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Enhancing Sustainability in Malaysia: Strategic Policy Recommendations for Implementing District Cooling Systems in Mixed Development Settings

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Abstract

This study aims to address this issue by evaluating the potential environmental advantages and relevant policy challenges of implementing large-scale integrated cooling systems for districts in dense urban city areas in the country. We show that these systems can be an important first step in advancing urban sustainability, especially when embedded within the notion of smart/flexible cities (Kamarulzaman et al., 2023). This allows decision making on new systems to be based on optimal designs through a novel combination of computational fluid dynamics modelling, urban energy simulation, and energy-economic modelling of a wider range of demand-side management measures that minimize the life cycle costs and financial risk of district cooling (Singaravelloo & Salih, 2022). We aim to provide strategic policy recommendations and roadmap to steer the industry for innovation and transformation towards mix development settings and cooling industry in Malaysia. The main goal is to provide the next generation of smart, scalable, compact, sustainable and efficient mixed-use urban climate-responsible developments from the ground up

Keywords: District Cooling System, Strategic Policy, Urban Sustainability, Mixed Development Settings, Energy Efficiency

Introduction

The expansion and shift towards urban living have led the Malaysia to face a growing set of challenges, particularly concerning building sustainable cities (Butters, 2018). These problems often include and related to climate change, energy security, increasing energy demand, high greenhouse gas (GHG) emissions, energy waste, and environmental damage (Almulhim et al.,

2022). Typically, buildings consume the most electricity and generate the most greenhouse gas emissions in Malaysia. Uncontrolled urbanization has resulted in energy consumption increase and data reveal that due to over dependency on mechanical ventilation, air conditioning, heating, and cooling, air quality dramatically decrease (Gjoka et al., 2023). The challenge becomes increasingly critical when you consider how urbanization is contributing to climate change through energy production and transportation. The introduction of District Cooling Systems (DCS) can significantly decrease energy usage and greenhouse gas emissions and thus improve urban sustainability (Son et al., 2023). As outlined in Sharifi (2021), "Over the past forty years, long-term sustainability of economic, environmental, and social aspects of urban living has become an urgent goal for many planners and authorities in Malaysia."

The total energy consumption in Malaysia over the last 50 years has been steadily growing, averaging an annual growth rate of 6.2 percent, with the commercial and industrial sectors receiving 54% of electricity supplied in the country in 2004 (Samat et at., 2020). In Malaysia, fast growing cities like Kuala Lumpur, are expected to double the energy consumption every decade. This consistent annual growth contributes to corporations taking advantage of its short- term economic benefits without a complete awareness of the long-term environmental or health-related effect (Blasdell et al., 2022). Today, the majority of Malaysia's 25 million residents live in urban centres. By year 2020, 75–80 percent of all Malaysians are expected to become urbanites (Ahmad et al., 2020). As more people move to the cities, the need for space cooling, and thus electricity usage, will also increase. Meeting this demand has depended on electricity produced from non-renewable resources, including natural gas, coal and oil, with a heavy reliance on natural gas (Azari et al., 2022). The data showed that the industry used a significant amount of state-generated electricity. In 1992–2004, the non-residential sector in Malaysia consumed 61.6–73.4% electricity (Raihan et al., 2022).

Additionally, one-third of carbon emissions in Malaysia's commercial buildings are caused by inefficient energy consumption (Mustapa et al. 2021). Electricity consumption is projected to rise by an average of about 5.6 percent per year from 2011 to 2013, which translates to the need for at least 5,000 additional megawatts of generating capacity just for the peninsula (Rahman & Schmillen, 2023) due to economic growth and expected exuberant use of space cooling. So far, the Malaysian government has wisely responded to this demand by promoting energy efficiency through aggressive programs to retrofit and replace energy-hungry chillers and optimize the performance of the centralized chilled water systems (Lau et al, 2021). The importance of demand reduction and stability of the electric grid has made the energy storage technology a valuable technique capable of balancing the electricity production and demand. Nowadays, CTES systems are widely used in different applications for the buildings that are mainly occupied during the working hours, such as office buildings, hospitals, schools, churches and mosques (Rismanchi, Saidur, Masjuki, & Mahlia, 2012). In an effort to stay abreast with the global demands of sustainability the National Energy Policy was introduced in 2022. This was further extended through National Energy Transition Roadmap starting in 2023 (Ministry of Economy Malaysia, 2023). Inside NETR, one of key lever for decarbonization/national target to reach net zero carbon by 2050 is through energy efficiency lever. Aligning to the NETR, there are plans to gazette the Energy Efficiency and Conversation Act in 2025. There are three areas which will be regulated by the EECA which includes all office buildings exceeding 8,000 sq meters, large energy consumers, and energy using product. This effort is a crucial step towards achieving sustainability goals in Malaysia,

