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LIFE CYCLE ASSESSMENT FOR ENVIRONMENTALLY-CONSCIOUS RENOVATION OF BUILDINGS

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Summary

There are limits on the effective reduction of carbon dioxide emissions through measures related to new buildings alone. Energy-saving renovations are also needed for existing buildings, which constitute an enormous stock. However, although there is an environmental assessment technique (life cycle assessment, LCA) for new building construction, there is still no assessment technique for renovation projects. To rectify this situation, we have prepared a study tool that can be used at the renovation stage to assess both life cycle carbon dioxide emissions ($LCCO_2$) and life cycle cost (LCC).

1. Introduction

There is broad awareness of problems of the global environment as important issues. Consideration for the environment and energy conservation are important issues in the construction industry as well.

A great deal of attention is given to these issues with regard to new building construction. However, there are limits on the effective reduction of carbon dioxide emissions through measures related to new buildings alone. Energy-saving renovations are also needed for existing buildings, which constitute an enormous stock.

It is important to address all stages of a long-term life cycle with regard to environmental issues, including a building's design, construction, operation, repair, renovation, and demolition. It is necessary to assess life cycle cost and environmental burden in renovation plans as well.

The Building and Equipment Life Cycle Association (BELCA) was established in June 1989 under authorization by the (then) Minister of Construction. Its members are building owners and representatives of a wide variety of businesses, including the fields of design, construction, M&E systems, manufacturing, inspection, maintenance, assessment, public utilities, and insurance companies.

Drawing on the expertise of its diverse members, BELCA has been contributing to the formation of a high-quality stock of buildings by providing recognition for outstanding existing buildings (BELCA Award), training technical experts in maintenance and preservation (qualification programs for M&E system and finish assessment and for maintenance and preservation planning and execution), and conducting research studies on the life cycle of buildings and M&E systems (2002a).

For LC assessment of buildings in Japan, BELCA has prepared the appended tool for collected LC assessment data (BELCA's LCC tool, 2002b) which is publicly available and widely used.

On the other hand, for environmental burden assessment (LCA), the Architectural Institute of Japan's (AIJ) "Guidelines for Life Cycle Assessment of Buildings" (2003) and the "Life Cycle Assessment Tool" based on these guidelines are publicly available and widely used.

However, these tools and guidelines apply to new buildings. Complex work is required in order to evaluate renovation projects. Therefore, on the basis of these two tools, we have prepared an "LC Assessment Tool for Building Renovation" which helps develop measures to reduce life cycle environmental burden.

Below, we summarize the "LC Assessment Tool for Building Renovation."

2. LC assessment in building renovation

Various types of renovation work are performed in renovation projects with consideration for environmental burden (LC design), including renovations for energy conservation. Here, focusing on the prevention of global warming, we have taken $LCCO_2$ as a measure of environmental burden. For a more realistic LC assessment, we have included LCC as an assessment item.

In an assessment using $LCCO_2$, the total carbon dioxide emissions throughout the life cycle of a building, from construction to demolition, is calculated.

The "Life Cycle Assessment Tool," developed by AIJ (AIJ-LCA tool) as an evaluation tool for newly constructed buildings, assesses an inventory of four categories (energy consumption and emissions of carbon dioxide, sulfur oxides, and nitrogen oxides) throughout the life cycle of buildings from construction to demolition and disposal. It is also capable of assessing environmental impact including ozone layer destruction, global warming, and acid rain.

Here, we have based the assessment on the AIJ "Guidelines for Life Cycle Assessment of Buildings."

In addition to environmental burden, this tool is capable of estimating life cycle cost as an economic indicator. However, the conditions can be determined in greater detail by using BELCA's LCC tool. Therefore, although it is also possible to use the calculations obtained with the AIJ-LCA tool, our basic approach is to use BELCA's LCC tool.

3. Approach to LC assessment in renovation projects

For LC assessment in renovation plans, three kinds of evaluations are performed as described in parts (a) through (c) of Figs. 1 and 2.

