ZEB/ZEH ROADMAP

- TECHNOLOGY AND INSTITUTION –

March 2017

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Executive summary

(1) Background and purposes

Energy consumption in the buildings sector accounted for 31% of the final energy demand in the world in 2013. Its share is expected to reach 40% in 2050 according to a scenario close to the business as usual trend (IEA ETP2016 6DS). To achieve the 2ºC goal, it is essential to significantly reduce CO2 emissions. In order to pursue the possibility of achieving this goal, we have studied technologies and systems necessary for realization of the ZEB/ZEH (Zero Energy Building / Zero Energy House) concept intended to achieve net-zero energy consumption.

(2) Structure and contents of technology roadmap

We surveyed roadmaps prepared by international organizations, national governments, local governments, industrial associations, etc. It was found that their descriptions were mainly focused on building envelopes and equipment installed. Most of their descriptions of air conditioning are related to temperature control. However, in moderate and humid regions in Asia, etc. where a huge increase in energy demand is expected in the future, indoor comfort conditions cannot be achieved unless humidity is properly controlled. We proposed a roadmap for each climate zone with both temperature and humidity as important factors. We divided technologies into four groups: Active (equipment), Passive (structures), Renewable energy integration, and Energy management (Fig.ES-1,TableES-1,TableES-2), and indicated estimated periods for realization of each elements (Fig. ES-2). In the classification of technologies, we represent differences caused by the status of new/existing buildings, technical maturity, climatic conditions, etc.

(3) Research and development (R&D) and systems necessary for realizing ZEB/ZEH

In the buildings sector, various types of technologies are used and many stakeholders are involved. In promoting ZEB/ZEH, more advanced technologies are expected to be added and the number of stakeholders is estimated to increase. This trend can be summarized into three points as shown below:

- Involvement of stakeholders (coordination among stakeholders, support for skill development, design guidelines)
- Practical application of R&D results (realization of performance and/or costs exceeding the current technology level, demonstration of elemental technologies and buildings systems, mass-production technology)
- Diffusion (making compliance with building standards obligations, economic incentives such as subsidies and taxes, emphasis on non-energy benefits (human health, business continuity plans (BCPs), real-estate value))

(4) Recommendations

Formulation of the roadmap is consistent with purposes of ICEF. Roadmap direction is set to the development and promotion of introduction of technologies aiming at the reduction of CO2 emissions, a common goal to be pursued with worldwide cooperation, but not to individual goals of national or local governments and industries. In this framework, we would like to deliver the following three recommendations to the world:

- Sharing among the entire society the importance of the concept that net energy consumption in buildings should be zero;
- Involvement of stakeholders in government, municipalities, and the private sector at an early stage (taking into account building lifetimes and diversity of the parties concerned); and
- Sharing of international technologies and policies for their diffusion based on the roadmap.

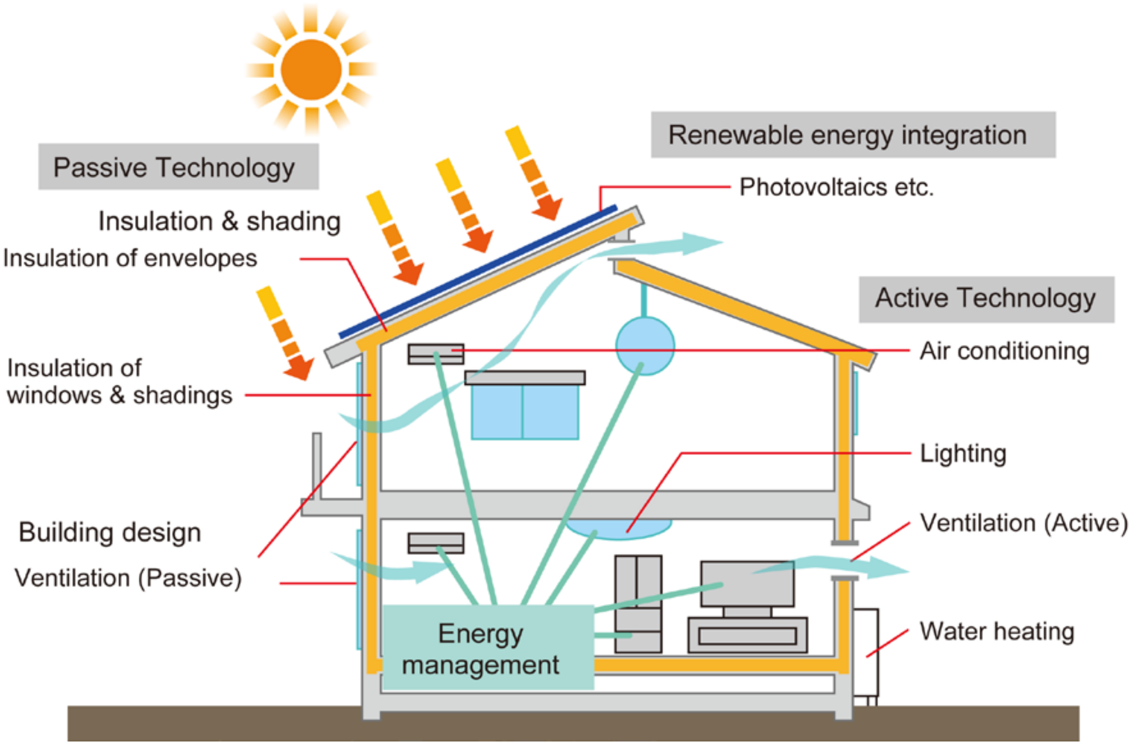

Fig ES-1 Technology categories of ZEB/ZEH

Table ES-1 List of technologies included in the roadmap

○ Passive technology Heat insulation (envelopes, interiors, windows), light shielding, heat reflection (envelopes, roofs, windows), transmission of heat, natural ventilation, realization of airtightness ○ Active technology (air conditioning) Boilers, solar heat source equipment, absorbing-type heat source equipment, heat pumps (electric type, internal combustion engine type), cogeneration (combined heat and power; CHP) (internal combustion engine type, fuel cell type), dehumidifiers (heat pumps, adsorbing type), heat storage ○ Active technology (hot-water supply) Boilers, solar water heaters, heat pumps, cogeneration (internal combustion engine type, fuel cell type), heat storage ○ Active technology (lighting) Incandescent lamps, fluorescent lamps, LED, organic EL ○ Energy management Energy Management System (EMS), communication, equipment corresponding to EMS, passive equipment control, linkage with EV batteries, linkage with smart grids, energy storage unit ○ Introduction of renewable energy Photovoltaics, wind power generation, use of unutilized energy

Table ES-2 Technologies included in the roadmaps

	Technology \ Climate		Moderate & Humid	Cold	Hot
Active technology	Air conditioning	HP (6<COP*1)	✔	✔	✔
		Absorption Chiller	✔		✔
		Solar Cooling	✔		✔
		Solar Heating	✔	✔	
		Dehumidification	✔		✔
	Water Heater	Condensing Boiler	✔	✔	✔
		CHP:(Engine)	✔	✔	✔
		HP	✔	✔	✔
		CHP(FC*2: Gas-fueled)	✔	✔	✔
		CHP(FC: H2-fueled)	✔	✔	✔
	Lighting	LED/Fluorescent	✔	✔	✔
		Organic EL	✔	✔	✔
Passive technology	Ventilation	Room, Floor, Roof, etc.	✔		✔
	Shading	Automatic-type etc.	✔		✔
	Insulation	Envelope UA*3<0.35	✔	✔	✔
		Windows U*4<0.6	✔	✔	✔
	Reflection	Material SR*5>0.75	✔		✔
	Sealing	ACH*6<0.5	✔	✔	✔
Renewables	PV*7	Rooftop use	✔	✔	✔
		Wall side use	✔	✔	✔
	Wind Power	Rooftop use	✔	✔	✔
	Unutilized energy	Earth thermal etc.	✔	✔	✔
Energy management	EMS*8 x IoT*9	Main System	✔	✔	✔
		ICT	✔	✔	✔
		Terminal Unit	✔	✔	✔
		Energy Storage Unit	✔	✔	✔
	Grid Connection	Smart Grid	✔	✔	✔

*1: Coefficient of Performance, Top level, IEA   *2: Fuel Cell
*3: U value is the heat transmission coefficient or amount of thermal transmission per material area and unit temperature - W/m2K). UA is the average U value for wall, floor and roof, IEA
*4: U value of whole window for ZEB, IEA
*5:Solar reflectance, white *6:Air Change per hour *7:Photovoltaics *8 :Energy management system *9:Intenet of things

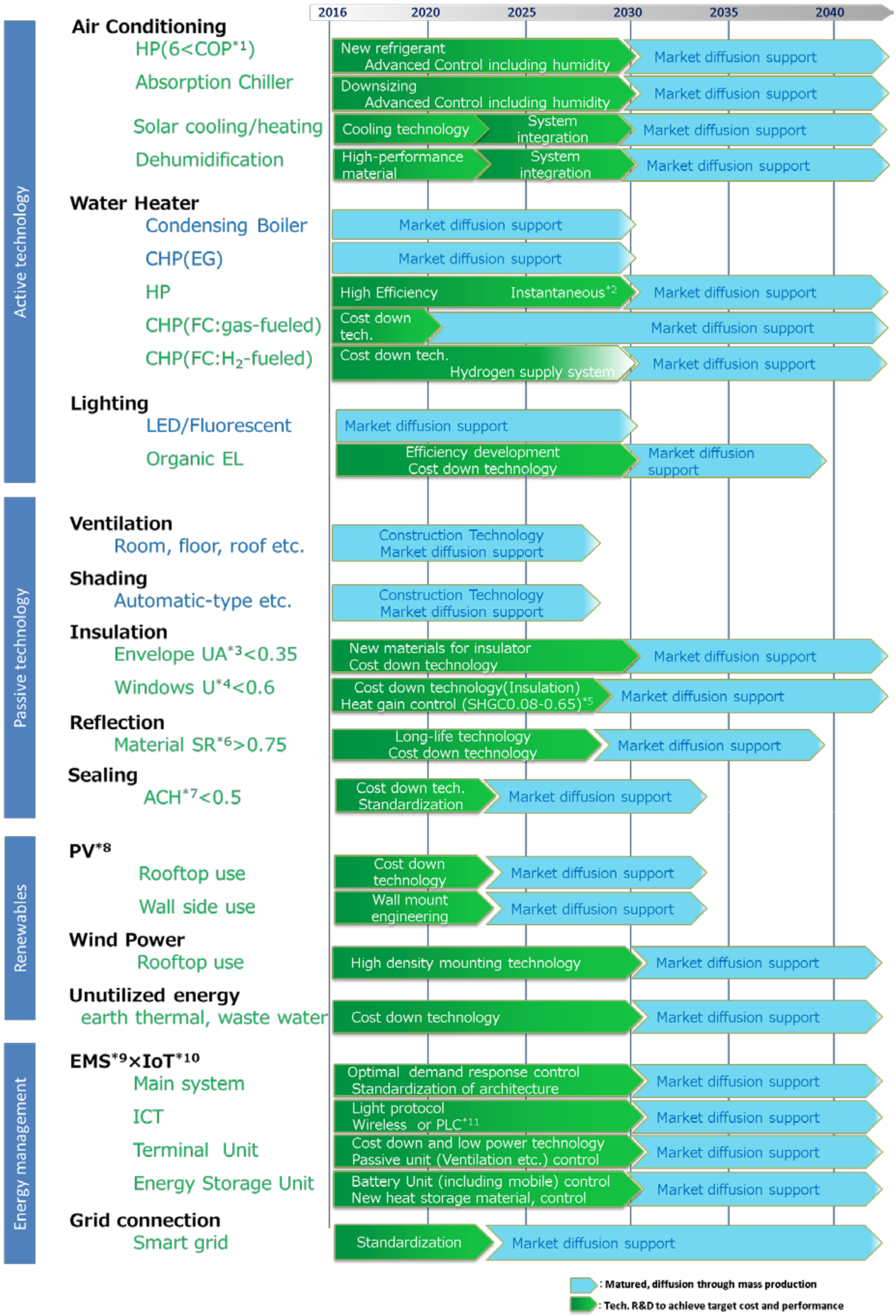

Fig.ES-2 ZEB/ZEH technology roadmap for moderate & humid region

*1:Top level, IEA *2: System without hot water tank *3Avarage U value for wall and roof, IEA *4:U value of whole window for ZEB, IEA *5:Solar Heat Gain Coefficient, IEA *6:Solar reflectance, white *7:Air Change per hour *8:Photovoltaics *9:Energy management system *10:Intenet of things *11:Power line communication

About the authors

This roadmap was created under the research contract of Ministry of Trade, Economy and Industry (METI), by the following team to facilitate discussion at the 2016 Innovation for Cool Earth Forum and for release at COP22:

The Institute of Applied Energy
(http://www.iae.or.jp/e/)
The Institute of Applied Energy (IAE) is a nonprofit organization conducting technology related research in broad energy areas. To secure stable energy supply and address global environmental issues, strategic planning and implementation from long-term and global perspectives are prerequisites. The IAE conducts studies and organizes projects with broad network among industry, academia and the government. The activities of IAE are supported by the contributions from the industry members and research contracts with government agencies, private industries, etc.

Innovation for Cool Earth Forum
(http://www.icef-forum.org/)
The Innovation for Cool Earth Forum (ICEF) is aimed at addressing climate change through innovation. ICEF investigates via discussion what innovative measures should be developed, how innovation should be promoted and how cooperation should be enhanced among stakeholders in fighting climate change.
ICEF is annual event in Tokyo, Japan. The ICEF Steering Committee helps make decisions regarding the agenda and program to reflect the wide range of views of the international community. Policymakers, businesses and researchers from around the globe participate. The ICEF Roadmap Project helps to promote the development and deployment of clean energy technologies with roadmaps released each year.

Acknowledgement

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1. Introduction

1.1 Objectives

It has now become clear that greenhouse gas emissions worldwide will continue on an increasing trend until about 2030, when summing up the goals of the countries (for 2025 or 2030) for the reduction of greenhouse gases submitted, called INDC(Intended Nationally Determined Contributions) in preparation for the 21st session of the Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change.

On the other hand, it goes without saying that accelerated introduction of breakthrough technology related to energy and environment is essential on a long-term basis in order to achieve the goal of keeping the post-Industrial Revolution temperature rise at 2ºC or less in line with the Paris Agreement adopted in COP21. In COP21, "Mission Innovation" was proposed with the support of 20 countries, resulting in agreement on further promotion of investment in research and development. In addition, promotion of harmonization with innovation activities in the private sector was advocated, which led to a renewal of the industry's understanding of the importance of breakthrough technology. In past ICEF conferences, a "Statement" was issued on the last day of each conference to reemphasize the importance of development of breakthrough technology.

In the ICEF conference in 2015, a "Roadmap" was reported where barriers to introduction to the global market of photovoltaic cells and batteries combined are summarized for each region of the world. It is highly necessary in other fields as well to summarize a roadmap for each field as an ICEF initiative.

As a result of a discussion made by the Steering Committee, it was decided in ICEF2016 to develop a roadmap for facilitating development and introduction of technology related to ZEB/ZEH together with CO_2 utilization.

1.2 Background of the study

Roadmaps for facilitating development and introduction of technology related to ZEB/ZEH have been formulated by international organizations, national or local governments, industrial associations, non-governmental organizations, etc. To develop the ICEF2016 Roadmap this time, existing major roadmaps were referred to, and the directionality of facilitation of development and introduction of technology in targeted regions was evaluated and organized.

In preparation for this Roadmap, our efforts were directed, in light of ICEF's objectives, to the facilitation of development and introduction of technology needed for achieving the common goal of reducing CO_2 emissions to be pursued with worldwide cooperation, but were not directed to individual goals set by national or local governments and industrial circles.

1.3 Significance of roadmaps in the ZEB and ZEH fields

Figure 1.3-1 shows a conceptual diagram of the energy system of the building sector. It shows that occupant comfort and other benefits are provided for residents and workers through operation of various types of equipment using energy brought in from outside of the building sector boundary and energy available within the boundary but not yet utilized.

Dotted rectangle represents urban energy system boundary, including three layers. They are urban, buildings, residents/workers. To satisfy services in buildings, end-use equipment consumes energy. There are several energy carriers like electricity, gas, oil products. Generally, oil, gas and electricity are supplied from outside of the boundary, while electricity and heat can be supplied locally within the boundary. In this graph, traditional biomass is not included. However, it is still important supply source in developing regions.

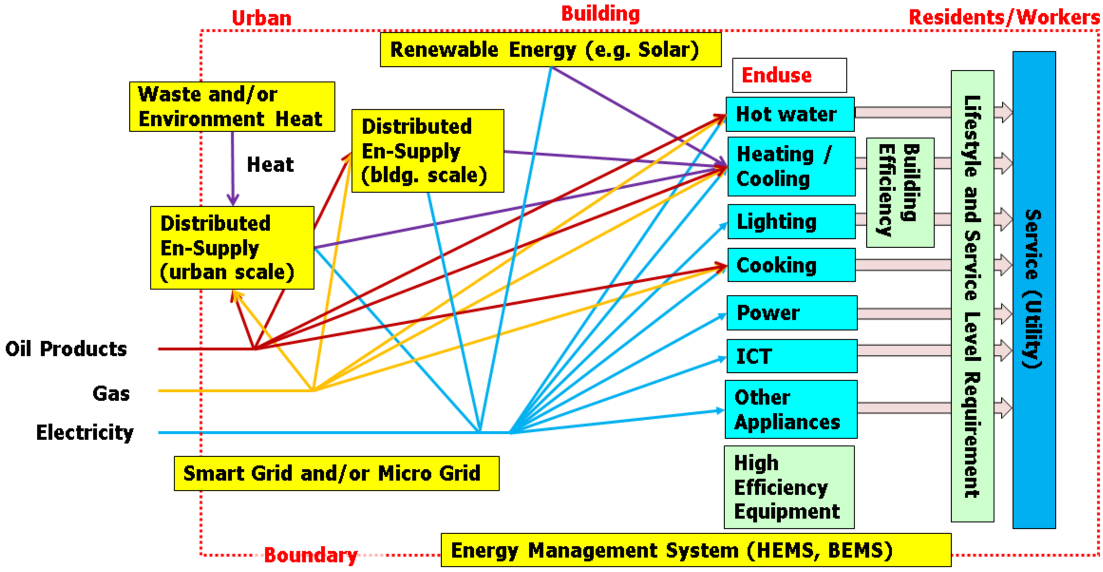

Fig.1.3-1 Energy system in building sector[1]

As discussed later, when studying ZEB/ZEH, it is important to define the scope of benefits in total in which zero energy should be achieved.

Figure 1.3-2 shows energy demand and CO_2 emissions in buildings worldwide in each scenario.

The share of building is 31% of final demand in 2013, while 40% in 2050 in 6DS, assuming 6 degree stabilization (6DS). Most of the growth is from that of developing regions. The main drivers are number of household for residential, floor space for commercial, and appliance increase in type, size and numbers, etc.

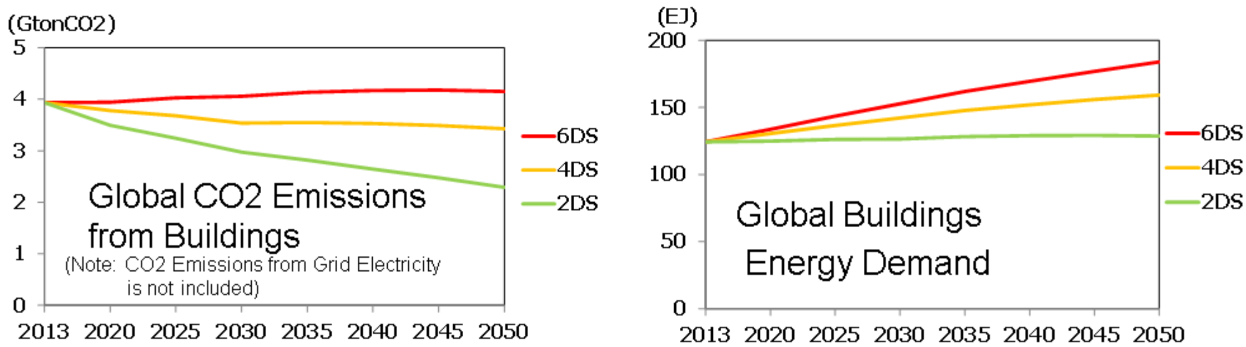

Fig. 1.3-2 Global Buildings Energy Demand and CO_2 emissions from Buildings [1]

However, deep CO_2 cut are required to satisfy temperature rise target adopted in Paris agreement. As for CO_2 emissions reduction from building, IEA ETP's assumption in 2DS, 2 degree stabilization, is around 40% reduction with relative to 2013, and 45% reduction compared to 6DS.

We have to pay attention that this number does not include emissions from grid electricity. In that sense, low CO_2 energy carrier development and its share increase is also crucial.

We propose ZEB/ZEH roadmap as a guide for international cooperation and stakeholder involvement to assist deep cut challenge.

[1] Modified from 'Urban Energy System', Y.Shimoda(2014)

1.4 Survey of existing ZEB/ZEH roadmaps

Various roadmaps related to ZEB/ZEH have been formulated and made public by various international organizations, national governments, local governments, industrial associations, non-governmental organizations, etc. Figure 1.4-1 shows organizations that have developed representative roadmaps, by plotting them on a world map. It shows that, in particular, there are many cases in Europe where this task has been addressed. In North America, industrial circles are dominantly engaged. In Asia, Japan, South Korea, and Singapore have worked on the preparation of roadmaps.

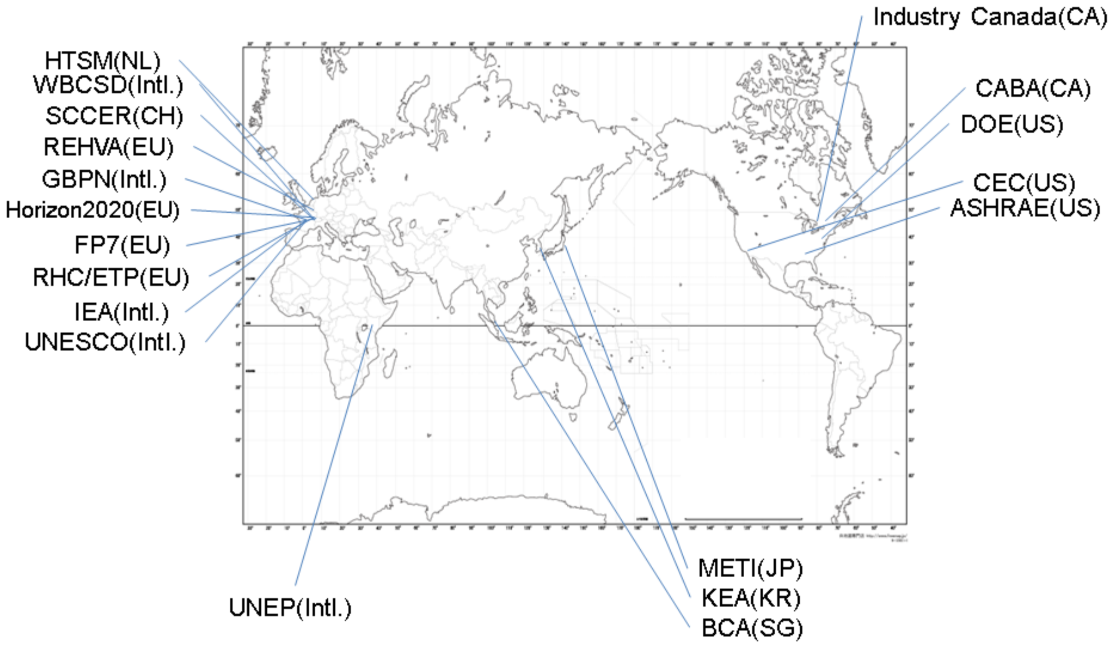

Fig. 1.4-1 World atlas of ZEB/ZEH roadmaps

1.4.1 Roadmaps of international organizations

1.4.1.1 International Energy Agency (IEA)

1) Technology Roadmap Energy-efficient Buildings: Heating and Cooling Equipment [2]

Author: IEA

Date of publication: 2011

Summary:

A roadmap that requires improvement of efficiency of heat source equipment used for heating of buildings and a scenario for introduction of renewable energy. It specifies an introduction goal to respond to the blue scenario.

2) Technology Roadmap Energy efficient building envelopes [3]

Author: IEA

Date of publication: 2013

Summary:

Deals with efficient insulation technology applied to measures to save energy in buildings that require big investment. The roadmap focuses on performance metrics and contents that help improve penetration into the market. However, behaviors of residents and issues of maintenance and durability are not considered here.

3) Transition to Sustainable Buildings Strategies and Opportunities to 2050 [4]

Author: IEA

Date of publication: 2013
Summary:
Presents a detailed scenario and strategy for the shift to buildings with enhanced environmental features toward 2050, including low-cost technology, electricity demand, and leveling of its peaks.

4) Modernising Building Energy Codes to Secure our Global Energy Future The IEA Policy Pathway Series [5]
Author: IEA
Date of publication: 2013
Summary:
Studies how to effectively spread methods of efficient energy use in buildings.

1.4.1.2 World Business Council for Sustainable Development(WBCSD)

1) ENERGY EFFICIENCY in BUILDINGS Business realities and opportunities [6]
Author: WBCSD
Date of publication: 2010
Summary:
States that businesses that promptly engage can win superiority in the market since they can dramatically enhance their current energy efficiency using existing technology while actions are urgently needed to reduce energy use in buildings. It also upholds NZEB as a goal.

2) EFFICIENCY in BUILDINGS Roadmap for a Transformation of Energy Use in Business [7]
Author: WBCSD/Energy Efficiency in Buildings project
Date of publication: 2009.8
Summary:
Summarizes and organizes activities recommended to reduce energy use in buildings for each of short-term, medium-term, and long-term (until 2050) goals, targeting governments, investors, entities pursuing development, employees, energy operators, manufacturers and sellers, and engineers.

1.4.1.3 United Nation Environment Programme (UNEP)

Integrating Solar Thermal in Buildings A Quick Guide for Architects and Builders [8]
Author: UNEP
Date of publication: 2014
Summary:
A guide to spread the use of water heated by solar heat.

1.4.1.4 UNESCO

Roadmap on the Future Research Needs of Tall Buildings [9]
Author: Council on Tall Buildings and Urban Habitat / CIB (International Council for Research and Innovation in Building and Construction) / UNESCO Chair on Sustainability
Date of publication: 2014
Summary:
This roadmap was developed for the purpose of clarifying what research is important for high-rise buildings, how different the current study is from the actual status, and what the order of priority is in working on challenges to be addressed.

1.4.1.5 Global Buildings Performance Network (GBPN)

Best Practice Policies for Low Carbon & Energy Buildings Based on Scenario Analysis [10]
Author: Global Buildings Performance Network
Issuance: 2012
Abstract:

The author conducts scenario-based model analyses on the energy consumption and greenhouse gas emissions in buildings and discusses the lock-in effect and actions that need to be taken in developing countries, urban areas, and each global region.

1.4.2 Roadmaps of governments

1.4.2.1 Japan

1) ZEB Roadmap [11]
Author: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Date of publication: 2015.12
Summary:
Summarized by the ZEB Roadmap Study Committee in December 2015 so as to achieve the policy objective of “seeking to realize ZEB in newly constructed public buildings, etc. by 2020 and in newly constructed buildings on average by 2030” as specified in the Basic Energy Plan (April 2014). It states that a definition should be established within FY2016, and the goal is set at realizing autonomous spread of ZEB toward FY2020 through subsidized projects, initiatives for introduction of ZEB into newly constructed public buildings, branding, training of engineers, setting up of voluntary goals in the private sector, etc.

2) ZEH Roadmap [12]
Author: Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Date of publication: 2015.12
Summary:
Summarized by the ZEB Roadmap Study Committee in December 2015 so as to achieve the policy objective of “seeking to realize Net Zero Energy House (ZEH) in newly built ordinary residences by 2020 and in newly built residences on average by 2030” as specified in the Basic Energy Plan (April 2014). It states that a definition should be established by 2016, and the goal should be to realize ZEH in a majority of newly built residences in 2020 through execution of policies on subsidy for construction, establishment of know-how in builders’ offices, branding, adoption of standard specifications, voluntary action plans set by industry groups, periodic reporting, etc.

3) Energy Efficiency Technology Strategy 2016 Formulated [13]
Author: Agency for Natural Resources and Energy, NEDO
Date of publication: 2016.9
Summary:
Formulated as a guide for turning Japan to an energy-saving nation of the highest level in the world and promoting economic growth through development of energy efficient technology that contributes to “building of a multi-layered and diversified flexible energy supply-demand structure,” “realization of an intensive energy-saving society,” etc. and through steady spread of introduction and global deployment of the technology. It also specifies important fields that can truly contribute to promotion of energy saving, since energy conservation technology related to wide and various fields needs to be prioritized.
For selection of key technologies, the target is technologies that are expected to produce a big effect in 2030, and ZEB and ZEH are positioned as key technological fields in the household and business sectors. It also appraises as cross-sectoral technologies “innovative energy management technology,” “power electronics,” and the “next-generation heat pump system.”

4) Roadmap for Energy-related Technical Development [14]
Author: Advisory Committee for Natural Resources and Energy, Ministry of Economy, Trade and Industry
Date of publication: 2014.11
Summary:

Revises appreciation of the technical development project and others that were summarized in the "Innovation Plan for Environmental Energy Technology" (decided in September 2013 by the Council for Science and Technology Policy), based on the above-stated issues subject to the Fourth Basic Energy Plan. As for energy-saving residences and buildings, it describes the intention to develop energy-saving technology, optimization technology for heat-insulating materials and windows, and construction technology suitable for the climate and natural features of Japan to achieve the goal of realizing ZEB/ZEH in newly constructed residences and buildings on average by around 2030.

5) Innovation Plan for Environmental Energy Technology [15]
Author: Council for Science and Technology Policy, Cabinet Office
Date of publication: 2013.9
Summary:
Summarized for the G8 Hokkaido Toyako Summit of 2008. It states that there is a need for research and development of innovative technologies in addition to further spread of existing technologies. As for energy-saving residences and buildings, it describes in the attached roadmap its intention to develop energy-saving technology, optimization technology for heat-insulating materials and windows, and construction technology suitable for the climate and natural features of Japan to achieve the goal of realizing ZEB/ZEH in newly constructed residences and buildings on average by around 2030.

6) About Future Energy-Saving Measures for Houses and Buildings（First Report） [16]
Author: Infrastructure Development Council
Issuance: 2015
Abstract:
The author discusses regulatory approaches to the promotion of energy savings in buildings and, in combination with other supportive measures (incentives, information provision, etc.), suggests policy directions. The author also suggests measures for new and existing buildings and different measures for privately-owned and leasehold buildings.

1.4.2.2 USA

1) Research & Development Roadmap for Emerging HVAC Technologies [17]
Author: DOE / BTO[2] ＆EERE[3] / Prepared by Navigant Consulting, Inc.
Date of publication: 2014.10
Summary:
BTO has made it a goal to reduce primary energy consumption related to buildings by 50% by 2030 in comparison with 2010, and especially set the HVAC energy-saving objective at reduction by 12% by 2020 and by 24% by 2030. In order to achieve the goal and objective, this Roadmap extracts challenges in related fields, prioritizes the challenges to be addressed, and specifies guidelines for necessary activities.

2) Research & Development Roadmap for Emerging Water Heating Technologies [18]
Author: DOE / BTO＆EERE / Prepared by Navigant Consulting, Inc.
Date of publication: 2014.9
Summary:
BTO has made it a goal to reduce primary energy consumption related to buildings by 50% by 2030 in comparison with 2010, and especially set the heated-water energy-saving objective at reduction by 19% by 2020 and by 37% by 2030. In order to achieve the said goal and objective, this Roadmap extracts challenges in related fields, prioritizes the challenges to be addressed, and specifies guidelines for necessary activities, including

[2] Building Technologies Office, DOE
[3] Office of Energy Efficiency and Renewable Energy

formulation of systems that are simple and low cost, easily used by the entities who install them and end-users, and based on an understanding of the relationship between water and energy.

3) Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies [19]
Author: DOE／BTO＆EERE/ Prepared by Energetics Incorporated
Date of publication: 2014.2
Summary:
Commercial buildings for residence, the number of which is 85 million, account for about 40% in carbon dioxide emissions from the primary energy in the US. Construction of this type of buildings continues, and it is expected that their number will exceed 100 million by 2035. The 2013 State of the Union Message stated that energy loss in this sector would be reduced by 50% in the next 20 years, and it also developed a roadmap for technical development to address this issue. The main target of the technical development is heat insulation using heat-insulating materials and window glass.

4) Solid-State Lighting R&D Plan [20]
Author: DOE／BTO＆EERE
Date of publication: 2015.5
Summary:
A technical development plan for LED lights. The goal is set at 250 lm/W, and it is intended to carry out improvement of materials, heat-resistant sealing materials, optical radiation structures, integration technologies, etc., where cost reduction is also taken into account.
Budgetary measures have been taken with 25.8 million dollars allocated to Solid-state lighting (SSL) research and development in FY2015, with the industrial sector given 90% and universities given 10% of the amount.

5) Manufacturing Roadmap Solid-State Lighting Research and Development [21]
Author: DOE/Prepared by Bardsley Consulting, Navigant Consulting, SB Consulting, and SSLS, Inc.
Date of publication: 2014.8
Summary:
A technical development roadmap for LED lights and OLED[4] where a very detailed analysis is made related to the current status of a wide range of technologies, covering materials, methods of manufacture, and costs, and thereby challenges to be addressed are extracted. It estimates that costs can be reduced by 50%, with a view to 2020, through integration of various types of technical development.

6) Research & Development Roadmap for Next-Generation Appliances [22]
Author: DOE / BTO＆EERE / Prepared by Navigant Consulting, Inc.
Date of publication: 2014.10
Summary:
This roadmap was developed under the recognition that previous efforts towards energy saving were insufficient, although equipment for household use, such as refrigerators, dishwashers, and washing machines, accounted for 12% of the primary energy consumption in the residential sector. It focuses on deployment of innovative technologies, including linear compression machines, vacuum insulation, magnetic refrigeration, HP drying machines, control equipment, etc.

7) Research & Development Roadmap for Next-Generation Low Global Warming Potential Refrigerants [23]

[4] Organic Light Emitting Diode

Author: DOE / BTO＆EERE / Prepared by Navigant Consulting, Inc.
Date of publication: 2014.11
Summary:
A roadmap for the development of an alternative refrigerant.

8) Final Report Federal R&D Agenda for Net Zero Energy High-Performance Green Buildings [24]
Author: Approved by the NSTC[5] Committee on Technology
Date of publication: 2008.9
Summary:
A U.S. government document that defines the contents needed for Net Zero Energy Building and establishes the directionality of the technical development needed to achieve these contents.

9) INDOOR ENVIRONMENTAL QUALITY RESEARCH ROADMAP 2012–2030: ENERGY-RELATED PRIORITIES [25]
Author: for California Energy Commission
Date of publication: 2013.6
Summary:
The objective is to verify the 2002 Report and clarify needs of the Indoor Environmental Quality (IEQ) study for policies to achieve full introduction of ZEB/ZEH into newly constructed buildings.

10) Quadrennial Technology Review, An Assessment of Energy Technology and Research Opportunities, Chapter 5 — Increasing Efficiency of Buildings Systems and Technologies [26]
Author: DOE
Date of publication: 2015
Summary:
The author describes energy-saving technologies of buildings comprehensively and summarizes the current status and future direction of research and development. In addition to technological issues, the author discusses how to improve the inefficient behavior of consumers and, in this context, suggests energy-saving measures from the viewpoint of behavioral science using big data.

1.4.2.3 EU

1) ENERGY EFFICIENT BUILDINGS Multi-annual roadmap for the contractual PPP under Horizon 2020 [27]
Author: EU International Non for Profit Industrial Association E2B European Construction Technology Platform
Date of publication: 2013
Summary:
It intends to contribute to a 50% reduction in energy and an 80% reduction in carbon dioxide in comparison with 2010 through establishment of 40 or more new technologies and their product commercialization, aiming to achieve the strategic goal of fostering a highly efficient building industry and raising energy efficiency to a sustainable level.
It also refers to the innovation of ICT with cross-sectional functions in addition to improvement of efficiency of individual technologies related to structure, heat insulation, heat source, etc.

2) How to Refurbish All Buildings by 2050 Final Report [28]
Author: THINK[6] EU

[5] National Science and Technology Council

Date of publication: 2012.6
Summary:
Summarized in the SET Plan[7] as support for a policy decision by EC.

3) Draft of Innovation and Research Roadmap [29]
Author: READY4SmartCities[8] EU
Date of publication: 2015.9
Summary:
This report is a draft of innovation and research roadmap suggesting research and technical development (RTD) and innovation activities in short, medium and long term for ICT supporting energy systems of smart cities. This document is purposed to be used as a draft roadmap for expert consultations.

4) EREADY4SmartCities - ICT Roadmap and Data Interoperability for Energy Systems in Smart Cities [30]
Author: EVTT Technical Research Centre of Finland
Date of publication: 2014
Summary:
The author discusses energy systems in ICT-based smart cities and offers suggestions about future buildings in this context. The author enumerates actions that need to be taken by each group of stakeholders including citizens, the building industry, energy companies, and local governments and points out the importance of coordination among all stakeholders.

1.4.2.4 Swiss

Future Energy Efficient Buildings & Districts-Research and Innovation Roadmap [31]
Author: Swiss Competence Center for Energy Research
Date of publication: 2015.3
Summary:
Specifies each work plan for penetration of the insulation structure, energy management, the distributed energy system, and technology with the target set at a 63% reduction in energy demand and a 77% reduction in carbon dioxide emission in 2050.

1.4.2.5 Singapore

1) 3rd GREEN BUILDING MASTERPLAN [32]
Author: Building Construction Authority, Singapore
Date of publication: 2014.9
Summary:
This is a master plan concerning the Green Building concept launched by the Singaporean government, and it specifies an ideal state of Green Buildings. It describes guidelines for establishing technology suitable for tropical and subtropical zones, processes to manage resource usage, the marking system for Green Buildings, and education and training of experts while stating that budgetary measures should be taken with support from subsidies, etc.

2) Building Energy Efficiency R&D Roadmap [33]
Author: Building Construction Authority, Singapore / NATIONAL RESEARCH FOUNDATION PRIME MINISTER'S OFFICE / National Climate Change Secretariat Prime Minister's Office
Date of publication: 2013

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[6] THINK was an FP7-financed project that advised the European Commission (DG Energy) on a diverse set of energy policy topics from June 2010 until May 2013. In total, 12 reports were produced over this period
[7] The European Strategic Energy Technology Plan (SET-Plan), aims to accelerate the development and deployment of low-carbon technologies.
[8] ICT Roadmap and Data Interoperability for Energy Systems in Smart Cities financed by FP7

Summary:
Mainly aims at providing short-term (2013-2016), medium-term (2016-2020), and long-term (2020-2030) recommended policies while determining the gap with the current technology, prioritizing issues, and creating a roadmap to enhance the energy efficiency of buildings.

1.4.2.6 Korea

Korea Energy Efficiency Policies [34]
Author: Ministry of Trade, Industry and Energy / Korea Energy Agency
Date of publication: 2014.9
Summary:
Specifies the energy standards and the labeling system in South Korea and states the intention to spread them. It also introduces policies adopted by other countries in order to disseminate them. The labeling system is also applied to buildings.

1.4.3 Roadmaps of business communities

1.4.3.1 HVAC industry

1) REHVA nZEB technical definition and system boundaries for nearly zero energy buildings, 2013 revision for uniformed national implementation of EPBD recast prepared in cooperation with European standardization organization CEN Report No.4 [35]
Author: REHVA[9]
Date of publication: 2016.6.15
Summary:
Summarized and compiled, with a focus on ZEB, mainly for related definitions by the Refrigeration and Air Conditioning Industry Association of the EU in cooperation with the European Committee for Standardization (CEN[10]).

2) ASHRAE's Sustainability Roadmap The approach to defining a leadership position in sustainability [36]
Author: ASHRAE[11]
Date of publication: 2006.1
Summary:
A technical development roadmap of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). Its focus is on education.

3) ASHRAE Vision 2020, Providing tools by 2020 that enable the building community to produce market-viable NZEBs by 2030 [37]
Author: ASHRAE
Date of publication: 2008.1
Summary:
The American Society of Heating, Refrigerating, and Air-Conditioning Engineers presents its visions for achieving Net Zero Energy Building (NZEB) by 2030.

1.4.3.2 Chemical industry

ICCA Building Technology Roadmap, The Chemical Industry's Contributions to Energy and Greenhouse Gas Savings in Residential and Commercial Construction [38]
Author: ICCA [12]

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[9] Federation of European Heating, Ventilation and Air Conditioning Associations
[10] Comité Européen de Normalisation
[11] American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.
[12] International Council of Chemical Associations

Date of publication: 2014.8
Summary:
Presented by an international organization of the chemicals industry to summarize technologies applicable by 2050 so as to contribute to reduction in CO_2 emissions in the buildings sector.

1.4.3.3 Others

Intelligent Buildings: The Pase and the Future [39]
Author: CABA[13]
Date of publication: 2015.9
Summary:
An effort arranged by the industry of building instrumentation, where the directionality of Building Energy Management System (BEMS) is summarized.

[13] Continental Automated Buildings Association

1.5 Definition and Goal of ZEB/ZEH

ZEB or ZEH is acronym of net zero energy building or house, assuming annual net energy consumption is nearly zero. The goal is net zero consumption in buildings around mid-century to prepare long-term zero emission target.

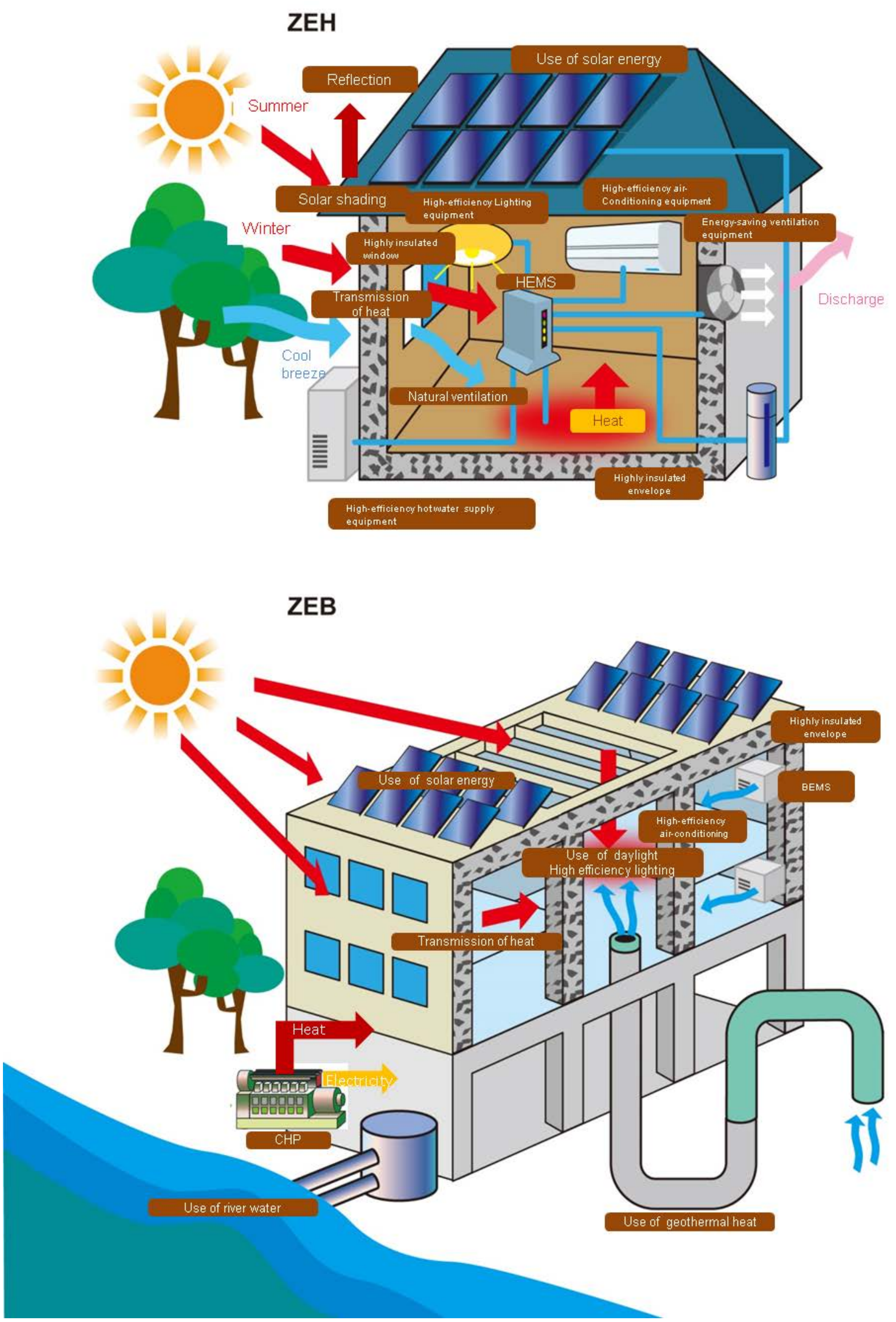


Fig.1.5-1 Images of ZEB & ZEH

It will be achieved by energy conservation and renewable energy integration, but criteria of certain degree of energy conservation should be satisfied.
There are several ZEB/ZEH definitions. Four examples from US, Europe and Japan were picked up and listed in Table 1.5-1.

Table 1.5-1 Definitions of ZEB/ZEH[14]

	DOE[15], USA	NREL[16], USA	REHVA[17], Europe	Japan[15]
Year	2015	2006/2010	2013	2015
Design or Operation	Operation	Design/ Operation	Design	Design
Target Devices	HVAC[18], Water heating, Lighting, Power outlet, Energy exchanged and transformed in building	HVAC, Water heating, Lighting, Power outlet, Energy exchanged and transformed in building	HVAC, Water heating, Lighting	HVAC, Water heating, Lighting, Elevators and moving stairs
Renewable Energy Integration	On-site, On-site + Off-site (for small houses)	Categorized On-site On-site + Off-site	Only On-site	Only On-site
Category of ZEBs	ZEB: annual primary energy use is recovered by on-site renewable energy	ZEB: annual energy use is recovered by renewable energy Near ZEB: built as ZEB, but does not met because of weather and operation etc.	PEB[19]: net AnREU[20] < $0kWh/m^2yr$ ZEB: AnREU < $0kWh/m^2yr$, self sufficient nZEB: net AnREU = $0kWh/m^2yr$ nnZEB: $0kWh/m^2yr$ < net AnREU < limit of individual country	ZEB/ZEH: PEC[21] is less than 100% from the standards Nearly ZEB/ZEH: PEC is less than 75% from the standards ZEB ready: PEC is less than 50% form the standards
Building types	Building, Campus, Portfolio, Community	Building	Building	ZEB: Building ZEH: Detached house

There exist some differences in assessment phase (design and operation), target devices, as well as treatment of renewable energy integration (on-site and off-site). Some differences in ZEB/ZEH categories and building types are found. About categorization, some focus on net primary energy, while European REHVA indicator is annual non-renewable energy use.

[14] ZEB/ZEH roadmap committee report, Dec,2015(in Japanese)
[15] Department of Energy
[16] National Renewable energy Laboratory
[17] Federation of European Heating, Ventilation and Air Conditioning Associations
[18] Heating, Ventilation and Air Conditioning
[19] Plus energy building
[20] Annual non-Renewable Energy Use
[21] Primary energy consumption

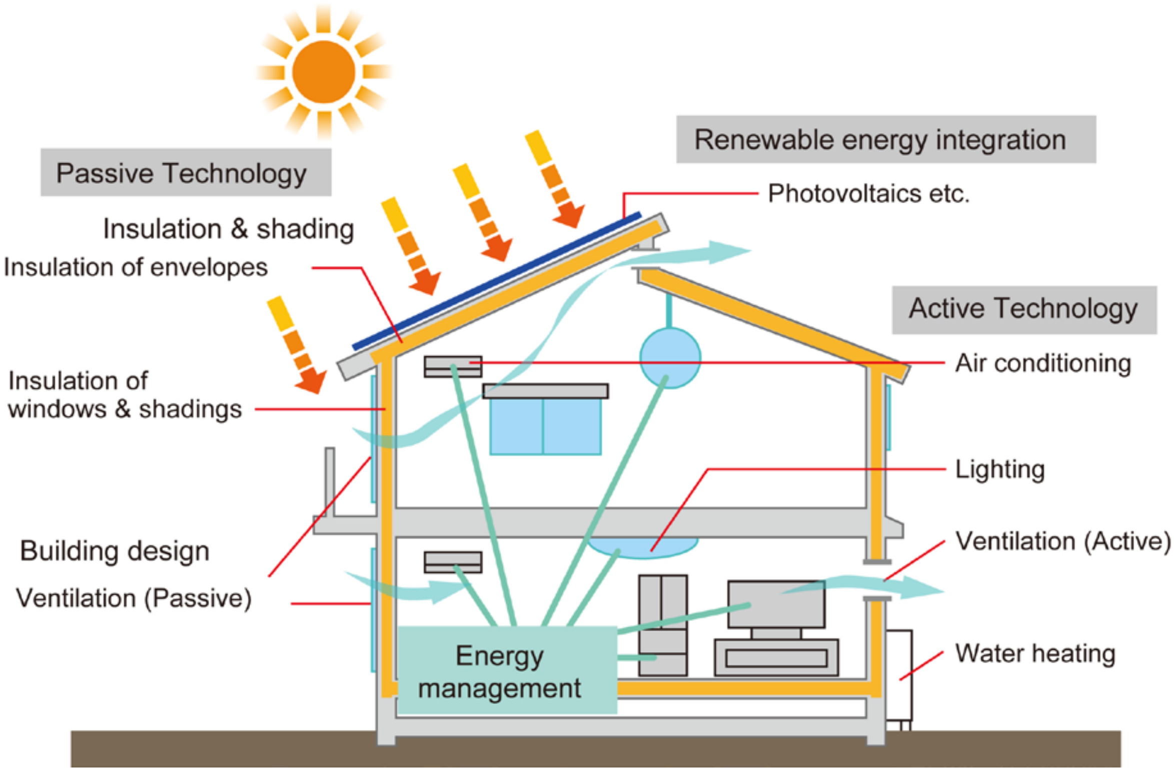


Fig 1.5-2 Technology categories for ZEB/ZEH

We propose four technology categories indicated in Fig.1.5-2. They are passive, active, renewable energy integration and energy management. Most of our work focuses on passive and active. As for renewable integration and energy management, we thought most issues are covered by existing energy roadmaps such as photovoltaics and smart grid.

1.6 Roadmap Variations by Climate and Air Conditioning

1.6.1 Climate and Air Conditioning

One of the characteristics of new roadmap proposal is representation in air conditioning. Most roadmaps in the past had little attention to humidity in air conditioning. Both temperature and humidity should be controlled within proper ranges, to satisfy the comfort, health and productivity objectives.

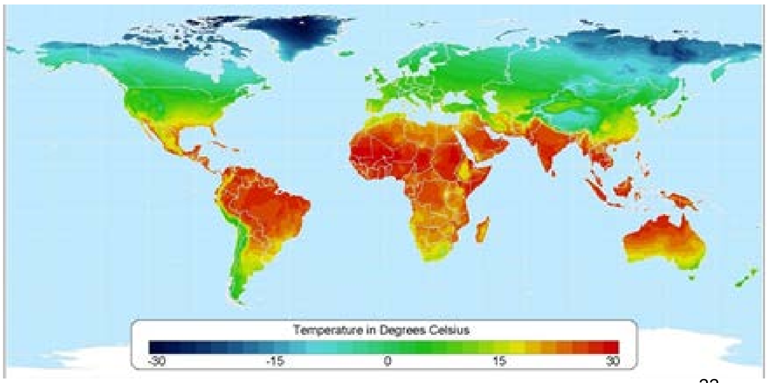


Fig.1.6.1-1 Average temperature map of the world[22]

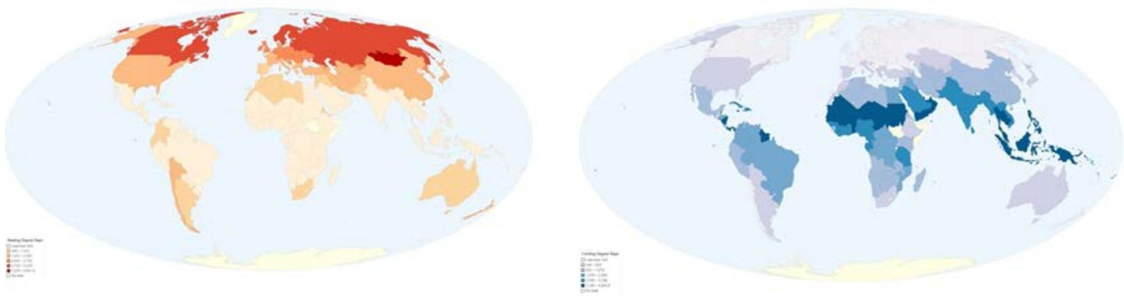


Fig.1.6.1-2 Heating and Cooling demand of the world[23]

Figure 1.6.1-1 shows the global average temperature. There is a difference in average temperature of 60°C among regions where people live. Figure 1.6.1-2 shows the geographical distribution of demand for heating and cooling. The world map on the left shows demand for heating, and the deeper the red color of a region is, the larger the demand in the region is; the world map on the right shows demand for cooling, and the deeper the blue color of a region is, the larger the demand in the region is. In most of the roadmaps presented so far, demand for air conditioning has been judged based on temperature.

The objective of use of air conditioning in buildings is to properly prepare and set an environment so that people can live comfortably and work efficiently for their business. Environmental factors that have an influence on people's comfort are the four elements, namely temperature, humidity, air current, and radiation, in addition to factors on the human side, the metabolic quantity (quantity of work) and the amount of clothing. The environmental factor next to temperature that has the largest influence on people's comfort is humidity.

[22] Source: Wisconsin U. original data from CRU, U. East Anglia
[23] Source: WRI

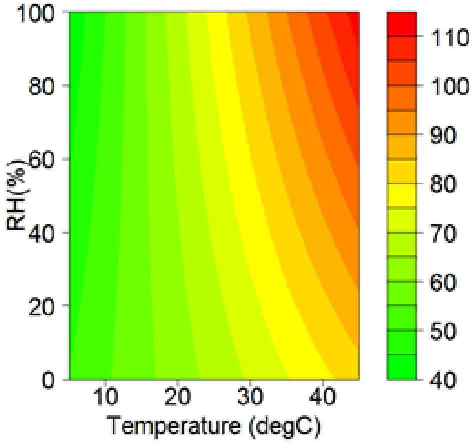


Fig.1.6.1-3 Discomfort index

Figure 1.6.1-3 shows the Discomfort Index (DI) distribution. DI is expressed by the following formula.

$$DI = 0.81T + 0.01H(0.99T - 14.3) + 46.3$$

Where T is the ambient temperature in Celsius and H is the relative humidity

Although it is said that, generally speaking, everybody feels discomfort and work efficiency decreases when the DI exceeds 80, attention should be paid to the fact that the DI becomes 80 at a temperature of 37℃ with a relative humidity of 20% but also at 27℃ with a relative humidity of 90%, which shows a temperature difference of 10℃. This temperature difference is expanded to 15℃ between 0% and 100% of relative humidity. When using the current technology, the amount of energy needed for air conditioning changes significantly subject to difference between ambient temperature and temperature inside the room. Therefore, there is a technical possibility that energy for air conditioning can be substantially reduced while maintaining comfort by reducing the difference between temperatures inside and outside the room while properly controlling humidity.

1.6.2 Roadmap variations

Figure 1.6.2-1 shows the average relative humidity distribution in the world. It shows that heavily populated regions such as southern China, Southeast Asia, India, and tropic Africa / Latin America have high relative humidity. Figure 1.6.2-2 shows a difference in energy demand for cooling between different scenarios, which was summarized by IEA in ETP2016. The growth of demand for cooling is very large in non-OECD countries and, furthermore, the difference between the 6°C and 2°C scenarios in these countries is also large, so that they need to cut the demand by half. Even from this point of view, it is important to suppress energy demand for air conditioning in non-OECD countries. Of course, it is important to suppress energy demand for air conditioning in OECD countries, and, specifically in the 2°C scenario, energy saving of 10% or so from the current level of energy used is required.

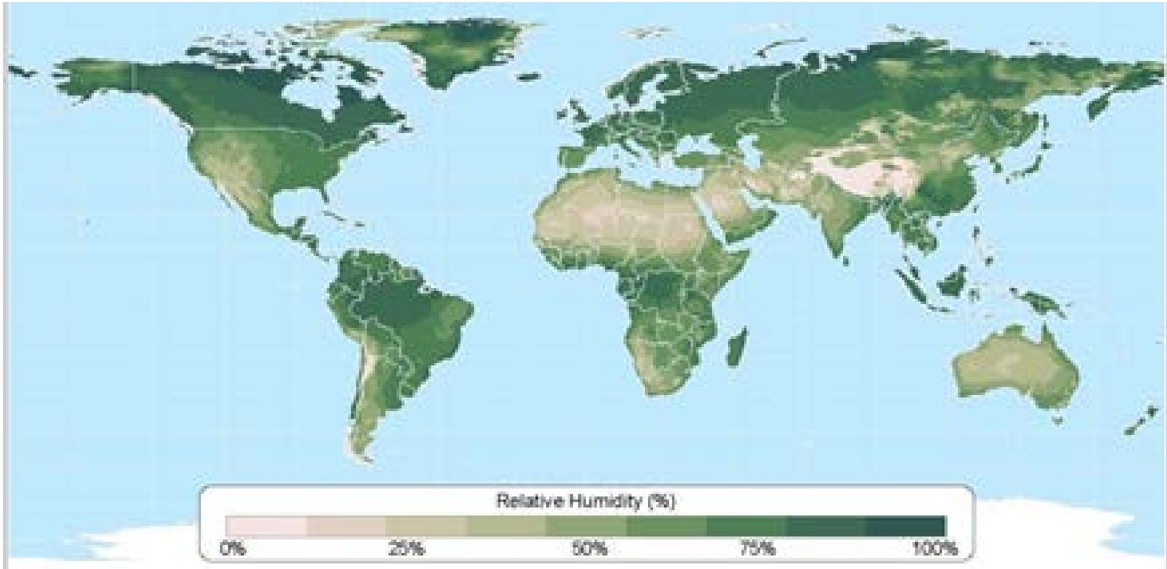


Fig.1.6.2-1 Average Relative Humidity of the world[24]

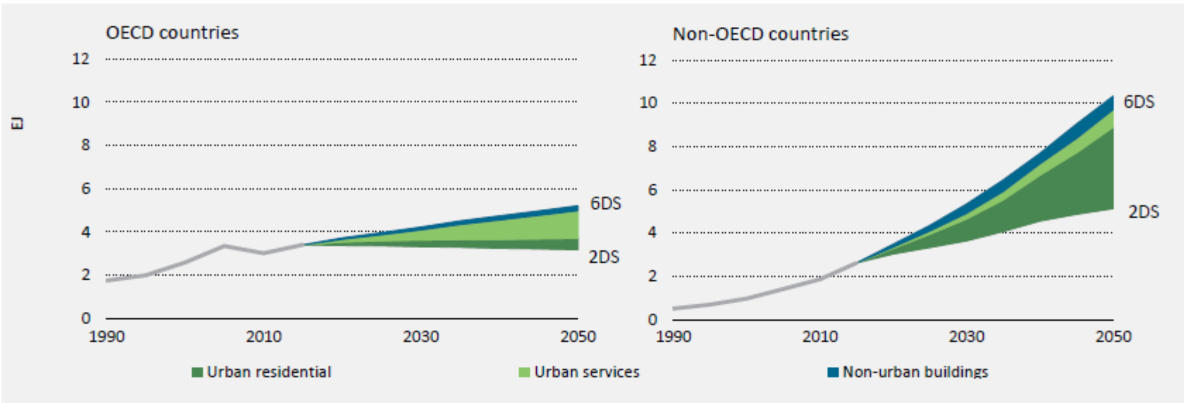
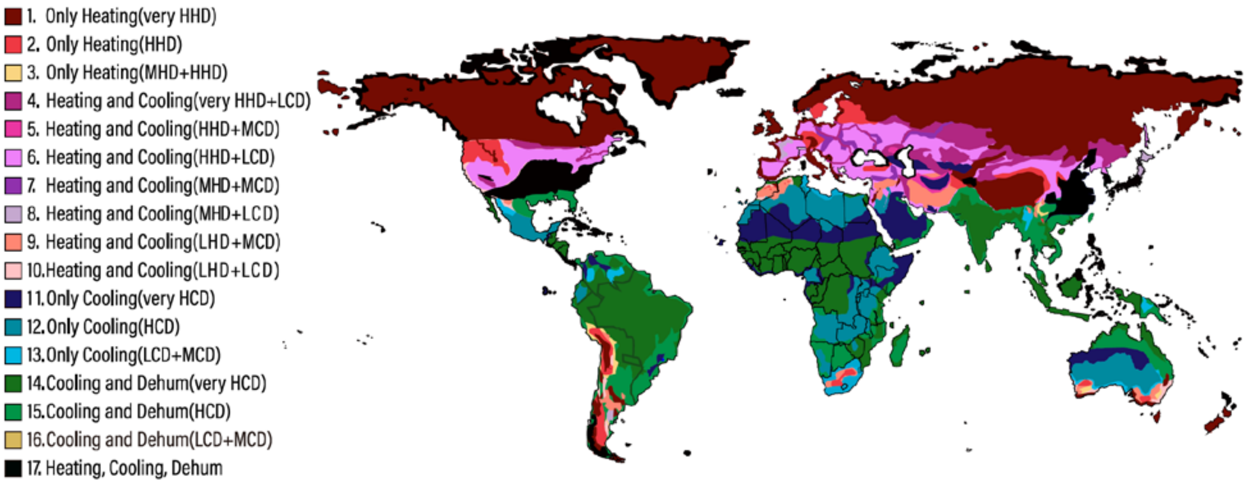


Fig.1.6.2-2 Cooling energy demand and savings, 6DS to 2DS [1]

Efforts to examine climate zones with humidity added in a detailed manner and to study effects of cutting carbon dioxide have been made by the Global Buildings Performance Network, etc., but they have been made mainly through desk study analysis.

[24] Source: Wisconsin U. original data from CRU, U. East Anglia



	Climate Zone	CDD10	HDD18	RH	Ave. T	Colour Code
1	Only Heating (Very high heating demand)	<1000	>=5000	<50	Or =<23	
2	Only heating (High heating demand)	<1000	>=3000 and <5000	<50	Or =<23	
3	Only Heating (Low and moderate heating demand)	<1000	>= 1000and <3000	<50	Or =<23	
4	Heating and Cooling (Very high heating demand and mostly Low cooling demand)	>=1000 and <2000[6]	>=5000	<50	Or =<23	
5	Heating and Cooling (High heating demand and mostly Moderate cooling demand)	>=2000 and <3000[7]	>=3000 and <5000	<50	Or =<23	
6	Heating and Cooling (High heating demand and Low cooling demand)	>=1000 and <2000	>=3000 and <5000	<50	Or =<23	
7	Heating and Cooling (Moderate heating demand and Moderate cooling demand)	>=2000 and <3000[2]	>=2000 and <3000	<50	Or =<23	
8	Heating and Cooling (Moderate heating demand and Low cooling demand)	>=1000 and <2000	>=2000 and <3000	<50	Or =<23	
9	Heating and Cooling (Low heating demand and Moderate cooling demand)	>=2000 and <3000[2]	>=1000 and <2000	<50	Or =<23	
10	Heating and Cooling (Low heating demand and Low cooling demand)	>=1000 and <2000	>=1000 and <2000	<50	Or =<23	
11	Only Cooling (Very high cooling demand)	>=5000	<1000	<50	Or =<23	
12	Only Cooling (High cooling demand)	>=3000 and <5000	<1000	<50	Or =<23	
13	Only Cooling (Low and moderate cooling demand)	>=1000 and <3000	<1000	<50	Or =<23	
14	Cooling and Dehumidification (Very high cooling demand)	>=5000	<1000	>=50	And >23	
15	Cooling and Dehumidification (High cooling demand)	>=3000 and <5000	<1000	>=50	And >23	
16	Cooling and Dehumidification (Low and moderate cooling demand)	>=1000 and <3000	<1000	>=50	And >23	
17	Heating and Cooling and Dehumidification	>=1000	>=1000	>=50	And >23	

Fig.1.6.2-3 Composite Climate Split [10]
(Note. CDD: Cooling degree days HDD: Heating degree days)

In this study of roadmap types, focus was placed on the following three regions, since this Roadmap spotlights technical development:

*Moderate & humid Region (Heating, cooling & dehumidification)
*Cold Region (High heating demand, Only heating)
*Hot Region (High cooling demand with dehumidification, Only cooling)

Considering air conditioning from the viewpoint of comfort, reduction in energy for air conditioning by separating control of humidity from control of temperature was taken into account.

