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A Centralized Cooling System As An Alternative To Conventional Air Conditioning: A Sustainable TransitionTowards Green-Energy

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Abstract: According to various studies, the cooling sector is a major energy consumer and a significant contributor to greenhouse gas emissions. These studies will delve into advances in district cooling systems (DCS), their relationship to renewable energy sources, and innovative control strategies to improve efficiency. This review aims to highlight the potential of DCS compared to conventional cooling systems. A district cooling system works as a centralized system that provides thermal energy using chilled water to cool the space. DCS presents practical, environmental, and safety benefits. The assimilation of renewable energy technologies increases its sustainability. Treated wastewater is a medium for supplying thermal energy, especially for cooling and dehumidifying premises. In addition, solar photovoltaic energy, biomass energy, and geothermal energy are identified as suitable energy sources for DCS. The study suggests that district cooling systems that use renewable energy systems show considerable potential to provide sustainable and clean cooling energy for the future world.
Keywords: District cooling system (DCS), Treated wastewater, Renewable energy, Greenhouse gas, Geographic information system (GIS).

I. INTRODUCTION

District cooling systems are centralized energy distribution networks that provide cooling services for multi-story buildings or facilities in a specific area. These systems offer a more efficient and sustainable alternative to traditional air conditioning systems, as they use large chillers located in a central plant to produce chilled water that is then distributed to buildings for cooling. District cooling systems offer several advantages, especially when combined with renewable energy sources like Low consumption of drinking water, [1] Reduced ecological footprint, flexibility in resource combination, and maximizing the usage of renewable energy [2].

Overall, district cooling systems that use renewable energy sources offer numerous advantages. They are economically and environmentally viable alternatives to traditional air conditioning systems with benefits such as increased energy efficiency, reduced dependence on fossil fuels, improved grid stability, increased sustainability, increased resilience to climate change, improved air quality, and reduced noise pollution. The integration of sustainable energy sources with district cooling systems has the potential to revolutionize the way we cool our buildings and communities. They have the potential to reduce energy consumption, reduce greenhouse gas emissions, improve air quality, and create economic opportunities. Renewable energy sources with district cooling systems: Advantages and challenges [3]. One important consideration for the integration of sustainable energy sources with district cooling systems is the availability and reliability of these energy sources [2].The construction and analysis of a district heating/cooling network system based on a thermal bus is an innovative approach that can further enhance the efficiency and sustainability of district cooling systems.

This approach involvesuse of a centralized thermal energy system that produces chilled water to fulfill the air conditioning demand of an entire district [4]. The thermal bus serves as a centralized distribution system for the chilled water, eliminating the need for individual cooling units in buildings. In a review paper titled "Sustainable District Cooling Systems: Status, Challenges, and Future Opportunities, with Emphasis on Cooling-Dominated Regions," authors Valerie Eveloy and Dereje S. Ayou provide a comprehensive analysis of current and future district cooling technologies, operational aspects, economic considerations, and environmental impacts [5].

II. REVIEW OF LITERATURE

Renewable energy sources play an important role in district cooling systems as they provide a sustainable and environmentally friendly alternative to traditional energy sources. Renewable energy sources such as solar energy, wind energy, geothermal energy, and biomass can be used to generate electricity or heat for use in district cooling systems. These renewable energy sources offer a number of advantages for district cooling systems. First, solar energy can be harnessed through photovoltaic panels energy can be harnessed through photovoltaic panels to generate electricity for cooling systems. Solar energy offers a clean and abundant source of energy with the potential for on-site generation, reducing transmission losses. In addition, wind energy can be used to generate electricity for district cooling systems. Wind energy is a clean and renewable source of energy that can be harnessed through wind turbines. Geothermal energy is another renewable energy source that can be used in district cooling systems. It harnesses the heat stored in the earth's crust and uses it to generate electricity or directly provide heat for cooling systems. Biomass is one of the renewable energy sources that can be used in district cooling systems. It involves the use of organic materials such as crops, agricultural residues, and wood waste to generate heat or electricity for cooling systems. Combining these renewable energy sources into district cooling systems offers numerous advantages. First, it reduces greenhouse gas emissions and helps mitigate climate change. Second, it reduces dependence on fossil fuels and increases energy security. Integrating sustainable energy sources into district cooling systems not only reduces greenhouse gas emissions but also increases energy security by reducing dependence on fossil fuels. Thermal energy storage helps optimize the efficiency of district cooling systems by providing a buffer between energy production and consumption. This buffer allows cooling equipment to operate efficiently because excess energy can be stored when demand is low and used when demand is high.

