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Development of "SOLAMO" gas hot water system with combined use of solar heat

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1. Abstract

This paper details the work involved in integrating gas and renewable energy. “SOLAMO”, a gas-fired hot water system utilizing solar power, was developed by Tokyo Gas and Osaka Gas. With this system, customers can cover part of their domestic thermal demand for hot water and heating by using solar heat. “SOLAMO” was named after our belief that gas can make better use of solar power.

The subjects relating to “SOLAMO” are as follows:

- Major specifications and characteristics of each system
- SOLAMO system for installation on balconies of newly-built condominiums
- SOLAMO system for houses

Every SOLAMO system consists of a solar heat collection unit, a hot water tank unit which stores solar heat, and a remote control panel. SOLAMO also has a mode that allows hot water to be heated by solar power alone.

The latent heat recovery-type highly efficient gas water heating system called “ECO-JOES” is a constituent of the SOLAMO system. When solar radiation is not sufficient and solar heat is not available, the gas water heater can always provide hot water demand instantly. Moreover, with a remote control panel featuring a solar heat monitor, the solar heat collection status is indicated in real time, making users aware that they are using solar energy.

The major specifications and characteristics are included in this paper.

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2. Introduction

Recently, the gas industry has focused on integrating gas and renewable energy to help create a low-carbon society.

The Japanese national government and the Tokyo metropolitan government are accelerating their promotion of renewable energy. Solar energy does not run out and emits no CO_2. To combat global warming, we need to make active use of solar energy.

Every year, the required level of residential energy efficiency increases, and the need for a flagship system that performs even better than “ECO-JOES”, that is a latent heat recovery-type highly efficient gas water heating system, is growing.

Meanwhile, due to the earthquake that occured recently, the needs of using energy autonomously in disaster are growing. It is expected that, as a combination of gas and solar, products which utilizie natural energy receive much attention.

Solar thermal systems using solar heat directly as heat, offering high energy conversion efficiency compared to solar energy, are suitable for effective use of solar energy on balconies and other areas where space is limited.

Given this background, Tokyo Gas and Osaka Gas have developed “SOLAMO”, a gas-fired hot water system utilizing solar power. With this system, customers can cover part of their domestic thermal demand for hot water and heating by using solar heat. “SOLAMO” was named after our belief that gas can make better use of solar power[1)].

The SOLAMO system for installation on the balconies of newly-built condominiums was released in February 2010 (joint development by Tokyo Gas, Sankyo Tateyama Aluminium, Yazaki, Rinnai and Gastar). SOLAMO systems for detached houses were launched in January 2010 (manufactured by Chofu Seisakusho), in May 2010 (Takagi Industrial) and in October 2010 (Noritz).

The SOLAMO system consists of a solar heat collection unit, a hot water tank unit which stores solar heat, and a remote control panel. Every system has “ECO-JOES”, and comes with a mode that allows hot water to be heated by solar power alone. When sufficient heat is not available due to the weather, the gas water heater can provide hot water instantly at any time. Moreover, the remote control panel features a solar heat monitor and a display that indicates the solar heat collection status in real time, making users aware that they are using solar energy. The annual energy reduction is about 5.3 GJ in the case of condominiums and about 10.9 GJ in the case of detached houses.

This report outlines the major specifications and characteristics of the system.

3. Major Specifications and Characteristics of Each System

3.1. SOLAMO system for installation on balconies of newly-built condominiums

The major specifications of the SOLAMO system for condominiums are shown in Table 1. This system was commercialized with priority on the following points:

Table 1 Major specifications of the SOLAMO system
for installation on balconies of newly-built condominiums

Hot water storage unit	100 L tank (installed in the hot water supply loop)
Heat collection unit	Handrail built-in type, flat type (vertical installation) approx. 3 m^2 (1 m^2 ×3 panels) Solar battery attached to drive a solar heat collecting pump
Remote control panel	Remote control touch panel equipped with solar heat monitor

3.1.1. Heat collection unit

Heat collectors built vertically into the handrails of balconies are designed to blend in with the appearance of buildings. The key point was to make the frames of the handrails as low in profile as possible. By placing two solar batteries at both ends of a heat collector, we succeeded in making the frame look slim and simple.

This system has the feature that, as the heat collectors are installed vertically, solar heat collection increases even in winter when solar elevation is low and demand for hot water is high.

