded from the NBI website, www.newbuildings.org, Which is based on extensive research by NBI as well as input from many of the key organizations, states and design firms that are leading the ZNE market (Hootman, 2012).

The Getting to 50 (GT50) & Beyond Program

NBI has compiled projects which have demonstrated or predicted performance that is 30% above the Commercial Building Energy Consumption Survey (CBECS) average for their building use type. Some buildings have also met or exceeded a level of 50 percent better than code requirement for energy use. In each building every effort was made to gather measured energy data, either from utility billings or performance meters, to confirm the actual performance level. NBI regards measured performance as a fundamental necessity in the move towards increasingly lower EUI buildings. The Getting to 50 (GT50) & Beyond database has compiled information on over 100 U.S. commercial buildings with stated energy savings at least 30% beyond comparable or code buildings.

4.7 Architecture 2030

In 2002 architect Edward Mazria, AIA, launched Architecture 2030[17], a nonprofit, non-partisan, independent organization (Mazria E & Kershner K, 2008). The group's mission is to rapidly transform the U.S. and global building sector from being the major contributor to greenhouse gas emissions, to instead becoming central to the solution to climate change, excessive energy consumption, and the resulting economic crises.

Mazria issued the 2030 Challenge, and recently introduced the 2030 Palette, a revolutionary new platform that puts the principles behind low-carbon/zero carbon and resilient built environments at the fingertips of architects, planners, and designers worldwide. This year, he issued the Roadmap to Zero Emissions, and the 2050 Imperative, which had been adopted by the International Union of Architects representing over 1.3 million architects in 124 countries worldwide, as well as all the Regional Architects Councils of Europe, Asia, North America and Latin America.

The organization's 2030 Challenge asks the global architecture and building community to adopt the following targets (Architecture 2030, 2010):

- All new buildings and major renovations shall be designed to meet an energy consumption performance standard of 60% below the regional (or economy) average.
- At a minimum, an equal amount of existing building area shall be renovated annually to meet an energy consumption performance standard of 60% of the regional (or economy) average.
- The fossil fuel reduction standard for all new buildings and major renovations shall be increased to:
  - 70% in 2015
  - 80% in 2020
  - 90% in 2025
  - Carbon-neutral in 2030 (using no fossil-fuel GHG-emitting energy to operate)

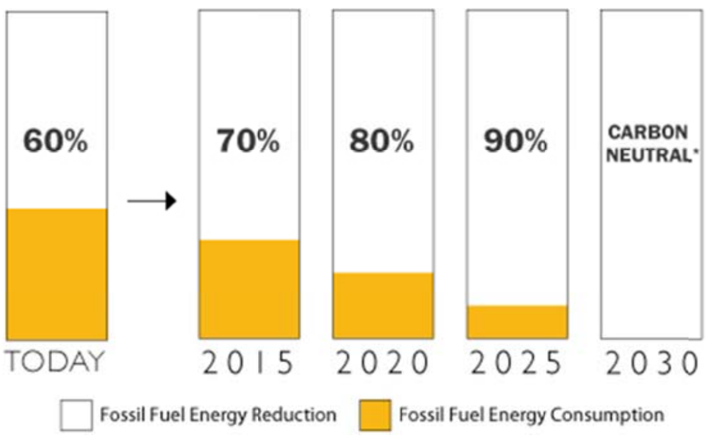


Figure 4.2 The 2030 Challenge

Source: 2010 2030. Inc / Architecture 2030. All Rights Reserved

*Using no fossil fuel GHG-emitting energy to operate

4.8 Conclusion

1. Major institute, council, society and Industry programs have all established Net Zero Energy or similar targets, most of them are more stringent than the federal goal.
2. Different networks and organizations are working on the separately area related about NZEB, which could impact the original task and responsibility of the organization itself while support each other's activities and study at the same time.
3. The activities originated from different networks and alliances have a strong support positive impact on the promotion of the goal set up by the government and have a widely influence to the experts, designers, engineers and all stake holders related with NZEB, which make contribution to the whole value chain.

5.Demonstration Projects

With the consistent efforts that come from all over the world, the number of ZEBs has increased exponentially since 2012. There are 32 ZNE verified buildings and one ZNE verified community district according to NBI research. This set of ZNE verified buildings has a highly impressive average EUI of just 21 kBtu/sf/year — just one quarter of the national average for commercial buildings. Overall EUIs for most of the verified buildings range from 3 to 33 kBtu/sf/year.

