From air-conditioned modernity to lower-carbon alternatives: The case of Singapore responding to the climate crisis

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(3199 words with 2 images)

As planetary temperatures rise due to human-induced greenhouse gases, both the frequency and length of heatwaves have increased. The increase in temperature caused by the climate crisis is projected to disproportionately affect the countries in the tropical and subtropical regions. These are the very countries expected to have the fastest rates of growth in income and population, which in turn means that their ownership rates and usage of energy-profligate air-conditioning will surge. If we do not wish to increase carbon emission and further exacerbate the climate crisis, we need to find ways to reduce our dependency on conventional air-conditioning. The common approach taken globally is to increase the energy efficiency of both air-conditioning technologies and buildings.

This short essay takes a broader approach to understand air-conditioning dependency so as to find lower carbon ways of living with heat. It charts the trajectory of the strategies – architectural, technological, and social – of dealing with heat, first across Singapore's development from tropical colony to modern air-conditioned nation, followed by how it has been moving towards to lower-carbon methods of cooling which make use of novel and hybrid technologies and strategies. As Singapore developed economically after her independence in 1965, it has not just followed the industrialised countries, especially the United States and Japan's lead in embracing air-conditioning, it has also used their air-conditioning technologies. Singapore subsequently became known as an 'air-conditioned nation'. But recently, Singapore has been restructuring itself to become a global hub in researching and testing alternatives to air-conditioning technologies.

Before air-conditioning became widespread, people living in the hot and humid tropics adopted various strategies to keep cool throughout the day. These range from living in porous and well-ventilated buildings, wearing loose-fitting and lightweight clothing, and using handheld and electric fans. These also entailed adjusting their living patterns to the diurnal changes by, for example, having the street markets operating during the cooler hours in the morning and evening of the day. Besides adjusting the rhythms of their everyday lives, inhabitants of the tropics also adapt to living in the thresholds between the indoor and the outdoor, shade and sun. Comfort is a complex socio-physical concept that depends on not just bodily sensations but also how bodily perceptions of and bodily practices in the environment are socialised. This complex understanding of comfort was ignored when a group of researchers linked to the air-conditioning industry attempted to quantify thermal comfort from the early to mid- twentieth century. They conducted experiments within a hermetically sealed, windowless room known as the psychometric chamber, where contextual socio-environmental conditions central to practices of maintaining comfort

were minimised if not eliminated, to find out the exact "scientific" temperature and humidity range in which a person would feel comfortable. The reductionist laboratory method gave rise to a longstanding idea, which would inform air-conditioning design and usage globally, that human beings are most comfortable at very narrow temperature and relative humidity ranges. This reductive thermal comfort standard subsequently became the international norm that guided the design of air-conditioning system till today.

Towards air-conditioned nation

In colonial discourse, the tropics were considered to be a torrid environment where the sweltering heat would render the population unproductive and indolent. What Singapore's first Prime Minister Lee Kuan Yew said in a 1999 interview reveals the latent influence of such colonial ideas about the tropics on him and post-independent Singapore:

> *Air-conditioning was a most important invention for us; perhaps one of the signal inventions of history. It changed the nature of civilisation by making development possible in the tropics…Without air-conditioning, you can work well only in the cool early morning hours, or at dusk. The first thing I did upon becoming prime minister was to install air conditioners in buildings where the civil service worked. This was key to public efficiency.*

The critical importance of air-conditioning in the socio-economic development of the newly independent city-state is evident in the quote. Lee's technocratic perspective would steer government policies towards embedding air-conditioning in the built environment in the following decades. Unsurprisingly, the offices of the newly formed Singapore civil service were among the first to air-conditioned in the 1960s.

Within a political discourse of governance concerning urban renewal and new urban typologies, air-conditioned comfort was central to post-independence socio-economic development policies. Singapore was then characterised as a 'developmental state', one in which market and society were dominated by an interventionist state. The main strategy for economic growth was to transform the entrepot economy into an industrial economy by attracting foreign investment from multinational corporations. In order to do so, Singapore had to modernise the city centre which was then populated by the low-rise shophouse typology.

