# Factory and Community Energy-saving System Solutions for Low-carbon Society

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*OVERVIEW: As society moves towards a low-carbon future, the adoption of renewable energy and the utilization of previously untapped energy sources have grown in importance along with ongoing improvements in energy efficiency at manufacturing plants. Meanwhile, compliance with host country regulations and coordination with the local community are also important factors for plant construction. Hitachi supplies factory and community energy-saving system solutions for a low-carbon society.*

## INTRODUCTION

AS global carbon dioxide ($CO_2$) emissions continue to increase, energy saving technologies have become increasingly important as momentum gathers for the shift to a low-carbon society based around emissions reduction measures.

Increasingly, manufacturing plants that consume large amounts of energy are adopting renewable energy, utilizing previously untapped energy sources (such as energy from plant waste heat or temperature differences), and installing distributed power supplies (such as gas cogeneration and fuel cells). Also, amid moves to save energy, energy service company (ESCO) businesses are making a major contribution to improving energy efficiency in the industrial and commercial sectors. Meanwhile a newly emerging requirement is to take account of the environment in which manufacturing plants operate, including business continuity planning (BCP) and integrating operations with neighboring communities.

In the case of new plant construction and the practice of operating multiple production sites, important factors include creating a low-carbon society, compliance with energy regulations in the host country, and integration into the communities in which the plants are located.

This article provides examples of energy-saving initiatives and community integration, and describes factory and community energy-saving system solutions for a low-carbon society.

## COMPUTER-INTEGRATED FACTORY CONCEPT

Factory energy management systems (FEMSs) that integrate plant, machinery and other manufacturing systems with electric power, heat, and associated utilities systems play an essential role in achieving an advanced level of energy management at factories.

Manufacturing systems seek to eliminate waste and achieve highly efficient production through the use of “visualized” production information made available by applications such as manufacturing execution systems (MESs) or warehouse management systems (WMSs).

FEMSs utilize production plans and demand forecast information to minimize unit energy costs by controlling the supply and demand for the different forms of energy consumed at a plant. Specifically, they improve energy efficiency by selecting the best mix of energy sources, and ensure that production equipment operates reliably despite the use of fluctuation-prone renewable energy.

This approach to achieving overall optimization of manufacturing and energy through the integrated and coordinated management of these production and energy supply plans is the basis of Hitachi’s concept of computer-integrated factories made possible by information and control technology (see Fig. 1).

### Best Energy Mix

While renewable energy systems such as photovoltaic or wind power generation are essential for eliminating consumption of fossil fuels and emissions of $CO_2$, the amount of electric power generated by these systems varies widely depending on weather and climate factors.

The way to deal with this is to adopt a system configuration that uses gas engines or other forms of fuel-burning power generation for the base load together with storage batteries that can be discharged to compensate for variable demand, or fluctuations in the output of renewable energy. For disaster preparedness, meanwhile, while electric power can be supplied during an emergency by renewable energy, batteries, and fuel-burning power generation equipment, this requires stockpiles of gas and oil, and plans for how to obtain supplies during a disaster.

