Initiatives for energy efficiency and CO_2 reduction in houses and buildings

1. Outline of Studies and Activities

Events	Issues	Research	Reflection of results
[International Movements to Combat Global Warming] 1997 Creation of the Kyoto Protocol 2002 Framework for the Promotion of Global Warming Countermeasure 2005 Kyoto Protocol comes into force	■Energy conservation standards for housing only provide an index for insulation and do not provide a quantitative evaluation of the energy efficiency of the entire house 1. Unknown preconditions and equipment performance, including effective rates based on the weather and the usage of all equipment in the house 2. Overall energy efficiency of houses in hot and cold regions differ in terms of prerequisites and equipment performance	**Target: Quantitative evaluation of the energy efficiency of the entire house** ■Low Energy Housing with Validated Effectiveness PJT (2001-2004) 1①Development of design and evaluation technologies for energy-saving elemental technologies to halve the energy consumption of the entire house compared to the 2000 level 1②Establishment of a method for calculating the annual primary energy consumption of the entire house ■Matter: Research on Supportive Technology for Improving the Energy Efficiency of Houses (2005-2007) 2①Evaluation including equipment that enables zero-energy, such as solar power generation, etc. 2②Creation of a quantitative evaluation method for energy efficiency considering regional housing specifications	[Maintenance of technical materials, etc.] ・Design Guidelines for Low Energy Housing with Validated Effectiveness (Warm Climate Version) ・Design Guidelines for Low Energy Housing with Validated Effectiveness (Humid Area Version) ・Design Guidelines for Low Energy Housing with Validated Effectiveness (Semi-Cold Region Version) [Reflection of laws] ★Energy Conservation Act (2009), Criteria for judgment by builders of housing projects concerning improvements in performance required for specified houses [Notification]
March 2011 Great East Japan Earthquake	■In the energy conservation standards for commercial buildings (nonresidential), there are independent evaluations of each facility, etc., but a comprehensive evaluation method for the entire building has not been established. In addition, there is a lack of actual data on energy efficient equipment, etc.	**Target: Overall evaluation of the energy efficiency of all nonresidential buildings** ■ Research on a comprehensive evaluation method and a design method for energy conservation performance of commercial buildings (2008-2010) ① Study of a comprehensive evaluation method that takes into account various building uses and usage patterns ② Actual measurement and verification of central air conditioning, energy consumption survey of office automation equipment, etc.	[Reflection of laws ★Energy Conservation Act (H25), Standards of judgment for building owners and owners of specified buildings concerning the rational use of energy [Public notice] [Maintenance of technical materials, etc.] ・Explanatory document for calculation and judgment criteria, Web programs (nonresidential and residential)
July 2015 Promulgation of the Building Energy Efficiency Act July 2015 Japan's Commitment Draft November 2016 Paris Agreement comes into force, ratified by Japan April 2017 Obligation to comply with the Building Energy Efficiency Act	■It is necessary to raise the level of residential energy efficiency by evaluating the ingenuity of the frame design in accordance with local production technology ■It is necessary to establish a system for designers and reviewers to promote energy efficiency and CO_2 reduction by making regulatory measures mandatory (conformance determination) and providing incentives for inducement measures	**Target: Building Energy Efficiency Act and improvement of its effectiveness** ■ Research on evaluation methods for energy efficiency technologies corresponding to local production technologies (2013-2015). ・ Energy efficiency evaluation of the frame devices such as edges and underflooring in housing considering regional characteristics ・ Development of a framework and methodology to properly evaluate the energy-saving effects of automatic controls that guarantee energy efficiency of air conditioning and lighting equipment	[Reflection of laws] ★Building Energy Efficiency Act (Act on Improvement of Energy Consumption Performance of Buildings) (2015) ★The same Act (2016), ministerial ordinances, public notices, etc., concerning building energy consumption performance standards, etc. [Maintenance of technical materials, etc.] ・Explanatory manuals for revised Act, Web programs (nonresidential and residential), conformity assessment manuals, completion inspection manuals, performance indication system (BELS), voluntary grading guidelines, etc.
July 2018 Fifth Strategic Energy Plan December 2020 Green Growth Strategies for Carbon Neutrality	■For further energy efficiency in nonresidential buildings, it is necessary to reduce air conditioning loads related to equipment and devices by designing the exterior skin (façade design) of exterior walls, windows, and roofs, etc.	**Target: Energy efficiency and conservation evaluation of nonresidential envelope design** ・ Among the exterior skin of nonresidential buildings, especially around openings to reduce the load from the outdoors, and to establish an energy conservation performance evaluation method that links air conditioning and lighting equipment	

