Development of an Integrated Energy Simulation Tool for Buildings and MEP Systems, the BEST (Part 1) Macro design of the Tool

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Prevention of global warming, i.e., the reduction of CO_2 emission, is an urgent and serious issue of worldwide concern. In Japan, CO_2 emission due to fossil energy consumption in the residences and commerce buildings has been increasing every year since 1990. For energy savings in these buildings, the development of the BEST (Building Energy Simulation Tool) is indispensable. The Ministry of Land, and Infrastructure and Transport Japan formed a committee to study the necessity of a new energy simulation tool that could assist the promotion of energy saving policies of the government. In this paper, an outline of the report of the committee is provided.

Background of BEST development

Global warming prevention has been a critical issue, not only for Japan, but also for every country. Accordingly, the reduction of CO_2 emissions due to energy consumption (i.e. the promotion of energy conservation) is of significant importance as a concrete measure against global warming. In actuality, energy consumption in the commercial buildings and residences has been increasing since 1990 (Figure 1). Therefore, the government has been working on various measures, including revision of the Law Concerning the Rational Use of Energy. As part of these measures, the Ministry of Land, Infrastructure and Transport (MLIT) developed and released the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in 2002 to improve the framework for promoting sustainable buildings.

The majority of energy supplied to commercial buildings and residences consumed by air-conditioning, lighting and domestic hot water supply. However, there are no appropriate tools to accurately estimate energy consumption and to study energy consumption reduction approaches at this time. In the past, software such as HASP/ACLD/ACSS, which was used to simulate annual energy consumption in air-conditioning equipment, was developed in 1985 as a response to the oil crisis of the 1970's. Later on,

various tools such as BECS were developed based on HASP/ACLD/ACSS to calculate the CEC/AC of the Law Concerning the Rational Use of Energy. Such tools have greatly contributed to energy conservation in air-conditioning in Japan. However, it is hard to say that the use of such software has spread, due to poor maintenance.

In the United States, the EnergyPlus software was developed at the initiative of U.S. Department of Energy (DOE) to calculate annual energy consumption through air-conditioning. EnergyPlus has been managed and maintained continuously. In China, DeST was developed and has also been continuously managed and maintained, just like EnergyPlus. From the viewpoint of the development, maintenance and management of simulation tools, it's undeniable that Japan lags behind these countries.

As a response to this fact, the Development Committee was established at the Institute for Building Environment and Energy Conservation (IBEC) in 2005 to promote the development of BEST (Building Energy Simulation Tool) as a new energy-simulation tool at the initiative of MLIT through the combined efforts of industry, government and academia. This report describes the study results obtained by the Development Committee.

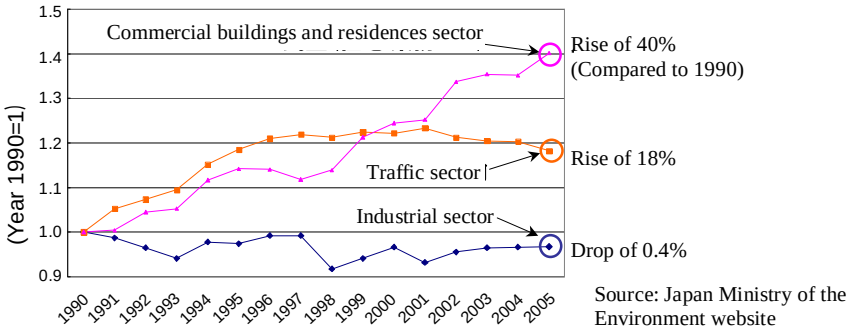

Figure 1 Transition of CO_2 emissions in each sector

1. Investigation of current situation regarding energy consumption calculation tools

The current situation regarding the development of similar overseas programs was investigated for creating the macro design of BEST.

1.1 BLAST (Building Loads Analysis and System Thermodynamics)

BLAST was developed by the U.S. Army Construction Engineering Research Laboratory in 1977. The origin is Kusuda's heat balance method. The final version, BLAST3.0, was developed in 1998 and is maintained and managed by Illinois University. BLAST calculates thermal loads and energy in air-conditioning systems and heating equipment systems separately. BLAST evolved into iBLAST, which can calculate values for both buildings and systems at the same time.