ZNE buildings and districts are located in 36 U.S. states. In Figure 5.1 the 36 states with ZNE buildings — either verified or emerging — have a dark solid color and reflect a wide variety of climate zones. ZNE Verified buildings are located in 17 states and the quantity per state is shown in the circle. California is a leader with ten ZNE Verified buildings, and Florida has three.

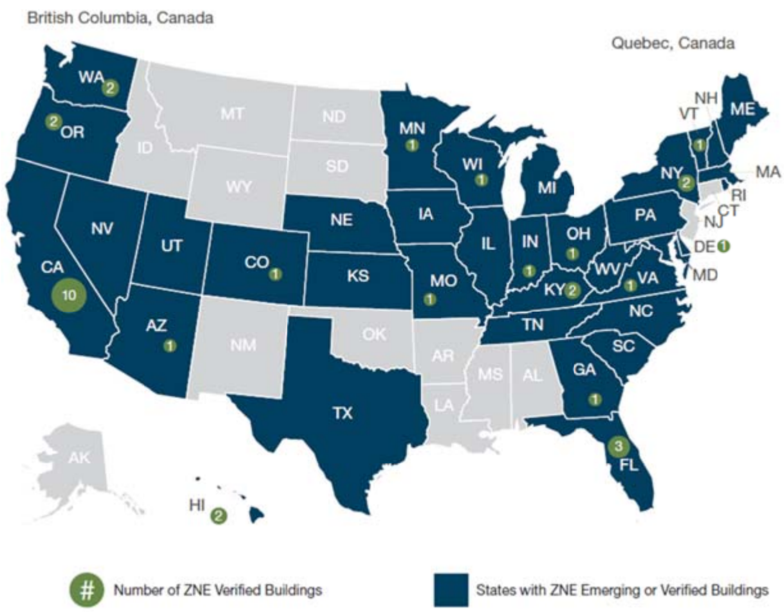


Figure5.1 Locations of ZNE Buildings and Districts
Source: 2014 Getting to Zero Status Update

The status of ZNE buildings show clear growth in every category previously reviewed for the Getting to Zero 2012 Status Update. In 2014 Getting to Zero Status Update, NBI found a total of 160 ZNE buildings and districts compared to 60 in the 2012 report. The ZNE totals for 2014 include 32 buildings and one district that have verified energy performance and 110 buildings and 17 districts that are emerging projects. The 2014 ZNE Emerging list shows the greatest increase — a 182% increase from the 39 buildings identified in 2012. These totals are summarized in Table 5.1.

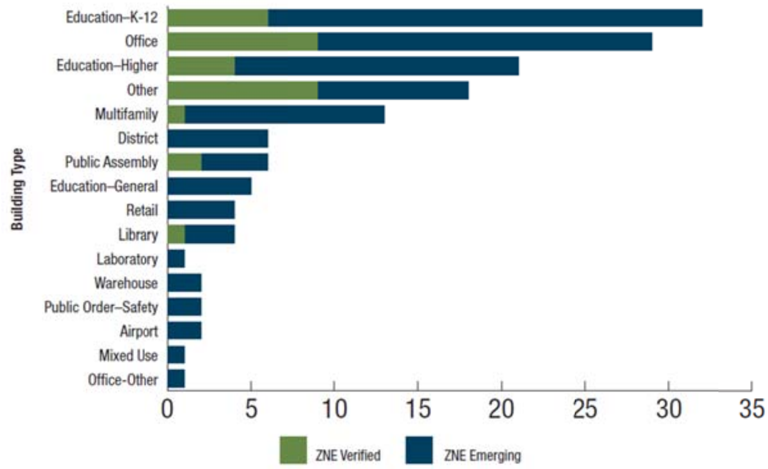


Figure5.2 ZNE Buildings by Type

Source: Cortese A, Higgins C, 2014

The number of buildings achieving ZNE verified performance or those targeting ZNE has more than doubled in just two years, from 60 in 2012 to a listing of 160 projects in this report, although the market is still very small.