particularly on energy saving. This DCS initiative are also aligned to sustainable development goals (SDG) number 7, affordable and clean energy (General Assembly Economic and Social Council, 2024). Despite improvements in energy intensity and renewable energy growth, international financial flows for clean energy in developing countries remain insufficient. The table below shows the target of SDG 7 in the report:

Table 1
Target for Sustainable Development Goals 7

Target	Remarks
7.1	o In 2022, global electricity access remained at 91%, but the number without access increased by 10 million from 2021 to 685 million people. Factors such as COVID-19 and the Ukraine conflict disrupted progress. Projections suggest that by 2030, 660 million will still lack electricity. Sub-Saharan Africa accounted for 83% of the deficit in 2022. However, Central and Southern Asia reduced their gap from 235 million in 2015 to 33 million in 2022. Annual progress slowed to 0.4% between 2020 and 2022, requiring a 1.08% increase until 2030 to meet the target. o In 2022, around 74% of the world used clean fuels for cooking. Yet, about 2.1 billion still relied on polluting fuels and technologies such as charcoal, coal, crop waste, dung, kerosene, and wood. The global access deficit decreased from 36% to 26% since 2015. However, current trends suggest a 21% shortfall in achieving universal access by 2030, leaving 1.8 billion without access to clean cooking by 2030.
7.2	In 2021 the global share of renewable sources in total final energy consumption stood at 18.7%. Excluding traditional use of biomass, the share of modern renewable sources rose gradually from 10% in 2015 to 12.5% in 2021. The electricity sector led the charge with renewables, contributing 28.2% to total final electricity consumption. However, insufficient progress in the heat and transport sectors underscores the need for stronger conservation measures and policy actions. Tripling world's installed renewable energy generation agreed at the COP28 is an important step aligning with the SDG7.
7.3	In 2021, the primary energy intensity improved by 0.8%, falling below both the 1.2% five- year average and the SDG 7.3 target of 2.6%. To meet the 2030 target, annual improvements must now average around 4%. The robust economic recovery in 2021 led to the largest annual rise in energy consumption in 50 years, exceeding 5%. This surge was driven by a shift towards energy intensive industries and the resurgence of other demand sectors after lockdowns were lifted.
7.a	In 2022, international public financial flows supporting clean energy in developing countries rose to $15.4 billion, a 25% increase from 2021 but still half of the 2016 peak of $28.5 billion. However, in 2023, it was anticipated a decrease in global five-year average flows by $450 million. The decreasing trend in these flows may hinder SDG 7 achievement, especially for LDCs, LLDCs and SIDS.

7.b	Installed renewable energy capacity is on the rise worldwide, reaching 424 watts per person globally in 2022. Developed nations averaged 1,073 watts per person, while developing countries averaged 293 watts per person. This represents an 8.5% increase from 2021, maintaining a steady compound annual growth rate of 8.1% over five-year periods.

Source: (General Assembly Economic and Social Council, 2024)

Research Objectives

This research aims to investigate and examine district cooling systems in Malaysia by comparing it with other studies through empirical data. The following objectives forms the foundation of this research:

a. To evaluate the environmental advantages of implementing large-scale integrated

District Cooling Systems (DCS) in mixed development settings in Malaysia.

b. To identify and analyse the policy challenges associated with the adoption and implementation of District Cooling Systems in mixed development settings in Malaysia.

Research Questions

The research questions of this study are as follows:

a. What are the specific environmental benefits of implementing large-scale integrated District Cooling Systems (DCS) in mixed development settings in Malaysia.?
b. What are the key policy challenges hindering the adoption and effective implementation of District Cooling Systems (DCS) mixed development settings in Malaysia.?