1.2 EnergyPlus

EnergyPlus was developed by the U.S. Post Office based on iBLAST and the global standard program DOE-2 (HASP type; Lawrence Berkeley National Research Laboratory) in 2001. The software is freely downloadable from the U.S. DOE website and is the most popular program in the world now without a user-friendly interface.

1.3 Programs registered with DOE

More than 300 programs have been registered with DOE by more than 20 countries. About 80 of these programs are available for free. The registrants are the United States, England, Canada, Germany, Sweden and Switzerland (10 programs or more) in descending order. Japan has not registered anything yet. The purpose classification shows that use in energy simulations is dominant (about one third of the total) followed by use in load calculations (about a quarter of the total).

1.4 Maintenance framework

DOE-2.2 is maintained by the Lawrence Berkeley National Research Laboratory. BLAST (iBLAST) is usually managed by about 10 researchers at Illinois University. EnergyPlus administrators accept questions via E-mail for discussion using the IBPSA (International Building Performance Simulation Association) mailing list. TRANSYS is supported by the Solar Energy Laboratory of the University of Wisconsin. HVACSIM+ is managed by the U.S. National Institute of Standards and Technology (NIST). DeST is normally managed by the DeST Group of more than 20 researchers at Tsinghua University in China. Each tool has a clear maintenance framework. Accordingly, it is significantly important to consider a maintenance framework for BEST to be used after development.

1.5 New global trends

IBPSA has held an international academic conference on simulation for buildings every two years. The International Energy Agency (IEA) has developed simulation programs for solar thermal utilization and HVAC systems and a tool verification system, BESTEST. The IEA plans to establish a simulation information center on the Internet. The STEDI project plans to integrate TRANSYS and CFD. Other efforts have also been implemented, such as consolidation of various environmental simulations (EVA) using the CAD Standard and establishment of a unified expression method to be applied in software such as NMF and Proforma.

2. Macro design of BEST

The best path that BEST should follow was studied repeatedly based on the investigation results described in Chapter-1 to create the macro design for BEST.

2.1 Object-oriented program[*1]

Object-Oriented Programming (OOP) is a concept to design and develop programs while focusing on the operating objects rather than the operating procedures. Several related datasets and corresponding procedures (called methods) are combined into and managed as a single "Object." Object-oriented programs are developed by integrating several objects. Each object can work just by receiving messages without understanding detailed inner structures and operational principles. The OOP concept is appropriate for developing large-scale software because many people can share the work of making the smaller subsystems and components.

The advantages of object-oriented programs are a) easy reuse of models[*2], b) easy function expansion and c) easy modeling. In BEST development, the following ideas have been complied with as much as possible for conducting OOP.

(1) Design of the program using UML (Unified Modeling Language)

(2) Utilization of Java, which is considered an object-oriented language

(3) XP (eXtreme Programming)[*3] development method

*1: The Object Cells Method has been used in the development of LCEM（Life Cycle Energy Management), which has preceded BEST. LCEM can simulate energy in air-conditioning systems by using general-purpose spreadsheet software. It was developed by a committee (Chaired by Shuzo Murakami) of the Public Buildings Association with the support of the Government Buildings Department of the Minister's Secretariat at MLIT, as well as other contributors.

*2: Reuse ranges widely from small object units to an entire program.

*3: XP has 12 practices, such as Small Release and Simple Design.

2.2 Comprehensive analysis for energy in air-conditioning, electrical and hydraulic equipment

Traditional energy simulation programs were designed to calculate energy consumption in air-conditioning equipment. However, considering only energy consumption in air-conditioning equipment is insufficient if energy conservation of entire buildings needs to be dealt. Accordingly, BEST aims to enable the calculation of not only energy consumption in air-conditioning equipment, but also that in electrical and hydraulic equipment, as well as water consumption. With this ability, BEST can share boundary conditions between equipment, making for more consistent calculations.

