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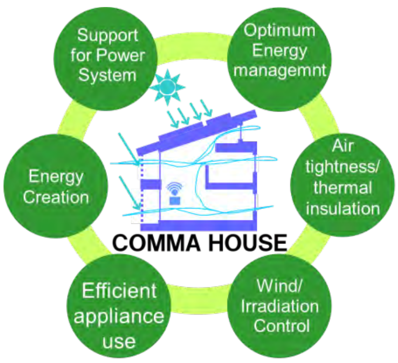
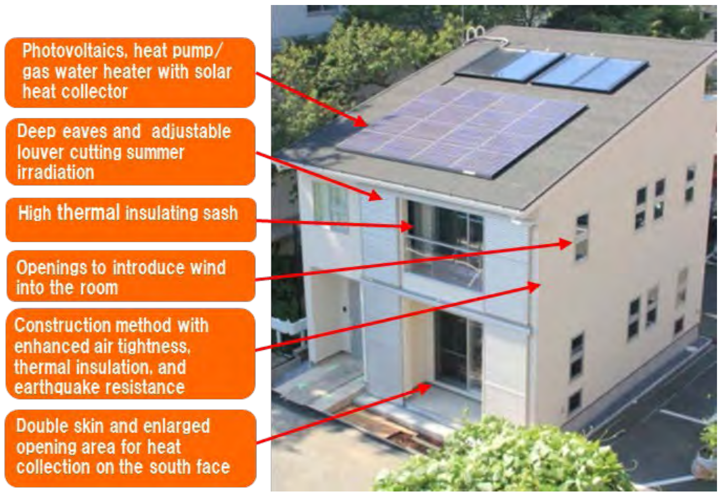
Institute of Industrial Science
The University of Tokyo, Japan

Residential Energy Management Research Program at the COMMA House

The COMMA (COMfort MAnagement) House is an experimental smart house with demonstration purpose built in the Komaba Research Campus at the University of Tokyo, Japan. Since its completion in August 2011, experimental programs are ongoing with the aim of establishing concepts and technologies for smart houses that will become popular by 2020. The programs cover various aspects including architectural design, facilities, appliances, multi-vendor system integration, and data management. Accomplishments in these areas should lead to the realization of a smart house that achieves comfort and sustainability while attaining the efficient use of energy and coordination within a total energy system.

