【*Technical Paper*】

FEASIBILITY STUDY FOR ZWB ON A SUSTAINABLE OFFICE

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ABSTRACT

Our innovation center (hereafter referred to as “the building”), designed as a sustainable building, achieved a net-zero energy performance. Additionally, the building incorporated a highly efficient water-usage system for resource conservation. As a result of evaluating the building according to net-zero water building (ZWB) as defined by the U.S. Department of Energy, the potential for achieving ZWB is suggested. However, there are ambiguous aspects when applying this definition to a building’s water usage system, necessitating further discussion. Conversely, when evaluated based on the definition of LEED Zero Water (hereafter referred to as “LEED-ZW”) certification proposed by the U.S. Green Building Council, our approach to heat utilization of groundwater differed from the certification definition, resulting in a value greater than zero. Therefore, we explored methods for improving water usage to achieve a ZWB according to the LEED-ZW definition. These methods include reducing groundwater usage through improved building operations and utilizing underground rainwater infiltration and groundwater.

1. INTRODUCTION

The building is a research facility designed for energy independence through the use of renewable energy. In previous reports,[1,2] we reported the operational status of the groundwater heat utilization system installed in FY2022. In this report, in addition to the operational results of the groundwater heat utilization system in FY2023, we focus on the effective use of water resources as a new perspective for transforming the research facility into a more sustainable one while making effective use of its location and other resources. We then report the estimation result based on the net-zero water building (ZWB) evaluation method.

2. Groundwater Heat Utilization System Operation Results

2.1 Groundwater heat

2.1.1 Groundwater heat utilization status

Fig. 1 illustrates a diagram of the groundwater heat utilization system. In this system, groundwater is extracted by pumping wells and is used for heat utilization. The system consists of two systems: a direct-use system in which groundwater is pumped during the day for air conditioning, and a cascade system in which groundwater is stored at night for cascading use. In the cascade system, groundwater is used to cool the upper floor of the reservoir (zero primary use), personal air conditioning and radiant air conditioning in offices (primary use), and as the heat source for a water source heat pump (secondary use). After heat utilization, a portion of the groundwater is reused as well water (gray water) and the remainder is returned to the ground through return wells.

This article is update of “The 49th International Symposium on Water Supply and Drainage for Buildings (CIB W062), August 19-21, 2024, Northampton, UK.”

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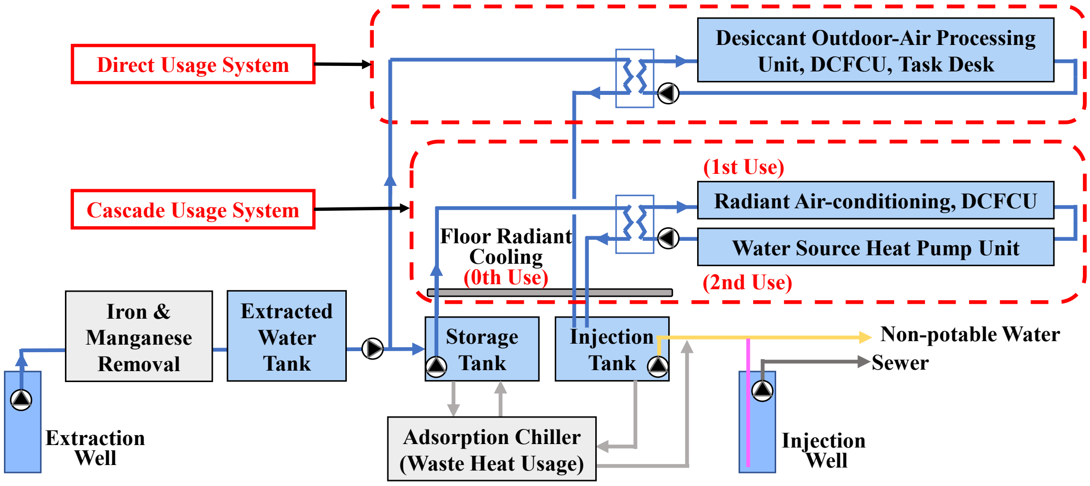