(a) LC assessment of renovated portions after renovations

LC assessment on renovated portions, beginning at the time of renovation, from renovation work through repair, renewal, operation, and demolition.

(b) LC assessment of entire building after renovations

LC assessment on the entire building, including both renovated and non-renovated portions, beginning at the time of renovation, from renovation work through repair, renewal, operation, and demolition.

(c) LC assessment of entire building since its completion

LC assessment on the entire building, beginning at the time it was completed as a new building. In other words, the results of LC assessment from the time of new construction until the time of renovation are added together with the results of LC assessment for the entire building after renovation.

Renovation: Renovation work based on a review that includes the building's structure and M&E systems.

Repair: Regular partial repairs and the like.

Renewal: Replacement of M&E systems and the like (without fundamentally changing specifications) after the usable lifetime has elapsed.

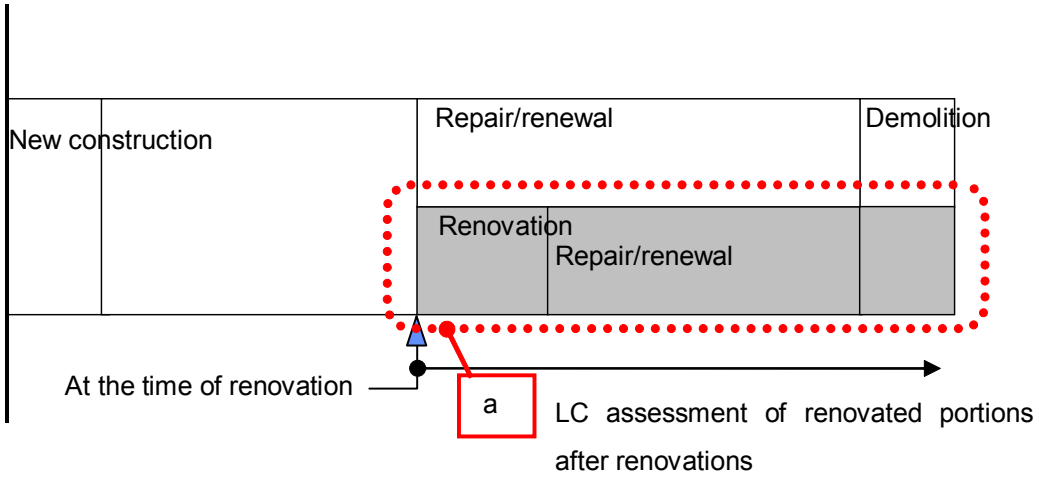

Figure 1 LC assessment of renovated portions after renovations

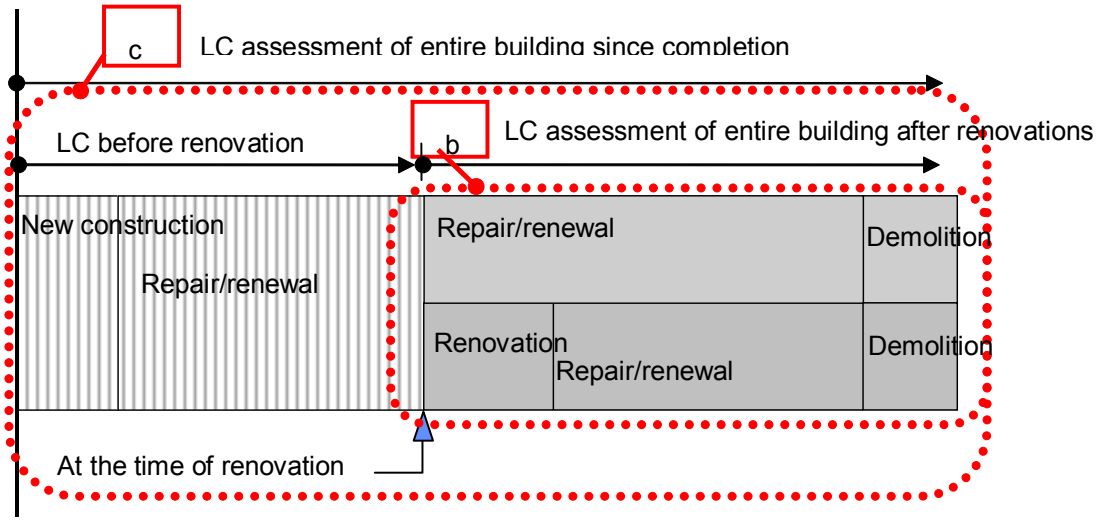

Figure 2 LC assessment of entire building since completion and after renovation

4. Summary of "LC Assessment Tool for Building Renovation"

This tool is used to calculate $LCCO_2$ according to the AIJ-LCA tool, based on input of building data. At the same time, reference data based on $LCCO_2$ calculations is used to calculate LCC with BELCA's LCC tool. A general assessment can be achieved by indicating the assessment data with two measures, $LCCO_2$ and LCC. With regard to LCC, the results of LCC calculations performed at the same time as $LCCO_2$ calculations with the AIJ-LCA tool can be displayed along with the results obtained with BELCA's LCC tool. Fig. 3 shows the overall flow.

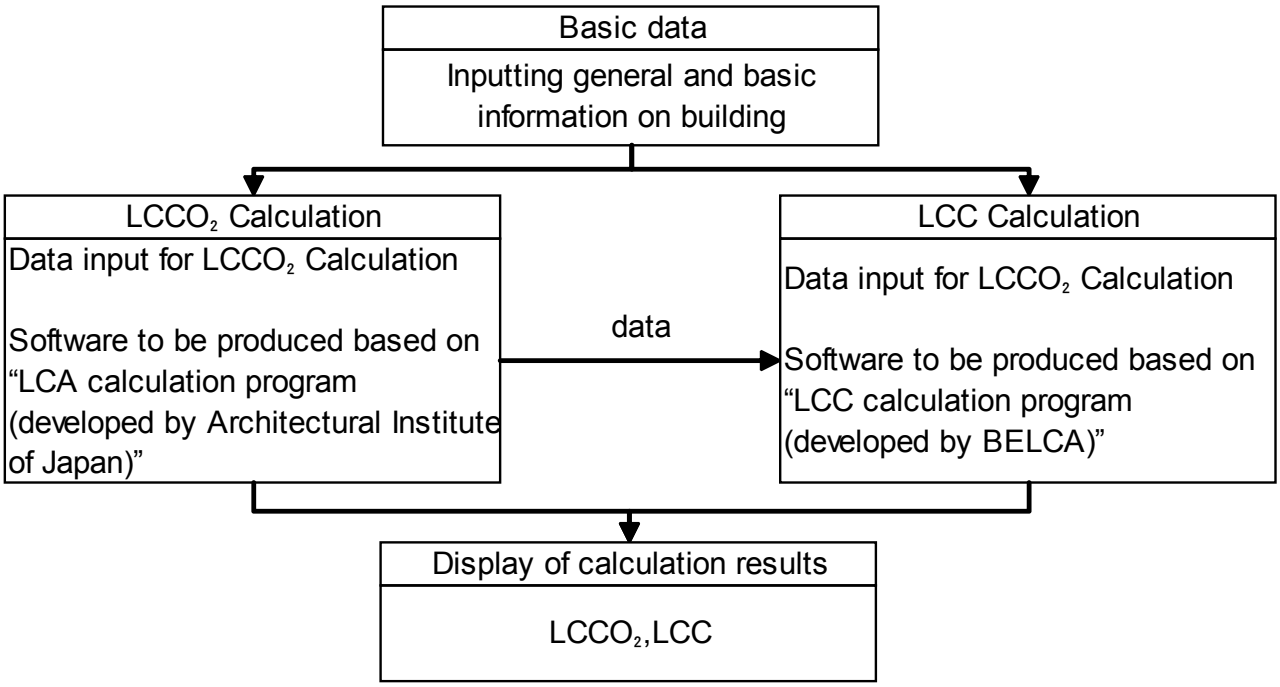

Figure 3 Overall flow

The tool's features are described below.