Research Methodology

Based on the descriptive and analytical approach, this study analyses the importance as well as the current issues and presents suggestions on how DCS can be adopted and developed in Malaysia. This methodology aims to provide a systematic exploration into the issues related to the DCS implementation in Malaysian context.

The study completed an extensive review of the literature on the theoretical application of district cooling systems utilizing academic journals, government publications, industry reports, and case studies. This search was done through Google Scholar using the Boolean operator “AND/OR District Cooling System”. Most of the findings of the study would be based on these secondary data sources such as reports, government publications and peer-reviewed journal articles. Subsequently, a thorough examination of these secondary sources will inform direction in terms of understanding critical barriers to DCS delivery and factors influencing DCS uptake and sustainability. Such a methodology would lead to a nuanced understanding of the complex dynamics at play with DCS and provide policy and industry-makers with actionable insight.

Table 2
List of Literature on District Cooling System

Author(s) and	Title	Relevance to Research
Kamarulzaman	UAV Implementations in Urban Planning and	Relevant for understanding technological trends
Singaravelloo	Cities, urbanization and infrastructure	Directly related to district cooling systems and
Gjoka et al.	Fifth-generation district heating and cooling	Provides insights into future directions for DCS
Sharifi (2021)	Urban sustainability assessment	Useful for evaluating sustainability in urban
Son et al.	Algorithmic urban planning for smart and	Relevant for the integration of smart
Raihan et al. (2023)	From growth to green: navigating the complexities of economic development, energy sources, health	Provides context for the energy use and emissions aspects of DCS
Fry et al.	A review of district energy technology with	Relevant for improving efficiency of DCS in
Mustafa et al.	Challenges and way forward towards best practices	Provides insights for energy-efficient practices
Matak et al.	Integration of WtE and district cooling in existing	Relevant for optimizing energy use in DCS
Khakdaman et al. (2024)	System dynamics supply chain analysis for the sustainability transition of European rolled	Useful for system-level sustainability analysis in DCS transitions
Energy Policy	Energy Policy Act	Supports potential for DCS subsidies to
Energy Independence	Energy Independence Act	Provides a model for offering tax incentives for DCS in Malaysia, encouraging energy-
Tokyo Metropolitan Government	30% Carbon Reduction in Tokyo Waterfront DCS	Highlights the effectiveness of regulatory support and energy standards in DCS implementation.
Danish Energy	HOFOR DCS Uses Wind Power Surplus, Achieving 70% GHG Cuts	Shows potential for integrating renewable energy sources, like wind power, with DCS in Malaysia

Empower District Cooling (UAE)	50% Energy Savings Using DCS in Dubai	Demonstrates the potential for energy savings and efficient cooling systems in large urban developments in Malaysia.
IDEA (International District Energy	TES Reduces Peak Electricity Use by 30-40%	Suggests TES could improve Malaysia's cooling-related electricity demand and contribute to grid stability.
Frost & Sullivan (2021)	DCS Accounts for <5% of Total Cooling in Malaysia	Highlights the need for greater adoption of DCS

Literature Review

Malaysia is currently undergoing rapid urbanization which leads to a rise in energy demand, as many people would consume more energy to provide cooling services by working and living in the urban areas (Raihan, 2024). A study identified key barriers to the implementation of district cooling as a sustainable cooling system in urban areas, actionable items to overcome these barriers and a potential nationwide government and industry joint action plan (Lebdioui et al, 2021). Sustainability performances of district cooling could be compared with the sustainability benefits of currently available conventional decentralized air conditioning systems (Chachuli et al., 2021). District cooling systems can lower energy use and greenhouse gas emission, leading to environmental and public health benefits, through centralized cooling production (Wei et al., 2023).

Current Challenges and Opportunities

One of the key challenges for DCS deployment is the existing government policy landscape; the country needing to have the right parameters and rules in place to support effective DCS implementation. Particularly condensing district cooling energy needs, while reducing both the over-dependent resources of electricity and water (Sharifi & Khavarian-Garmsir, 2020). Indeed, Malaysia has a strong complement in the capacity to promote technological innovation and investment. This is particularly relevant considering the financial restructuring that is currently underway on national power utility (Capolongo et al., 2020).