China: A review that mentioned the use of thermal energy storage also helps reduce the overall operating cost of district cooling systems. By shifting energy use from peak to off-peak hours, thermal energy storage allows the use of cheaper electricity rates during off-peak periods. In addition, thermal energy storage in district cooling systems can increase system resilience and reliability. During power outages or power outages, the stored thermal energy can be used to continue providing cooling services. In addition, the combination of thermal energy storage in district cooling systems can also contribute to the optimal use of renewable energy sources. By storing excess renewable energy, thermal energy storage enables more efficient and consistent cooling delivery, maximizes the use of renewable energy, and minimizes the need for backup energy from fossil fuel sources. Overall, the combination of thermal energy storage in district cooling systems offers numerous advantages. It enables efficient use of renewable energy sources, increases overall system performance and sustainability, balances energy supply and demand, optimizes system efficiency, reduces operating costs, and improves system resilience and reliability. Several notable benefits can be achieved by incorporating renewable energy sources and thermal energy storage into district cooling systems [6]. Additionally, the integration of sustainable energy sources in district cooling systems can contribute to the reduction of greenhouse gas emissions [2] through the displacement of fossil fuel-based energy sources [7]. Furthermore, district cooling systems integrated with renewable energy sources and thermal energy storage have the capacity to make a meaningful impact on the transition toward a more sustainable and efficient built environment. Sustainable energy options like geothermal energy, solar energy, and waste heat can be effectively integrated into district cooling systems through the use of thermal energy storage. Moreover, the intelligent control strategies implemented in district cooling systems can significantly improve their energy-saving performance and economic potential. Incorporating low-temperature sustainable energy options like geothermal energy, solar energy, and waste heat into district heating and cooling systems is expected to increase their overall efficiency and reduce their environmental impact [8].

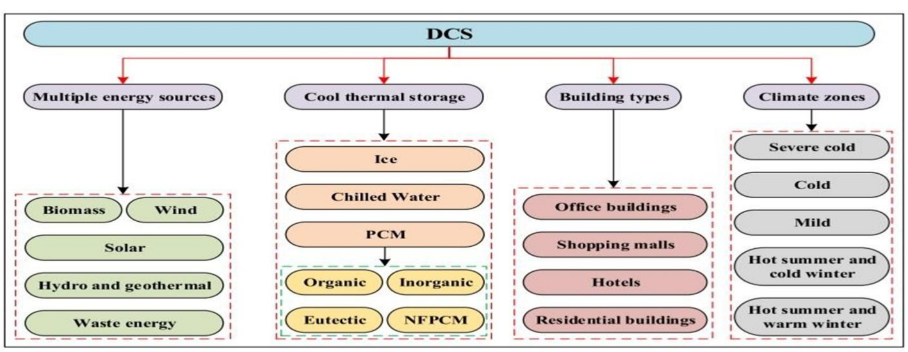

Fig. 1. The various features and factors of DCS

(Source: The application and development of district cooling system in China: A review)

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A. District Cooling Systems

Powered By Renewable Energy

District cooling systems are an innovative and sustainable approach to providing cooling services to buildings and communities. These systems offer several advantages over traditional air conditioning systems, including improved energy efficiency, reduced environmental impact, and increased system reliability. One of the main strategies for increasing the sustainability and efficiency of district cooling systems is the integration of sustainable energy sources [9]. Sustainable energy options such as geothermal energy, solar energy, and waste heat can be efficiently integrated into district cooling systems by storing thermal energy. This combination not only reduces dependence on fossil fuels but also increases the body's ability to withstand changes in demand. District air conditioning systems powered by renewable energy have many advantages over conventional systems. First, it has a lower impact on the environment than fossil fuels-based systems. Using renewable energy in district cooling will help reduce greenhouse gas emissions and reduce dependence on fossil fuels. Second, district air conditioners powered by renewable energy are more expensive in the long run. District cooling operating costs can be reduced by using sustainable energy options such as geothermal, solar, and waste heat. In addition, renewable energy sources provide a stable and reliable electricity supply, reducing the vulnerability of the central AC system for replacement and product costs associated with traditional electronic equipment. In addition, the integration of renewable energy can increase the efficiency of regional cooling energy. By using renewable energy nearby, district air conditioners can achieve higher energy efficiency than conventional air conditioners. In addition, combining thermal energy storage with district cooling systems powered by renewable energy can increase the sustainability and efficiency of these systems[3]. Energy-saving systems can store and use renewable energy and provide cooling and reliable equipment during times of high demand. This not only helps improve the use of renewable energy, but also allows for maximum load management and reduces the need for backup power.

