Exploring the Integration of Renewable Energy in Building Cooling Systems: A Review of Articles

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ABSTRACT

As the earth's global warming and other environmental problems keep getting worst, the world is moving towards sustainable practices both passive and technologically, especially in energy production and consumption. An important step towards these sustainable practices is the incorporation of renewable energies into our systems. The integration of renewable energy in building cooling systems represents an important shift towards sustainable energy practices. There have been recent research works on the integration of wind, geothermal, and solar energy systems into buildings cooling system in order to minimize environmental effects and increase efficiencies, while making the world more sustainable. This paper seeks to explore the feasibility and effectiveness of using sustainable technologies of solar-powered or geothermal cooling systems in commercial or residential buildings, by reviewing articles on these sustainable practices, aimed to provide a comprehensive overview of existing literature, highlight trends, and identify gaps in the articles. These articles to be reviewed are valuable resources for understanding the current state of research on sustainable cooling systems.

Keywords: Renewable energy, Cooling systems, Sustainability, Geothermal, Solar.

INTRODUCTION

There is a significant rise in global energy demand for building cooling systems, driven by increasing climate change effects. This rise comes with the determination to reduce the amount of carbon emissions, and move onto renewable energy-driven cooling technologies of buildings. Buildings account for 40% of global energy consumption, underscoring the urgency of integrating renewable energy solutions (Zhang et al., 2022). The need for a clean energy transition globally and the goal of closing Net Zero Energy Buildings, efficient Renewable Energy Based heating/cooling systems for buildings became crucial and important (Zhang et al., 2022). Renewable energies provides significant contributions to reducing traditional energy consumption and the emission of greenhouse gases (Zang et al., 2019). The integration of Solar and geothermal systems into the cooling systems of buildings, provides promising solutions to the world climate challenges and energy usage due to their sustainability and potential for significant energy savings

This study seeks to address the challenges in the integration of renewable energy solutions, solar and geo-thermal systems, into building's cooling systems. This research is relevant and important because it studies and review what has already been documented on renewable energies in cooling systems and to set a framework on the need to reduce the environmental impact of energy consumption and use in buildings cooling systems, using geothermal and solar energies. The methodology of this paper is primarily Literature

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review and analysis of existing papers on the topic. It was adopted to review, analysis and compare literatures and works on Renewable energies in cooling systems of buildings.

LITERATURE REVIEW

The worlds movements and demand for sustainable practices has driven interest in integrating renewable energies such as solar, wind and geothermal, into the cooling systems of buildings, (Reddy et al., 2024). This is to reduce the greenhouse gas emissions, reliance on fossil fuels and also to increase the efficiency of cooling systems.

In this section, literature on various concepts as pertaining to the topic are discussed.

Renewable Energy

Renewable energies are sources derived from natural processes that replenish faster than their consumption, (United Nations, 2022 and Lund, 2005). Unlike the conventional fossil fuels, like coal, oil and gas, that takes long period of time to form and does not replenish themselves when exhausted, renewable energies are sustainable and have very little or no environmental impacts. Despite fossil fuels still accounting for more than 80 percent of global energy production, renewable energy sources are gaining ground, contributing 29 percent of global electricity in 2022 (United Nations, 2022). Renewable energies have positive impact on the world's quest for sustainable practices. This papers focus on solar and geo-thermal energies aligns with these positive impacts of renewable energies, emphasizing how solar and geo-thermal harness natural energy of sun and underground heat respectively to improve and contribute global sustainability and environmental conservation.

Types of Renewable Energy

The different types of renewable energies as stated by United Nations (2022) include:

a. Solar energy from the sun captured using photovoltaic panels
b. Wind energy from the available air captured using wind turbines
c. Geothermal energy sourced from earth's surface
d. Hydropower energy from flowing water
e. Bioenergy from organic materials
f. Ocean Energy that uses kinetic and thermal energy of seawater (waves and currents)

This Research work is focusing on using Solar and geothermal energies for cooling systems of buildings.

