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Development of solar heating using information and communication technologies for northern houses

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Abstract

The purpose of this study is to construct an integrated system that uses information and communication technologies (ICT) and solar energy more effectively to reduce energy consumption in houses at higher northern latitudes, i.e., in colder climates [1-2]. The core technology of this system is an active indoor environment control system that regulates temperature and illuminance only in the vicinity of the occupants. A goal of this technology is to decrease unnecessary energy consumption caused by controlling the average temperature and illuminance of an entire room. With this technology, a room is divided into multiple zones. Two radiators are installed on opposite-facing walls in two adjacent zones, and one distributed power-saving light is installed in each zone. Two sensors that detect the presence of occupants are installed at the ceiling corners to monitor the room. The occupant positions and the illuminance in sunlit locations are detected by these sensors. In this study, measurements of solar energy were taken in the northern part of Japan, and it was confirmed that there exists an adequate amount of solar energy in winter. Several essential technologies were developed to regulate temperature and illuminance only in the vicinity of the occupants, and the effectiveness of these technologies was partially confirmed using a subset of the final system.
The integrated system will be installed in an experimental house this winter.

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1. Introduction

The east (Pacific) coast of the Japanese island of Hokkaido (the Doto area) has low temperatures throughout the year, which can fall below -20 °C in winter. The Doto area of Hokkaido has little snowfall, and the number of daylight hours is equal to that of Kanto (approximately 2,000 hours a year). The average number of daylight hours in winter is approximately 700 – 800, and the amount of sunlight during winter is 20 – 25 MJ/m^2/day. The ambient temperature is often below freezing, even in the daytime on clear days in winter; on average, there are 45 – 60 ice days per year.

Therefore, much of the energy consumption (nearly 370 MJ/m^2/year) in houses in the Doto area is from heating and generating hot water. Improvements in construction and the use of the energy-saving devices have been encouraged to reduce energy consumption. Examples of improved construction practices in northern houses include greater air-tightness and better thermal insulation. The coefficient of heat loss in these houses is approximately 1.6 W/m^2/K. However, heat pumps, which are common energy-saving devices, are not functionally or economically realistic in the coldest area, where temperatures can be lower than -20 °C.

In recent years, Home Energy Management Systems (HEMS) using ICT have made remarkable progress in reducing energy consumption in household appliances, heating, plumbing and lighting [3]. However, HEMS in cold climates such as the Doto area do not exist.

The Doto area receives a large amount of sunlight in winter. To significantly reduce residential energy consumption in the Doto area, the objective of this study is to construct an integrated system that effectively uses ICT and solar energy, as shown in Figure 1. This integrated system has the following features:

1) Hybrid storage for a photovoltaic (PV) power generation system. This system stores surplus electric power, and some of the surplus electric power can be stored as heat as needed.

2) A solar heating (heating and hot water) system. This system stores solar energy in a non-freezing fluid that can be used for heating or making hot water in winter.

3) An active indoor environmental control system. This system detects the locations of the occupants and regulates the temperature and the illuminance only in the vicinity of the occupants. The objective of this system is to save energy without sacrificing comfort.

4) An intelligent HEMS. The objective of this system is to minimize energy consumption, cost or the carbon footprint by controlling the aforementioned technologies.

In this paper, the results of basic solar energy measurements taken at a northern experimental house are described first. Next, a summary of the development of the active indoor environmental control system is given. Here, the solar energy is used for generating electric power and for heating. The experimental house was built at the Kushiro National College of Technology in the Doto area.