1.7 Concept of ZEB/ZEH Technology Roadmap

As stated above, the situation surrounding the ZEB/ZEH Roadmap was studied based on which the concept of this Roadmap is summarized in the following way.

1) Climate zones

It was decided to divide the climate zones roughly into three and formulate a roadmap for each of the three zones. In particular, since energy demand in regions of moderate to high temperature and humidity would increase drastically, the focus was placed on humidity control.

2) Technology categories

Technologies were grouped into four major categories. Technologies available at the time of design were taken into account, but equipment, devices, etc. to be added during operation were excluded from consideration.

Active - Air conditioning, hot water, lighting
Passive - Envelope, aperture
Energy Management
Renewable energy integration

3) Technology indicators

As criteria for judgment of technologies, efficiency, cost, fuel, and maturity were taken into account. Correspondence to climate zones based on the characteristics of being moderate & humid, cold, and hot was also taken into consideration.

4) Building vintage

Addressing retrofitting, while adopting technologies applied to new construction as a basis, was taken into consideration.

5) Common technological elements for ZEB and ZEH

Technologies that can be applied to both ZEB and ZEH were intended. However, realization of ZEH could be faster than ZEB, because of its relatively low energy density.

6) References

Consistency with major roadmaps developed by IEA [1] [2] [3] [4] [5] , METI [11] [12] [14], NEDO [13], etc. was taken into account to the extent possible.

2. Where we are

2.1 Perspectives of Technology for ZEB/ZEH

A wide range of technologies has been applied to buildings, but there are many types of advanced technologies that have not been adopted due to the need to suppress costs. As stated in Section 1.5, technologies are summarized into four categories for clarification: passive, active, energy management, and renewable energy integration. In addition, air conditioning and hot-water supply technologies needed at the design phase were included as targets, while technologies (including devices that use receptacle outlets, etc.) to be added during operation are excluded from consideration.

TOPIC1 ZEB Demonstration Building[25]

・Building Outline

In recent years, the number of ZEB in Japan is increasing. Following example is ZEB demonstration building as an office building located in TAISEI Technology Center in Yokohama, Japan, completed in May 2014. This building was constructed in order to verify the feasibility of urban ZEB. And demonstration tests for energy saving technologies toward ZEB have been conducted. Rational design was aimed in the plan by the co-operation among the designers, structural engineers and mechanical engineers. One of the important designs factors is balcony in each floor. This balcony enables collecting sunlight, introducing outer fresh air, using photovoltaics and working outside. Skeleton ceiling introduced by adopting reversed beam and flat slab is used for multiple purpose such as diffusing surface of daylighting system and radiating surface of the thermal active building system.(see Table T1-1 and Fig. T1-1)

Table T1-1 Outline of the building

Location	Yokohama city, JAPAN
Building Area	427.57 ㎡
Total Floor Area	1,277.32 ㎡
Structure	Reinforced concrete structure
Number of Stories	3 (Penthouse is 1 story)
Building Use	Office
Construction Period	August 2013 - May 2014

Fig. T1-1 Building facade

・Technologies Outline

Energy consumption was minimized by the basic principle of the HVAC and lighting load reduction by passive designs and energy efficient equipment. This principle includes active usage of natural energy and task ambient control using human detection sensor. Also, in order to enhance the comfort while reducing the energy use, individual controlling system was introduced so that office workers could adjust their thermal and lighting environment according to their preference.

[25] Taisei Corporation

Lighting system

Low-illumination task and ambient lighting system was introduced to enhance its brightness with low illuminance (Fig. T1-2). To obtain maximum effect with minimal light, the role of the light was separated into two types: enhancing the impression of brightness in the room and providing the illumination necessary for office work. Hence, lighting system consists of four light sources and controls. Fundamental brightness impression is realized by daylighting system. The rest of the luminance on the ceiling surface was added by LED indirect lighting. As for the illumination for office work, LED direct lighting is used with automated ON/OFF control by human detection sensor. In addition, organic EL lighting is also used with manual control by the office workers.

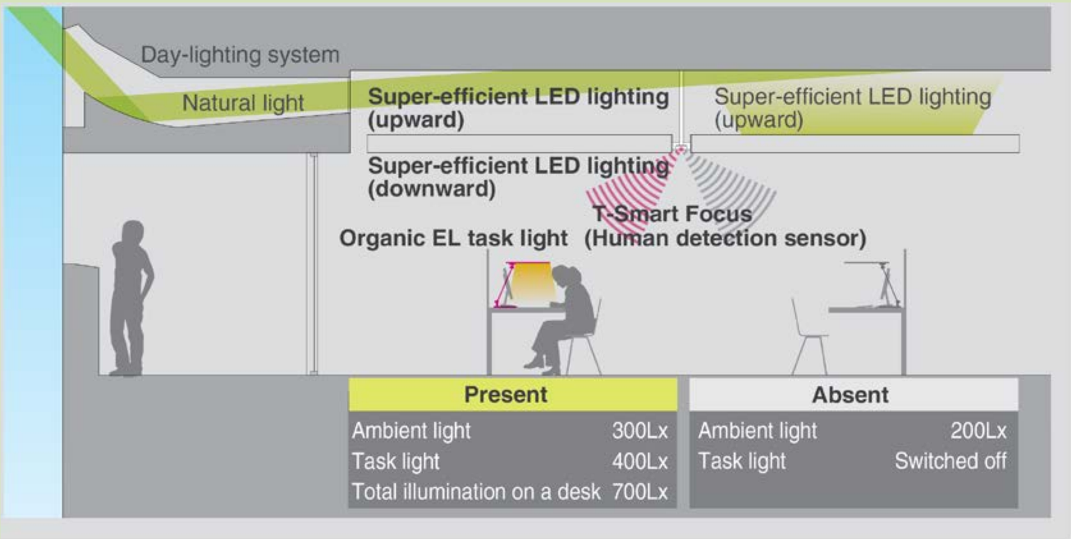


Fig. T1-2 Outline of the lighting system

HVAC

Japan is located in a temperate climate, so it is necessary to install both cooling and heating system in the buildings. Also high performance HVAC which is high in periodical performance and partial load efficiency is needed. In addition, high value -added HVAC like personal air-conditioning system is popular recently.(Fig. T1-3)
In this building, separation process of latent and sensible heat and task and ambient system deal with the fluctuating cooling and heating load efficiently throughout the year. In addition, during intermediary season, natural ventilation work and reduce the cooling load.

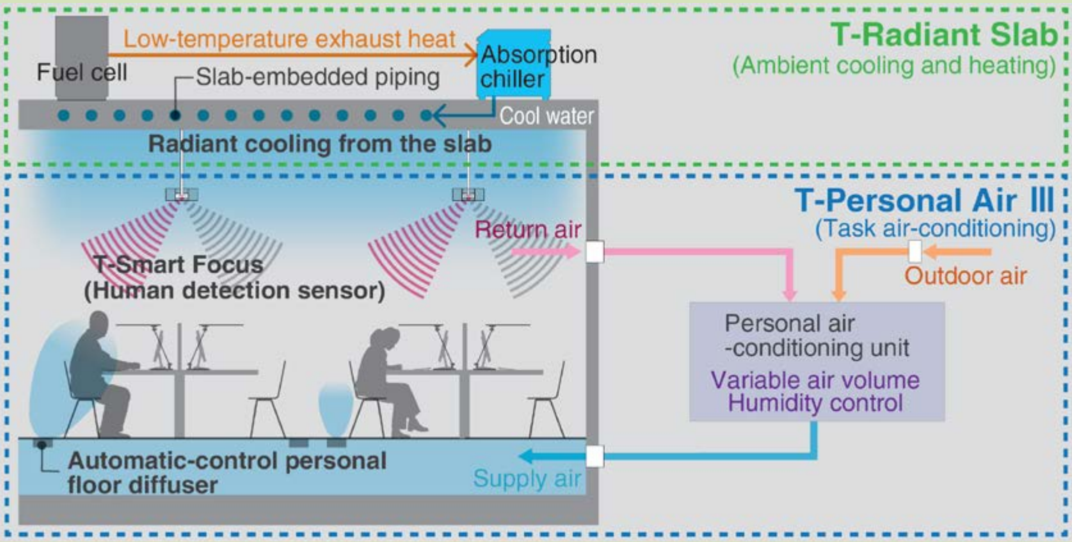


Fig. T1-3 Outline of the air-conditioning system

Power generation

The concept of power generation includes maximum utilization of renewable energies, the usage of high efficient power generators and securing the business continuous plan (BCP). For the ZEB dissemination into high rise buildings in the future, photovoltaics was installed on the wall in addition to the roof so that the amount of photovoltaics could be maximized.(Fig. T1-4)

Fig. T1-4 BIPV by the organic thin film

Energy performance

Actual primary energy balance in 2015 was shown in fig. T1-5. Annual primary energy consumption was reduced by 77% compared to that of the normal conventional building. Annual primary energy consumption was 439 [MJ/m2] for all end uses and 386 [MJ/m2] with the exclusion of plug load. And the amount of annual power generation was 484 [MJ/m2] in primary energy. In total, annual primary net energy balance was 45 [MJ/m2], can be called "Positive Energy Building (PEB)".There is a room for further energy saving in operation phase not considered in design phase. Currently, operation data is analyzed aiming at miscellaneous end use energy saving such as like standby power.

As for the award, this building got the platinum certification in LEED -NC by USGBC. And this was the first platinum certification in the new buildings in Japan. Also, this building was certified as the highest rank in Building Energy-efficiency Labelling System (BELS) in Japan.

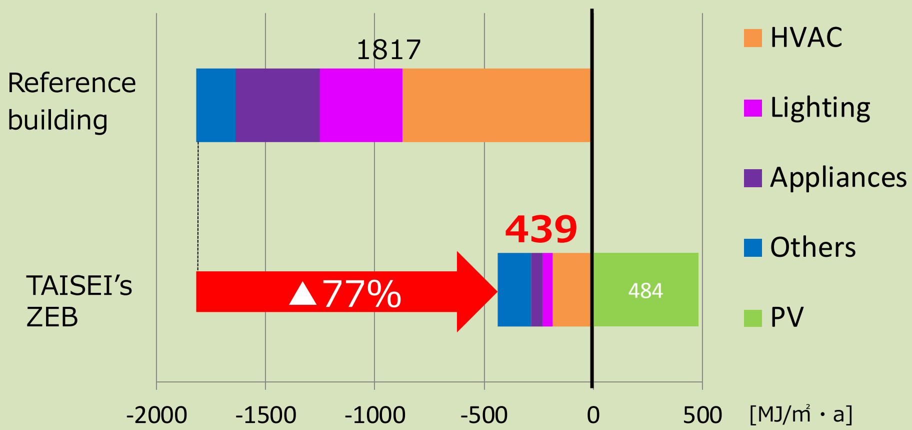


Fig. T1-5 Annual Energy Performance in 2015

2.2 Technologies for ZEB/ZEH

2.2.1 Passive technology

Classification as a passive technology was based on technological features, such as heat insulation, heat reflection/transmission of heat, ventilation, airtightness, etc., that can prevent external influences or allow use of natural energy as it is. These technologies have been employed for a long time according to the regional environment. However, there is a case where different technologies should be selected from a different point of view such as fire safety and earthquake resistance. In addition, efforts are being made to enhance performance through development of new materials.

Table 2.2.1-1 shows installation locations of passive technology, distinction in application between newly constructed and existing buildings, degrees of maturity of the technology, and applicable climate zones. In terms of heat insulation and reflection, efforts to enhance material technology are still being made. Ventilation and use of shade must be allowed for at the design phase due to the need for matching with the design of the buildings. Details are discussed below.

Table 2.2.1-1 Present status of Passive technology

Technology	Installation location	New Retrofit*	Maturity**	Climate***	Other Information
Insulation	Envelope	NR	M-H	C,M,H	
	Interior	R	M-H	C,M	
Insulated Window	Window	NR	M-H	C,M,H	
Shading	Window	NR	L-M	M,H	Reduce thermal radiation input
Thermal reflection	Window, Envelope Window roof	NR	M-H	M,H	Reflective glass
	Roof	NR	M-H	M,H	Integrated to PV panels
Ventilation	Roofs, Lattice	N	M-H	M,H	
Air sealing	Window, Envelope, Door	NR	H	C,M,H	

* N:New R:Retrofit / **L:Low, M:Midium, H:High / ** C:Cold, M:Moderate & Humid, H:Hot

2.2.1.1 Insulation

The insulation efficiency of building materials is expressed by the U value (heat transmission coefficient or amount of thermal transmission per material area and unit temperature - W/m2K), and the smaller the U value is, the higher the efficiency is. In many cases, the insulation performance of a residence is expressed by the UA value (average heat transmission coefficient or amount of thermal transmission per total area, including the envelope and openings of a residence, and unit temperature - W/m2K), and it is judged that the smaller the UA value is, the higher the efficiency is.

The recommendation for ZEB in IEA's roadmap is UA < 0.35 and Uw < 0.6.

2.2.1.1.1 Insulation of envelope

Various types of materials are used for heat insulation of building envelopes. Some examples of materials that are commercially available are shown below.

Table 2.2.1.1.1-1 Insulation materials commercially available for building envelope[26]

Name	Material/form	Heat conductivity (W/m・K)	Thermal resistance (m・k/W)[27]	Price ratio
Glass wool 40K	Mineral fiber form	0.034	22-30	3.75
Glass wool 24K	Mineral fiber form	0.036	22-30	1.5
Glass wool 16K	Mineral fiber form	0.038	22-30	1
Rock wool	Mineral fiber form	0.038	20-27	1
Cellulose fiber	Wood fiber form	0.040	20-26	2
Wool	Wood fiber form	0.040		2
Beaded polystyrene foam	Polystyrene foaming	0.034		2
Extruded polystyrene foam	Polystyrene foaming	0.028		2
Rigid urethane foam	Urethane foaming	0.024	38-45	2.5-3
Polyethylene foam	Polyethylene foaming	0.039	20	1.5
Phenol foam	Phenol foaming	0.020	33-48	3

Heat-insulating materials of buildings suppress heat transfer mainly by preventing air convection. Currently distributed and used are the fibrous form type that confines air between fine fibers and the foamed plastic type that confines air in independent air bubbles. Heat-insulating materials of buildings need to have not only high insulation efficiency but also fire safety and fire resistance, durability, sound absorbability, etc., and specific materials should be selected according to the features of the applicable location.
In the research and development (R&D) of heat-insulating materials of buildings, various types of technological development are being carried out, for example, to mass produce materials based on advanced technologies used in the space field at allowable costs and to utilize natural resources or waste. Table 2.2.1.1.1-2 shows examples of materials having high insulation efficiency that are now under R&D for practical use.

Table 2.2.1.1.1-2 Building insulation materials [28]

material	Material/form	Thermal resistance (m・K/W)
Vacuum insulated panel	Metal membrane wall filled with highly-porous material	208-346
Silica aerogel	Highly-porous silica	69

A vacuum-insulated panel is a board-shaped container made with a metal film and filled with a material having a high void ratio and low heat conduction, and it has heat resistance about 10 times that of glass wool and other heat-insulating materials. However, in the current status, its manufacturing cost is high, and care is required to prevent damage to its film so as to maintain the vacuum, resulting in a drawback in its application method.
Silica aerogel is synthetic porous ultralight silicon oxides derived from a gel, in which the liquid component of the gel has been replaced with a gas. Although it has insulation efficiency twice or more that of current insulation materials, it is fragile in the current status, resulting in a drawback in its application method, etc.

[26] Source: http://dannetsujyutaku.com/basic/knowledge/material
[27] Source: https://en.wikipedia.org/wiki/Building_insulation_materials
[28] Source: https://en.wikipedia.org/wiki/Building_insulation_materials

2.2.1.1.2 Insulated interiors

For heat insulation of interiors, insulating panels to be pasted inside, curtains, and the like are used. They can easily address the need for retrofitting, but matching with the design weighs heavily in adoption of either of them, so the taste of residents has an influence on whether to adopt such materials. For insulating panels to be pasted inside, some envelope-insulating materials can be used.

2.2.1.1.3 Insulated windows

Window insulation efficiency depends on the design of a whole window. In particular, insulation efficiency differs widely depending on whether or not a window can be opened. Windows account for a large share of heat release from a building, so North European countries situated in cold-weather regions set a strict minimum standard (Uw < 1.0 to 2.0) for window insulation efficiency. Uw indicates the overall U-value of the window.

The heat transfer coefficient Uw relates to the entire window. This value also incorporates the U-values for the glazing and the frame Uf. The overall value Uw is also influenced by the linear heat transfer coefficient (g = glazing) and the size of the window. In recent years, movements to introduce insulated windows are spreading globally as China recommends Uw < 2.0 and South Korea recommends Uw < 1.6.

In regions with four seasons, windows that can be widely opened are needed. For single-layer glass aluminum sashes with the common structure of a glass-fitted Japanese shoji that can be opened, Uw = 6.5, and for double-layer glass aluminum sashes, Uw = 4.7 or so. Therefore, it is understood that the North European standard is very stringent. In summer, in general detached houses in moderate & humid regions, nearly 70% of hot air heated by solar insolation passes windows to enter the room. In winter, nearly 50% of air warmed in a house passes through windows to escape outside. [29] Accordingly, heat insulation of windows that can be opened is an important issue.

A window consists of glass and a window frame, so insulation efficiency of the glass and that of the window frame are both important. Due to technology development in recent years, vacuum triple-layer glass having a resin window frame with Uw < 1[30] has been commercialized. However, the price of the current product is fairly high, so development of a technology to realize cost reduction is needed.

It is also important to take measures to address the need for retrofitting of existing buildings, including technology to make construction easy.

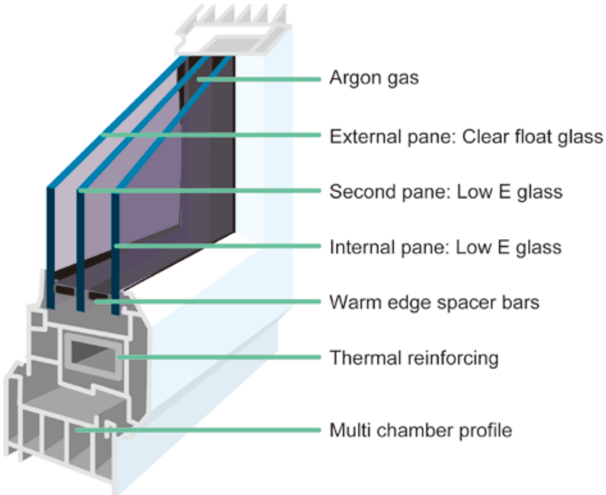


Fig. 2.2.1.1.3-1 Triple glazing window

Fig. 2.2.1.1.3-2 Insulated glass sashes with the structure of a glass-fitted Japanese shoji

[29] YKK AP http://www.ykkap.co.jp/info/pvc-windows/summary/
[30] YKK AP http://www.ykkap.co.jp/apw/apw430/variation/sliding.html

2.2.1.2 Shading

Shading is a method of blocking solar insolation using means such as eaves, side fins, etc., and there are many cases where residents of detached houses employ this method by installing bamboo blinds, etc. after they start living in their houses. It can easily address the need for retrofitting, but matching with the design weighs heavily in adoption of either of these means, so the taste of residents has an influence on whether to adopt such means. On the other hand, in the case of buildings, it is difficult to address the need for retrofitting, so it is necessary to study this issue at the design phase.
Considering the directionality of technology development, it is possible to apply some of the heat reflection technology.

2.2.1.3 Reflection

Reflective performance of buildings is evaluated using the SR value. Solar reflectivity or reflectance (SR) is the ability of a material to reflect solar energy from its surface back into the atmosphere. The SR value is a number from 0 to 1.0. A value of 0 indicates that the material absorbs all solar energy and a value of 1.0 indicates total reflectance. In regions with strong solar insolation, this technology is demanded for application to reflection materials to be used especially for roofs and walls. If windows are installed in a region with four seasons, reflection is needed in the summer, while passing of heat rays is needed in the winter.

2.2.1.3.1 Reflection materials of envelopes and roofs

The efficiency of reflection materials is basically related to color, and the initial SR value is roughly 0.7 for metallic luster, 0.6 for white, and 0.2 for black. When actually installed and then exposed to rain and wind, the efficiency of reflection materials decreases. In R&D, emphasis is placed on how to provide durability so as to keep the initial efficiency.
In addition, especially when reflection materials are used for an envelope or a roof installed with a high slope degree, reflection from them may cause the neighborhood annoyance, so it is necessary to study this issue at the design phase.

2.2.1.3.2 Heat reflection by windows

Figure 2.2.1.3.2-1 shows images of heat reflection by windows and passing of heat rays. “Low-e” means that the amount of heat radiation is small. In cold-weather regions, heat reflection by windows reflects heat in the room and keeps it inside and thereby enhances the heat-insulating effect. To realize this, a reflection film should be formed on the glass surface on the room side. In this case, it is effective to pass solar heat from the outdoors into the room. Passing of solar heat will be discussed in the following item, but it is evaluated using solar heat gain coefficient (SHGC). For transmission of solar heat, it is effective to form an antireflection film on the glass surface on the outdoor side and adopt glass featuring low absorption of heat rays.
On the other hand, in high-temperature regions, if heat entering the room is reduced by reflecting sun rays and outdoor heat, the heat-insulating effect is enhanced. In this case, from a technical point of view, it is effective to form a heat reflection film on the glass surface on the outdoor side.
The challenges for Low-e technology are cost reduction and durability improvement.

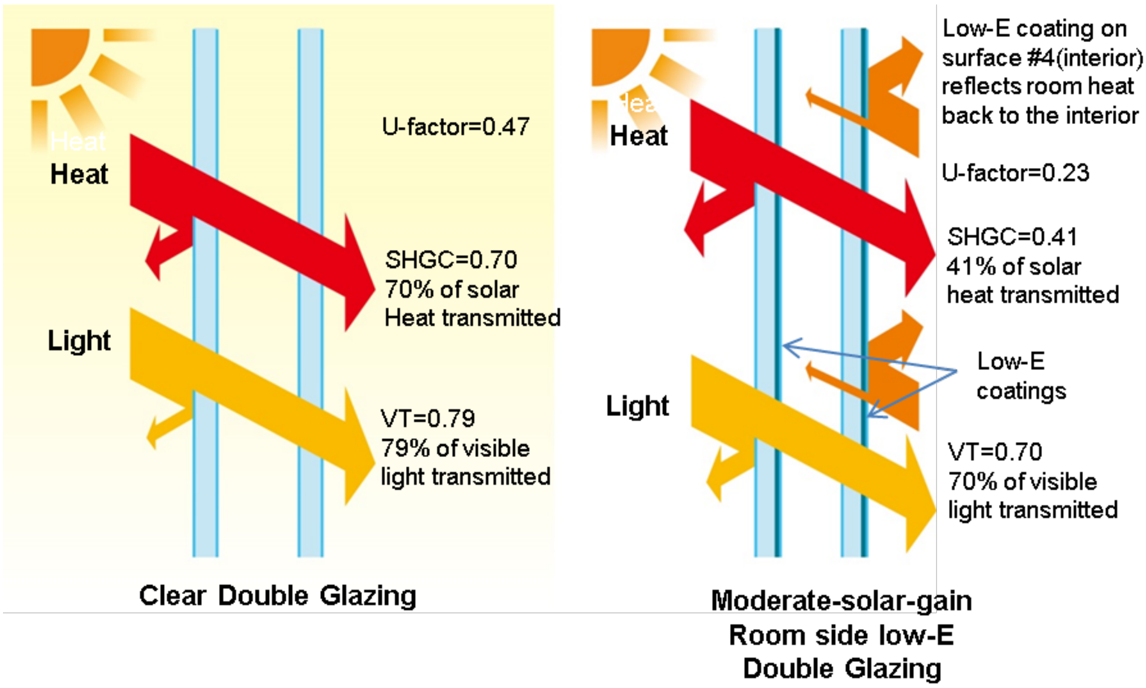


Fig. 2.2.1.3.2-1 Schematic images of Low-e glazing[31]

In regions with four seasons, it is necessary to change the direction of the side of glass where a heat reflection film is formed when the season changes between summer and winter, which makes it difficult to effectively introduce Low-e technology. However, technology development is ongoing, aiming at control of reflection performance according to the change in seasons by applying an electric field to the reflection film or making contact between the film and a reactant gas.

2.2.1.4 Transmission of heat

This technology, whose technical aspects are discussed in 2.2.1.3.2, is effective in cold-weather regions.

2.2.1.5 Natural ventilation

There are two methods of implementing natural ventilation. They are wind-induced ventilation that uses a pressure gap caused by outdoor wind, etc. between an inlet and an exhaust port; and density-difference ventilation that uses ascending air current generated by density difference in air caused by the heat generated in the room, etc.
Air conditioning by wind-induced ventilation can be conducted by opening an inlet and an exhaust port and thereby securing a ventilating route, when there is wind outdoors and the indoor environment has suitable temperature and humidity. Air conditioning by wind-induced ventilation is affected by natural conditions, so alternative means are necessary in cases where natural conditions are unsuitable for air conditioning.
Air conditioning by density-difference ventilation takes advantage of air ventilation that makes use of air density difference caused by heat from residents or their equipment, and therefore it is not readily affected by natural conditions such as presence/absence of wind. When designing a building, the focus should be placed on design of locations where heat is generated and ducts that lead ascending air current to ventilation. In such a case as when the intended purpose of using a building is changed, the effect of the ventilation will be lost. Figure 2.2.1.5-1 shows an image of density-difference ventilation in a building.

[31] Source: http://www.efficientwindows.org/lowe.php

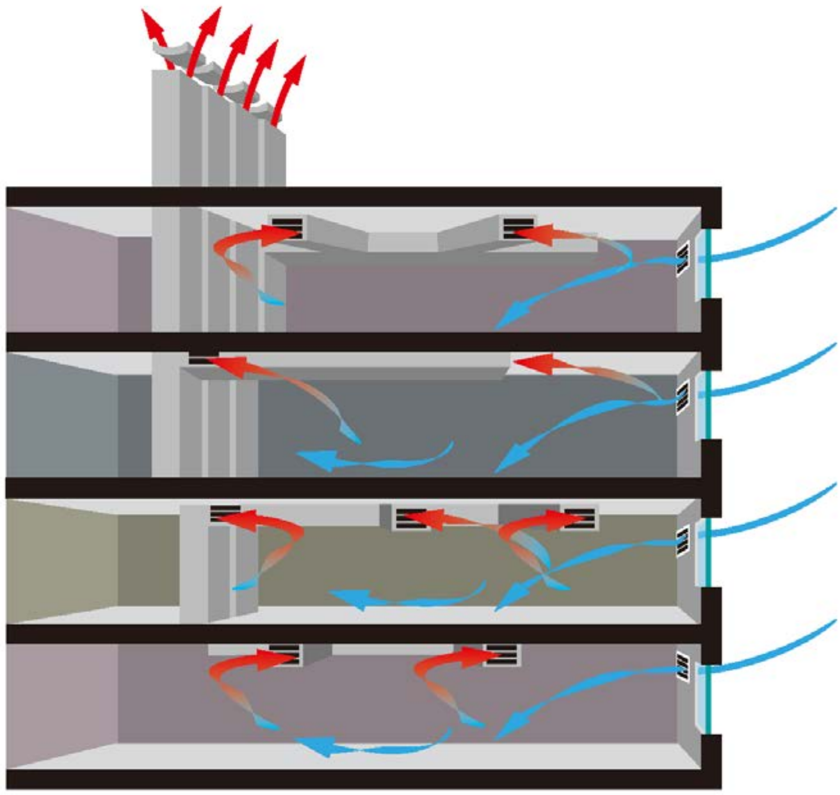


Fig. 2.2.1.5-1 Schematic images of natural ventilation for a building

On the other hand, as for houses, their intended use cannot be substantially changed, making it easy to apply density-difference ventilation to them for air conditioning. Figure 2.2.1.5-2 shows an example of application of natural ventilation as a means of air conditioning to a detached house built in a region with four seasons. In this application, in the summer, by forming the first vent layer outside the heat-insulating material of the building envelope, it is possible to discharge heat received from the sun to outdoors through ventilation, and by forming a second vent layer inside the heat-insulating material of the building envelope, it is possible to wrap the interior in cool air; in the winter, formation of a heat-insulating layer of air is possible by blocking these vent layers with a shape-memory alloy, etc.

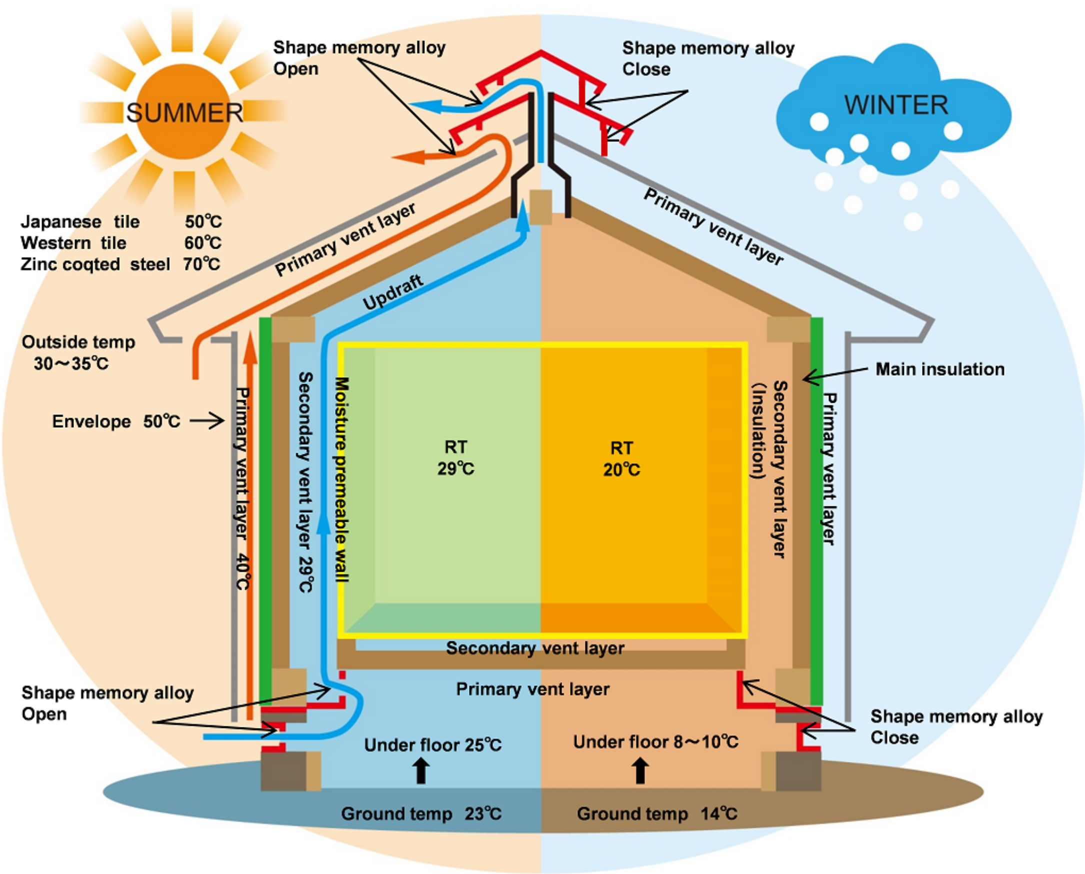


Fig. 2.2.1.5-2 Schematic images of natural ventilation for a house

Necessary care should be taken at the design phase in the case of either buildings or houses, and efforts should be made to adopt advanced design using fluid simulation, etc. and to lower the costs of construction based on the design.