Overall, there are many benefits to combining renewable energy with thermal energy storage in the field of cooling. It not only promotes sustainability and reduces the environmental impact of air conditioning systems, but also increases energy efficiency, productivity and effectiveness. In addition to the above results, many studies and reports support the advantages of combining renewable energy and thermal energy storage in district cooling. For example, Zhang et al. The best control method for combining hot water in the pump with ice in the cold storage has been discovered. The study found that the management strategy not only saves energy but also reduces operating costs by 8.7-9.3% [10]. To investigate the potential of integrating geothermal energy into district cooling. The study concludes that the integration of geothermal energy reduces energy consumption in the region cooling system by 44.3% and decreases carbon emissions by 67%. Furthermore, the combination of solar energy within district cooling systems has also been explored [11]. innovative district cooling systems implement various strategies to enhance energy efficiency. These strategies include optimizing the working of water-source heat pumps, utilizing ice storage systems, and incorporating intelligent control strategies. These strategies not only maximize the usage of renewable energy but also improve the overall performance and efficiency of district cooling systems[12].

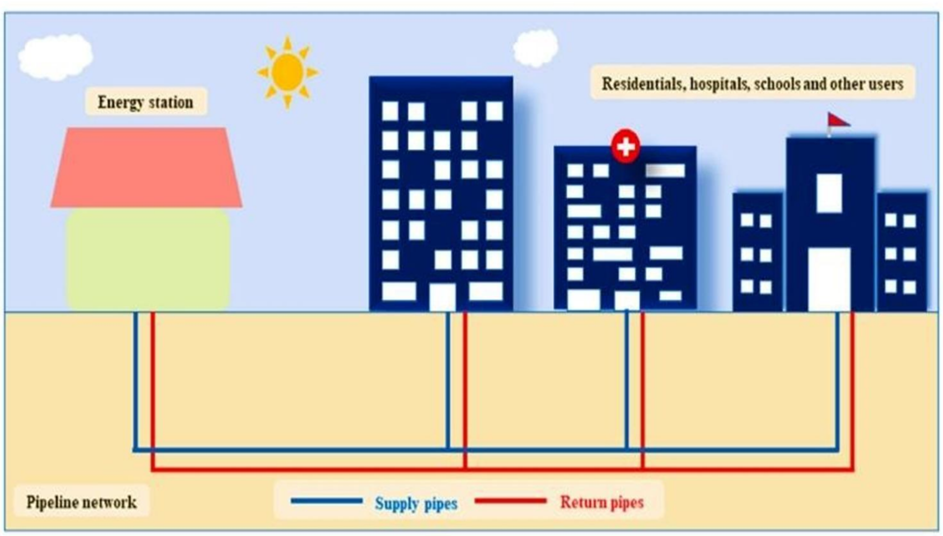

Fig. 2. Schematic diagram of DCS.
(Source: The application and development of district cooling system in China: A review)

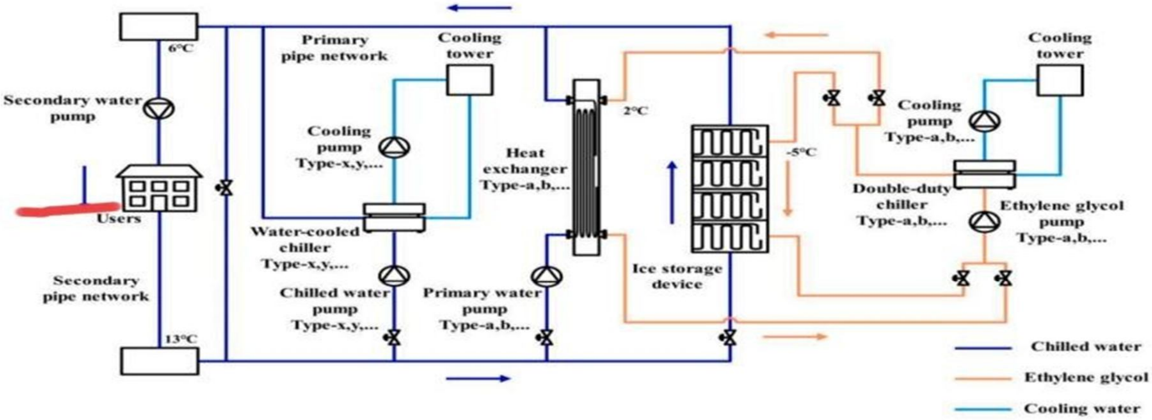

Fig. 3. Schematic diagram of a district cooling system

(Source: Multi-objective optimization of district cooling systems considering cooling load characteristics)

The optimal design approach developed is applied to an existing district cooling system in Singapore. The simulation results show that the optimal design developed provides the best financial performance. Compared to other conventional cooling system designs, the developed optimization reduces the life cycle cost by 7% to 21% and the payback period by almost 20%. This study provides a promising techno-economic optimization tool for energy-efficient design and efficient operation of district cooling systems, especially when incorporating renewable energy sources.