Moreover, BEST provides various functionalities such as calculations of building thermal loads, indoor thermal environments and environmental loads such as exhausts resulting from energy consumption. With these functionalities, BEST could set goals of not only becoming a simulation tool that can meet the various needs of users, but also calculating PAL and CEC as described in the Law Concerning the Rational Use of Energy and of being a performance evaluation support tool like CASBEE.

2.3 User-friendliness

It is important for programs to be user-friendly before anything else. The ultimate in user-friendliness is considered to be "tools that can be handled without reading the manual." Aspiring to become a user-friendly tool, BEST is planned to be equipped with pre-processing user interfaces (UI) for assisting with input methods, such as a GUI (Graphical User Interface) that enables users to enter data as if they were painting and a CUI (Character-based User Interface) that makes input methods easier. Post-processing UIs for output, which can create the graphs and tables, required by users, are also planned. Additionally, development support from third parties is also in the works.

BEST will be able to meet various needs because it is an object-oriented program. It is assumed that BEST will be used in commissioning, etc., using real data.

2.4 Integrated analysis for buildings and MEP systems

Recently, there are many cases where the boundaries between buildings and HVAC systems are not clear. Typical examples of this are air flow windows, double skin systems, building thermal storage systems, etc. To calculate thermal loads and the natural room air temperature, etc., of systems containing such equipment and systems, it is necessary to conduct integrated calculations of buildings and HVAC systems.

There are many integrated calculation methods for buildings and HVAC systems. BEST follows a concept where unknown information regarding each object is calculated by receiving data from previous points in time (Figure 3).

In this concept, software compatibility increases, but arithmetic precision causes problems. Accordingly, it has been decided that arithmetic precision should be ensured with segmentation of the Δt. The thermal transfer rate, quantity of heat, temperature, humidity, etc., will be used as the delivery variables of buildings and HVAC systems.

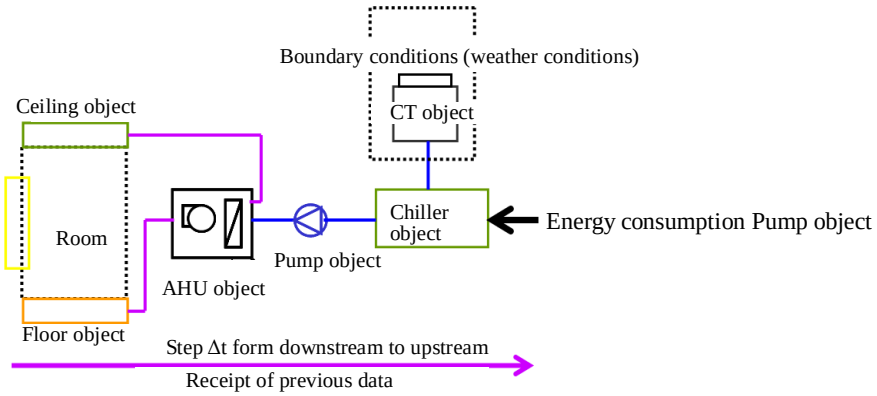

Figure 3 Schematic view of integrated calculation method for buildings and HVAC systems

2.5 Variability of calculation time interval

One hour calculation time intervals have been used in traditional energy-simulation software such as HASP/ACSS and BECS. The interval is a fixed value in any program.

If the segmentation of Δt described above is applied to traditional software as an integrated calculation method for buildings and HVAC systems, computing time length may increase unnecessarily. Accordingly, techniques to achieve both a reduction of the computing time length and ensuring arithmetic precision are required. As one such technique, applying variable calculation time intervals is practical, such as one minute for pre-heating/pre-cooling periods and 15 minutes for normal operating periods. With this technique, BEST aims to make calculations based on the required arithmetic precision and to select suitable calculation time intervals based on the purpose of use.

2.6 Utilization of the Internet

In BEST development, aggressive utilization of the Internet as shown in Figure 4 has been planned. With the Internet, ASP (Application Service Provider) services will be possible and users will be able to utilize BEST. In addition, many engineers will be able to update objects for the maintenance and management of BEST. Various programs for BEST have been created using general-purpose languages such as XML (eXtensible Markup Language), making BEST a multipurpose tool.