(a)An "ordinary option," based on continuing to use the building with its existing specifications without any renovation, is compared to a renovation plan based on energy-saving renovation work.

(b)Two cases of renovation plans can be studied at the same time.

(c)The environmental and economic effects can be evaluated at the same time using $LCCO_2$ and LCC.

(d)For a highly precise evaluation of renovation, it is necessary to input the specifications and quantities in a relatively detailed manner, instead of estimated input for new construction. To simplify this process, we have prepared a database of M&E materials and composite unit data for standard specifications in all building components.

(e)The input data for LCC calculation is prepared automatically after data for $LCCO_2$ calculation has been input. Therefore, LCC calculations can be performed by simply revising the costs and rates of repair, as necessary.

(f)The calculation tool is prepared using Excel, a general-purpose program; so the results of calculations and other data can easily be utilized in other documents.

Fig. 4 shows its overall configuration.

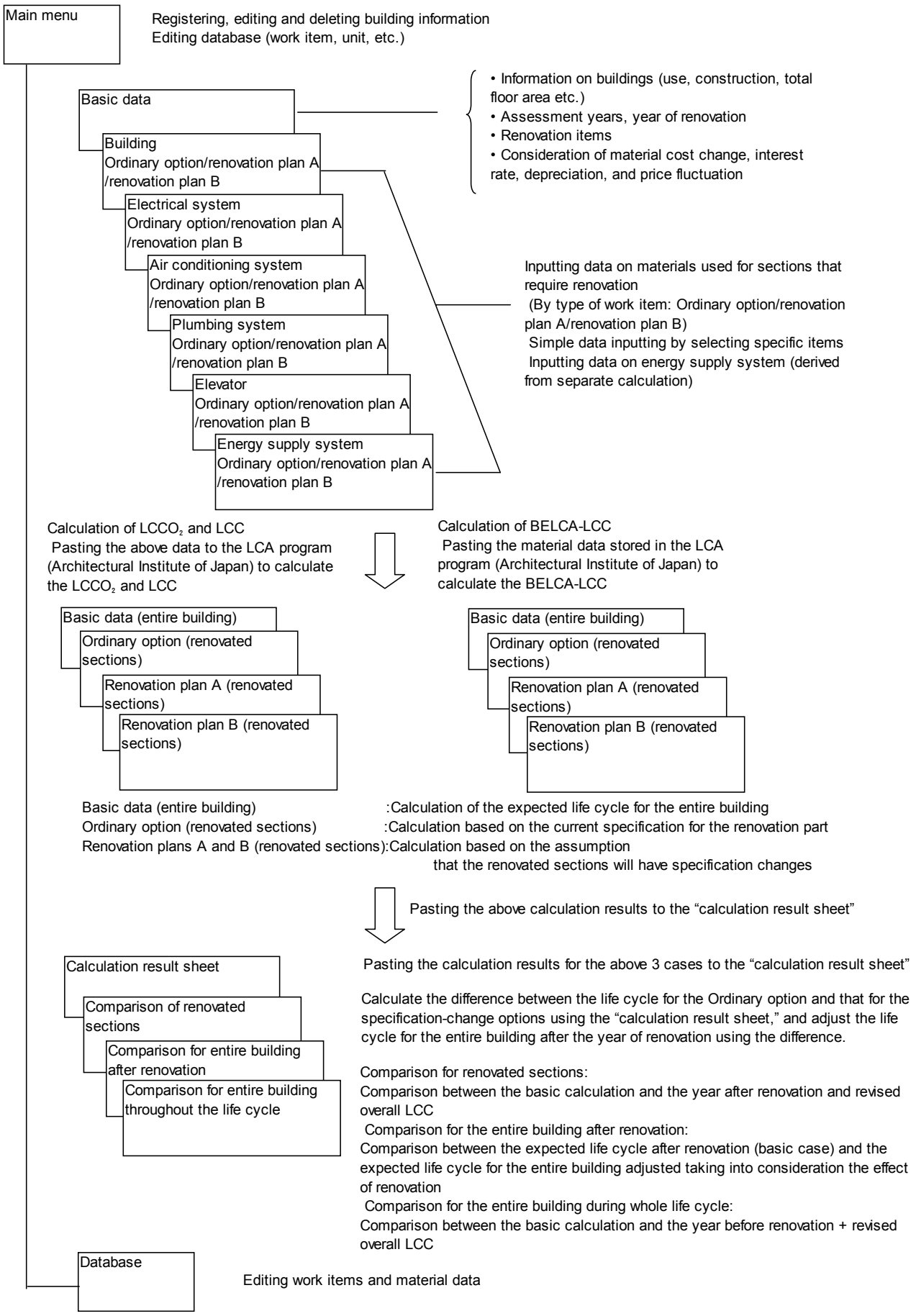

Figure 4 Tool configuration

5. Sample estimate

As an example, an LCC calculation was performed assuming a case in which air conditioning and heating systems are renovated

5.1 Summary of property

Table 1 Summary of property

Property name	Building N
Location	Chiyoda-ku, Tokyo
Use	Office
Structure type, number of floors	Structure type: SRC Number of floors: one-level basement and 9 stories above-ground
Total floor area	10,000 m^2
Life cycle to be considered	50 years
Time of renovation	25th year

5.2 Summary of renovation

We assumed two options, renovation plan A (no specification change option) and renovation plan B (specification change option), which are outlined in Table 2. Compared to renovation plan A, renovation plan B encompasses a wider scope of renovation and includes renovation for the purpose of saving energy. The existing air conditioning and heating system consists of a fan coil central unit and an AHU with a chiller and boiler. In renovation plan A, the heat source is changed to a cold/hot water generator; while in renovation plan B, the air conditioners and pumps are changed, respectively, to a variable air volume (VAV) type and a variable water volume (VWV) type, which are designed to reduce energy consumption.

