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NEW ECOWILL - A NEW GENERATION GAS ENGINE MICRO-CHP

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1. ABSTRACT

The ECOWILL, a micro-CHP system using an internal combustion gas engine, was unveiled in Japan in 2003 as the world's first mass-market product of its kind and has succeeded in establishing a new market in micro-CHP for household use [1][2]. The ECOWILL consists of a 1kW output gas engine-powered generator unit developed by Honda and a hot water/space heating unit developed jointly by Osaka Gas, Tokyo Gas, Toho Gas, Saibu Gas and Noritz. The system uses gas as its primary energy source and is able to make efficient use of both heat and electrical power within the home. Combining energy savings with comfort, ease of use and convenience (usually mutually exclusive characteristics), the ECOWILL has been very well received by the market and has sold a total of 100,000 units nationwide as of 2010.

This report describes the development of a new model of ECOWILL system with greater commercial appeal, aimed at the further popularization of micro-CHP, that addresses such issues as the need for installation in Japan's typically small urban dwellings and compatibility with Japanese energy-efficient housing, where technical progress is continually being made.

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2. Introduction

Since the Kyoto Protocol came into effect, global warming has been recognized as a very serious issue. Energy consumption by household appliances has grown particularly rapidly as compared with industrial equipment, and if targets for the reduction of greenhouse gas emissions are to be met it is important that active efforts be made to develop and promote the use of energy-saving technology for household appliances. Electric power and heating (hot water and space heating) account for nearly half of all the energy consumed by households in Japan. The development of CHP systems for household use that are able to supply electrical power and heat simultaneously would therefore be an effective way to promote efficient use of energy in the home. If efforts to promote energy saving among ordinary households are to be effective, it is important that appliances should offer even greater comfort, ease of use and convenience than before, as well as enhanced energy-saving performance. This combination of attributes will make it possible to encourage active efforts to save energy without reducing the user's quality of lifestyle.

The ECOWILL was developed to meet these social demands and promote energy saving in the home and is the world's first and smallest 1kW micro-CHP system based on an internal combustion gas engine. It is able both to use electrical power that it generates from gas in the home and to make efficient use of waste heat produced during the power generation process. Since its launch on the Japanese market in 2003, the ECOWILL has won high acclaim from the market as fulfilling the conflicting demands of energy saving and comfort, ease of use and convenience. Figure 1 shows the cumulative number of ECOWILL units installed in Japan. As of 2010 the ECOWILL has sold a cumulative total of 100,000 units and succeeded in establishing a new market in micro-CHP systems for household use.

