TECHNOLOGIES FOR AIR CONDIOTIONING POWERED BY ALTERNATIVE ENERGY SOURCES: A BRIEF REVIEW

Ana Caroline Neves dos Santos[a], Alex Álisson Bandeira Santos[a]

[a] SENAI CIMATEC – Campus Integrado de Manufatura e Tecnologias, Brazil.

Abstract: Air conditioning systems have been widely applied to promote human comfort and this can represent an energy consumption of up to 30% in building. Although electric chillers are still widely used for thermal comfort, absorption chillers have proved to be a promising alternative for air conditioning by using renewable energy sources (solar energy, natural gas, waste heat, geothermal and biomass). Taking these considerations into account, the search for efficient, economic and ecological solutions becomes evident. This article proposes a brief bibliographical review on chillers powered by alternative energy sources to electricity. Awareness of the application of alternative energy sources in these systems contributes to sustainable practice and the diversification of the energy matrix.

Keywords: absorption chiller, air conditioning, alternative energy sources.

TECNOLOGIAS PARA CONDICIONAMENTO DE AR MOVIDOS ÀS FONTES ALTERNATIVAS DE ENERGIA: UMA BREVE REVISÃO

Resumo: Os sistemas de condicionamento de ar vêm sendo aplicados largamente para promoção de conforto humano e isso pode representar um consumo energético de até 30% no edifício. Embora os chillers elétricos ainda sejam amplamente usados para conforto térmico, os chillers de absorção têm se revelado como alternativa promissora para condicionamento de ar por utilizar fontes renováveis de energia (energia solar, gás natural, calor residual, geotérmica e de biomassa). Levando em consideração tais considerações, a busca por soluções eficientes, econômicas e ecológicas se torna evidente. Este artigo propõe uma sucinta revisão bibliográfica sobre chillers movidos às fontes de energia alternativas à energia elétrica. A conscientização da aplicação das fontes alternativas de energia nesses sistemas contribui com a pratica sustentável e com a diversificação da matriz energética.

Palavras-chave: chiller de absorção, condicionamento de ar, fontes alternativas de energia.

1. INTRODUCTION

The balance between environmental conservation and sustainable economic development has been a recurring issue in society. In order to preserve the environment at the expense of exacerbated consumption, environmental policies are becoming increasingly strict regarding primary energy consumption [1]. In view of the global energy scenario, the need to expand energy matrix and promote sustainable development is evident, seeking alternative and renewable energy sources, as well as the use and better application of these becomes evidently 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%), hydraulic (2.5%), others - solar, wind and geothermal (2.0%) [3]; compared to the Brazilian scenario, it appears that 46.2% of the energy matrix comes from a renewable source. However, when analyzing the renewable part of the Brazilian energy matrix, it is noticed that only 7% is derived from solar, wind and geothermal energy, and the other 39.2% comes from hydraulics (12.4%), from sugarcane derivatives (18%) and from 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]

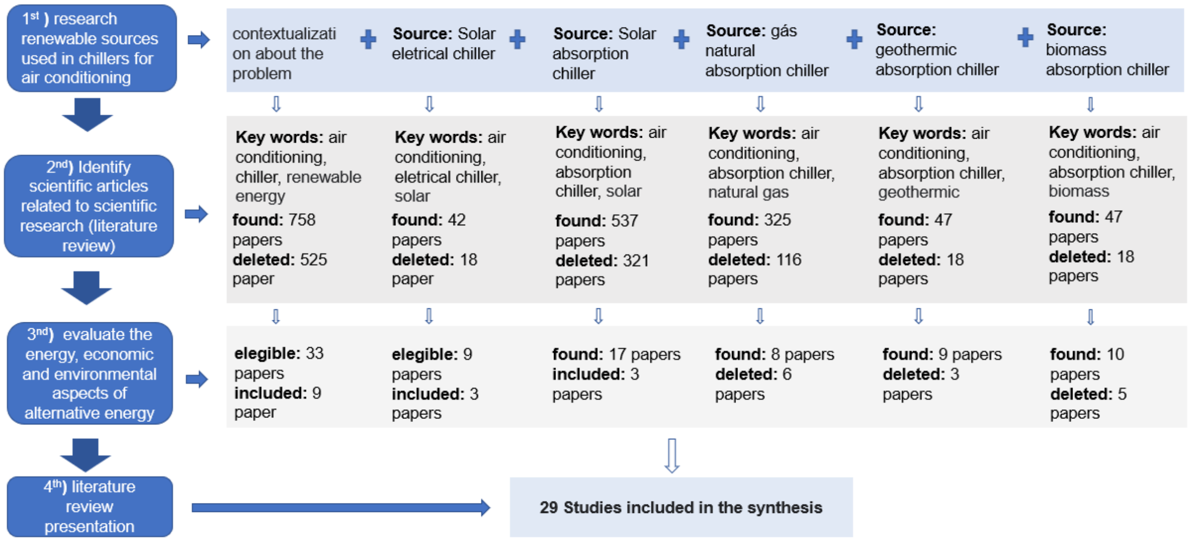
The correlation between the evolution of energy demand and economic growth measured by GDP has been recurrent, and the increase in energy consumption can be attributed to air conditioning systems [6]. The demand for the expansion of the use of air conditioning and refrigeration systems can be perceived due to population growth, global warming, the increase in the social standard of living (increase in equipment inside buildings, lighting, increased demand for occupant comfort) and architectural characteristics, such as: the huge facades and the use of heat-absorbing surfaces [7,8]. In addition, it is known that around 30% of the energy demand of an enterprise is destined to air conditioning systems in different sectors (homes, schools, canteens, public offices, hospitals, markets, etc.) and our society needs the minimum guarantee of comfort [9].

