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Case analysis of utilizing alternative energy sources and technologies for the single family detached house

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Abstract

The new energy policy in Japan is implemented by renewable energy resources which are given a large slice of the total for their contribution to energy sources. In addition, there is a government plan to minimize, if not to eliminate nuclear power sources. Building sector energy consumption is increasing every year, hence, utilization and development of alternative energy sources and technologies to support the requirements of every house are important. Numerical performance evaluation of the alternative energy and technologies supported single family detached house was conducted in a transient system simulation (TRNSYS) program to evaluate its performance and energy requirements, and to test the cases for a possible upgrade to an energy generating house. The evaluation of the house performance is compared for possible application to the situation in different areas of Japan. 82.6% of the total primary energy supply could be supported by renewable energy sources – solar energy and biomass fueled auxiliary heater. 69.7% of the consumed energy is electricity; grid line electricity is still needed in the present installed photovoltaic roof tiles of the house. Solar energy collection can support up to 26% of the primary thermal energy requirement of the single family detached house. The remaining 70% should be supported by the back-up water heater of which fuel can be sourced from different sources such as biomass, kerosene, etc. In general, making a house yield higher thermal performance by employing energy conservation measures (ECM) coupled with the utilization of different alternative energy sources readily available in the house's vicinity has an impact on the reduction of the house's energy consumption. In addition, application of new technologies which could be supported by different energy sources has an impact on the diverse utilization of the available energy sources in the house's vicinity.

Keywords: Alternative energy sources; Clean energy technologies; Energy efficient house

1. Introduction

The building sector is one of the major consumers of conventional energy resources through primary and

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Nomenclature

A	solar collector area (m^2)
C_P	specific heat (kJ/kg K)
d	day
E	electric energy (kW h)
$\dot{E}$	electric power (kW)
$\dot{Q}$	thermal power (kW)
Q	thermal energy (kW h)
h	moist air enthalpy (kJ/kg)
I_R	Solar Irradiance (kW/m^2)
$\dot{m}$	mass flow
t	time (s)
T	temperature (°C)
LHV	low heating value (kW/kg)
STF	solar thermal fraction (–)
SEF	solar electric fraction (–)
FIT	feed-in tariff
DHW	domestic hot water
EA	exit air
SA	supply air
BA	back-up heater
EC	evaporative cooler
AC	air cooler
PV	photovoltaic

Greek Symbol

η	efficiency
¥	Japanese Yen (US$1 ≈ ¥97 @ 2013)

Subscript

1, 2…	HVAC system notation
$a, b\ldots$	thermal system notation
APP	appliances
Aux	auxiliary thermal/electric energy
EC	electric consumption
F	fuel
CL	cooling load
GL	grid line electricity
HC	heating coil
HL	heating load
HVAC	heating, ventilating and air-conditioning system
HW	hot water
I	inverter
PV	photovoltaic
PP	photovoltaic panel
SA	supply air
SC	solar collector
SE	solar thermal energy
TE	thermal energy
W	water
WS	water solution

secondary energy consumption (IEA, 2011). Energy consumption in buildings – including climate control, appliances, lighting and other installed equipment – represents nearly 40% of the world's total energy use (ISO). At the same time, the building sector is one of the major contributors of greenhouse gases (IEA, 2011). Several energy conservation measures are being suggested and implemented to lessen the conventional energy consumption and contribution to greenhouse gases of the building sector such as energy conservation (Kolokotsa et al., 2005), energy efficiency (Mui et al., 2008; Theodosiou and Ordoumpozanis, 2008), passive system (Persson et al., 2006; Kumar et al., 2007) and alternative energy utilization (Lucas et al., 2006; Deng et al., 2011).

In Japan, the new energy policy was implemented by which renewable energy resources are given a large slice for their contribution to energy sources (Feed-In tariff scheme in Japan). In addition, there is a government plan to eliminate nuclear power sources by 2030 (Zero-nuclear policy). In this situation, utilization and development of alternative energy sources such as renewable energy sources are important. Furthermore, energy conservation and efficiency through application of new technologies will cater to the utilization of alternative energy sources (Enteria et al., 2008). Hence, as buildings are one of the main energy users (Komiyama and Marnay, 2008), one of the main focuses of renewable energy application, conservation and efficiency implementations is in the building sector (Japan energy situation). In Japan, there is a project for the life cycle carbon minus (LCCM) house. This is the same as different studies of developing an energy efficient home (EEH), energy plus home (EPH), zero emission house (ZEH) and others. The main objective of all these projects is to implement a practical building/house concept and technologies which can be mass produced and commercialized. In Japan, the feed-in tariff law was just implemented in July of 2012 (Feed-in tariff scheme). With the country's new energy policy of renewable energy utilization and the plan for the elimination of nuclear energy sources (Zero-nuclear policy), it is expected that utilization of renewable energy sources for building sector will increase.

As a building in general is a fixed object, measures for energy conservation, energy efficiency, and non-conventional energy utilization can be implemented (Voss, 2000; Santamouris et al., 2007; Day et al., 2009; Pavlovski et al., 2010). However, one of the main problems is the adaptation of the building occupants in those measures due to inexperience in new methods and the cost in the