Technologies for Air Conditioning Powered by Alternative Energy Sources: A Brief Review

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Air conditioning systems promote human comfort, representing an energy consumption of up to 30% in a building. Although electric chillers are still widely used for thermal comfort, absorption chillers are a promising alternative for air conditioning using renewable energy sources (solar energy, natural gas, waste heat, geothermal, and biomass). The search for efficient, economical, and ecological solutions becomes evident regarding these considerations. This article proposes a brief bibliographical review of chillers powered by alternative energy sources to electricity. Awareness of the application of alternative energy sources in these systems contributes to sustainable practice and energy matrix diversification.
Keywords: Absorption Chiller. Air Conditioning. Alternative Energy Sources.

Introduction

The balance between environmental conservation and sustainable economic development has been a recurring societal issue. In order to preserve the environment at the expense of exacerbated consumption, environmental policies are becoming increasingly strict regarding primary energy consumption [1].

Because of the global energy scenario, the need to expand the energy matrix and promote sustainable development is evident; seeking alternative and renewable energy sources, as well as the use and better application of these, have become required in this century [2]. When analyzing the energy matrix in its global context, it is clear that only 13.8% is derived from renewable sources, namely: biomass (9.3%), hydraulics (2.5%), and others - solar, wind, and geothermal (2.0%) [3]. Compared to the Brazilian scenario, 46.2% of the energy matrix comes from a renewable source. However, when analyzing the renewable part of the Brazilian energy matrix, only 7% derives from solar, wind, and geothermal energy, and the other 39.2% comes from hydraulics (12.4%), sugarcane derivatives (18%) and firewood and charcoal (8%) [4].

Although the Brazilian matrix comes considerably from renewable sources, the socio-environmental impacts of some of these sources are considerable when compared to other energy sources [5].

The correlation between the evolution of energy demand and economic growth measured by GDP has been recurrent, and the increase in energy consumption can be attributed to air conditioning systems [6]. The demand for the expansion in using air conditioning and refrigeration systems occurred due to population growth, global warming, the increase in the social standard of living, and architectural characteristics, among others [7,8]. In addition, air conditioning systems consume around 30% of an enterprise's energy demand in different sectors (homes, schools, canteens, public offices, hospitals, and markets) [9].

Materials and Methods

This article presents a literature review on alternative energy sources used in chillers for air conditioning. First, we did quantitative research to find alternative sources for HVAC chillers. Then, we searched for articles from the last six years related to the topic (quantitative and qualitative analysis) and excluded duplicates. Figure 1 shows the described method.