3.1.2. Remote control panel

A remote control unit was developed based on the touch panel type EneLook remote controller (which displays gas, water and electricity consumption on the remote control) for heat source devices of the Gas Central Heating system (GCH), with the function of a solar heat monitor. On the display, users can check the heat collection status, the utilization rate of solar heat (showing the proportion of hot water supplied by solar heat compared to the total demand), the reduction in gas consumption, and the reduction in CO_2 emissions made possible by the SOLAMO system.

In addition, by turning off the switch, the customers can change the mode to use hot water heated only by solar power when using lukewarm water for washing hands, dishes and so on.

3.1.3. Hot water storage unit

The concept of development was to reduce CO2 emissions by using solar heat and installing hot water storage units in condominiums.

One of the specifications that embody the concept is the variable installation mode which can correspond to the width of the balcony. Three patterns are assumed, i.e. large window area and small wall area, narrow depth of balcony, and very small depth of porch, and the system configuration can respond to each pattern.

During the test operation of the heat collection loop, a method suitable for a small-output solar battery powered pump was developed. This method makes it possible to check automatically that heat transfer liquid has been completely injected. Figure 1 shows the appearance of the SOLAMO system for installation on the balconies of newly-built condominiums.

Figure 1. Appearance of the SOLAMO system for installation on balconies of newly-built condominiums

3.1.4. Performance of the SOLAMO system for condominiums

- Summary

In order to calculate the annual solar heat collection efficiency, the rate of dependence on solar heat, and the primary energy conversion of COP (Coefficient Of Performance), the actual efficiency was computed and evaluated with a system installed in an experimental residence[2-3)].

- Measurement system

Natural conditions such as solar radiation and outdoor temperature, the temperature of the solar heat collector and water, the flow of water and the hot water supply, and the power consumed by

the gas heater boiler were measured.

- Hot water demand patterns

Hot water demand used for the experiment was the modified M1 mode, as reported by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.

The modified M1 mode has 6 patterns, i.e. “small weekday”, “large weekday”, “small holiday (in)”, “large holiday (in)”, “small holiday (out)”, “large holiday (out)”, in order of the amounts used, created on the assumption that the number of people in the household was four.

Figure 2 shows hot water demand patterns assuming application of the modified M1 mode.

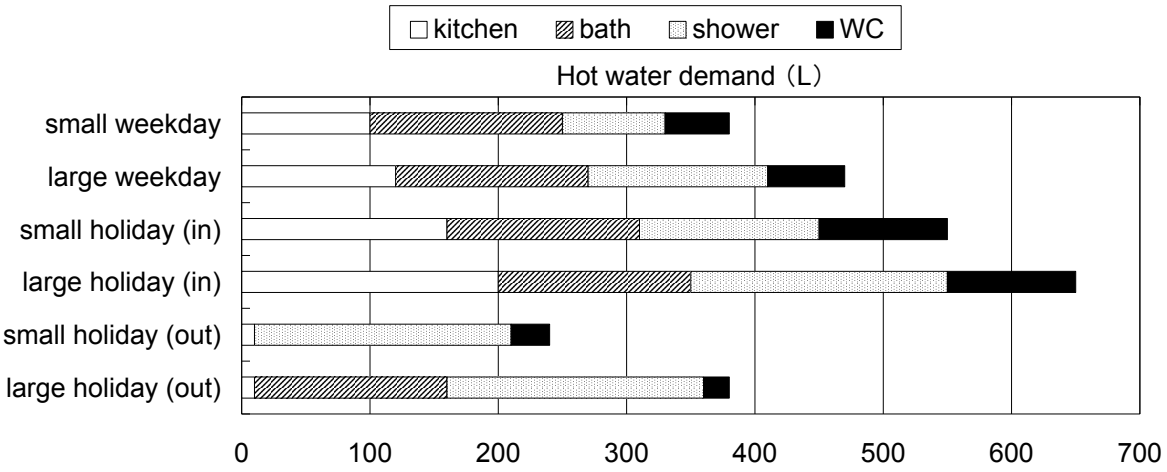

Figure 2. Hot water demand patterns assuming application of the modified M1

- Experimental period

From October 8, 2009 through October 14, 2010 (total run of 346 days)

- Test results
  - Solar heat collection efficiency

The solar heat collection efficiency is defined as "solar heat collected by solar collector per vertical solar radiation".