The state acquired and cleared shophouses which were regarded as insanitary and overcrowded 'slums.' Land was consolidated into extensive plots suitable for the construction of large modern office buildings to serve the burgeoning industrial economy. The consolidated plots of land were sold in phases through the Government Land Sales programme from 1967. These large tracts of land subsequently made up a major proportion of the Central Business District. Replacing the old colonial shophouse

typology and its urban fabric of narrow streets and back lanes was a new air-conditioned typology – the podium-tower typology characterised by big urban plots and large hermetically-sealed interiors. While this typology is by no means endemic to Singapore, the scale, speed, and extent of the urban renewal programme, coupled with its socio-political ideology, made Singapore a distinctive case.

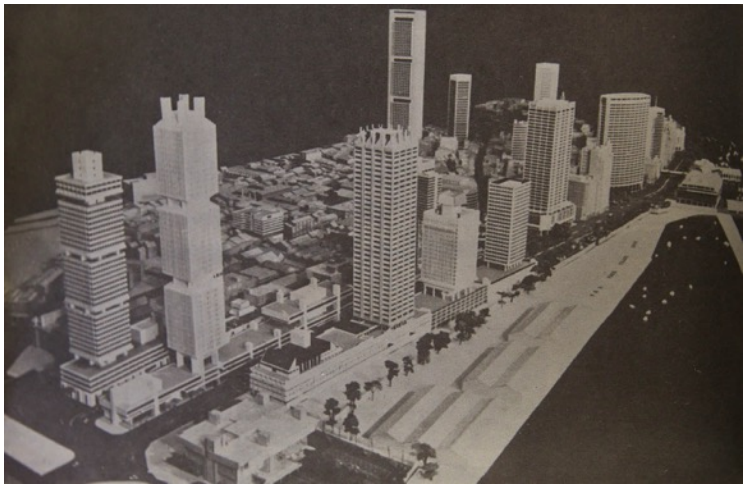

Figure 1. A model of the air-conditioned podium-tower buildings at the Central Business District of Singapore, c. 1970s.

Architect Rem Koolhaas described the drastic erasure and radical transformation of the old colonial urban environment as the *tabula rasa* approach: 'the razed plane as the basis for a genuinely new beginning'. This erasure allowed a new air-conditioned thermal modernity to be forged through the podium-tower typology. Many podium-tower buildings in 1970s became 'multi-use complexes' where podiums housed shopping arcades, upon which rose towers of offices, residence, and hotels.

Cooled, dried, and sheltered from the heat and humidity of the tropical climate, what was formerly the exterior street was transformed into interiorised atrium and corridor with the arrival of air-conditioning. By 1972, there were 12 air-conditioned shopping complexes that were in operation, bringing about a new way of shopping – 'the instant way and in cool comfort', and what a Carrier air-conditioner advertisement touted as an 'oasis of comfort'. Sales would no longer be affected by outdoor conditions such as bad weather, and unhampered by the oppressive heat, operational hours could be longer than traditional markets.

Air-conditioning later transformed from building services to urban infrastructure with the arrival of the district cooling system. Although dismissed in the 1970s due to land scarcity, Singapore later implemented district cooling in the Marina Bay area after Singaporean planners studied its use in the Yokohama Minato Mirai 21 district. Singapore's Marina Bay subsequently installed one of the largest district cooling systems in the world. Centralised planning and close coordination between state planning

agencies like the Urban Redevelopment Authority (URA) and government linked companies, such as Singapore District Cooling, has supported the operation of large-scale cooling infrastructure. These district cooling systems have in turn facilitated the enclosure of large urban spaces, such as the mega-developments from the 2000s, through air-conditioning, a phenomenon termed by geographer Simon Marvin as 'volumetric urbanism'. By rescaling enclosure of air-conditioned spaces from a building to an urban scale, uncomfortable exterior spaces that are at the mercy of the weather become substituted with new artificially cooled interiors. These controlled environments possess a new spatial logic where the 'outside' matters less because the exterior is brought into the urban 'interior'.

