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# Performance investigation of an independent dedicated outdoor air system for energy-plus houses

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## HIGHLIGHTS

- An independent dedicated outdoor air system was proposed for an energy-plus house.
- The energy saving potential of the dedicated outdoor air system was investigated.
- The proposed system saved 37% of operating energy compared to conventional systems.
- The proposed system generated 38% more surplus energy via the conventional systems.

## ARTICLE INFO

*Keywords:*
Dedicated outdoor air system
Dehumidification
Ventilation
Heat pump
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## ABSTRACT

This study proposes an independent dedicated outdoor air system (IDOAS) for energy-plus houses under the humid subtropical climate located in Daejeon, South Korea. The proposed IDOAS can be used as a stand-alone ventilation and dehumidification system. In order to investigate the energy efficiency of the IDOAS, four different types of systems are simulated including the conventional dehumidifier (i.e., Case 1) and conventional dedicated outdoor air system (DOAS) (i.e., Case 2). The first IDOAS (i.e., Case 3) is designed such that the evaporator of the heat pump is located at the supply air (SA) side and the two separated condensers are located on the SA and exhaust air sides, respectively. The second IDOAS (i.e., Case 4) has a direct evaporative cooler located on the exhaust air side to improve the heat extraction rate. It is shown that the conventional DOAS and IDOAS-2 yielded the highest energy efficient system.

## 1. Introduction

As part of the concerted efforts to reduce global $CO_2$ emissions, many countries support actions to reduce energy consumption and increase efficiency in residential houses. A net energy-plus house means that the net energy balance of generation and consumption of the house is positive. Thus, the net energy-plus house generates surplus energy in contrast to a house that consumes energy over a year. The energy consumption includes that used for cooling, heating, hot water, ventilation, lighting, and plug energy. In order to achieve an energy-plus house, the house should maximize the energy generation from the renewable energy systems and minimizes the heating and cooling load. The heat pump system, which is responsible for most of the energy consumption of the house [1], should be well-matched with the renewable energy systems. The heat pump system shall supply the indoor air conditioning, heating, and hot water. The major renewable energy systems for integrating the heat pump to increase the overall system efficiency are photovoltaic (PV), solar thermal, and photovoltaic combined solar thermal (PVT) systems. During the last decades, many studies on passive houses, net-zero, or net-plus energy houses have been performed [2–4].

In this type of low-energy consumption houses, the cooling and heating demand could be effectively reduced with high insulation and increased air-tightness under hot and humid climate conditions. However, the latent cooling load (i.e., dehumidification) is always dependent on variable sources, such as occupants' breathing, cooking, ventilation, and opening of doors and windows, regardless of the reduction in cooling demand. During the cooling season, the absence of humidity control influences the thermal comfort as well as condensation on walls. Condensation inside the building causes mold growth,

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**Nomenclature**

| | |
|---|---|
| $c_{p,a}$ | specific heat of air (kJ/kg °C) |
| $I$ | photovoltaic (PV) module output current |
| $I_L$ | module photocurrent |
| $I_0$ | diode reverse saturation current |
| $\gamma$ | empirical PV curve-fitting parameter |
| $\dot{m}$ | mass flow rate (kg/s) |
| P | power (kW) |
| $R_s$ | module series resistance |
| $\dot{Q}_C$ | cooling capacity of the system (kW) |
| T | temperature (°C) |

*Greek symbols*

| | |
|---|---|
| $\beta$ | ratio of the number of transfer units for moisture |
| $\varepsilon$ | effectiveness (%) |
| $\eta$ | efficiency of pump |
| $\Delta P$ | pressure loss |
| $\rho_a$ | density of air (kg/m$^3$) |

*Subscripts*

| | |
|---|---|
| c | PV cell |
| ch | chiller |
| cond | condenser water |
| cw | chilled water |
| e | entering |
| l | leaving |
| max | maximum |
| min | minimum |
| pri | primary |
| ref | reference |
| sec | secondary |