Fig. 1 Overview of the groundwater heat utilization system

Fig. 2 depicts the average groundwater and outdoor air temperatures for each month in FY2022 and FY2023 during the system operation. The groundwater temperature was not affected by the ambient air temperature and fluctuated approximately 3 °C throughout the year in FY2023, with an annual average of 16.6 °C. The groundwater temperature in FY2022 also displayed little fluctuation, with an annual average of 16.8 °C. This study will continue in anticipation of future changes in the usage and groundwater veins.

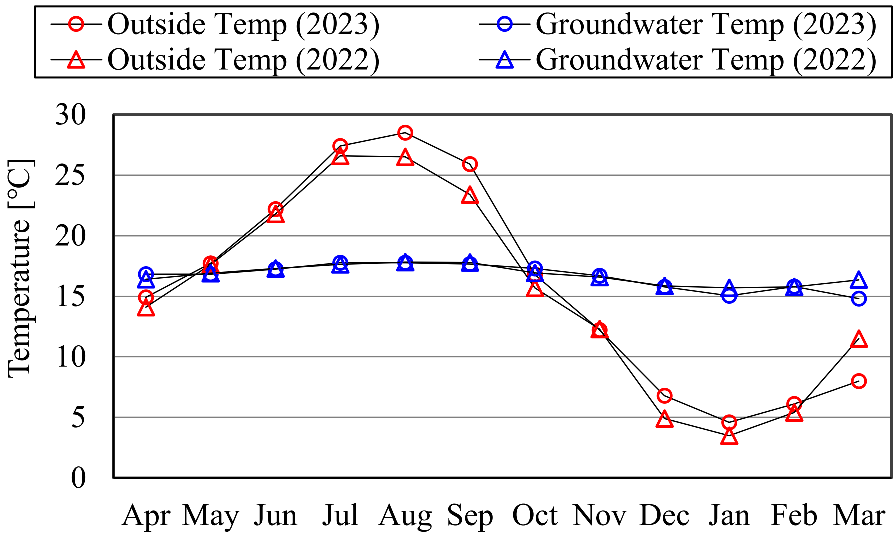

Fig. 2 Groundwater and outside temperatures for each month

In this building, groundwater heat is used according to the cold heat demand, contributing to energy conservation and the reduction of CO_2 emissions.[2] The monthly accumulated cold heat (illustrated in Fig. 3) is the sum of the cold heat from the direct groundwater heat and cascade utilization systems. The left side of the bar graph depicts the value for FY2022, and the right side depicts the value for FY2023. The total amount of cold heat accumulated in the cascade use system in August and September increased by approximately 5,000 kWh in FY2023 compared with FY2022 because the secondary side outlet temperature of the heat exchanger was set at a lower value than in FY2022.