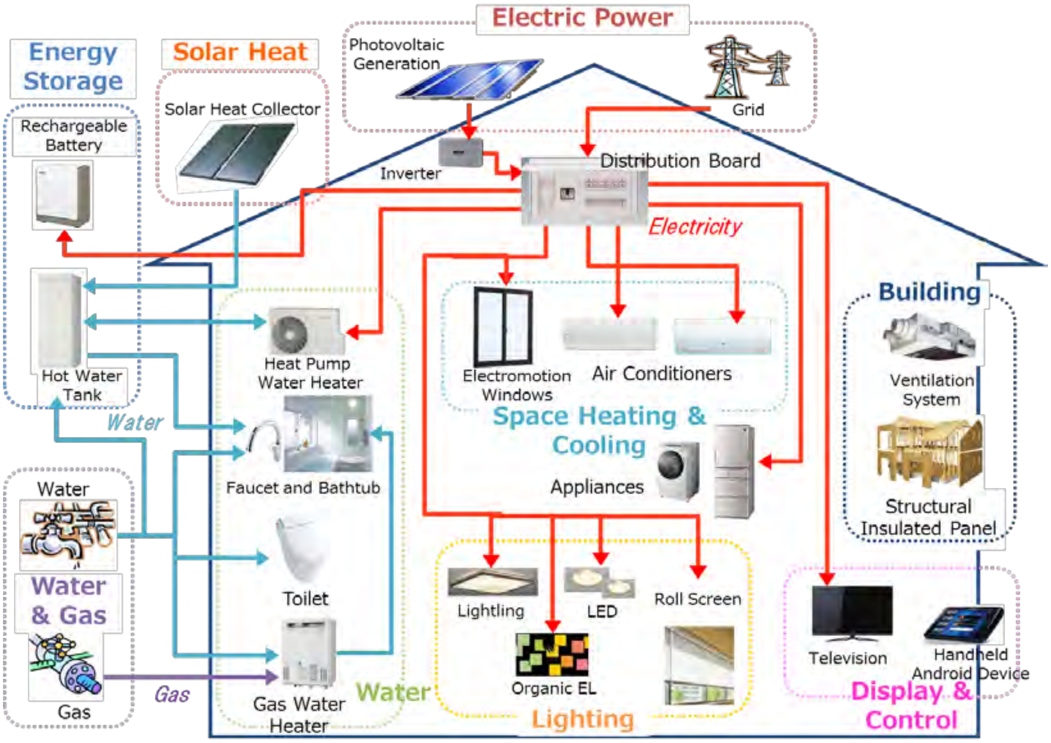




Outline of the construction

- Floor area: 93.31 m^2 (typical for an urban detached house in Japan).
- Environmental performance: improved air tightness and thermal insulation, which will be common by 2020. The Q value, which is a measure of thermal insulation performance, is adjustable between 1.6 and 2.4 W/m^2K.

Equipment, appliances, and information systems are shown in the following diagram.



1. Energy management platform

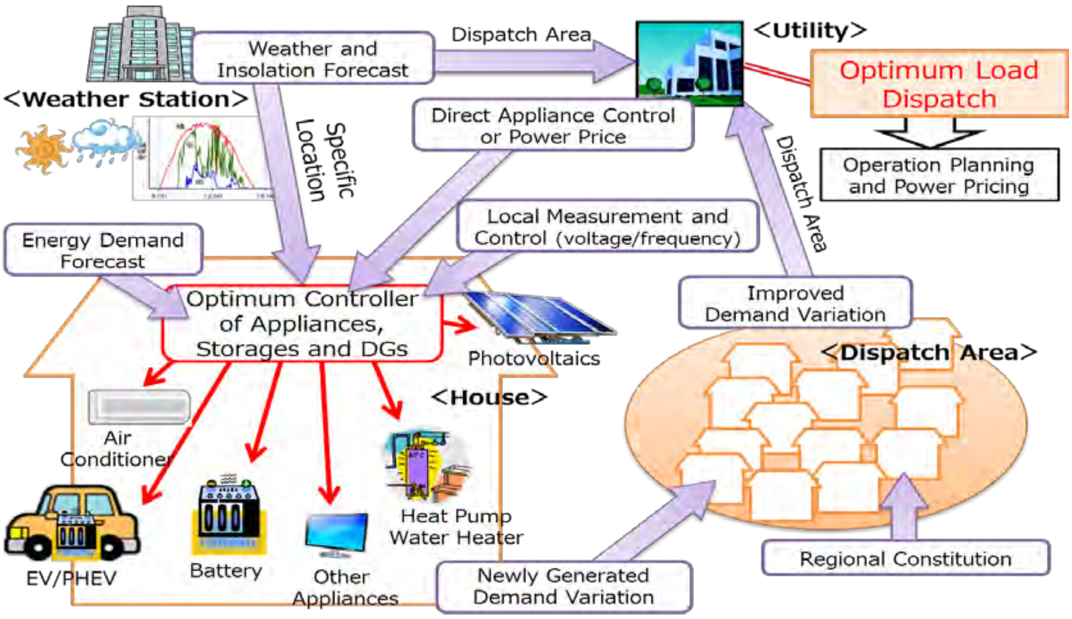
1.1 Platform and data retrieval

Air conditioners, electro motion windows, power measurement units, and energy management servers are connected to an ECHONET Lite based network. The servers have interfaces to retrieve power demand forecast, weather condition/forecast, solar power/heat forecast, internal temperature/humidity, and water usage, which are utilized to control the system. The internal temperature is estimated on the basis of sensors embedded within the wall, which is then verified and integrated to the energy management system.

