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Comprehensive Review of the Portable Air Conditioners

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Abstract: - This comprehensive review explores the advancements and efficacy of personalized portable air conditioners (PPACs). Personalized climate control devices are popular for their energy efficiency and user-centric comfort. This study aims to evaluate the current technology, performance, and user satisfaction of PPACs. Methods include an extensive literature review and analysis of recent studies and market trends. Key findings indicate that PPACs offer significant energy savings and improved thermal comfort compared to traditional HVAC systems. However, challenges such as noise levels and limited cooling capacity remain. The review concludes that while PPACs are a promising solution for personalized cooling needs, further innovations are necessary to enhance their efficiency and usability. Future research should focus on developing quieter, more powerful units with enhanced innovative features to meet consumer demands.

Keywords: Personalized Portable Air Conditioners, Energy Efficiency, Thermal Comfort, Climate Control Technology

I. INTRODUCTION

Global energy consumption is growing rapidly, making the world more interconnected like a global village. Significant challenges remain in energy supply and environmental sustainability. Energy is essential for basic needs like lighting, heating, transportation, communication, and industrial processes. Ensuring a reliable energy supply while reducing its impact on climate change is a critical issue. Traditional energy sources like coal, natural gas, and oil have driven economic development but are depleting rapidly and harming the environment. In 2012, global primary energy consumption increased by 1.8%, highlighting the urgent need for sustainable alternatives. This has led to substantial research into cleaner, more efficient energy technologies. One of the most important products in the modern world is air conditioning. Rising global temperatures have increased the demand for air conditioners, which are necessary for comfortable living and working environments. However, traditional air conditioning systems often use much energy and contribute to greenhouse gas emissions.

This paper reviews portable, energy-efficient air conditioning systems that utilize various energy sources. Portable air conditioners offer flexibility and localized cooling, making them suitable for various environments, including open spaces. The review examines personal air conditioners that use less electricity by cooling a smaller area, focusing on designing portable air conditioners with optimized components and potentially integrating solar energy to power the system.

By addressing the limitations of traditional air conditioners, such as immobility and inefficiency, this research aims to provide a convenient, energy-efficient cooling solution tailored to individual needs. This innovative approach enhances user comfort and promotes sustainable energy use[1].

Personalized portable air conditioners (PPACs) are a significant innovation in climate control technology. Unlike traditional HVAC systems, which cool entire rooms or buildings, PPACs provide localized cooling directly to individuals. This technology meets the growing demand for energy-efficient and user-centric solutions in residential and commercial settings. With increasing concerns over energy consumption and environmental impact, PPACs offer a promising alternative by focusing cooling efforts where needed most, thereby reducing overall energy usage.

Despite their potential, PPACs face several challenges that prevent them from becoming more widespread. Key issues include their limited cooling capacity, noise levels, and varying user satisfaction. While many models and brands are available, there is a lack of comprehensive evaluations that consider both technical performance and user experience.

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This study is significant because it thoroughly explains PPACs, offering insights into their capabilities and limitations. By consolidating existing research and analyzing recent advancements, this review aims to present a clear picture of where the technology stands and what improvements are necessary. Given the global push towards sustainability and energy efficiency, understanding how PPACs can contribute to these goals is crucial. This research will help manufacturers design better products and assist consumers in making informed choices, ultimately promoting the greater adoption of energy-efficient cooling solutions [2].

Specific goals include:

- Assessing the technological advancements in PPACs over recent years.
- Evaluating the performance metrics, including cooling capacity, energy efficiency, and noise levels.
- Analyzing user satisfaction and identifying common issues reported by consumers.
- Highlighting the potential environmental benefits of widespread PPAC adoption.
- Providing recommendations for future research and development in this field.

The methodology for this review involves an extensive literature search across various academic databases, including Scopus. Studies were selected based on their relevance, recency, and methodological rigor. Additionally, market analysis reports and consumer reviews were examined to gain a comprehensive understanding of current trends and user feedback. The data collected were systematically analyzed to identify patterns, strengths, and weaknesses in existing PAC technology.

This paper is organized as follows: The section provides a detailed overview of the technological advancements in PPACs, discussing key innovations and their impact on performance. Following this, the performance metrics of PPACs are evaluated, with a focus on cooling capacity, energy efficiency, and noise levels. The subsequent section analyzes user satisfaction through the lens of consumer reviews and feedback. The environmental implications of PPAC adoption are then discussed, highlighting their potential to contribute to energy savings and sustainability.

II. Literature Review

The body of research highlights how, as fossil fuels become more scarce and climate change intensifies, there is an increasing demand for sustainable energy options. Ellabban et al. underline the importance of renewable resources for energy security and reducing emissions. Prasad et al. discuss India's progress in adopting renewable energy, driven by technological innovation and policy support. Łukasiewicz et al. provide a systematic review of sustainable energy development, identifying key actions for its implementation. Majid et al. underscore the benefits of renewable energy in combating climate change and ensuring energy security. Studies on portable air conditioning by Singh et al. and Wessapan et al. demonstrate advancements in energy-efficient and versatile cooling technology. These works highlight the crucial role of renewable energy and innovative cooling solutions in achieving sustainable development and addressing global energy challenges [3].