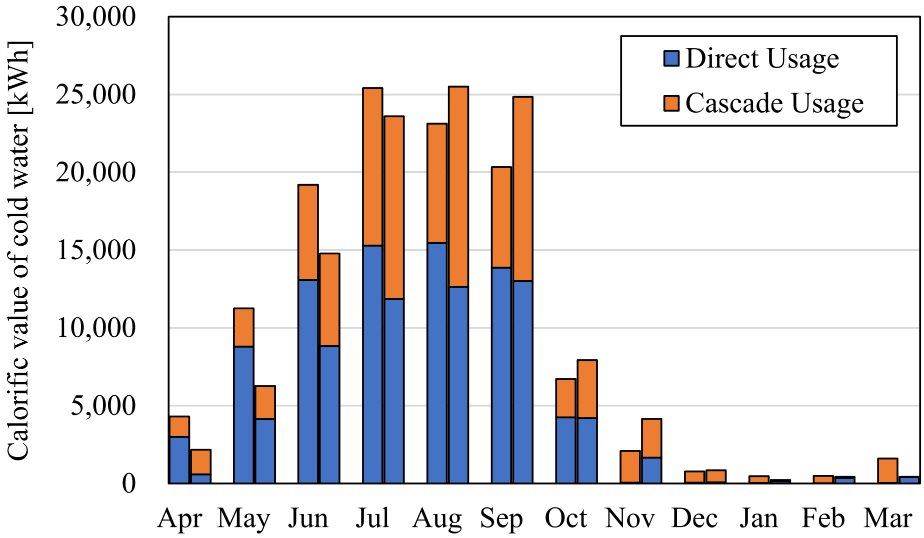

Fig. 3 Quantity of cold heat
(The left bar: FY2022, The right bar: FY2023)

2.2 Water consumption

2.2.1 Water and well water usage

In this building, a portion of the groundwater used for heating via air conditioning was also used as well water. Fig. 4 illustrates the usage of tap water and groundwater as well as the actual results. As presented in Fig. 4, tap water consumption doubled from 600 m^3/year in FY2022 to 1,260 m^3/year in FY2023, mostly because of an increase in the laboratory building supply system (620 m^3/year) for experimental use. Additionally, it is believed that an increase in the number of people in the building increases the volume of water used. The well water used for experiments, toilets, hand washing, etc. increased by 120 m^3, from 1,470 m^3 in FY2022 to 1,590 m^3 in FY2023. This is due to the increase in the volume of water used for experiments in the laboratory building as well as for drinking water. The backwash water for the de-ironing and de-manganizing equipment decreased by 900 m^3/year. This was a result of the reduced backwash frequency conditions during the demonstration test for the optimization of backwash conditions to reduce backwash water, which started in FY2023. The volume of groundwater restored to the return wells increased by 6,930 m^3, from 16,500 m^3 in FY2022 to 23,430 m^3 in FY2023, owing to an increase of 5,540 m^3 in groundwater pumped for air conditioning use, from 24,760 m^3 in FY2022 to 30,300 m^3 in FY2023, and a decrease in total well water (gray water) use.

Fig. 5 illustrates the water consumption for each month and the ratio of tap water to groundwater in the pie chart. Groundwater consumption in FY2023 was approximately 96 % of the tap water and groundwater used in the facility, and tap water consumption was approximately 4 % (1260/32450). Groundwater pumping, used as a source of cold heat for air conditioning, increased by 5,760 m^3/year, from 25,430 m^3/year in FY2022 to 31,190 m^3/year in FY2023. This was attributed to an increase in groundwater pumping because the outlet temperature of the heat exchanger operated at a lower set point. Approximately 23 % of the groundwater used for air conditioning was reused as well water.