The correlation between the average annual vertical solar radiation and heat collection efficiency can be expressed as shown in Figure 3. When vertical solar radiation is around 10,000 kJ/(m2･day), heat collection efficiency is 40% or more. The period average is 38.3 percent.

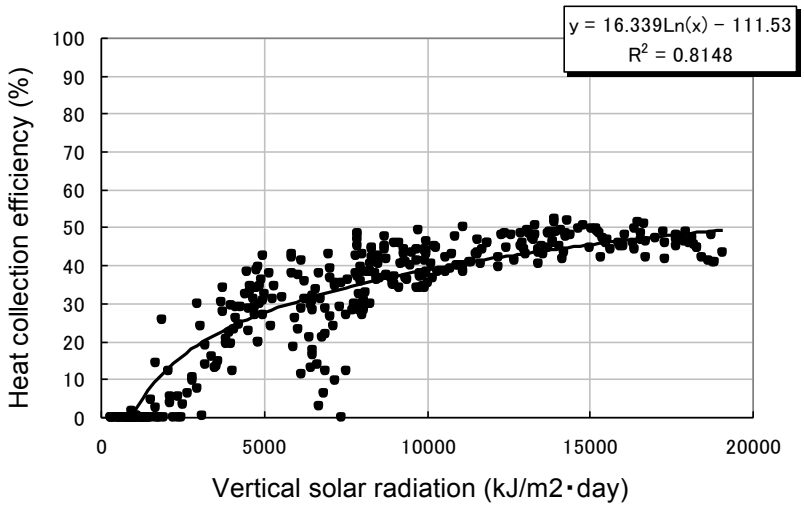

Figure 3. Correlation between average annual vertical solar radiation and heat collection efficiency

- Rate of dependence on solar heat

The rate of dependence on solar heat is defined as "usage of solar heat per hot water demand". It is also found that vertical solar radiation and the rate of dependence on solar heat are related to each other.

The correlation between average annual vertical solar radiation and the rate of dependence on solar heat can be expressed as shown in Figure 4. The period average is 15.9 percent.

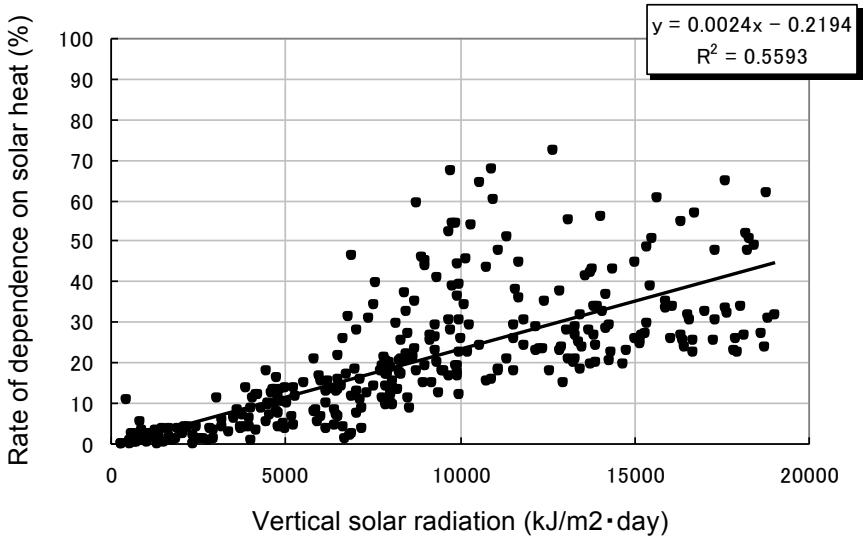

Figure 4. Correlation between average annual vertical solar radiation and the rate of dependence on solar heat

- Usage of solar heat

Solar energy usage is the amount of solar heat compared to the total hot water demand. The correlation between the average annual vertical solar radiation and usage of solar heat can be expressed as shown in Figure 5. The period average of this value is 2.1MJ / (m * day).

The system efficiency (= effective heat collection efficiency) is defined as "usage of solar heat per vertical solar radiation". The period average is 30.7 percent.

The annual amount of solar heat usage is 2.25GJ. Combined with energy saving by Eco-JOES, the primary energy savings can be about 5.3GJ compared to conventional equipment.