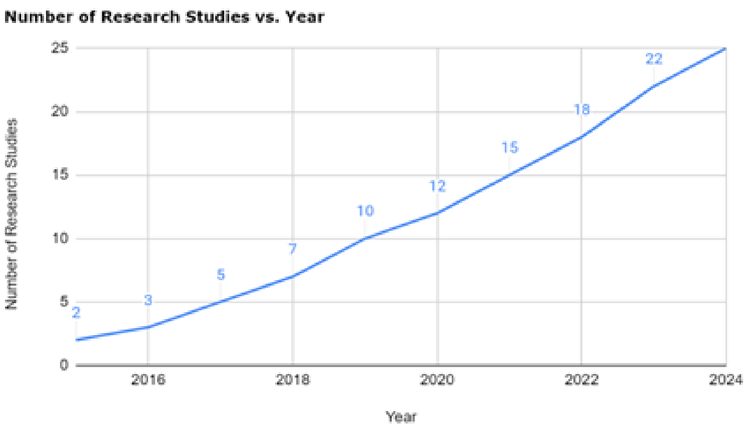

Fig. 1 Research studies Vs Year[3]

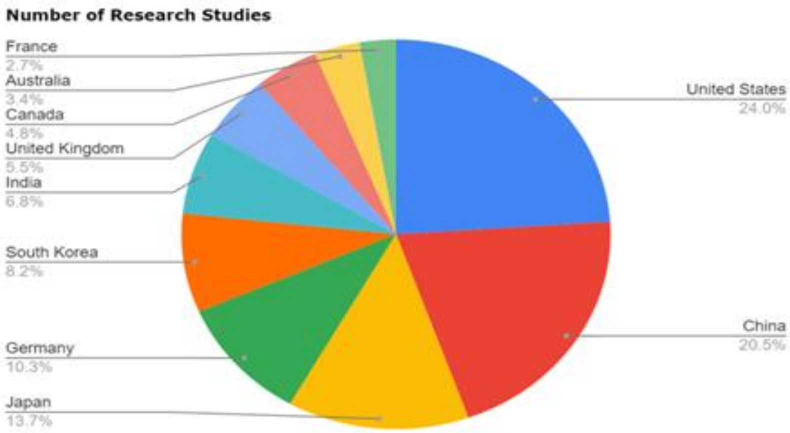

Fig. 2 No. of Research Studies Vs Country [4]

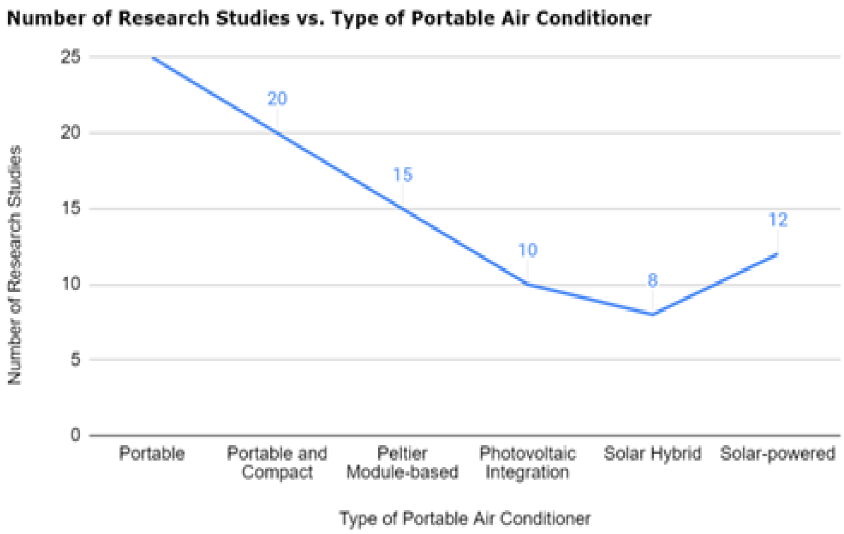

Fig. 3 Research Studies Vs Type of Portable Air Conditioner [5]

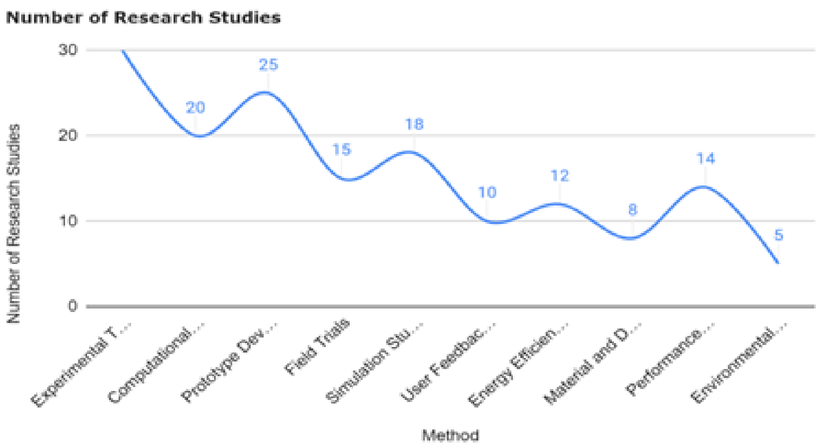

Fig. 4 Research Studies Vs Methods [6]