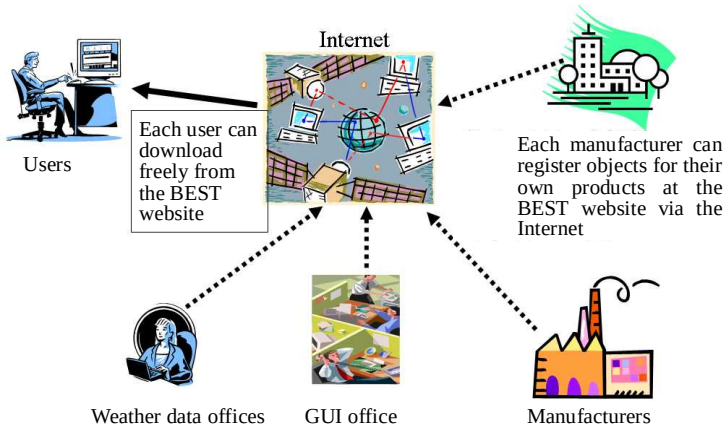

Figure 4: Schematic view of utilization of the Internet

2.7 Abundant weather data

Expanded AMeDAS Weather Data (EA weather data) is weather data obtained by meteorological observation stations (i.e. AMeDAS: Automated Meteorological Data Acquisition System) of the Japan Meteorological Agency. The EA weather data is created by replacing missing data, correcting suspected abnormal data and complementing unobserved data such as insolation, humidity and atmospheric radiation. Standard annual weather data, weather data for designing purposes and real weather data for 20

years are available. Current EA weather data is one-hour interval weather data. In BEST, however, the use of one-minute interval data created based on the EA weather data has been planned, as has the use of overseas weather data complying with the EPW (EnergyPlus Weather Data) format, in addition to data created by users.

2.8 Equipment performance data expressing partial load performance

For creation and collection of equipment performance data, BEST will carry out independent investigation while making reference to legacy code in existing programs, if available. If data on equipment dynamics is not supplied by manufacturers, alternative procedures, such as the use of thermal capacities, will be considered.

Traditional maximum load calculation methods mostly evaluate equipment performance at the rated point. BEST will enable the estimation of annual energy consumption where consumption during low load operations is included. Consequently, improvement of arithmetic precision can be expected.

3. Further challenges and tool development

As described at the beginning of this paper, it is necessary to more energetically promote energy conservation for the prevention of global warming, especially in the commercial buildings and residences where energy consumption has been increasing significantly. In order to stop this increasing trend, the development of BEST began at the initiative of MLIT under a combined effort by industry, government and academia. For the development of BEST, a Development Committee consisting of many specialized and qualified individuals was established to carefully discuss and summarize issues regarding the macro design of BEST. The discussion results are described in this report.

In the phases of building design and system/equipment selection, calculations of annual energy consumption where partial loads were considered have mostly been omitted so far. However, BEST will enable the revision of the traditional design phase. Accordingly, it is important that BEST can be used at anytime by anybody regardless of whether the building in question is new or being refurbished. To reach this goal, it is planned to develop the tools separately (Table 1). For details about each of the tools, see the follow-up reports.

Table 1 Name and outline of BEST

	Abbreviation	Name	Outline
Tool-1	BEST (or BEST-B)	BEST BEST-Basic	Basic software to be used widely as a administration support tool
Tool-2	BEST-P	BEST-Professional	Software to be used by engineers for detailed general design purposes, also may become a administration support tool

The following Tool-3 is also planned to be developed.

	Abbreviation	Name	Remarks
Tool-3	BEST-E (tentative name)	BEST-Extended (tentative name)	Software to be developed especially from specialized viewpoints for specific purposes

Acknowledgement

This report describes some of the project achievements conducted by the "Study Group for the Development and Promotion of BEST (Chairperson: Shuzo Murakami)" and the Development Committee, which aims to develop a comprehensive tool to calculate energy consumption. The Study Group and the Development Committee are part of the Institute for Building Environment and Energy Conservation (IBEC). We would like to express our gratitude to all of the parties involved.