## Hybrid Integrated Energy Management for Power and Heat

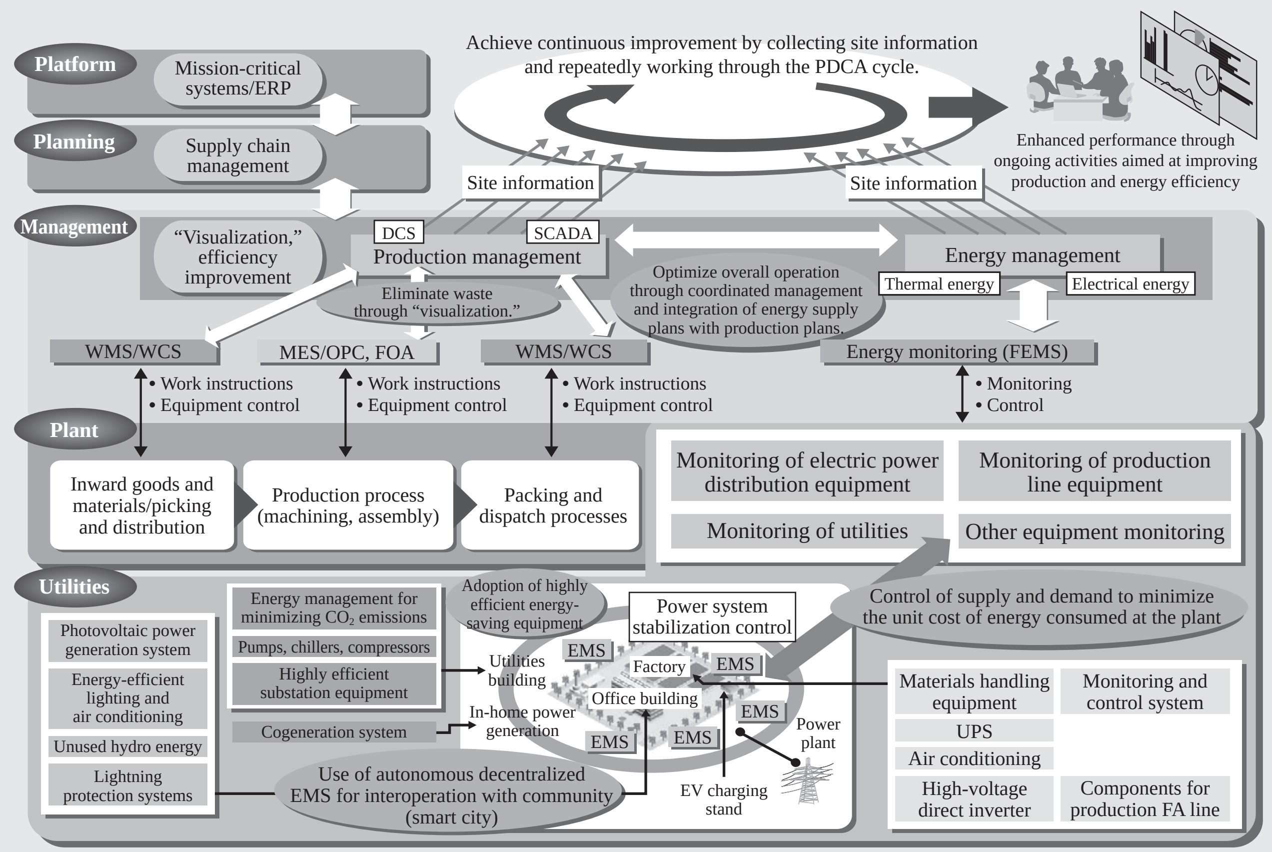
Plant utility systems include the supply of heat, and this can be retained in piping and machinery without necessarily fitting thermal storage tanks. Next-generation FEMS are designed for hybrid integrated energy management, using simulations of supply and demand that include not only electric power but also thermal energy such as these forms of latent heat storage and the generation of power from waste heat (see Fig. 2).

## Demonstration Cases at Hitachi

Hitachi provides solutions for social infrastructure that fuse information and control. In its first step toward realizing this concept of computer-integrated factories, the company commenced a project in 2011 that involved the installation of 940 kW of photovoltaic power generation, 4.2 MWh of batteries, and an FEMS (see Fig. 3).

Starting initially with a system for cutting peak demand and "visualization" capabilities associated with the installation of the photovoltaic power plant and batteries, the intention is that the project scope will expand to also encompass testing of a symbiosis autonomous decentralized energy management system (EMS) and integration with electric vehicle (EV) charging.

The symbiosis autonomous decentralized EMS allows multiple systems to share common objectives by presenting information on resources that each system has available to share with other systems so that these other systems can then autonomously determine the resources they want to access. Specifically, during




PDCA: plan, do, check, and act ERP: enterprise resource planning DCS: distributed control system SCADA: supervisory control and data acquisition WMS: warehouse management system WCS: warehouse control system MES: manufacturing execution system OPC: OLE* for Process Control FOA: flow-oriented approach FEMS: factory energy management system EMS: energy management system EV: electric vehicle UPS: uninterruptible power system FA: factory automation
* OLE is the name of software developed by Microsoft Corporation of the USA.

*Fig. 1—Concept of Computer-integrated Factories Made Possible by Information and Control Technology.*
*The concept aims to achieve energy efficiency, stable plant operation, and higher productivity through the overall optimization of production and energy.*

a disaster or other emergency, the system provides communities with information about which resources the plant can make available, thereby allowing the communities to get access to resources in accordance with their own demand requirements.