Table 1

THE COMPARISON OF DCS POWER CONSUMPTION WITH AND WITHOUT PROVIDING REGULATION SERVICES

Days	Power consumption without regulation	Power consumption with regulation	Power consumption differences
Day 01	1508.64 MWh	1443.84 MWh	-64.8 MWh (-4.30%)
Day 02	1651.20 MWh	1682.88 MWh	-31.68 MWh(1.92%)
Day 03	71.65 MWh	72.80 MWh	1.15 MWh(1.61%)
Day 04	1719.6 MWh	1886.16 MWh	-65.28 MWh(-3.35%)
Day 05	1189.2 MWh	1225.44 MWh	36.24 MWh (3.05%)
Day 06	1560.48 MWh	1439.04 MWh	-49.92 MWh (-3.32%)
Day 07	1658.88 MWh	1649.76 MWh	-9.12 MWh (-0.55%)
Average	**1595.28 MWh**	**1582.08 MWh**	**-13.2 MWh(-0.70%)**

(Source: Frequency Regulation Capacity Offering of District Cooling System: An Intrinsic-Motivated Reinforcement Learning Method)

B. Benefits And Challenges Of Renewable Energy In District Cooling

The integration of sustainable energy sources in district cooling systems offers several benefits [2].

First, it reduces greenhouse gas emissions and dependence on finite fossil fuel resources, which also lowers environmental impact. By using sustainable energy options like geothermal, solar, and waste heat, district cooling systems can significantly decrease their carbon footprint and contribute to global efforts toward mitigating climate change. Second, the use of renewable energy in district cooling systems can lead to lower operational costs. Renewable energy sources, like solar and geothermal, are typically abundant and widely available, which can lead to cost savings for district cooling systems in terms of fuel procurement and maintenance [13]. Additionally, renewable energy sources are generally more stable in price compared to fossil fuels, which can help mitigate the financial risks associated with fluctuating energy costs. Third, the integration of sustainable energy sources in district cooling systems can enhance energy independence and resilience. By diversifying energy sources and reducing reliance on traditional fossil fuels, district cooling systems powered by renewable energy become less vulnerable to price fluctuations and supply disruptions.

Moreover, the use of thermal energy storage in conjunction with renewable energy sources allows for better management of energy supply and demand [3].This can allow district cooling systems to store excess energy during periods of low demand and use it during times of high demand, providing reliable and consistent cooling service. However, there are also challenges associated with integrating sustainable energy sources into district cooling systems. The main challenge is the intermittent nature of renewable energy sources. For example, solar and wind power depend on weather conditions and may not be available when cooling demand is highest. To overcome this challenge, energy storage systems can be built to store excess renewable energy during peak production periods and use it during peak demand periods. In addition, grid coordination and balancing mechanisms are needed to ensure reliable energy supply for district cooling systems. In addition, the design and optimization of the district cooling system using renewable energy sources requires careful consideration of factors such as power generation capacity, thermal conductivity, and system reliability. Another challenge is the scalability of renewable energy sources in district cooling systems. Although renewable energy sources have potential for electric cooling systems, their scale can be limited by factors such as land availability, resource variability, and grid capacity. Innovative solutions and technologies have been developed to overcome these challenges. For example, advances in energy storage technologies such as advanced batteries and thermal energy can improve the reliability and durability of renewable energy combinations in district cooling systems. One of the potential solutions to overcome the challenge of renewable energy integration in the district cooling system is to use surplus production from combined heat and power plants. These plants generate electricity and heat by burning waste materials such as solid waste or municipal biomass[10] .Waste-energy combined heat and power generation can provide a sustainable source of thermal energy that can be used for district cooling systems. In addition, the use of geothermal energy can be explored as a renewable energy source for district cooling systems. Geothermal energy is a reliable and constant source of heat that can be used for heating and cooling. The use of liquefied natural gas vapor as a cold energy source in the district cooling system is studied by analyzing the possibility of cold energy recovery from LNG vaporization. Research has found that by using LNG vapor as a cooling energy source, district cooling systems can reduce their reliance on traditional cooling technology and achieve significant energy savings.[14]. Strategic work based on the study of district cooling systems and ice storage systems plays an important role in optimizing the use of renewable energy sources. Using machine learning algorithms and prediction models, the operation of the cooling system of the district is coordinated with the pattern of renewable energy generation. This allows the system to utilize renewable energy sources such as solar or wind power during peak production periods.[15]The high volatility of wind generation causes frequent startups and shutdowns of thermal power plants because of the lack of flexibility in power systems, which poses a challenge to economic operation. Strategies such as demand response and energy storage can be implemented in district cooling systems to address this issue. Demand response allows the district cooling system to adjust its load based on the availability of renewable energy. Energy storage such as batteries or thermal storage can store excess renewable energy during periods of high production and discharge it during periods of low production.[16]To provide high-quality services and maximize DCS's revenue from the electricity market, an accurate estimation of DCS's regulation capacity is indispensable. Various techniques, such as data-driven modeling and optimization algorithms, can be used to accurately estimate the regulation capacity of a district cooling system.[17]Moreover, the combination of energy storage technologies, such as thermal storage or advanced batteries, in district cooling systems can enhance their ability to use renewable energy sources effectively. By storing excess energy during periods of high renewable energy generation, these storage technologies allow district cooling systems to use the stored energy for cooling during periods of low renewable energy generation.