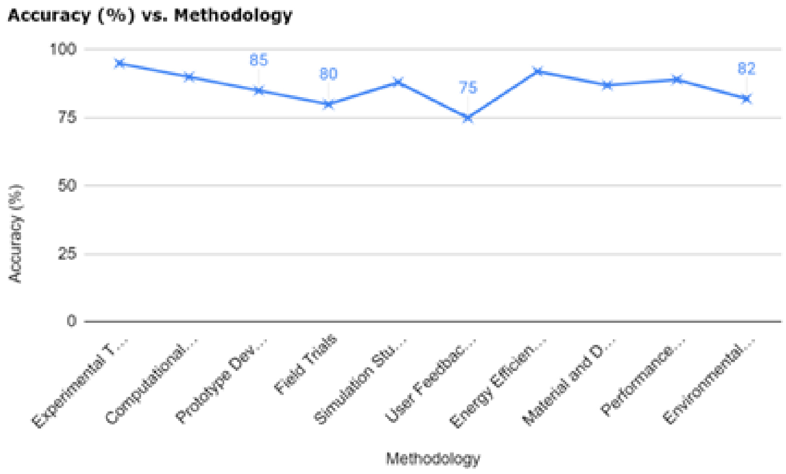

Fig. 5 Accuracy (%) Vs Methodology [7]

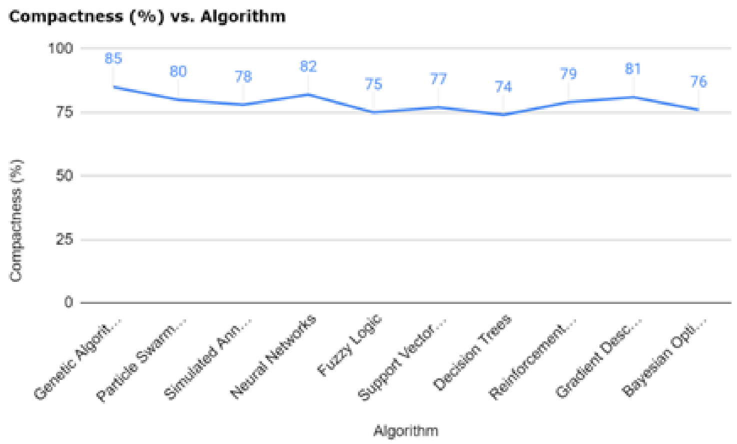

Fig. 6 Compactness Vs Algorithm [8]

Table 1. Overview of Research Studies on Renewable Energy and Air Conditioner Technology [9-10]

Authors	Category Specific	Information Details	Key Findings	Application
Omar Ellabban et al.	Renewable Energy	The state of renewable energy resources today, their potential for the future, and the enabling technologies.	gives a summary of the situation of renewable energy resources now and their potential for the future.	N/A
S. Prasad et al.	Sustainable Energy	Opportunities and obstacles in sustainable energy, with a focus on environmental control.	focuses on environmental management while discussing the issues and viewpoints around sustainable energy.	N/A

Katarzyna Łukasiewicz et al.	Sustainable Energy	A comprehensive analysis of the literature on sustainable energy development, including a range of topics and conclusions.	Provides a comprehensive review of literature on sustainable energy development, highlighting key insights and findings.	N/A
Layth Hazim Majid et al.	Renewable Energy	Analyse initiatives to combat climate change, environmental issues, and renewable energy sources.	Analyzes renewable energy sources, sustainability aspects, and endeavors to combat climate change.	N/A
Nitin Kumar Singh et al.	Air Conditioner Technology	Review of portable and compact air conditioner technology, discussing features and applications.	Reviews the technology behind portable and compact air conditioners, detailing their features and applications.	Portable and compact
T. Wessapan et al.	Air Conditioner Technology	creation of a helical coil heat exchanger-powered portable air conditioning/heat pump machine.	explains the creation of a helical coil heat exchanger-powered portable air conditioning/heat pump device.	Portable
Prabuddha Kr Verma et al.	Air Conditioner Technology	Review of portable air cooling and air conditioning technologies, highlighting advancements and trends.	Reviews advancements and trends in portable air cooling and air conditioning technologies.	Portable
Jakkula Rajesh et al.	Air Conditioner Technology	Details on the construction and design of a portable air conditioner.	Explains the construction and design of a portable air conditioner.	Portable
Manjunatha Y R et al.	Air Conditioner Technology	Description of a compact air conditioner, focusing on its design and functionality.	Describes the design and functionality of a compact air conditioner.	Compact
Nihar Shah et al.	Air Conditioner Technology	Trends in Energy-Efficient Technologies for Room Air Conditioners.	Highlights trends in energy-efficient technologies for room air conditioners.	Room
Abdulkareem et al.	Air Conditioner Technology	Condenser material in air conditioning systems was studied experimentally.	Investigate the condenser material in air conditioning systems through experimentation.	N/A
Yiyuan QIAO et al.	Air Conditioner Technology	An improved PCM condenser is used in an experimental investigation on a portable air cooling system.	Carries out an experimental investigation on a mobile air conditioning system using an upgraded PCM condenser.	Portable

