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Potential application of a centralized solar water-heating system for a high-rise residential building in Hong Kong

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Abstract

There is a growing, government-led trend of applying renewable energy in Hong Kong. One area of interest lies in the wider use of solar-energy systems. The worldwide fast development of building-integrated solar technology has prompted the design alternative of fixing the solar panels on the external façades of buildings. In Hong Kong, high-rise buildings are found everywhere in the urban districts. How to make full use of the vertical facades of these buildings to capture the most solar radiation can be an important area in the technology promotion. In this numerical study, the potential application of a centralized solar water-heating system in high-rise residence was evaluated. Arrays of solar thermal collectors, that occupied the top two-third of the south and west façades of a hypothetical high-rise residence, were proposed for supporting the domestic hot-water system. Based on typical meteorological data, it was found that the annual efficiency of the vertical solar collectors could reach 38.4% on average, giving a solar fraction of 53.4% and a payback period of 9.2 years. Since the solar collectors were able to reduce the heat transmission through the building envelope, the payback was in fact even shorter if the energy saving in air-conditioner operation was considered.

Keywords: Solar water-heating; Solar thermal collector; Plant simulation; Renewable energy

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Nomenclature

A_c	total collector-array aperture area (m^2)
c_{HX}	heat-capacitance of coiled heat-exchanger inside calorifier (kJ/K)
c_{pc}	specific heat of collector fluid (kJ/(kg K))
c_{tank}	heat capacitance of calorifier tank (kJ/K)
c_w	wind speed (m/s)
f_c	collector-fin efficiency factor
f_r	overall collector heat-removal efficiency factor
h_w	wind heat-transfer coefficient (W/(m^2 K))
I_b	incident-beam radiation per unit area (kJ/(h m^2))
I_d	horizontal diffuse radiation per unit area (kJ/(h m^2))
I_t	total horizontal radiation per unit area (kJ/(h m^2))
I_{ti}	total incident-radiation on a flat surface per unit area (kJ/(h m^2))
m_c	collector fluid mass-flow rate (kg/h)
n_c	number of identical collectors that are mounted in series
n_g	number of glass covers
Q_c	rate of heat gain of total collector array (kJ/h)
$Q_{in,HX}$	rate of heat gain of a coiled heat-exchanger inside the calorifier (kW)
$Q_{in,tank}$	rate of heat gain of calorifier tank (kW)
$Q_{out,HX}$	rate of heat loss of coiled heat-exchanger inside the calorifier (kW)
$Q_{out,tank}$	rate of heat loss from calorifier tank (kW)
r_g	ground reflectance
T_a	ambient temperature (°C)
T_{av}	average collector-fluid's temperature (°C)
T_{hwa}	hot-water average temperature inside tank (°C)
T_{hw1}	hot-water initial temperature (°C)
T_{hw2}	hot-water final temperature (°C)
T_{HX}	temperature of coiled heat-exchanger inside the calorifier (°C)
T_i	temperature of fluid entering the collector (°C)
T_p	collector-plate's temperature at stagnation (°C)
T_{tank}	temperature of calorifier tank (°C)
U_{be}	loss coefficient for bottom and edge of collector per unit area (kJ/(h m^2 K))
U_c	overall loss-coefficient of collector per unit aperture area (kJ/(h m^2 K))

Greek symbols

α	absorptance of absorber plate
β	collector slope (°)
ε_g	emissivity of glass covers
ε_p	absorber plate emittance
σ	Stefan–Boltzmann constant (5.6697×10^{-8} W/(m^2 K^4))
τ	transmittance of absorber plate
Δt	simulation time-step (h)