Hitachi's intention for the future is to strengthen community involvement through its participation in the Future City Model Projects run by the Japan Business Federation.

## ESCO CONTRACT WITH GUN EI CHEMICAL INDUSTRY CO., LTD.

Established in 1946, Gun Ei Chemical Industry Co., Ltd. is a chemical company that has been operating for more than 50 years. Its two primary activities are a food business producing starch sugars and a chemical business producing phenolic resins.

The company's Gunma Plant was established in January 1989 and has been recognized as a "Type 1 Designated Energy Management Factory," with FY2011 energy consumption equivalent to 16,940 kL of oil. Having maintained a focus on $CO_2$ reduction and energy efficiency improvement over many years, a survey and analysis of energy efficiency at the plant was conducted jointly by Hitachi and the plant's energy efficiency committee. This resulted in the installation of a system for utilizing waste heat.

### Energy-saving Systems

This section describes the energy-saving systems installed at Gun Ei Chemical Industry Co., Ltd. under the ESCO contract (see Fig. 4).

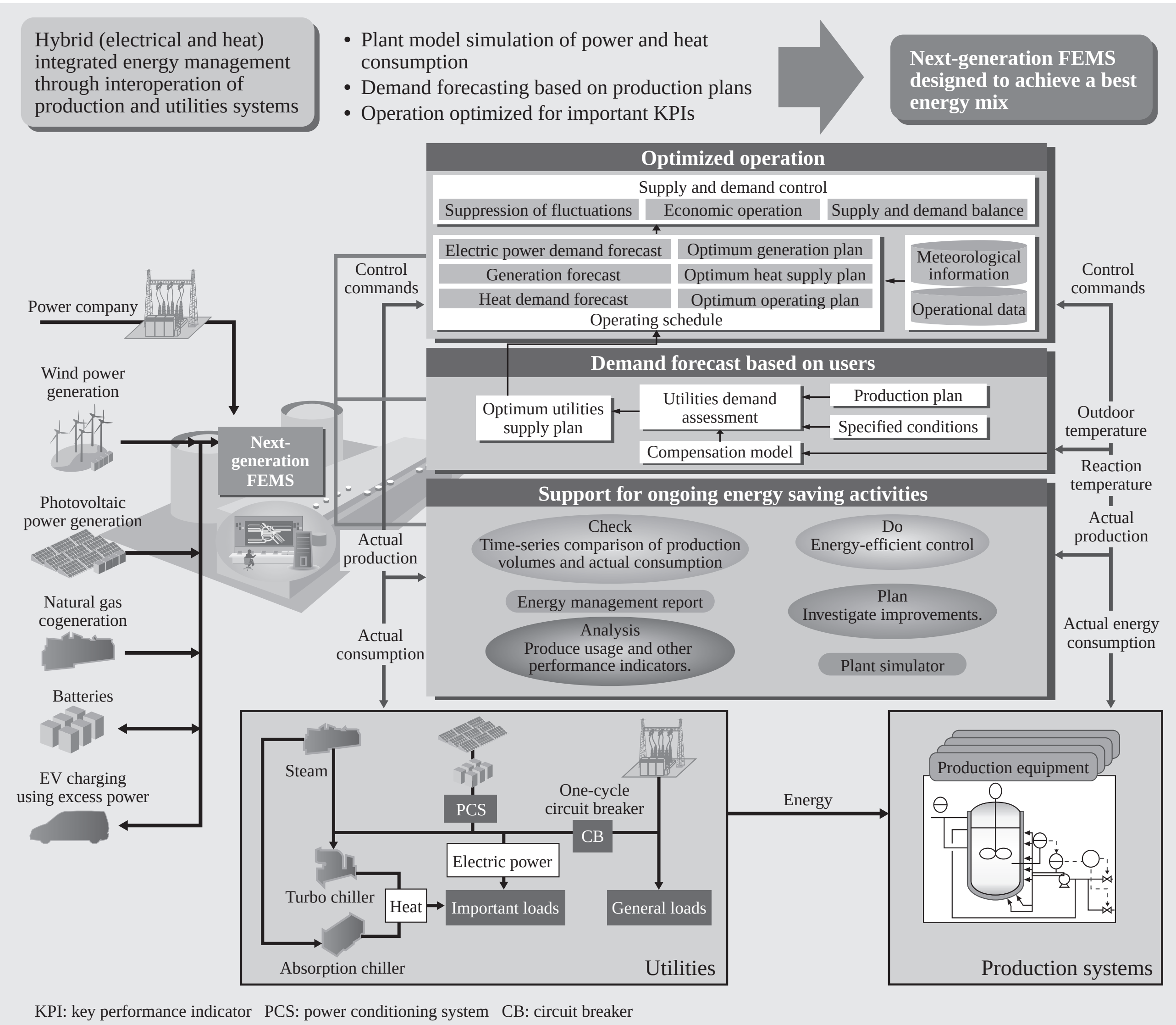



*Fig. 2—Hybrid Integrated Energy Management.*
*Simulation of energy supply and demand that includes heat as well as electric power is used to support integrated energy management.*

(1) Waste steam recovery system

The production process at the No. 1 Resin Plant used high-pressure steam in evaporators. Steam that had served its purpose in the evaporators was subsequently released into the atmosphere as waste. Although they had previously considered heat recovery from this waste steam, it had been ruled out by the characteristics of the reaction in the evaporators, which could not tolerate back pressure at the steam outlet. Subsequently, Hitachi conducted a study into how heat recovery could be performed without creating back pressure. Based on the results of this study, they were able to install a waste steam recovery system based around a shell and tube heat exchanger that could recover the latent heat from the steam without back pressure.