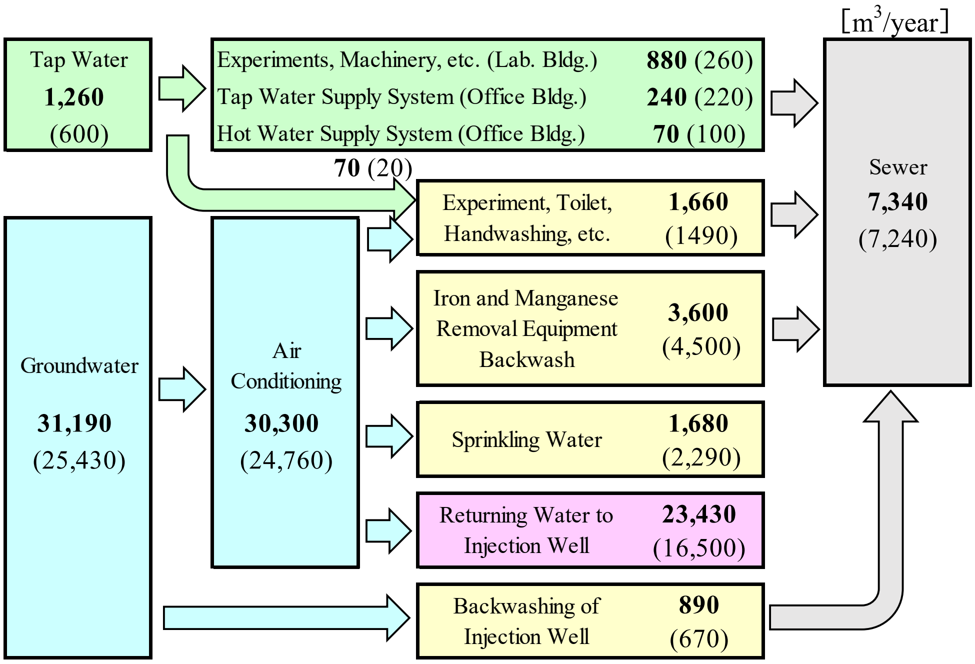

Fig. 4 Diagram of the flow of water usage in the facility [m^3/year]
(Bold: FY2023 results; In parentheses: FY2022 results)

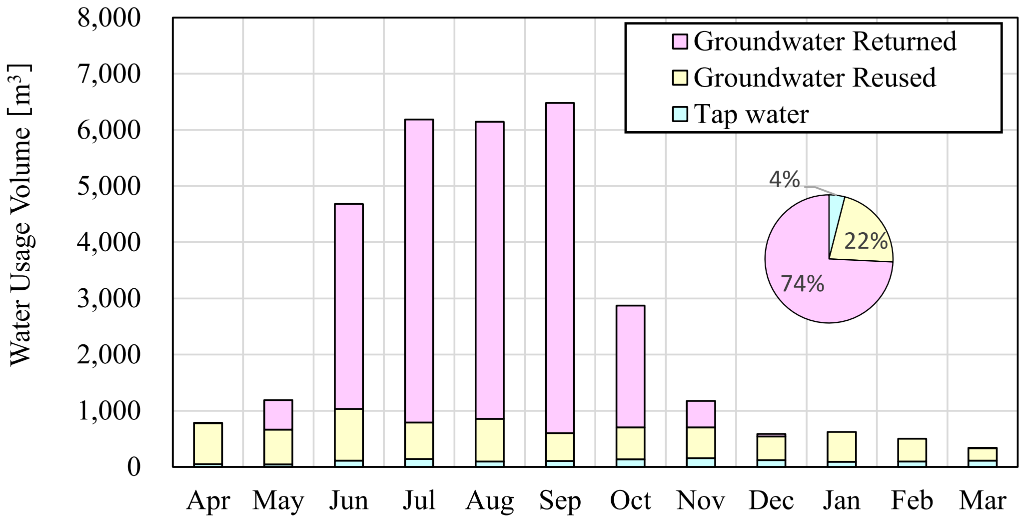

Fig.5 Monthly quantity of tap water and groundwater

2.2.2 Volume of sewage

As presented in Fig. 4, the sewage volume in FY2023 was 7,340 m^3/year, which is an increase of 100 m^3/year compared to FY2022. This was a result of 660 m^3/year increase in drinking water, 120 m^3/year in well water used for hand washing in experimental toilets, and 220 m^3/year in backwash water from return wells, for a total of 1,000 m^3 increase and 900 m^3/year decrease in backwash water from the iron and manganese removal equipment.

3. ESTIMATED EVALUATION BY ZWB INDEX

A growing interest in the ZWB as a new water resource recycling building goes beyond conventional water conservation and recycling to consider reducing the load on the water supply and sewage infrastructure. In this section, we estimate this building from the perspective of water resource recycling using the ZWB evaluation method.

3.1 ZWB trial evaluation

In this report, we estimate and discuss the ZWB evaluation method proposed by LEED Zero Water (LEED-ZW), a LEED Zero Certification.

