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Solar Photovoltaic Driven Air-Conditioning for Commercial Buildings: A Case of Botswana

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Abstract : The global demand for cooling has grown exponentially over the past century to meet economic development and social needs, accounting for approximately 10% of the global electricity consumption. As global temperatures continue to rise, the demand for cooling and heating, ventilation and air-conditioning (HVAC) equipment is set to rise with it. The increased use of HVAC equipment has significantly contributed to the growth of greenhouse gas (GHG) emissions which aid the climate crisis- one of the biggest challenges faced by the current generation. The need to address emissions caused directly by HVAC equipment and electricity generated to meet the cooling or heating demand is ever more pressing. Currently, developed countries account for the largest cooling and heating demand, however developing countries are anticipated to experience a huge increase in population growth in 10 years, resulting in a shift in energy demand. Developing countries, which are projected to account for nearly 60% of the world's GDP by 2030, are rapidly building infrastructure and economies to meet their growing needs and meet these projections. Cooling, a very energy-intensive process that can account for 20 % to 75% of a building's energy, depending on the building's use. Solar photovoltaic (PV) driven air-conditioning offers a great cost-effective alternative for adoption in both residential and non-residential buildings to offset grid electricity, particularly in countries with high irradiation, such as Botswana. This research paper explores the potential of a grid-connected solar photovoltaic vapor-compression air-conditioning system for the Peter-Smith herbarium at the Okavango Research Institute (ORI) University of Botswana campus in Maun, Botswana. The herbarium plays a critical role in the collection and preservation of botanical data, dating back over 100 years, with pristine collection from the Okavango Delta, a UNESCO world heritage site and serves as a reference and research site. Due to the herbarium’s specific needs, it operates throughout the day and year in an attempt to maintain a constant herbarium temperature of 16°?. The herbarium model studied simulates a variable-air-volume HVAC system with a system rating of 30 kW. Simulation results show that the HVAC system accounts for 68.9% of the building's total electricity at 296 509.60 kWh annually. To offset the grid electricity, a 175.1 kWp nominal power rated PV system requiring 416 modules to match the required power, covering an area of 928 m2 is used to meet the HVAC system annual needs. An economic assessment using PVsyst found that for an installation priced with average solar PV prices in Botswana totalled to be 787 090.00 BWP, with annual operating costs of 30 500 BWP/year. With self-project financing, the project is estimated to have recouped its initial investment within 6.7 years. At an estimated project lifetime of 20 years, the Net Present Value is projected at 1 565 687.00 BWP with a ROI of 198.9%, with 74 070.67 tons of CO2 saved at the end of the project lifetime. This study investigates the performance of the HVAC system to meet the indoor air comfort requirements, the annual PV system performance, and the building model has been simulated using DesignBuilder Software.

Keywords : vapor compression refrigeration, solar cooling, renewable energy, herbarium
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