Novel energy efficient integration of chimney ventilation, liquid desiccant dehumidification, and evaporative cooling for humid climates

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The chimney effect for driving passively building ventilation is effective in dry and moderate climates to introduce cool fresh air into the space. However, its application in hot humid climates is limited due to the high energy demands associated with dehumidifying and cooling outdoor air. Thus, a novel energy-efficient assistive system is proposed integrating a chimney-driven ventilation with liquid desiccant dehumidification membrane loop and indirect evaporative cooling. This system leverages natural buoyancy to supply ventilation airflow and uses potassium formate loops through semi-permeable membranes for effective dehumidification. The objective is to dehumidify and cool the induced outdoor air to the room conditions of 24°C and relative humidity between 40% and 60% at minimal energy consumption. Mathematical models were developed to simulate the heat and mass transfer processes in the air and liquid desiccant flows within the system components. The system was sized, and its operation was optimized using an advanced machine learning-genetic algorithm model for a typical office space in Beirut. During the summer, the chimney air flowrate ranged from 45L/s to 48L/s, and it was delivered at the target room conditions. The system saved around 350kWh of electrical energy during the summer months due to elimination of the need to treat ventilation air by room cooling system. This was equivalent to the total energy required to handle the ventilation load during the summer season and resulted in a saving of $50/month in the case study.