Benefits of Renewable Energies

Renewable energies have many advantages, hence making them ideal for a more sustainable world. According to United Nation (2022), these benefits include;

a. Healthier and Environmental Protection by reducing greenhouse emissions, global warming and climate change.
b. Cheaper although has high initial cost
c. Promotes local energy production and use.
d. Helps in mitigating air and water pollution, thereby reducing health issues.
e. Promotes sustainability as the energy sources are clean and can replenish themselves.
f. Provides continuous energy use as it does not exhaust.
g. Makes Economic sense since it creates a system less prone to market shocks which improves resilience and energy security by diversifying power supply options.

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Fig. 1 below is a schematic illustration of a Renewable Energy System, showing the different types of renewable energies and their integration into buildings.

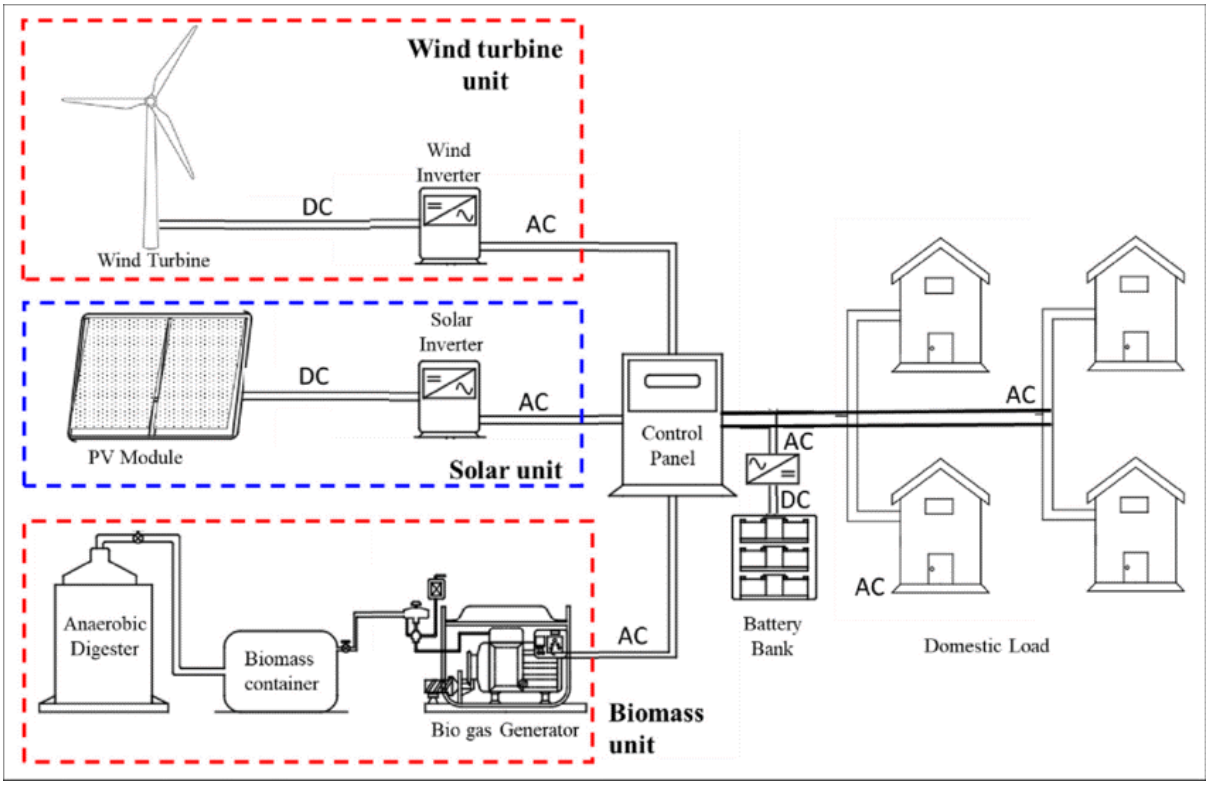

Figure 1: Schematic of an Integrated Hybrid Renewable Energy system

Source: Vijay, et al (2019)

Challenges of Renewable Energies

With the much benefits derived from renewable energies, they also have some limitations and challenges. According to REGEN POWER (2024), they include;

a. Dependency on weather conditions and time of day:

The dependency of solar systems on sunlight, makes them less effective during days with minimal or no sunlight or during the night, which may require energy storage (IRENA, 2021). This dependency of the solar cooling systems on sunlight reduces efficiency and increases cost. Although not greatly affected by weather, Geo-thermal on the other hand can face efficiency issues in areas with limited geothermal gradient or seasonal variations affecting ground temperatures (Boyd et al., 2020).