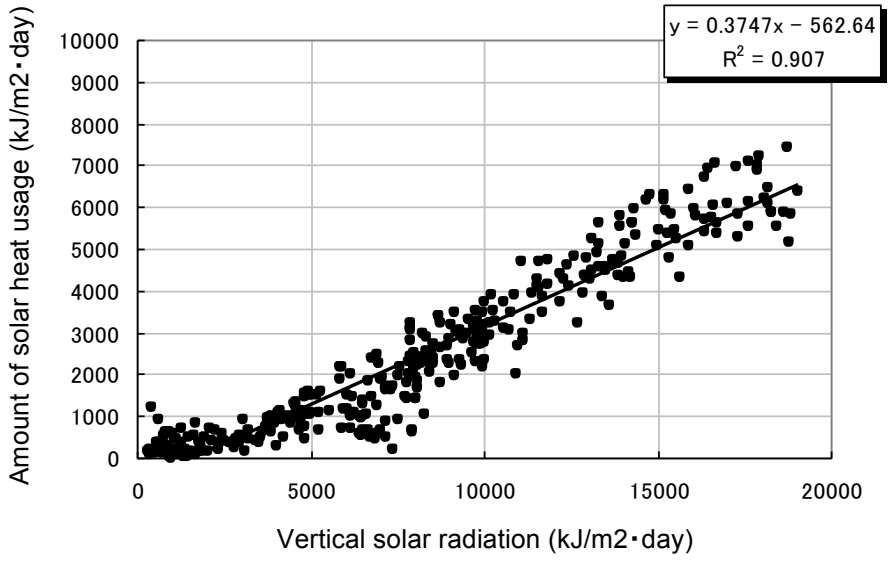

Figure 5. Correlation between average annual vertical solar radiation and the amount of solar heat usage

- The primary energy conversion of COP

The primary energy conversion of COP is defined as "hot water demand per volume of gas consumption".

Figure 6 shows the relationship between the average annual vertical solar radiation and COP.

When vertical solar radiation exceeds 3,000 kJ/(m2・day), COP has a tendency to be more than 1.0, indicating that it is affected by solar radiation conditions. The period average is 1.082.

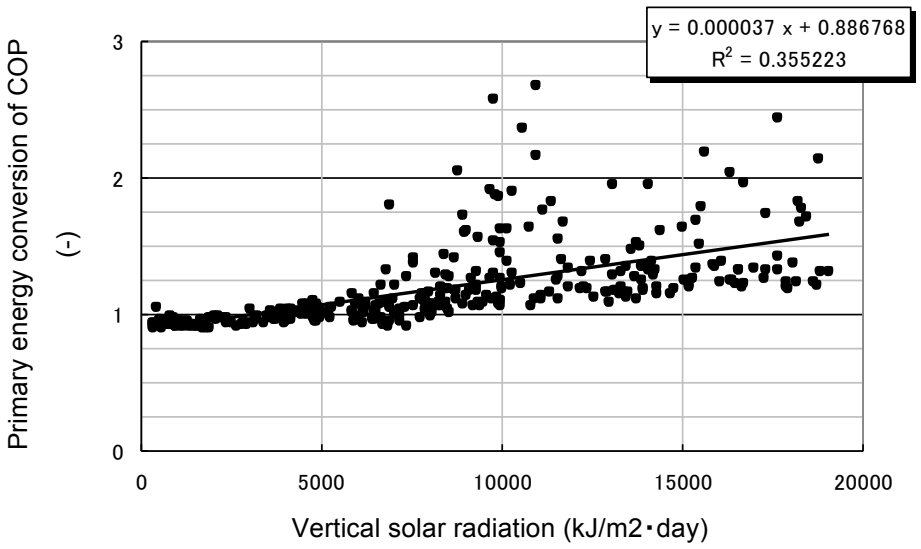

Figure 6 Correlation between average annual vertical solar radiation and primary energy conversion of COP

- East-west orientation

In principle, the orientation of heat collectors installed in the handrails of balconies is south-facing. However, the orientation of balconies depends on that of the buildings, and therefore an enhancement in the orientation of heat collectors was required.

To address this requirement, the reduction of vertical solar radiation was reflected to annual usage of solar heat, and a method of calculating the value of each orientation was established.

Heat collector panels, facing south, east, and west respectively, were set in the same location, and performance tests were carried out under those conditions.