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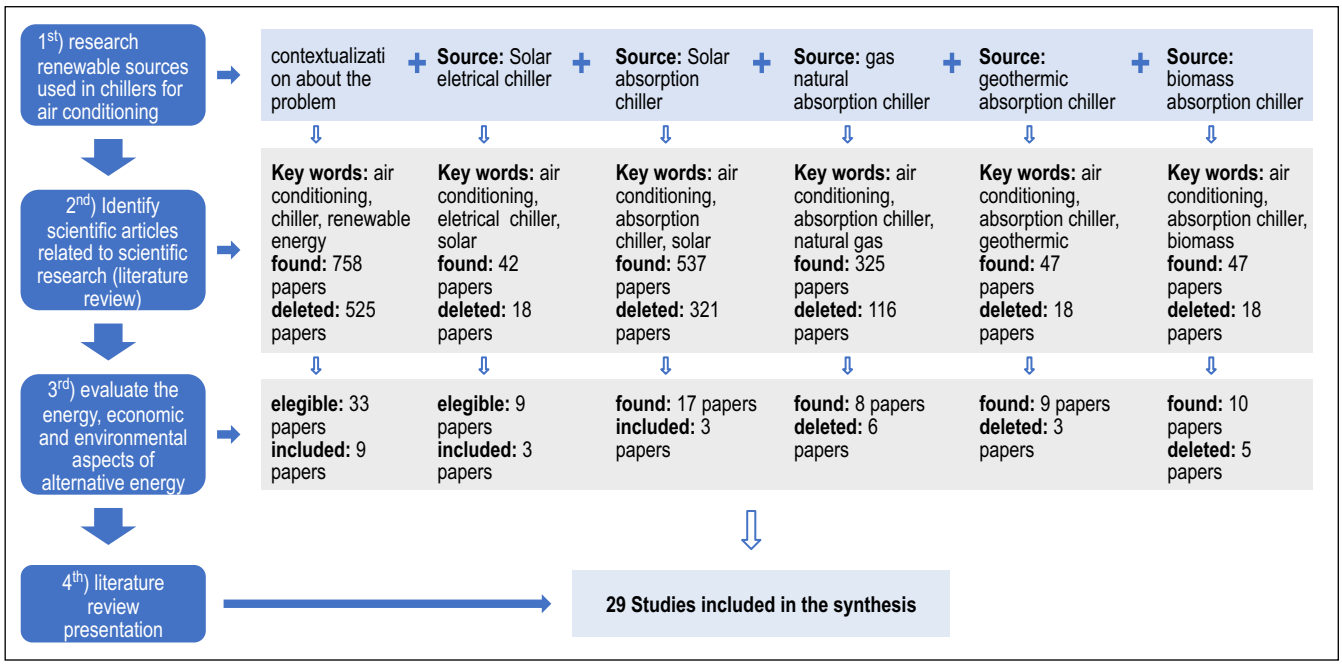
Figure 1. Literature review method.



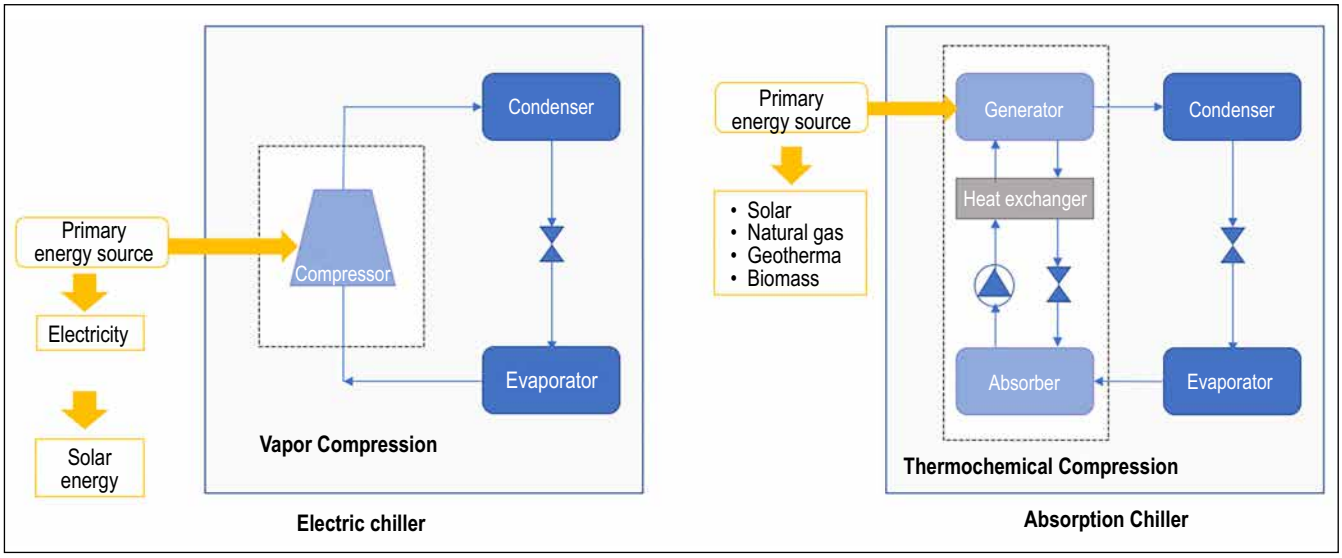
Source: By authors.