*Abbreviations*

| | |
|---|---|
| CAPFT | cooling capacity function of the temperature curve |
| COP | coefficient of performance |
| DEC | direct evaporative cooler |
| DOAS | dedicated outdoor air system |
| EIRFT | energy input to the cooling output ratio function of the temperature curve |
| EIRFPLR | energy input to the cooling output ratio function of partial load ratio curve |
| EA | exhaust air |
| HVAC | heating, ventilation, and air conditioning |
| IDOAS | independent dedicated outdoor air system |
| MEE | membrane enthalpy heat exchanger |
| NTU | number of transfer units |
| OA | outdoor air |
| PLR | partial load ratio |
| PV | photovoltaic |
| PVT | photovoltaic combined solar thermal |
| STC | standard test condition |
| RA | return air |
| SA | supply air |

which ultimately has a detrimental influence on the occupant's health, such as the sick building syndrome [5,6]. During the cooling season, it is necessary to provide latent cooling or moisture removal using active dehumidification systems.

A dedicated outdoor air system (DOAS) can ensure the proper ventilation rate and control the humidity of a conditioned space. The DOAS also separately controls the sensible and latent cooling of the space with a parallel cooling system. During the past few decades, many studies have been conducted on DOAS, and this system has been adopted world-wide to save operating energy in buildings. DOAS with radiant cooling panels, such as passive chilled beams, active chilled beams, and ceiling radiant cooling panels, has also lead to increase operating energy savings compared to conventional variable-air conditioning systems [7,8]. Li et al. [9] proposed a DOAS consisting of a

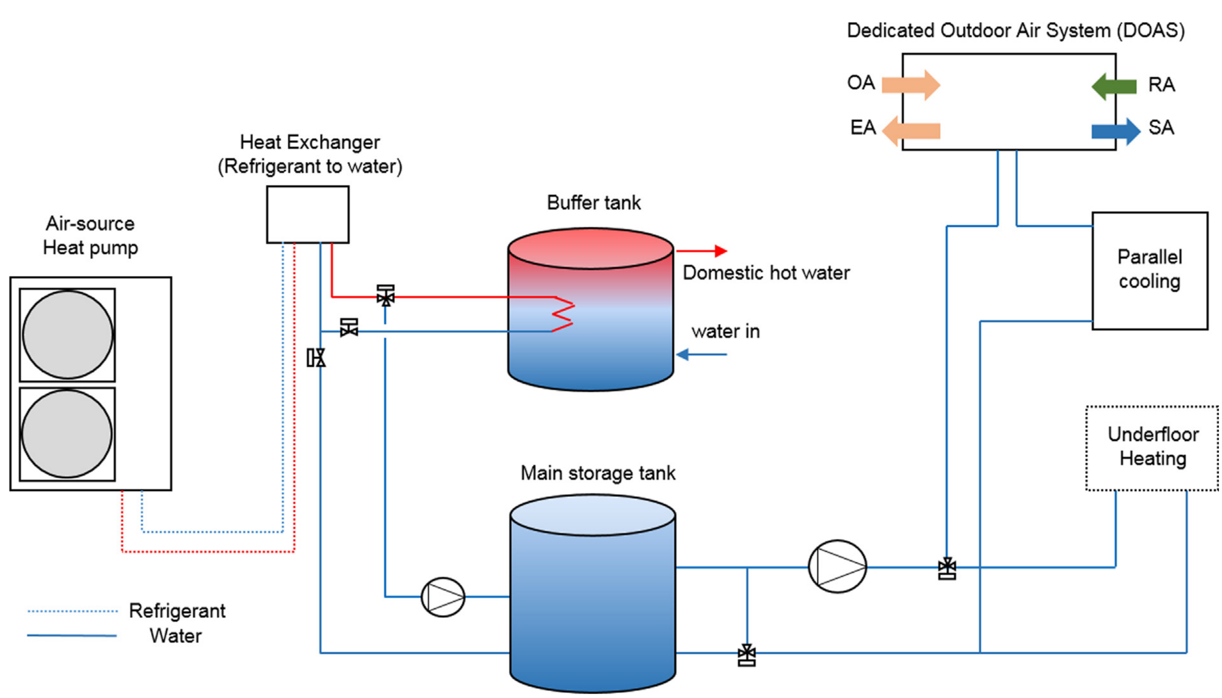


**Fig. 1.** Schematic of hybrid HVAC system.