From the results of this study, solar heat collection efficiency was determined by the vertical solar radiation and heat collection in each orientation.

Then, based on the measured system performance in the south-facing orientation, it became possible to calculate the rate of degradation of system performance in east- and west-facing orientations.

3.2. SOLAMO system for houses

The major specifications of the SOLAMO systems manufactured by Chofu Seisakusho, Noritz and Takagi Industrial are shown in Table 2. These systems are designed for detached houses. All systems can adopt the same heating medium.

Table 2. Major specifications of the SOLAMO system for houses

Manufacturer	Chofu Seisakusho	Takagi Industrial	Noritz
Hot water storage unit	200 L tank (installed in the hot water supply loop)	Open type 180 L tank (installed in the heating loop)	90 L tank (installed in the hot water supply loop)
Heat collection unit	Flat type, approx. 4 m^2	Flat type approx. 4 m^2	Flat type, approx. 4 m^2, 3 m^2, 2 m^2
Remote controller	EneLook remote control panel with a solar heat monitoring function	EneLook remote controller equipped with solar heat monitor function	EneLook remote control panel with a solar heat monitoring function

3.2.1. SOLAMO system manufactured by Chofu Seisakusho

Figure 7 shows the appearance of the SOLAMO system manufactured by Chofu Seisakusho. This system is designed to be used in detached houses.

A 200-liter hot water storage tank and 42kW class ECO-JOES gas water heating system as a supplementary heat source are installed in the hot water storage unit. The remote control panel is also equipped with EneLook and a solar heat monitoring function.

On the solar heat monitor, users can check the utilization rate of solar heat (%), which shows the proportion of hot water supplied by solar heat compared to total demand, as well as the reduction in gas consumption (m3, yen) and CO_2 emissions (kg) made possible by the SOLAMO system.

In addition, sophisticated mechanisms such as the “Eco-Yu” mode, which supplies hot water heated by solar power alone, and a changing backlight in the remote control panel during solar heat collection give customers a sense of achievement that they are collecting or using solar energy at that very moment.

There is also a version of the SOLAMO system that comes with a designated calorimeter in the hot water storage unit, for compliance with the Green Heat Certification System. This is designed to encourage the use of equipment utilizing solar power in houses (a subsidy system of the Tokyo Metropolitan Government).

While collecting solar energy, this system uses much less power with a direct-current pump because of its variable circulating volume. Moreover, as the heat collecting circuit is semi-closed, filling or replacement of the heating medium is unnecessary for ten years.

Hot water storage unit

Heat collection unit

Remote control panel

Figure 7. Appearance of the SOLAMO system manufactured by Chofu Seisakusho

3.2.2. SOLAMO system manufactured by Takagi Industrial

By adopting a high-temperature water distribution method, hot water in the tank can be used not only for heating equipment but also for the hot water supply and bath heating, by means of liquid-to-liquid heat exchangers (Figure 8).

This system makes it possible to utilize latent heat efficiently. This is because, when the system provides hot water heated by both solar heat and gas, the feed water can obtain latent heat before being exchanged with hot water for heating. In addition, this system offers another advantage in that neither pressure reducing valves nor mixing units are required since no hot water storage tank is installed in the feed water loop.

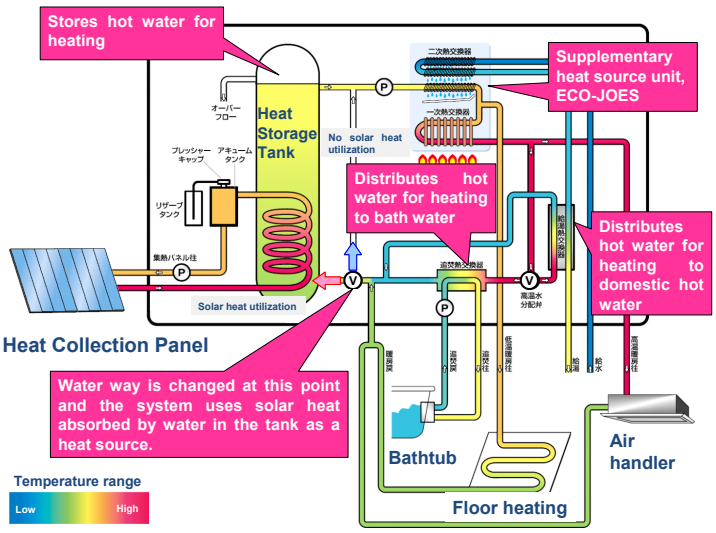

Figure 8. Components in the loop of the SOLAMO system manufactured by Takagi Industrial

3.2.3. SOLAMO system manufactured by Noritz

Figure 9 shows the appearance of the SOLAMO system manufactured by Noritz. This system is accommodated to existing detached houses located in the metropolitan area, where space for installing hot water storage tanks and heat collectors is limited.