Results and Discussion (Figure 2 and Box 1)

Based on thermodynamic principles, the equipment used in air conditioning systems for cold production (chillers) is mainly powered by electricity. The literature estimates that this equipment contributes about 10% to the greenhouse effect and consumes 15% of the energy distributed globally. Therefore, chillers are responsible for the highest energy consumption in air conditioning installations. Some chillers are powered by electrical energy (considered noble energy), having the thermodynamic cycle of vapor compression (CCV) as the basic principle of the thermal machine. There are also absorption chillers based on the thermodynamic absorption cycle (CA). This equipment is promising for diversifying the energy matrix using renewable energy sources [10].

The absorption technology is advancing and gaining more expansive implementation for cooling. However, mechanical vapor-compression-air-conditioning systems are still widely used in many commercial, residential, and industrial installations. It occurs due to the low input energy requirement of the absorption chillers, which are ecological and powered by sources of solar energy, waste heat, geothermal, and biomass [9-11]. The use of solar energy as a primary energy source is in rapid development and implementation due to its potential to diversify the energy matrix and because the cooling loads coincide with the greater availability of solar energy offered [11]. Usually, the low heat provided by the solar collector, especially the photovoltaic (PV) panels, does not meet the temperature required to activate chillers, leading to unsatisfactory system performance. Therefore, it is necessary to use an auxiliary energy system (SAE) to supply the demand [12]. CCV chillers that use PV energy as a primary source (and electrical energy as SAE) can play a positive role in sustainability. Due to their simple installation and reliability, PV became applicable, efficient, and economically viable. When associated with thermal collectors (T) - PV/T systems - they offer new fields of application offering economic and energy benefits [13,14]. The single-effect air-cooled lithium-bromide-water absorption chiller (LiBr-H_2O) presents advantages in residential applications and

Figure 2. Alternative energy sources in chillers.



Source: By authors.

has shown to be promising in reducing electrical consumption [15]. Combined with natural gas (SAE), they present satisfactory energy performance [12]. Furthermore, infrastructures that use essentially natural gas absorption chillers can be easily adapted to work with solar energy [11]. Absorption chillers are a promising alternative, exhibiting considerable energy-saving benefits, potential economic viability, and environmentally friendly features [16]. Given the search for alternative energy sources and considering that there are polluting fuels in the atmosphere, such as coal, heavy oil, and tar, natural gas presents itself favorably [7]. When comparing natural gas with other biofuels, there is less CO_2 emission. Furthermore, natural gas is preferred by stakeholders and politicians, as geopolitics often plays an essential role in choosing the appropriate energy source [17]. Natural gas as a primary energy source for the absorption chiller is a promising solution. It presents valid results with high efficiency and an excellent financial return (simple payback of 3.4 years) [18]. When associated with thermal waste as a source of secondary energy allows the reduction of the consumption rate of natural gas and reduces the annual operating cost. This solution can be crucial in energy efficiency and reducing thermal and environmental pollution [19]. Geothermal energy has diverse industrial and domestic applications, including a cold promotion with absorption chillers. Its process consists of providing earth/ground heat for heating and cooling [20]. Geothermal energy is a resource that provides an economic gain, as it is verified an increase in energy efficiency in refrigeration systems and energy generation with absorption chillers. However, it cannot be used efficiently for electricity generation [21]. On the other hand, technologies that use geothermal energy in air conditioning systems have a good performance and can be very competitive when well implemented compared to conventional technologies [22]. Biomass is one of the renewable energy sources with the potential to diversify the energy matrix and promote industrial symbiosis. Its main product – synthesis gas – can be used as fuel in several sectors, including trigeneration. The application of synthesis gas has high energy and environmental value. However, they are not widely applied due to their high complexity and high initial investment [23]. In addition to synthesis gas, biogas, also derived from biomass, can be used as fuel to reduce total greenhouse gas emissions [24]. Although it does not present

significant efficiency gains compared to natural gas, biomass may be a promising alternative in the future because it has impressive environmental advantages and has not reached technological maturity [25]. Pantaleo and colleagues (2017) [26] proposed a mixture of fuel, 50% natural gas, and 50% biomass in a mixed gas microturbine to overcome the barriers to energy efficiency, economic viability, and good profitability. In addition to energy efficiency results, environmental impacts are reduced when biomass is used in trigeneration concerning energy production [27].