Table 2 : Benefits and challenges of different types of district cooling system

DCS Type	Benefits	Challenges
Centralized DCS	Improved air quality, high energy efficiency, reduced carbon footprint, and high initial investment.	Long-term maintenance costs and complex infrastructure.
Decentralized DCS	Flexibility to adapt to changing demand, lower initial investment, and lower maintenance costs.	Lower energy efficiency, higher energy consumption and costs, and limited cooling capacity.
Hybrid DCS	Combines the benefits of both centralized and decentralized systems and lowers energy consumption and costs.	Long-term maintenance costs and complex infrastructure.
Absorption chiller-based DCS	High energy efficiency, and reduced energy consumption and costs.	Dependence on waste heat or renewable energy sources and complex technology.

Chilled-water DCS	Reduced energy consumption and costs; reduced carbon footprint and high energy efficiency.	The high initial investment, complex infrastructure, and long-term maintenance costs.
Direct-expansion DCS	High energy efficiency, reduced energy consumption and costs, improved air quality, and minimized carbon footprint.	The high initial investment, complex infrastructure, and highly dependent on refrigerants and cooling fluids.

(Source: A Review on Green Cooling: Exploring the Benefits of Sustainable Energy-Powered District Cooling with Thermal Energy Storage)

III. RESULT AND DISCUSSION

Several case studies were conducted to evaluate the feasibility and effectiveness of connecting renewable energy sources to the district cooling system. One such case study in Copenhagen, Denmark evaluated the integration of geothermal energy into a district cooling system. Research has found that geothermal energy provides a consistent and reliable source of cooling with minimal environmental impact. Another case study in Singapore investigated the appropriate use of solar energy in a district cooling system. Research has found that integrating solar energy into district cooling systems can significantly reduce electricity consumption and greenhouse gas emissions. In addition, a case study in Stockholm, Sweden, analyzed the combination of a district cooling system with a biomass and waste-to-energy plant.

The study found that the combination of biomass and waste-to-energy sources provides a sustainable and reliable source of cooling for the district. The use of renewable energy in district cooling systems has significant economic and environmental benefits. It will reduce dependence on fossil fuels, reduce greenhouse gas emissions and increase energy independence. It can also contribute to cost savings for consumers and the sustainability and resilience of the built environment. Field trial of active night cooling provided by district cooling in three commercial buildings A field trial in Australia evaluated the performance and effectiveness of active night cooling provided by district cooling systems.

A study found that the use of district cooling for nighttime active cooling not only reduces electricity consumption but also improves indoor thermal comfort for residents. In addition, research in Barcelona, Spain explored the integration of high-temperature solar technology into district cooling systems[11]. The study depicts that the use of high-temperature solar technology in district cooling systems can significantly enhance energy efficiency and reduce reliance on conventional energy sources. Overall, these case studies and field tests demonstrate the feasibility and effectiveness of integrating renewable energy sources into district cooling systems.

An optimal design approach was developed and applicable to a district cooling system located in Singapore. The simulation results show that the optimal design developed provides the best financial performance. Compared to other conventional cooling system designs, the developed optimization reduces the life cycle cost by 7% to 21% and the payback period by about 20%. This study provides a promising techno-commercial optimization tool for energy-efficient design as well as cost-effective operation of district cooling systems, especially when incorporating renewable energy sources[18].

Consideration of the effect of home air conditioning usage patterns is important in the technical assessment of residential cooling systems. In addition, a study conducted in China investigated the effect of home air conditioning usage patterns on the evaluation of residential cooling systems.