The Malaysian government has increasingly strived to advocate for sustainable development policies and practices over the years, pro environmental commitment however, remains to be fully enshrined (Chapagain et al., 2022) There is already a risk-averse culture that impedes infrastructure innovation (Azevedo et al., 2021).

To overcome similar challenges, a lot of cities in various regions of Western Europe have designed sustainable development based on principles that meets the needs of the present without compromising the ability of future generations to meet their own needs (Sessa et al.,

2022). Cities that pursue this realize that there can be no sustainable balance at the level of human beings and natural eco-system capacity where the patterns of development consume enormous quantities of resources and produce toxic wastes which fundamentally change our withering land, and our turgid air and water (Fry et al., 2024). For this reason, urban sustainability in the developing world must be recognized as central to national sustainability minding the fact that the process of urbanization is virtually irreversible (Wei et al., 2024). Urban sustainability is thus a statement about the risks of the future, risks posed by the activities and decisions through which the processes of planning, design, and construction of the urban experience take place (Allam et al., 2022).

District Cooling Systems

If sufficient and efficiently operated, district cooling systems can constitute a potential for clean energy production and GHG emissions demand reduction. The analytical potential for such district cooling networks, and indeed the tangible benefits suggest they have the scope to be a financially profitable agent of urban renewal, and a cheap aspect of urban sustainability (Kamarulzaman et al., 2023). Urban heat islands exist from the compact island to the tropical city (Singaravelloo & Salih, 2022); and, because tall urban buildings already exist or are planned for many, the urban heat island impacts people. The surrounding countryside can alleviate the heat island-related excessive heat and thereby be a release valve for the large volumes of urban heat; however, it does not prevent residents of tropical cities from experiencing heat-related stress (Almulhim et al., 2022, Gjoka et al., 2023). This paper identifies some potential applications that could be connected and energized by effluent- relevant district cooling system that offers thermal balance, in Malaysia.

A major advantage of centralized cooling systems is when customers can save on energy costs if economies of scale is achieved (Son et al., 2023). Furthermore, district cooling systems offer greater access to replacing inefficient decentralized systems and provide an incentive for technologies to develop high-efficiency, renewable, and low-pollutant (Qiu et al. 2021). District cooling systems typically involve low or zero cooling water demand. (Raihan & Tuspekova, 2020).

Unlike evaporators used for individual cooling units, district cooling systems reject heat using heat exchangers; therefore, there is no condensation produced by district cooling systems (Blasdell et al., 2022). This is beneficial in humid climates, where the condensate management of single systems is problematic (Samat et al., 2020). A reliable supply of chilled water is as attractive as the cost savings associated with the construction of DCS systems (Ahmad et al., 2020). However, district cooling system requires commitment for the system operator to be able to plan efficiently to capacity, cooling load and energy generation requirements (Azari et al., 2022).

National Policies and Initiatives

In developing countries like Malaysia, policy challenges risk undermining the country's capacity to decarbonize, as carbon emissions continues to rise. However, it can be challenging to meet these mounting emissions whilst pursuing carbon reductions, particularly in rapidly growing economies (Azevedo et al., 2021). At the same time, there is pressure from the global community to curb urban carbon emissions, as cities, especially in Asia, are significant contributors to global carbon emissions (Sessa et al., 2022, Capolongo et al., 2020, Chapagain

et al., 2022). The onus for such impacts is heavily placed on the nation to improve and create a sustainable development initiative (Fry et al., 2024).

However, while national-level targets remain as the main initiatives for combating climate change in Malaysia, subnational policies represent a challenge (Wei et al., 2024). As such, policy is likely to be directly affected on whether any sustainability agenda, strongly assisted by subnational synergy, and effective adoption of energy-efficiency (Allam, et al., 2022). Policies which promote the adoption of an energy-efficient cooling systems will be advantageous (Huan et al., 2021). However, this will depend on how national policies on renewable energy feed-in tariff, feed-in system, resource security initiative and general national and subnational green financing measures are implemented (Matak et al., 2021).