3.1.1 Estimation method of ZWB

The definition of ZWB in the LEED Zero Program Guide[3] is presented in Table 1. LEED-ZW certification can be obtained if the difference (a-b) between the total water use (a) and the sum (b) of the volume of alternative water (①) used and the volume of reduced water (②) returned to the ground etc.; (b) is a negative value. However, the building must be LEED certified. In this estimation, the calculations were made not only for the office building area subject to LEED certification but also for the entire site, including the laboratory building area.

Table 1 Definition of ZWB by LEED-ZW

Item	Description
POTABLE WATER CONSUMED	
Water consumption	Total potable water consumed by the project
(a)Total Potable Water Consumed	
ALTERNATIVE WATER SOURCES(①) and WATER RETURNED(②)	
①-1 Off-site Water Sources	Reclaimed water delivered from municipality
	Municipally renovated wastewater
	Other off-site source – specify
①-2 On-site Water Sources	Captured rainwater (roof)
	Captured rainwater runoff (site)
	Captured rainwater overflow
	AHU Condensate
	Steam recovery
	Greywater reuse
	Other on-site water source – specify
② Water Returned	Water collected from building systems (e.g. green infrastructure, on-site treated wastewater) and returned to original water source
(b)Total Alternative Water Sources + Water Returned	(①-1)+(①-2)＋(②)
WATER BALANCE	
(a)-(b)	If difference is ≤ 0, project can submit for certification.

3.1.2 Current status of water use in this building

To estimate the ZWB, we examined the details of water use by checking with LEED certification organizations to determine which items were applied. Fig. 6 illustrates the results of the ZWB evaluation calculations. The total water consumption (a) in the building depicted in Fig. 5 is 9,020 m^3/year, which is the sum of tap water and groundwater used for the experiments, toilets, backwash water for hand washing, de-ironing and de-manganizing equipment, return wells, and irrigation water. However, the total volume of alternative and reduced water was 0 m^3/year because such water was not used. The water balance (a-b) was estimated to be 9,020 m^3/year.

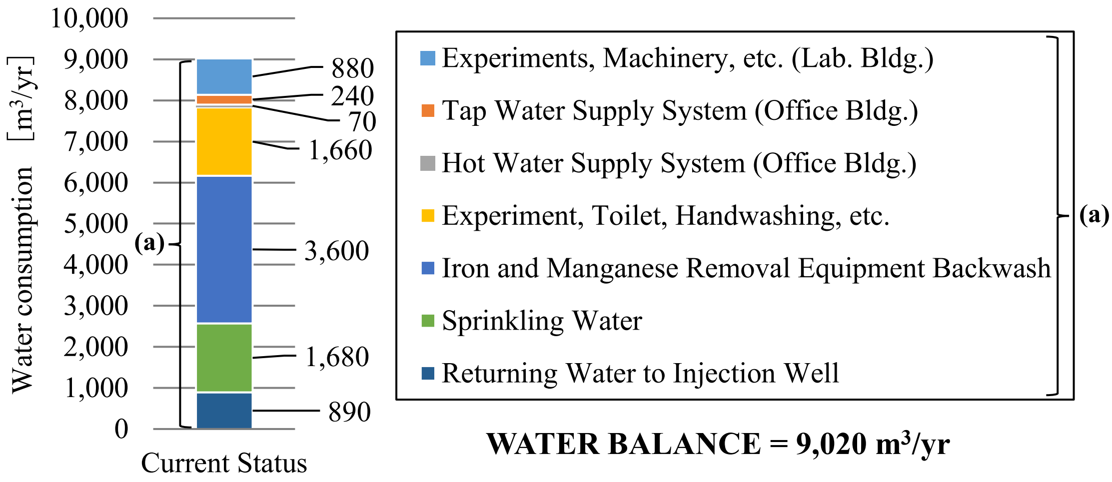

Fig. 6 LEED-ZW estimate for this building

3.2 Potential for ZWB with this building renovation

Based on the current values, studies and estimates were conducted for the ZWB conversion. To achieve this goal, the volume of water to be replaced and reduced was considered.