Amid the worldwide movement to combat global warming, the Kyoto Protocol of 1997 set targets for reducing domestic greenhouse gas emissions, but CO_2 emissions from energy consumption in houses and commercial buildings (the consumer sector) have increased. Even today, these emissions are still relatively large, and the Paris Agreement and other treaties require further strengthening of energy conservation measures. In order to promote effective energy conservation measures in houses and buildings as a whole through regulation and guidance, the following research was conducted to develop a quantitative comprehensive evaluation method for energy efficiency and implement a calculation program to facilitate evaluation, which led to the formulation of the Building Energy Efficiency Act and improved its effectiveness.

◆Research on quantitative evaluation of the energy efficiency of entire houses (2001-2007)

[Background/Issues] Against the backdrop of the Kyoto Protocol to the United Nations Framework Convention on Climate Change, a trend arose towards strengthening the energy conservation standards under the Energy Conservation Act (at that time). Since even the strengthened 1999 standards for houses only had indicators for the insulation of walls and windows, and energy consumption could not be evaluated, it was necessary to start with houses for an energy efficiency evaluation.

[Research Outline and Results Implementation] With the aim of quantitatively evaluating the energy consumption of the entire house in terms of its envelope and equipment (including home appliances) according to the occupants' lifestyle, we developed design and evaluation technologies for energy-saving elemental technologies that reduce energy consumption by 50% from the 2000 level, established a method for calculating the primary energy consumption (J/year), and improved the efficiency of equipment, including power generation, to make zero-energy houses possible. In addition, we established evaluation methods by regions, created design guidelines, and disseminated them throughout the country by providing training courses. These technical data were reflected in the 2009 Energy Conservation Act's "Criteria for Judgment by Builders of Housing Projects on Improvements in the Performance Required of Specified Houses."

◆Research on comprehensive evaluation of energy efficiency of entire nonresidential buildings (2008-2013)

[Background/Issues] The energy conservation standards for nonresidential buildings (commercial buildings) already had an index called PAL (Perimeter Annual Load) for the thermal performance of the building envelope and CEC (Coefficient of Energy Consumption) for the energy efficiency of facilities, which differed for each facility. However, the calculated performance of equipment was not consistent with the actual performance, and there was insufficient evidence because of the large number of different building types and room usages, making a comprehensive evaluation of energy efficiency difficult.

[Research Outline and Results Implementation] Based on a nationwide survey of actual data on the energy efficiency of various existing building uses, the Comprehensive Evaluation Method was examined, and the actual energy efficiency of air conditioning systems and OA equipment was measured for office buildings, which are the most numerous among commercial buildings. We also conducted complementary surveys to grasp the actual status of each type of equipment in various buildings and room usages. These results were reflected in the 2013 Energy Conservation Act's "Criteria for Judgment by Builders and Owners of Specified Buildings on the Rational Use of Energy," and were prepared as technical materials in the form of a manual for calculation and judgment and an easy-to-use Web program for designers.

◆Research on broad assessment and effectiveness improvement for the Building Energy Efficiency Act (2013-2018)

[Background/Issues] As further measures for energy efficiency were implemented through the Paris Agreement, a highly valid evaluation method that can be applied to a wide range of levels became necessary in order to gradually make regulatory measures mandatory under the Building Energy Efficiency Act and to provide incentives for inducement measures.