1.2 Control

The coordinated control of windows and air conditioners has been implemented on the basis of the internal environment and meteorological information. Opening of each window is automatically controlled to make the interior environment comfortable when the exterior conditions are favorable. However, when external conditions are unfavorable, the windows are closed and air conditioning is used as necessary.

An energy management system has been implemented to integrate the battery and photovoltaic power system. Power demand information provided by the utility company is used for system control, and the domestic power consumption is reduced when power supply is tight, while residents' satisfaction is prioritized under normal conditions.



A cloud based energy management system, which enables monitoring from televisions and tablet computers, has been implemented.

2. Experiments focusing on architectural features for energy management

2.1 Ventilation experiment with novel building materials

One of major characteristics of the COMMA House is the effective use of wind. The house has a double-skin construction on the south side and 68 windows arranged from the top to the bottom. Adjustable external louvers are also installed. This experiment showed that the cross ventilation rate increases approximately ten-fold because of the wind catcher effect of projected windows.

2.2 Natural ventilation through top and bottom windows

The COMMA House can also introduce outside air by using top and bottom windows, even during calm weather conditions. This was demonstrated using a visualization experiment of airflow using balloons. As shown in the pictures, balloons in the living room on the first floor gradually rise and eventually reach the highest elevation of the house.

2.3 Modeling of the COMMA House for air conditioning and verification of the pre-cooling effect

A model for the COMMA House has been created to demonstrate the building construction, air conditioners, power consumption, and comfort. The model is utilized to evaluate precooling and preheating effects, which aims towards peak energy shifting while maintaining residents' comfort.

2.4 Retractable membrane ceiling

The COMMA House has a large open floor, which makes the interiors spacious and improves ventilation. However, it has an adverse effect on heating during winter. Retractable membrane ceilings have been installed to divide the floor levels, which has resulted in improvement in heating efficiency, as shown by measurements.

3. Installation and commissioning of facilities

3.1 Water system

Equipment for efficient water use, including a toilet (4 liters per flush), a water tap with a non-contact sensor, and flow sensors powered by energy harvested from running water, has been installed. These products, along with water-consumption measurement devices and a monitoring terminal, have been installed.

3.2 Electricity storage

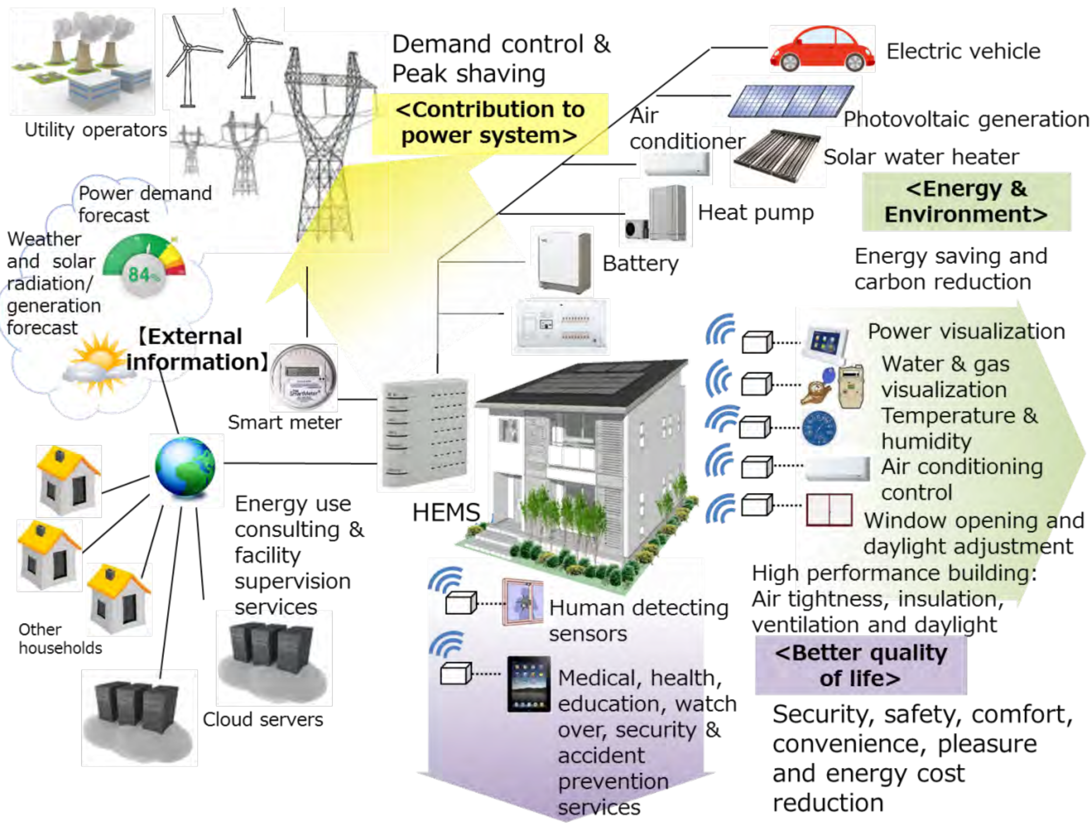
A commercially available lithium-ion battery system has been integrated into a gateway to enable control through the ECHONET Lite protocol. The system is connected to a Home Energy Management System (HEMS) in order to facilitate two-way communication. Coordinated operations based on photovoltaic generation and domestic demand has been programmed and confirmed to function as expected.