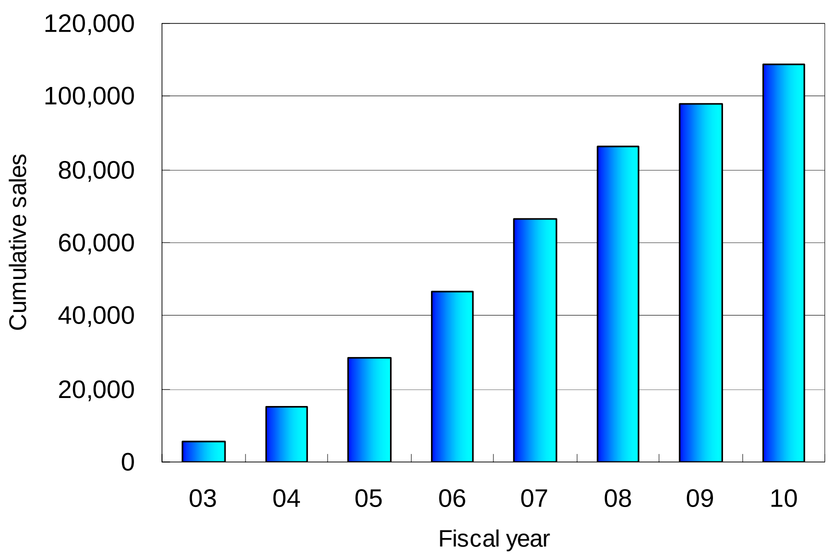

Figure 1 : Cumulative sales of ECOWILL in Japan

As shown in Figure 2, since 2003 the ECOWILL has undergone a series of minor changes, centering on enhancing the efficiency of the gas engine and reducing the size of the hot water/space heating unit. In parallel with the evolution of the ECOWILL, the Japanese market for energy appliances has in recent years been growing more sophisticated and diverse at an increasingly rapid rate. Japanese housing manufacturers have taken a leading role in the promotion of energy savings through the building of highly insulated dwellings. In 2009 city gas-powered fuel cell systems for household use were introduced and subsidies for household solar power generation systems were reinstated. A scheme for buying back surplus electrical power generated by household solar power systems at a fixed rate (feed-in tariff) was also established. Against this backdrop, the ECOWILL underwent a full model change in June 2011 with a view to enhancing its commercial appeal and ensuring its continued and wide diffusion as a micro-CHP system based on a gas engine, offering the advantages of low cost and high reliability.

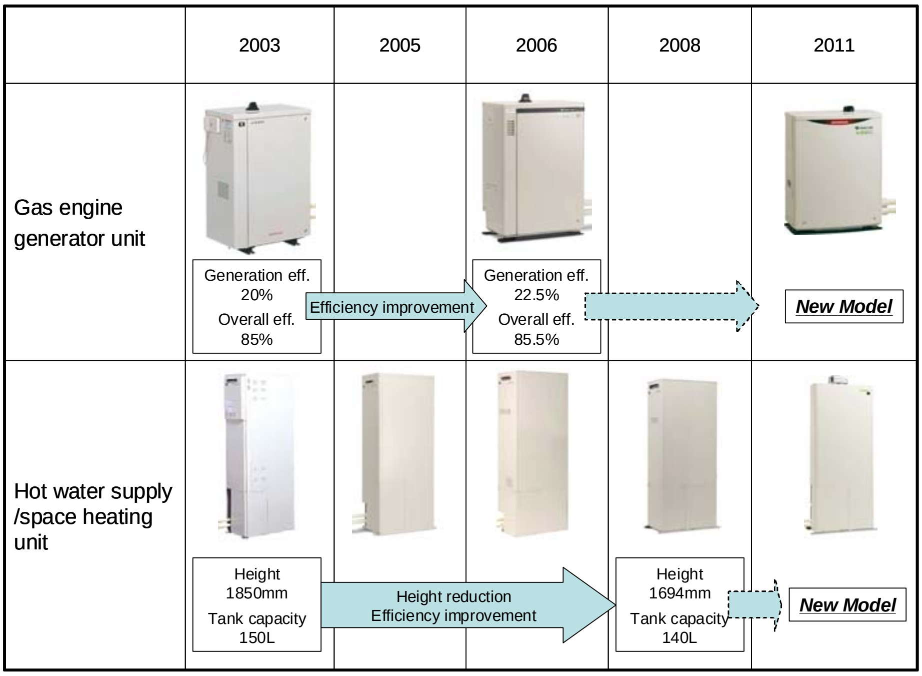

Figure 2 : History of model changes

3. Development Concepts

This full model change was aimed at creating a product suited to Japan’s typically small urban dwellings and advanced energy-saving housing, and was based on the following concepts:

(1) Enhanced energy saving through improved efficiency

(2) Enhanced ease of installation through downsizing

(3) Energy visualization by means of an advanced interface

4. Main Specifications and Features

4.1 System composition

Figure 3 show the schematic view of the system as installed in a dwelling. The system is made up of a 1kW gas engine generator unit developed by Honda and a hot water/space heating unit jointly developed by Osaka Gas, Tokyo Gas, Toho Gas, Saibu Gas and Noritz. The electricity generated by the engine is supplied to the user's dwelling in parallel with the grid supply and can be used to power lights and electrical appliances. The hot water/space heating unit allows the waste heat produced during the power generation process to be used to heat water for the household's hot water supply, to reheat baths or for space heating applications such as under-floor heating or bathroom heating/drying[3]. The basic composition is identical to that of conventional systems, so that the ECOWILL is interchangeable with typical Japanese hot water/space heating systems based on boilers.