[Research Outline and Results Implementation] To raise the level of energy efficiency for residential buildings, we developed an energy efficiency evaluation method that does not use much equipment by devising a framework that takes advantage of the

local climate. For nonresidential buildings, an evaluation method was established for automatic controls, which are increasingly used in advanced buildings. These achievements were reflected in the 2015 Building Energy Efficiency Act (Act on Improvement of Energy Consumption Performance of Buildings) and related ministerial ordinances and notifications in 2016. In addition, technical materials, etc., including Web programs, were used as a framework to explain notifications and examinations for conformity assessment, model building method, completion assessment, etc. The framework was developed as an inspection manual and voluntary evaluation guideline for performance indication (BELS), etc.

◆Research on energy efficiency evaluation through the design of the envelope of nonresidential buildings (especially around openings) (2017-2019)

[Background/Issues] To further improve the energy efficiency of nonresidential buildings, it was necessary to reduce the load on the equipment itself, and an energy efficiency evaluation of the air conditioning and lighting was sought for design innovations centered around openings in the building envelope, which have a large impact from the outdoors.

[Research Outline and Results Implementation] A design method and an evaluation method were developed to improve the energy efficiency by reducing outdoor loads, securing the thermal and light environment, and coordinating the air conditioning and lighting systems through the use of openings in nonresidential buildings. The results of this study will be reflected in the energy efficiency standards through further research and study.

2. Main Research Results

◆Research results on the quantitative evaluation of the energy saving performance of entire houses - Integration and demonstration of envelope and equipment

- The energy conservation standards of the 1980 Energy Conservation Law, which was triggered by the oil shocks, provided only insulation standards for the envelope of houses, and it was necessary to establish an energy conservation evaluation integrated with energy-consuming equipment.
- Therefore, in the general technology development project “Development of Energy Self-Sustaining Circulation-Oriented Building and Urban System Technologies” (abbreviated as “Low Energy Housing with Validated Effectiveness Project”) (2001-2004), we first developed design and evaluation technologies for energy-saving elements that can reduce the primary energy consumption of new houses by 50% in 10 years from the 2000 level in warm regions with the largest number of dwelling units. Based on the study of individual energy-saving elemental technologies, a demonstration experiment was conducted in which one of two rooms of a full-scale experimental house (housing complex type) was used as a “conventional (comparative standard) dwelling unit” and the other as an “energy-saving dwelling unit” to mechanically reproduce living behavior in the house under common weather conditions and the use of equipment and devices, and the energy consumption, etc. was compared on an annual basis. As a result, it was demonstrated that the energy-saving dwelling unit reduced the primary energy consumption by 50% compared to the conventional dwelling unit through the accumulation of energy-saving elemental technologies. Based on these results, we established a simple method for calculating the quantitative primary energy consumption and CO_2 emissions of an entire house, published the design guidelines for practitioners, and disseminated them through seminars.

- Subsequently, in the “Research on Promoting Technologies for Improving the Energy Efficiency of Residential Buildings” (2005-2007), a study was conducted on the advancement of energy-saving elemental technologies such as insulation, envelope and equipment including solar power generation, the performance of which has improved to the level of widespread use, so that a reduction rate of the primary energy consumption of 100% (zero energy) is now possible for homes in temperate regions. Furthermore, studies were conducted for humid and semi-cold regions, as the energy-saving performance of entire houses in hot and cold regions differ in terms of preconditions and equipment performance. These results enabled nationwide energy efficiency evaluations and led to the formulation of the “Criteria for Judgment by Builders of Housing Projects on Improvements in Performance Required for Specified Houses” in 2009 under the Act on the Rational Use of Energy.