Like in many others large, affluent metropolises around the world, vast labyrinthine air-conditioned walkways connect office buildings to transport nodes in Singapore, creating all-weather comfort as pedestrians circulate throughout the city. Pedestrians in Singapore often retreat into the interiors of large interconnected buildings and underground complexes as they travel from underground Mass Rapid Transit (MRT) stations along air-conditioned linkways into offices, shops and even residences. As such, the traditional figure-ground, interior-exterior reading based on a horizontal understanding of the city is now being challenged. Urban inhabitants now navigate a volumetric city in which vertical, multi-levelled relations and movements are as important.

Before air-conditioning became widespread, most buildings in Singapore were built with passive designs to combat the heat. Developing alongside Singapore's air-conditioned buildings post-independence was the high-rise public housing by the Housing and Development Board (HDB) that houses around 80% of the nation's population at its peak. HDB apartments were initially designed to be passively instead of mechanically cooled. With their long sides facing north-south, solar heat gain is minimised, and interior spaces were planned such that they facilitate cross ventilation. Similar cooling design principles were applied to public amenities within housing estates such as wet markets and hawker centres.

As the Singaporean population became more affluent, home ownership of air-conditioner increased. According to the 1972/73 Household Expenditure Survey, only 3% of Singapore households owned an air-conditioner. The next decade saw a twofold increase in air-conditioner ownership between 1982/83 and 1987/88, from one in ten to one in five households. Previously hindered by public housing rules which only allowed one small condenser unit per apartment, new advances in air-conditioning technology meant that all rooms could be cooled despite the restrictions. The Daikin Econair, introduced in 1978, was the first ductless, split AC system that could run up to four indoor fan coil units to be powered by a single outdoor condenser. Despite the thermal comfort it provides, air-conditioning took a toll on the country's energy supply where sharp spikes in electricity demand on Monday mornings used to be a cause for concern for power stations. Working within this milieu were architects who have alternative architectural visions of Singapore where air-conditioning would not necessarily be dominant.

In 1989, Tay Kheng Soon published *Mega-cities in the tropics* which pushed an architectural agenda for tropical urban design. The following year, he implemented his idea in the 'Kampong Bugis Development Guide Plan', a proposal for a test site in central Singapore. Tay noted that in other tropical modernist cities such as Brasilia and Chandigarh, climatically responsive design was only applied to the building rather than the holistic planning of urban space and infrastructure. He proposed a high-dense and multi-tiered city where residential, commercial, and educational needs could be met in a compact space.

While modern tropical architecture was expected to provide thermal comfort to inhabitant through the amelioration of heat and humidity, Tay took this to another level by thinking about how heat and humidity could productively work for the benefit of inhabitants. By trying to replicate the microclimatic conditions of a tropical rainforest canopy, Tay was attempting to mitigate the urban heat island effect. He learned from the findings of a Malaysian researcher studying the Kallang Valley that urban centres can be up to 8°C warmer than the surrounding natural environments. Nevertheless, Tay's ideas were not adopted by Singapore's state planning agencies back in the day, that is, until recently as the government pushed for ecological modernisation due to the urgency of the now widely recognised climate crisis.