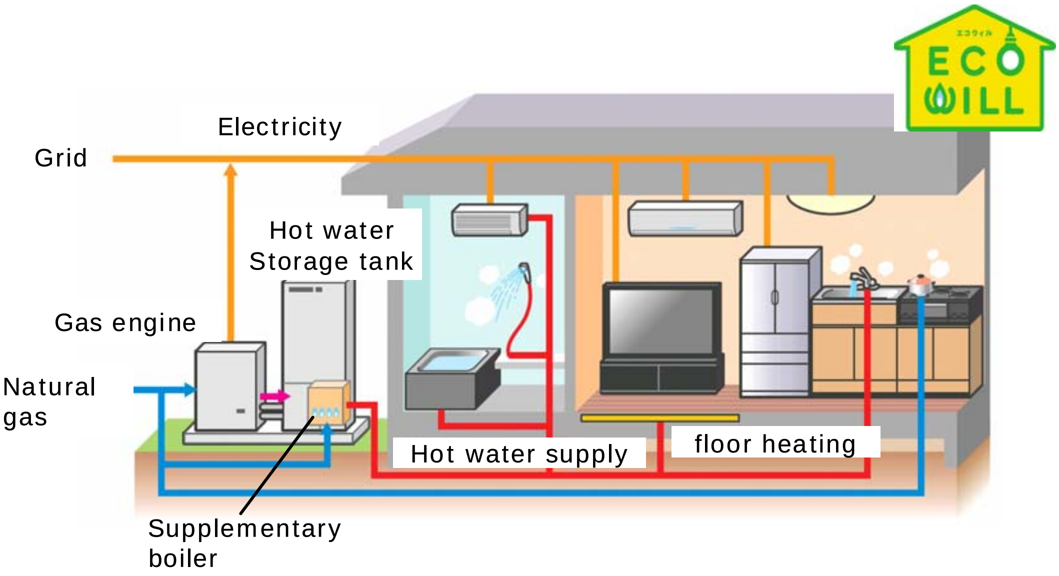

Figure 3 : Schematic view of the system as installed in a dwelling

4.2 Specifications

Figure 4 shows the external appearance of the ECOWILL, Tables 1 and 2 the major specifications (comparing old and new models). As mentioned above, the principal features of the new system include (1) enhanced energy saving through improved efficiency, (2) enhanced ease of installation through downsizing and (3) visualization of energy by means of an advanced remote control panel. The next section describes the content of these features.

Figure 4 : External appearance of the new ECOWILL

Table 1 : Specifications of the power generation unit

	New model	Previous model
Power output	1.0kW	
Generation efficiency	26.3% (LHV)	22.5% (LHV)
Overall efficiency	92.0% (LHV)	85.5% (LHV)
Dimensions	W580×D298×H750 mm	W580×D380×H880 mm
Weight	71kg (dry)	82kg (dry)
Noise	43dB(A)	44dB(A)
Fuel	Natural Gas (Japanese 13A), LPG	

Table 2 : Specifications of the hot water/space heating unit

	New model	Previous model
Hot water storage temperature	75 degree C	73 degree C
Hot water storage capacity	90L	140L
Heating capacity	17.4kW	
Bathwater reheating capacity	12kW	
Hot water supply capacity	41.9kW	
Supplementary boiler capacity	41.9kW	
Dimensions	W720×D300×H1690(mm)	W700×D400×H1694(mm)
Weight	83kg	96kg
Heat utilization	Hot water supply, floor heating, bathroom heating/drying, etc.	
Function of Displays and control panels	Energy Saving Navigation Energy visualization	

5. New Technology

5.1 Enhanced energy saving through improved efficiency

- **Enhanced engine efficiency**

The ECOWILL uses a gas engine specially developed by Honda. The use of the “EXlink”, a compact, mass-produced engine with a high expansion ratio, which features a longer expansion/exhaust stroke than intake/compression stroke made possible by a unique multi-link expansion linkage mechanism, has substantially improved generating efficiency, which has risen from 22.5% to 26.3%.