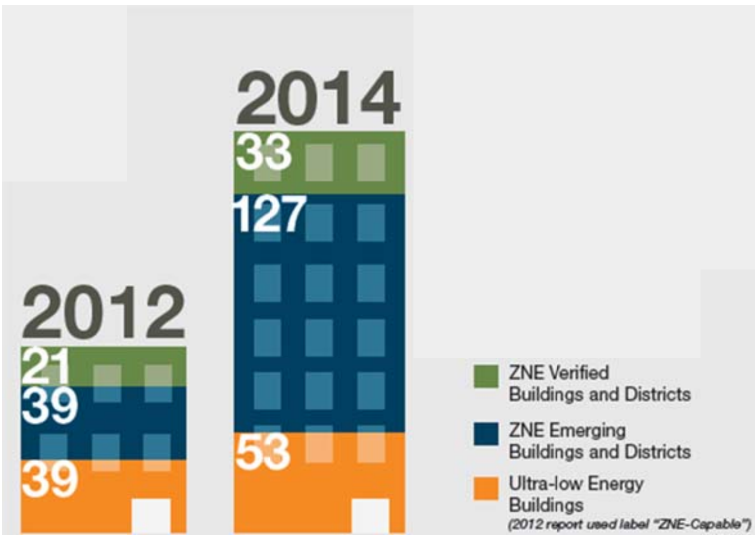


Figure5.3 Number of ZNE projects from 2012 to 2014

Source: Cortese A, Higgins C, 2014

According to the investigation conducted by NBI, More than 50% of the buildings also report using a high performance envelope with increased insulation and well-insulated glazing. Half of the buildings use natural ventilation. These strategies align well with the proven design approach of starting with a good building envelope, access to natural light and ventilation, and an integrated design of building systems.

Table5.1 NZE Totals from 2012 to 2014 Study
Source: Cortese A, Higgins C, 2014

Year	ZNE Verified		ZNE Emerging		Total ZNE Projects
	Buildings	Districts	Buildings	Districts	
2012	21		39		60
2014	32	1	110	17	160

As more documented examples are consolidated, important design strategies are summarized. One noteworthy characteristic of the reported strategies is that nearly all refer to measures and equipment that are commercially available today. Figure5.4 is based on the full set of net zero-capable buildings, The primary difference between the ZEBs and the other ZEC buildings is the addition of PV panels for renewable energy generation, used for each of the 21 ZEB cases listed. In looking more specifically at the ZEB features:

- Four ZEBs in mild climates have completely eliminated traditional HVAC systems and utilize passive strategies to maintain thermal comfort. This includes natural ventilation, thermal mass to moderate temperature fluctuations, and nighttime flushing with cold air.
- When HVAC systems are used, about half of the ZEBs report using a radiant heating/cooling system, often in conjunction with ground source heat pumps.
- The one example of a multi-family building uses a solar thermal system for domestic water heating — typically a large load in residential buildings. Building use patterns and climate also become important when striving for net zero. Based on anecdotal information, many of the net zero buildings are occupied primarily during daylight hours, resulting in little need for artificial lighting.

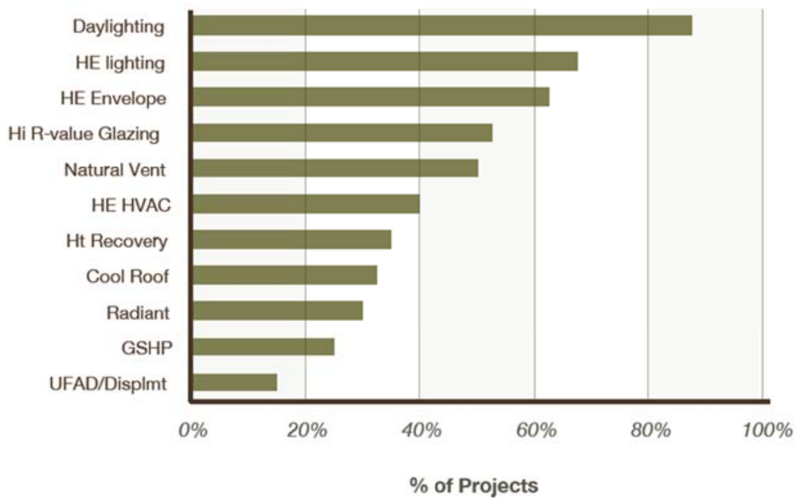


Figure5.4 Technologies used in ZEB and ZEB and ZEC Buildings: Technology Penetration zero energy-capable buildings

5.1 Economic Analysis

Apart from the mandated policies, the best way to spread ZEB is to get consumers to embrace it, not only for residential households, but also for commercial buildings.

The incremental costs to achieve ZNE homes include energy efficiency measures and renewable energy generation costs, typically solar. Builder standard practice costs are the baseline for assessing such costs. Utility and state incentive programs for energy efficiency and solar are then designed to offset a portion of these costs to motivate higher market adoption levels for these measures and practices.