2. METHODOLOGY

This article presents a literature review on alternative energy sources used in chillers for air conditioning. Initially, quantitative research was carried out on which alternative sources are found in HVAC chillers. After this identification, its applications were studied. A search was initially carried out for articles of the last six years related to the topic (quantitative analysis), then, after reading the title and abstract, duplicate articles that were not part of the study were excluded (quantitative and qualitative analysis), and by end after reading the articles (qualitative analysis) some were eligible. Fig.1 better shows the described methodology.

ISSN: 2357-7592

Figure 1. Literature review methodology

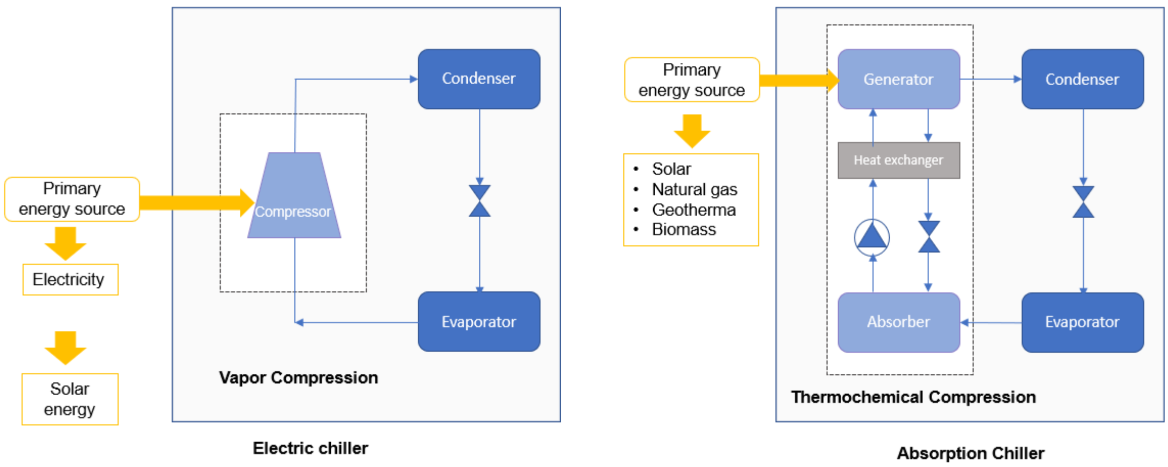


Source: Prepared by the author

3. RESULTS AND DISCUSSION

Based on thermodynamic principles, the equipment used in air conditioning systems for cold production (chillers) are mostly powered by electricity. It is estimated that 15% of the energy distributed globally is destined to this equipment and contributes about 10% to the greenhouse effect. 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 that are based on the thermodynamic cycle of absorption (CA), this equipment has been shown to be promising for the diversification of the energy matrix by using renewable energy sources [10].

Figure 2. Alternative energy sources in chillers.



Source: Prepared by the author

Although mechanical vapor compression air conditioning systems have been and still are widely used in many installations, including commercial, residential and industrial buildings for comfort, absorption technology is advancing and gaining wider implementation for cooling. This is due to the low input energy requirement of the absorption chillers, which are ecological and can be powered by sources of solar energy, waste heat, geothermal and biomass [9,10,11].