The 90-liter hot water storage tank is smaller than the conventional 140-200-liter tanks for detached houses. Two types of heat collectors are available, the 2 m^2 type and the 1 m^2 type. Depending on the customer's thermal demand for hot water and the roof shape, installation areas are selected from a variety of sizes, i.e. 4 m^2, 3 m^2 and 2 m^2.

Moreover, full-fledged solar floor heating is also possible with this SOLAMO system.

When there is enough solar heat to afford it, using solar heat for floor heating takes priority under control by pumping heated water. On the other hand, when there is no solar radiation, the temperature of heated water is controlled by using a backup boiler. Figure 10 shows the actual measurement results of this system.

This feature has led to the use of floor heating for customers who seldom use floor heating because of the high cost. This is expected to lead to increased use of floor heating.

Figure 9. Appearance of the SOLAMO system manufactured by Noritz

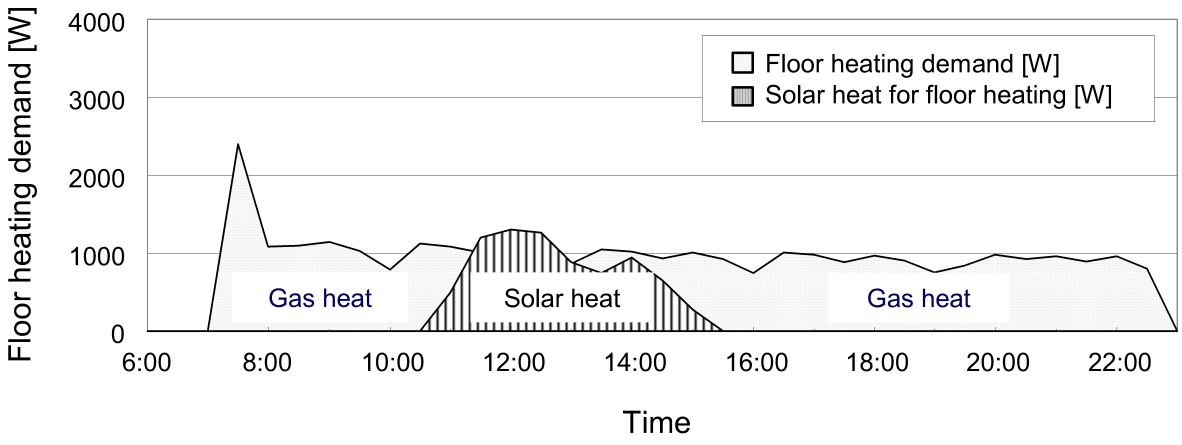

Figure 10. Measurement result of solar floor heating for the system manufactured by Noritz

3.2.4. SOLAMO system retrofit to existing gas water heater

There are some markets in the metropolitan area where the system cannot support existing detached houses as it is. To target this market, a SOLAMO system retrofit to existing gas water heaters was developed. This system is designed to be transported and installed in narrow areas.

New features of this system are heat transfer from the bathtub to the hot water storage tank ("bath heat recovery operation") and the use of solar heat to boil water left in the bathtub during sunny daylight hours ("boiling water in bathtub with solar heat operation"). With these features, this system is expected to save even more energy.

For security, the water in the hot water storage tank is drained when 100 liters of hot water are

not used within 100 hours.

4. Conclusions

- “SOLAMO” was developed to integrate renewable energy and gas-fired hot water supply systems using solar power.

- The SOLAMO system for installation on the balconies of newly-built condominiums has been released.

- The SOLAMO system for detached houses and the system retrofit to existing gas water heaters have now been released, and the product range will continue to be improved and expanded.

5. References

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2) S. Ito, et al., Annual Meeting of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, pp.987-900, 2008.
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4) Y. Hamada, et al., Transactions of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (143), 31-45, 2009.

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