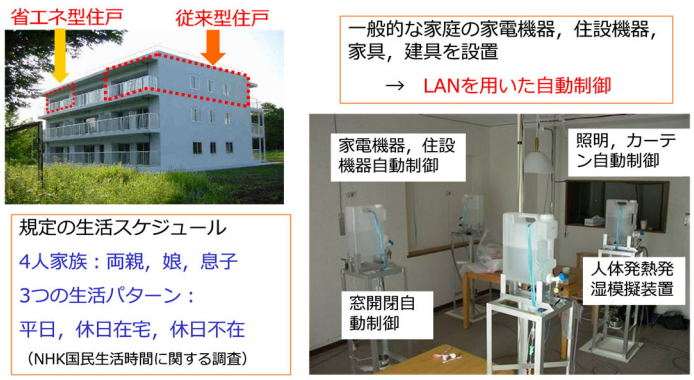


Figure-1 Demonstration of energy-saving effect by reproducing the lifestyle

Table-1 Calculation table for reduction in energy

用途	エネルギー基準値	要素技術		エネルギー消費率（基準値を1.0とした場合）			
				レベル1	レベル2	レベル3	レベル4
暖房	12.8GJ (43.2GJ)	断熱外皮計画	部分間欠暖房	0.8	0.65	0.55	0.45
			全館連続暖房	0.6	0.5	0.4	0.3
		日射熱の利用（断熱外皮計画のレベル3以上を前提）		0.95	0.9	0.8	0.6
		暖冷房設備計画（暖房）	エアコン	0.8	0.7	0.6	
			床暖＋エアコン	0.85	0.8	0.75	
			セントラル	0.85	0.8		
冷房	2.4GJ (5.3GJ)	自然風の利用		0.9	0.8	0.7	
		日射遮蔽手法	南向き	0.85	0.7	0.55	
			南東・南西向き	0.8	0.75	0.65	
			東・西向き	0.8	0.75	0.65	
		暖冷房設備計画（冷房）	エアコン	0.8	0.7	0.6	
			セントラル	0.85	0.8		
換気	4.7GJ	換気設備計画		0.7	0.6	0.4	
給湯	24.5GJ	太陽熱給湯・給湯設備計画		0.9	0.8	0.7	0.5
照明	10.7GJ	昼光利用		0.97~0.98	0.95	0.9	
		照明設備計画		0.7	0.6	0.5	
家電	23.7GJ	高効率家電機器の導入		0.8	0.6		
その他（調理）	4.4GJ						
合計	83.2GJ (116.5GJ)						
電力		太陽光発電		29.3GJ 削減	39.1GJ 削減		

◆Research results on comprehensive evaluation of energy efficiency of nonresidential buildings as a whole - Reflection of actual conditions for each building type and room usage

- The energy efficiency and conservation standards for nonresidential buildings (commercial buildings) include independent energy efficiency evaluation methods for each facility, but there is little basis for the energy efficiency and actual usage, and there is a discrepancy regarding the actual energy consumption in the building. The comprehensive evaluation of an entire building based on the primary energy consumption, which had been achieved earlier for residential buildings, needed to be established for nonresidential buildings, which are used for many purposes.
- Therefore, we conducted the “Research on a Comprehensive Evaluation Method and Design Method Related to the Energy Conservation Performance of Nonresidential Buildings” (2008-2010). First, based on a nationwide survey of actual data on energy efficiency of various existing building types, we analyzed the energy consumption ratios of the air conditioning, lighting, hot water supply, elevators, etc. for each building type, and studied the ideal comprehensive evaluation method for nonresidential buildings as a whole. Next, the actual energy consumption of the air conditioning systems in office buildings, which are the most numerous among commercial buildings, and the actual usage and energy consumption of office automation equipment, which has increased due to digitalization of the work environment, were determined by verifying the actual measurements of multiple buildings with central air conditioning systems and by investigating the actual usage of PCs and multifunction printers, and the primary energy consumption of nonresidential buildings as a whole was examined. The framework for a comprehensive evaluation of the primary energy consumption for all nonresidential buildings and the basis for calculating the primary energy consumption of the most major office buildings were obtained.

- Based on the results of the above research, we added complementary results from the Building Standard Development Promotion Project on air conditioning systems, lighting control, hot water supply, internal heat generation, etc. for various building and room uses, including hospitals, schools, retail stores, assembly halls, etc. other than offices. Finally, based on the time of day and conditions of use, a method was developed that allows for a comprehensive evaluation of the annual primary energy consumption for designs that incorporate a variety of energy-saving technologies. Even if the energy consumption of one facility is high, it only needs to be reduced in total with other facilities, and this was an epoch that enabled evaluation in line with the actual status of energy efficiency. These achievements led to the preparation of a commentary on the "Criteria for Judgment of Building Owners and Owners of Specified Buildings on the Rational Use of Energy" of the Energy Conservation Act and support for the development of a Web-based program in 2013.