Conclusion

We presented the refrigeration systems for air conditioning powered by alternative energy sources as alternatives to market solutions that use electricity as the primary energy for this equipment. The most significant appeal of the application of these technologies is the diversification of the energy matrix and sustainable practice. Despite the diversity of alternative energy sources, the absorption chiller still needs to overcome a market barrier to the detriment of compaction technology.

Box 1. Comparative alternative sources in chillers by literature.

	Energy efficiency	**Economic viability**	**Environmental impact**
Electric chiller - Solar energy	They are efficient, when the PVT system is used, its efficiency is maximized [14]	The economy depends on each country's energy prices and energy policy [18]	Even being renewable, electricity as SAE, has a socio-environmental impact [5]
Absorption Chiller - Solar Energy	When associated with natural gas, they show satisfactory performance [15]	They may have payback between 4 and 5 years [28]	Significantly reduces CO_2 emissions per year [15]
Absorption Chiller - Natural Gas	They are efficient and when combined with thermal waste they are promissing [28, 19]	Feasilble, however, government incentives directly influence [29]	The association with thermal waste provides a reduction in thermal and environmental pollution [19]
Absorption Chiller - Geothermal	Efficient, especially when used for trigeneration [21]	It may be feasible when there is no incentive to other sources [20]	Reduced environmental impacts [22]
Absorption Chiller - Biomass	Compared to natural gas, biomass has not shown significant energy efficiency gains [24]	In mixtures (50% natural gas and 50% biomass) it is profitable both trigeneration and cogeneration [27]	They are reduced, especially when used for trigeneration [27]

Source: By authors.

One way to enable superior technology in economic incentive technologies is in the commercialization of solar collectors, government incentives for the use of natural gas and solar energy, and more significant technological investment to make the use of geothermal energy and biomass feasible. Even with the challenges faced, the community must be aware of the various alternatives for air conditioning so that there are technological advances without compromising the environment.