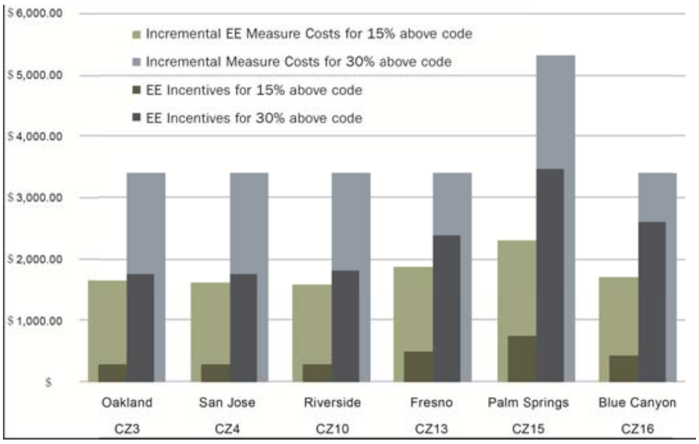


Figure5.5 Incremental cost of achieving 15% and 30% above 2013 Title 24 building energy code and the corresponding offset
Source: NSHP Workshop Dec 2012 presentation

The key in developing ZNE buildings is to reduce their energy demand (Cassidy R, Schneider J W, 2011). An emerging standard for good building performance is a source (or primary) energy use of 100kWh per square meter per year (Knaack U, 2008).2 This translates to a site energy use intensity (EUI) goal of about 12 (thousand Btu/sf/year). (See Table 5.2)

Table 5.2 Assumption for a zone building with PV power
Source: Yudelson Associates, 2011

Required maximum energy demand(source)	100 kWh/sm/year (EUI=31)
Required maximum energy demand(site)	40 kWh/sm/year (EUI=12)
Annual PV system output	1500kWh/kW(peak),AC output
PV system efficiency	15kW/1000sf
PV system cost	$5000/kW(peak), installed
Value of solar PV incentives (tax credits, utility rebates, depreciation)	$2000/kW (peak)

100 kWh/sm/yr @ 3414 Btu/ kWh and 1 sm/10.89 sf, giving a total source EUI of about 30. Ratio of site to source energy use is about 2.5 kWh/kWh for fossil-fuel-fired U.S. electric power, resulting in a site EUI goal of 12.

For energy-efficient and green buildings, enhanced economic benefits can take a variety of forms, starting with lower operating costs. Benefit can acquired from three main aspects: Reduced operating costs; Lower maintenance costs; Tax benefits and other financial incentives. The following lists the wide-ranging benefits of ZNE buildings (Cassidy R, Schneider J W, 2011):

1. Utility cost savings for energy and water, typically $3.00-4.00/sf, along with reducing the

building's carbon footprint due to zero-net-energy use.

2. Maintenance cost reductions from commissioning, monitoring, metering, and other measures to assure proper HVAC system performance.

3. In commercial buildings, increased value from higher net operating income (NOI) and better public relations, owing to higher rents and greater occupancy in LEED-certified buildings.

4. Tax benefits for specific investments in renewable energy and other sustainable technologies, such as those specified in state and federal legislation since 2005.

5. More competitive real estate holdings for private-sector owners over the long run, especially in comparison with LEED-certified new buildings and others that offer lower energy costs.

6. Risk mitigation, especially against future increases in electricity prices (electricity use comprises 70% or more of building energy use).

7. Marketing benefits, especially for developers and building owners.

8. Public relations benefits, especially for developers, building owners, and building management firms.

9. Improved recruitment and retention of key employees.

10. Higher morale for tenants and building owners and managers.

11. Greater availability of equity funding (such as from institutions engaged in so-called "responsible property investing"), including funding for building sales and for upgrading existing building performance to ZNE standards.

12. Demonstration of commitment to sustainability and environmental stewardship, as well as enhancing shared values with key stakeholders.

13. Integrate all the economic factors above, the Database of State Incentives for Renewable Energy and Energy Efficiency, available from the North Carolina Solar Energy Center, is a reliable and fairly complete source of current information on all types of incentives.

5.2 Demonstration Programs

5.2.1 The Research Support Facility

The Research Support Facility (RSF) is the National Renewable Energy Laboratory (NREL) 's newest sustainable green building. This 360,000 ft^2 buildingoccupied by the U.S. Department of Energy's NREL employees, uses 50% less energy than if it were built to current commercial code and achieves the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) Platinum rating. The energy consumption goal for the building is 35kBtu/ft2/year, which is completely offset by onsite photovoltaic electric generation. A rooftop photovoltaic system was implemented through a Power Purchase Agreement; daylighting (Guglielmetti R, Scheib J, and Torcellini P, 2011); natural ventilation; and a next-generation, energy efficient data center are just a few of the energy features of the building.

The RSF is changing the way commercial office buildings are designed and built.