(2) Waste gas steam boiler

The plant uses a sludge dryer that dries and deodorizes the sludge discharged from the production process. This in turn produces waste gas at approximately 400°C from the deodorizing furnace that was being discharged into the atmosphere without its energy being utilized. Two ways of recovering heat from the waste gas are to use it to produce either steam or hot water. As the Gunma Plant requires a large amount of steam, it chose to install a waste gas steam boiler at the final stage of the sludge dryer.

(3) Waste hot water recovery system

Wastewater from the production process is discharged from the plant after appropriate treatment, including steam heating. The water exits the steam heating process at approximately 90°C and was being discharged without its energy being utilized. Accordingly, Hitachi installed a waste hot water recovery system that utilizes the waste hot water to heat clean water.

(4) Air conditioning heat pump/chiller

The air conditioning in the headquarters and laboratory building is based on use of a central heat source, with a steam absorption chiller used for cooling and a steam/hot water heat exchanger for heating. Because the aging steam absorption chiller was due for upgrading, Hitachi undertook a comparative study of the alternatives to simply replacing the unit with another of the same type. Their ultimate conclusion was that an air conditioning heat pump/chiller represented the best option because it was able to fit in the space available while having lower running costs than the current systems for both heating and cooling.

(5) Air compressors

The three aging units at the No. 1 Saccharification Plant included a compressor that frequently switched