Building renovations often require replacement or renewal of the ceilings and walls in conjunction with M&E renovation. With renovation plan B, in addition, the toilets are replaced with water-saving fixtures, and the lighting equipment is changed to Hf fluorescent lamps.

Table 2 Summary of renovation

	Building	Facility
1) Ordinary option	Floor: Replacement of carpet tiles Wall: Paint finish Ceiling: Paint finish	Electricity: transformer, panel, light electric equipment, fire prevention equipment, lighting fixtures (fluorescent lamps: 2×40 W) Air conditioning: refrigerator-hot water boiler + AHU-FCU Plumbing system: water receiving tank, lift pump, hot water heater
2) Renovation plan A	Floor: Replacement of carpet tiles Wall: Paint finish Ceiling: Paint finish (sheet replacement for some parts)	Electricity: transformer, panel, light electric equipment, fire prevention equipment, lighting fixtures (fluorescent lamps: 2×40 W) Air conditioning: cold/hot water generator + AHU-FCU Plumbing system: water receiving tank, lift pump, hot water heater
3) Renovation planB	Eaves: New steel eaves installed Glass: Replaced with heat reflective glass Floor: Replacement of carpet tiles Wall: Plaster board, paint finish Ceiling: Replacement of rock wool acoustic panels	Electricity: Same as renovation plan A, plus lighting (Hf fluorescent lamps, 32W x 2) Air conditioning/heating: Cold/hot water generator plus AHU/FCU, VAV, VWV Plumbing: Same as renovation plan A, plus water-saving toilet fixtures

5.3 Summary of assessment results

The following three methods were used for renovation LC assessment.

(a) LC assessment of renovated portions after renovations (Fig. 5)

(b) LC assessment of entire building after renovations (Fig. 6)

(c) LC assessment of entire building since completion (Fig. 7)

• Method (a) provides LC assessment with greater emphasis given to the difference in environmental burden and cost due to renovation work. With regard to the scope of carbon dioxide and cost calculations, the portion subject to renovation work is expressed in relation to the total floor area, so in fact, this difference is a meaningful figure.