2.2.1.6 Introduction of airtightness

Introduction of airtightness is a technology considered especially important in cold-weather regions and outdoor places in harsh environmental conditions. From a technical viewpoint, this technology is in completed status, so it is important to consider how to include this technology in design.

In addition, there are cases, depending on the region, where no difference is found between the amount of energy saved by introduction of airtightness and the amount of energy increased in order to properly implement humidity conditioning and ventilation. So, standardization is needed in terms of what regions can effectively adopt introduction of airtightness and what level of airtightness is needed.

2.2.1.7 Natural lighting

Technologies of natural lighting are in matured stage, so it is important to consider how to include this technology in building design.

2.2.2 Active technology (Air conditioning)

The active technology is summarized as a technology that provides air conditioning mainly by use of energy brought in from the outside. The main pillar of active technology innovation in application to ZEB/ZEH is thorough pursuit of energy saving through improvement of equipment efficiency. Although there are various forms of heating, including fireplaces, hearths, heaters, and ondols, technologies difficult to apply to ZEB/ZEH were excluded.
The current status of the active technology for air conditioning is presented in Table 2.2.2-1.

Table 2.2.2-1 Present status of Active technology (Air Conditioning)

Technology	COP [32]%	Equipment cost*	Fuel type**	Fuel cost*	Maturity*	Climate***	Other Information
Boiler	70-88	L	G/O/B	M-H	H	C,M	Floor, Panel heating
Absorption Chiller	70-120	M	G/O/B	M-H	H	M,H	
Heat Pump(Electricity)	200-600	L-M	E	M-H	H	All	
Heat Pump(Engine)	120-200	L-M	G/O/B	L-M	H	All	
CHP[33](Engine)	70-90	M-H	G/O/B	L-M	H	All	with Elec. supply
CHP(FC)	80-90	H	G/H	L-H	M	All	with Elec. supply
Dehumidifier	n.a.	H	E	H	M-H	M,H	heat pump, desiccant, compressor, wet
Humidifier	n.a.	L-H	G/E/O	L-H	H		evaporation, steam, ultrasonic
Solar System	n.a.	H	S	0	L-M	All	Renewables
Outdoor air cooling	n.a.	H	E	L	L-M	All	

* L:Low, M:Midium, H:High ** G:gas, O:Oil, B:Biomass, S:Solar, E:Electricity, H:Hydrogen,
*** C:Cold M:Moderate & Humid H:Hot

2.2.2.1 Boilers

Boilers are heat source equipment that generates steam and warm water in heating systems based on heat exchange at a floor heating system or a panel heater set in the room as well as at a fan convector.
In the basic structure of boilers, water is fed to a heat exchanger and then high-temperature combustion gas, produced by burning fuel, is passed through the heat exchanger, in order to heat water. As a result, warm water and steam are generated. When gas is used as fuel, dew may form on the heat exchanger where cool water passes, because combustion gas contains water generated from hydrogen included in the fuel. Usually, heat exchangers are manufactured using copper and aluminum, which causes deterioration of the equipment

[32] Coefficient of Performance, same as efficiency, COP=Qo/Qi where Qo is the heat supplied to or removed from the reservoir and Qi is the heat supplied to the system operation. Qi is supplied by electricity to heat pump(electricity) and by fuels to others.
[33] Combined heat and power

because rust is generated if dew formation continues. For this reason, heat exchangers in ordinary boilers are designed so as to prevent dew formation. However, in this case, the temperature of the exhaust gas discharged after heat exchange is about 200°C and the efficiency is about 70%. Put simply, this is a major factor that prevents efficiency improvement of boilers.

Furthermore, combustion gas contains sensible heat generated by the temperature difference in the gas and latent heat in the form of water steam. If sensible heat is recovered by a heat exchanger designed to withstand dew formation, the exhaust gas temperature would be about 80°C and the efficiency would be enhanced to almost 90%. Figure 2.2.2.1-1 shows the basic structure of a latent heat recovery-type boiler. However, the manufacturing costs of this boiler are high because it is equipped with additional components, namely a durable heat exchanger that can cope with dew formation to recover latent heat and a mechanism to treat dew condensation water.

The directionality of technology development is set to cost reduction; for this reason, mass production should be put into operation by promoting deployment of this type of boiler.

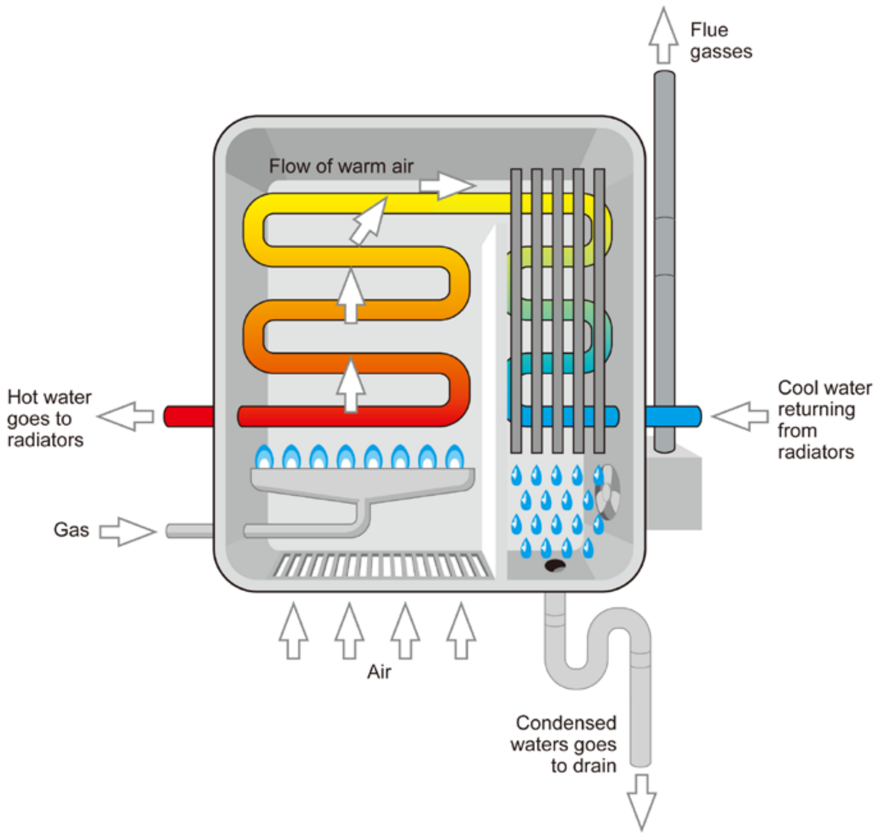


Fig2.2.2.1-1 Schematic diagram of condensing boiler

2.2.2.2 Absorption chiller

Absorption chillers are refrigerating machines to realize low temperature through the effect of a refrigerant being vaporized due to low pressure generated by high-absorbency liquid when it absorbs another refrigerant in a different location. In addition, an absorption chiller can be also used as a heat-driven heat pump. As for cooling media and/or absorbing liquid, products made of the water-lithium bromide system for air conditioning and the ammonia-water system for refrigeration have already been commercialized. When an absorption chiller is used for heating, warm water is often produced by applying heat exchange to a high-temperature heat medium as it is, which is provided by a high-temperature regenerator without using a refrigerating cycle.

Figure 2.2.2.2-1 shows an absorption chiller system. In its basic cycle, cold water and cold liquid are produced through evaporation of a refrigerant in an evaporator set at low

temperature and low pressure, and the evaporated refrigerant is then absorbed by absorbing liquid in an absorber (this absorption causes a low-pressure state that makes the refrigerant evaporate in the evaporator). When the absorbing liquid that has absorbed the refrigerant is heated by a regenerator, the refrigerant is evaporated and separated, and the relevant solvent is returned to the absorber. The refrigerant, after evaporation and separation, is cooled and liquefied in a condenser and then reused in the evaporator.
As for a system using an absorption chiller for air conditioning, it has been confirmed that when using the water-lithium bromide system, which is an absorbing liquid currently regarded as the most appropriate, the efficiency or the coefficient of performance (COP) can be enhanced to around 160% in a system where the absorption cycle is increased to three tiers (for triple effect). However, the manufacturing costs for this system are higher, and it is therefore required to develop a technology that can enhance the efficiency at low cost.

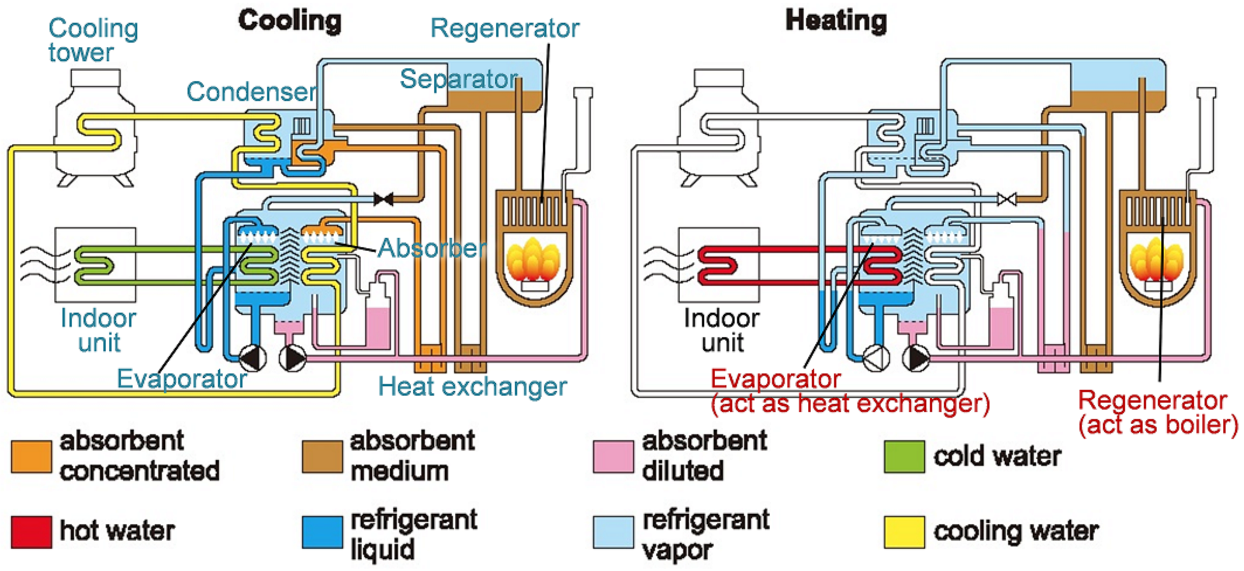


Fig.2.2.2.2-1 Schematic diagram of absorption chiller.

2.2.2.3 Heat pump

Heat pumps can be widely defined as a technology to transfer heat from a low-temperature part to a high-temperature part using a heat medium, a semiconductor (Peltier device), etc. and are characterized by various types of system such as the vapor compression type, the Stirling type, the absorption type, the absorption type, the chemical reaction type, etc. When discussing air-conditioning systems, a heat pump is usually of the vapor compression type. Therefore, here, the focus is on this type as well.
The working principle of a heat pump is illustrated in the following figure showing four elements: a compressor, a condenser, an expansion valve, and an evaporator. The compressor driven by electric power compresses a refrigerant, and the refrigerant now at high pressure is then led to the condenser for heat exchange to be cooled, resulting in condensation of the refrigerant. At this time, condensation heat is released to the outside from the condenser. The refrigerant in liquid form expands at the expansion valve and is sent to the evaporator. The expanded refrigerant decreases in temperature, and the evaporator is thereby cooled and starts to absorb heat from the outside. After that, this cycle is repeated with the refrigerant evaporating, undergoing heat exchange, and returning to the compressor. A valve mechanism can be used to switch the configuration so that the evaporator works on the room side and the condenser works on the outdoor side for cooling and so that the evaporator works on the outdoor side and the condenser works on the room side for heating.

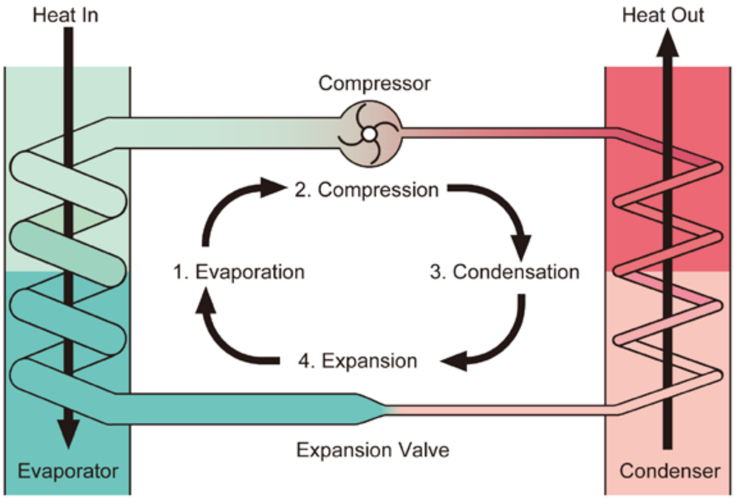


Fig.2.2.2.3-1 Schematic diagram of heat pump

Chlorofluorocarbons (CFCs) were used at the initial phase of commercialization of this technology as a refrigerant that can be evaporated and condensed at ranges of temperature and pressure convenient for constituting a refrigerating cycle in air conditioning. Currently, however, substitutes for CFCs are used as cooling media, since CFCs are substances that have a large GWP[34].

In theory, the efficiency (COP) of heat pumps has an upper limit specified by the reverse Carnot cycle and it is expressed using the following formula in the case of cooling.

$$COP = T_C / (T_H - T_C)$$

T_C: temperature of a refrigerant during absorption of heat (evaporation temperature, on the room side)

T_H: temperature of a refrigerant during heat release (condensation temperature, on the outdoor side)

In actual equipment, efforts to enhance efficiency can be consolidated into the following two activities:

1) Efficiency improvement of heat exchangers

Evaporators and condensers have their own heat exchangers to perform heat exchange between a refrigerant and air. In high-performance heat exchangers, the difference in temperature between a refrigerant and air is small. By indicating the temperature differences in an evaporator and a condenser by ΔTEV and ΔTCD, respectively, the efficiency of actual equipment can be expressed using the following formula:

$$COP \propto (T_C - \Delta T_{EV} / \{(T_H + \Delta T_{CD}) - (T_C - T_{EV})\}$$

If expressed briefly, the smaller the ΔT_{EV} and ΔT_{CD} are, the higher the performance of a heat exchanger is. In particular, since the installation space is limited in a room, further improvement of smaller and higher-performance heat exchanger technology is required.

2) Efficiency improvement of compressors

For the efficiency of compressors, the focus should be placed on a technology to suppress power loss caused by friction. Today, scroll compressors are one of such examples that have been commercialized as high-efficiency compressors.

[34] Global Warming Potential

2.2.2.3.1 Electric heat pumps

Electric heat pumps are equipment that uses an electric motor for driving a compressor. In recent years, there are examples of using a drive system with a combination of inverter control and a high-efficiency motor built with a strong permanent magnet and a magnetic steel sheet whose loss is small.
For efficiency improvement of electric heat pumps, it is necessary to further enhance the efficiency of electric motors and their drive control system.

2.2.2.3.2 Internal-combustion engine heat pumps

Internal-combustion engine heat pumps are equipment that uses a reciprocating engine for driving a compressor. In recent years, there are examples of using high-efficiency reciprocating engines of the high-compression-ratio type.
For efficiency improvement of internal-combustion engine heat pumps, it is necessary to further enhance the efficiency of internal-combustion engines.

2.2.2.4 Combined Heat and Power

Cogeneration (combined heat and power) is a system that simultaneously uses motive power or electric power as well as waste heat generated by motors, fuel cells, etc. This system is applied to ships, motor vehicles, factories, cities, buildings, etc. In the buildings sector, motive power is converted to electric power that is used as part of the electric power to be supplied to a building. Heat is used for direct heating or converted to cold heat by an absorption chiller and then used for cooling.

2.2.2.4.1 Internal-combustion engines and gas turbines

Typical internal-combustion engines used for combined heat and power are reciprocating engines and gas turbines. However, due to conditions on the ratio between generated electric power and heat and the system scale, there are many cases where reciprocating engines are adopted for systems to be applied to buildings. The following figure shows an example of a combined heat and power system of the reciprocating engine type.

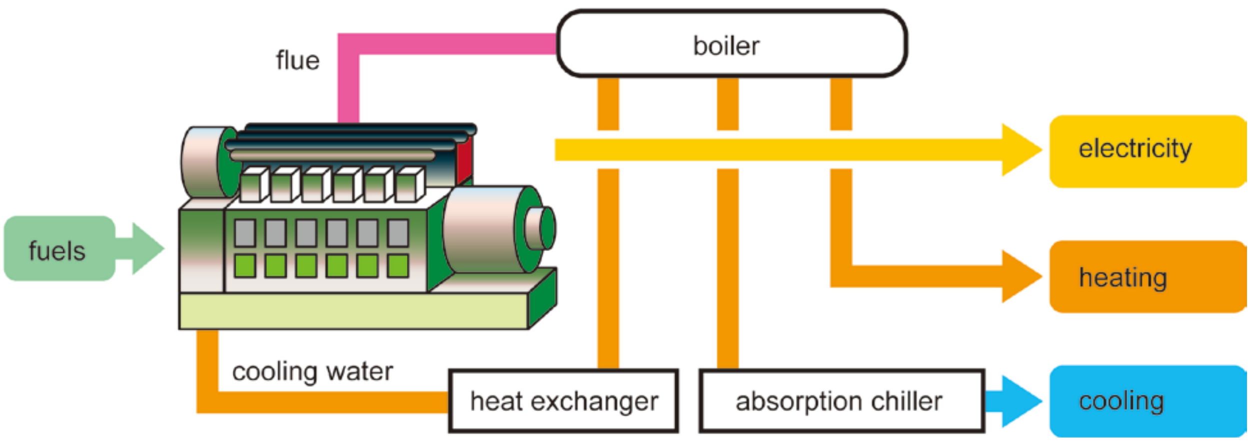


Fig.2.2.2.4.1-1 Reciprocating engine type combined heat and power for buildings

In this system, the engine generates motive power that is converted to electric power by a generator. Electric power is linked to systems in a building and used by power-consuming equipment such as personal computers. The reciprocating engine generates heat in the form of combustion exhaust gas and cooling water both of which are sent to a heat exchanger to recover heat and then used for heating, or for cooling after converting it to cold water by an absorption chiller. Energy contained in fuel is used as electric power and heat at a high efficiency of between 70 and 90%. When using a combined heat and power system, if the ratio between generated electric power and heat matches the ratio between electric power and heat required by a building, energy efficiency is increased. Therefore, it is necessary to promote wider deployment of this method by use of appropriate engineering.

2.2.2.4.2 Fuel cells

The fuel cell type of combined heat and power system is a combined heat and power system that is realized by replacing the internal-combustion engine described in the preceding item with a fuel cell. Fuel cells have a cell structure where electrodes are arranged at both ends of an oxygen ion conductor or a hydrogen ion conductor. Electric power is generated due to voltage caused by localization of electrons generated on both electrodes through a mechanism whereby fuel is introduced into one side (fuel electrode) of the electrodes so that ions near the fuel electrode and fuel enter an electrochemical reaction to exchange electrons; on the other hand, on the opposite electrode (air electrode), oxygen in the air and ions enter an electrochemical reaction to exchange electrons. Depending on the type of ionic conductor, the temperature at which cells work properly varies. For example, it is about 80°C for polymer electrolyte fuel cell (PEFC[35]), the most widely used type, and about 700 to 900°C for solid electrolyte fuel cell (SOFC[36]). According to these conditions, different systems are used for utilization of exhaust gas. The basic structure of a PEFC stack and its electrode part is shown in the figure below.

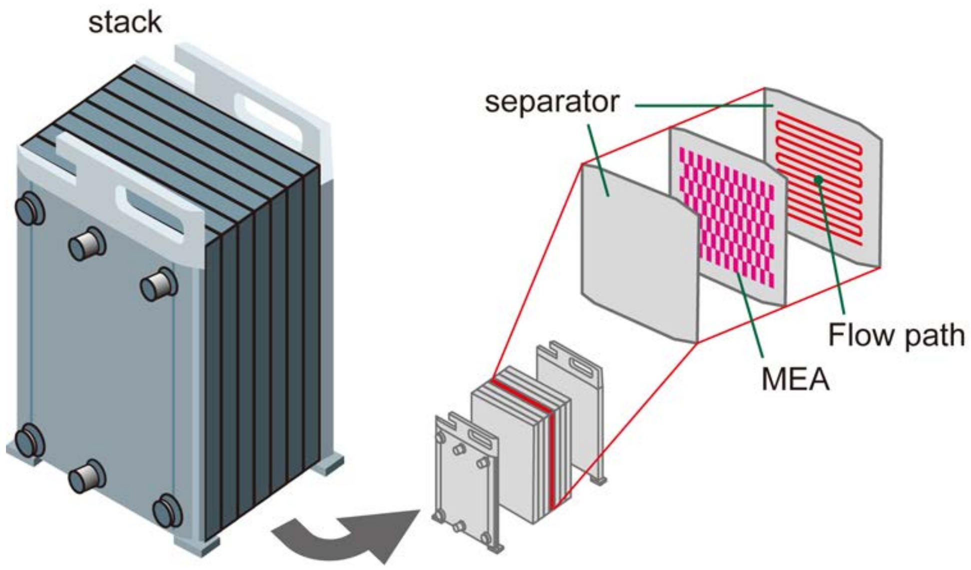


Fig.2.2.2.4.2-1 Cell stack of PEFC

[35] Polymer electrolyte fuel cell

[36] Solid electrolyte fuel cell

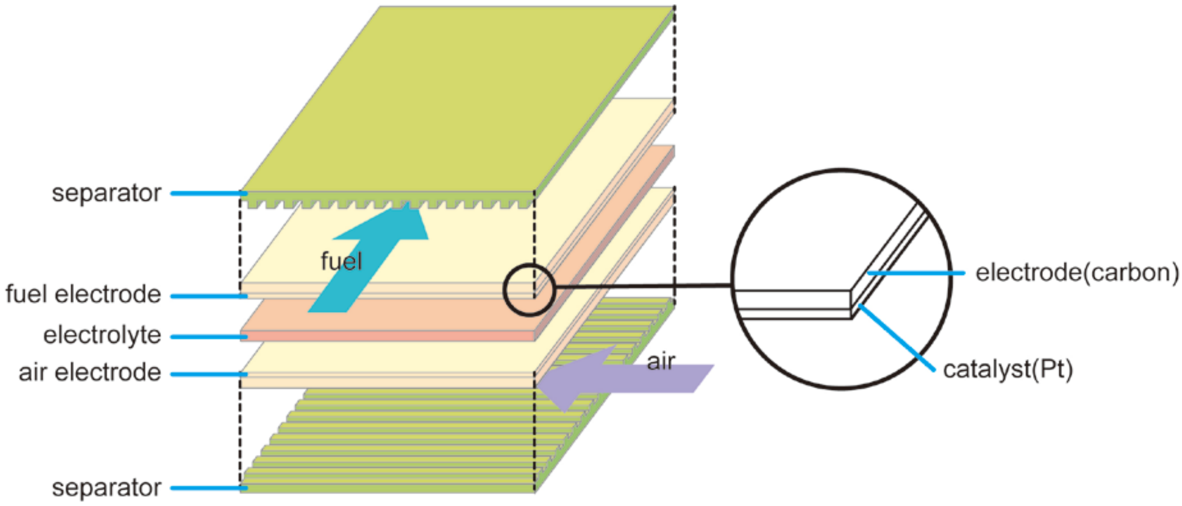


Fig.2.2.2.4.2-2 Configuration of PEFC cell

In this system, DC power is generated in the fuel cell, which is linked with the system through an inverter. The generated power is then used by power-consuming equipment. On the other hand, the fuel cell generates waste heat from exhaust gas after reaction, which is recovered by a heat exchanger to be utilized for heating. However, in PEFC whose operating temperature is low, absorption chillers cannot be operated with waste heat. On the other hand, in SOFC and the like whose operating temperature is high, it is possible to build a system where absorption chillers can operate after generating power with an expansion turbine using waste heat.
Energy contained in fuel is used as electric power and heat at a high efficiency of between 80 and 90%. High-efficiency systems can be more easily built with the fuel cell type of combined heat and power system, because this type has a ratio between generated electric power and heat that is closer to the ratio between electric power and heat required by a building than the internal-combustion engine type. Promotion of wider deployment is needed through cost reduction, development of high-efficiency technology, and appropriate engineering.

2.2.2.5 Humidity control equipment

Humidity control equipment is air-conditioning equipment that is used for humidity conditioning and performs dehumidification during the hot and humid seasons and humidification in the dry season. There are various dehumidification systems such as the cooling method where dehumidification is achieved by lowering the temperature of functioning parts with a refrigerating machine below the dew-point temperature; adsorption/absorption methods where dehumidification is achieved by passing air through a solid substance or liquid to which moisture content can easily adhere; and the compression method where air is compressed by a compressor to generate dew drops and dew condensation water is then removed. In the buildings sector, the cooling method and the adsorption method are adopted.

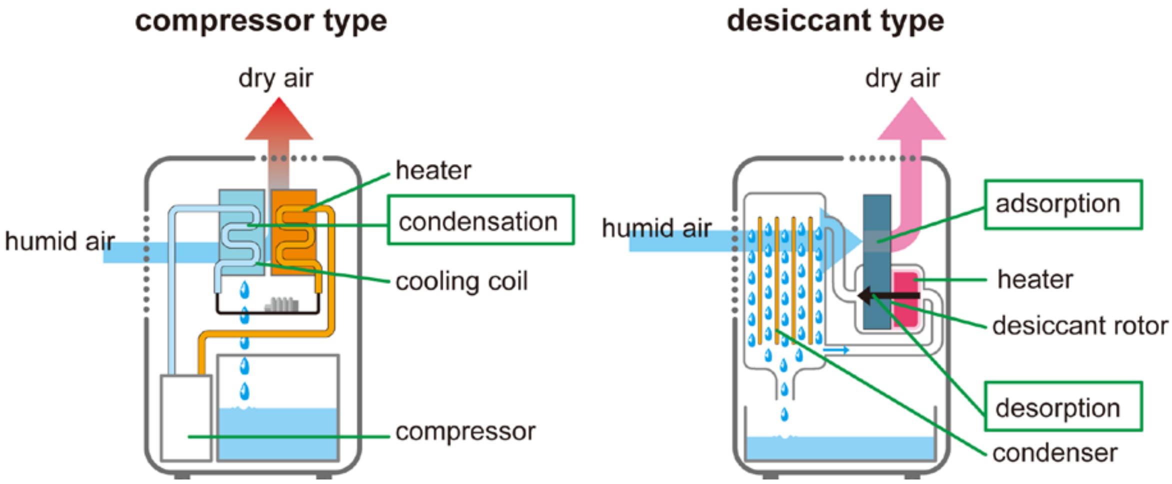


Fig.2.2.2.5-1 Schematic diagrams of dehumidifier

Methods of humidification are as follows: the steam method where water vapor is sprayed; the vaporization method where humidification is achieved by heating and vaporizing water; and the water spray method where humidification is achieved by spraying water in a fine misty form with an ultrasonic spray system or a high-pressure spray.
As for dehumidification technologies, the dehumidification performance of the desiccant type of technology keeps acceptable level even if the ambient temperature is low; however, since the amount of energy used for thermal regeneration is large, it is required to develop materials whose thermal regeneration is easy.
As stated in Item 1.6.1, although it is said that, generally speaking, everybody feels discomfort and work efficiency decreases when the DI exceeds 80, attention should be paid to the fact that the DI becomes 80 at a temperature of 37°C with a relative humidity of 20% but also at 27°C with a relative humidity of 90%, which shows a temperature difference of 10°C. As stated in Item 2.2.2.3, in the heat pump type of cooling now widely used, efficiency during cooling is inversely related to the difference between outdoor temperature and indoor temperature. As for effective application of dehumidification technology, there is a technical possibility of significantly reducing the amount of energy used for air conditioning while maintaining comfort by reducing the difference between outdoor temperature and indoor temperature while properly controlling humidity.
As for heating, it is also said that people feel warm even when the temperature set for air conditioning is low, if humidification is conducted properly. Therefore, it is necessary to develop air-conditioning technology where humidity conditioning is properly integrated.

2.2.2.6 Heat storage

Heat storage means storing heat in a heat storage tank and using the stored heat at the time of maximum demand so as to allow for reduction in the capacity of heat-source equipment and efficient operation with a constant load. In addition, in mobile facilities, installation or operation of heat-source equipment can be omitted while meeting demand only with stored heat.
Familiar examples of heat storage in households are water heaters of the hot-water storage type as well as ice making and cold storage in a cool box with refrigerants. Various media are used for heat storage, including water (ice) in heat storage tanks, latent heat storage materials, space in the underground, and building frames. However, installation of a heat storage tank is often avoided due to its large size, so it is necessary to develop high-density thermal energy storage technology. It can be used as an elemental technology to reduce the amount of total energy in cooperation with EMS to be discussed later.

2.2.2.7 Solar systems

Solar air-conditioning systems collect solar heat with a heat collection panel and store the heat in a heat storage tank.
For heating, the stored heat is transferred by a heat medium to a heat exchanger where it forwards a heat-exchange process with air in the room, and the room is consequently warmed.
For cooling, the heat stored in a heat storage tank is provided for the absorption-type cooler or desiccant-type cooler so as to generate cold heat that is carried by a refrigerant to a heat exchanger where it enables a heat-exchange process with air in the room, and the room is consequently cooled.
An example of a solar air-conditioning system is shown in the figure below.

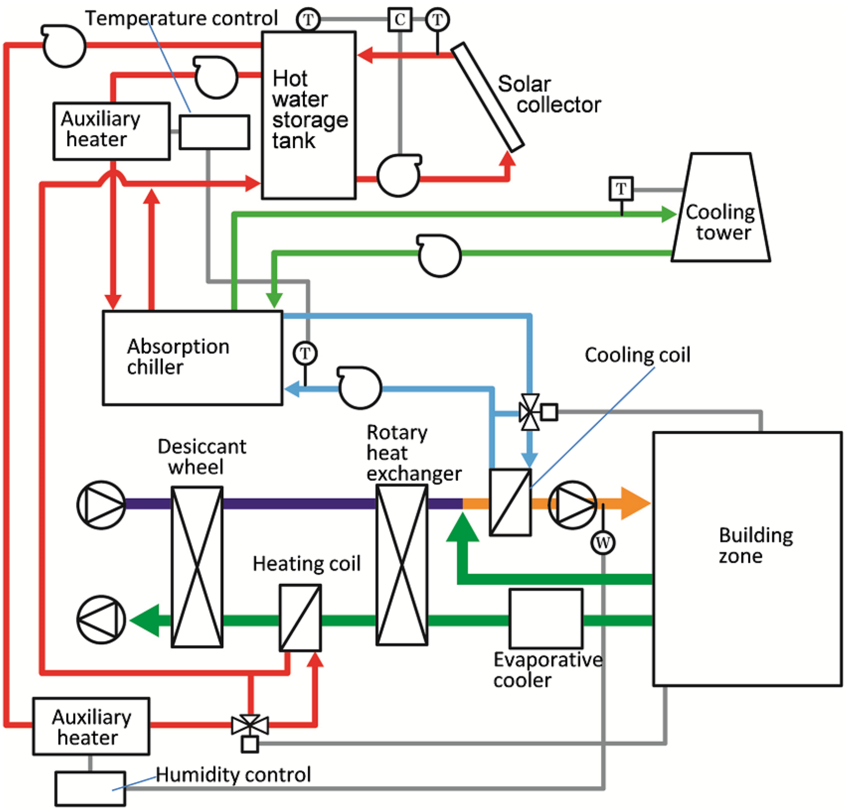


Fig.2.2.2.7-1 Schematic diagram of solar air conditioning system

The system shown in the figure is equipped with a large solar heat collection panel because the density of energy obtained from sunlight is small. In addition, to address variation and lack of heat caused by weather changes, it is also equipped with a heat storage tank and auxiliary heat sources. Heat provided by the sun and then stored is usually of low temperature and the efficiency of conversion to cold heat through a chiller is thus low, so the size of the chiller has to be large. For this reason, solar air-conditioning systems have a complicated mechanism and their size is large, resulting in high costs for system structure building and thus the slow spread of such systems. To promote wider deployment, it is necessary to establish efficiency improvement technology of chillers and technology to reduce system costs.

