Heat load profile for ZEB and requirements for heat pump technology

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The heat load characteristics of ZEB-oriented buildings were analysed to survey the effects of ZEB on the building heat load. ZEB reduces the annual integral heat load and maximum heat load and lowers the ratio of the heat load to the maximum heat load. A major factor for a lower heat load is the reduction of the room sensible heat load, and it was found that this would cause changes to the reduction of the sensible heat ratio and the cooling/heating ratio of the heat load. In response to these effects, technological development required for heat pumps was considered. Here we describe a full product lineup of low-capacity heat pumps, improvement operation efficiency under partial load, standby power and energy consumption of auxiliary devices for heat transfer.

Introduction

Japan intends to reduce CO_2 emissions by 26 % by 2030, compared to 2013. To realize this, energy conservation efforts must be made in each of the public, transportation and industrial sectors. Particularly, the public sector must achieve a high goal of approximately 40 % reduction [1]; ZEB will be one of the effective measures to that end. Setting the goals of ZEB introduction into newly constructed public buildings by 2020 and into new buildings on average by 2030, the Japanese government is enhancing its efforts [2].

For recent efforts related to ZEB, the Society of Heating, Air-conditioning and Sanitary Engineers of Japan published the definition and evaluation method of ZEB in 2015 [3], and the Ministry of Economy, Trade and Industry formulated and published the roadmap and the definition of ZEB in November 2015 [4] and published a design guideline in 2017 [5]. Also, a subsidy system has been operated since 2012 to promote ZEB, realizing approximately 270 subsidized projects so far [6]. Under these circumstances, the superiority of heat pumps has been recognized more than ever as a necessity in order to achieve ZEB. As ZEB implementation has increased, the performance demanded for the heat pumps includes not only higher efficiency, but also the use for a variety of needs.

In this article, we consider the heat load change of ZEB-oriented buildings, and review the effects of ZEB on heat load. We then consider technological development required for heat pumps in response to those effects.

Heat load profile for ZEB

The following describes the heat load characteristics of ZEB-oriented buildings. Assumed for the purpose of analysis was a 5-story office building located in Tokyo (latitude 35 degrees North), Japan and having a total floor area of approximately 10 000 m² and a standard floor area of approximately 2 000 m². Also, model buildings were setup based on the standard and

Table 1. The model building based on the energy conservation specifications adopted maximum heat load reduction technologies.

Envelope performance	Exterior wall: 0.4 W/m²K Roof: 0.55 W/m²K Window: 1.6 W/m²K Shading coefficient: 0.24
Internal heat gain intensity	Lighting: 2W/m² , 500 lx (LED+Lighting control+Blind control) Plug Daytime: 5 W/m² Nighttime: 1.25 W/m²
Other	Natural ventilation Air-to-air total heat exchanger

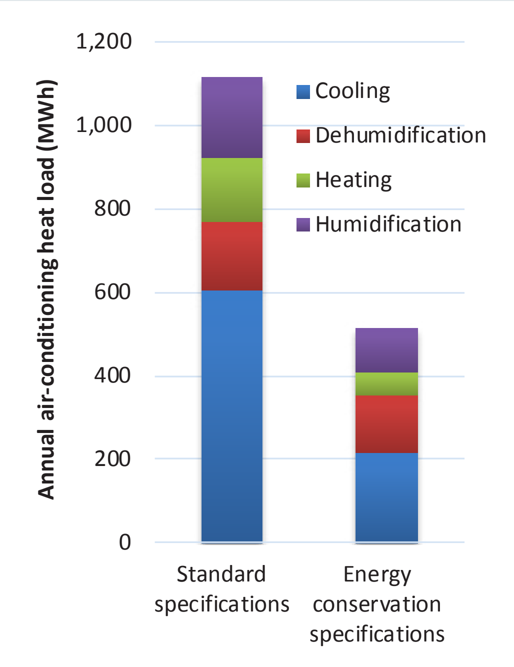


Figure 1. Comparison of annual integral heat load values of model buildings.

energy conservation specifications with respect to this office building. The model building based on the standard specifications adopted conventional general specifications. The one based on the energy conservation specifications adopted maximum heat load reduction technologies, such as higher building envelope performance, indoor temperature/humidity mitigation, heat load conditions reflecting the use of high-efficiency devices, natural ventilation and the use of total heat exchangers (see Table 1) [7].