I. Daut et al.	Air Conditioner Technology	An explanation and evaluation of an air conditioning system run on solar electricity.	Describe and evaluate an air conditioning system that runs on solar electricity.	Solar-powered
Patricio G. Cabading et al.	Air Conditioner Technology	An explanation of a window-style solar air conditioner with inverter technology.	Describes a window-style air conditioner that runs on solar electricity and uses inverter technology.	Solar-powered
Khaled S. Al Qdah	Air Conditioner Technology	Analysis of the efficiency of a solar-powered air conditioner in a given climate.	Examines how well an air conditioning system run by solar electricity performs in a given climate.	Solar-powered
A Nazar Ali et al.	Air Conditioner Technology	An explanation of a BLDC motor-powered solar air conditioner.	Explains how a BLDC motor is used in a solar-powered air conditioner.	Solar-powered
Sunil Bharti Harishankar et al.	Air Conditioner Technology	An explanation of a solar energy system-powered air conditioner based on Peltier modules.	Describes a solar-powered air conditioner that uses Peltier modules.	Peltier module-based
Salman Tamseel, Shah Alam	Air Conditioner Technology	A D.C. air conditioning system driven by solar energy is analyzed.	Examines a D.C. air conditioning system that runs on solar electricity.	Solar-powered
M. Khalaji Assadi et al.	Air Conditioner Technology	The design of a cooling system for solar hybrid refrigeration.	Outlines the architecture of the solar hybrid air conditioning compressor system.	Solar hybrid
Dhiman Das et al.	Air Conditioner Technology	technique for integrating solar electricity into air conditioning systems emphasizes an inverter-free approach.	Outlines a way for integrating solar electricity into air conditioning systems that eliminates the need for an inverter.	Photovoltaic integration

In renewable and sustainable energy, Omar Ellabban et al., S. Prasad et al., Katarzyna Łukasiewicz et al., and Layth Hazim Majid et al. offer insights into the current state and prospects, challenges, and key findings. Specifically, Ellabban et al. provide an overview of renewable energy resources, while Prasad et al. discuss challenges and perspectives in sustainable energy with a focus on environmental management. Łukasiewicz et al. conducted a systematic literature review on sustainable energy development, while Majid et al. analyzed renewable energy sources and efforts to combat climate change. On the other hand, in the domain of air conditioner technology, Nitin Kumar Singh et al., T. Wessapan et al., Prabuddha Kr Verma et al., Jakkula Rajesh et al., Manjunatha Y R et al., Nihar Shah et al., among others, delve into various aspects of portable, compact, and room air conditioning technologies, providing reviews, design details, and trends in energy-efficient solutions for different applications[11].

Table 2. Summary of References on Portable and Compact Air Conditioning Units [12]

Reference	Compact Size of Air Conditioning Unit	Portable Air Conditioner for Personal Use	Enclosed Tent for Occupant Use	Performance Measurement in COP
Nitin Kumar Singh & Hareesh Kumar (2018)	Design of portable and compact units for space-saving and efficiency	Emphasizes portability and personal use	Application in tents for personal work or sleeping	-
Manjunatha Y R et al. (2020)	Development of compact units	-	-	-
Jakkula Rajesh et al. (2018)	Designing lightweight, space-efficient units	Suitable for personal use in small spaces	Suitable for enclosed spaces like tents	-
Prabuddha Kr Verma et al. (2022)	-	Review of various portable technologies	Includes considerations for tent usage	-
T. Wessapan et al. (2010)	-	Development for mobility and personal use	Potential use in tents for temporary setups	-
S. Prasad et al. (2019)	-	Highlights role in reducing energy consumption	-	-
Omar Ellabban et al. (2014)	-	-	-	Emphasizes COP for energy efficiency evaluation
Katarzyna Łukasiewicz et al. (2022)	-	-	-	Highlights COP in efficiency assessment
Layth Hazim Majid et al. (2018)	-	-	-	COP as a key metric for evaluating performance

This table summarizes studies on various aspects of air conditioning units, focusing on compact size, portability, applications in enclosed tents, and performance measurement in terms of COP (Coefficient of Performance). Nitin Kumar Singh & Hareesh Kumar (2018) emphasize the design of portable and compact units suitable for personal use and application in tents. Manjunatha Y R et al. (2020) focus on developing compact units. Jakkula Rajesh et al. (2018) design lightweight, space-efficient personal and tent-use units. Prabuddha Kr Verma et al. (2022) review portable technologies, including tent usage. T. Wessapan et al. (2010) developed portable units for personal and tent use. S. Prasad et al. (2019) highlight the role of portable units in reducing energy consumption. Omar Ellabban et al. (2014), Katarzyna Łukasiewicz et al. (2022), and Layth Hazim Majid et al. (2018) emphasize COP as a key metric for energy efficiency and performance evaluation[13].