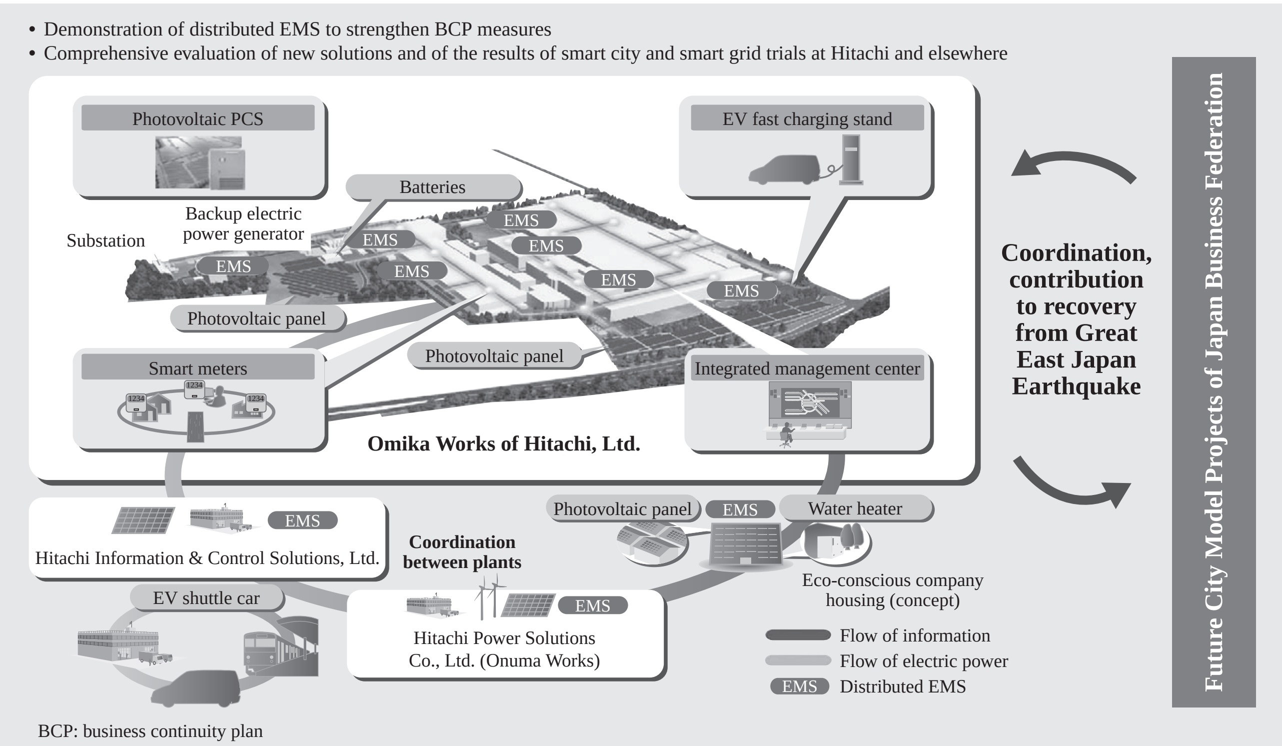



*Fig. 3—Example Computer-integrated Factory.*

*As part of its BCP measures, Omika Works of Hitachi, Ltd. has embarked on the installation of photovoltaic power generation, batteries, and a distributed EMS.*

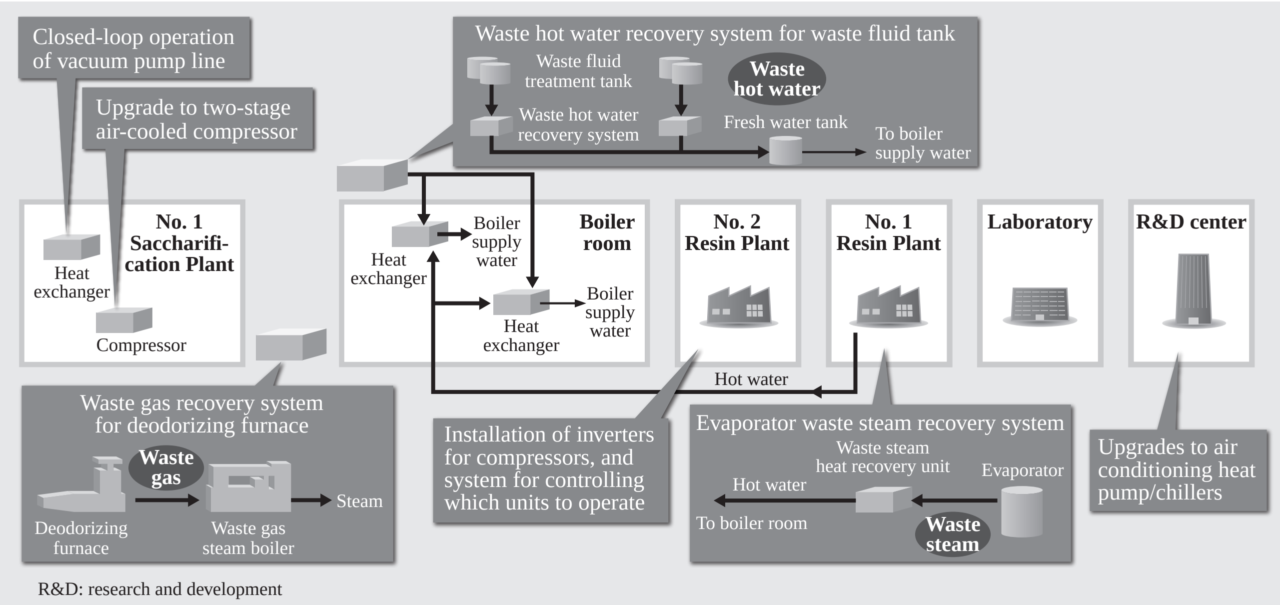



*Fig. 4—Energy-saving Systems at Gun Ei Chemical Industry Co., Ltd.*
*The figure shows an overview of the energy-saving systems installed at the Gunma Plant of Gun Ei Chemical Industry Co., Ltd.*