Figure 1 shows the results of the heat load calculation of the target buildings. In the breakdown of the annual heat load of each building, cooling and dehumidification load, related to the cooling load, accounts for more than half of the total in the case of the building with the standard specifications (left in Figure 1). In the case of high-level energy conservation specifications aiming at achievement of ZEB (right in Figure 1), it is confirmed that the annual heat load is greatly reduced. A major factor for such halved annual heat load is the reduced room sensible heat load due to higher building envelope performance and use of high-efficiency lighting device and others.

In the breakdown of the annual heat load, it is seen that the heat load related to dehumidification hardly changes with respect to the sensible heat load such as cooling and heating. This is because the latent heat processing of indispensable fresh outside air accounts for the majority. This suggests that when designing a system for realization of ZEB, it is an important issue to build a high-efficiency system for processing a latent heat load.

Furthermore, based on the result that the room sensible heat load is reduced, but the latent heat load hardly changes, it is presumed that the sensible heat factor is reduced. In most cases, it is expected that sufficient dehumidification cannot be achieved by conventional supercooling and dehumidification.

Figure 2 shows the frequency of a ratio (load factor) of the hourly heat load to the maximum heat load. Indicated in the figure is the maximum heat load of the buildings with different specifications. The maximum heat load in both cooling and heating were lowered. It is seen that a ratio of the heat load to the maximum heat load was reduced more for the energy-conserving building than the standard one. This reduction was particularly considerable with the heating load; a period of less than 10 % was 274 hours for the standard specifications and 428 hours for the energy conservation specifications.

Requirements for heat pump technology

Full product lineup of small-capacity heat pumps available for heat load reduction

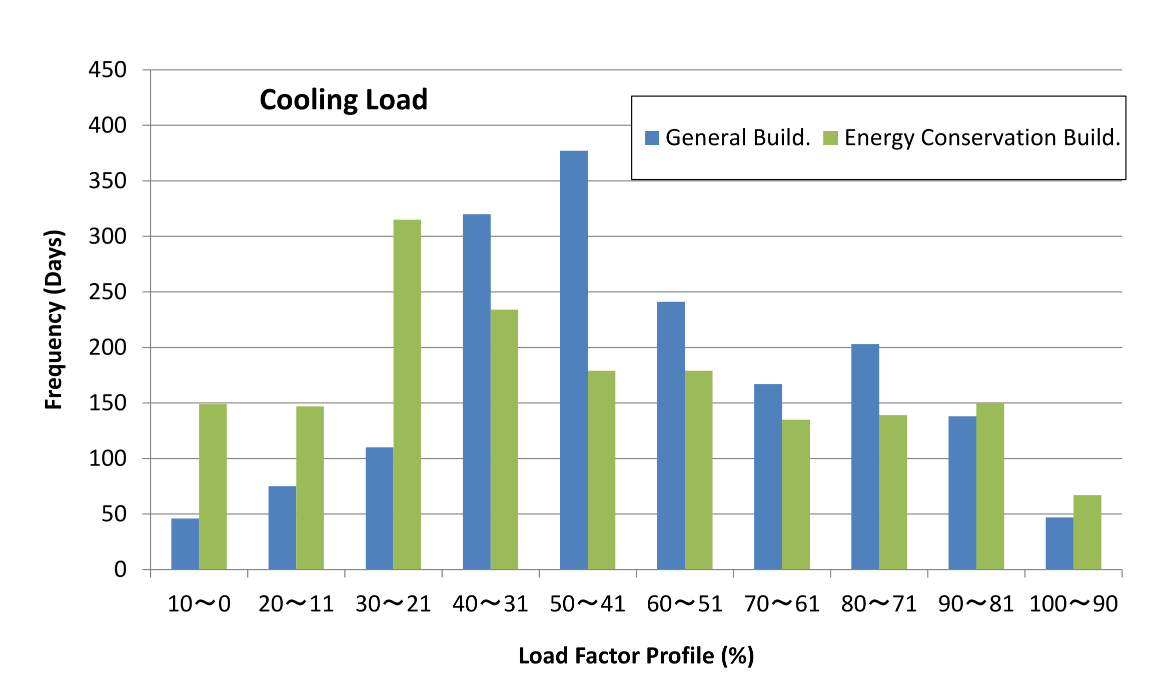
It is presumed that promotion of ZEB will accelerate heat load change such as a reduction of the annual integral heat load and the maximum heat load. It is likely that there will be an increasing demand for smaller-capacity heat pumps than the existing ones. Accordingly, it is necessary to augment the product lineup of small-capacity heat pumps.