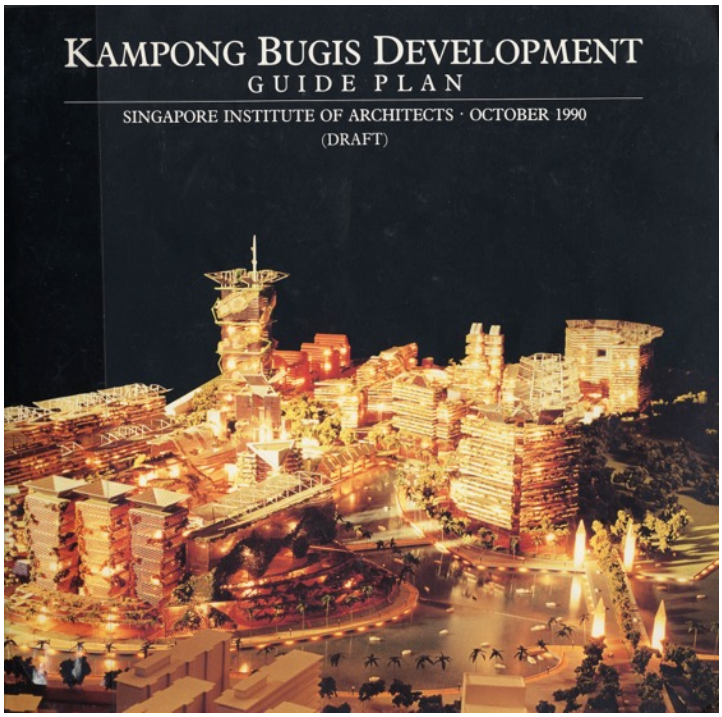

Figure 2. The cover of the Kampong Bugis Development Guide Plan prepared by a team led by Tay Kheng Soon.

The climate crisis and moving beyond air-conditioning

While the idea of environmental sustainability has been discussed as early as the 1970s, the precariousness of the climate crisis became much more recognised from the late 1980s with the publication of *Our Common Future* (1987), the report by the Brundtland Commission that popularised the phrase 'sustainable development', and the various reports from the Intergovernmental Panel on Climate Change since 1992. The Paris Agreement adopted in 2015 further established the goal to limit global warming to below 2 degrees Celsius and the aim to reach global peak of carbon emission as soon as possible. However, rising temperature and increasing frequency of heatwaves caused by climate change, and increasing affluence of the developing countries have only lead to escalating demand for air-conditioning. In a recent report, the International Energy Agency calls the threat posed by the 'rampant growth in demand for space cooling' using air-conditioning and its far-reaching implications a 'looming cold crunch'. Air-conditioning accounts for nearly 20% of the total electricity used in buildings globally today. This figure is set to triple by 2050 if the current rate of increase is left unchecked.

In response to the energy-profligate air-conditioning technology, there has been attempts at developing alternative cooling technologies which can be used to augment comfort in the non-enclosed space of the outdoor and the semi-outdoor. Airbitat is one such example that utilises a combination of refrigerated and evaporative cooling to lower ambient temperatures. First launched in August 2016 at the Singapore Zoo's ticketing area, the Airbitat provides more cooling than a standard evaporative cooler and is more energy efficient than an air-conditioner. It is designed by Innosparks, a start-up within ST Engineering, one of Asia's largest defence and engineering groups that has the Singapore government as a major shareholder through its sovereign wealth fund Temasek Holdings.

The Airbitat is one of many forms of novel technologies to beat the heat. Another technology that is currently being tested in Singapore by an international group of researchers is the 'Cold Tube', a radiant cooling technology. Using funding from the National Research Foundation of Singapore, the researchers created an outdoor pavilion lined with insulted radiant panels that contained cold water pipes. As participants walked through, their bodies shed heat through radiation towards the panels, making them feel cool even though the air itself had temperature and humidity levels that would usually be stifling.

Other novel technologies that cool non-enclosed spaces include new fanning technologies that have been widely deployed by both public and private sector organisations in many spaces throughout Singapore, owing to their effectiveness and low operating costs. For example, high volume low speed (HVLS) fans have been incorporated into public spaces such as naturally ventilated MRT stations and school halls. They are valued for creating comfort in large spaces while consuming little energy and creating less noise and less draft than traditional fanning technologies. In addition to cooling existing spaces, Airbitats and HVLS fans are also helping to reconfigure architectural and urban spaces. In recent years, buildings utilizing mixed-mode cooling—including both active cooling by air-conditioning and