b. High initial cost:

Solar and geothermal energy systems for cooling have high installation cost and capital intensive. The have significant upfront costs for equipment, labor, and infrastructure, but operational savings may balance these costs over time, (Lund et al., 2021). This high initial cost limits their adoptions especially in low-income and developing regions.

c. Non-renewable energy monopoly:

Fossil fuels are still the major dominated energies globally and as such subsidies and infrastructure investments favour non-renewable sources, downgrading renewable energy development. This domination by the fossil fuels industries slows the growth of solar and geothermal systems.

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d. Requires professionals for installation and maintenance:

The design, installation and maintenance of solar and geothermal energies require specialised skills and labour, which are scarce, and as such increases the labor costs.

e. Little knowledge and awareness of its potentials especially in the developing regions:

There is huge lack of knowledge and awareness about solar and geothermal cooling systems in many developing nations, which hinders their adoption and use in buildings

f. Lack of policies, subsidies:

There are few or no governmental policies, incentives, and subsidies to support renewable energy systems, thus creating financial and regulatory barriers to adoption, making businesses and households struggle to justify the transition to solar and geothermal cooling.

Renewable energy is expected to dominate future energy landscapes, power buildings and cooling systems, when harnessed to their capacity, thereby helping in combating climate change.

Cooling Systems in Buildings

Building cooling systems refers to those systems that are designed to regulate indoor temperatures as well as ensuring indoor thermal comfort and energy efficiency (Fouad et al., 2024). The use of building cooling systems usually depends on the building design, local climate, and energy sources. Cooling systems in buildings are categorized into two types: passive cooling, which utilizes natural processes like ventilation, and mechanical cooling, which relies on energy-intensive systems such as air conditioning. The emerging trends in building's cooling systems involves the integration and use of Renewable energy-based cooling systems such as the Solar-powered systems and geothermal systems (Mali et al., 2021).

Solar-Powered Energy in Cooling Systems

Solar energy which is sourced from harnessing the sun is one of the renewable energies greatly used to power buildings. Solar cooling technologies such as the solar-assisted air conditioning and desiccant cooling systems are greatly being adopted by harnessing sun energy (Zhang et al., 2022). Solar energy has been introduced as a crucial alternative for many applications, including cooling and air-conditioning, which has been proven to be a reliable and excellent energy source (Al-Yasiri et al., 2022).

A research by Andres et al. (2023), assessed the integration of solar thermal and photovoltaic system for cooling needs of a green house, where the system achieved a coefficient of performance, COP of 0.75, which show the proficiency to maintain optimal temperatures for plant growth while utilizing renewable energy sources. Another work by Daniel et al (2017), which uses solar cooling system in an absorption chiller, and the system provided over 90% of the seasonal cooling requirements for an experimental residential building, with average COP levels of 1.0, highlighting its efficiency in utilizing solar energy for both cooling and heating purposes.

Solar cooling systems are usually converting sun energy by the use of solar panels into energy, which then powers the cooling systems. These systems have absorption chillers that converts solar heat into cooling. The photovoltaic panels are used to power the conventional cooling systems in buildings, which are referred to as Solar Electric/Vapour Compression Refrigeration (SE-VCR) systems (Al-Yasiri et al., 2022).

Figure 2 below show the working principle, as well as components of a solar-powered cooling system. It is a working mechanism of solar-powered cooling system that uses photovoltaic panels to harness sun radiation and converts it into electricity (DC), which powers the air conditioning system. The harnessed sun radiation turned into Direct current (DC) is regulated by the solar regulator and the inverter, then stored in the battery for use by the cooling system.