Research has shown that including different home AC usage patterns in the evaluation of the cooling system can significantly affect the energy efficiency and performance of the district cooling system, and it is important to consider user behavior and preferences in the design and operation of the district. cooling system[19]. Sea water-cooled chilled water plants have been popular in Hong Kong and have been preferred for district cooling systems[20].These plants utilize the cold water from the sea for cooling purposes, reducing the energy consumption and environmental impact associated with traditional cooling methods.

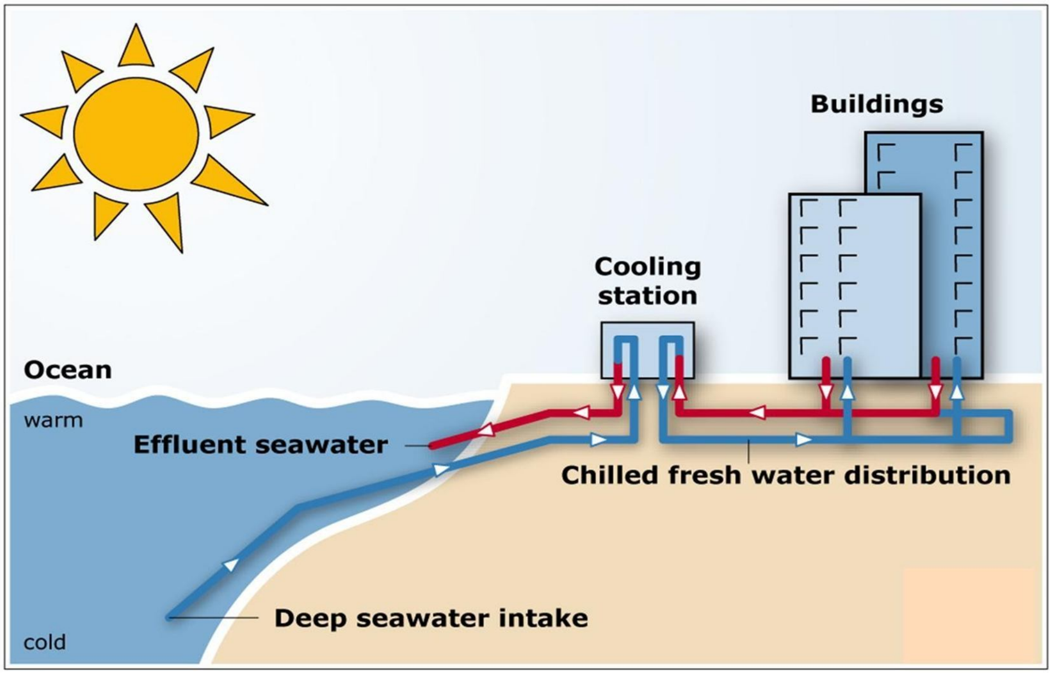

Fig. 4.Schematic diagram of a district cooling system using sea water
(Source: Sea Water Cooled Chiller Plant and Other District Cooling Systems Viability, Selection Criteria, andMaster Planning)

IV. INNOVATIVE TECHNOLOGIES IN RENEWABLE ENERGY DISTRICT COOLING

In addition to the integration of sustainable energy sources, several innovative technologies are developed to enhance the efficiency and effectiveness of district cooling systems. One such technology is the use of advanced control systems and intelligent plans. This technology optimizes the operation of the cooling zone and ensures efficient use. Advanced management and smart planning can reduce waste and improve overall performance by monitoring and coordinating the energy consumption of various buildings in the area. Another new technology is the use of thermal energy storage technology. These systems can store excess heat from renewable energy during periods of low demand and use it to meet cooling needs during periods of high demand. This helps to balance supply and demand, reduce reliance on the grid during peak times, and improve the overall efficiency of the district cooling system. Furthermore, advancements in heat pump technology are also contributing to the effectiveness of renewable energy district cooling systems. Today, district cooling systems are able to use heat pumps to convert low-grade heat from renewable energy sources into usable cooling energy. This process not only increases the efficiency of the system but also reduces the need for conventional cooling methods that rely on fossil fuels. In general, the integration of sustainable energy sources and innovative technologies into district cooling systems is a promising solution for solving energy and environmental problems. This system provides cost savings and increases sustainability for communities while significantly reducing greenhouse gas emissions and reducing dependence on fossil fuels. The use of renewable energy sources in the district cooling system has a real potential to reduce greenhouse gas emissions and reduce dependence on fossil fuels. [21]. Overall, integrating sustainable energy sources into district cooling systems has shown promising results in reducing greenhouse gas emissions and reducing dependence on fossil fuels. An approach to optimizing district heating and cooling systems is essential to achieve maximum energy efficiency and cost effectiveness. Furthermore, the implementation of smart grid technologies can enhance the performance of district cooling systems [23]. The DHC system shows the highest efficiency in terms of energy savings, whatever the location. The 5GDHC system reaches a compromise between installation and operational costs while still maintaining a high level of energy efficiency [24]. In conclusion, the integration of sustainable energy sources in district cooling systems is a promising solution to reduce greenhouse gas emissions and decreasing reliance on fossil fuels [25].Recent studies have shown that DCSs can effectively participate in the regulation of power systems by utilizing the flexibility of TCLs. Optimization approaches in district heating and cooling systems are crucial for achieving maximum energy efficiency and cost-effectiveness.