passive cooling through natural ventilation and sun-shading—have begun to be built in Singapore. These include shopping malls like the Star Vista and Westgate, community buildings such as Kampung Admiralty, and education buildings like NUS SDE4. Many of these buildings—especially the shopping malls—would previously have been fully-air-conditioned. But the use of HVLS fans to augment clever passive cooling architectural strategies enable a significant proportion of the spaces in these buildings to be sufficiently comfortable without air-conditioning. HVLS fans have also begun to transform how spaces around transportation hubs and between buildings are designed in recent years. Instead of interiorising the exterior to further entrench volumetric urbanism, HVLS fans and high-level shading have kept these spaces airy and permeable, blurring the boundaries between the indoors and the outdoors. These novel technologies have also contributed to a built environment of greater thermal diversity. Instead of two zones previously—the air-conditioned interior and the hot exterior—we now have a gradation of in-between zones with a wide spectrum of thermal properties.

Another take on fanning technologies is the OACIS (Outdoor Active Cooling) bladeless fan by the North Carolina-based startup Phononic. Making use of thermoelectrics to cool air, the OACIS is seen as a "disruptive climate control project" by its investor Temasek Foundation Ecosperity, an arm of Singapore's Sovereign Wealth Fund. Indeed, disruption is the buzzword that has in the past few years been closely connected to cooling technologies. With climate change and rising temperature, the cooling sector is seen as a market with tremendous growth potential. Many investors see the air-conditioning industry as being ripe for disruption, especially by low carbon alternatives. One of those alternatives that has attracted significant research and development investment is personalised, wearable "air-conditioning" that deliver instant cooling through a small device using thermoelectrics to create the Peltier effect. If the wearable "air-conditioning" proves to be effective, it would be a realisation of the late Lee Kuan Yew's wish for an air-conditioned underwear.

Other than hedging on novel and unproven cooling technologies to address the climate crisis, Singapore has also relied on traditional and proven means of cooling the environment. Besides the aforementioned passive design strategies typical of tropical architecture, Singapore government also depends on the tried and tested use of greenery to reduce ambient environmental temperature and ameliorate urban heat island effect through shading and evapotranspiration. Taking into consideration Singapore's high density and high-rise urban fabric, and probably also inspired by Tay's 1990 proposal for Kampong Bugis, planning authorities launched the Landscaping for Urban Spaces and High Rises (LUSH) initiative from 2009 to promote vertical greenery through features such as rooftop gardens, sky terraces and green walls. These ways of increasing the density of greenery within a site helps with not just lowering the ambient temperature but also provides environmental benefits like increasing biodiversity, improving urban hydrology, and bettering human well-being.

Conclusion

There have been at least two types of responses to attaining comfort in the tropics in face of the climate crisis. The first is the technocentric one of designing energy-efficient air-conditioning technologies for the tropics. The second is for the cities in the tropics to scale back on its reliance on air-conditioning and return to the climatic design strategies of tropical architecture. Both are sensible suggestions, but they are insufficient on their own. In the case of the former, history has shown us that increase efficiency has led to rebound effect in which the efficiency gained was offset by increased consumption. In the case of the latter, it is important to note that tropical architecture was devised in the mid-twentieth century, at a time when cities in the tropics were of a different scale and density from today. The nature of the architectural problems and solutions were dissimilar too. In today's high-density tropical environment, designing a permeable building may introduce not just breezes into the interior but also noise and dust particles. Furthermore, passive strategies of cooling alone may not be enough to address the temperature increase introduced by the urban heat island effect and rising temperature of climate change.

Instead of choosing between them, the two approaches should be combined. Hybrid approaches combining passive strategies with low-carbon active strategies and/or architectural solutions with landscape features and urban planning approaches may be more effective. Even then, technological solutions in conjunction with design strategies may prove to be inadequate if they are not accompanied by the requisite political will, economic incentives, and social values to support and embrace them. Like many other advanced economies around the world, Singapore has invested significantly to address the challenge of keeping its inhabitants comfortable and well in the Anthropocene. Is that enough? Will its inhabitants have the social values to make these physical provision work? We shall see.

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