Figures 5 and 6 show the mechanism of the EXlink and the principles of its operation. To achieve an extended expansion stroke (the stroke that produces the output power), the EXlink has 3 more components than are found in a basic conventional engine - a trigonal link, a swing rod and an eccentric shaft, which together make up the multi-link mechanism [4][5]. By compressing a small quantity of fuel and air and causing the combusted gas to expand to a greater volume, the EXlink achieves a expansion ratio 1.4 times higher than a compression ratio and maximizes the power that can be derived from the heat energy produced by the combustion. The short intake stroke also reduces the pumping loss caused by intake resistance. Figure 7 compares the energy balance of the new generator unit with that of the previous model. The adoption of the EXlink allows a significant improvement in thermal efficiency and a reduction in fuel consumption of approximately 15% as compared with a conventional engine whose compression and expansion ratios are the same.

Overall efficiency has been significantly enhanced, from 85.5% to 92%. The adoption of an exhaust heat exchanger with a combined heat exchanger and catalyst and improvements to the internal cooling system, among other measures, have achieved a high waste heat recovery efficiency of 65.7％. The heat produced by the engine itself during combustion and the exhaust heat are recovered at a high temperature of 75 degree C, allowing efficient use to be made of this waste heat, to heat water for the household’s hot water supply, to reheat baths and for under-floor heating.

