Trial of Creation of ZEB Retrofitting Plan for Existing Government Office Building

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Housing Department, Building Environment Division

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1. Background and Purpose of Research

To realize decarbonization, further energy conservation is necessary and indispensable, not only in new construction, but also in existing buildings (**Fig. 1**). In nonresidential buildings (office buildings, etc.), air-conditioning, lighting and other equipment and devices are renewed (renovated) every 10 to 20 years, but in many cases, this renovation work is limited to easy equipment exchanges at present. When undertaking repairs, it may be possible to achieve substantial energy saving effects at a rational additional investment cost if the equipment is redesigned based on a survey of the existing conditions (**Fig. 2**). However, because concrete methods have not been established, the current situation is that surveys and redesign work are almost never carried out, and as a result, opportunities for energy saving are missed.

To address this problem, NILIM is developing technical guidelines (current condition diagnosis method, retrofitting design method) aimed at maximizing the energy-saving and CO_2 reduction effects of retrofitting, as well as evaluation tools for evaluating their cost-effectiveness. This report describes the results when a concrete "ZEB retrofitting plan" (ZEB: net Zero Energy Building) was created on a trial basis for an actually-existing government office building (NILIM Tachihara Office; completed in March 1978, 7 above-ground floors, 1 basement, total floor area: 13,467 m^2) to obtain concrete knowledge concerning retrofitting design.

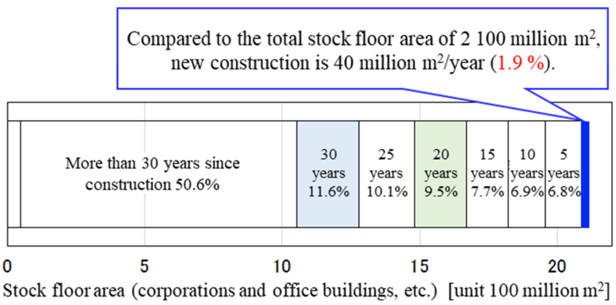

Fig. 1 Stock floor area by building age

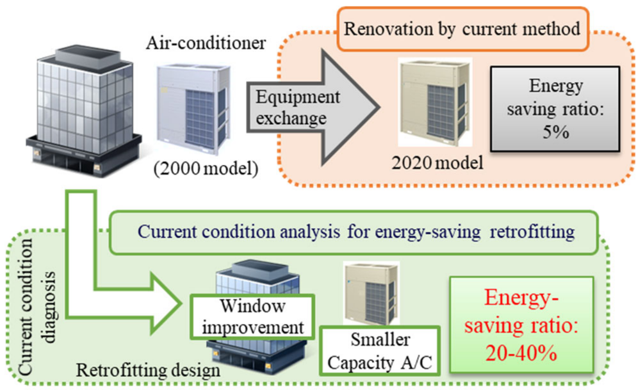

Fig. 2 Energy-saving retrofitting based on current condition diagnosis

2. Setting the Retrofitting Level

In this trial, the three retrofitting levels (1, 2, 2+) shown below were set, and retrofitting plans were created.

- (Level 0) Current condition as-is
- (Level 1) Standard equipment renovation:
  The type of air-conditioning system is not changed from the current "Central air-conditioning system using a direct-fired absorption water heating and cooling machine," and are only upgraded to the most recent machine of the same type. The building envelope is not changed, and equipment other than the air-conditioning system is simply upgraded to the general equipment specification which is currently in use.
- (Level 2) Retrofitting targeting ZEB:
  Retrofitting is carried out, aiming at a condition in which its energy consumption after the retrofit is equivalent to "ZEB Ready (building with energy consumption reduced to no more than one-half of the standard value, without considering energy creation by solar power generation)." Improvement of the building envelope is also included in the study targets, and changing the type of air-conditioning system, introduction of an automatic control system, etc. are also included in the study targets.
- (Level 2+) Level 2 + introduction of solar power generation:
  In addition to Level 2, introduction of solar power generation is studied.