Figure5.6 The front entrance of the RSF
Source: NREL[18]

The RSF showcases numerous high-performance design features, many of which are a direct result of NREL research efforts, including passive energy strategies and renewable energy technology[19].

1. Building orientation and geometry provide daylighting while minimizing unwanted heat losses and gains.
2. A labyrinth thermal storage concrete structure in the crawl space provides passive heating and cooling.
3. Transpired solar collectors passively preheat outside air on the building's south face before delivery to the labyrinth and occupied space.
4. Daylighting from south-facing windows is reflected to the ceiling and deep into the space with light-reflecting devices. All workstations are daylit.
5. Triple glazed, operable windows bring in fresh air to cool the building naturally. Individual window sunshades provide shade when needed.
6. Precast concrete insulated panels provide significant thermal mass to moderate the building's internal temperature.
7. The building is hydronically heated and cooled using thermal slabs in the ceiling instead of forced air. Approximately 70 miles of radiant piping runs through all floors.
8. Underfloor ventilation distributed via a demand-controlled dedicated outside air system when windows are closed on hot and cool days. Evaporative cooling and energy recovery systems further reduce outdoor air heating and cooling loads.
9. An energy-efficient data center uses a combination of evaporative cooling, outside air ventilation, waste heat capture, and more efficient servers to reduce the data center's energy use by 50% over traditional approaches.
10. RSF on-site solar energy (2.5 MW) is installed on the RSF rooftop, visitor parking lot, and

staff parking garage.

The RSF is a living laboratory and researchers use real-time building performance data to study building energy use and make adjustments. The building energy performance will be a matter of great concern. During the first year of occupancy, the RSF's measured whole building energy use is meeting the predicted annual energy use targets. NREL continues to monitor performance and educate RSF occupants about their role in helping ensure that annual energy use goals will be met (Pless S & Torcellini P, 2010). View the Energy Performance Update by NREL's Commercial Buildings Research Group to see predicted versus actual data for lighting, plug loads, heating and cooling use, rooftop PV production, and more.

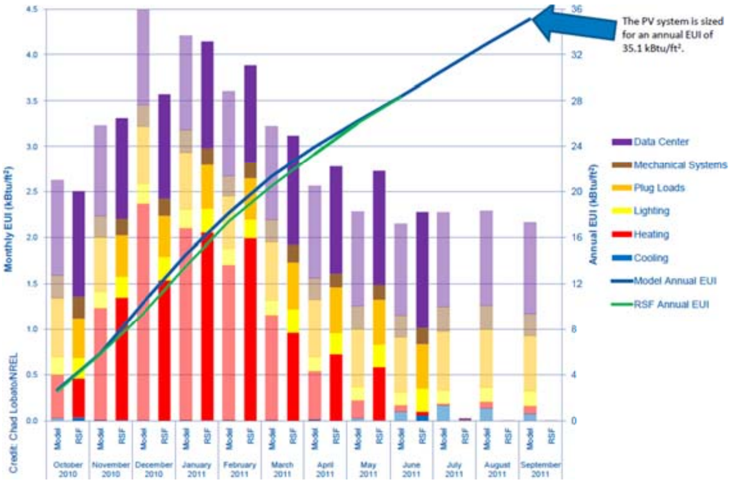


Figure 5.7 Measured versus modeled monthly and cumulative EUI
Source: Energy Goals and Design Features

The technology roadmap for NREL RSF could be summarized as: performance based-procurement, predicting energy use, passive architecture and load reduction, low energy active system, integrated renewable energy, zero energy operation.

5.2.2 The Bullitt Center

Founded by the Bullitt Foundation, the Bullitt Center[20] is known as "the greenest commercial building in the world". The Bullitt Center is achieving extraordinary levels of energy efficiency through integrated architectural and engineering design, cutting-edge technology and components, carefully selected building materials, and conscious choices by tenants who care about their environmental footprints. These elements will reduce the six-story building's annual energy requirement to the point where it can be provided by a solar array on the building's roof.