2.2.2.8 Outdoor air cooling

Outdoor air cooling is an HVAC control technology that uses cool natural outdoor air in intermediate seasons such as spring, autumn, as well as winter.

The HVAC system consists of a Chiller Plant that provides chilled / hot water and Air Handling Units that supply chilled / hot air to rooms for cooling / heating by utilizing heat generated by the chiller plant.

Outdoor air cooling uses an air damper to control cool outdoor air volume to control the desired room temperature. Therefore, outdoor air cooling will achieve large energy savings because the HVAC system is able to omit the use of chilled water for cooling and even completely stop the chiller plant.

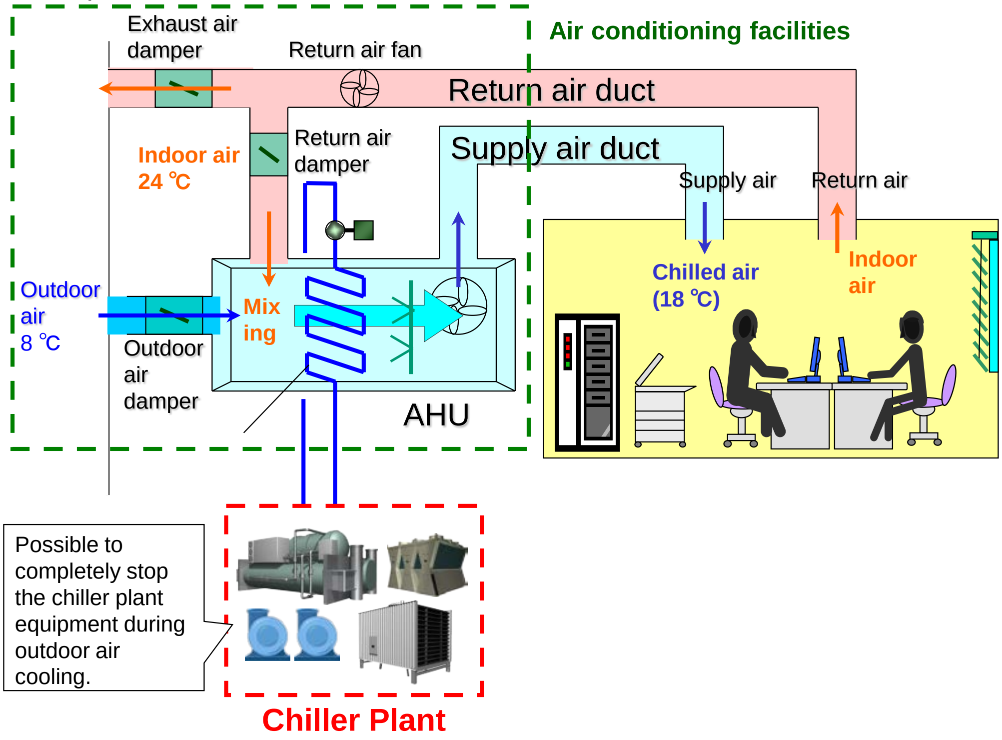


Fig.2.2.2.8-1 Air Conditioning Facility with Outdoor Air Cooling

2.2.2.9 Refrigerant distribution control

Power to run pumps is required for transporting a refrigerant from a heat source to heat exchangers such as the Air Handling Unit (AHU) coil. Optimizing flow rates of refrigerant for each AHU enable effective reduction of pump power consumption. One resolution is to apply an Intelligent Control Valve, a motorized two-way valve with flow measurement and control function as a temperature control valve for the AHU coil.

This built-in sensor measures pressure across the valve and utilizes it to measure the flow rate and contribute to the energy saving measures as stated below.

1. Reducing power consumption by water distribution

An Optimized flow rate control reduces excess water supply and pump power consumption.

2. Improving chiller efficiency

An Optimized flow rate control assures differences between supply and return water temperatures and improves chiller COP.

3. Providing data of each AHU for energy management

Visualization of energy consumption at each AHU shows where energy is wasted most. That helps the Energy Manager to consider countermeasures to save energy.

Fig.2.2.2.9-1 Intelligent Control Valve

2.2.3 Active technology (Water heating)

The target of the Active technology (for water heating) is hot water, and its temperature range in use is thus different from that of air-conditioning technology. In addition, cooling technology is not included in this technology as a target. However, the engineering principle to be applied to this technology is almost the same as that of air-conditioning technology, and the main pillar of innovation of the active technology for water heating is also to pursue energy saving to the extent possible through efficiency improvement.
The present status of the active technology for water heating is shown in the table below.

Table 2.2.3-1 Present status of active technology (Water heating)

Technology	COP %	Equipment cost*	Fuel type**	Fuel cost*	Maturity*	Climate***	Other Information
Boiler	70-95	L	GOB	M-H	H	All	
Heat Pump(Electricity)	200-600	M-H	E	M-H	H	All	
CHP(Engine)	70-95	M-H	G/O/B	L-M	H	All	with Elec. supply
CHP(FC)	80-95	H	G/H	L-H	M	All	with Elec. supply
Thermal Storage	50-100	L-H			M	All	
Solar System	n.a.	L-H	S	0	M-H	All	Renewables

* L:Low, M:Midium, H:High ** G:gas, O:Oil, B:Biomass, S:Solar, E:Electricity, H:Hydrogen,
*** C:Cold M:Moderate & Humid H:Hot

Detailed explanations for each technological item are given below.

2.2.3.1 Boilers

Boilers for water heating are almost the same as those for heating. However, as cold water is boiled to generate hot water in boilers for water heating, they can suppress exhaust gas temperature to a level lower than that required for heating, leading to higher efficiency.

2.2.3.2 Heat pump type

Heat pump-type water heaters can be realized based on almost the same mechanism as that of equipment for heating, but since their temperature ranges for heating are different from each other, it is necessary to change the refrigerant and optimize the heat exchanger. In addition, to realize instant hot-water supply, they are currently equipped with an additional system to store warm water in a hot-water tank. Although the energy source that this type uses is electricity only, they feature high efficiency, so wider deployment of this type is expected.
Because warm-water storage in a hot-water tank causes heat radiation loss and becomes a factor in cost increase, it is required to develop a technology that realizes instant hot-water supply without using a hot-water tank.

2.2.3.3 Combined heat and power

Water heaters using the combined heat and power system can also be realized based on almost the same mechanism as that of equipment for heating. However, the combined heat and power type where the thermal load is appropriate and continuous operation can be realized only by adding a heat exchanger for hot-water supply to equipment for air conditioning. Its efficiency of using primary energy is high, so wider deployment of this type is expected. In household applications, most of the thermal load is generated by hot water, making installation of a hot-water tank essential. Therefore, it is desirable to develop high-insulation technology for hot-water tanks.

2.2.3.4 Heat storage

This is equivalent to the heat storage technology used in air conditioning.

2.2.3.5 Solar water heaters

Solar water heaters have already been widely deployed, including an inexpensive type, because they can be realized by use of only the heat collection panels and hot-water tanks mentioned in Item 2.2.2.7 “Solar systems.” However, costs will increase if the amount of hot water and the water pressure must be kept at comfortable levels.

2.2.4 Active technology (Lighting)

Lighting efficiency is expressed by total luminous flux (lm/W) per input energy. The present status of high-efficiency lighting technology is presented in the table below. Depending on the light source, objects under lighting look different. The influence of lighting on how an object looks is called color rendering. Generally speaking, incandescent lamps emitting light including various wavelengths are said to have excellent color-rendering properties.

Table 2.2.4-1 Present status of Active technology (Lighting)

Technology	Advanced technologies	Luminous Efficiency (lm/W)	Efficiency (%)	Maturity*	Other Information
Incandescent lamp[37]		2-18	0.3-2.6	H	5-100W type
	Halogen	20-26	2.9-3.8	H	
Fluorescent lamp[38]		40-95	5.9-14	H	
	Inverter	110	16.1	H	At High frequency
Metal halide lamp[39]		80-130	11.7-19.0	H	Slow start
LED[40]		30-100	4.4-14.6	M-H	
Organic EL[41]		102	14.9	L	

* L:Low, M:Midium, H:High

2.2.4.1 Incandescent lamps

Incandescent lamps have a structure with a transparent heat-resistant container in which a filament (a metallic wire) made of tungsten, etc. is arranged and they have a ball-like shape, while their container is vacuum-filled or filled with inert gas. A filament is heated by Joule heat generated by energization in order to emit light. In ordinary filament lamps, the higher the temperature of the filament is, the higher the luminous efficiency is. However, the high temperature accelerates metallic evaporation from the filament and shortens the product lifetime, setting a limit on improvement of the luminous efficiency.

Incandescent lamps cannot be replaced by other types in applications that require good color-rendering properties and thus have deeply rooted demand. Accordingly, replacement with halogen lamps is expected.

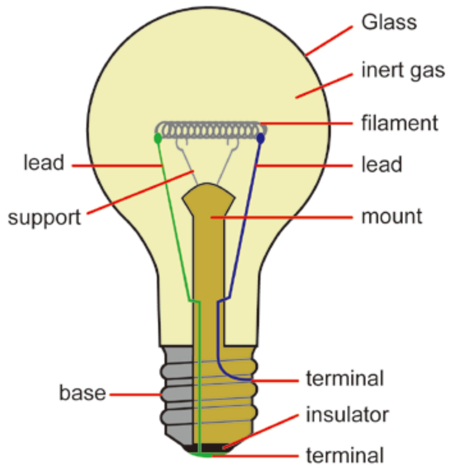


Fig.2.2.4.1-1 Structure of Incandescent lamp

One example of efficiency improvement technologies of incandescent lamps is halogen lamps leveraging the halogen cycle. Their containers are made of high-temperature-resistant materials and are filled with a small amount of iodine, bromine, or other halogen element. Metal evaporated from the filament reacts with the halogen inside the container or on the

[37] Ushio Inc. https://www.ushio.co.jp/documents/technology/lightedge/lightedge_22/ushio_le22-07.pdf
[38] http://www.prince-d.co.jp/feature/helpful/
[39] http://page2.cextension.jp/c4061/book/index.html#target/page_no=131
[40] https://ja.wikipedia.org/wiki/%E7%99%BA%E5%85%89%E5%8A%B9%E7%8E%87
[41] Universal Display Corp.

container wall and then turns into a metallic halide. The vapor pressure of metallic halide is high, so it evaporates from the container wall and floats inside the container. A metallic halide that reaches the vicinity of a filament decomposes due to high temperature, discharging metal to the filament and turning itself back into a halogen gas. Due to this mechanism, the filament lifetime is extended, and the filament temperature can thus be increased, resulting in improvement of luminous efficiency. It is possible to enhance the efficiency to almost 1.5 times that of ordinary incandescent lamps.

Incandescent lamps cannot be replaced by other types in applications that require good color-rendering properties and thus have deeply rooted demand. Accordingly, replacement with halogen lamps is expected.

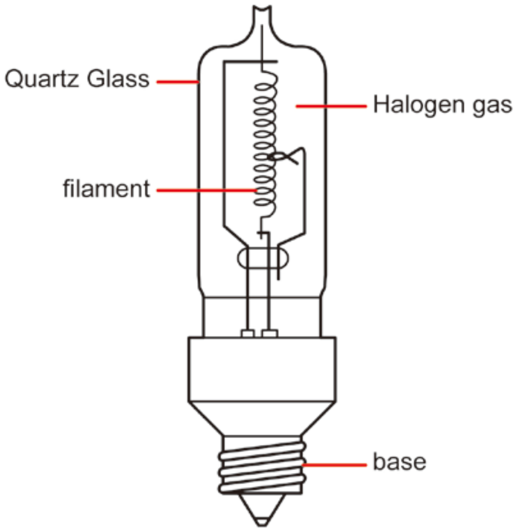


Fig.2.2.4.1-2 Structure of halogen lamp

2.2.4.2 Fluorescent lamps

Fluorescent lamps are light sources where ultraviolet rays are generated through electric discharge, irradiated to a fluorescent substance, and converted to visible light. The type of fluorescent lamp most widely used has a structure with electrodes set in a glass tube (the internal electrode type) and uses 253.7 nm light generated by arc discharge in a low-pressure mercury vapor. The luminous efficiency of fluorescent lamps is 40 to 95 lm/W even for old types where a choke coil is used as ballast; this value is about eight times that of incandescent lamps, which is making fluorescent lamps popular. Fluorescent lamps emit light with wavelengths unique to the fluorescent substance used therein, so their color-rendering properties are limited compared with incandescent lamps. Accordingly, technology development is underway with a focus on improving color-rendering properties, for example, by combining multiple fluorescent substances.

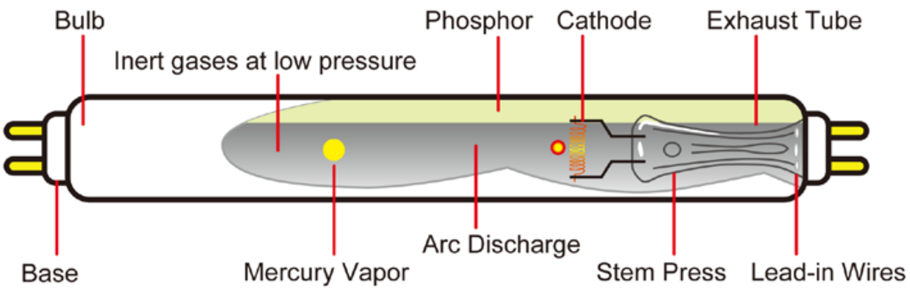


Fig.2.2.4.2-1 Structure of Fluorescent lamp

In efforts to enhance efficiency, inverters have been adopted for a ballast to control light generation, resulting in commercialization of products with efficiency exceeding 110 lm/W. These products have luminous efficiency higher than that of the LED lights widely used today, so it is desirable to update old types of fluorescent lighting fittings to the inverter type.

2.2.4.3 Metal halide lamp

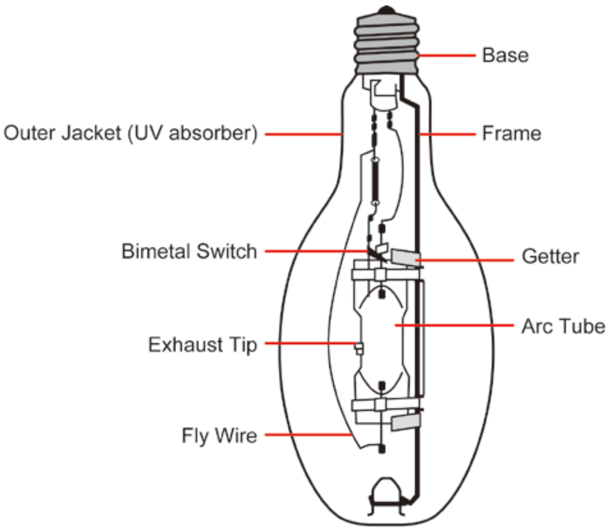


Fig.2.2.4.3-1 Structure of Metal halide lamp

Metal halide lamps are lamps that use light emitted by arc discharge in mixed vapor consisting of mercury and metal halide.

Metal halide lamps have the same basic structure as that of mercury lamps that use light radiation generated by arc discharge in mercury vapor within a quartz glass tube. They leverage emission of light caused by electron transition in sodium, scandium, and other metallic elements to improve the color-rendering properties of mercury lamps. For metal halides, sodium iodide, scandium iodide, etc. are used. Because these color-rendering properties can be adjusted by changing the type and the ratio of metal halides, they are adopted for base illuminating lamps in open-ceiling spaces or indoor atriums of large commercial facilities and high-rise buildings. In recent years, production of metal halide lamps has been promoted on a commercial basis for the automobile sector.

Metal halide lamps are lighting devices that have the highest luminous efficiency among those now in commercial use, but because they take some time to light up to full brightness, they are not used for lighting in living spaces. As for the directionality of technology development, translucent ceramics are used for arc-discharge tubes to enhance durability and luminous efficiency. Metal halide lamps have the highest luminous efficiency among lighting equipment that illuminates a wider area, so the development of technology to further enhance the efficiency is expected.

2.2.4.4 LED lights

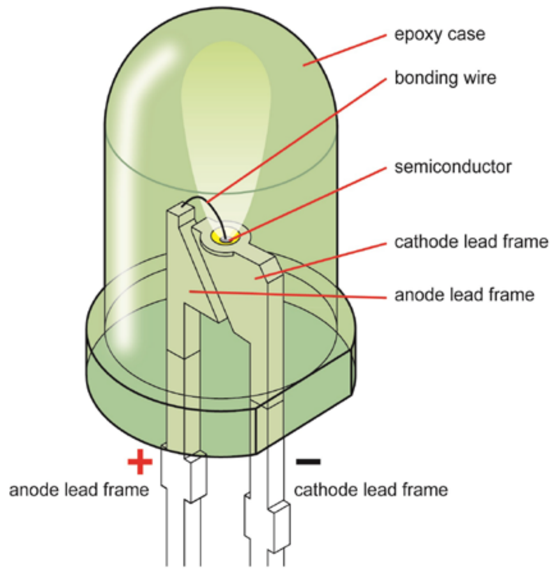


Fig.2.2.4.4-1 Structure of LED lamp

Since the invention of blue light-emitting diodes, development of technology for LED lights has been accelerated and put into commercial use for living spaces and automobiles.

LED lighting has been improved so that it has come to show a luminous efficiency of the same level as, or a little lower level than, that of fluorescent lamps, leading to its wider use as an alternative lighting method to incandescent lamps. Because white light cannot be emitted from a single LED, a combination of a blue LED with a luminous body that absorbs blue color and emits yellow color is adopted for products to be widely used. A product based on a combination of two luminous bodies that emit red and green colors, respectively, has excellent color-rendering properties but low luminous efficiency.

LEDs can have the following properties if they are properly designed and manufactured:

- Longer lifetime
- High impact resistance
- High-speed lighting
- No use of mercury unlike fluorescent lamps and metal halide lamps

- Higher luminous efficiency than incandescent lamps
Their drawbacks are:
- Lower color-rendering properties than incandescent lamps
- Low resistance to heat (requiring a sophisticated heat radiation mechanism)
- High price
- Possibility of harm to human health due to too strong a blue color

As for the directionality of technology development, efforts are needed in various areas covering semiconductor technology, heat radiation technology, circuit design technology, and fluorescent substance technology in order to enhance luminous efficiency and color-rendering properties. It is estimated that luminous efficiency can be enhanced to twice to three times the current level, so the future development of this technology is highly expected.

2.2.4.5 Organic EL

The luminous principle of organic electroluminescence (EL) is that voltage is applied to each of the cathode and the anode so that each electrode moves electrons or holes, respectively. Electrons and holes pass their transport layers and are then bonded in the luminous layer. Luminescence material in the luminous layer is excited to upper energy level. When an excited state returns to the ground state, light is emitted. The light emitted in transit from an exited state (singlet) to the ground state is fluorescence, and the light emitted in transit from a singlet state to the ground state via a triplet state at an energy level a little lower than the singlet state is used as phosphorescence. For the cathode, aluminum, silver-magnesium alloys, calcium, and other metallic thin films are used, while transparent metallic thin films, such as indium tin oxide (called ITO), are used for the anode. Generated light is reflected onto a reflecting surface, penetrates through transparent electrodes and a substrate (a glass plate, a plastic plate, etc.), and finally escapes outside.

In reality, this technology is put into practical use as organic EL displays where light is emitted from individual fine elements. Unlike liquid crystal, they do not use polarized light, so they allow for a wider viewing angle.

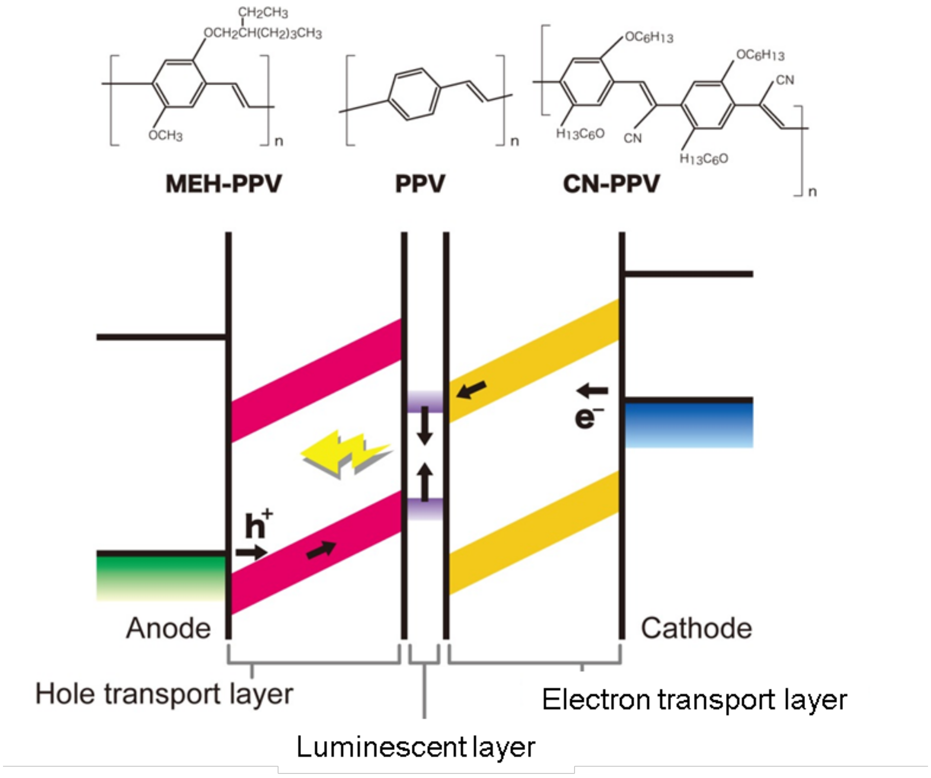


Fig.2.2.4.5-1 Structure of Organic EL Element

Although organic EL is not currently applied to lighting, there is a possibility that it will be used for high-efficiency lighting due to the significant improvement of luminous efficiency in recent years. Therefore, experimental introduction has been started.
In particular, due to the features of organic EL such as “surface emission,” which cannot be realized with LED lighting, as well as “no restriction on shape” and “transparency,” it is considered that there is a possibility that separation of usage between organic EL and LED lighting will proceed in the future or that organic EL will be used more widely than LEDs. There are organic EL products that can be flexibly bent, which is realized by adopting plastic films and similar substrates instead of the glass substrates currently used as the mainstream substrates for organic EL. The printing of organic EL on flexible materials can be found in large screen TVs as products.
As for technical problems now faced by organic EL, efficiency of emitting light is low at around 25%; variation in temperature and electric current occurs depending on the location of the luminous plate, leading to luminance variation; and indium as a scarce resource (used as ITO of transparent conductive film) whose alternative substance does not exist in the display sector is consumed in large quantity, so there are concerns that indium resources might be exhausted.
As for the directionality of future technology development, improvement of luminous efficiency, technology to replace indium with other substances, etc. are required; therefore, many businesses are working on these issues. Accordingly, it is necessary to take support measures to promote technology development.

2.2.5 Renewable Energy Integration

Renewable energy is a type of energy recognized as capable of being used on a permanent basis as an energy source and is in the forms of solar light, wind force, hydraulic power, geothermal power, solar heat, heat in the air, other types of heat in nature, biomass, etc. Examples of renewable energy that can be applied to ZEB/ZEH are solar light, solar heat, wind force, and unutilized thermal energy in sewage water and ground heat.
The status of application of renewable energy to buildings is shown in the table below.

Table 2.2.5-1 Present status of Renewable Energy Integration

Technology	Installation site	New / Retrofit*	Maturity**	Climate	Other Information
PV	Roof	NR	M-H	All	
PV	Wall	N	L-M	All	
Wind power	Roof, Wall	NR	L	All	
Sewage water/ground heat recovery	Heat source	N	M	All	
Solar thermal system	Roof	NR	L-M	All	Active technology (reprint)

* N:New R:Retrofit ** L:Low, M:Midium, H:High

2.2.5.1 Photovoltaics

Photovoltaics is a power generation method of converting solar light directly to electricity through photovoltaic cells. Solar cells provide DC power only when solar light is available. For this reason, electric power generated in the daytime is stored in storage batteries for use during the night, or it is consumed or sold by households that have electricity generated through a connection to an electric power system.

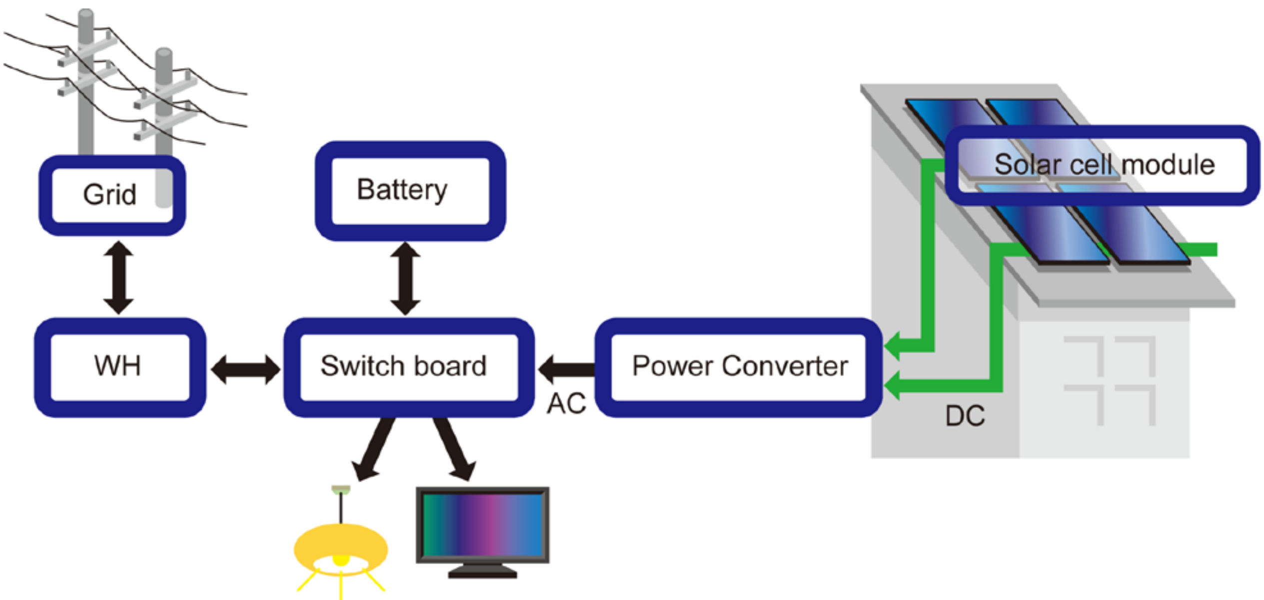


Fig.2.2.5.1-1 Schematics of PV system

Mass production of PV systems to be mounted on roofs for use in buildings is now substantially expanding due to a synergy of technology development for enhancing efficiency and measures taken to promote introduction of feed in tariff (FIT), etc., resulting in lower unit prices for power generation. However, it is necessary to further advance the technology for cost reduction. On the other hand, for PV systems to be mounted on walls as building-integration PV (BIPV), it is necessary to take into account matters such as matching with the external appearance of buildings, so it is also necessary to pursue technology development with an emphasis on excellent design.

Fig.2.2.5.1-2 Building with wall installed PV

2.2.5.2 Wind power

Wind power generation is a method of converting natural wind kinetic energy into electric power using windmills and power generators. The magnitude of wind energy is proportional to the cube of wind velocity, and windmill efficiency is proportional to the square of its diameter. Wind power generation facilities of large-scale windmills have usually been located on mountain peaks and the coast because these locations have strong wind. Power generation costs for large-scale windmills are said to be lower than those for PV systems. On the other hand, there has been no smooth deployment of wind power generation facilities on buildings due to wind conditions more adverse than those on mountain peaks and the coast, concerns about scenery and safety, high costs of power generation facilities, etc. Development of technologies necessary for high-efficiency wind power generation systems for ZEB is an urgent issue.

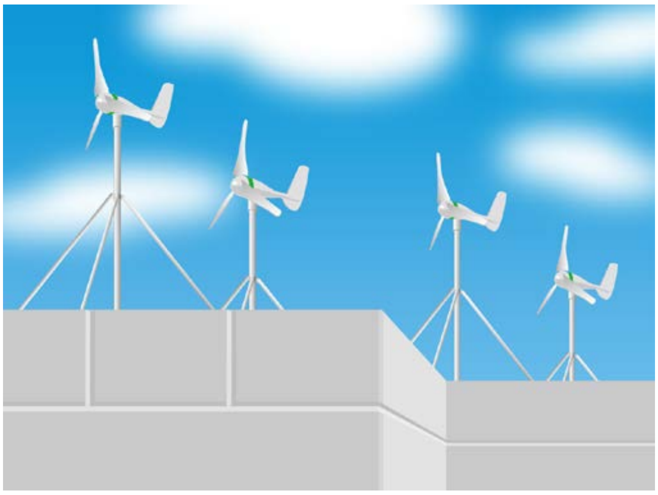


Fig.2.2.5.2-1 Building with Wind power system

2.2.5.3 Use of unutilized energy

Unutilized energy is a general term for energy that has not been used so far despite a possibility of effective use, including factory exhaust heat, exhaust heat from cooling and heating systems used in underground railways and underground malls, river and sewage water having a temperature difference from the outdoor temperature, and snow and ice heat. An image of use of unutilized energy is shown below. Unutilized energy has the feature of "wide and thin" distribution and its sources of supply are often remote from areas of demand, so technologies to effectively use the energy are required. Specifically, these technologies include heat pump technology, technology to use snow and ice, off-line heat supply (transfer) technology, technology to use the temperature difference of seawater/lakewater, etc.

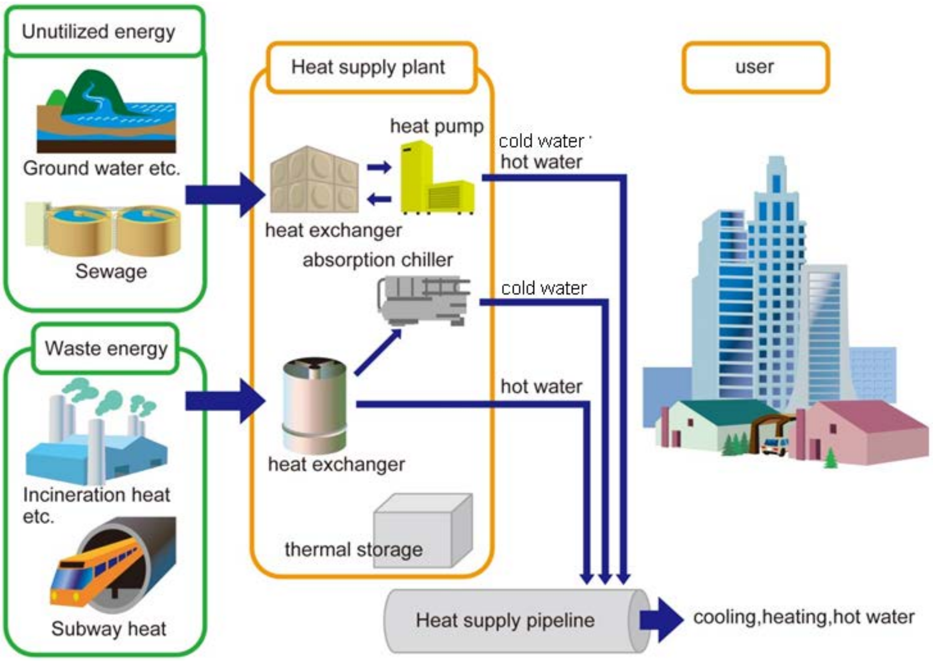


Fig.2.2.5.3-1 Schematics of waste thermal energy utilization system

For application of unutilized energy to ZEB/ZEH, a study has been made on the forms of recovery of heat to sewage water and utilization of earth thermal. In either form, it is necessary to start studying its introduction at the building design phase. In addition, measures to facilitate introduction of these forms should be taken, and their standardization is desirable.