Efforts to reduce the volume of backwash water for de-ironing and de-manganizing that started last year are planned not only to reduce the volume of wastewater but also to eventually return it to the ground. In this estimation, the amount of sewage effluent could be reduced to zero by reducing the current volume of de-ironed and de-manganized backwash water by half (1,800 m^3/year) and by infiltrating this water into the ground.

The site also has a stormwater runoff control facility to meet the allowable discharge of stormwater, and two rainwater storage tanks (capacities: 261 m^3 and 200 m^3). This rainwater harvesting facility has an underground infiltration capacity, but it is built as a rainwater harvesting type structure; therefore, its infiltration function is not fully utilized, and there is a possibility that it can be improved through renovation. Therefore, we estimated the amount of rainwater infiltration that could be expected by retrofitting to improve the infiltration function, based on the calculation method outlined in “Rainwater Management”[4] in the LEED-ZW rainwater infiltration calculations; however, for the sake of simplicity in this calculation, we used the following formula: building roof area x rainfall x runoff coefficient (= 0.9). Rainfall data (Fig. 7) recorded by the Japan Meteorological Agency (Tateno Meteorological Station, Tsukuba City, Japan) were used. As a result, it was estimated that the renovated rainwater-harvesting tanks could infiltrate 7,760 m^3/year of rainwater collected from the rooftops of the office and laboratory buildings, as illustrated in Fig. 8.

The ZWB evaluation value was -2,340, a negative value, when the aforementioned reduction in the volume of backwash water from the iron and manganese removal equipment and renovation of the rainwater infiltration tank were implemented, and the trial calculation results satisfied the ZWB conditions. This result suggests that the ZWB, by securing reduced water through rainwater infiltration, is effective for facilities with large sites, such as this research facility.

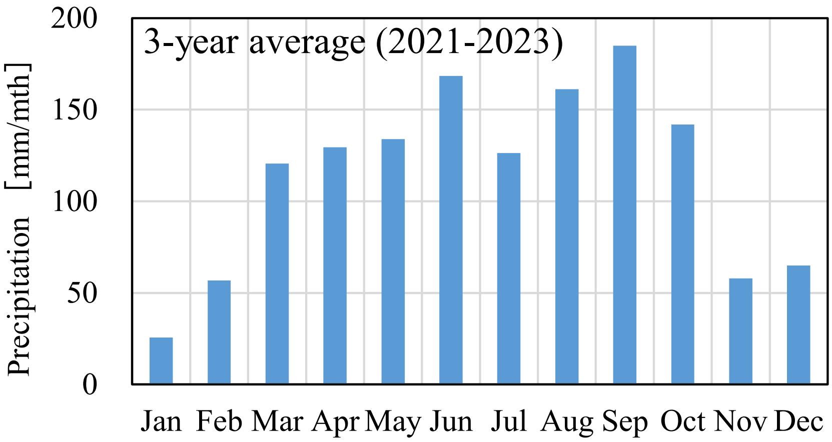

Fig.7 Precipitation (Tateno Weather Station, Tsukuba City)