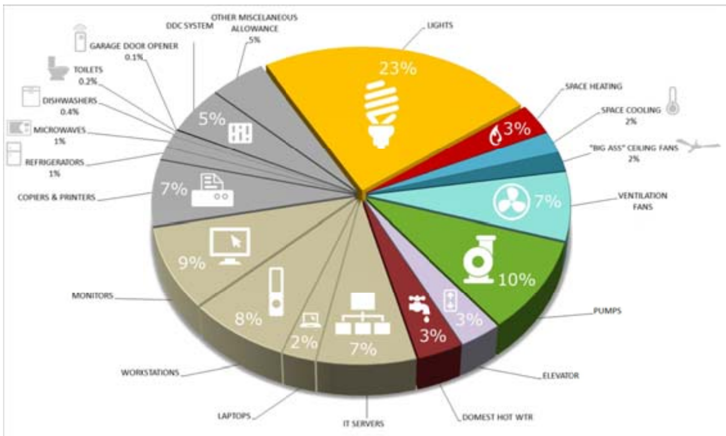


Figure5.8 Bullitt Center Energy Use

In order to achieve the high energy performance goal, designers took a great effort to:

- High performance envelope
- Closed-loop geothermal system and Ventilation
- Radiant floor heating and cooling with passive cooling and natural ventilation
- Daylight dimming and efficient lighting design
- Aggressive reduction of plug loads

Performance data for the building:

Building floor areas:

• Gross Floor Area in square feet (G ft^2): 52,000

• Treated Floor Area in square feet (TFA, common in Europe): 39,000

The building heating, cooling, ventilating and pumping energy combined are only 3.96 kbtu/sf/yr.

Annual End Use Energy Breakdown (in KWH, multiply by 3.412 to convert to kBtu)

The resulting EUI (Energy Use Intensity) for the project is:

• 16 kBtu/ ft^2 based on G ft^2

• 21 kBtu/ ft^2 based on TFA

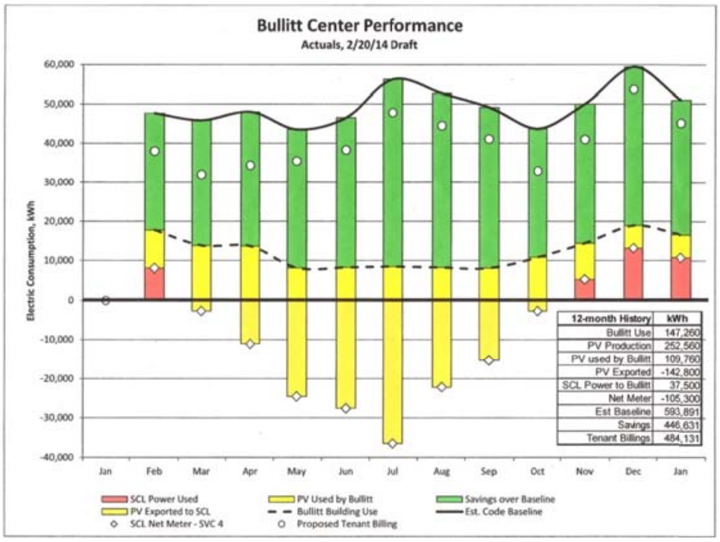


Figure5.9 The first year's energy performance for Bullitt Center

Comparing with other high-performing buildings, there is a lack of good data[21] on high-performing buildings in North America, but from the first year's energy performance data that is available (Figure 5.9) it appears the Bullitt Center will perform at the forefront of energy efficiency.

5.2.3 IDeAs Z2

One good example of a successful NZEB project is the IDeAs Z2 Design Facility. This 6,560-square-foot building in San Jose, CA, reached net zero by renovating a windowless 1960's era bank building. The project team added skylights, high performance windows, and increased insulation. A radiant heating and cooling system is coupled with a ground-source heat pump and displacement ventilation.

Very importantly, extra attention was placed on minimizing plug loads, both through the selection of equipment as well as controls, and designing systems to that managed level of internal loads. Lighting is controlled with occupancy and photo sensors. A custom control sequence was also implemented to shut off specified circuits when the security system is armed at night. This eliminates phantom loads and ensures equipment is not left on overnight. This building is an excellent example of how existing building forms can be adapted into functional zero energy office spaces.

Figure5.10 IDeAs Z2 Design Facility, San Jose, CA

5.3 Conclusion

1. The number of buildings achieving ZNE verified performance or those targeting ZNE has more than doubled from 60 in 2012 to a listing of 160 projects in 2014, although the market is still very small.

2. Net Zero buildings are a reality with successful examples in operation today in almost all the climate zones and most of the building types.

3. The technology roadmap for a demonstration project could be summarized as:

performance based-procurement, predicting energy use, passive architecture and load reduction, low energy active system, integrated renewable energy, zero energy operation.