The use of solar energy as a primary source of energy is in rapid development and implementation due to its potential to diversify energy matrix and because the cooling loads coincide with greater availability of solar energy offered [11]. Normally, the low heat provided by the solar collector, especially the photovoltaic (PV) panels do not meet the temperature requirement to activate chillers, leading to unsatisfactory system performance. It is necessary to use 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 for sustainability. Due to their simple installation and reliability, PV became applicable, efficient, economically viable and when associated with thermal collectors (T) - PV/T system - they offer new fields of application offering economic and energy benefits [13] [14]. The single-effect air-cooled lithium bromide water absorption chiller (LiBr-H2O) has shown advantages in residential applications and shows to be promising in reducing electrical consumption [15]. When 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 given that the technology has already been proven on a commercial scale, exhibiting considerable energy saving benefits, potential economic viability and environmentally friendly features [16].

In view of 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 CO2 emission. Furthermore, natural gas is preferred by stakeholders and politicians, as geopolitics often plays an important role in choosing the appropriate energy source [17]. Natural gas as a primary source of energy for the absorption chiller is a promising solution as it presents useful results with high efficiency and a good financial return (simple payback of 3.4 years) [18]. When associated with thermal waste as a source secondary energy allows the reduction of the consumption rate of natural gas allowing a reduction in the annual operating cost. This solution can play a key role in energy efficiency and in reducing thermal and environmental pollution [19].

Geothermal energy has a wide range of industrial and domestic applications, including 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]. 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 a high energy and environmental value, however, due to their high

ISSN: 2357-7592

complexity and high initial investment, they are not widely applied [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 when compared to natural gas, biomass may be a promising alternative in the future because it has great environmental advantages and has not reached technological maturity [25]. To overcome the barriers of energy efficiency and economic viability, Pantaleo, et al., (2017) [26] proposed using a mixture of fuel, 50% natural gas and 50% biomass in a hybrid gas microturbine that showed good profitability as in the trigeneration when in cogeneration. In addition to energy efficiency impacts, environmental impacts are reduced when biomass is used in trigeneration in relation to energy production [27].

Table 1. Comparison between alternative energy sources

	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 CO2 emissions per year [15]
Absorption Chiller - Natural Gas	They are efficient and when combined with thermal waste they are promising [28,19]	Feasible, 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: Prepared by the author

ISSN: 2357-7592

4. CONCLUSION

Refrigeration systems for air conditioning powered by alternative energy sources are presented as alternatives to market solutions that use electricity as the main energy for this equipment. The greatest 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. One of the ways to enable greater technology in economic incentive technologies in the commercialization of solar collectors, government incentives for the use of natural gas and solar energy, and greater technological investment in order 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.

Acknowledgments

The authors would like to thank FAPESB and SENAI/CIMATEC for their support and encouragement to the research.

5. REFERENCES

1 PETELA, Karolina; MANFRIDA, Giampaolo; SZLEK, Andrzej. Advantages of variable driving temperature in solar absorption chiller. **Renewable Energy**, v. 114, p. 716-724, dez 2017.

2 SILVA, Darly Henriques da. Protocolos de Montreal e Kyoto: pontos em comum e diferenças fundamentais. **Revista Brasileira de Política Internacional**, [S.L.], v. 52, n. 2, p. 155-172, dez. 2009.

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, Paula Galbiatti. Energia e mudanças climáticas: impactos socioambientais das hidrelétricas e diversificação da matriz energética brasileira. **Opinión Jurídica**, v. 17, n. 33, p. 123-148, 2018.

[6] MURA, Paolo Giuseppe; INNAMORATI, Roberto. Design of a New System of High-power Efficiency Conditioning Cogeneration Energy for a Building of the University of Cagliari with Fossil Fuel Plants. **Energy Procedia,** v. 78, p.1111-1116, nov. 2015.

[7] MEHMOOD, Sajid *et al*. Energetic, Economic and Environmental (3E) Assessment and Design of Solar-Powered HVAC Systems in Pakistan. **Energies**, v. 13, n. 17, p. 4333-4363, 21 ago. 2020.

[8] ALLOUHI, Amine et al. Solar driven cooling systems: Ver updated review. **Renewable and Sustainable Energy Reviews**, v. 44, p. 159-181, 2015.

[9] MANSOURI, Rami et al. Modelling and testing the performance of a 7omercial ammonia/water absorption chiller using Aspen-Plus platform. **Energy,** v. 93, p.2374-2383, dez. 2015.

