Demonstration of Next-Generation Energy System through NEXT 21 Habitation Experiment

Hiroyuki Sasakura,
Technology Planning Team, Planning Department, Residential Energy Business Unit

Tomoyuki Hirai
Electric Power Engineering Team, Engineering Department

Katsuki Higaki
SOFC micro-CHP Development Team, Residential Energy Development Department

Naokatsu Akioka
Smart Home Technology Development Team, Residential Energy System Development Department

Hikaru Morita
Thermal Engineering Team, Energy Technology Laboratories
Osaka Gas Co., Ltd.

1. Introduction
NEXT21 is an experimental residential complex constructed in October 1993 by Osaka Gas Co., Ltd. for the purpose of proposing how neo-futuristic urban housing should be. Establishing themes and issues reflecting the times, demonstration experiments at NEXT21 have been conducted over three phases during the last 15 years, with the company’s employees and their families actually residing there.

![Figure 1. Overview of NEXT21](image)

<table>
<thead>
<tr>
<th>Completion</th>
<th>October 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Tennoji Ward, Osaka City</td>
</tr>
<tr>
<td>Site area</td>
<td>1,543 m²</td>
</tr>
<tr>
<td>Scale</td>
<td>6 floors above ground and 1 basement floor</td>
</tr>
<tr>
<td>No. of units</td>
<td>18 units</td>
</tr>
<tr>
<td>Total floor area</td>
<td>4,577 m²</td>
</tr>
<tr>
<td>Fourth phase launched</td>
<td>June 2013</td>
</tr>
</tbody>
</table>

2. Phase-4 Habitation Experiment Concepts
The fourth phase of the demonstration experiments is designed to pursue "an eco-friendly, enriching life" on the premises of the urban multiple-unit housing complex through around 2020. As such, focus has been placed on conducting habitation experiments in the "residence" and "energy system" fields to achieve "reconstruction of the relationship between people and nature," "creation of links among people" and "realization of an energy-saving, smart lifestyle."

![Figure 3. Phase-4 Habitation Experiment Concepts](image)
3. Overview of the Energy System Habitation Experiment

In the latest habitation experiment, cogeneration systems are effectively utilized in association with characteristics of the multiple-unit housing complex in order to conduct a demonstration experiment for smart systems and technologies devised to pursue further energy saving, as well as addressing issues related to energy supply (including distributed energy sources, energy self-sufficiency, energy saving and peak saving) that have clearly surfaced following the Great East Japan Earthquake.

Figure 3. Overview of the Energy System Habitation Experiment

The major experiments being conducted are the five experiments shown in Figure 3: A) distributed arrangement of SOFCs (solid oxide fuel cells) in individual housing units and energy interchange among them, B) demand response service and operation to export power back to the grid, C) system for self-sustained operation at power failure, D) introduction of the home energy management system (HEMS) and E) combination with renewable energy.

Of these, this report focuses on the experiments that utilize SOFCs (Ene-Farm Type S) (centering on A, B and C).

SOFCs are fuel cells that use solid oxide and feature high power generation efficiency. Experiments are being conducted to exert the maximum potential of SOFCs for the multiple-unit housing complex, so as to evaluate their energy-saving performance and other capabilities, search optimum specifications and operational conditions, and identify issues to be overcome for practical applications.

The items and significance of the demonstration experiments are as follows:

1. Demonstration of reversal (i.e. exporting power back to the grid) and interchange of the power output generated by SOFCs
   ⇒ Realize the high power generation efficiency at rated operation
2. Demonstration of heat interchange in a system that utilizes both SOFCs and solar heat
   ⇒ Supplement the low heat-to-power ratio by combining SOFCs with solar heat
3. Demonstration of a self-sufficient system during power failure
   ⇒ Increase power supply by combining SOFCs with self-sufficient power sources
4. Test operation of next-generation, highly-efficient SOFC prototypes
   ⇒ Pursue possibilities for higher efficiency and downsizing

4. Energy System Habitation Experiment Demonstration Results

4-1. Demonstration of reversal and power output interchange generated by SOFCs

Demonstrations were conducted separately for “constant reversal of power,” in which constantly operating SOFCs with a rated output of 700W export back to the grid excess power that surpasses that used by respective residential units (practically within the residential building) around the clock, and for “DR (demand and response)-type reversal of power,” in which power from the grid is reduced through conserving residents’ power use and through power generation by the SOFCs.

In the case of constant reversal of power (for 4 units on the 4th floor), reductions were effectively
confirmed in areas of purchased electric power, primary energy consumption and CO₂ emissions, due to operation of the SOFCs with a rated output of 700W around the clock.