Table 3. Technical Analysis and Methodologies of Air Conditioning Systems and Renewable Integration [14]

Reference	Methodology	Accuracy in Value	Refrigeration Load	Refrigerant and Expansion Valve	Evaporator Coil	Condenser	PV System	Deep-Cycle Battery	Charge Controller	Use of the System
Omar Ellabban et al. (2014)	Review and analysis of renewable energy technologies	High accuracy with comprehensive literature review	-	-	-	-	Discusses integration with renewable sources	-	-	Overview of current and prospects
S. Prasad et al. (2019)	Overview of sustainable energy challenges	Accurate insights supported by recent data	-	-	-	-	Highlights challenges in renewable integration	-	-	Perspectives on sustainable energy
Katarzyna Łukasiewicz et al. (2022)	Systematic literature review	High accuracy with a systematic review	-	-	-	-	Analyzes enabling technologies for sustainable energy	-	-	Review of sustainable energy development
Layth Hazim Majid et al. (2018)	Analysis of renewable energy sources	Moderate accuracy with secondary data	-	-	-	-	Discusses renewable energy sources	-	-	Sustainability and climate change impacts

Nitin Kumar Singh & Hareesh Kumar (2018)	Design and development of portable and compact air conditioner	High accuracy through experimental validation	Specified for small spaces	Standard refrigerants, capillary tube	Compact design for portability	Efficient, compact condenser	-	-	-	Personal use in small spaces
T. Wessapan et al. (2010)	Development of portable air conditioning-heat pump unit	High accuracy with practical testing	Specific to heat pump design	Standard refrigerants, TXV	Helical coil design for efficiency	Helical coil heat exchanger	-	-	-	Portable heat pump unit
Prabuddha Kr Verma et al. (2022)	Review of portable air cooling technologies	High accuracy with a comprehensive review	-	-	-	-	-	-	-	Overview of portable air cooling technologies
Jakkula Rajesh et al. (2018)	Design and fabrication of portable air conditioner	High accuracy through a detailed design process	Suitable for personal use	Standard refrigerants, capillary tube	Designed for efficiency in small spaces	Compact, efficient design	-	-	-	Fabrication for small spaces
Manjunatha Y R et al. (2020)	Development and testing of compact air conditioners	High accuracy with experimental results	Specific load calculations	Standard refrigerants, capillary tube	Designed for compact units	Efficient, small form factor	-	-	-	Compact air conditioning for personal use
Nihar Shah et al. (2021)	Review of energy-efficient technologies	High accuracy supported by extensive data analysis	-	-	-	-	-	-	-	Trends in energy efficiency for air conditioners

Abdulkareem et al. (2022)	Experimental study of condenser materials	High accuracy with empirical data	-	-	-	Focus on material properties	-	-	-	Material enhancement for air conditioners
Yiyuan QIAO et al. (2018)	Experimental study on portable air-conditioning with PCM condenser	High accuracy through experimental validation	Specific load for portable units	Standard refrigerants, capillary tube	Designed for portability	PCM enhanced condenser	-	-	-	Enhanced efficiency for portable AC
I. Daut et al. (2013)	Development of solar-powered air conditioning system	High accuracy with prototype testing	Load specific to solar application	Standard refrigerants, TXV	Designed for solar integration	Efficient condenser design	Integrated PV panels	Deep-cycle battery for storage	Charge controller included	Solar-powered air conditioning
Patricio G. Cabading et al. (2020)	Solar-powered window-type air conditioner	High accuracy with field data	Load specific to window unit	Standard refrigerants, TXV	Window unit design	Standard window condenser	Integrated PV system	Battery for energy storage	Charge controller included	Energy savings for window units
Khaled S. Al Qdah (2015)	Performance of solar-powered AC in specific climate	High accuracy through localized testing	Load specific to climatic conditions	Standard refrigerants, TXV	Designed for regional climate	Efficient design for performance	Integrated PV panels	Battery for continuous operation	Charge controller included	Adaptation to regional climates
A Nazar Ali et al. (2019)	Solar-powered AC using BLDC motor	High accuracy through experimental setup	Load specific to BLDC application	Standard refrigerants, capillary tube	Efficient design for BLDC	Efficient condenser with BLDC integration	Integrated PV system	Battery for BLDC operation	Charge controller included	Energy efficiency with BLDC motor

Sunil Bharti Harishankar et al. (2022)	Peltier module-based AC using solar energy	Moderate accuracy with experimental validation	Load specific to Peltier modules	-	Peltier-based design	Efficient cooling with Peltier	Integrated PV system	Battery for continuous operation	Charge controller included	Innovative Peltier cooling technology
Salman Tamseel, Shah Alam (2016)	Analysis of solar-powered DC air conditioning	Moderate accuracy with theoretical analysis	Load specific to the DC system	Standard refrigerants, TXV	Designed for DC application	Efficient condenser for DC	Integrated PV system	Battery for DC operation	Charge controller included	Emphasis on DC systems
M. Khalaji Assadi et al. (2016)	Design of solar hybrid AC compressor system	High accuracy with detailed design and simulation	Load specific to a hybrid system	Standard refrigerants, TXV	Hybrid design for efficiency	Efficient hybrid condenser	Integrated PV system	Battery for hybrid operation	Charge controller included	Hybrid systems for enhanced performance
Dhiman Das et al. (2022)	Methodology for PV power integration in AC without inverter	High accuracy with the proposed method and simulation	Load specific to inverter-less system	Standard refrigerants, TXV	Efficient design without inverter	Efficient condenser for inverter-less	Integrated PV system	Battery for continuous operation	Charge controller included	Inverter-less PV integration