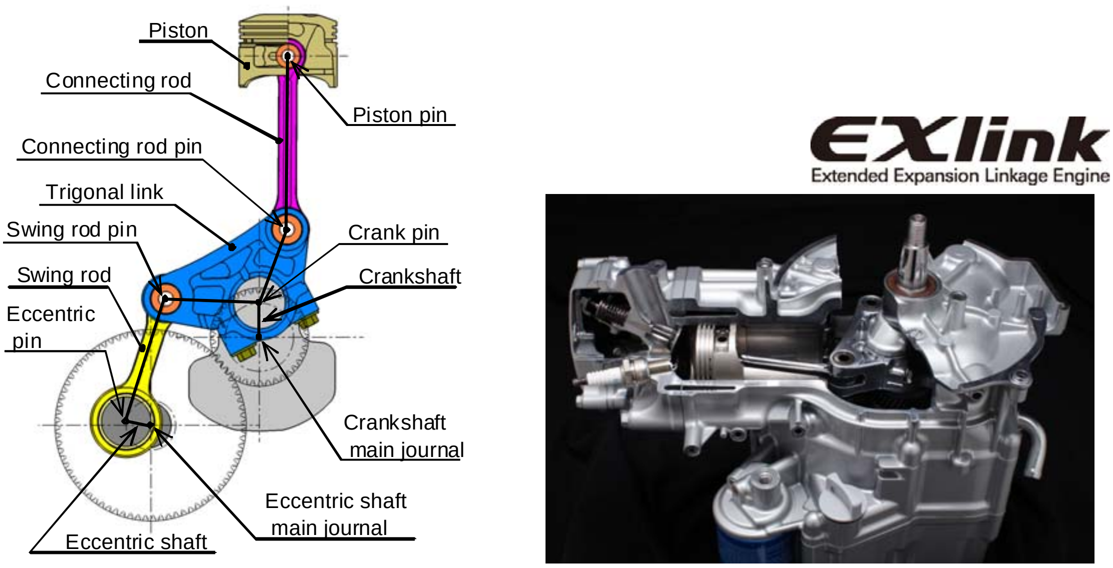

Figure 5 : Mechanism of the Exlink

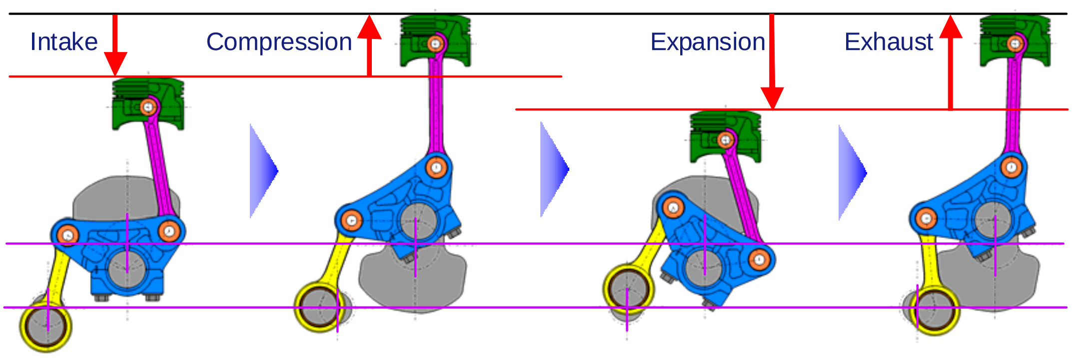

Figure 6 : Principles of the EXlink operation

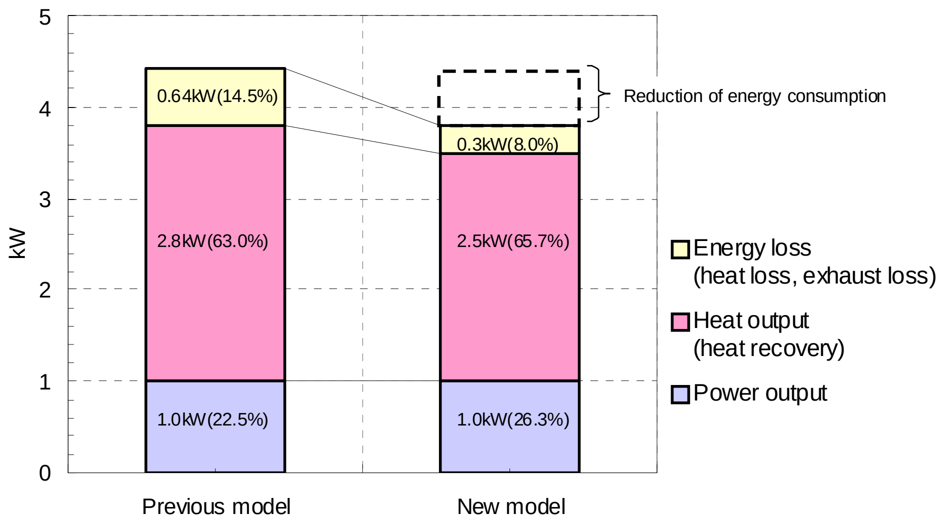

Figure 7 : Comparison of energy balance between the new and previous model

- **Enhanced hot water/space heating unit efficiency**

In the previous model, waste heat accumulated in the hot water tank can only be used for hot water supply purposes. Waste heat can only be used for space heating while the engine is running. This system has a number of disadvantages, such as the fact that the engine cannot be run while the hot water tank is full and the fact that in heating systems with an On-Off control, when the system is On, the auxiliary boiler frequently fires up. In the new model, these issues have been resolved by the adoption of a system that is able to take waste heat accumulated in the hot water tank and use it for space heating purposes. Through simulations and tests with actual systems it was determined that the ideal tank capacity for the purpose of energy savings over the course of a full year purposes was 90L, making it possible to slim down the hot water/space heating unit and to perfect learning controls for the system.