2.2.6 Energy management

Energy management means, in a broad sense, to organically combine generation, conversion, accumulation, transfer, and consumption of various forms of energy and link them to one another so as to achieve efficient energy use. With a focus on areas related to ZEB/ZEH, energy management can be understood as a system to control introduction of active energy, passive energy, and new energy in the most effective manner. The table below shows the present status of technologies related to energy management that can be applied to ZEB/ZEH.

Table 2.2.6-1 Present status of Renewable Energy Management System for ZEB/ZEH

Technology	Key Component	New/ Retrofit*	Maturity**	Other Information
EMS(Control protocol)	Home server	NR	M	Including architecture
EMS(ICT)	Communication methods	NR	M-H	Wireless, PLC
EMS(communication terminal)	Electric appliances	NR	M-H	
	Passive technology	NR	L-M	Auto controlled window shading etc.
	Energy saving control	NR	M-H	
Integration with other system	Batteries in EVs	NR	L-M	
	Interface between smart grids	NR	L-M	

* N:New R:Retrofit ** L:Low, M:Midium, H:High

TOPIC2 Example of Energy Management in building sector[42]

In Amarin Plaza in Bangkok, Thailand, a BEMS has been introduced since 2014. BEMS controls the HVAC system for a large-scale building complex (including offices and a shopping mall), and saves energy by efficient control of the facilities (see the figure below).

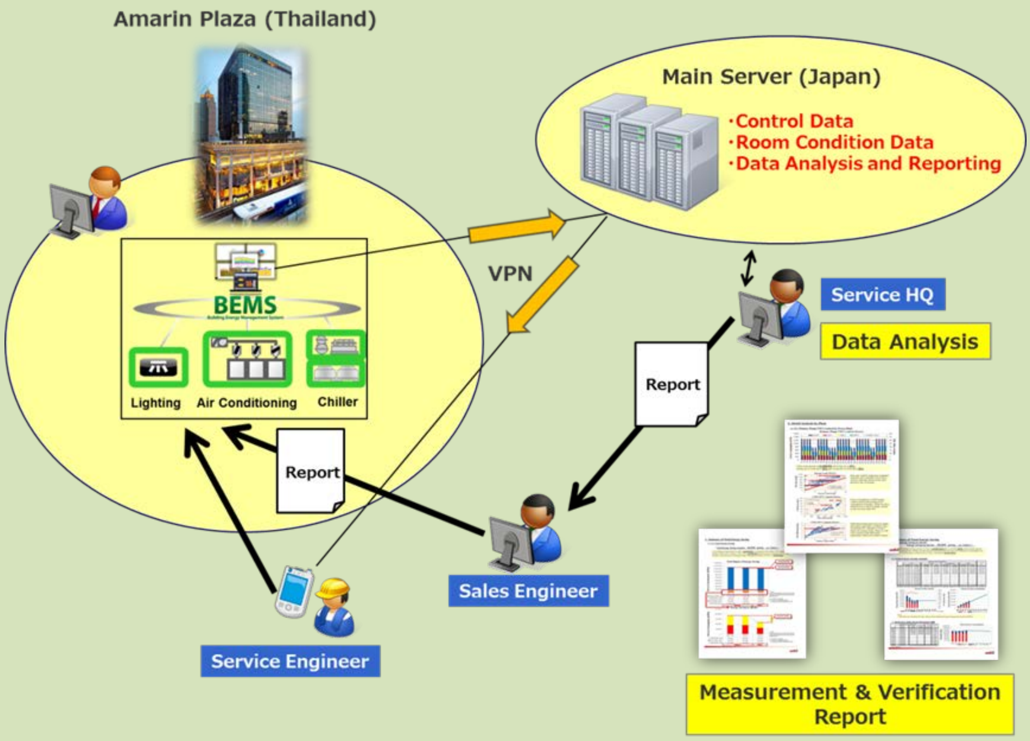


Fig. T2-1 BEMS Scheme at Amarin Plaza

The BEMS transmits measured and control data on site to main servers in Japan via the virtual private network (VPN). The Energy Manager in service department in Japan specifically analyzes data and reports the results with issues found. Then sales engineers in Thailand provide the reports to customers. Furthermore, service engineers on site are able to retrieve data stored in the server via VPN. The BEMS will help service engineers to carry out timely facility maintenance.

This BEMS was introduced for the purpose of optimizing the chiller plant facility operation as an ESCO project[43]. This system saves energy by 4% for the total building complex, and even 50 to 60 % of the energy consumed by the chilled water pumps.

[42] Azbil Corporation

[43] In an ESCO (energy service company) project, the service provider guarantees energy savings and provides comprehensive energy services at plants or buildings. For an ESCO project, a BEMS is an essential tool for attaining energy conservation, as well as for measurement and verification (M&V).

2.2.6.1 Energy management system

The Energy Management System (EMS) is a system that manages energy consumed by several types of buildings. EMS differs depending on the use for building types such as “HEMS” for homes, “BEMS” for commercial buildings, and “CEMS” for communities (for both homes and other types of buildings).

An HEMS is able to visualize the amount of electricity both generated and consumed as well as the consumption of gas and water, on a monitor. That also controls electric appliances and other home equipment. In Japan, EMSs have been developed and are gaining popularity as a part of smart community demonstration projects. On the other hand, development of the BEMS was based on the building automation system (BAS), which was introduced in the 1970s, with the addition of energy management features in order to respond to the trend toward energy conservation. Its development is accelerated greatly in line with international climate change issues arising in the 1990s. In Japan, most buildings larger than a certain size have a BEMS because of amendments to energy legislation and because of promotion by NEDO. Recently, with the spread of IT technologies and services, the BEMS has begun to use cloud computing technology. This allows the energy management of not only single buildings, but also multiple buildings regardless of the time or location.

Furthermore, remote support services that provide energy conservation by specialists and the utilization of automated demand response (ADR) systems are being promoted.

A cluster energy management system, also called a community energy management system (CEMS) enables the effective use of renewable energies, heat, electricity, and energy by leveling the load in order to regulate supply and demand and reduce CO2 emissions. Demonstration projects for the concept of the smart community have appeared, and experiments for its implementation are being carried out worldwide for many types of development area, from microgrids for a whole area to cluster types for scattered facilities.

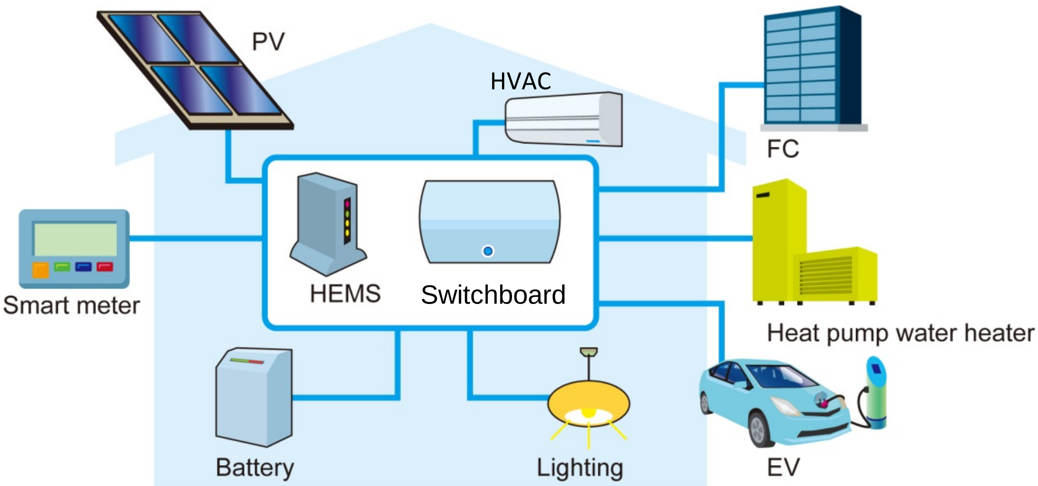


Fig.2.2.6.1-1 Schematics of HEMS in the market

Efforts should be made towards optimization of control, performance evaluation, standardization, etc.

2.2.6.2 Communication

In order for an EMS controller to intercommunicate with various types of home electronics and household equipment, common communication specifications should be adopted. As examples of such specifications, SEP2.0 is used in the U.S. and KNX is used in Europe. In Japan, ECHONET Lite was recently established. KNX has been applied to qualify more than 7,000 types of products manufactured by 370 or more companies worldwide, and KNX itself was approved by the standardization bodies of Europe, China, and the U.S. as well as by the international organization ISO. SEP2.0 was formulated based on its preceding specification “ZigBee Smart Energy Profile 1.0,” and it allows for some general control such as turning on/off of equipment. Currently, organizations such as ZigBee Alliance, Wi-Fi Alliance, and HomePlug Alliance that use the SEP2.0 specification have established a consortium to discuss mutual operation of their products and their tie-ups.

If EMS standards are unified across nations and regions, it will encourage smart houses and their related equipment to be used more widely. As for ECHONET Lite, it is said that it has advantages in the ability to control equipment in a more detailed manner than other specifications, raising expectations of future applications.

On the other hand, BEMS manufacturers have used proprietary protocols for communication protocols throughout the 40 years of BEMS history. But now, BEMS uses standard communication protocols such as Modbus, LonWorks, and BACnet in order to integrate building facilities and realizes an open environment using ICT technologies. In particular, BACnet was developed by ASHRAE in the U.S. and standardized as ANSI/ASHRAE. BACnet has been recognized as a useful protocol for BAS/BEMS and is gaining popularity worldwide. It is now registered as the international standard ISO 16484-5. In accordance with the evolution of communication technology and customer requirements, BACnet is continually enhanced and updated in its protocol architecture, objects, and services. Various protocols for communication among HEMSs, BEMSs, and CEMSs are being studied widely. In Japan, JIPDEC proposes a standard protocol. JIPDEC supports BACnet as the protocol for use between a BEMS and CEMS. Also, IEEE 1888 (a standard protocol for general facilities) and OpenADR, which enables automatic demand/response, are being studied as international standards.

2.2.6.3 Equipment corresponding to EMS

Equipment corresponding to EMS has a function as a communication terminal to communicate with EMS. It is desirable to globally unified communication standards in order to increase the number of equipment corresponding to EMS i.e. interoperability.

As mentioned above, since BACnet is now a global standard and device manufacturers are implementing it for BEMSs, BACnet will enable the establishment of an open interoperability environment for central monitoring systems, sub-controllers, devices in the field, and inter-system communication. However, the service life of facility equipment in buildings varies depending on the product, so it is necessary to connect the existing devices that use old communication protocols such as Modbus and LonWorks to the EMS.

2.2.6.4 Equipment control based on the passive technology

Air conditioning based on the passive technology uses light shielding, natural ventilation, etc., but it is usually implemented by human who use window shades or open/close windows. If air-conditioning equipment can be activated by control devices equipped with EMS terminals, there is a possibility of realizing optimum control. It is expected that this type of device will be widely used along with the advancement of EMS.

2.2.6.5 Energy saving control

There are many energy-saving technologies for automated air conditioning control systems, including heat sources in relatively larger scale buildings. The technologies can be categorized into 3 groups as follows: (See the following table and figure.)

(1)Technologies to control generation of the heat load in rooms

(2)Technologies to efficiently remove the generated heat load

(3)Technologies to efficiently generate and transfer the required heat/cold

It is very important to prioritize the application of these three technology groups to obtain energy savings in buildings. It is important to take the following steps: (1) reduce the heat load as much as possible, (2) minimize the required amount of heat/cold as much as possible by improving the heat load handling process, and (3) generate the required heat efficiently.

Table 2.2.6.5-1 Energy-Saving Technologies for HVAC

Group	Automatic control technology for energy conservation	Description
(1) Suppresses heat load generated	Automatic adjustment of room temperature set point	Automatically reduces the heat load by changing excessive temperature setpoints.
	Demand based control (CO_2)	Controls the volume of ventilation according to the CO_2 concentration in order to reduce the outdoor air load.
	AHU control according to human presence	Reduces air conditioning in zones where no human presence is detected in order to reduce the load.
	Lighting control according to human presence	Turns off lights in zones where no human presence is detected in order to reduce the load.
	Automatic dimmer control for lighting	Lowers brightness in a room when there is abundant ambient light (such as in daytime) in order to reduce the load.
(2) Efficiently removes the generated heat load	Outdoor air cooling	Utilize cool outdoor air to reduce the load for cooling rooms.
	VAV control	Controls the supply air volume for each zone to reduce AHU fan power consumption.
	AHU variable air volume control	Using VSD to reduce AHU fan speed to save power consumption
	Humidification Cooling Control	Generates chilled air using vaporization type humidifier to reduce AHU load.
(3) Efficiently generates and transfers heats	Chiller Number Control	Runs only the number of chillers required for air conditioning.
	Chiller load distribution control	Allocates more load for the heat sources that efficiently generate heat.
	Temperature setpoint control for the outlet of chillers	Improves the efficiency of chillers by reducing the temperature setpoint at their outlet.
	Variable condenser water volume control	Controls the volume of condenser water according to the amount of generated heat.
	Airflow control for the cooling tower fans	Reduces the cooling tower fan airflow according to the radiated heat from the chillers.
	Controls the number of operating water pumps	Operates only the number of pumps required for conveying heat.
	Variable water volume control for water pumps	Controls the water pressure required for conveying heat.

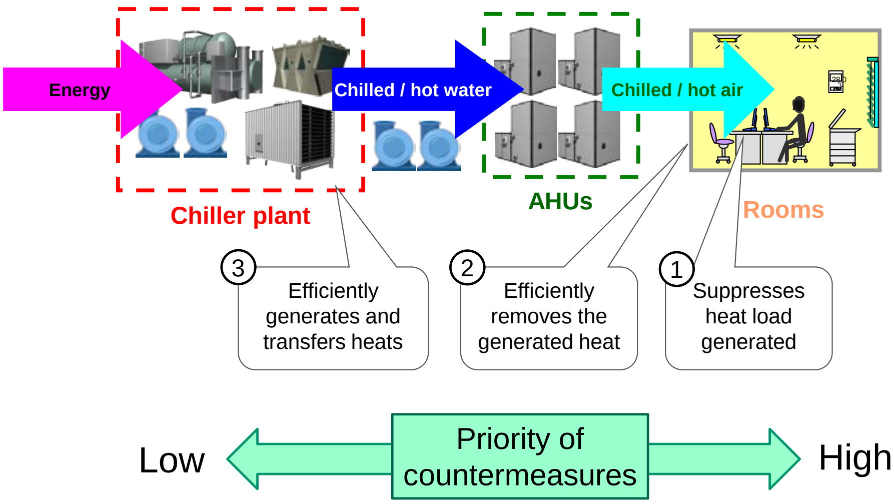


Fig. 2.2.6.5-1 Applicable Area of Energy-Saving Technologies for HVAC

2.2.6.6 Linkage with EV batteries

If EMS has an internal electricity storage function, renewable energy can be used more efficiently. Therefore, electric vehicles (EVs) that can be linked with EMS are expected to be more widely used. EV charging system basically works in stand-alone, but, it may work through a cloud management especially in commercial buildings. Though some standalone EV charging systems already have interface with BACnet, it is necessary for cloud-base EV charging systems to develop interface between BEMS and cloud center. It is desirable to standardize V2B (Vehicle to Building) like V2G (Vehicle to Grid).

2.2.6.7 Linkage with smart grids

Although this is a different issue from the purposes of ZEB/ZEH, it is effective for efficiency improvement at the grid level to link EMS systems with smart grids. So, it is desirable to promote technology development aiming at effective linkage of EMS design architecture with smart grids. One of the typical examples of interface between EMS and Smart Grid is DR (Demand Response) which is popular in the United States and elsewhere.
OpenADR etc. is adopted as the communication standard for DR, but further technical development is desired.

2.3. Policies for promoting ZEB/ZEH introduction in the existing Road Maps

2.3.1 Barriers in implementing and diffusing ZEB/ZEH

On November 4th 2016, a new climate change policy framework beyond 2020, "Paris Agreement under United Nations Framework Convention Climate Change (UNFCCC)", came into effect, backed by over 190 countries worldwide. The Agreement has established a shared long-term global GHG reductions target for limiting temperature rises below 2℃. This requires us to make great changes to the way we live and run our economy, starting with energy policy. With final energy consumption remaining high in developed countries, and energy demand also expected to increase in developing countries as they push for economic growth, the building sector is especially in need of tougher energy-efficiency policies.

We have noted the following barriers in relation to the implementation and diffusion of ZEB/ZEH. Firstly, information regarding the costs and benefits of products applicable to ZEB/ZEH is not being put out effectively, meaning that levels of awareness and understanding among consumers are failing to rise. Secondly, the roles of the many government ministries involved in ZEB/ZEH policy remain blurred, and thirdly, insufficient cost estimations can be carried out and the feasibility of ZEB/ZEH cannot be properly assessed. Fourthly, there is a human capacity problem as few architects, technical experts and equipment installers either have sufficient knowledge of energy-saving and low-carbon technologies, or possess the relevant capability to design ZEB/ZEH and calculate its energy-saving potentials. A host of challenges thus remains as to how to plan the implementation and diffusion of ZEB/ZEH in developing countries where energy demand is vastly increasing.

(Outreach)
The average consumer is simply not expanding his or her knowledge about the costs and benefits of ZEB/ZEH products. Specifically, the average consumer lacks awareness and understanding of the components of ZEB/ZEH and therefore cannot appreciate the performance and energy-efficiency aspects of such products. This means that we are unable to sufficiently insist the benefits such as reductions in energy expenses, improvements to health and comfort stemming from better insulation and resilience (contribution to Business Continuity Planning) based on energy self-sufficiency.

(Governance)
Long-term budget commitments are necessary if we have to achieve lifecycle optimums. Unfortunately, a great number of government ministries are involved in ZEB/ZEH policy, but with a lack of clarity in their respective roles. Government sector cannot make an appropriate estimation of ZEB/ZEH profitability and other investment benefits, which give insufficient motivation to building owners (decision-makers to develop and construct ZEB). Furthermore, although some countries have established several support and labeling schemes for environment-friendly or energy-efficient housings and buildings, some people seemingly fail to grasp the difference made by such schemes, meaning that effectiveness has been limited. In addition, from the standpoint of privacy protection, there is a need for sufficient consideration over the private data about energy behavior disclosure. Yet the government sector must provide more details on security regulations.

(Costs)
As there is a lack of cost estimations on ZEB/ZEH, the feasibilities for ZEB/ZEH are difficult to be assessed. As diffusion of ZEB/ZEH has been so limited, market competition remains weak and costs have remained high, the building owners who develop and design ZEB/ZEH cannot cover its additional costs. Moreover, as buildings are not mass-produced goods, there appears great difficulty in sharing information about costs of buildings.

(Lack of human resources)
It is also difficult to encourage implementation and diffusion of ZEB/ZEH due to a human resource shortage. Few architects, technical experts and equipment installers either have sufficient knowledge of energy-efficiency or low-carbon technology, or possess the requisite capability to design ZEB/ZEH and calculate its energy-saving potentials.

(Landlord-tenant problem)
This has occurred within rented properties, whereby even though the building owners must cover the costs of ZEB conversion, the benefits are accrued by the tenants in terms of lower energy costs.

(Behavior)
Significant behavioral and lifestyle changes are required to reduce building energy demand.

(Regional Difference)
In future, the major increase in energy use and consequent CO_2 emissions will come from the developing world. However, in developed countries, the depth of building renovation is also crucial, as retrofit buildings will command the largest share of total building stock by 2050. There is thus enormous potential for emissions reduction within the cool and moderate climate zone in which most rich countries are located. Urban areas will account for most of the growth in energy use, both in developed and developing countries. However, rural regions also have a crucial role to play.

2.3.2 Policy Elements for Promoting ZEB/ZEH Introduction
Many policies and measures are already listed within the existing roadmaps. However, the following diffusion/deployment policies, which are common in many roadmaps, can be listed as important policy elements.

2.3.2.1 Stakeholder Involvement
Firstly, for governments and other stakeholders who play a role in shaping the ZEB/ZEH market:

i. Policy coordination in public sector, stakeholder participation, and governance reform.

In many countries, ZEB/ZEH policy-making responsibilities are divided between various ministries such as those for Energy and Building / House Construction. In order for these policies to be positively driven forward, it is important to clarify the authorities among these ministries.

The diffusion/deployment of ZEB/ZEH will require market alterations. In addition to improving the availability and relevance of information provided to decision-makers, policies are needed to improve the knowledge and ability of private sector actors involved with ZEB/ZEH. Quality assurance in that sector should be increased to foster greater trust among consumers.

ii. Improving the availability, quality and effects of information provided by stakeholders to decision-makers, and ZEB/ZEH-related public information

The ZEB/ZEH market is characterized by incomplete information. In conjunction with improvements to information provided to consumers, we need more robust ways to measure and analyze the energy and CO_2 reductions and the lifecycle financial benefits from the use of ZEB/ZEH technology. User-friendly information must be provided to buyers and consumers.

iii. Improving knowledge in private sector within the construction industry and among equipment installers; building infrastructure and human resources; drawing up and diffusing design guidelines and increasing knowledge sharing; and developing technical experts

People involved with ZEB/ZEH such as architects, technical experts and equipment installers need to improve their knowledge and capability on energy-saving and low-carbon technologies. It is important to widely diffuse knowhow, especially among small-scale building owners and architectural firms, by preparing and updating design guidelines based on information gathered on technologies, design methods, and costs and benefits. We must train up individuals who can propose ZEB/ZEH to technical experts, building owners and tenants involved in ZEB/ZEH.

Embedding new technologies into products and successfully penetrating them into the market requires policies appropriate to the maturity of market. At the R&D and demonstration phase, R&D promotion and case studies will be key policies, while market incentives and mandatory building codes must form the kernel of policy at the diffusion/deployment and marketization stage.

2.3.2.2 Research, Development and Demonstration

(R&D and Demonstration Phase)

iv. Enhanced technology R&D, demonstration programs, development of technology which beyond BAT (Best Available Technology); development of innovative technology through R&D promotion and case studies; development of technology for higher performance and lower cost

It is essential to both improve the performance of and lower the cost of component technology by the development of technology and for production on a larger scale.

2.3.2.3 Diffusion/Deployment

(Diffusion/Deployment and Marketization Phase)

v. Diffusion regulations and policies; the drawing up, publication and enforcement of mandatory building codes; the use of financial incentives; incentives to building owners; and clarifying benefits of ZEB/ZEH.

We must implement policies which make use of economies of scale to accelerate diffusion and lower costs. The policy most used to ensure energy efficiency in new buildings is the introduction, publication and enforcement of mandatory building codes, while the main direct policy for promoting deep renovation of existing energy-inefficient buildings consists of financial incentives. A certain level of subsidies to the introduction of highly insulated envelope and higher performance equipment and appliances has proved effective in triggering building owners to convert to ZEH. Benefits other than energy saving such as improvements to health and comfort, labor productivity and market value may also become good incentives. It is necessary to clarify benefits other than reductions in energy expenses such as improvements in: resilience through independent energy provision; comfort/health and labor productivity through enhanced quality of the indoor environment; and real-estate value. We also need to increase understanding of these benefits among building owners, tenants and consumers.

TOPIC3 Diffusion situation of ZEH in Japan today

Definition and Technology for ZEH

A ZEH is a house with an annual net energy consumption around zero (or less) by saving as much energy as possible keeping comfortable living. As shown in Figure below, this can be achieved through better heat insulation, high-efficiency equipment, and creating energy with photovoltaic power generation etc. [12] The concept of ZEH has been widely accepted and diffused the numbers of ZEH built is increasing.

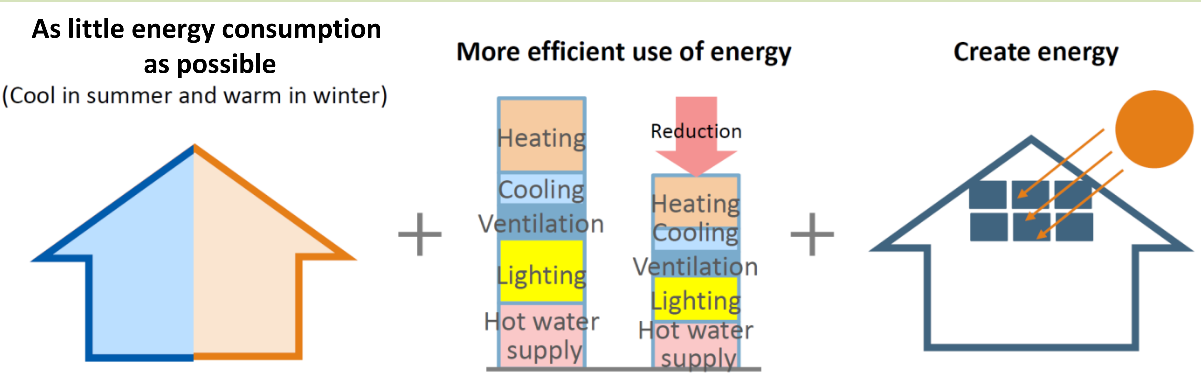
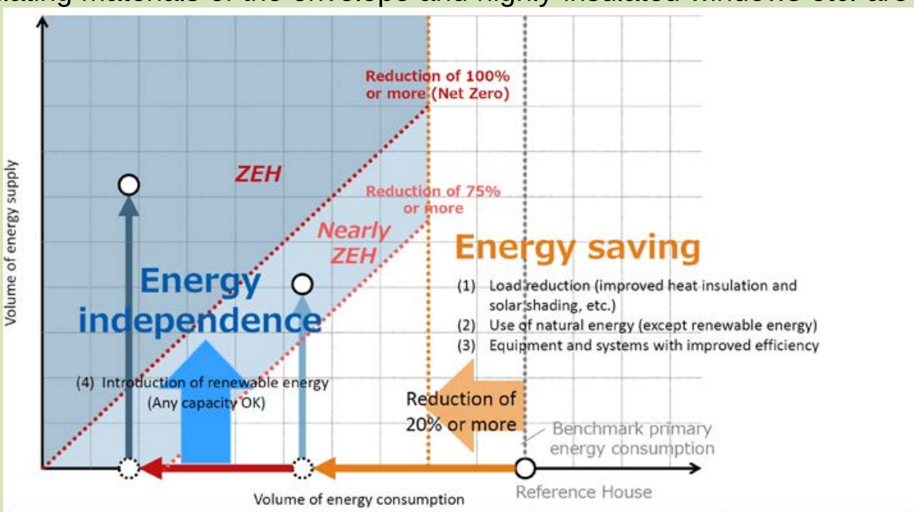


Fig. T3-1 Conceptual diagram of ZEH[44]

ZEH requires energy saving of 20% or more and creating the rest to attain net zero energy. High-performance insulating materials of the envelope and highly-insulated windows etc. are used for low consumption of energy and high-efficiency equipment of the house such as air conditioner, ventilator, lighting and water heater is introduced to use energy more efficient. Photovoltaic is mainly used to create power for ZEH. Nearly ZEH status (75% reduction of energy) is introduced to save poor sunshine area.



Region category	Region 1 (Asahikawa, etc.)	Region 2 (Sapporo, etc.)	Region 3 (Morioka, etc.)	Region 4 (Sendai, etc.)	Region 5 (Tsukuba, etc.)	Region 6 (Tokyo, etc.)	Region 7 (Kagoshima, etc.)	Region 8 (Naha, etc.)
ZEH Standard	0.4	0.4	0.5	0.6	0.6	0.6	0.6	–
Energy Saving Standard	0.46	0.46	0.56	0.75	0.87	0.87	0.87	–

Table: Standards for the average heat transmission coefficient of the envelope (UA value)

Fig. T3-2 Schematic diagram for the definition of ZEH[44]

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[44] Sustainable open Innovation Initiative, as of 2016/11/22
https://sii.or.jp/zeh28/file/doc_1122.pdf

Diffusion policies

Diffusion policies settled by Agency for Natural Resources and Energy (METI Japan) are shown in the chart below. The goals in FY2020 are autonomous diffusion of ZEHs and attainment of 50% or more of ZEBs in newly-built houses. In the policies, establishment of the definition of ZEH, subsidies for construction, training policy of construction engineers are included as the role of national government. Public relations, technology development (adapting ZEH as a standard specification) and setting voluntary action plan for diffusion of ZEHs are required for construction company.

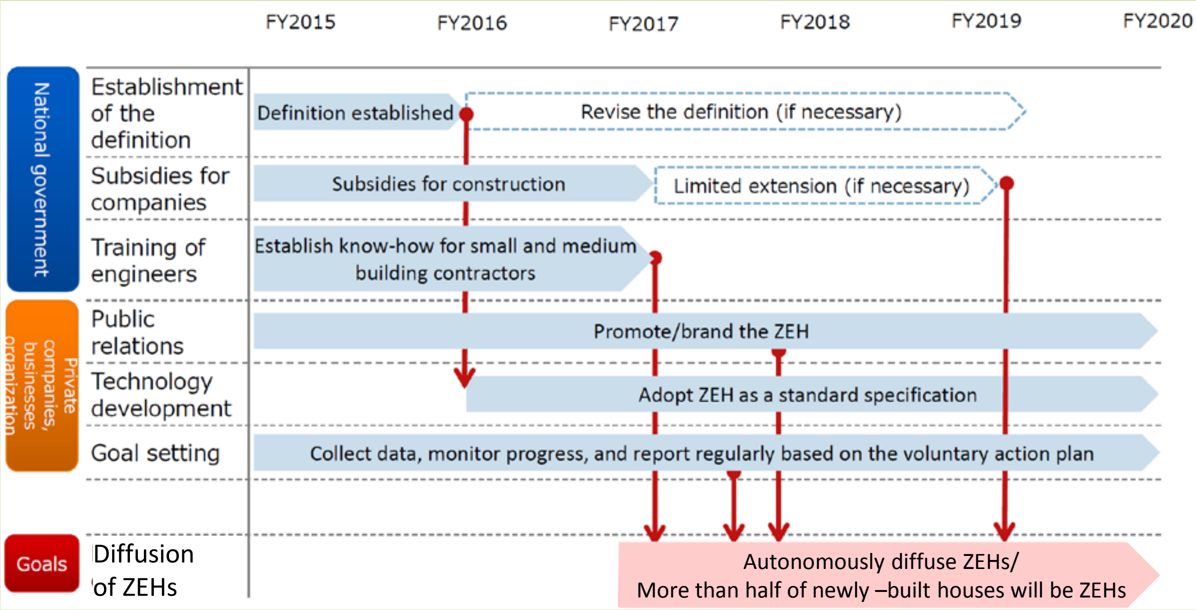
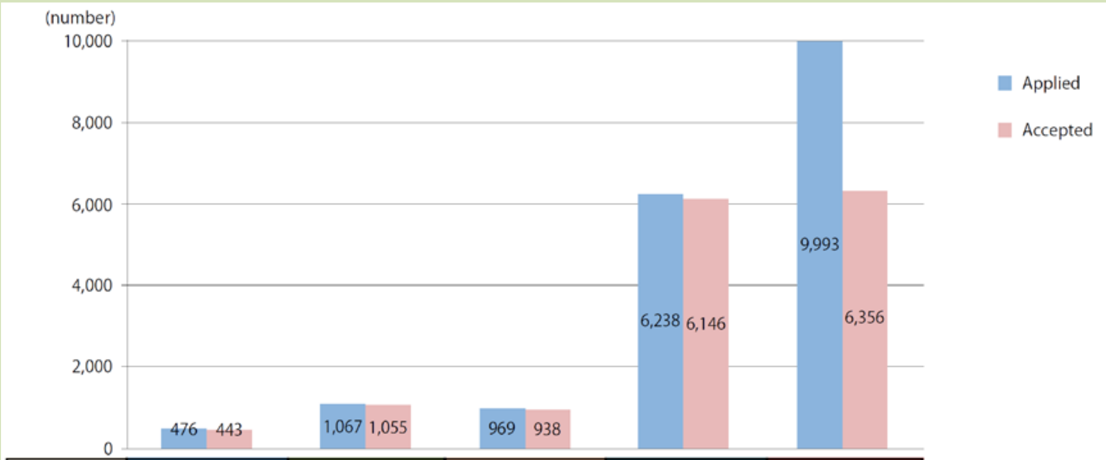


Fig. T3-3 Chart of ZEH diffusion policies in Japan[44]

ZEH is becoming popular and reached nearly 15,000 cases on the basis of subsidy grant decision in FY2016 owing to those policies.



