COOLING INFRASTRUCTURE FOR THE COMMONS: ENERGY-ECONOMIC ASSESSMENT OF NEIGHBOURHOOD-SCALE COOLING SYSTEM IN THE TROPICS

Dr. Marcel Bruelisauer, FRS/SEC Singapore, +6585870713, marcel.bruelisauer@frs.ethz.ch
Prof. Dr. Renate Schubert, ETH Zurich & FRS/SEC Singapore, +41446324717, schubert@econ.gess.ethz.ch

Overview

Climate change is one of our key global challenges, largely driven by anthropogenically induced CO_2 emissions, of which more than 50% are attributed to activities related to buildings. In tropical climates like Singapore, the operation of buildings and households represent 50% of the electricity consumption, of which air-conditioning takes up the lion share with 60%[1]. While Singapore's electricity generation has reduced its carbon emissions by shifting to natural gas, it is still based on fossil fuels.

The impact of air-conditioning depends not only on the required cooling capacity but also on the cooling system. Air-cooled split type air-conditioners, prevalent in South East, are the cheapest but also least energy efficient cooling equipment to purchase. However, their externalities are not considered, neither on a global/national scale nor as direct impacts on the urban microclimate and on the aesthetics and usability of valuable urban spaces, such as shophouse neighbourhoods.

Shophouses are historic buildings of mercantile-type origin in Singapore and South East Asia. They are separated by small lanes at their back that are noisy, dirty and uncomfortable because of the number of air-conditioning units and other infrastructures and service functions. By extending the dialogue on urban regeneration between heritage conservation, urban design and building technology beyond the physical mass of a shophouse, backlanes offer a prospect to act as strategic urban connectors and economic facilitators. This study forms part of the research project 'Reclaiming Backlanes', an interdisciplinary design research project that originated at the Future Cities Laboratory of the Singapore ETH-Centre[2].

The introduction of a shared, neighbourhood-scale cooling system – as a small-scale district cooling system or a novel hybrid system called heat bus system – not only reduces energy use from cooling and improves the thermal comfort in the backlanes, but also allows the decluttering of façades from the numerous air-conditioning units. However, these cooling infrastructures extend beyond each individual shophouse and are shared within a neighbourhood, a novelty for low-rise neighbourhoods in Singapore; their feasibility with regard to implementation, financing and operation needs thus to be evaluated. This study looks at the economic feasibility of such neighbourhood scale cooling systems at the example of the predominantly commercial neighbourhood Boat Quay in Singapore with a cluster of 22 shophouse buildings.

Methods

We use first-order engineering calculations to evaluate the economic viability of these cooling systems. The cooling capacity is taken as installed now without looking into reduction potentials on the demand side. Capital cost is based upon data received from building contractors, specifically for this neighbourhood. Operation cost are based upon energy use calculations,

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[1] Chua, K.J., S.K. Chou, W.M. Yang and J. Yan (2013). 'Achieving Better Energy-Efficient Air Conditioning – A Review of Technologies and Strategies', *Applied Energy* 104: 87–104.

[2] Bruelisauer, Marcel and Sonja Berthold (eds.) (2015). *Reclaiming Backlanes - Design Vision for Increasing Building Performance and Reprogramming Common Spaces*. Singapore: World Scientific Publishing Co.

taking into account typical operational parameters and optimising according to Low Exergy design principles[3]. We evaluate life-cycle cost of the different options and put these cost in relation to potential increase of the real estate value.

Results

The calculations show much higher investment cost for both neighbourhood-scale cooling systems than for the current decentralised split units (Figure 1). For the operation though, the heat bus system requires 37% less power and the district cooling system even 47% less power to cover the exact same cooling demand, resulting in annual operational cost savings of SGD 8,500 and SGD 11,500 respectively per building.

Considering cumulative discounted cost, the district cooling system becomes more economical after 5 years, the heat bus system after 8 years. These calculations indicate that such common systems can only be implemented with this scale of time horizon in mind (Figure 2). But while these investments represent about 2.5% of the current real estate value of these shophouses, their value has in the last decade increased on average by more than 10% every single year.

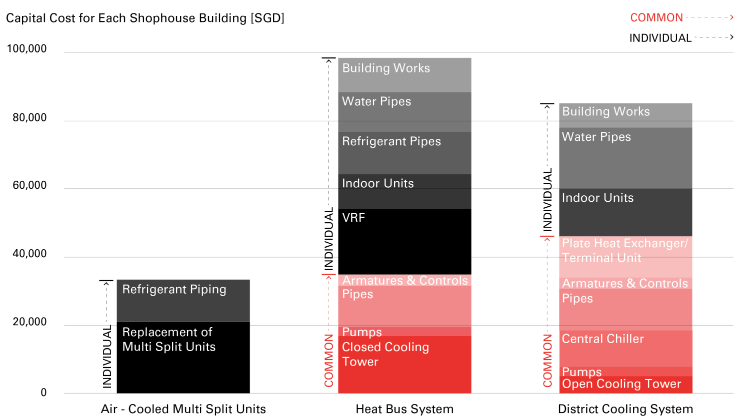

Figure 1: Capital expenditures for the different options for the cooling system for each shophouse building. We separate between common and individual cost (adapted from Bruelisauer et al. 2015).

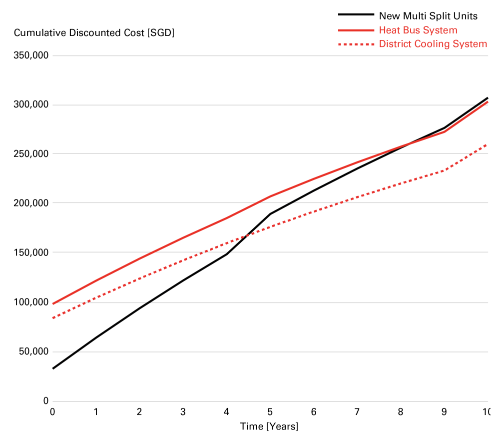

Figure 2: Cumulated discounted cost for the different options for each building (adapted from Bruelisauer et al. 2015).

Conclusions

The results are more favourable for the common cooling systems than anticipated: The payback periods are below 10 years, considering only energy cost savings. Despite purchasing more expensive equipment and requiring major building works, the shared cooling systems are economically viable in a relatively short timeframe. It helps that we compare to some of the worst possible cooling systems with regard to operational efficiency.

Other factors – such as better spatial quality and thus increased activities, a more attractive neighbourhood, more footfall and thus additional business opportunities – will contribute to value increase of the real estate and will render the neighbourhood scale options economically viable in much shorter time frames. The upgrade in the backlanes will render the whole neighbourhood more attractive, key from a real estate perspective.

The implementation of these systems is not simple, not only because of the backlane as an contested urban space with existing services and infrastructures but also because of the fragmented nature of ownership and tenancy of the neighbourhood. However, they also promise interesting emerging business models for energy service providers of the future.

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[3] Leibundgut, Hansjürg (2012). *LowEx Building Design für eine ZeroEmission Architecture*. Zurich, Switzerland: vdf Hochschulverlag AG.