These approaches involve optimizing factors such as temperature set points, flow rates, and thermal energy storage capacities to ensure that the system operates at its maximum efficiency and performance. To address the challenges of controlling a DCS to provide high-quality regulation services, a novel safe deep reinforcement learning control method has been proposed [26]. Geographic information system (GIS) software has been essential for visualizing and determining heating and cooling requirements, sources of industrial excess heat, natural bodies of water, and municipalities. By utilizing GIS technology, planners can determine the most optimal locations for district cooling systems, taking into account factors such as proximity to heat sources, cooling demand, and availability of renewable energy sources[27]

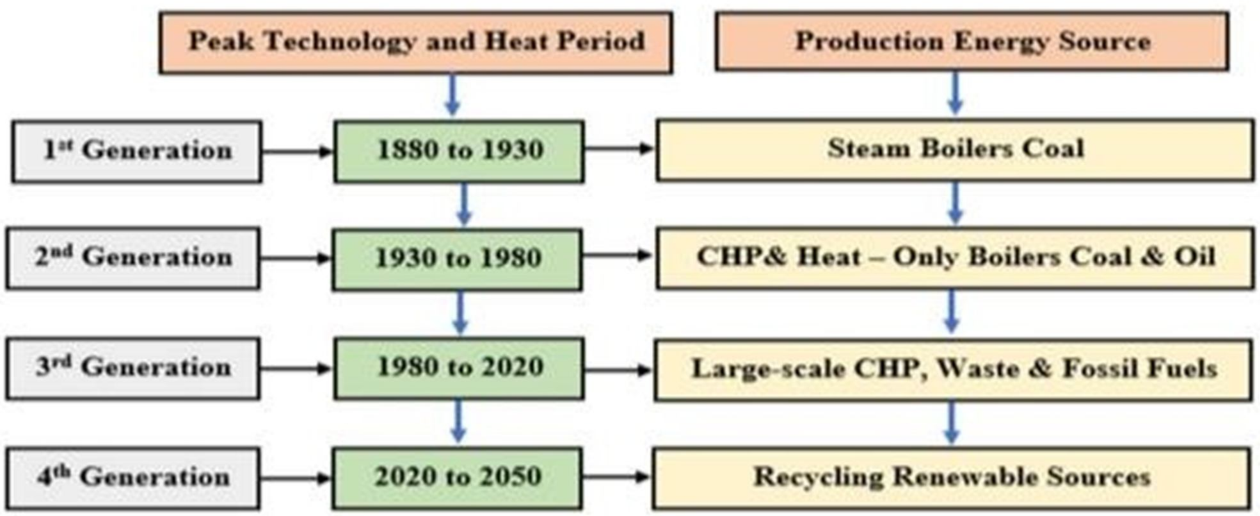

Fig. 5. Production and energy sources for district cooling system

(Source: A Review on Green Cooling: Exploring the Benefits of Sustainable Energy-Powered District Coolingwith Thermal Energy Storage)

V. RECOMMENDATIONS FOR IMPLEMENTING RENEWABLE ENERGY IN DISTRICT COOLING

Although district cooling systems with renewable energy sources offer many benefits, successful implementation requires careful planning and consideration. Before applying renewable energy in the district cooling system, it is important to thoroughly analyze the existing local renewable energy sources. Factors such as solar radiation, wind patterns, and geothermal potential must be considered in this analysis. [3]

The design of a renewable energy-powered district cooling system should take into account the specific cooling demands of the area, as well as the available renewable energy resources.

Additionally, the system should be designed with optimal sizing of renewable energy generation and thermal energy storage components to ensure efficient operation. Depending on the local resource availability, it may be beneficial to include multiple renewable energy sources in the district cooling system [2]. This could include solar photovoltaics, wind turbines, geothermal energy, and biomass. district cooling systems with renewable energy sources offer a sustainable and efficient solution for meeting the cooling demands of tropical climates [30].

By utilizing sustainable energy options like solar, wind, geothermal, and biomass, district cooling systems can reduce their reliance on fossil fuels and mitigate the environmental impacts associated with traditional cooling systems. Additionally, integrating renewable energy sources into district cooling systems can increase energy efficiency, reduce greenhouse gas emissions, and promote a more sustainable built environment.