[10] SHE, Xiaohui; CONG, Lin; NIE, Binjian; LENG, Guanghui; PENG, Hao; CHEN, Yi; ZHANG, Xiaosong; WEN, Tao; YANG, Hongxing; LUO, Yimo. Energy-efficient and -economic technologies for air conditioning with vapor compression refrigeration: a comprehensive review. **Applied Energy**, v. 232, p. 157-186, dez. 2018.

[11] SHIRAZI, Ali et al. A comprehensive, multi-objective optimization of solar-powered absorption chiller systems for air-conditioning applications. **Energy Conversion And Management**, v. 132, p. 281-306, jan. 2017.

[12] LI, Zeyu Lia et al. Comprehensive evaluation of low-grade solar trigeneration system by photovoltaic-thermal collectors. **Energy Conversion and Management**, v. 215, n. 112895, april 2020.

[13] AL-FALAHI, Adil *et al*. A New Design of ver Integrated Solar Absorption Cooling System Driven by ver Evacuated Tube Collector: a case study for 7omerci, iraq. **Applied Sciences**, v. 10, n. 10, p. 3622-3645, 23 maio 2020.

[14] MAO, Yunshou; WU, Jiekang; ZHANG, Wenjie. An Effective Operation Strategy for CCHP System Integrated with Photovoltaic/Thermal Panels and Thermal Energy Storage. **Energies**, [S.L.], v. 13, n. 23, p. 6418, 4 dez. 2020.

[15] ALHAMI, M. Idrus et al. Energy Analysis for the Solar Thermal Cooling System in Universitas Indonesia. **International Journal of Air-Conditioning and Refrigeration**. Vol. 27, No. 3 (2019)

[16] SARBU, Ioan *et al*. General review of solar-powered closed sorption refrigeration systems. **Energy Conversion And Management**, v. 105, p. 403-422, nov. 2015.

[17] BALITSKIY, Sergey et al. Energy efficiency and natural gas consumption in the comercial of economic development in the European Union. **Renewable And Sustainable Energy Reviews,** v. 55, p.156-168, mar. 2016

[18] ALCÂNTARA, S.C.s et al. Natural gas based trigeneration system proposal to an ice cream factory: an energetic and economic assessment. **Energy Conversion And Management**, v. 197, p. 111860, out. 2019.

ISSN: 2357-7592

[19] SEMMARI, Hamza et al. Flare Gas Waste Heat Recovery: assessment of organic rankine cycle for electricity production and possible coupling with absorption chiller. **Energies**, v. 13, n. 9, p. 2265, 4 maio 2020.

[20] ZARE, V.. A comparative thermodynamic analysis of two tri-generation systems utilizing low-grade geothermal energy. **Energy Conversion And Management**, v. 118, p. 264-274, jun. 2016.

[21] KECECILER, Abdullah; ACAR, H. brahim; DOGEAN, Ayla . Thermodynamic analysis of the absorption refrigeration system with geothermal energy: an experimental study. **Energy Conversion & Management** , n. 41, p. 37-48, 2000.

[22] THORNTON, J. W.; MCDOWELL, T. P.; 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)**, 103, 1997

[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**, v. 103, p. 501-514, abr. 2019

[24] JABARI, Farkhondeh et al. Design and performance investigation of a biogas fueled combined cooling and power generation system. **Energy Conversion And Management**, v. 169, p. 371-382, ago. 2018.

[25] FREIRE, Rafael Magalhães de Melo; SANTOS, Alex Álisson Bandeira; ALMEIDA, Antônio Gabriel Souza. 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**, v. 42, n. 8, 440, 31 jul. 2020

[26] PANTALEO, Antonio M et al. Energy Performance and Thermo-economic Assessment of a Microturbine-based Dual-fuel Gas-biomass Trigeneration System. **Energy Procedia**, v. 105, p. 764-772, maio 2017.

[27] GHOLAMIAN, E.; ZARE, V.; MOUSAVI, Seyed Mostafa. 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**, v. 41, n. 44, p. 20396-20406, nov. 2016.

[28] IBRAHIM, Nasiru I.; AL-SULAIMAN, Fahad A.; ANI, Farid Nasir. A detailed parametric study of a solar driven double-effect absorption chiller under various solar radiation data. **Journal Of Cleaner Production**, v. 251, p. 119750, abr. 2020.

[29] LINJAWI, Majid T.; TALAL, Qazi; AL-SULAIMAN, Fahad A.. Evaluation of solar thermal driven cooling system in office buildings in Saudi Arabia. **E3S Web Of Conferences**, [S.L.], v. 23, p. 05001, 2017.