between loading and unloading operations and another that works solely for unloading operation for long periods of time. The No. 2 Resin Plant, meanwhile, which was fitted with comparatively new equipment, also had compressors that frequently switched between loading and unloading operations. After reviewing the conditions of the equipment at each plant, the No. 1 Saccharification Plant was upgraded with three new 37-kW units (one of which was inverter-driven) together with a system for controlling the number of units in operation, and the existing compressors at the No. 2 Resin Plant were retrofitted with the system for controlling the number of units in operation, and one was upgraded to inverter drive.

(6) Closed-loop operation of vacuum pump line

Plant water (treated bore water) is used as seal water for the vacuum pumps in the No. 1 Saccharification Plant. Because the temperature of the seal water affects the degree of vacuum produced by the vacuum pumps if it becomes too hot, the plant had previously used an open-loop configuration in which the plant water was discharged after use. After assessing the actual situation, a closed-loop system was introduced whereby the seal water is indirectly cooled by water from an existing cooling tower and reused.

## Benefits of Introducing ESCO Contract

The energy-saving systems described above represented a step forward in transforming the plant into one suitable for a low-carbon society.

It needs to be emphasized that building the organic energy-saving systems described in this example demands not only the capabilities of the ESCO supplier, but also the wholehearted cooperation of the client. That is, success is difficult to achieve if all of the effort is put in by one side only. Rather, it comes about through the ESCO supplier and client working together. In its search for ways of reducing $CO_2$ emissions, Hitachi has for a long time enjoyed

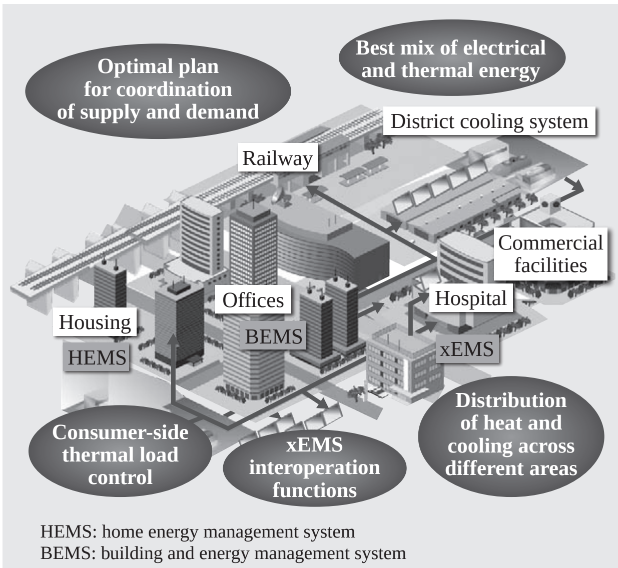



*Fig. 5—Scope of Smart Energy Network and Functional Overview.*
*The network combines electric power with heat, renewable energy, and previously untapped energy sources, and optimizes energy use through exchanges between consumers.*

unstinting cooperation from the technical staff at the Gunma Plant of Gun Ei Chemical Industry Co., Ltd.

The plan for the future is to make further reductions in $CO_2$ emissions by installing cogeneration.

## SMART ENERGY NETWORK

In addition to the energy efficiency and environmental aspects, the period since the Great East Japan Earthquake has seen rapid growth in demand in Japan for the optimized operation of a best mix of energy sources (electric power and heat) across entire communities, and their use in ways that go beyond the boundaries between individual companies or facilities. This has prompted new initiatives involving smart energy networks that allow the sharing of energy (electric power and heat) between different users, with the prospect of their application in the new urban developments that will form part of regional reconstruction.

Smart energy networks combine renewable energy and highly efficient cogeneration systems (CGSs) to deliver an optimal supply of energy at the community level. They need to exercise optimal control within their geographical scope over both the consumers of electric power and heat energy on the demand side and the consolidated suppliers who serve them (see Fig. 5).