Figure 4. Effect of Constant Reversal of Power (27-day average per unit of 4 residential units from Dec. 5 through Mar. 23)

In the case of DR-type reversal of power (for 1 unit on the 6th floor), power supply during winter was curbed from 9 a.m. through 9 p.m. Along with an increase in the amount charged per unit of power, requests to reduce power consumption during these times were made to the apartment’s residents via cell phone e-mails and HEMS terminal screens in order to encourage them to curb their usage, while the SOFCs conducted rated operations during the time zone. As a result, reductions in usage from the grid doubled due to the residents’ attempts to reduce power consumption, as well as increased power generation by SOFCs.

Figure 5. Effect of DR-type Reversal of Power (8-day average of one residential unit from Jan. 16 through Feb. 14)

The SOFCs set at three residential units on the 5th floor conduct power load following operations. Meanwhile, heat collected by a solar panel (6m²) on the rooftop is temporarily stored in a common tank. The residential units receive heat from the common tank when heat is inadequate, and give heat back to the common tank when there is a surplus, so that heat interchange is conducted.

Breakdown of Heat Sources Used for Hot-Water Supply

Figure 6. Use Volume of Auxiliary Boilers and Effect of Reductions in Consumption of Primary Energy (Total of 3 residential units during a week in winter)

Improvements in methods to control hot water supply, etc. made it possible for 13% of its entire demand to be sourced from solar heat, enabling a reduction equivalent to approximately 25% of the use volume of auxiliary boilers. Moreover, primary energy consumption fell by 4.3 points compared with when SOFCs were used alone.

4-2. Demonstration of heat interchange in a system that utilizes both SOFCs and solar heat

Anticipating increased power generation efficiency and a declining trend of SOFCs thermal output in the future, the system uses solar heat to supplement inadequate thermal output in winter.

4-3. Demonstration of a self-sufficient system during power failure

An experiment was conducted to verify operations of a self-sufficient back-up system during power failure that combines a power failure-compatible gas engine cogeneration (GE) for the residential
building and SOFCs for residential units, and to evaluate the system’s worth as a self-sufficient power source. The experiment covered 10 residential units on the 3rd to the 5th floors (of which 8 residential units are equipped with SOFCs) and power supply to some common loads, such as lighting and power loads including service water and sewage pumps. In the system configuration, power supply was equally distributed to respective residential units and power consumption limiters were installed at respective units. The experiment was conducted at 5 p.m. through 8 p.m. on multiple days in October through December, with the residents staying in their units, under conditions as described in (1) and (2) below. As a result of interviews with the residents regarding their electricity consumption and tolerance limits under conditions (1) and (2), it was confirmed that tolerance (evaluation scored between +3 and -3) improves if SOFC power supply is added, allowing the residents to use more devices. However, as no information was available regarding surplus power supply, the self-sufficient power sources were not fully utilized.

(1) Power is supplied from the GE alone (up to 500W)
(2) Power is supplied from GE and SOFCs installed at residential units (extra 700W)

4-4. Operating test of next-generation highly-efficient SOFC prototypes
An operating test was conducted of next-generation, highly-efficient SOFC prototypes that could be easily installed at a multiple-unit housing complex due to a significant increase in power generation efficiency and downsizing (installed at a vacant residential unit on the 3rd floor).

The test allowed effective data for practical applications, to be obtained, as it demonstrated high part load performance with the rated value (lower heating, value, LHV) of 55% for sending-end (output efficiency).

<table>
<thead>
<tr>
<th></th>
<th>Equipment launched in fiscal 2014</th>
<th>Next-generation equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation efficiency</td>
<td>46.5%</td>
<td>55%</td>
</tr>
<tr>
<td>Exhaust heat recovery efficiency</td>
<td>43.5%</td>
<td>30%</td>
</tr>
<tr>
<td>Capacity of hot-water storage tank</td>
<td>90L</td>
<td>10~30L</td>
</tr>
</tbody>
</table>

<Based on lower heating values>

![Backup boiler](image)
![Highly-efficient power generation unit](image)

Figure 8. Target Specifications and Status of On-Site Installation

5. Closing
As various potential systems utilizing SOFCs with actual residents and improved operational conditions and other factors have demonstrated, assumed performance levels were largely able to be confirmed. Going forward, demonstration experiments will be conducted on an ongoing basis to review and evaluate energy-saving performance, etc. throughout the year, as well as modify operational conditions and system specifications.