5.2 Enhanced ease of installation through downsizing

- **Reduced depth of installation space**

The height and depth of the gas engine generator unit have been reduced, giving a reduction in volume of 33% and a weight reduction of 11 kg (see Table 1). The depth of the hot water/space heating unit has been reduced from 400 mm to 300 mm its weight has been reduced by 13 kg (see Table 2).
The gas engine takes advantage of the compact, vertical layout of the previous model, in which the crankshaft was mounted vertically, but also of the small intake volume of the EXlink to allow a reduction in the size of intake system components, which has made it possible to achieve further weight and size reductions. In the new generator unit itself, component integration and careful layout, among other measures, have made it possible to reduce volume by 33% and weight by 11 kg as compared with the previous model. In the hot water/space heating unit, the capacity of the hot water tank has been reduced from 140L to 90L, giving a 23% reduction in volume and 13 kg reduction in weight as

compared with the previous model.

In addition to the reducing the size of the ECOWILL unit itself, greater ease of maintenance has reduced the rear maintenance space required from 50 mm to 10 mm, and the front maintenance space required from 500 mm to 340 mm, so that the total depth of the installation space required has been reduced from 950 mm to 650 mm (see Figure 8).

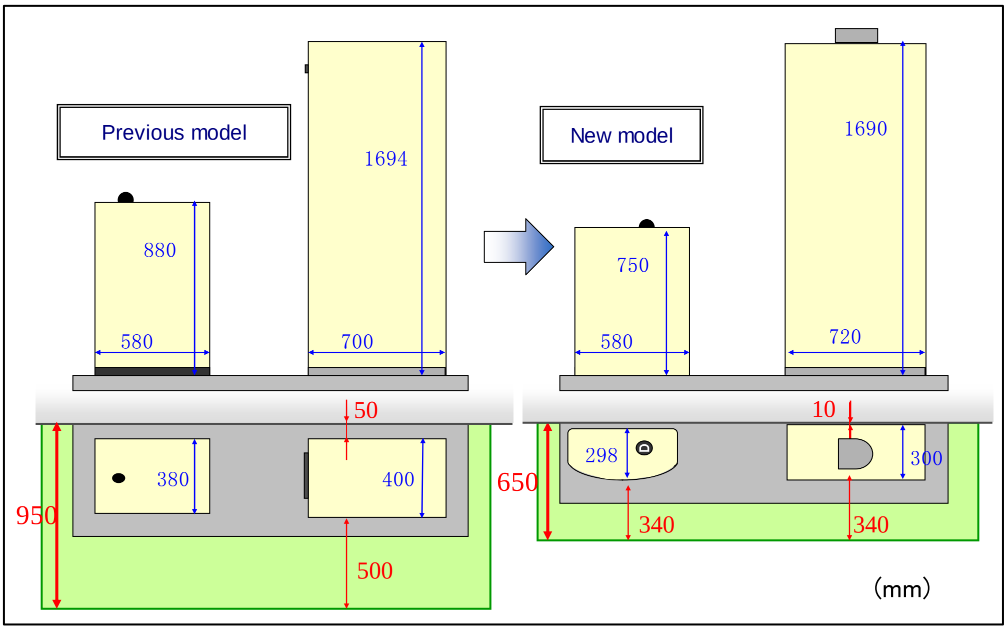

Figure 8 : Installation space required for the new model

- **Reduced noise**

As the new model ECOWILL is more likely to be installed in small dwellings, steps have been taken to reduce the noise produced by the gas engine generator unit. Modifying the structure of the mountings at the bottom of the engine, reducing intake and exhaust pulses and flow noise from the intake and exhaust system, and optimal distribution of insulating materials has resulted in a low vibration and noise level of 43 dB(A), comparable to the levels achieved by the outdoor units of household air conditioners. The noise level in the previous model was 44 dB(A). Steps have also been taken to improve frequency characteristics on the basis not only of overall noise levels as evaluated in an anechoic chamber but also of repeated measurement and analysis of noise at actual installation sites.

5.3 Energy visualization

The remote control panel, which serves as the system's user interface, is normally installed in the kitchen or the bathroom. As shown in Figure 9, the display has been redesigned and an arrow key has been added to enhance ease of operation. The new panel is an interface worthy of an advanced energy saving product in terms of both appearance and functions, featuring a full range of energy display functions including the CO_2 emission savings index, electrical power and heat consumption.