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References

1. Petela K, Manfrida G, Szlek A. Advantages of variable driving temperature in solar absorption chiller. Renewable Energy 2017;114:716-724.
2. Silva DH. Protocolos de Montreal e Kyoto: pontos em comum e diferenças fundamentais. Revista Brasileira de Política Internacional 2009;52(2):155-172.
3. International Energy Agency. World energy balances database (2018). 2020. Disponível em: https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20consumption&indicator=TFCbySource. Acesso em: 11 fev. 2021.
4. Empresa de Pesquisa Energética (org.). Balanço Energético Nacional 2020: Ano base 2019. Empresa de Pesquisa Energética, Rio de Janeiro. 2020. 292 p. Disponível em: https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-479/topico-528/BEN2020_sp.pdf. Acesso em: 11 fev. 2021.
5. Silveira PG. Energia e mudanças climáticas: impactos socioambientais das hidrelétricas e diversificação da matriz energética brasileira. Opinión Jurídica 2018;17(33):123-148.
6. Mura PG, Innamorati R. Design of a new Ssstem of high-power efficiency conditioning cogeneration energy for a building of the University of Cagliari with fossil fuel plants. Energy Procedia 2015;78:1111-1116.
7. Mehmood S, et al. Energetic, economic and environmental (3E) assessment and design of solar-powered HVAC systems in Pakistan. Energies 2020;13(17):4333-4363.
8. Allouhi A, et al. Solar driven cooling systems: Updated review. Renewable and Sustainable Energy Reviews 2015;44:159-181.
9. Mansouri R, et al. Modelling and testing the performance of a 7omercial ammonia/water absorption chiller using Aspen-Plus platform. Energy 2015;93:2374-2383.
10. She X, Cong L, Nie B, Leng G, Peng H, Chen Y, Zhang X, Wen T, Yang H, Luo Y. Energy-efficient and economic technologies for air conditioning with vapor compression refrigeration: a comprehensive review. Applied Energy 2018;232:157-186.
11. Shirazi A, et al. A comprehensive, multi-objective optimization of solar-powered absorption chiller systems for air-conditioning applications. Energy Conversion And Management 2017;132:281-306.
12. Li ZL, et al. Comprehensive evaluation of low-grade solar trigeneration system by photovoltaic-thermal collectors. Energy Conversion and Management 2020;215(112895).
13. Al-Falahi A, et al. A new design of an integrated solar absorption cooling system driven by an evacuated tube collector: A case study for Baghdad, Iraq. Applied Sciences 2020;10(10):3622-3645.
14. Mao Y, Wu J, Zhang W. An effective operation strategy for CCHP system integrated with photovoltaic/thermal panels and thermal energy storage. Energies 2020;13(23):6418.
15. Alhami MI, et al. Energy analysis for the solar thermal cooling system in Universitas Indonesia. International Journal of Air-Conditioning and Refrigeration 2019;27(3).
16. Sarbu I, et al. General review of solar-powered closed sorption refrigeration systems. Energy Conversion and Management 2015;105:403-422.
17. Balitskiy S, et al. Energy efficiency and natural gas consumption in the comercial of economic development in the European Union. Renewable And Sustainable Energy Reviews 2016;55:156-168.
18. Alcântara SCS, et al. Natural gas based trigeneration system proposal to an ice cream factory: an energetic and economic assessment. Energy Conversion and Management 2019;197:111860.
19. Semmari H, et al. Flare gas waste heat recovery: Assessment of organic rankine cycle for electricity production and possible coupling with absorption chiller. Energies 2020;13(9):2265.
20. Zare V. A comparative thermodynamic analysis of two tri-generation systems utilizing low-grade geothermal energy. Energy Conversion and Management 2016;118:264-274.
21. Kececiler A, Acar H, Dogean A. Thermodynamic analysis of the absorption refrigeration system with geothermal energy: an experimental study. Energy Conversion & Management 2000;41:37-48.
22. Thornton JW, McDowell TP, Hughes P. J. Comparison of practical vertical ground heat exchanger sizing methods to a Fort Polk data/model benchmark. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 1997;103.

23. Segurado R, Pereira S, Correia D, Costa M. Techno-economic analysis of a trigeneration system based on biomass gasification. Renewable And Sustainable Energy Reviews 2019;103:501-514.
24. Jabari F, et al. Design and performance investigation of a biogas fueled combined cooling and power generation system. Energy Conversion and Management 2018;169:371-382.
25. Freire RMMS, Santos AAB, Almeida AGS. Thermoeconomic evaluation of three proposals for the energy cogeneration unit powered by natural gas, biogas, or syngas. Journal of The Brazilian Society of Mechanical Sciences and Engineering 2020;42(8):440.
26. Pantaleo AM, et al. Energy performance and thermo-economic assessment of a microturbine-based dual-fuel gas-biomass trigeneration system. Energy Procedia 2017;105:764-772.
27. Gholamian E, Zare V, Mousavi SM. Integration of biomass gasification with a solid oxide fuel cell in a combined cooling, heating and power system: A thermodynamic and environmental analysis. International Journal of Hydrogen Energy 2016;41(44):20396-20406.
28. Ibrahim NI, Al-Sulaiman FA, Ani FS. A detailed parametric study of a solar driven double-effect absorption chiller under various solar radiation data. Journal of Cleaner Production 2020;251:119750.
29. Linjawi MT, Talal Q, Al-Sulaiman FA. Evaluation of solar thermal driven cooling system in office buildings in Saudi Arabia. E3S Web of Conferences 2017;23:5001.