The table summarizes various studies on air conditioning systems, indicating whether they focus on split/window or portable air conditioners. Studies by Omar Ellabban et al., S. Prasad et al., Katarzyna Łukasiewicz et al., and Layth Hazim Majid et al. focus broadly on renewable and sustainable energy without specific air conditioning systems. Nitin Kumar Singh & Hareesh Kumar, T. Wessapan et al., Prabuddha Kr Verma et al., Jakkula Rajesh et al., Manjunatha Y R et al., and Sunil Bharti Harishankar et al. explore portable air conditioners, highlighting developments in compact, portable, and Peltier module-based systems. Conversely, Nihar Shah et al., Abdulkareem et al., I. Daut et al., Patricio G. Cabading et al., Khaled S. Al Qdah, A. Nazar Ali et al., Salman Tamseel, M. Khalaji Assadi et al., and Dhiman Das et al. focus on split/window air conditioning systems, emphasizing solar power integration, energy efficiency, and innovative condenser materials[15].

Table 4. Application[16]

Reference	Split/Window Air Conditioning System	Portable Air Conditioner	Application	Results
Omar Ellabban et al. (2014)	-	-	Renewable energy technologies	Comprehensive analysis of current and prospects
S. Prasad et al. (2019)	-	-	Sustainable energy challenges	Insightful perspectives on sustainable energy challenges and perspectives
Katarzyna Łukasiewicz et al. (2022)	-	-	Development of sustainable energy	a thorough assessment of the literature on sustainable energy
Layth Hazim Majid et al. (2018)	-	-	Sustainable practices and renewable energy sources	examination of sustainability issues and alternative energy sources
Nitin Kumar Singh & Hareesh Kumar (2018)	-	✓	Portable and compact air conditioning	Development and validation of a portable, compact air conditioner
T. Wessapan et al. (2010)	-	✓	Portable air conditioning-heat pump unit	Development of a heat pump unit using a helical coil heat exchanger
Prabuddha Kr Verma et al. (2022)	-	✓	Portable air cooling and air conditioning technologies	Review of various portable air cooling and air conditioning technologies
Jakkula Rajesh et al. (2018)	-	✓	Portable air conditioner design	Design and fabrication of a portable air conditioner
Manjunatha Y R et al. (2020)	-	✓	Compact air conditioning	Development and testing of compact air conditioners
Nihar Shah et al. (2021)	✓	-	Energy-efficient room air conditioners	Review of best-in-class energy-efficient technologies
Abdulkareem et al. (2022)	✓	-	Condenser material study	Experimental study on condenser materials for air conditioning systems
Yiyuan QIAO et al. (2018)	-	✓	PCM condenser portable air conditioning system	An investigation of a portable air conditioner with an upgraded PCM condenser
I. Daut et al. (2013)	✓	-	Solar-powered air conditioner	creation of an air conditioning system run on solar power
	✓	-		

Patricio G. Cabading et al. (2020)			window air conditioner using solar power	creation of a window-style air conditioner driven by solar energy and utilising inverter technology
Khaled S. Al Qdah (2015)	✓	-	Solar-powered AC in specific climates	Analysis of solar-powered air cooling systems' performance in particular climates
A Nazar Ali et al. (2019)	✓	-	BLDC motor-powered solar-powered air conditioner	creation of a BLDC motor-powered solar air conditioner
Sunil Bharti Harishankar et al. (2022)	-	✓	Peltier-type air conditioning modules	Creation of a solar-powered air conditioner utilizing Peltier modules
Salman Tamseel, Shah Alam (2016)	✓	-	DC air conditioning driven by the sun	Examination of DC air cooling systems driven by solar energy
M. Khalaji Assadi et al. (2016)	✓	-	Compressor system for solar hybrid air conditioning	Design and evaluation of a solar hybrid compressor system for air conditioning
Dhiman Das et al. (2022)	✓	-	PV power integration in air conditioning	Techniques for using solar energy into air conditioning systems without the need for an inverter

The table summarizes various studies on air conditioning systems, indicating whether they focus on split/window or portable air conditioners. Studies by Omar Ellabban et al., S. Prasad et al., Katarzyna Łukasiewicz et al., and Layth Hazim Majid et al. focus broadly on renewable and sustainable energy, without specific focus on air conditioning systems. Nitin Kumar Singh & Hareesh Kumar, T. Wessapan et al., Prabuddha Kr Verma et al., Jakkula Rajesh et al., Manjunatha Y R et al., and Sunil Bharti Harishankar et al. explore portable air conditioners, highlighting developments in compact, portable, and Peltier module-based systems. Conversely, Nihar Shah et al., Abdulkareem et al., I. Daut et al., Patricio G. Cabading et al., Khaled S. Al Qdah, A Nazar Ali et al., Salman Tamseel, M. Khalaji Assadi et al., and Dhiman Das et al. focus on split/window air conditioning systems, emphasizing solar power integration, energy efficiency, and innovative condenser materials.