The display of the flow of electrical power within the dwelling now also supports installation of an ECOWILL system in parallel with a solar power generation system (see Figure 10).

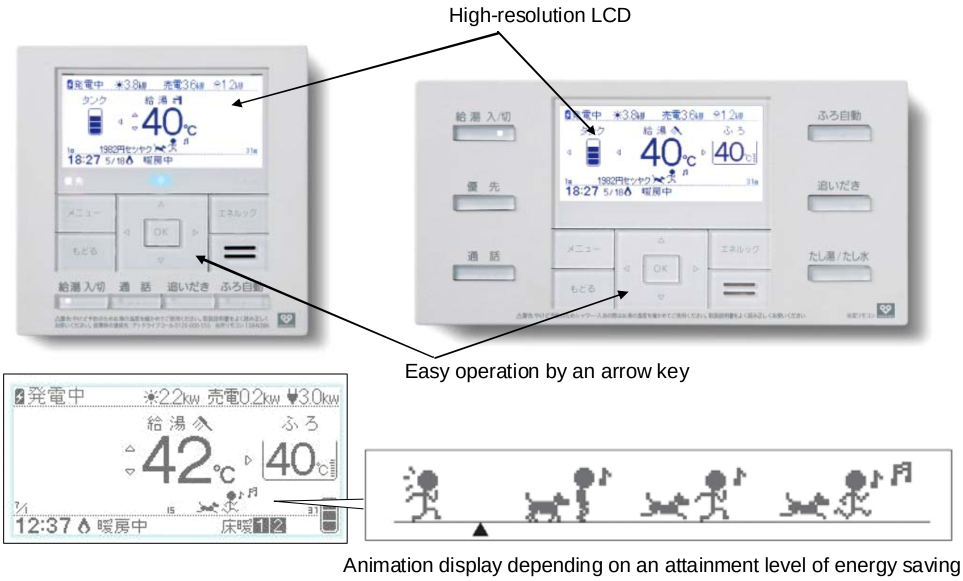

Figure 9 : Schematic view of a remote control panel

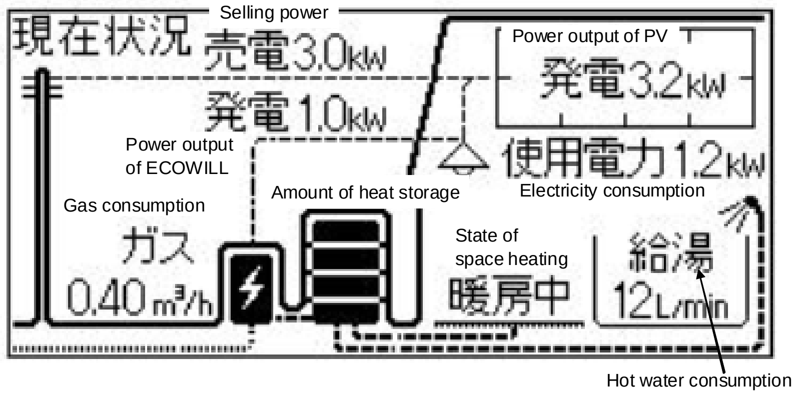

Figure 10 : Energy flow display

6. Conclusion

This full model change has made the ECOWILL suitable for installation in Japan's typically small urban dwellings and enhanced its compatibility with Japan's advanced energy-efficient housing, and has transformed it into a real mass-market model. Gas engine-powered micro-CHP systems such as the ECOWILL are likely to attract growing interest in the future for their combination of environmental friendliness and comfort/ease of use. By pursuing the development of technology that allows still more efficient use of energy and increasing the ECOWILL system's commercial appeal we aim to make a positive contribution to the propagation of energy-saving micro-CHP technology, which will help to build a low-carbon society.

7. References

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8. List Tables

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