3.3 Hot water system

A combination of gas, heat pump, and solar heat are used for heating water in the COMMA House. Operational data is collected and utilized for analysis and modeling.

4. Prospects

Based on the accomplishments described above, we plan to conduct further extensive research activities with enhanced partnerships. The objective is to utilize internal and external environmental conditions, data gathered from equipment, and power system information for the simultaneous achievement of the three objectives required for HEMS, i.e., carbon emission reduction (energy and environment), supply and demand adjustment in the overall system (contribution to power system), and improved quality of life.



Schedule

	2013			2014				2015				2016
	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q
Internal environment and comfort	Data gathering	Environment control experiments				Model development						
Visual presentation of information	Application software development											
Energy management: Energy efficiency of equipment		Management system develpment						Implementation				
Energy management: Power efficiency of equipment	Management system develpment					Implementation						
Energy management: Coordination control of equipment by power system information		Management system develpment						Implementation				
Energy management: Control aiming bette quality of life		Management system develpment					Implementation					

Project members

Institute of Industrial Science, The University of Tokyo

Kazuhiko Ogimoto*, Project Professor	Energy System Integration
Ryozo Ooka, Professor	Urban Energy Engineering
Naoki Shikazono*, Professor	Thermal Energy Engineering
Yumiko Iwafune*, Associate Professor	Sustainable Energy System
Kotaro Imai, Professor	Architectural Space System
Ken'ichi Kawaguchi, Professor	Spatial Structure Engineering
Tomonari Yashiro, Professor	Management of Project

* Collaborative Research Center for Energy Engineering

Research Partners

LIXIL Corporation	Ventilation and water system
Toshiba Solutions Corporation	Energy management system
NEC Corporation	Battery system
Family Net Japan Corporation	Energy management system
Tokyo Electric Power Company	Power system
Nomura Research Institute, Ltd.	HEMS applications

Contributors

LIXIL Corporation (construction and donation of the COMMA House)

Center for Low Carbon Society Strategy, Japan Science and Technology Agency

Weather News Inc.	Weather Information
Sankyo Shoji Co., Ltd.	Retractable membrane ceiling
Sharp Corporation	Photovoltaic Power System
Taiyo Kogyo Corporation	Retractable membrane ceiling
Toshiba Home Appliances Corporation	Air conditioners and appliances
Toshiba Lighting & Technology Corporation	ECHONET/ECHINET Lite based HEMS equipment
Mitsubishi Chemical Corporation	Organic Electro-Luminescence Lighting
Yazaki Corporation	Solar heat collector and hot water system
Yamada Shomei Lighting Co., Ltd.	Lighting
Lutron Asuka Co., Ltd.	Lighting, Remote controlled shade, and control unit

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