• Method (b) provides LC assessment from the time of renovation until final demolition and disposal, without considering any of the environmental burden or costs incurred in the past. In general, this method can be used to form a judgment on whether to perform renovations and which types of renovation work to select.

• Method (c) provides LC assessment over the building's entire life cycle, going back in time to its completion as a new building, in order to evaluate the overall environmental burden and costs. This method is true to the approach of considering the environmental burden in LCA over the entire life cycle, from cradle to grave.

The differences obtained with each of these methods appear to show differing ratios, but they all point to the same order of relative merit.

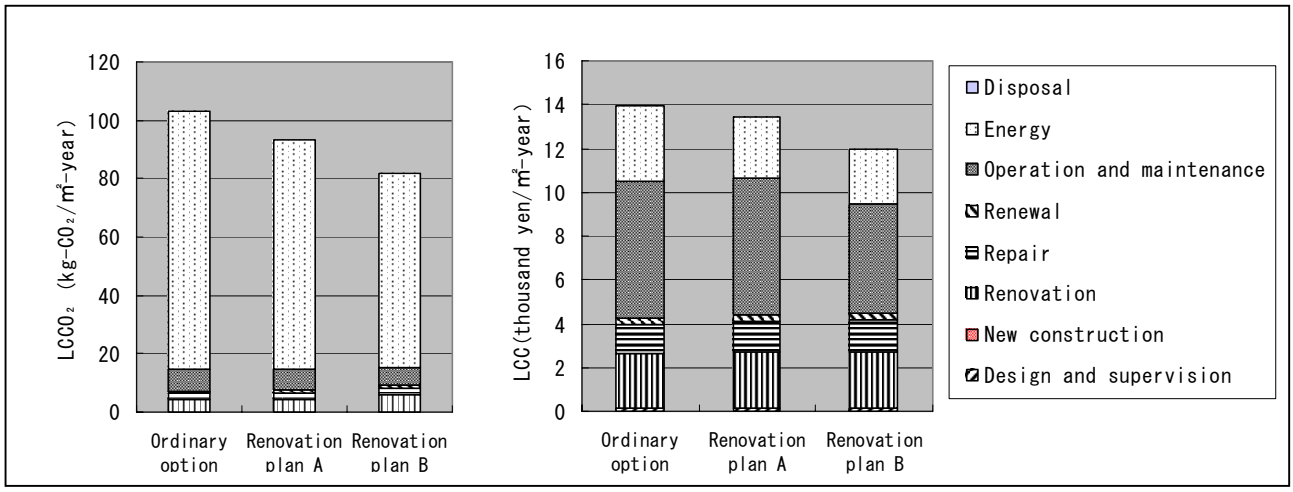

Figure 5 LC assessment of renovated portions after renovations (left: $LCCO_2$, right: LCC)