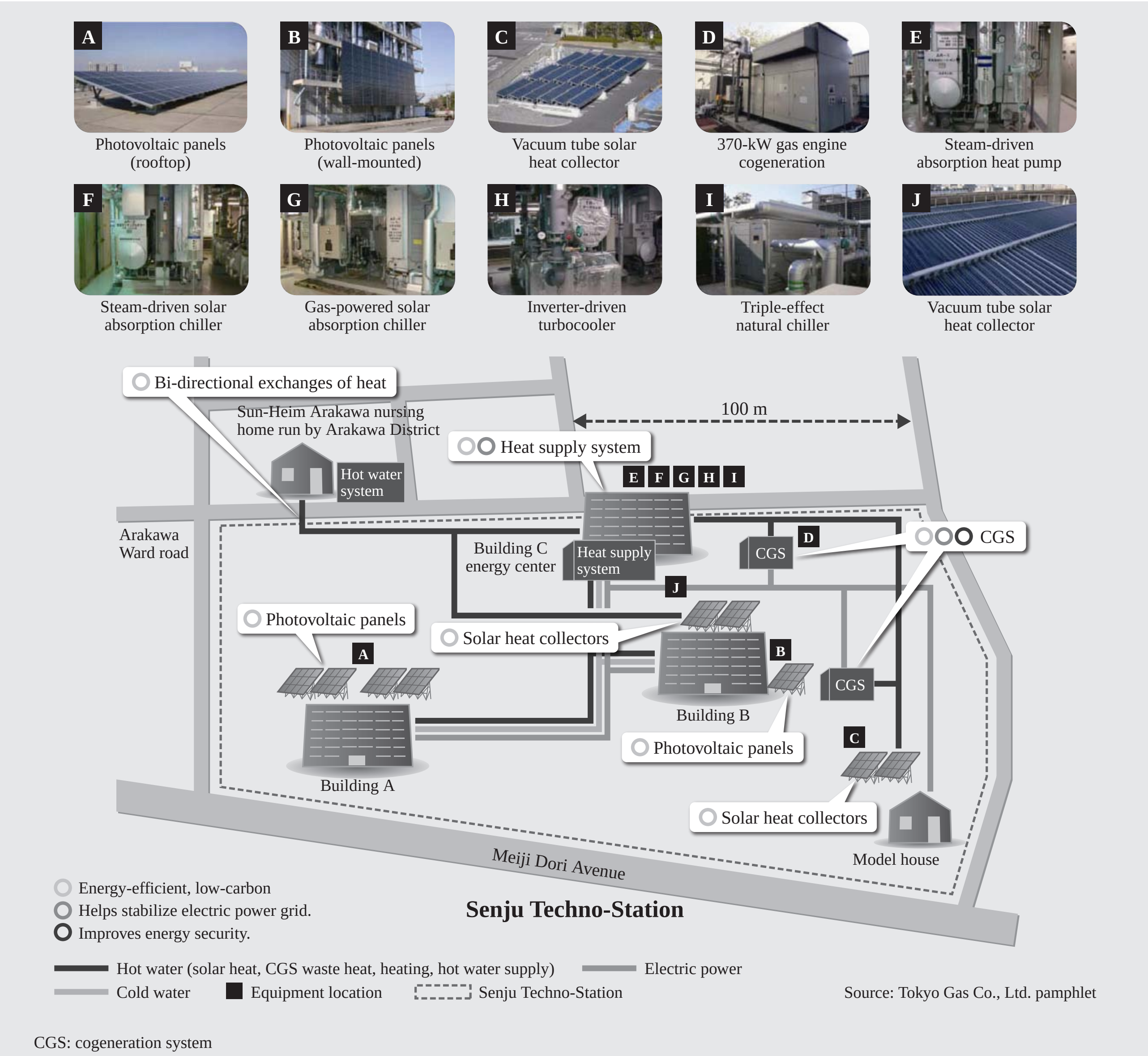



*Fig. 6—Overview of Senju Smart Energy Network Operated by Tokyo Gas Co., Ltd.*
*A heat redistribution network that consolidates demand for heat within an area with a high concentration of demand is being demonstrated at Senju Techno-Station in the Arakawa district of Tokyo. Images A to J show photographs of equipment used in the project.*

Hitachi is currently collaborating with energy suppliers and others on the trialing and commercialization of community-level smart energy networks.

### Demonstration Project at Tokyo Gas Co., Ltd.

The Senju Smart Energy Network is a demonstration project being run by Tokyo Gas Co., Ltd. at Senju Techno-Station in the Arakawa district of Tokyo.