Table 1 Procedure for creation of ZEB retrofitting plan

No	Item	Content
STEP-1) Determine current energy consumption performance		
1-1	Check and arrange existing drawings	• Check whether drawings and materials exist or not. (Architectural drawings, equipment ledgers, structural calculation sheets) • In the existing drawings, check the insulation performance and types and positions of fixtures and equipment.
1-2	Field survey	• Visit the building, and check and record the current arrangement, number of units, serial Nos., etc. of the equipment. • Interview the equipment manager regarding the condition of the equipment.
1-3	Evaluation of energy consumption performance	• Using a building energy consumption performance calculation program (non-residential), calculate primary energy consumption.
STEP-2) Perform standard equipment renovation design		
2-1	Perform renovation design	• Perform standard equipment renovation design (equipment updating).
2-2	Evaluate energy consumption performance	• Using the building energy consumption performance calculation program (non-residential), calculate primary energy consumption.
2-3	Calculate renovation cost	• Calculate the estimated cost.
STEP-3) Perform retrofitting design aiming at ZEB		
3-1	Perform retrofitting design	• Create a ZEB proposal.
3-2	Evaluate energy consumption performance	• Using the building energy consumption performance calculation program (non-residential), calculate primary energy consumption.
3-3	Calculate the retrofitting cost	• Calculate the estimated cost.
STEP 4) Analyze energy-saving performance and economics		
4-1	Analysis of energy-saving performance	• Calculate and compare the results of general energy-saving improvements and the energy-saving and CO2 reduction effects, etc. of the ZEB retrofit.
4-2	Analysis of economics	• Using the cost of the general energy-saving improvements and cost of the ZEB retrofit, and the monetary effect of energy-saving under the two scenarios, compare the payback periods (years to recover investment).
STEP 5) Create the ZEB retrofitting plan		
5-1	Summarize the content, cost-effectiveness, etc. of retrofitting	• Summarize the content, cost-effectiveness, etc. of the retrofitting proposal so that the study results are easy to understand. • If it is possible to use a financial support project, calculate the actual cost in case that financial support is used.
5-2	Create the retrofitting schedule	• Create an implementation schedule for all processes from retrofitting design to completion of construction.

3. Creation of ZEB Retrofitting Plan

Table-1 shows the procedure used to create the ZEB retrofitting plan in this trial. First, as STEP-1, the energy consumption performance in the current condition (Level 0) was determined. Because the target government office building has undergone repeated renovations, and drawings were only prepared of the parts necessary in the work at the time, the transition over time was understood by combining multiple drawings. The current condition of parts that were unclear in the drawings was determined by a field survey. Based on the survey results, the primary energy consumption was calculated by using a program for judging compliance with building energy standards (Web program, standard inputting method).[1] The result was 2,655.5 MJ/m^2/year (BEI = 2.08).

Next, as STEP-2, standard equipment renovation design (Level 1) was carried out. The equipment was selected using Building Equipment Design Standards, and the equipment efficiency was set based on a market survey. Primary energy consumption was reduced to 2,377.5 MJ/m^2/year (BEI = 1.87), for a reduction of about 10 % compared with Level 0.

In STEP-3, retrofitting design targeting ZEB (Level 2) was carried out. The air-conditioning equipment was changed to the individual distributed type using packaged air-conditioning units, and improvements (strengthening of heat insulation of openings, introduction of total heat exchangers, adjustment of precooling time, etc.) were introduced to keep the peak load to within 150 W/m^2 by utilizing dynamic load calculations by BEST (Expert Ed.). As a result, primary energy consumption was reduced to 517.5 MJ/m^2/year (BEI = 0.41). At Level 2+, based on the current roof area, etc., it was judged that 236 kW of solar power generation capacity can be introduced. In this case, primary energy consumption is 349.6 MJ/m^2/year (BEI = 0.28).

In STEP-4, the utility expenses before and after retrofitting and the cost of the retrofitting work were calculated. The calculation results are shown in **Fig. 3**. Utility expenses were calculated assuming prices of ¥32.29/kWh for electricity, ¥193.8/m^3 for gas, and ¥120/L for kerosene. A rough calculation of the cost of retrofitting work was made using Life Cycle Cost of Buildings, 2nd Ed. (2019), published by the Building Maintenance and Management Center.

Finally, as STEP-5, cost-effectiveness was analyzed. Comparing Level 1 and Level 2+, the difference in utility costs was ¥42.8 million, and the difference in retrofitting costs was ¥614 million. This means that payback period of 14.3 years is required to recover the investment from Level 1 to Level 2+ (difference of retrofitting cost/annual difference of utility costs).

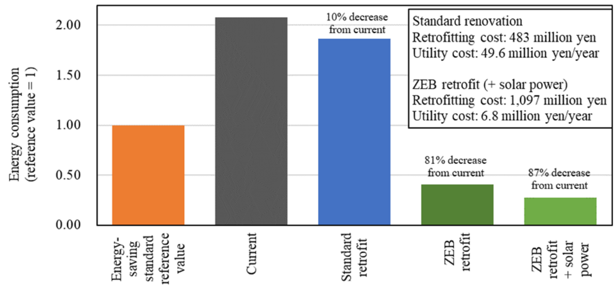

Fig. 3 Energy consumption reduction effect of retrofitting

4. Summary and Issues

A trial ZEB retrofitting plan was created for an actually-existing government office building. It was found ZEB Ready can be achieved even in an office building that was completed in 1978. On the other hand, the investment payback period was 14.3 years. Thus, it will be necessary to appeal to potential users based on benefits other than the reduction in utility costs, for example, improvement of the indoor thermal environment. This is an issue for future study.

☞For more information:

1) Building Research Institute: Technical Information on Energy Consumption Performance of Buildings (in cooperation with NILIM)
https://www.kenken.go.jp/becc/index.html