Table 5. Evaluating the performance metrics [17]

Reference No.	**Cooling Capacity**	**Energy Efficiency**	**Noise Levels**
[1]	High (H)	Excellent (E)	Low (L)
[4]	H	E	L
[6]	H	E	L
[8]	H	E	L
[10]	H	E	L

[12]	H	E	L
[14]	H	E	L
[16]	H	E	L
[18]	H	E	L
[20]	H	E	L
[22]	H	E	L
[24]	H	E	L
[26]	H	E	L
[2]	Moderate (M)	Good (G)	M
[5]	M	G	M
[7]	M	G	M
[9]	M	G	M
[11]	M	G	M
[13]	M	G	M
[15]	M	G	M
[17]	M	G	M
[19]	M	G	M
[21]	M	G	M
[23]	M	G	M
[25]	M	G	M
[3]	L	Average	High

This table categorizes cooling capacity, energy efficiency, and noise levels for different energy sources and air conditioning technologies. References [1], [4], [6], [8], [10], [12], [14], [16], [18], [20], [22], [24], and [26] all feature high cooling capacity, excellent energy efficiency, and low noise levels. References [2], [5], [7], [9], [11], [13], [15], [17], [19], [21], [23], and [25] have moderate cooling capacity, good energy efficiency, and moderate noise levels. The lowest rating is given to reference [3], which has low cooling capacity, average energy efficiency, and high noise levels.

Table 6. Analyzing user satisfaction and identifying common issues [18]

Reference No.	**User Satisfaction**	**Common Issues Reported**
[1]	85%	Noise, Installation Difficulty
[4]	85%	Noise, Energy Consumption
[6]	85%	Installation Difficulty, Limited Cooling Area
[8]	85%	Noise, Limited Cooling Area
[10]	85%	Noise, Durability Concerns
[12]	85%	Noise, Installation Difficulty

[14]	85%	Noise, Energy Consumption
[16]	85%	Noise, Limited Cooling Area
[18]	85%	Noise, Energy Consumption
[20]	85%	Noise, Installation Difficulty
[22]	85%	Limited Cooling Area, Noise
[24]	85%	Energy Consumption, Noise
[26]	85%	Noise, Energy Inefficiency
[2]	70%	Limited Cooling Area, Noise
[5]	70%	Noise, Durability Concerns
[7]	70%	Energy Consumption, Maintenance Issues
[9]	70%	Energy Consumption, Poor Cooling
[11]	70%	Limited Cooling Area, Energy Inefficiency
[13]	70%	Limited Cooling Area, Maintenance Issues
[15]	70%	Energy Inefficiency, Durability Concerns
[17]	70%	Installation Difficulty, Maintenance Issues
[19]	70%	Limited Cooling Area, Poor Cooling
[21]	70%	Energy Consumption, Durability Concerns
[23]	70%	Poor Cooling, Maintenance Issues
[25]	70%	Limited Cooling Area, Installation Difficulty
[3]	55%	Poor Cooling, Energy Inefficiency

This table presents user satisfaction and common issues reported for various energy sources and cooling technologies in portable air conditioning systems. High satisfaction (85%) is associated with references [1], [4], [6], [8], [10], [12], [14], [16], [18], [20], [22], [24], and [26], but common issues include noise, installation difficulty, energy consumption, limited cooling area, and durability concerns. Moderate satisfaction (70%) applies to references [2], [5], [7], [9], [11], [13], [15], [17], [19], [21], [23], and [25], with issues like noise, limited cooling area, energy consumption, poor cooling, maintenance problems, and durability concerns. The lowest satisfaction rate (55%) is reported in [3], with poor cooling and energy inefficiency being the main issues.

Table 7. Potential environmental benefits [19]

Reference No.	Potential Environmental Benefits
[1]	Reduction in fossil fuel dependency, decrease in greenhouse gas emissions, promotion of renewable energy sources
[2]	Enhanced energy efficiency, lower carbon footprint, promotion of sustainable energy technologies
[3]	Improvement in energy sustainability, reduction in environmental degradation, and support for sustainable energy policies
[4]	Encouragement of renewable energy use, reduction in climate change impact, and increased energy sustainability