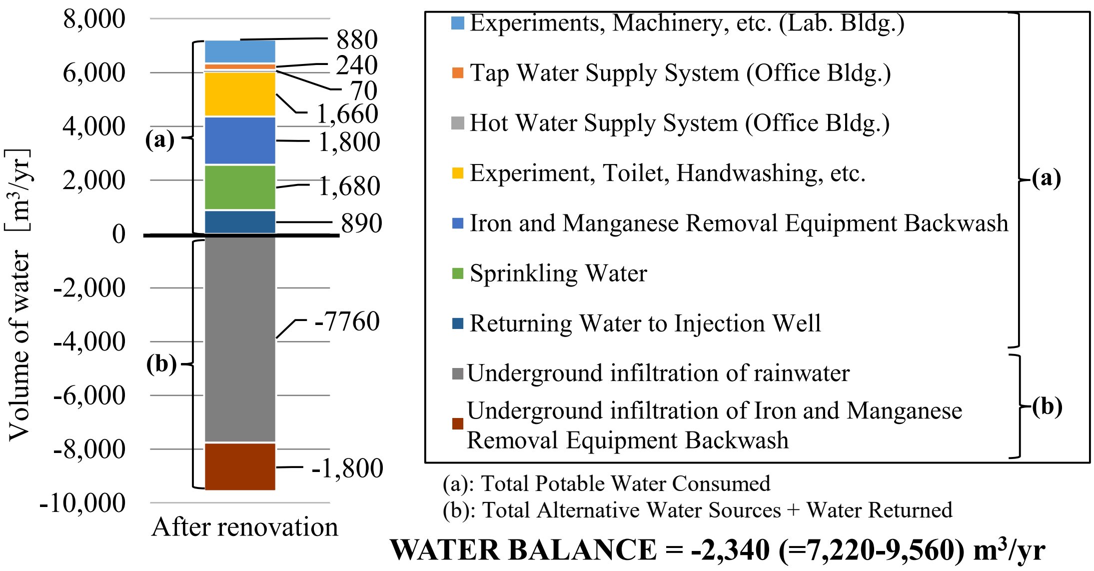

Fig.8 Estimated results after renovations for ZWB

4. CONCLUSIONS

The following findings were obtained from the operation of the groundwater heat utilization system in the building, which aims for energy independence through renewable energy in FY2023 and from the evaluation of water use through the ZWB evaluation method.

1) Of the water and groundwater used at the facility in FY2023, approximately groundwater usage was 96 %, and water use 4 %. Approximately 97 % of the groundwater usage was used as a source of cold heat for air conditioning and approximately 22 % of it was reused as gray water.
2) ZWB was estimated based on water consumption in FY2023, resulting in a water balance value of 9,020 m^3/year.
3) If the volume of backwash water from the de-ironing and de-manganizing equipment is reduced and the rainwater infiltration tank is renovated, the water balance is estimated to be -2,340 m^3/year,

indicating the possibility of a ZWB.

In this report, it is estimated that an existing ZEB facility can be retrofitted to a ZWB by rainwater infiltration, and the possibility of improving it into a more sustainable facility is demonstrated. In addition to the ZWB estimates, we would like to estimate and evaluate the energy and cost impacts of the improvements in the future.

In the ZWB evaluation by LEED-ZW, groundwater pumped underground and returned to the ground after heat utilization was not included in the water consumption. It is expected that an increasing number of facilities will have diverse water use methods, such as heat use. It is necessary to discuss a definition of ZWB that matches the characteristics of Japan as soon as possible while adding factors such as the use of heat from water as a resource, rather than simply evaluating water consumption in conventional water supply, drainage, and sanitation systems.

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[2] Kosuke Osako, Uwais Roslan, Katsuhiko Shibata, Naoki Aizawa, Masayuki Otsuka, Advanced building facilities embodying the transition to carbon neutrality, 2023 Symposium CIB W062 – Leuven, Belgium, pp269-280, 2023.

[3] U.S. Green Building Council：「LEED Zero Program Guide April 2020.」

[4] U.S. Green Building Council：「LEED v4 Sustainable Sites credit Rainwater Management.」

要　約

サスティナブル建築として設計された高砂熱学イノベーションセンターは、運用データから ZEB の基準を達成した建物であることを報告した。この建物に対し、水資源の保全や水の再利用への関心の高まりから近年注目されている Zero Water Building(ZWB)について、地下水熱・水利用における評価を行った。米国グリーンビルディング協会が提唱する LEED Zero Water の定義に基づき ZWB 評価を行ったところ、評価が厳しい結果となった。そこで、LEED Zero Water の定義における ZWB 達成に向けた水利用の改善方法を検討し、設備運用改善による地下水の使用量削減や地下浸透の活用などを組み合わせることで、同定義における ZWB 達成への可能性を得た。今後は ZWB 値への効果だけではなく、改善によってもたらされるエネルギーやコスト面への影響についても評価していきたい。