The successful implementation of energy-integrated district cooling systems often requires cooperation with local governments and utilities. This partnership can facilitate access to necessary permits and approvals, finance and incentives, and ensure compatibility with existing energy infrastructure.

To maximize the benefits of renewable energy combination in district cooling systems, several management strategies need to be implemented [2]. These strategies include proper planning and design, efficient operation and maintenance, continuous monitoring and evaluation, promotion of public awareness and participation, and collaboration with local governments and utilities.

VI. CONCLUSION

In conclusion, the integration of sustainable energy sources into the district cooling system offers significant benefits in terms of energy efficiency, environmental sustainability and cost efficiency. The use of renewable energy sources in the district cooling system helps reduce greenhouse gas emissions, reduce dependence on fossil fuels, and contribute to a more sustainable and efficient built environment. By using technologies such as solar thermal energy, geothermal energy, and waste heat recovery systems, district cooling systems can access a consistent and reliable supply of renewable energy, providing a more stable and resilient cooling infrastructure. In addition, the integration of sustainable energy sources into district cooling systems can lead to economic benefits, including lower energy costs and long-term cost stability. In addition, the integration of sustainable energy sources into the district cooling system promotes community involvement and participation, and the adoption of sustainable behavior. These advantages, along with advances in energy management systems, smart grids, and thermal energy storage, will change the way we cool our buildings and cities, creating a more sustainable and efficient future. In today's fast-changing world, the importance of weather accuracy cannot be overstated. AC combines with renewable energy to replace the cooling of our homes and cities. It offers many benefits of air conditioning, including energy efficiency, reduced environmental impact, and increased cost-effectiveness. By using sustainable energy options such as solar thermal, geothermal, and waste heat recovery, the district AC system can enjoy a consistent and reliable energy supply, while also being more stable and cool. In addition, the integration of thermal energy storage systems can reduce the dependence on fossil fuels using renewable energy and increase the ability to meet changing needs. Combining sustainable energy and thermal energy storage in the field of cooling not only reduces carbon dioxide emissions but also supports environmental sustainability and the use of money. Air conditioning applications are estimated to use about 17% of electricity generation and cause about 8% of greenhouse gas emissions. DCS technology can have a direct impact on global warming, and the energy consumption of these systems can cause environmental stress. To solve this problem, the integration of sustainable and thermal energy storage into the district cooling system is a promising solution. These systems can help create a more sustainable and efficient environment by reducing energy consumption related to cooling and greenhouse gas emissions. The benefits of combining district cooling with renewable energy and thermal energy are many. ambient air, combined with renewable energy and thermal energy, provides an efficient and environmentally friendly AC system.

VII. FUTURE SCOPE

As ambient cooling systems evolve, future trends emerge that can further improve sustainability and efficiency. One of these areas is the combination of advanced energy management systems and smart grids. This system will allow for real-time monitoring and control of energy consumption, allowing for optimal operation and increased efficiency. Another future trend is the use of advanced technologies such as artificial intelligence and machine learning algorithms to improve the efficiency of district cooling systems. This technology can analyze data from multiple sources and make adjustments in real-time to optimize energy use and reduce costs. In addition, more attention is paid to the integration of thermal energy storage systems into district cooling systems. This system can withstand excessive cooling power when it is turned off -release during peak periods and peak demand, improving overall efficiency and reducing the need for additional peak demand times. In addition, the integration of sustainable energy products into the cooling sector should continue to improve [2].

Today, the recovery of thermal heat, geothermal heat, and waste includes integration into district cooling systems. These renewable energy sources can reduce dependence on conventional energy sources by providing a continuous supply of energy to air-conditioned spaces. Incorporating sustainable energy products into your air conditioning system has economic benefits as well as environmental benefits. Renewable energy in district cooling can provide long-term benefits by reducing energy costs and reducing dependence on fossil fuels. There is also a growing awareness of the importance of community participation and cooperation in the cooling zone.

This includes ensuring that stakeholders are involved in decision-making, as well as raising awareness and encouraging positive attitudes in the community.

Overall, better energy management systems, smart grids, advanced technologies, thermal energy products and renewable energy, and regional cooling capacity will change the way we cool buildings and cities [28]. These developments not only improve energy efficiency and reduce environmental impact but also provide economic benefits and encourage community participation. These advances can improve energy efficiency, reduce environmental impact, and increase profitability. As a result, the numerical simulation shows that the project will reduce the operating cost by 15.78% on the day of delivery and the wind output will be close to zero.

VIII. ACKNOWLEDGEMENT

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