◆Research results on broader evaluation methods and improved effectiveness for the building energy efficiency act -

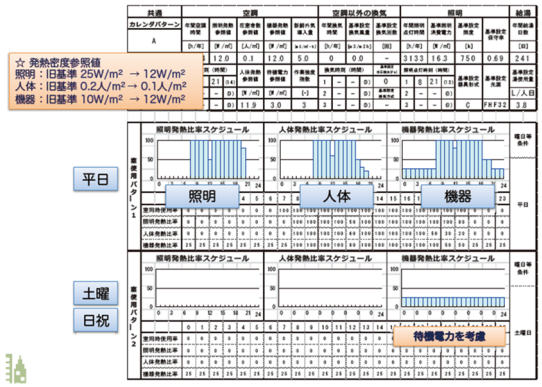


Figure-2 Example of conditions of use of the equipment in an office

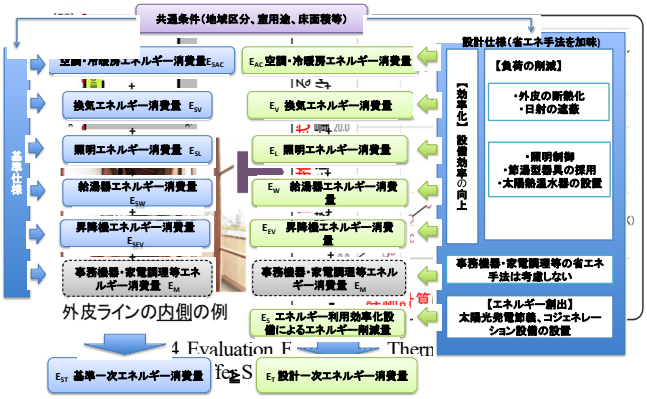
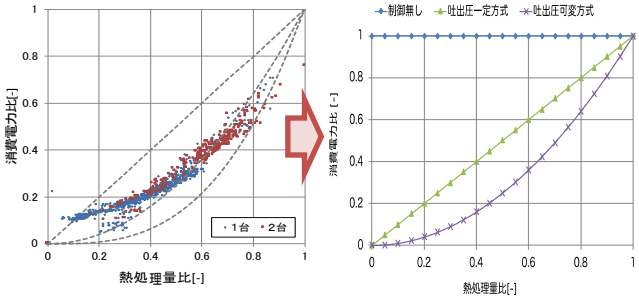


Figure-3 Concept of overall evaluation of energy efficiency for nonresidential buildings

Addressing regulations and guidelines

- By 2020, the Building Energy Efficiency Act will make it mandatory for nonresidential buildings to undergo the step-by-step process of a standard conformity assessment (starting with large buildings) and other regulatory measures, as well as incentives for rating through performance labeling, etc., and it has become necessary to establish a system for designers and examiners to improve the conformity rates for both residential and nonresidential buildings and promote energy conservation and CO_2 emissions reduction.

- Therefore, in the “Research on Evaluation Methods for Energy-Saving Technologies Corresponding to Local Production Technologies” (2013-2015), a research project was conducted for small- and medium-sized carpentry and contracting companies in rural areas, which account for approximately 60% of new detached conventional wood construction starts (they are good at energy-saving technologies by devising frames that correspond to local housing production technologies). The purpose of the study was to raise the level of energy conservation by examining energy conservation evaluation methods that were inadequate under the previous energy conservation standards, such as thermal buffer space on the porch, solar radiation shielding by sunshades, and the use of geothermal heat under the floor. In addition, in the research on “Development of Evaluation Methods for Energy Reduction Effects of Automatic Control of Building Equipment” (2016-2018), for automatic control of air conditioning and lighting equipment, which has begun to be used in advanced nonresidential buildings, we classified types and specifications as standard control and advanced control, and investigated the corresponding energy-saving effects through surveys, experiments, and simulations, and developed a framework and methodology for appropriate evaluation.