FY	2012	2013	2014	2014 (supplementary)	2016
Applied	476	1,067	969	6,238	9,993
Accepted	443	1,055	938	6,146	6,356

Fig. T3-4 Numbers of annual ZEH support cases in Japan.[44]

3. Path to innovation and spread of technology

3.1 Directionality of technology innovation

As stated in 2.1, various technologies are applied to buildings; yet there are many sophisticated technologies that have not been applied to buildings in order to suppress costs. There are also domains in the buildings sector where high performance is achieved at low cost by introducing innovative technologies.
This technology roadmap shows issues to be addressed in the future with a focus on innovative technology, cost reduction, and development of high-efficiency technology.

3.2 Technology roadmap

Technology roadmaps shown below indicate the expected years when the advanced technologies should be available in the market put into use. Many of them are consistent to the road maps of IEA and Energy Efficiency Technology Strategy 2016 Formulated (ANRE / NEDO).
Table 3.2-1 shows the technologies included in the each climate zone roadmap. Especially in the Moderate and Humid region, all technologies pointed out in this roadmap are required for realizing ZEB/ZEH.

Table 3.2-1 Comparison of the roadmaps by the climate zone

	Technology	Climate	Moderate & Humid	Cold	Hot
Active technology	Air conditioning	HP (6<COP*1)	✔	✔	✔
		Absorption Chiller	✔		✔
		Solar Cooling	✔		✔
		Solar Heating	✔	✔	
		Dehumidification	✔		✔
	Water Heater	Condensing Boiler	✔	✔	✔
		CHP:(EG: Engine)	✔	✔	✔
		HP	✔	✔	✔
		CHP(FC: Gas-fueled)	✔	✔	✔
		CHP(FC: H2-fueled)	✔	✔	✔
	Lighting	LED/Fluorescent	✔	✔	✔
		Organic EL	✔	✔	✔
Passive technology	Ventilation	Room, Floor, Roof, etc.	✔		✔
	Shading	Automatic-type etc.	✔		✔
	Insulation	Envelope UA*2<0.35	✔	✔	✔
		Windows U*3<0.6	✔	✔	✔
	Reflection	Material SR*4>0.75	✔		✔
	Sealing	ACH*5<0.5	✔	✔	✔
Renewables	PV*6	Rooftop use	✔	✔	✔
		Wall side use	✔	✔	✔
	Wind Power	Rooftop use	✔	✔	✔
	Unutilized energy	Earth thermal etc.	✔	✔	✔
Energy management	EMS*7 x IoT*8	Main System	✔	✔	✔
		ICT	✔	✔	✔
		Terminal Unit	✔	✔	✔
		Energy Storage Unit	✔	✔	✔
	Grid Connection	Smart Grid	✔	✔	✔

*1:Top level, IEA *2: Avarage U value for wall and roof, IEA *3: U value of whole window for ZEB, IEA *4:Solar reflectance, white *5:Air Change per hour *6:Photovoltaics *7:Energy management system *8:Intenet of things

3.2.1 Roadmap for moderate and humid regions

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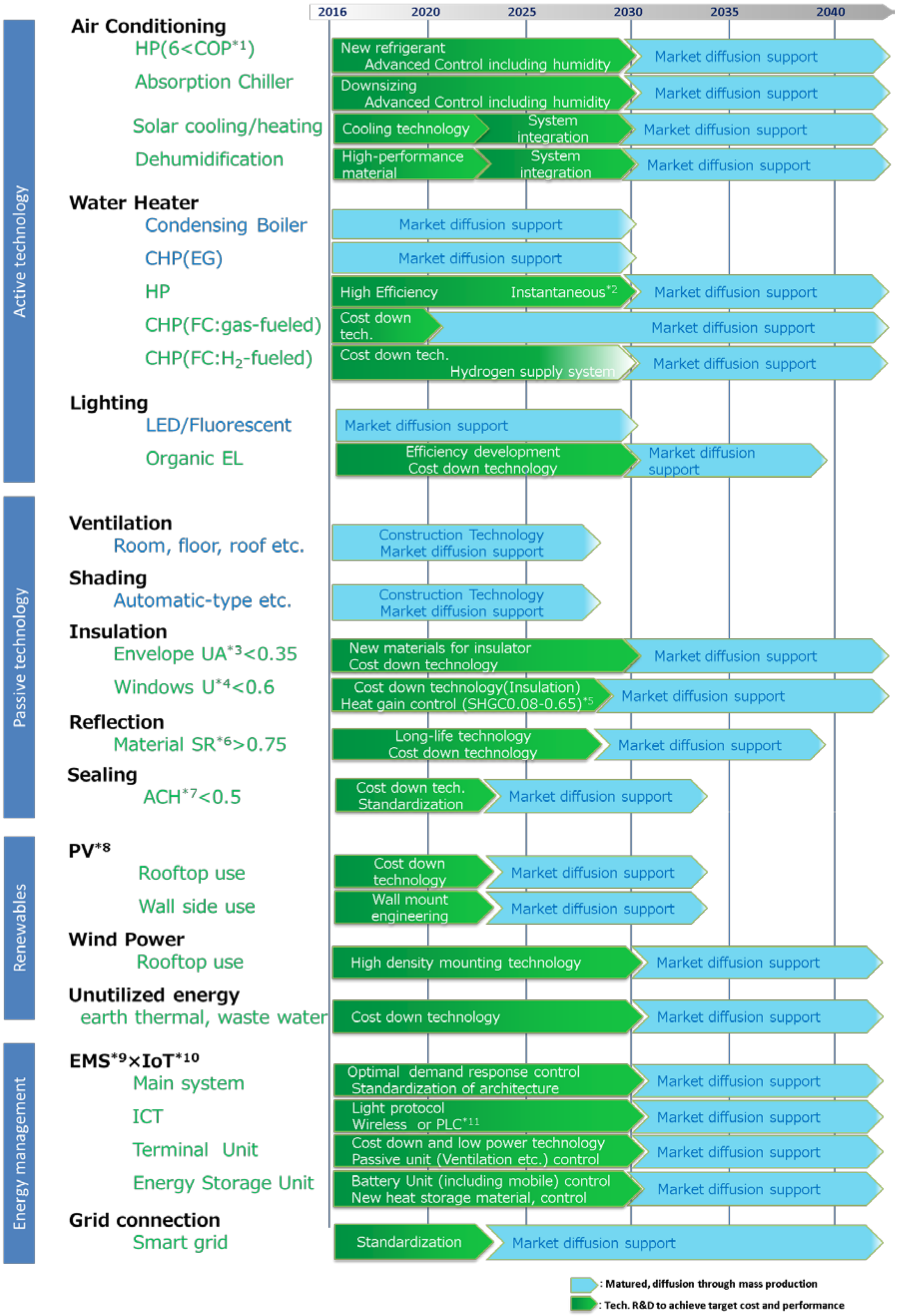

Fig.3.2.1-1 ZEB/ZEH technology roadmap for moderate & humid regions

*1:Top level, IEA *2: System without hot water tank *3: Average U value for wall and roof, IEA *4:U value of whole window for ZEB, IEA *5:Solar Heat Gain Coefficient, IEA *6:Solar reflectance, white *7:Air Change per hour *8:Photo voltaics *9:Energy management system *10:Intenet of things *11:Power line communication

Figure 3.2.1-1 shows a roadmap for moderate and humid regions.
As stated in 1.6, there are many cases where application of energy in the ZEB/ZEH fields in moderate and humid regions is directed to reduction in humidity, so various types of technology are adopted as targets in the roadmap.

3.2.1.1 Active technology

A) Air conditioning

Equipment necessary to be considered for technology development and promotion of diffusion of the active technology (air conditioning) are high-efficiency heat pumps, absorption chillers, and dehumidification technology.
High-efficiency heat pumps can be realized by leveraging technology development mainly in two fields: optimization of heat exchangers (including development of high-efficiency cooling media and design of refrigeration cycles suitable for the media) and efficiency improvement of compressors.
In principle, the more the performance of heat exchangers is improved, the more the efficiency of heat pump cycles is enhanced. In contrast, however, costs increase. Therefore, the key point is technology for material and structure design of heat exchangers that helps achieve high efficiency while keeping costs at a minimal level.
For efficiency improvement of compressors, emphasis should be placed on technology to suppress power loss caused by friction. Although scroll compressors and the like are put into practical use as high-efficiency compressors, it is also necessary to develop compressors that feature higher efficiency and that are suitable for refrigeration cycles in high-performance cooling media. In addition, in humid regions, dehumidification is conducted simultaneously with cooling when using heat pumps for cooling, which causes an increase in the energy required for air conditioning. Therefore, it is necessary to develop control technology with optimization of dehumidification taken into account.
Absorption chillers are refrigerating machines that can use various types of heat sources, but a technology to remove cold energy at high efficiency from relatively low-temperature heat sources such as solar heat is required. In addition, since their heat exchangers are of large size, development of a compactification technology and a control technology where optimization of dehumidification is taken into account like in heat pumps is also required.
Currently, there are many cases where dehumidification in cooling is often not taken into account, but the mainstream is adoption of a cooling control method based on temperature setting. For this reason, there are cases where energy is wasted in some facilities by conducting excessive dehumidification, etc. To improve this situation, in parallel with development of material technology, namely a key technology to realize dehumidification technology, it is desirable to promote development of a control system to achieve energy saving and provision of comfort simultaneously by, for example, separately conducting dehumidification and temperature control.

TOPIC4 Air-conditioning system with separation of latent and sensible heat

Concept of air-conditioning system with separation of latent and sensible heat

The purpose of air-conditioning is to control the temperature, humidity, cleanliness and flow of the air in a place to improve the comfort of humans and help with industrial activities in handling goods, such as those related to production, management and storage. In the air-conditioning of office spaces, it is necessary to take in the outside air to remove carbon dioxide generated from human activities. It is necessary to cool the outside air to remove humidity in the summer and to heat and humidify the outside air in the winter to keep the indoor temperature and humidity at an appropriate level. Figure T4-1 schematically shows the change in the outside air temperature and humidity during air-conditioning. To take an example of an outside air temperature of 37°C and an outside air relative humidity (RH) of 75% in the summer, the absolute humidity of the outside air, which is the ratio of the mass of water vapor to the mass of dry air, is 0.030 kg/kgDA. The absolute humidity of the air in an environment comfortable for humans is 0.011 kg/kgDA. To achieve this, it is necessary to lower the temperature from 37 to 25°C and reduce the absolute humidity by 0.019 kg/kgDA. To dehumidify and cool the air with a commonly used cooling coil, air conditioning involves the process of (I) cooling, (II) cooling plus dehumidification and (III) heating. In Step I for cooling, the outside air is cooled to the temperature at which dehumidification is started. Thereafter, in Step II, the outside air is cooled and dehumidified until the absolute humidity decreases to 0.011 kg/kgDA. At this point, condensation occurs near the cooling coil. The outside air is cooled and dehumidified along the saturated vapor pressure curve of air with a relative humidity of 100%. The absolute humidity reaches 0.011 kg/kgDA at a temperature of 15°C. Therefore, to perform Step II of the process, the cooling coil temperature needs to be lowered to 15°C or less. In actual cooling, the cooling coil is cooled to about 7°C considering the cooling rate. This contributes to the decrease in the cooling efficiency. To perform Step III following Step II, the air needs to be heated to 25°C by the heating coil at a temperature of 25°C or higher. This step also consumes energy. If another method is used for reducing humidity, the humidity can be reduced by directly lowering the outside air temperature from 37 to 25°C. This allows the temperature of the cooling coil to be set to a higher temperature to increase the cooling efficiency. This is the concept of air-conditioning system with separation of latent and sensible heat. An example of the system is the process of (i) desiccant dehumidification plus (ii) cooling. If the energy efficiency of desiccant dehumidification is high, the cooling efficiency of this system dramatically increases.

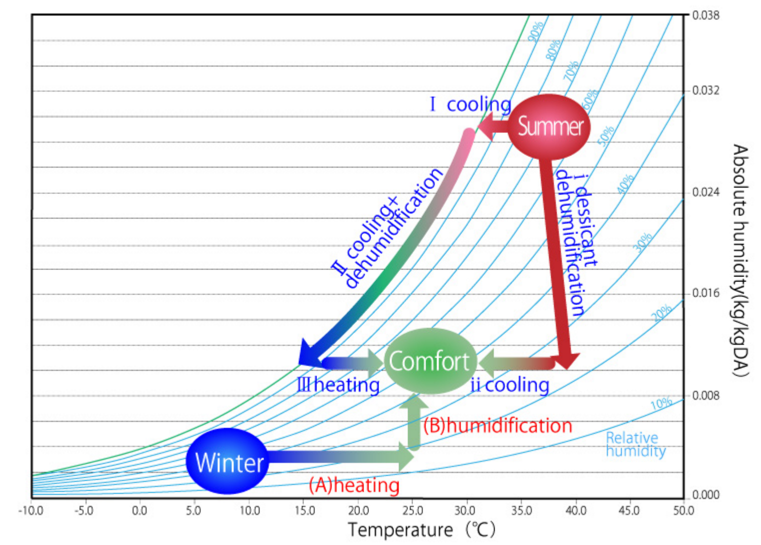

Fig. T4-1 Image of air conditioning on psychrometric chart

Figure T4-2 is a flow diagram of an air-conditioning system with a desiccant rotor. A system that uses the dehumidification process of a desiccant rotor is huge

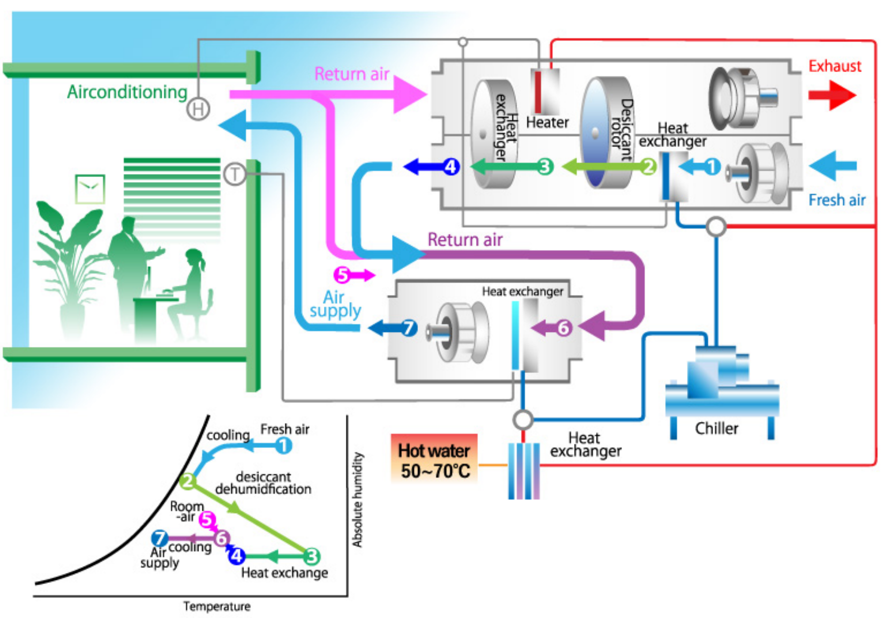

Fig. T4-2 Air conditioning system with a desiccant rotor and expensive, and it is difficult to say that such a system is widely used for the actual process.

High-efficiency air-conditioning system with Hybrid Heat Exchangers

A high-efficiency dehumidification/humidification system with a heat exchanger integrated with a desiccant element is commercially available.[45] As shown in Figure T4-3, the system has two hybrid heat exchangers, with each heat exchanger integrated with a desiccant element. They make up a compression heat pump. In the dehumidification mode in the

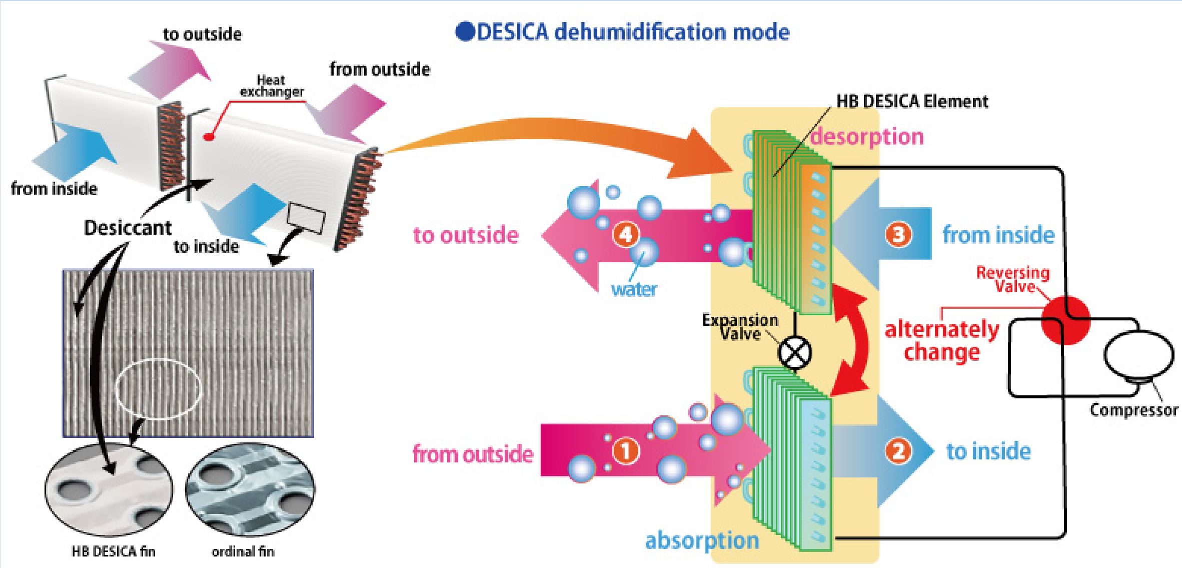

Fig. T4-3 Schematic images of DESICA system

summer, one hybrid heat exchanger is cooled and moisture from outside is adsorbed. The cooled and dehumidified outside air is brought inside. At the same time, the other hybrid heat exchanger is heated and the adsorbed moisture is discharged outside, regenerating the desiccant. The continuous operation of the system is possible by changing the direction of the air flow and switching between cooling and heating at the same time. The use of hybrid heat exchanger allows for high-efficiency dehumidification with a heat pump at the temperature on the heat-releasing side and on the heat-absorbing side.

In the humidification mode in the winter, the air flow in the dehumidification mode is reversed and moisture is released into the inside air, whereas moisture in the inside air is adsorbed in the dehumidification mode.

Figure T4-4 shows the change in temperature and humidity when the air is cooled by the system. The outside air is cooled by the process from (iii) to (iv). Since it goes through step (iii),

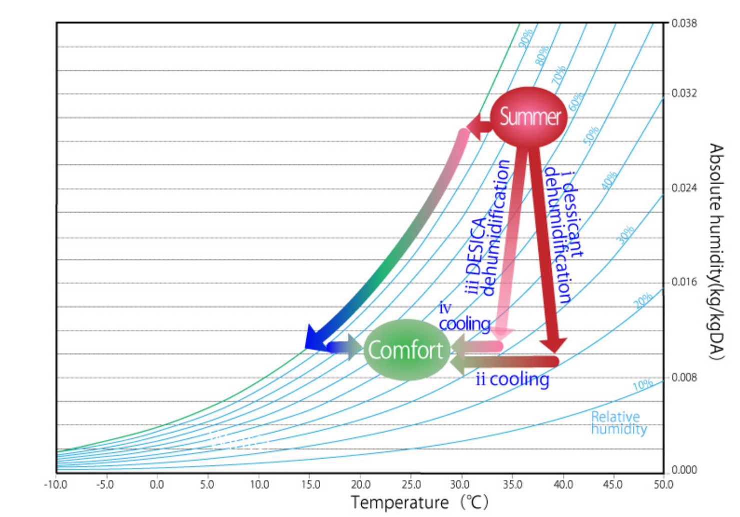

Fig. T4-4 Image of DESICA system on psychrometric chart

[45] DAIKIN INDUSTRIES, LTD.

this system, which is an adsorption dehumidification system, can dehumidify the air without increasing the temperature and thus can reduce the load of the cooling process in (ⅳ). The energy efficiency of the process in (ⅲ) is high, and the energy efficiency of the system as a whole is high. A system such as this is effective in regions where dehumidification is an important element of cooling.

B) Hot-water supply

Equipment necessary to be considered for promotion of diffusion of the active technology (hot-water supply) is hot-water heaters of the latent heat recovery type and CHP. Both allow for more efficient use of energy than ordinary hot-water heaters, but their equipment costs are high. It is necessary to formulate measures to promote the spread of the equipment.

Other equipment candidates are heat pumps and fuel-cell CHP.

Although the fundamental principles of a heat pump are the same as those of air conditioning, the required temperature range is different between air conditioning and hot-water supply, so it is necessary to further achieve higher efficiency through optimization of refrigeration cycles and cooling media. In addition, since output from current hot-water heaters of the heat pump type is small, heat accumulation in a hot-water tank is necessary. Due to radiation loss from the hot-water tank, it is also necessary to develop a technology to achieve high efficiency and high output that can eliminate the need for hot-water tanks.

Fuel-cell CHP offers higher generating efficiency than other types of CHP and enables easy high-efficiency operation in ZEB/ZEH. Moreover It is possible to operate fuel cell CHP with higher efficiency when surplus electric power is reversed to the grid. Therefore, it is desired to accelerate deployment of this technology through development of cost reduction technology and institution to accelerate grid connection. If CO_2-free hydrogen is used, no CO_2 is emitted from fuel-cell CHP, so it is also desired to develop technology for, and promote deployment of, hydrogen supply systems.

C) Lighting

Lighting has a special feature called color-rendering properties that have an influence on human senses like comfort in air conditioning. Basically, human beings have a preference for an aggregate of light having various wavelengths such as sunlight. However, current technology cannot satisfy both high levels of color-rendering properties and luminous efficiency.

LED lamps and inverter-based fluorescent lamps have relatively good color-rendering properties and work with high efficiency, so it is expected that they will be widely used. As for organic EL, it can become a highly efficient light source having good color-rendering properties due to its working principles, so it is hoped that innovation of organic EL technology will be accelerated and that the technology will be widely deployed.

3.2.1.2 Passive technology

A) Ventilation and shading

Promotion measures should be taken so that natural ventilation and shading are fully taken into consideration at the construction design stage. It is also desirable to take promotion measures for introduction of this technology through adoption of the sophisticated Passive technology by linkage with EMS, etc. and for common use of parts through standardization.

B) Insulation

Technology development for insulation in building sector has been made for mass production of the materials at acceptable costs based on advanced technologies that have been used in the space sector and for utilization of natural materials and waste. Vacuum insulation panels are made by filling a board-shaped container made of metal films with material having a high void ratio and low heat conduction and by vacuating the inside of the container, and they have a thermal resistance about 10 times that of other insulating materials such as glass wool. However, at the present time, their manufacturing costs are high, and special care to prevent damage to the films is necessary so as to maintain the vacuum state, posing a problem for construction methods.

Silica aerogel is a synthetic porous ultralight silicon oxide derived from a gel in which the liquid component of the gel has been replaced with a gas. It has insulation efficiency more than twice that of current insulating materials, but in the present state, it is fragile, thus posing a problem for construction methods, etc. Therefore, it is necessary to develop technologies to solve these material problems and create new materials.

TOPIC5 Aerogel for ZEB/ZEH

Transparent Insulation Material

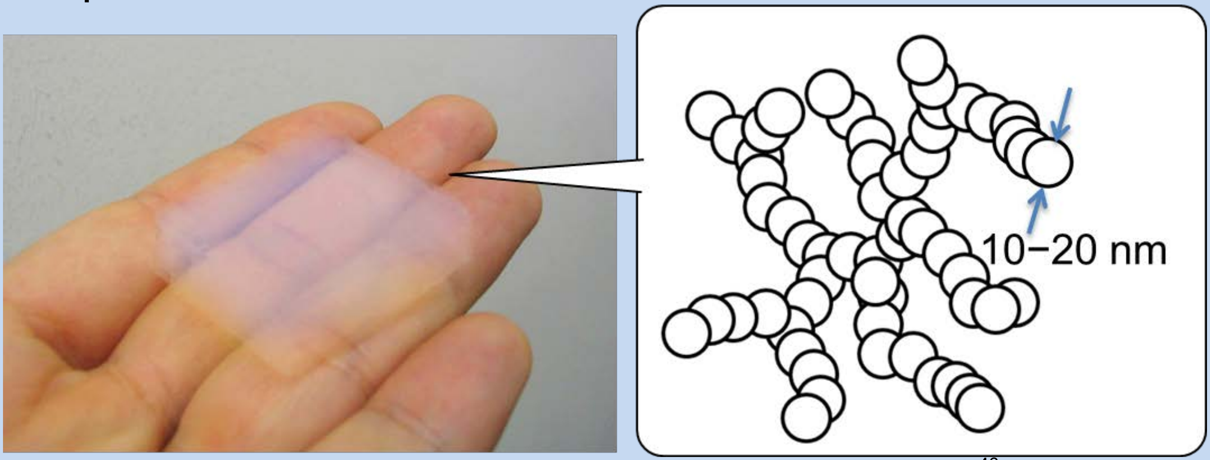

Fig. T5-1 Appearance and structure of typical silica aerogel[46]

Aerogel is a low-density solid with transparent appearance which exhibits the lowest thermal conductivity among all solidus substances (See Figs. T5-1,2).
The first report on the synthesis of silica (SiO_2) aerogel dates back to 1931[47]. Although being highly tenuous with 80-90 % porosity, the well-controlled pores smaller than 50 nm in diameter suppress the heat conduction by gas molecules as well as the scattering of visible light travelling through the solid. Despite these unique physical properties, aerogel has suffered from its mechanical friability which prevents its use as a practical thermal insulation material. Aerogels are prepared by removing the solvent liquid contained initially in the nanoscale pores frameworked by very thin (~10 %) solid components (See Fig. 1), which necessitates the "supercritical drying" process. The costly and time-consuming drying process kept aerogel commercially undeveloped for over many decades.

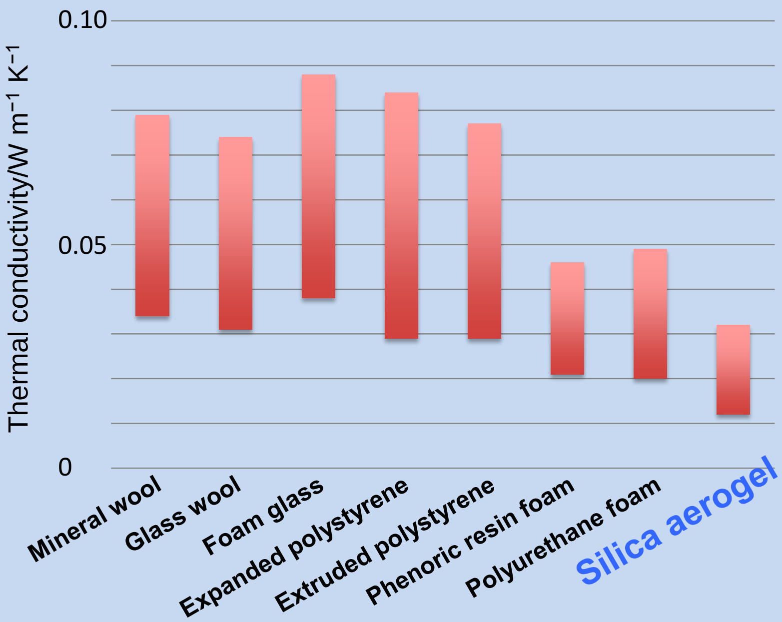

Fig. T5-2 Thermal conductivities of insulating materials[48]

Hybrid Aerogel

As silica has been the most popular composition of aerogels, numerous attempts have been made to reinforce or chemically modify the fragile gel network. Some of them were successful in improving the mechanical strength to a large extent, but instead, the

[46] Partly taken from T. Shimizu, K. Kanamori, K. Nakanishi, Chem. Eur. J., in press (2017).
[47] S. S. Kistler, Nature 127,741(1931)
[48] Numerical data were taken from M. Koebel, A. Rigacci, P. Achard, J. Sol-Gel Sci. Technol 63, 315-339 (2012).

transparency and thermal insulation property have been sacrificed. A recent breakthrough was made by the use of organically-modified siloxane (Si-O-Si) compositions – organic-inorganic hybrid – in place of pure silica. In the typical poly(methylsilsesquioxane), PMSQ, composition, nanoscale networks composed of three siloxane bridges and one terminal methyl group connected to the central Si atom exhibit higher flexibility than those of pure silica with rigid four siloxane bridges. The flexible network further enabled one to remove the solvent liquid without utilizing the supercritical drying; transparent, low-density xerogels equivalent to the aerogels can now be obtained by "ambient pressure drying"[49] .
Well processed aerogels exhibit the thermal conductivity of 0.012W/mK and the > 90 % visible light transmission at 10 mm thickness. Heat insulating windows utilizing aerogels have been limited to those with double-glass window with its gap filled with granular silica aerogels with hydrophobic surface modification, which exhibit substantially higher thermal conductivity and much lower transparency than those of monolithic aerogel tiles. Using the hybrid aerogel tiles with 25 mm thickness, it is possible to fabricate a highly transparent double-glass window (an aerogel tile sandwitched between protecting glasses) with a U-value of 0.5-0.6 W/m^{2}K at ca. 30 mm total thickness. The equivalent performance is only possible with the state-of-the-art quintuple-glass window with the thickness of 66-68 mm and 50 % visible transmission (See Fig T5-3). Much simpler setup, light weight and no need of gas-tight structure will be favorable in their application to ZEB windows. Provided that the constant manufacture of hybrid aerogel tiles with large enough area and optical homogeneity becomes possible at a reasonable cost, those "aerogel window" will take a substantial market share.

LEGARIS (The flagship model of LIXIL) **Conceptual hybrid aerogel window**

Under development by Tiem Factory Inc.

Dimension: W1690×H1370

Fig. T5-3 Estimated performance of hybrid aerogel window[50]

[49] K. Kanamori, K. Nakanishi, Chem. Soc. Rev. 40, 754-770 (2010).
[50] LIXIL corporation, Tiem Factory Inc.

C) Reflection
This technology is required for producing reflectors, especially for roofs and walls in regions where solar insolation is strong. Windows subjected to four seasons are required to reflect solar insolation in the summer but pass heat rays in the winter. Technologies for reflection include paint application and surface treatment of glass. These technologies meet specifications at an early stage of construction but, after long periods, performance deterioration often occurs due to pollution and degradation of performance. Therefore, it is necessary to develop a technology that can maintain a specified performance for a long period of time.

TOPIC6 ARPA-E's commitment[51]

What is ARPA-E
ARPA-E, or Advanced Research Projects Agency-Energy, is a program of the U.S. Department of Energy (US DOE) to support the development of technologies that could potentially impact the energy industry but are relatively risky. ARPA-E, which covers energy technology in general, began substantial activities in fiscal 2009 with an annual budget of nearly 300 million dollars. Its budget request for fiscal 2017 is 500 million dollars.

