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# Energy-supported Solar Houses

## Summary

Demonstration SOLARCHIS autonomous houses built in the Shonai district in Yamagata Prefecture facing the Sea of Japan, feature thermal energy storage in concrete walls and floors, large triple-glazed windows facing the south, high-performance thermal insulation for the exterior walls, grid-connected photovoltaic arrays and solar water heaters. Even under the severe climate conditions of the winter in the district, the thermal storage in the concrete structure with a large thermal mass enables the SOLARCHIS solar house to provide a comfortable indoor environment and to realise significant energy savings.

## Highlights

- ▼ **Concrete structure used for thermal storage**
- ▼ **Large windows facing south and high-performance thermal insulation**
- ▼ **Photovoltaic panels and solar collectors on the roof**

**The Iyama Autonomous House.**

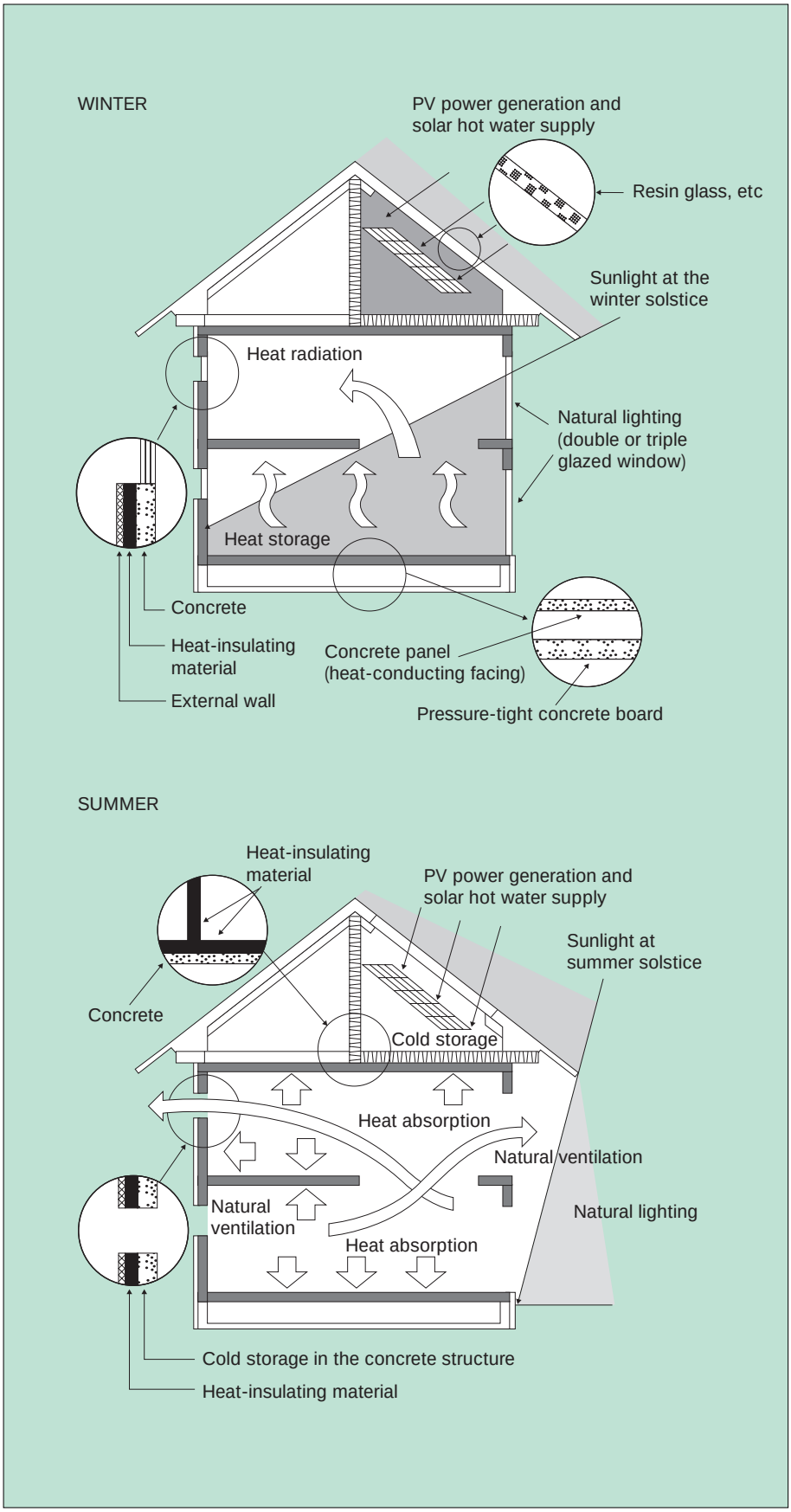
## Project Background

The Shonai district suffers severe weather conditions in winter with ice-cold strong winds blowing in across the Sea of Japan from Siberia. The SOLARCHIS is an autonomous housing system based on the study and design of passive solar houses pursued for nearly 20 years by the resident architect of the Solar Architecture Studio. Since 1994, the Studio and the Maeta Concrete Industry Ltd, a manufacturer of concrete products, have conducted a development project, aimed at getting this technology onto the market. Three SOLARCHIS houses, built in the Shonai district, have been monitored to demonstrate their energy performance.