Local Government Regulations

Local governments play a major role in land use and building development issues related to the development of district energy systems (Hadipour et al., 2021). Local authorities in Malaysia can accept or deny building designs submitted for development (Jang et al., 2022). Local government can encourage the construction of DCS through regulations of local authorities on building development (Dong et al., 2022), The sustainability of a city should be a joint responsibility of public and private sectors (Østergaard et al., 2022). A systematic policy-promotion model significantly contributes to success in district cooling systems (Huang et al., 2024). For example, local authorities can establish development charges for the developers (Huang et al., 2020). The government can also provide incentives and lower taxes and exemptions from import duties for designers and developers to kick-start many high-temperature heating and cooling applications for commercial applications (Nasir & Go, 2024) For the participation of local governments, the government can enact by-laws that would allow district cooling to be planned and commissioned in any city (Murthy & Ramakrishna, 2022). This statutory requirement should be placed by the government when amending the legislation and regulations for the architects, developing institutions, and other establishments to implement them to ensure the sustainable and constant establishment of the district cooling systems (Wu & Murphy, 2022, Khakdaman et al., 2024).

Case Studies of District Cooling Systems Implementation

Successful Projects in Other Countries

Private developers have successfully embraced and implemented district cooling systems in various countries worldwide for example in Toronto City and Riyadh Climate City.

In Toronto, a central district cooling plant was constructed to promote the cooling infrastructure of the city. All the goals of the first phase of development, planning, constructing, and eventually operating the Toronto system were met (Romanov & Leiss, 2022). The plant was later purchased and is currently owned by a private firm.

Riyadh Climate City covers 2 urban large neighborhoods in the city of Riyadh providing residential, commercial and office buildings along with other services and green recreational areas. The private sector participation in financing and construction of district cooling system-without the municipality taking any risk- was the underlying idea for the project. The project was won in a public tender by a private developer with the assumption that the municipality

would add the necessary incentives to ensure its development; nevertheless, the private developer decided to finance, build, and eventually operate the district cooling system (Azimov & Avezova, 2022). Similar setups have been established for the operations of central cooling plants and have also reached great successes (Ali et al., 2020).

Innovative approaches to these district cooling systems (DCS) have been implemented by several countries which Malaysia could learn from. Singapore's integrated Marina Bay District Cooling plant is one of the largest in Southeast Asia and achieves a 25% reduction in peak power capacity demand through a chilled water distribution network, while further development integrates renewable energy as well as waste-to-energy (WTE) generation plants to improve sustainability (Energy Market Authority, 2021). Similar systems could be employed in Malaysia as well, particularly in high density mixed development areas to maximize the efficient use of alternative source of energy.

Dubai's DCS decrease power demand, resulting in 1.4 million tonnes of CO2 savings per year in the UAE, and the system is planned to supply with solar energy progressively (Empower, 2022). Meanwhile, in Denmark, its DCS blends district heating and cooling, they utilize biofuels and geothermal energy combined with seasonal storage, reducing emissions by 665,000 tonnes of CO2/y (Danish Energy Agency, 2023; C40 Cities, 2023) providing a model for Malaysia's decarbonization goals.
The US and Japan also offer important lessons. Hudson Yards DCS cuts cooling energy use by

30% in New York. Tokyo's Midtown DCS provides up to 50% energy savings of providing energy using natural gas cogeneration (Tokyo Metropolitan Government, 2022).
Thus, district cooling systems can meet better and more effective ways of Malaysia's urgent need for sustainable mix development. A study of district cooling system projects in Malaysia shows that there are certain barriers hindering the implementation and advancement of such systems (Waqar et al., 2023). The study selected Malaysia and interviewed key stakeholders involved with the implementation of district cooling systems within Malaysia through strategic policy recommendations to remove the barriers and accelerate progress (Waqar et al., 2023)

Strategic Policy Recommendations for Malaysia
A proliferation of studies has examined the factors and examined issues pertaining to DCS, ranging from policy level solutions to effective implementation of DCS (Wang et al., 2022, Mustaffa et al. 2021, Baker et al., 2023, Gjoka et al., 2023).