This system consists of a heat redistribution network that consolidates demand for heat within an area with a high concentration of demand and combines cogeneration, solar heat collectors, and photovoltaic power generation to exchange heat and electric power between a number of buildings (see Fig. 6).

The project is trialing the following features.

(1) Exchange of heat between adjacent buildings

(2) Integrated control of heat supply equipment that makes preferential use of solar heat and waste heat from cogeneration

(3) Control of cogeneration and turbochillers to compensate for weather-related fluctuations in the output of photovoltaic power generation

The project has also been selected by the Ministry of Economy, Trade and Industry for a program trialing the distributed optimization of different forms of energy.

Table 1 lists the main equipment installed as part of the project.

TABLE 1. Key Equipment Installed for Senju Smart Energy Network

*The key equipment installed for the demonstration project included CGS and various heat sources.*

| Type | Name | Specifications | Quantity |
|---|---|---|---|
| CGS | D: Gas engine cogeneration | 370 kW | 1 |
| | Gas engine cogeneration | 700 kW | 1 |
| Heat sources | E: Steam-driven absorption heat pump* | • When operated for cooling only<br>Cooling : 422 kW<br>• When operated for cooling and heating<br>Cooling: 165 kW<br>Heating: 304 kW | 1 |
| | F: Steam-driven solar absorption chiller* | Cooling: 422 kW | 1 |
| | G: Gas-powered solar absorption chiller* | Cooling: 949 kW<br>Heating: 813 kW | 2 |
| | I: Triple-effect natural chiller | Cooling: 1,125 kW<br>Heating: 658 kW | 1 |
| | H: Inverter-driven turbocooler* | Cooling: 703 kW | 1 |
| | Air-cooled chiller (screw type) | Cooling: 132 kW | 1 |
| | Vacuum water heater | Hot water: 349 kW<br>Heating: 175 kW | 1 |
| | Multi-tube flow-through boiler | 2.0 t/h | 1 |
| Photovoltaic panels | CIS compound semiconductor | 10 kW | 1 |
| | CIGS compound semiconductor | 10 kW | 1 |
| | Polycrystalline silicon | 30 kW | 1 |
| | A: Monocrystalline silicon | 40 kW | 1 |
| | B: Monocrystalline silicon + thin film amorphous silicon | 16.7 kW | 1 |
| Solar heat collector | C: Vacuum tube solar heat collector | 130 kW (approx.) | 1 |
| | J: Vacuum tube solar heat collector | 36 kW (approx.) | 1 |

* Supplied by Hitachi
CIS: copper indium selenide CIGS: copper indium gallium selenide

### Preferential Use of Solar Heat and CGS Waste Heat (Integrated Control of Heat Supply)

This system performs supervisory control of the hybrid heat supply system that uses a number of different energy sources, controlling which combination of energy sources to use to optimize energy efficiency. Specifically, the system gives top priority to use of renewable solar heat and previously unused waste heat from heating and cooling. After that, the priority of heat sources is: (1) CGS waste heat, (2) electric power generated by the CGS, and (3) town gas. The control scheme maximizes energy savings and reductions in $CO_2$ emissions.

### Demonstration Project and Future Deployment

Installation of the demonstration project systems succeeded in reducing $CO_2$ emissions by 35.8% compared to the previous systems (actual results for FY2011).

The demonstrations also confirmed the favorable operational performance of integrated heat source control, and the results of the demonstration project will in the future be applied in other areas undergoing redevelopment.

## CONCLUSIONS

This article has described, with examples, Hitachi's concept of computer-integrated factories in which the overall optimization of production and energy in coordination with production plans achieves a best mix of energy sources and integrated management of electrical and thermal energy.

The article has also described an ESCO contract in which the client site and solution provider worked together to achieve energy savings. A system upgrade achieved energy savings through measures such as the utilization of discharged hot water, a previously overlooked source of heat.

Also discussed were the smart energy networks that extend the energy efficiency concept beyond individual factories to encompass entire communities.

## ABOUT THE AUTHOR

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*Joined Hitachi, Ltd. in 2007, and now works at the I&E Information and Control Systems Engineering Department, Infrastructure Security & Energy Solutions Division, Infrastructure Systems Company. He is currently engaged in coordinating industry and energy system businesses.*