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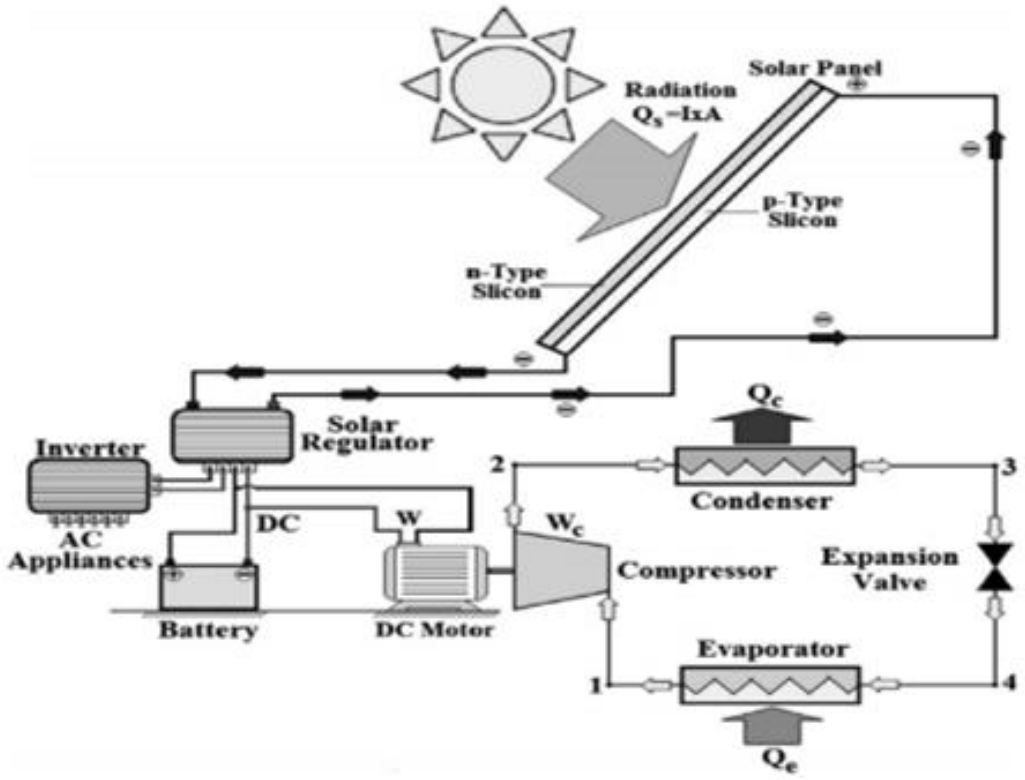

Figure 2: Schematic of a solar-powered cooling system

Source: Al-Yasiri et al., (2022)

Benefits of Solar Energy in Cooling Systems

Akshay, (2023), highlighted the benefits of solar energy in cooling systems as;

a. The reduction of greenhouse gas emissions helps in conserving the environment
b. It is cost efficient since it lowers utility bill expenses
c. It is highly energy efficient

Geothermal Energy in Cooling Systems

Geothermal energy is a renewable energy source by utilizing the earth's stable underground temperature to provide cooling needs in buildings (Mali et al., 2021). These system have the ability to reduce electricity consumption, urban heat islands and greenhouse gas emissions. This energy source for cooling systems integrates a device that uses heat exchanger to move water through underground pipelines that absorb heat from the structure and dissipate in into cooler space (Akshay, 2023).

A recent study on geothermal energy system by Fouad et al. (2024), which examines a residential building in Alexandria, Egypt, demonstrated that vertical closed-loop of geothermal systems could significantly reduce the cooling needs and energy consumption in a building. A real-life case study from a publication of Environmental Resilience Institute of Indiana University (2024) and Brynn, (2017), demonstrates the efficiency of integration of geothermal for cooling systems, where Ball State University in Muncie, Indiana, integrated the use of geothermal system, replacing its aging coal-fired boilers for cooling and heating needs in the campus. This helped the institute's annual savings to be between $2.2 million and $2.5 million and projected a reduction in its carbon emissions by more than 50%.

Figure 3 shows the working principle of a Geothermal System. It highlights the key components of the system, which includes heat exchanger, refrigerant compressor, and reversing valve, all working together to

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make the system operations efficiently and effectively. This system functions by cycling refrigerant through a closed-loop system with the ground to heat and cool. The compressor helps to expand the refrigerant and heat it up, an expansion valve to transform the cold refrigerant, and a reversing valve to toggle between heating and cooling. The heat exchangers transfer heat between the refrigerant and the ground as well as indoor air. The heated or cooled air is then distributed by a fan throughout the room for cooling needs.

