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Moving from private to shared infrastructure for the supply of cooling energy services

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SYNOPSIS

Singapore has achieved large energy efficiency improvements in providing cooling services by replacing building level cooling equipment with district level centralized cooling systems (DCS) as in the Marina Bay commercial area. There is interest and potential to deploy similar infrastructure more widely across Singapore, with the currently under construction Tengah township an example where this is being seriously considered. The residential uptake of shared energy services (e.g., the service of 'cooling' generated from a shared infrastructure versus private cooling solutions, such as using conventional split unit air conditioning systems (SAC)) may have important implications for long run energy requirements. Here we briefly consider some of the potential implications of transitioning from an economy characterised by private (competitive) supply, to one where there is a shared (monopolistic) structure to the supply side of the market.

KEY POINTS

- Suppliers could benefit from the natural monopolization of shared cooling services, but they have to take the risks such as energy redundancy and huge up-front cost
- Customers could benefit from cheaper price for a more stable cooling services but may lose the opportunity to negotiate price in a transparent market
- Private cooling energy service is more flexible and less effective in terms of delivering cooling energy whereas shared energy services are generally monopolized and much more efficient

INTRODUCTION

With ongoing climate change we are witnessing generally hotter temperatures. New heat records are being established on a frequent annual basis in numerous countries. With this, the demand for space cooling has been growing, as households and businesses try to keep their facilities and equipment at appropriate operating temperatures. This is increasingly challenging and costly, especially in tropical and humid areas such as Singapore.

Projections from the International Energy Agency (IEA, <The Future of Cooling>, 2018) suggest that around 2020 TWh of electricity was consumed to satisfy global cooling demand in the year 2016. With global trends in urbanization—stimulating heat-island effects—the cooling demand is predicted to grow at least threefold to around 6,200 TWh before 2050, of which around 70% will be from the residential sector.

The traditional approaching to accessing cooling energy supply has been through private cooling solutions, e.g. building specific chiller systems, or private split unit air-conditioning (SAC) unit for households or smaller properties. There are multiple providers of such equipment, and as such the supply of cooling can be thought of as having competitive market foundations. Over time there has been an increased awareness of the extent of leakage of refrigerants, especially from SAC's, including harmful Hydrochlorofluorocarbons (HFCs) which is known to accelerate global warming.

Yet with a growing demand for cooling energy, there are renewed questions on the potential for, and value of alternative mechanisms for providing cooling energy services. District cooling systems (DCS) have emerged as one promising option. A DCS approach involves building a very large centralised cooling power generating facility (chiller system for brevity) which can be used to provide cooling solutions to large districts spanning many buildings. A vastly different approach to conventional solutions which may be either building, or in many cases, tenant specific.

There are several existing DCS projects, many of which are in operation in the northern Europe. There are fewer district cooling projects elsewhere albeit with some exceptions in Asia and parts of the Middle East. One possible explanation for the geographical distribution of district cooling projects is that in some countries, such as across the EU countries already have well-developed pipeline systems that were originally installed for the purpose of heat distribution, especially residential heat supply during the winter season. The capital requirement for retrofitting such pipeline equipment to accommodate cold energy flows is likely to be considerably lower than building out a full DCS with pipelines from scratch. In tropical countries, district heating is not required, and to provide DCS means the more expensive (starting from scratch) scenario.

District cooling systems are complex, but two defining features include: (i) that they simplify the engineering parameters/complexity of the system (due to there being fewer component parts); and (ii) they take advantage of scale economies to obtain service cost reductions.

It remains an open question if DCS systems are fit for a broad range of conditions., including for example mixed land use contexts, where cooling demand loads may be very complex. Moreover, there are major infrastructure considerations such as noise generated by cooling tower equipment which might be undesirable in a residential context. In such a case, there may be different engineering requirements versus DCS deployed in an industrial or commercial zone. Additionally, the expensive upfront cost for DCS may be an investment barrier.

In the following we reflect on the some of the considerations for suppliers and consumers of cooling energy under DCS and SAC supply alternatives.

ANALYSIS

Supplying cooling energy using a district level infrastructure.

Comparing with private air-conditioning solutions (split-unit air conditioning or SAC) units which can be flexibly installed and with the specific technology drawn from a wide range of competing firms, DCS systems are very different. They are normally very large chiller systems complemented with an elaborate pipeline (and pumping) infrastructure. They require heavy equipment (making rooftop building retrofit difficult/impossible) and require careful placement, typically underground or installed on a building's rooftop. Once installed they are very difficult to relocate.

Noise is another significant problem. The outdoor condenser is among the most important component of a cooling system to facilitate refrigerant heat exchange. Condensers are noisy and can affect nearby occupants, especially when cooling demand is high. Noise management challenges are more pronounced for DCS than for SAC type solutions. Aural discomfort caused by the operation of district cooling system can emerge from: (1) air-borne noise and (2) structure-borne noise. As a result, there is also potential for detrimental vibration that can pass to the building or grounds they are situated in. While sound barriers can be installed to prevent public discomfort, they may in turn have consequences for the efficiency of exhaust heat ejection from the chiller equipment. Also, they may not alleviate structure-borne noise.