Improvement operation efficiency under partial load operation

As mentioned previously, the ratio of the heat load to maximum heat load is lowered along with promotion of ZEB. This increases the effect of operation efficiency at partial load on system operation efficiency. Accordingly, technological development will be continuously needed in the future for higher operation efficiency of the heat pumps under partial load. In addition to this, it is also indispensable in the system design to incorporate measures such as decrease the number of equipment and actively utilizing renewable energy sources such as ground-source energy.

Focus on standby power and energy consumption of auxiliary devices for heat transfer

Decreased heat load means lower energy consumption of the heat pumps. Lower energy consumption of the heat pumps cause energy consumption to draw more attention, which has not been noted due to its low ratio. For example, the standby power of the heat pumps and energy consumption of auxiliary devices such as heat transfer pumps. Development and design of heat pumps needs to focus on the energy consumption during standby and of auxiliary devices.



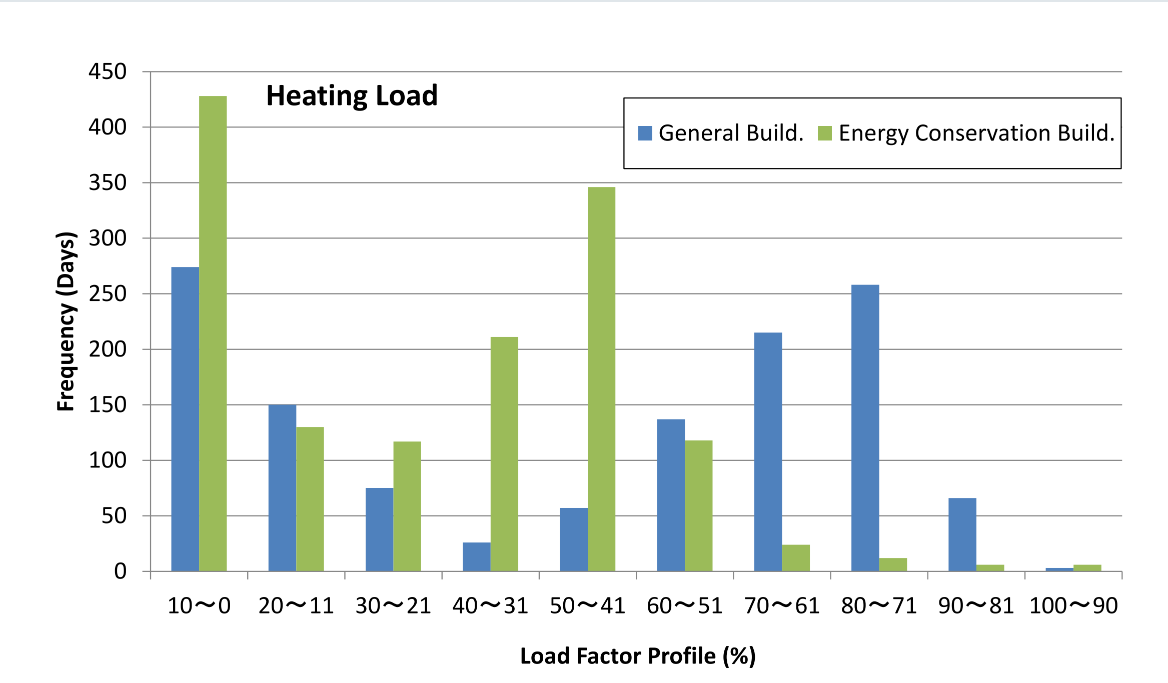


Figure 2. Ratios of hourly heat load to maximum heat load.

Conclusions

The heat load characteristics of ZEB-oriented buildings were analyzed to review the effects of ZEB on building heat load. In response to these effects, technological development demanded for the heat pumps was also described. In addition to the technological development of the heat pumps themselves, it will be necessary to successfully design and operate them as part of the system.

It is expected that use of renewable energy will continue to expand globally. Meanwhile, heat pumps capable of converting electric power into thermal energy can provide a method to effectively utilize surplus power from renewable energy, in combination with thermal storage technology. It is imagined that DC power supply technology capable of directly utilizing DC power without conversion losses will become more effective through increased use of renewable energy. Thus, the use of heat pumps that can use DC power is expected to grow.

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