Benefits of Geothermal Energy

Dandelion Energy, (2024), explored the benefits of Geothermal energy as follows;

a. It is energy efficient
b. It has positive environmental and human health impact

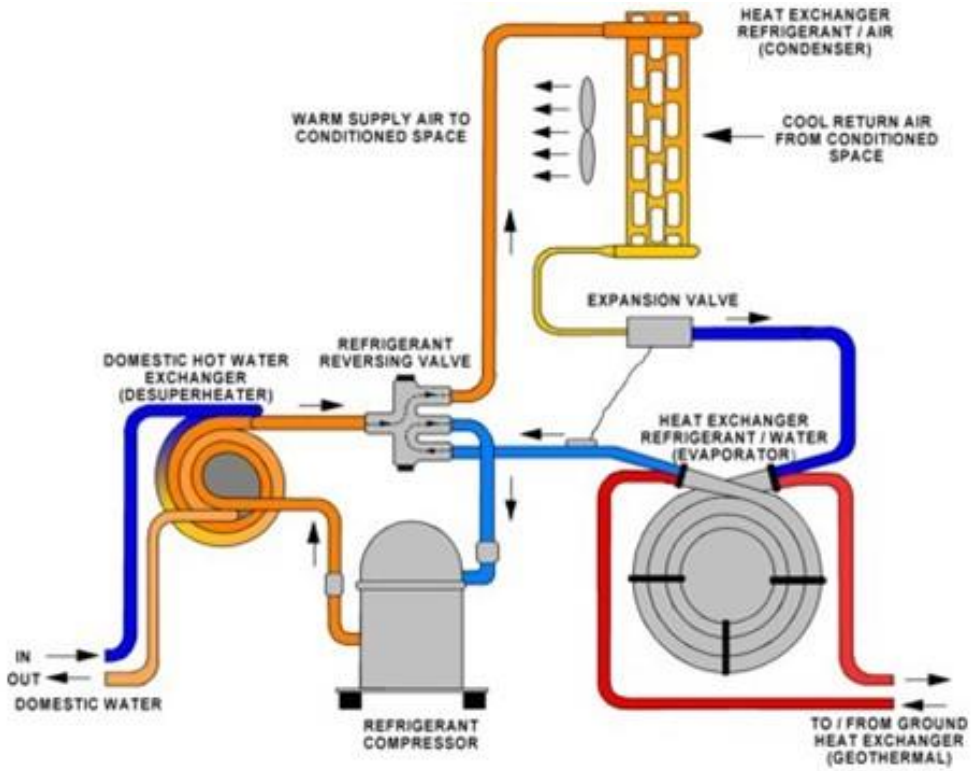

Figure 3: Schematics of Geothermal System

Source: https://www.ecomech.net/residential-geothermal-how-it-works/

CONCLUSION

Research Results

This paper in its entity is a review of existing research works from different researchers and does not present new research works. The outcomes of this review highlights the need for integrating renewable energies into the cooling systems of buildings as well as the effectiveness of the use of solar-powered or geothermal energies as sources of renewable energy in cooling systems. These energy sources show great potentials for reducing dependency on fossil fuels, energy efficient use and their potentials in helping to mitigate global climate change.

Gaps and Trends

The solar-powered, geothermal cooling systems as emerging technologies of renewable energies have been found useful in cooling applications and hence minimizing the cost of energy use and green House gas

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emissions. The several case studies in this review indicate that these systems are economically viable, particularly in areas with significant solar glare, even though issues like high initial start-up costs and technical difficulties still exist. Policy supports such as the provision of incentives and subsidies, and certification requirements that guarantee quality of performance are the emerging trends and are important for ensuring adoption of solar and geothermal energies. There are also applications of hybrid systems that incorporate renewable energy sources with conventional cooling systems for efficiency and cost savings.

Conclusion

The integration of renewable energies, like the solar and geothermal energies into the cooling systems of buildings, provides significant potentials for enhancing sustainability, curb climate change, reduction in greenhouse gases emission and over dependence on fossil fuels. They all provide effective and consistent performances with minimal environmental effects, although have certain limitations of cost, geographic and weather conditions. With the limitations on ground, the need for more innovation, research and development as well as policies on renewable energies are the trends in the contemporary world.

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