ZEB/ZEH-related programs
As many as 39 programs have been prepared, under which several to several tens of projects are implemented. The ARPA-E programs with specific objectives include BEETIT (Building Energy Efficiency Through Innovative Thermodevices) aimed at improving the efficiency of heat source equipment; DELTA (Delivering Efficient Local Thermal Amenities) aimed at improving the energy efficiency of buildings; GENSETS (Generators for Small Electrical and Thermal Systems) aimed at the proliferation of combined heat and power (CHP) systems; and SHIELD (Single-Pane Highly Insulating Efficient Lucid Designs) aimed at improved insulation of windows. ARPA-E has also implemented OPEN 2009, OPEN 2012, and OPEN 2015 programs, which are not designed for specific objectives, to support projects related to a wide range of technologies.

Radiative coolers for rooftops and cars[52]
One such high impact project, funded under the ARPA-E OPEN 2012 program, is aimed at enabling passive cooling for commercial and industrial buildings, 24 hours a day.
This passive cooling technology is based on a multi-layered film that reflects 97% of solar energy and radiates heat to the sky and outer space. This is known as the sky cooling effect and enables passive cooling during the day and at night.

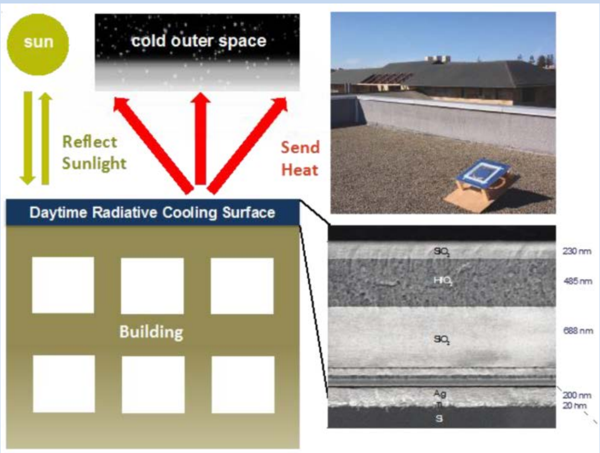

Fig. T6-1: Image of radiative cooling during the day

An initial experiment conducted at Stanford University on a winter day in California, showed 40 W/m^2 in heat rejection and a temperature drop of 3 to 5°C compared with the ambient air temperature. Experiments since then with their new films have cooled as much as 15°C

[51] https://arpa-e.energy.gov/?q=arpa-e-site-page/about
[52] Radiative Coolers for Rooftops and Cars https://arpa-e.energy.gov/?q=slick-sheet-project/radiative-coolers-rooftops-and-cars

below the ambient temperature on similar hot days. Based on such findings, the developers of this technology have founded a venture business called SkyCool Systems, which is developing rooftop panels that cool fluids passively. When their panels are combined with existing cooling systems, they improve the underlying cooling efficiency by 20 to 30 percent.

Fig. T6-2: Radiative cooling panels operable during the day[53]

D) Sealing
From a technical viewpoint, this technology is in a matured stage, and the focus is on how it should be considered at the design stage. Depending on the region, in some cases, there is no difference between the amount of energy saved through air sealing and that needed for appropriate humidity conditioning and ventilation. Therefore, standardization is needed as to what regions allow for effective air sealing and what level of air sealing is needed.

3.2.1.3 Renewable Energy Integration

A) PV
Mass production of PV systems to be mounted on roofs for use in buildings is now substantially expanding due to synergy of technology development for enhancing efficiency and measures taken to promote introduction of FIT, etc., resulting in lower unit prices for power generation. It is necessary to further advance the technology for reducing costs. On the other hand, for PV systems to be mounted on walls, it is necessary to take into account matching with the external appearance of buildings, so it is also necessary to pursue technology development with an emphasis on excellent design.

B) Wind power
There has been no smooth deployment of wind power generation facilities on buildings due to wind conditions more adverse than on mountain peaks and the coast, concerns about scenery and safety, high costs of power generation facilities, etc. Development of technologies necessary for high-efficiency wind power generation systems for ZEB is an urgent issue.

[53] ARPA-E Innovation Summit 2017 SkyCool Systems, Inc.

Working of Wind Thermal Power Generation

The concept of using thermal storage to address the instability of renewable power generation and to use stable and economical energy sources is wide spreading. Concentrated solar power (CSP) plants, which can stably supply 300 MW of power for 6 hours after sunset are being under operation in the United States.[54] In a CSP plant, solar energy is converted to heat and stored in the thermal storage and electric power is stably generated by a steam turbine. The thermoelectric conversion efficiency of CSP is as low as about half that of batteries, but the equipment cost is much less than that of batteries. Thus, CSP is more economical than the combination of solar cells and batteries. Local industry in developing countries, where electric power demand is expected to grow significantly, can utilize CSP.

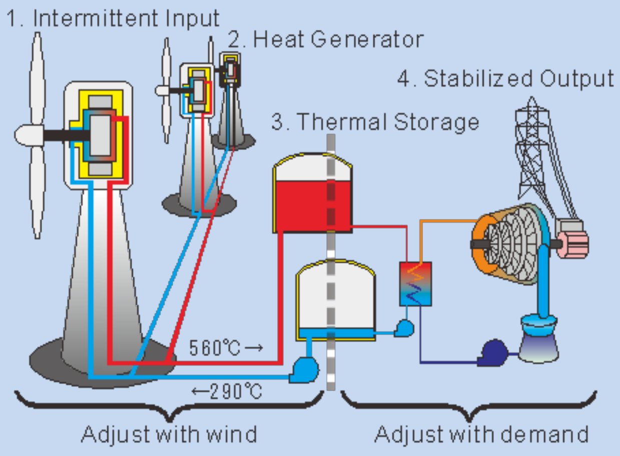

Fig. T7-1 Schematic of wind thermal power generation

The concept of employing the thermal storage for wind power is advantageous like solar power stated above. For example, German Siemens started to develop a system to store surplus power from wind power generation and the grid with electric heaters to stabilize the output power and generate power when needed.[55] This concept was further developed into wind thermal power generation as shown in Fig. T7-1. Intermittent wind energy is directly converted to thermal energy by a heat generator at the top of the wind turbine tower. The intermittent thermal energy is stabilized by the thermal storage and produce stable electric power like the CSP system. The heat generator employs the principle of eddy current, which makes it possible to achieve a very light-weight and robust direct drive system as well as further cost reduction. In the most simple and lightweight type, only heat is generated at the top of the wind turbine tower and electric power is generated by a steam turbine downstream of the thermal storage. [56]

Application to ZEB and its Issues

The system described above is a system with a view to large-scale power generation. Furthermore, it can be applied to small ZEB systems with the main purpose of supplying heat. The demand for heat accounts for about half of the energy demand in buildings and homes, and there is a problem that renewable energy has not been harnessed to meet the demand for heat. To meet the demand, thermal storage tanks are required to supply a required amount of heat when needed. If heat storage is carried out at about 100°C, to use a heat pump with a high coefficient of performance (COP) can be regarded as an alternative method. However, due to the low energy density, large hot water storage tanks are required. With power supply from wind turbines, the performance factor of the heat pump is low and

[54] M. Mendelsohn, T. Lowder, B. Canavan "Utility-scale concentrating solar power and photovoltaics projects: a technology and market overview" NREL/TP-6A20-51137 April 2012

[55] http://www.siemens.com/press/pool/de/pressemitteilungen/2016/windpower-renewables/PR2016090419WPEN.pdf (Retrieved Dec. 9, 2016)

[56] Toru Okazaki, Yasuyuki Shirai, Taketsune Nakamura "Concept study of wind power utilizing direct thermal energy conversion and thermal energy storage" Renewable Energy, 83 (Nov. 2015) pp. 332-338

the operating cost becomes high. Wind thermal power generation can be applied to this case. A wind turbine is installed on the rooftop of a building or house and a heat generator is used as a heat source. An air-cooled heat generator with an output power of a few hundred kW has been put into practical use as an automotive brake for large vehicles (See Fig. T7-2).

The following are the advantages, disadvantages and issues of wind thermal power generation.

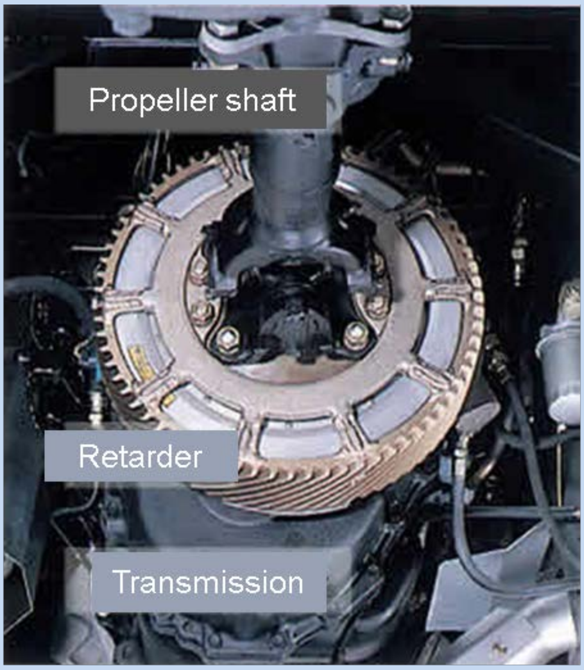

Fig. T7-2 Auxiliary brake for large vehicles (Courtesy of NSSMC)

Advantages

- The heat generator is simple, robust and easy to maintain. If multiple wind turbines are installed on the rooftop of a building, they can be maintained with ease.
- The heat generator can deliver heat at a temperature of up to 650°C. This realizes the thermal storage tank smaller than that of the hot water tank. The tank size can be reduced to 1/3 to 1/10.
- The stored energy can be used for various applications such as direct heat use, stable electric power generation and heat treatment processes. Depending on the heat storage material, the exergy density increases by nearly several dozen times, expanding its application. Affordable nitrates or carbonates, which have been used in CSP, are used as the heat storage material. A small heat storage system for heat source of cooking as shown in Fig. T7-3 that uses a molten nitrate has been put into a practical use.

Fig. T7-3 480°C molten nitrate thermal storage system (Courtesy of IIC / IHI)

Disadvantages

- This is a new technology and has not been used yet. Therefore, when actual engineering design and construction are implemented, the cost of wind thermal power generation may increase due to unexpected factors. Its performance and cost need to be evaluated in detail.
- Pipes to connect multiple wind turbines are required. Thick pipes taking account of heat insulation capacity are required to connect wind the turbines, whereas thin electrical cables are required for commonly used wind turbines.

]

C) Waste energy use

For application of utilization technologies of unutilized energy to ZEB/ZEH, a study has been made on the forms of recovery of heat discharged into sewage water and utilization of underground heat. In either form, it is necessary to start study of its introduction at the building design phase. In addition, measures to facilitate introduction of these forms should be taken, and their standardization is desirable.

3.2.1.4 Energy Management

A) EMS and IoT

EMS has been developed uniquely in each region in concurrence with dedicated controllers and communication standards. Though it is for different purposes from those of EMS, a concept called IoT is proposed for connecting each of the devices existing in buildings. It is desired to develop standards for both communication and terminals that allow for addition of EMS functions. A technology to store energy (electricity storage) has been developed in the automobile and power sectors, and further development of this technology including heat storage is expected.

B) Grid connection

Though it is for different purposes from those of ZEB/ZEH, linkage between EMS systems and smart grids is effective for efficiency improvement at the community level and the grid level. It is hoped that technology development is pursued in a manner that allows for effective linkage between EMS design architecture and smart grids.

3.2.2 Roadmap for cold regions

Figure 3.2.2-1 shows a roadmap for cold regions.

Because it is not necessary to take into account the need for dehumidification in cold regions, targets of technology development and support for promotion of spread of technology in these regions are different from those in other regions. However, the technical contents are the same as those indicated in the preceding items. Therefore, an explanation of them is omitted.

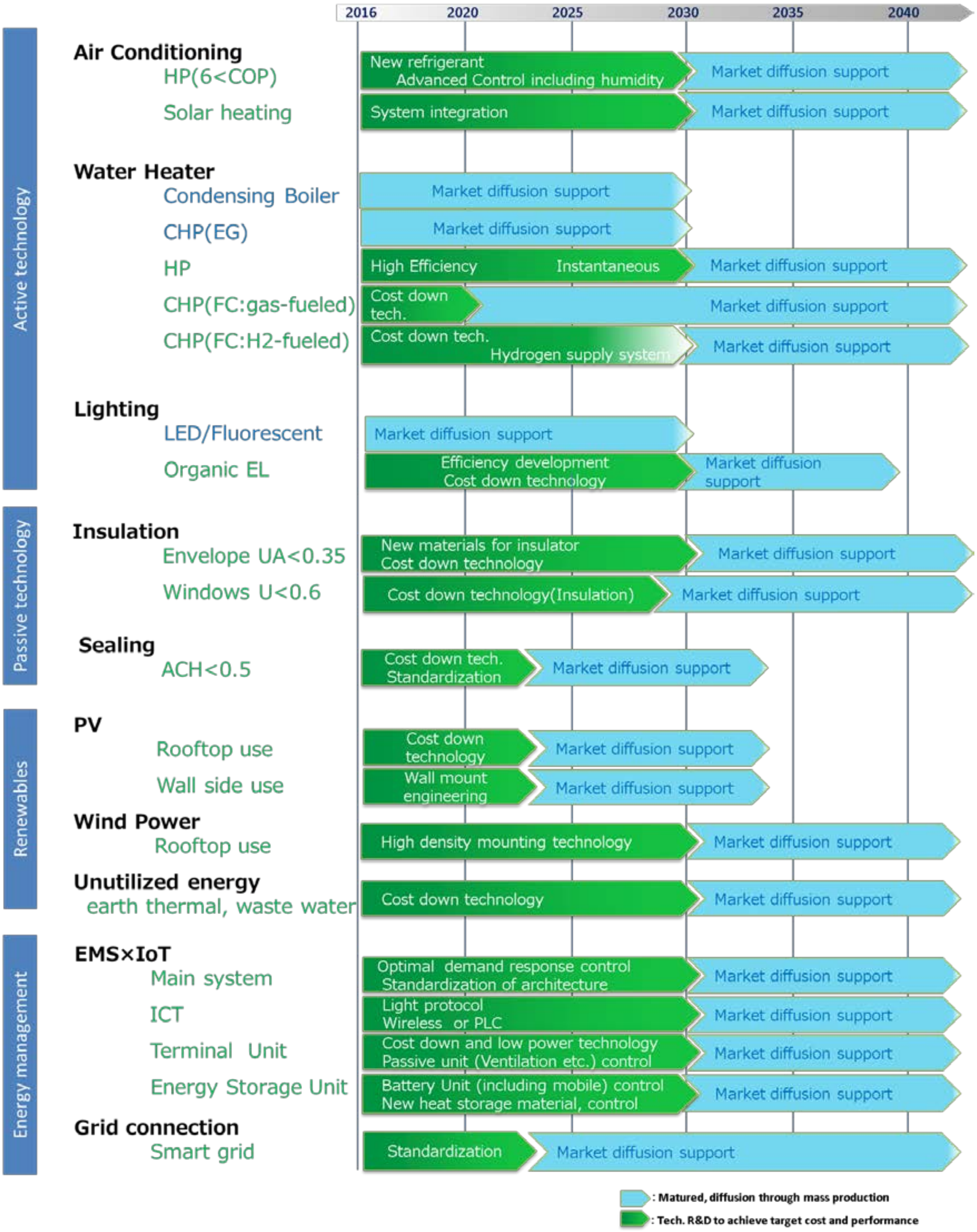

Fig.3.2.2-1 ZEB/ZEH technology roadmap for cold regions

3.2.3 Roadmap for hot regions

Figure 3.2.3-1 shows a roadmap for hot regions. It is not necessary to take into account the need for individual dehumidification because dehumidification is performed simultaneously with cooling at high demand. Therefore targets of technology development and support for market diffusion of technology are different from those in other regions.

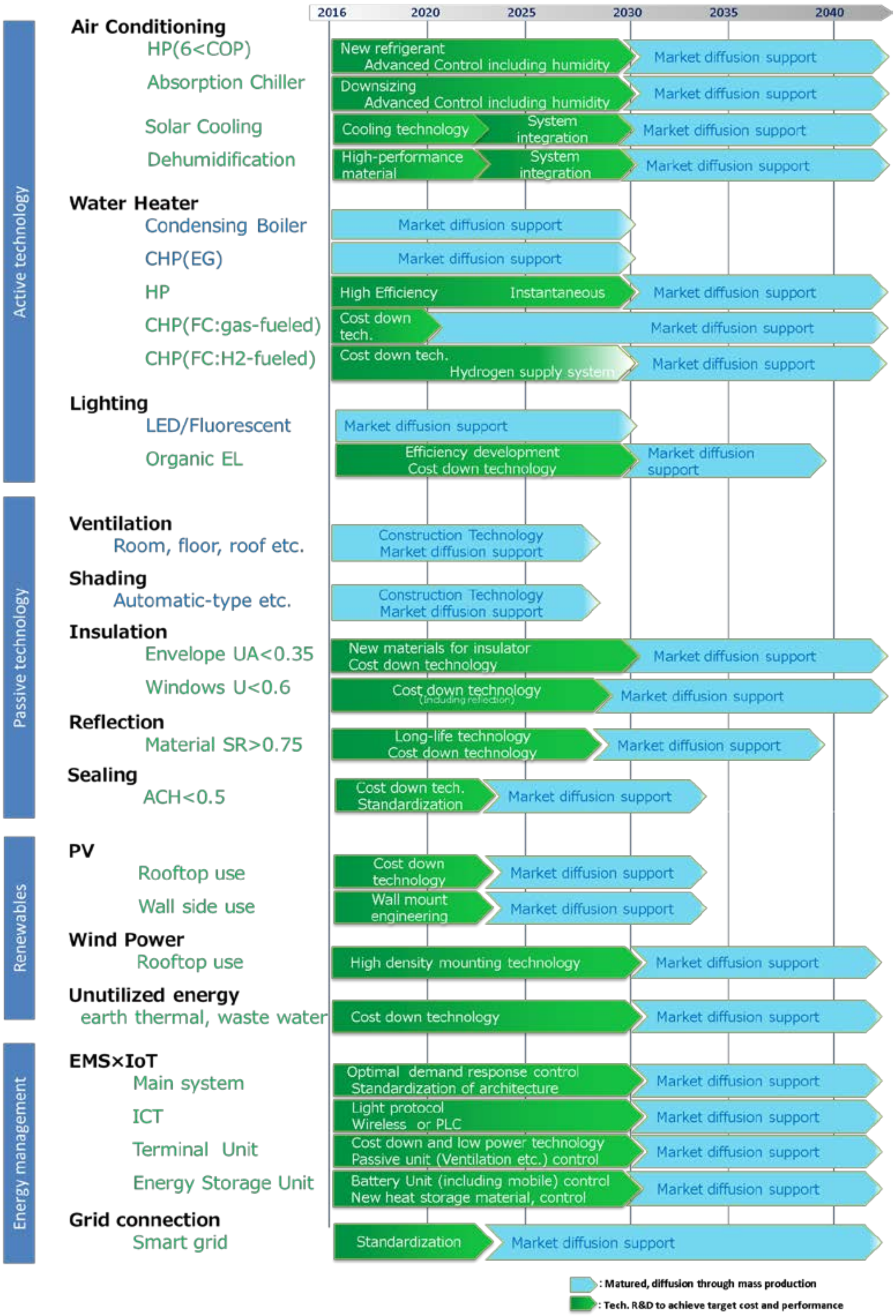

Fig.3.2.3-1 ZEB/ZEH technology roadmap for hot regions

3.3 Future Policy Responses

Actions

A diverse set of actions are required for R&D, and subsequent dissemination of ZEB/ZEH in the market to take place. It is crucial to ensure that all these individual actions are taken in line with long-term targets that provide a shared vision among stakeholders and market certainty. There must also be a supportive governance structure with a clear division of roles and responsibilities among relevant ministries and municipalities, and sound communication and coordination among stakeholders. As ZEB / ZEH only achieves optimization in "whole" form rather than as a compilation of diverse technologies, coordinated actions are necessary. For example, advanced insulation technologies would lower the requirements for air conditioner capacity, thus resulting in overall cost reductions. The ZEB / ZEH supply chain also involves various stakeholders such as developers, designers, builders and appliance manufacturers. It is therefore imperative to create a platform for these diverse actors to communicate and coordinate towards achieving the common goal of ZEB / ZEH conversion. Figure 3.3-1 provides an overview of the actions to be taken by the various stakeholders, including government, business, academia and civil society.

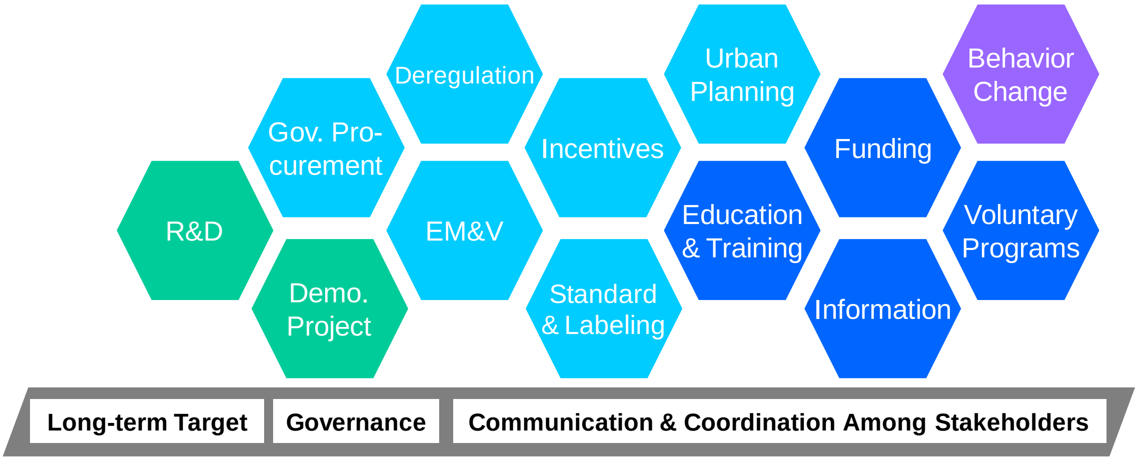

Fig.3.3-1 Overview of the Actions

(Note. EM&V: Evaluation, Measurement and Verification)

Role of Each Stakeholder

Each stakeholder should play an active role in the successful dissemination of ZEB / ZEH. Table 3.3-1 shows the available policy tools and suggested actions for relevant stakeholders. As humid regions will see the highest increase in both population and energy demand, this ICEF Road Map focused on humidity. From this standpoint, the following policy tools and suggested actions can be considered particularly important in humid developing countries.

- Establishing Strict Building Codes

A large portion of the increase in energy use and CO_2 emissions is expected to come from developing countries and, especially, new buildings within those countries. It is therefore vital that we adopt strict building codes sensitive to the local climate, as well as building certification and labeling. We must also boost technology transfer and research by expert architects, and even offer financial incentives.

- Connecting this to Urban Planning

As most of the increase in energy consumption is forecasted to come from urban areas in developing countries, we need urban plans embracing zoning.

In cold and moderate climate, where the potential to reduce CO_2 emissions is huge, extensive renovation programs must take place. The following policy tools and suggested actions can be considered of key importance.

- Various Incentives for Low-energy Renovation

In conjunction with various incentives (subsidies and tax breaks etc.) to encourage low-energy renovation, we also need to clarify the benefits other than energy saving, with respect to health and comfort, labor productivity, and market values.

Table 3.3-1 Available policy tools and suggested actions for relevant stakeholders

Government
General Policy • Set a long-term target of ZEB / ZEH dissemination which provides both a shared vision among diverse stakeholders and market certainty • Streamline the policy-making process with a clear division of roles and responsibilities among relevant ministries. • Promote R&D in the private sector and academia through financial and fiscal incentives • Provide financial support for demonstration projects • Create demand for ZEB / ZEH and lead by example through public procurement policy • Provide financial and fiscal incentives. Financial incentives can take the form of subsidies or tax credits, while fiscal incentives could involve accelerated depreciation of ZEB / ZEH. Incentives for replacement of inefficient buildings are crucial for improvement of the entire building stock • Provide information to consumers for the following purposes: ✓ Raising awareness of the benefits of ZEB / ZEH ✓ Notifying consumers via available support mechanisms and avoiding confusion arising from the implementation of multiple schemes ✓ Promoting energy-efficient behavioral change • Lead the development of expertise required to achieve ZEB / ZEH. Provide financial incentives for business to train their employee where necessary **For Energy Ministries** • Create methodologies for evaluation, measurement and verification of the energy performance of ZEB / ZEH • Establish test facilities for appliances • Set mandatory energy efficiency standards for appliances • Set additional voluntary standards which recognize manufacturers' efforts to improve the energy efficiency of their products • Mandate appliance and building providers to disclose the energy performances of products to consumers • Mandate utilities to offer prices that reward owners/tenants **For Construction Ministries** • Set mandatory energy-efficient building codes with labelling system and strengthen these codes over time. Create monitoring systems to verify the implementation of building codes **For Municipalities** • Incorporate ZEB / ZEH into urban planning. Zoning for ZEB / ZEH implementation can be especially effective in achieving community-based energy efficiency

International Organizations

- Facilitate communication among governments to share knowledge and experiences
- Promote cooperation in R&D and trials/demonstrations. Cooperation under similar climatic conditions can be effective in avoiding duplication of initiatives
- Harmonize energy efficiency standards for appliances. This allows manufacturers to produce products that can be sold in the global market, resulting in cost reductions due to scale merits

Business

For Developers

- Conduct R&D for ZEB / ZEH and the relevant technology
- Conduct trial/ demonstration projects
- Measure and quantify the benefits of ZEB / ZEH through lifecycle assessments. Together with improved energy performance and the resultant cost reductions, incorporate co-benefits of using ZEB / ZEH, such as improvements to the comfort and health of residents and workers. Embodied emissions should also be calculated
- Disclose energy performance of buildings to the owners and tenants
- Incorporate energy efficiency from the design stage. Developers should reward designers
- Provide information to consumers for the following purposes:
  - ✓ Raising awareness of benefit of ZEB / ZEH
  - ✓ Promoting energy-efficient behavioral change
- Create a viable business model for ZEB / ZEH
- Train employees and engineers for implementation and operation of ZEB / ZEH
- Increase participation in voluntary programs. Voluntary certification programs such as LEED(the US Green Building Council's Leadership in Energy and Environmental Design programme) and BREEAM(the UK Building Research Establishment's Environmental Assessment Method) have been very effective in increasing recognition of advanced sustainable buildings

For Utilities

- Measure and quantify the positive impact of ZEB / ZEH on the electric grid, such as peak cuts and improved reliability
- Provide pricing that rewards ZEB / ZEH owners/tenants
- Provide consumers with energy performance data in a way that stimulates energy-efficient behavior. Outsource such services where appropriate

For Finance

- Provide financing to ZEB / ZEH developments
- Consider the lifecycle costs of ZEB / ZEH when assessing provision of loans

Academia

- Conduct research on advanced and more affordable technologies
- Participate in demonstration projects as experts
- Provide expertise in evaluation of ZEB / ZEH and standardization
- Monitor and assess actions by government and business. Make recommendations where necessary
- Educate students, Outreach citizens and engineers

Civil Society

For Non-Profit Organizations

- Lead voluntary efforts to improve energy efficiency through certification of ZEB / ZEH
- Lead communication among stakeholders, assess their efforts and make recommendations where necessary
- Outreach citizens regarding the benefits of ZEB / ZEH and energy-efficient behavior

For Citizens

- Gain knowledge of ZEB / ZEH through participation in education and information campaigns
- Incorporate energy-efficient behavior into every aspect of their lifestyle. Create a culture of energy efficiency

For Building Owners and Tenants

- Communicate with each other regarding energy-efficient construction projects. Seek adequate cost and benefit sharing. (This is especially important in the case of retrofits)

As many of the above actions are not exclusive to a certain group of stakeholders, communication and coordination among diverse stakeholders is vital.

4. Proposal

(Sharing net zero energy building as a concept)
We can adapt ZEB/ZEH concept in newly constructed buildings and houses in the future, in addition, renovation to ZEB/ZEH at retrofitting timings would lead to achievement of net-zero building stocks as a whole in the long-run.

(Immediate action via stakeholder involvement)
There are a lot of challenges for ZEB/ZEH market creation. Some elemental technologies have been available already. Retrofit to ZEB/ZEH is big challenge. We can add the equipment after the completion of construction. However, large-scale renovation related to the envelope of the building requires a great deal of expense in usual situation. Immediate actions of public and private sectors are essential in terms of institution and technology, because the life of building is long and stakeholders are diverse.

(International technology collaboration and roadmap)
We can collaborate to accelerate the ZEB/ZEH diffusion. Various kinds of measures are available such as technology collaboration network outreach, diffusion policy comparison, harmonization with urban policies and establishment of international standards.
Transparent approaches via roadmap sharing among global regions and ZEB/ZEH roadmap reflection to climate policy will bring huge benefits through good practices and capacity building of stakeholders.

5. Abbreviations

2DS	the 2 ºC scenario
6DS	the 6 ºC scenario
AC	Alternative current
AHU	Air Handling Unit
ANRE	Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, Japan
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.
BEMS	Building energy management system
BAT	Best available technology
BCP	Business continuity plan
BREEAM	the UK Building Research Establishment's Environmental Assessment Method
BTO	Building Technologies Office, DOE
CABA	Continental Automated Buildings Association
CEN	Comité Européen de Normalisation, EU
CFC	Chlorofluorocarbon
CHP	Combined Heat and Power, Cogeneration
CIB	International Council for Research and Innovation in Building and Construction
CN-PPV	Cyano-Polyphenylene vinylene
COP	Coefficient of performance
COP21	the 21st session of the Conference of the Parties
COP22	the 22nd session of the Conference of the Parties
DC	Direct current
DI	Discomfort Index
DOE	Department of Energy, USA
ECHONET Light	Intelligent building control system for all areas in which people live and work, Japan
EERE	Office of Energy Efficiency and Renewable Energy, DOE
EL	Electroluminescent
EM&V	Evaluation, Measurement and Verification
EMS	Energy management system
ETP	Energy Technology Perspectives
EV	Electric vehicle
FC	Fuel cell
FP7	7th Framework Project, EU
GWP	Global Warming Potential
HEMS	Home energy management system
HP	Heat pump
HVAC	Heating, Ventilation and Air Conditioning
IAE	The Institute of Applied Energy
ICCA	International Council of Chemical Associations
ICEF	Innovation for Cool Earth Forum
ICT	Information communication technology
IEA	International Energy Agency
KNX	Intelligent building control system for all areas in which people live and work, EU
LED	Light emitting diode
LEED	the US Green Building Council's Leadership in Energy and

	Environmental Design programme
MEA	Membrane electrode assembly
MEH-PPV	Poly[2-methoxy-5-(2- ethylhexyloxy)-1,4-phenylenevinylene]
METI	Ministry of Economy, Trade and Industry, Japan
NEDO	New Energy and Industrial Technology, Japan
NREL	National Renewable energy Laboratory
NSTC	National Science and Technology Council, USA
NZEB	Net Zero Energy Building
OLED	Organic Light Emitting Diode
PEB	Plus energy building
PEC	Primary energy consumption
PEFC	Polymer electrolyte fuel cell
PPV	Polyphenylene vinylene
PV	Photovoltaics
R&D	Research and development
READY4 SmartCities	ICT Roadmap and Data Interoperability for Energy Systems in Smart Cities financed by FP7
RHEVA	Federation of European Heating, Ventilation and Air Conditioning Associations
RSI	Thermal resistance indicated by SI unit
SEC2.0	Intelligent building control system for all areas in which people live and work, USA
SHGC	Solar Heat Gain Coefficient
SOFC	Solid electrolyte fuel cell
SR	Surface Reflection
THINK	FP7-financed project that advised the European Commission (DG Energy) on a diverse set of energy policy topics from June 2010 until May 2013.
UNEP	United Nation Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
U	heat transmission coefficient or amount of thermal transmission per material area and unit temperature - W/m^2K
UA	Average of U
U_W	U of Window
ZEB	Zero Energy Building
ZEH	Zero Energy House
VT	Visible light Transmission
WBCSD	World Business Council for Sustainable Development
WH	Watt-hour meter
WRI	World Resources Institute

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