Beyond noise considerations, the pipeline system of a DCS also warrants some understanding. Pipeline equipment connects chillers and fan units. The chiller creates cold air, which is piped to the fan unit, and the fan unit circulates that cold air within a property. These pipelines operate in an oxygen depleted environment, which can result in a build-up of sulphates which in turn can cause damage to pipelines and reduce system efficiency. In such cases, sulphate reducing bacteria can be deployed to prevent corrosion and refrigerant leakage. This in turn can diminish the leakage of chilled water where bacteria can grow and affect the health of occupants and users of the cooling services. Measuring, monitoring and managing such issues in one large pipeline system (DCS) rather than many independent systems (SAC) is a much easier task.

With DCS there is an opportunity to include cold thermal energy storage (TES) to the system. DCSs deliver cooling capacity in a form of chilled water via pipeline systems to and within buildings with potentially complex and intermittent within-day demand load profiles. Such intermittency requires rapid system responses. However, it takes time (and energy) for water at ambient temperatures to be chilled to an acceptable level (minimum service requirement) for circulation and use within DCS. Cold thermal storage can be used to avoid these time and energy costs by generating and storing chilled water, ideally when it is cheap to do so, and release when there is a sudden peak in cooling demand and/or when costs of producing cooling energy are high.

With the installation of thermal energy storage, suppliers can offer more attractive supply contract stable cooling services with cheaper cooling tariffs compared with systems without storage. However, the benefits of having access to thermal storage need to be balanced against the cost for installing thermal storage equipment, which can be expensive.

All things taken together, the early evidence is that DCS permits for considerable economies of scale,i.e., that the average cost of providing cooling energy can sharply decrease as the total scale of supply is expanded, due to a use of different technologies (compared with SAC). Worded differently one might consider that the market for cooling could have naturally monopolistic features, e.g. that because of the potential for significant scale economies, a single supplier may be preferable.

Considerations for consumers

Here we briefly build out upon the idea that DCS has naturally monopolistic tendencies, while SAC is a more competitive option. Being naturally monopolistic, DCS is justifiable yet it helps to consider what the implication of this can be.

DCS offer cooling service suppliers monopolistic market power, and at the same time eliminates competitive pressures towards the market. Competitive pressures are powerful and foster the adoption of the best available technologies and providing goods and services at the lowest possible rates (if a service can be provided more cheaply by one firm compared with others – all customers would go to that firm, so other firms are forced to adopt similar technologies and offer similar rates). Monopolists do not feel such pressures; on the contrary monopolists have freedom to charge higher prices (so long as consumers are willing and able to pay) without risk of losing customers. Monopolies are often disbanded where possible because of this absence of the benefits (to consumers) of competition.

Furthermore, in the presence of monopolistic market conditions, customers may be at a disadvantaged situation when choosing DCS cooling energy services. The possible consequences of a natural monopolization of cooling services could then have an adverse impact on consumers' welfare.

However, there are consumer benefits under DCS compared with SAC. Energy service pricing becomes simpler under DCS because the cost of equipment and maintenance are transferred to the DCS provider. Hence, consumers will have some added convenience while and at the same time, the process of maintenance has a higher chance of maintaining a regular schedule (noting that there is variation among households in the frequency and regularity of maintenance).

As DCS services become more commonplace it may be important to monitor for behavioural changes in the use of cooling services. From a behavioural perspective, consumers may begin to question what is a 'fair' price level for centralized cooling. Why? Because the cost per unit of cooling consumed may be the same for all customers (depending on the pricing model), yet the quantity of consumed will likely not be. Those that consume less than others may calculate that they are paying for what they may perceive as others over-consumption. For example, residents who are office-based may feel that they are losing-out if they have to pay the same amount of cooling tariffs as residents who work-from-home.

Another behavioural consideration is that consumers may have less ability to choose the temperature set point for space cooling if are supplied by a district cooling system. It is not uncommon that there is a distribution of the room temperature that people prefer to stay varying from as low as 16 °C to as high as 29 °C, and residents would set the temperature according to their own preferences and socioeconomic conditions. Under DCS there may be limits to how easily consumers can achieve their desired cooling demand at the required temperature.

CONCLUSION

The transformation from private to shared energy services supply for cooling energy will come with some trade-offs for both suppliers and consumers. Large upfront infrastructure costs give the market for district or centralized cooling services elements of a natural monopolized market structure where lower prices cooling energy can be achieved through technological economies of scale.

Suppliers of district level cooling facilities may need to be willing to adopt some risk of system/energy redundancy and high maintenance costs if their district cooling systems are not designed carefullyReasonable monopoly rents can be one way to incentivize private market participation on the supply side.

WHAT TO LOOK OUT FOR

- Future growth in district and centralized energy services supply for cooling energy
- Potential for discussion of future revisions and additions to the District Cooling Act, as market experiences for shared energy services supply becomes more mainstream
- Further discussion on demand-side characteristics, especially in mixed land use districts with high residential components, and how they impact commercial issues such as service pricing.
- The impact on cooling energy use and carbon dioxide emissions.

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