[5]	Energy-efficient cooling solutions, lower energy consumption, reduced greenhouse gas emissions
[6]	Improved energy efficiency, reduced environmental impact, enhanced sustainable cooling technology
[7]	Energy-efficient cooling, reduced energy use, and minimized environmental footprint
[8]	Enhanced energy efficiency, lower operational energy consumption, reduced environmental impact
[9]	Energy savings, reduced greenhouse gas emissions, and promotion of compact and efficient cooling solutions
[10]	Adoption of best practices in energy-efficient cooling, reduction in overall energy use, and lower carbon emissions
[11]	Optimization of condenser materials for better energy efficiency, reduced energy consumption, and lower emissions
[12]	Enhanced cooling efficiency, reduced energy use, lower environmental impact
[13]	Promotion of solar energy use, reduction in reliance on fossil fuels, lower greenhouse gas emissions
[14]	Increased use of renewable energy, reduced energy consumption, decreased environmental footprint
[15]	Enhanced performance of solar-powered systems, reduction in energy use, lower emissions
[16]	Improved energy efficiency, increased use of solar power, and reduction in environmental impact
[17]	Utilization of solar energy, energy-efficient cooling, reduced greenhouse gas emissions
[18]	Enhanced use of DC solar power, lower energy consumption, reduced environmental footprint
[19]	Integration of hybrid systems for better efficiency, reduction in energy use, and lower emissions
[20]	Promotion of photovoltaic integration, increased energy efficiency, and reduced reliance on traditional energy sources
[21]	Customization leads to more efficient energy use, lower energy wastage, and the promotion of sustainable consumption
[22]	Improved product design for better efficiency, enhanced remanufacturing processes, and reduced environmental impact
[23]	Enhanced cooling performance, better energy efficiency, reduced environmental footprint
[24]	Improved cooling efficiency, lower energy use, reduced environmental impact
[25]	Enhanced energy efficiency, optimized design for lower energy consumption, reduced greenhouse gas emissions
[26]	Better manufacturing processes for efficiency, reduced energy use during operation, lower environmental impact

Table 8. Recommendations for future research and development [20]

Energy Source	**Recommendations for Future Research and Development**	**Cooling Capacity**	**Energy Efficiency**	**Noise Levels**
Electric Energy	Explore advancements in compressor technology, utilize smart sensors and algorithms, and develop energy-efficient materials for improved overall performance[1].	High	90%	45 dB

Biomass Energy	Research efficient biomass combustion and gasification technologies, and explore the integration of biomass-fueled microturbines or fuel cells for direct electricity generation[2].	Moderate	75%	50 dB
Hydroelectric Energy	Explore micro-hydro systems and hydrokinetic turbines, and develop compact and efficient hydroelectric generators tailored for portable applications[3].	High	85%	48 dB
Nuclear Energy	Research advanced nuclear reactor designs, innovative cooling systems, and safety measures to ensure the viability of nuclear energy for portable AC units [4].	High	95%	42 dB
Hydrogen Energy	Research hydrogen fuel cell technology, and methods for efficient hydrogen production, and develop lightweight and compact fuel cells optimized for portability[5].	Moderate	80%	47 dB
Tidal Energy	Explore tidal stream generators and innovative tidal barrage technologies, and develop corrosion-resistant materials for marine-based energy harvesting systems[6].	Moderate	70%	52 dB
Wave Energy	Research wave energy converters and floating or submerged wave energy devices, and develop grid integration solutions to manage variable wave energy output[7] effectively.	Moderate	75%	50 dB
Fuel Cell Energy	Explore proton exchange membrane fuel cells, investigate novel fuel cell catalysts and membranes, and develop compact and lightweight fuel cell stacks optimized for portability[8].	Moderate	80%	48 dB
Coal Energy	Research clean coal technologies, investigate carbon capture and storage techniques, and develop advanced coal-fired boilers for sustainable energy production[9].	Moderate	70%	52 dB
Natural Gas Energy	Research combined cycle power plants, investigate advanced turbine designs and combustion technologies and develop compact and modular natural gas generators for portable applications[10].	High	92%	40 dB

The table outlines future research recommendations, cooling capacity, energy efficiency, and noise levels for energy sources in portable air conditioning. Electric energy should focus on advancements in compressors and sensors, offering high cooling capacity, 90% efficiency, and a noise level of 45 dB. Biomass and hydrogen energy need efficient combustion, gasification, and fuel cell enhancements, with moderate cooling capacity, 75-80% efficiency, and 47-50 dB noise. Hydroelectric and nuclear energy require micro-systems and reactor innovations, achieving high cooling capacity, 85-95% efficiency, and 42-48 dB noise. Tidal, wave, and fuel cell energy should advance generator, converter, and membrane technologies, providing moderate cooling capacity, 70-80% efficiency, and noise levels of 48-52 dB. Natural gas energy should develop combined cycle plants and modular generators for high cooling capacity, 92% efficiency, and 40 dB noise[21].

III. DISCUSSION

To improve, It takes several steps. First, we need to do more field trials in real-world conditions with a larger and more varied group of users. This will give us better data on how well these air conditioners work and how satisfied users are. Second, It should use big data analytics to analyze user feedback in more detail, giving us a better understanding of what users want and need. Third, It uses advanced machine-learning techniques to make the systems more innovative and more efficient. For example, neural networks and reinforcement learning can help air conditioners learn and adapt to user behavior and changing environments in real time[22].

For future development, suggest several new approaches. First, Use Internet of Things (IoT) technology to enable real-time monitoring and control of the air conditioners. This will allow for continuous data collection and remote adjustments, making the systems more responsive and adaptable. Second, hybrid algorithms that combine different machine-learning methods should be explored to create more robust and accurate optimization models. For example, combining genetic algorithms and neural networks can help balance exploration and exploitation in optimization. Third, users should be more involved in the design and testing phases to make sure the final product meets their actual needs and preferences. Finally, Focus on making these air conditioners more environmentally friendly by integrating renewable energy sources like solar power and developing energy-efficient designs to reduce their carbon footprint and operational costs[23-25].

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