Measured results of pump variable airflow control

Constructed evaluation method

Figure-5 Evaluation of energy-saving performance of automatic air-conditioning control in buildings

- These results are reflected in the 2015 Building Energy Efficiency Act (Act on Improvement of Energy Consumption Performance of Buildings), the 2016 “Ministerial Ordinance Establishing Standards for the Energy Consumption Performance of Buildings, etc.,” the notification “Items Related to Calculation Methods, etc. in the Ministerial Ordinance Establishing Standards for Energy Consumption Performance of Buildings, etc.,” and the “Standards for Prevention of Heat Loss through External Walls and Windows in Residential Buildings and Standards for Primary Energy Consumption,” etc. The revised Act has been reflected in the “Ministerial Ordinance Establishing Building Energy Consumption Performance Standards, etc.,” and public notices “Standards for Prevention of Heat Loss through External Walls, Windows, etc., and Standards for Primary Energy Consumption,” etc., and has led to the creation of Web programs and explanatory documents, such as the model building method for easy evaluation for conformance determination, assessment inspection manuals, completion inspection manuals, and voluntary rating guidelines for the performance indication system (BELS), etc. The Web-based programs and explanatory manuals were developed in response to the revised Act.

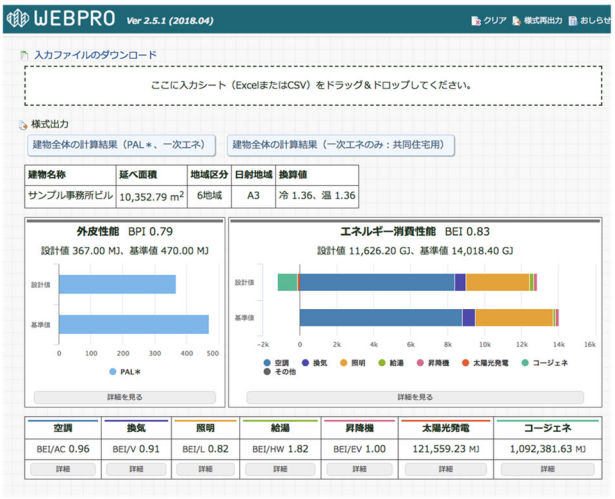


Figure-6 Web program used for conformance determination

◆Research results on the energy efficiency evaluation by designing the envelope of nonresidential buildings - Load reduction on equipment and coordination of air conditioning and lighting

- For further energy conservation in nonresidential buildings, design and evaluation methods are now required to reduce the load on facilities and improve the energy efficiency without compromising the indoor environment through the envelope

design (façade design) of exterior walls, windows, roofs, etc.

- Therefore, in the “Research on Facade Design Methods for Improving the Energy Consumption Performance of Buildings” (2017-2019), we developed an evaluation method that takes into account the combined effects of the air conditioning and lighting equipment by means of annual simulations of light and heat from time to time, targeting design innovations mainly around the openings in the building envelope. Furthermore, we developed technical materials for energy-saving facade design, including design considerations.
- Energy-saving facade design guidelines will be compiled and disseminated for practitioners, and will be reflected in the energy efficiency standards through studies conducted by the Building Standard Development Promotion Project.

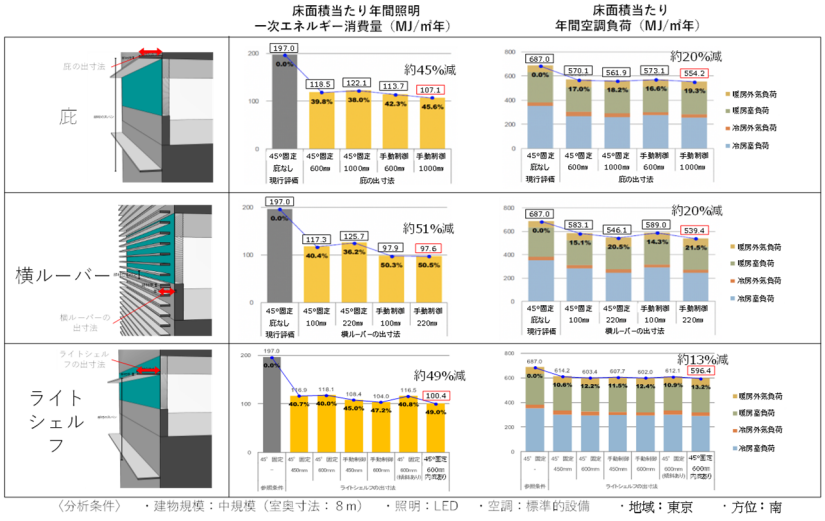


Figure-7 Reduction in lighting energy and air conditioning load due to different facades