6.Conclusion

1. Policy and Objective. 41% of U.S. primary energy was consumed by the buildings sector, compared to 30% by the industrial sector and 29% by the transportation sector. Total primary energy consumption is expected to reach more than 45 quads by 2035, a 17% increase over 2009 levels, with a 13% increase in residential sector and a 22% increase in commercial sector. Since the energy consumption of building have a rapid increasing tendency and cause more and more attention, long term bold goal and mid-term action plan are issued by federal government and states: for federal buildings, as of 2020, all planning for new Federal buildings requires design specifications that achieve Zero-Net-Energy use by 2030; for commercial buildings and residential buildings, marketable net zero energy homes by the year 2020 and commercial net zero energy buildings at low incremental cost by the year 2025.
2. Definition. The zero energy definition affects how buildings are designed to achieve the goal also have a relationship with the government subsidy potentially, Executive Order 13514,DOE,CPUC,NBI,ASHRAE,NREL all have the definition of NZEB or similar terms. The key challenge of making definition is how to keep common sense definition of ZNE intact and meaningful while being applicable to all buildings in the near future.
3. Energy reduction possibility and cost/benefit balance. Building energy consumption can be reduced by about 60%-70% by using a broad array of currently accessible and cost-effective technologies. The ZEB goal is not too aggressive and can be achieved for large segments of the commercial sector and residential buildings. Achieving net zero is not only a matter of design, it requires technical support, as well as careful attention to operations and maintenance, together with occupancy patterns and loads. While net zero buildings are possible in most of the buildings with today's technologies, the balance of cost and benefit became an important factor that effect its popularization and application. If the owner has sufficient tax appetite, tax credits and renewable energy credits make the return on investment approximately 30%, whereas the return on investment for energy efficiency alone was in the range of 5-12%.
4. Building codes and standards. Building codes and standards for energy conservation are the most basic and powerful measures of improving building energy efficiency and promoting NZEB development. Energy codes and standards play a vital role by setting minimum requirements for energy-efficient design and construction. ASHRAE 90.1 and related standards works as the Model Code as US building energy codes, together with Title 24 of California, all have a clear goal to achieve NZE step by step. The building energy evaluation standards, including Energy Star Portfolio Manager, LEED, The Home Energy Score, Building Energy Quotient, HERS, which will make revision according to the building energy design codes, all have a positive impact on the promotion of NZEB.
5. Networks and Organization's positive impact. Major institute, council, society and Industry programs related with building, architectures, real estate developers and all stake holders in the construction area have nearly all established Net Zero Energy or similar targets, most of them are more stringent than the federal goal, which could give a positive impact the

original task and responsibility of the organization itself while support each other's activities and future works at the same time. The successful activity of the networks and organizations make contribution to the whole value chain. The development of Net-Zero Energy Building needs cooperation with different industries: HVAC, solar, digital control， machinery manufacturing, etc.

6. The number of buildings achieving ZNE verified performance or those targeting ZNE has more than doubled from 60 in 2012 to a listing of 160 projects in 2014, although the market is still very small.Net Zero buildings are a reality with successful examples in operation today in almost all the climate zones and most of the building types. The technology roadmap for a demonstration project could be summarized as: performance based-procurement, predicting energy use, passive architecture and load reduction, low energy active system, integrated renewable energy, zero energy operation. Now the governments and associations have set up databases to keep the records of system design and operation data of these projects which in return provide guidance for NZEB construction all over the world.

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SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions & Recommendations

Accounting for around 60 percent of world energy demand, the APEC region is a net energy importer and its demand for energy is increasing rapidly. Recently, some APEC developed economies set the goal to achieve Nearly (Net) Zero Energy Building (NZEB) and already launched national policy and objective in the future 2020, 2030 and 2050. The key technology was studied in many research programs and successful demonstration projects were accomplished. This report collects as much as information about the NZEB latest progress in Canada, China, Japan, Korea and the United States, and make comparison and analysis according to the existing information and summary the final conclusion. Also this report makes recommendations and near-term action for stakeholders, which will benefit both developed economies and developing economies.

1. Conclusions

- **Long and Mid Term National Goal of NZEB**

25% to 40% of energy and carbon is consumed in buildings in APEC economies, the percentage could reach to more than 80% in the big cities. The building energy consumption is keeping on increasing and will be higher than the industry and transportation in the near future. Consider the pressure from energy self-sufficiency, environment protection and climate change and the great benefits in the social and economy, the United States, Japan and Korea already set up the goal to realizing ZEB. The goal of Japan is realizing ZEH and ZEB on average for all new buildings by 2030; The goal of Korea is all new buildings are mandatory design to achieve NZE by 2025; For the United States, federal buildings that enter the planning process in 2020 must be designed to achieve NZE by 2030 and Marketable NZEH will be reached by 2020, also Commercial NZEB will be a reality at low incremental cost by 2025

- **National Research Team and Stable Funding**

Comprehensive research Program and national research team set up are critical to reach the NZEB goal because the NZEB cover a broad range of topic, including but not limited to the passive technology, active technology and building energy management system. Canada and Korea had set up national research teams. SNEBRN of Canada has 30 researchers from 15 Canadian Universities, 20 industrial and government partners and 100 grad students, with 6.68 million C$ research funding for 5 years.