Malaysia's power demand and her need for sustainable commitment is essential as the country moves into the future (Nadeem et al., 2023). The aspiration to be a developed and high-income nation, Malaysia has seen a 5-6% growth in GDP per capita on an annual basis. This growth accelerated development of non-residential buildings and infrastructures in urban areas such as Kuala Lumpur, Penang, and Johor Bahru (Mustaffa & Kudus, 2022). Thus, the urban temperatures in these developed areas are also increasing faster than in other areas (Ali et al., 2021). Days associated with higher temperatures also continue this upward trajectory (Zaid et al., 2022).

The growing demand for space cooling in buildings increases the load on existing power grids. (Zhang et al., 2022). High urban heat is being observed in most cities and urban areas and space cooling demand is increasing, (Zhou, 2022).

In a recent study, seven strategic recommendations were proposed which includes the government support on DCS, technical assistance for district cooling plant owners, expansion of current cooling capacity, reduction in energy usage and greenhouse gas emissions, and continue to periodically revise the district cooling system development regulations (Pan et al., 2023, Perno et al., 2022).

A recent study analyzed Malaysian policies that encourage DCS for the renewable and efficient energy sources available (Allioui & Mourdi, 2023). These policies are grouped into five broad categories:

Targeted Subsidization

- A subsidy for the cooling service produced by the renewable energy-powered DCS system. This will render DCS the preferential option for air conditioning in Kuala Lumpur (Perno et al., 2022).

2. **Carbon Credit Recognition**

- The carbon credits that investors receive because of reaching the specified benchmarks (Romanov & Leiss, 2022).

3. **Promotion of Co-generation**

- Profitability under the carbon market or a grant for investment in co-generated energy (Zhang et al, 2022).

4. Efficiency Levels and Economic Adoption

- Reducing the cost of efficiency levels for co-generation required for district cooling (Mustaffa et al., 2021).

5. Integrated Legal Framework

- Bringing down other barriers primarily legal and market structures representing state and local interests. Incentivizing the ownership and use of District Cooling Systems (Ali et al., 2020).

Conclusion and Future Directions

Globally, increasing energy consumption and the infrastructure required to support such growth in rapidly expanding urban centres increasingly contribute to an economic, environmental and social burden (Zhang et al., 2022). It was reported in another study that the criteria that would increase the implementation of district cooling systems is increased policy resilience, improved environmental performance, sustainable building certification, effective capital and operational cost performance, and an increased ability to absorb other forms of urban waste energy (Allioui & Mourdi, 2023).

This research also satisfied both the research questions and objectives. First, the discussion on environmental benefits of DCS were thoroughly discussed by first highlighting the key

benefits that DCS offers like the total asset lifecycle cost saving and the use of thermal energy storage and heat exchangers with lesser environmental impact. This was also supplemented by a review of other countries with established DCS network, namely, Singapore, Japan, United States of America and Denmark.

Subsequently the discussion and review on policy highlights the importance of understanding the role of state and federal government in implementing DCS. This is a crucial step because the policymaking is only as good as the implementation. Findings from a proliferation of studies also suggest targeted subsidization, carbon credit recognition, promotion for co-generation, thermal energy storage, economic adoption and integrated legal framework to be crucial areas in establishing new policies on DCS.

This study contributes towards establishing regulatory and governance framework, it is also hoped that stakeholder engagement and collaborative initiatives could be built. It is pertinent for the development of DCS that stakeholders, from the government, private institutions and the community, are involved. Public-private partnerships can be a possible solution to expand the DCS industry in Malaysia. The government can play a major role in strengthening the framework for implementing DCS in Malaysia. This can range from establishing best practices guidelines, defining the roles and responsibilities of regulatory bodies and includes mechanism for monitoring and compliance.

It is recommended for future studies to investigate into the following major implementation challenges; financing and investments, human capital and capabilities, policy and regulation, technology and infrastructure, and governance. These challenges shows that while careful policy can lead to successful implementation, there are many other dimensions to fully grasp the nuances of district cooling systems in Malaysia. Finally, it is suggested for future researchers to adopt a mixed methods approach, where interviews with key stakeholders may enlighten researchers, in strategic policymaking for more effective findings.

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