## The Project

The design of the SOLARCHIS solar house, as illustrated in the figure, includes the following features:

- Large windows facing the south and open ceilings of the lower floor in the south-side zone of the house, to allow as much sunlight as possible into the house in winter. In summer, the deep eaves shade the windows.
- Walls and floors constructed of concrete, which function as thermal energy storage material: in winter, the concrete structure with large thermal mass stores the heat from the sun and radiates the stored heat into the room when the ambient temperature has fallen (direct heat gain/solar natural heating). In summer, the structure stores cold from the natural ventilation through the open windows and the open ceilings, and absorbs heat from the room by the difference in temperature (cold storage in the structure/natural cooling).




**Features of the SOLARCHIS solar house.**

- Insulation applied to the exterior walls and the roof, and double or triple glazing for the windows.
- Grid-connected photovoltaic arrays and solar collectors on the roof.

By these means, the SOLARCHIS house can keep a comfortable indoor climate with minimum back-up heating even under severe winter conditions and can achieve considerable energy savings.

The SOLARCHIS solar houses monitored are two-storey buildings with the lower floor of precast concrete construction and the upper floor of wooden structure. They use triple glazing with innermost or outermost panes of low-emissivity glass for all windows. Any back-up heating necessary in winter is provided by underfloor electric heating. The houses are:

- the Iyama Autonomous House, the SOLARCHIS developer's own dwelling, built in 1995;
- the House of the Sun (Taiyo no Ie), built in 1996 as a model house demonstrating environmentally-friendly architecture by the city of Sakata, the centre of the Shonai district;
- the Onuma House, a dwelling and shop completed in 1997.

The Iyama House, with a total floor area of 126.6 $m^2$, excluding the solarium and other attached parts, is equipped with a 3 $kW_p$ photovoltaic system. A solar water heater, installed in an attic covered with a transparent roof, produces domestic hot water at 50˚C in a 300 litre storage tank. Food is cooked mainly by a solar steam cooker with the support of an electromagnetic induction heater which uses high temperature solar domestic hot water from a 20 litre storage tank, heated by a second solar water heater. An induction cooker and other electric cooking means are also used when necessary.

The House of the Sun has a total floor area of 313.5 $m^2$ (the lower floor of 198.0 $m^2$, the upper floor of 115.5 $m^2$). It is used as an meeting hall for the citizens of Sakata and has a 10 $kW_p$ photovoltaic system and evacuated tubular solar collectors heating water stored in a 300 litre tank. The cooking system is similar to that used in the Iyama House.

The Onuma House with a total floor area of 277.5 $m^2$ has a 4 $kW_p$ photovoltaic system and evacuated tubular solar water heaters and storage tank with a total capacity of 320 litres.

## Performance

Backed by the power supply from the public grid, all the SOLARCHIS solar houses use only natural energy and grid electricity.

During the period April 1996 to March 1997, the Iyama House imported 3,597 kWh of day-time electricity and 10,147 kWh of night-time electricity, a total of 13,744 kWh from the grid. It generated 1,716 kWh by its photovoltaic system and exported 1,071 kWh to the public utility giving a net annual back-up electricity consumption of 12,673 kWh, ie 100.13 kWh per $m^2$ of floor area.

During the same period, the House of the Sun imported 10,394 kWh of day-time electricity and 19,044 kWh of night-time electricity, a total of 29,438 kWh. It generated 8,084 kWh by the photovoltaic system and sold 4,372 kWh giving a net annual back-up electricity consumption for the building of 25,066 kWh, ie 79.96 kWh per $m^2$ of floor area.

Back-up heating in winter for dwellings in the Shonai district normally consumes large amounts of electricity. However a computer simulation of room temperatures shows that the SOLARCHIS house hardly needs back-up heating in locations where there is ample sunshine in winter.

## Economics

Photovoltaic electricity sold to the public utility receives the same unit prices as the energy charged to consumers (day-time: JPY 28.59/kWh; night-time: JPY 6.85/kWh, where JPY is the Japanese yen). The net annual electricity expenses after the deduction of electricity sales revenue in the year 1996/97 were JPY 163,325, ie JPY 1,290.5/$m^2$ at the Iyama House, and JPY 371,302, ie JPY 1,184.4/$m^2$ at the House of the Sun, which are very low compared to those for ordinary houses.

The construction costs of the SOLARCHIS solar house, excluding the costs of a photovoltaic system and a solar hot water system, are JPY 150,000–240,000/$m^2$ – nearly the same as the costs for ordinary houses.

**The House of the Sun (Taiyo no Ie).**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