- **Building Codes Upgrading towards NZEB**

Building codes and standards are the most basic and powerful measures of promoting NZEB development. Energy codes and standards play a vital role by setting minimum requirements for energy-efficient design and construction. Since 1970s to now, the building energy codes already make 50%-70% energy saves and still have a 70%-90% energy saving potential in the future. ASHRAE90.1 and Title 24 of California in the United States have already set the goal to move to NZE step by step till 2020 and 2030.

- **Financial Support and Subsidy**

Financial support and subsidy of the demonstration project are extremely important in the infant stage of NZEB, which will speed up the development of zero energy building very quickly. Almost all economies in this research have some financial on NZEB related technologies utilization, while Japan and Korea all set up a special subsidy of NZEB. The subsidy received from the support measures in Korea even become higher than the incremental cost of NZEB.

- **Energy Reduction Potential of Demonstration Projects**

The number of buildings achieving ZNE verified performance is increasing very fast. 50% to 80% huge potential of energy reduction could be accomplished in demonstration buildings. Fast payback for energy efficiency investments makes NZEB more affordable.

- **Positive Social & Energy & Environment Influence**

NZEB have a great social & energy & environment influence. Only in Korea, it is estimated that if zero energy buildings are built 10% of the area permitted for building annually, it will not only reduce GHG by 670,000 TCO2eq/year, energy reduction by 180,000 TOE/year, but also create 50,000 jobs with additional cost of USD 4.5 billion.

- **Definition Harmonization in the Future**

The zero energy definition affects how buildings are designed to achieve the goal. It is also related to the government subsidy potentially; several definitions that have similar content need to harmonize in the future. The key challenge of making definition is how to keep common sense definition of ZNE intact and meaningful while being applicable to all buildings in the near future.

- **Networks and Organizations**

Major institutes, societies and alliances have all established Net Zero Energy or similar targets, most of them are more stringent than the federal (national) goal. The activities originated from different networks and alliances have a strong support positive impact on the promotion of the goal set up by the government and have a widely influence to the experts, designers, engineers and all stake holders related with NZEB, which make contribution to the whole value chain.

2. Recommendations

Right now, it is the most important opportunity to promote NZEB among APEC regions since most developed economies have an energy intensity reduction target and new construction is a one-time opportunity to make a big difference on future energy structure of developing economies. The recommendations are:

GOVERNMENT

- Set a long-term, aggressive national target to zero energy buildings with a clear mid-term objective for every step. The goal will support the R& D of research academies and give forward-thinking companies a boost for business planning.

- Financial incentives and subsidy for the pilot and demonstration projects.
- Funding in different climate zones to find the best technology and roadmap to achieve NZEB.
- Harmonize the definition of related terms which will be widely used in the government policies and future action plans.

RESEARCH ACADEMIES

- Kick-off R & D programs which cover passive technology, active technology, renewable energy system, and energy monitoring and management system and technology integration should be
- Testing, evaluation and certification the existing projects that was built with the goal to achieve nearly (net) zero.
- Participate the continuous improvement of building energy code.
- Deeply involvement in the pilot and demonstration buildings.

BUILDING CODES OFFICES AND ORGANIZATIONS

- The building energy code upgrading targets should that get tighter in every 2-5 years. Advanced Energy Design Guide could be developed to give the whole industry a period to prepare the future.
- Provide data and knowledge to researchers and manufacturers to assist in code improvements.
- Compared with the Unites States, funding on the basic research of building energy codes development in other economies should be raised much higher.

NON-GOVERNMENT ORGANIZATIONS

- Lead third-party testing and rating
- Training Programs for designers and architects about the latest, state-of-the-art building science, product development, and building integration opportunities.

REAL ESTATE DEVELOPERS AND ARCHITECTS AND DESIGNERS

- Successful demonstration projects of different type of building in various climate zones are urgently needed to showcase the future to all the related stakeholders, as it is the best way to show the direct energy reduction result and verify the latest research achievements.

INDUSTRY

- Strong regulations create advanced industries, in building envelope, lighting, control systems and other building materials. The materials, equipment and system strongly support the achievement of NZEB.

APEC Project EWG 03/2013A-Nearly (Net) Zero Energy Building

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