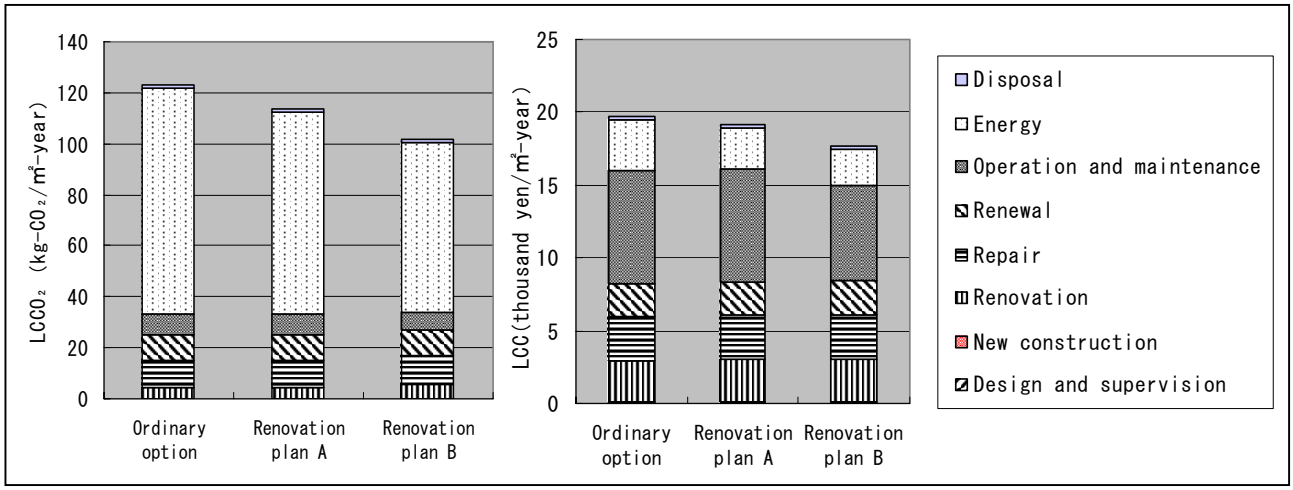

Figure 6 LC assessment of entire building after renovations (left: $LCCO_2$, right: LCC)

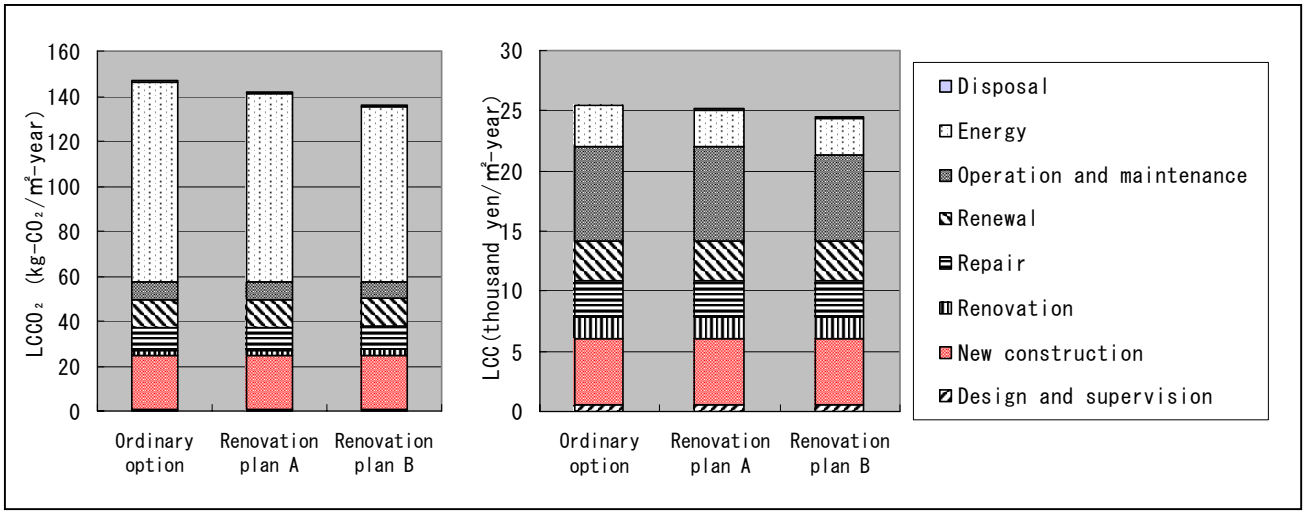

Figure 7 LC assessment of entire building since completion (left: $LCCO_2$, right: LCC)

6. Conclusion

LCA techniques for buildings are not carved in stone; these techniques will continue to be developed and improved in the future. Our future aim is to contribute to the use of LC design in renovation projects in cooperation with the study committees of AIJ which are related to LCA.

References

1 Building and Equipment Life Cycle Association (BELCA), 2002a, “Approach to New LC Design.”

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