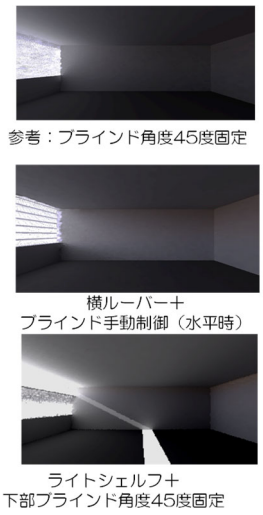


Figure-8 Effects on indoor light environment

3. List of Related Reports and Technical Documents

1) “Research on Promoting Technologies for Improving Energy Efficiency of Residential Buildings,” NILIM Project Research Report No. 25, February 2009

2) “Relevant Materials for Certification Standards of Low-Carbon Buildings (Promulgated in Dec. 2012) Manual of Program for Primary Energy Consumption in Houses,” NILIM Technical Note No. 701, December 2012

3) “Relevant Materials for Certification Standards of Low-Carbon Buildings (Promulgated in Dec. 2012) Manual of Program for Primary Energy Consumption in Buildings,” NILIM Technical Note No. 702, December 2012

4) “Relevant Materials for 2013 Energy Standard (Promulgated in Jan. 2013) Manual of Program for Primary Energy Consumption in Houses,” NILIM Technical Note No. 761, November 2013

5) “Relevant Materials for 2013 Energy Standard (Promulgated in Jan. 2013) Manual of Program for Primary Energy Consumption in Buildings,” NILIM Technical Note No. 762, November 2013

6) “Relevant Materials for 2013 Energy Standard (Promulgated in Sep. 2013) Manual of Program for Building Envelope Performance in Buildings,” NILIM Technical Note No. 763, November 2013

7) “Relevant Materials for 2013 Energy Standard (Promulgated in Sep. 2013) Manual of Program for Primary Energy Consumption in Buildings Using Main Room Input Method,” NILIM Technical Note No. 764, November 2013

8) “Relevant Materials for 2013 Energy Standard (Promulgated in Sep. 2013) Manual of Program for Evaluating Building Envelope Performance and Primary Energy Consumption Using Model Building Method,” NILIM Technical Note No. 765, November 2013

9) “Relevant Materials for 2016 Building Energy Efficiency Standard (Promulgated in Jan. 2016) Manual for Calculation Program of Primary Energy Consumption in Commercial Buildings,” NILIM Technical Note No. 973, June 2017
10) “Relevant Materials for 2016 Building Energy Efficiency Standard (Promulgated in Jan. 2016) Manual for Model Building Method Input Assistant Tool,” NILIM Technical Note No. 974, June 2017
11) “Research on a Comprehensive Evaluation Method and Design Method Related to Energy Conservation Performance of Nonresidential Building,” NILIM Project Research Report No. 58, September 2017
12) “Development of functional performance testing methods for building automatic control system of air conditioning and ventilation equipment,” NILIM Technical Note No. 1081, September 2019

4. Future Outlook

This theme is the process of accumulating empirical research and social implementation of highly effective results to address the urgent social issue of global warming, so that many practitioners who actually build houses and buildings will be able to evaluate the energy efficiency and CO_2 emissions in an appropriate and fair manner that can be used by a wide range of people. However, most of the research has focused on new construction, and the major issue for the future is how to apply the energy-saving technologies that have been systematically studied to the vast stock of existing houses and buildings, including their life cycle and the health and comfort of the indoor environment, in order to achieve the goal of carbon neutrality by 2050.